

US Army Corps of Engineers®

CHICAGO DISTRICT

MCCOOK LEVEE

MCCOOK, IL

Appendix D: Hydrology and Hydraulic Analysis

02 February 2018

MCCOOK, IL SECTION 205

APPENDIX D: HYDROLOGY AND HYDRAULIC ANALYSIS

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APPENDIX D: HYDROLOGIC AND HYDRAULIC ANALYSIS
MCCOOK, IL
SECTION 205 FLOOD RISK MANAGEMENT

INTRODUCTION

The Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) has performed a Hydrologic and Hydraulics (H & H) analysis in regards to their proposed Lyons Levee Improvement Project, which has been documented in the report "Lyons Levee Improvement Project, Hydrology and Hydraulics Technical Memorandum" dated December 2015. This analysis is also applicable to the McCook Levee Project which is located across the Des Plaines River from the Lyons Levee Project, however, sections specific to the Lyons Levee project will not apply to the McCook Levee project.

The report covers much of the H & H analysis that is normally required by the U.S. Army Corps of Engineers (USACE) for feasibility studies. The report is attached and will be considered as the main portion of the H & H Appendix, in addition to the supplemental analyses below that include additional items normally covered in a USACE Flood Risk Management (FRM) levee project. This supplemental appendix provides additional information to address such items as: risk and uncertainty analysis, superiority analysis, project impacts, and flood warning.

RISK AND UNCERTAINTY

The MWRDGC report includes a very comprehensive documentation of the H & H data available for the study reach. The associated analysis also includes a very recently updated model, which includes close calibrations for six recent historic flood events, three of which have peak flows exceeding the published FEMA 1% chance exceedance flood. Updated flow frequency analyses for the USGS gage on the Des Plaines River at Riverside, Illinois, located one and a half miles upstream of the project are also included.

USACE policy requires that flood risk management projects be designed using a risk-based analysis rather than designing to a level of protection.

A risk and uncertainty analysis was performed using data from the MWRDGC report and the associated hydraulic modeling. At the imminent overtopping location of the levee system, the levee crest is 1.5 feet above the one percent chance exceedance design water surface. Due to the 100 year period of record at the gage, and very close comparisons between the observed and computed stages for the calibration runs, the FDA analysis computed a 95.4% chance that the one percent chance exceedance flood event would not overtop the levee. Current USACE guidance (EC 1110-2-6067) requires a minimum of two feet of freeboard, even when there is a greater than 95% confidence level that the one percent flood will not exceed the crest elevation.

SUPERIORITY ANALYSIS

The existing West Lyons Levee includes a low area that would be the location of imminent overtopping of the McCook levee system. The West Lyons Levee is basically a continuation of the McCook Levee along the west side of the Des Plaines River north of 47th Street. The water surface profiles indicate that overtopping will occur at this location first and not in other areas where the levee is relatively higher.

In the development, design and coordination between the State of Illinois and MWRDGC for the Lyons Levee project on the east side of the Des Plaines River, it was decided that the levee heights on the east levee would remain six inches below the West Lyons Levee as has historically been the case. For the design of the McCook/West Lyons levee the USACE is accepting the agreements that have been previously made regarding the levee heights of the Lyons and West Lyons Levees. Any raising of these levees would need to be coordinated with these entities and would need to consider the impacts on both sides of the river.

With regard to the recently released guidance, ECB 2017-15 “Managed Overtopping of Levee Systems”, the overtopping location for the McCook/West Lyons Levee is not ideal. The location is along the back yards of a residential area. While the first floors of the homes are at or near the 100 year flood level, there is a low area in the back yards with a greater than an eight foot depth which brings up concerns of possible loss of life. The new guidance also recommends armoring the overtopping location. The top of the existing levee includes a paved bike, but no armoring on the back side of the levee.

For this instance, the volume in the interior is small north of 47th Street and would fill up rapidly whether it overtops or fails. There is a natural area that provides a secondary tieback for the McCook Levee with a minimum elevation of 602.0, so a failure of the West Lyons levee would have much less of an impact to the McCook levee interior than it would without this high ground. Flood warning would also decrease the risk. With consideration of these factors, the risk appears to be reasonably manageable.

PROJECT IMPACTS

There are no project induced stage impacts due to fill or storage on the Des Plaines River, however, the proposed diverting of flows from McCook Ditch into the Des Plaines River can cause increased stages.

The original project plan was to block off the culvert at Lawndale Avenue and add a diversion from McCook Ditch just south of Lawndale to the Des Plaines River. Currently all flow from McCook Ditch passes through the Lawndale culvert and then outlets to the Chicago Sanitary and Ship Canal through the Summit Conduit. The Summit Conduit is also the only outlet for the interior drainage of the project. See Figure 1 below for existing condition features. The project interior is located to the northern portion of the McCook Levee on the figure with Lawndale being the dividing line.

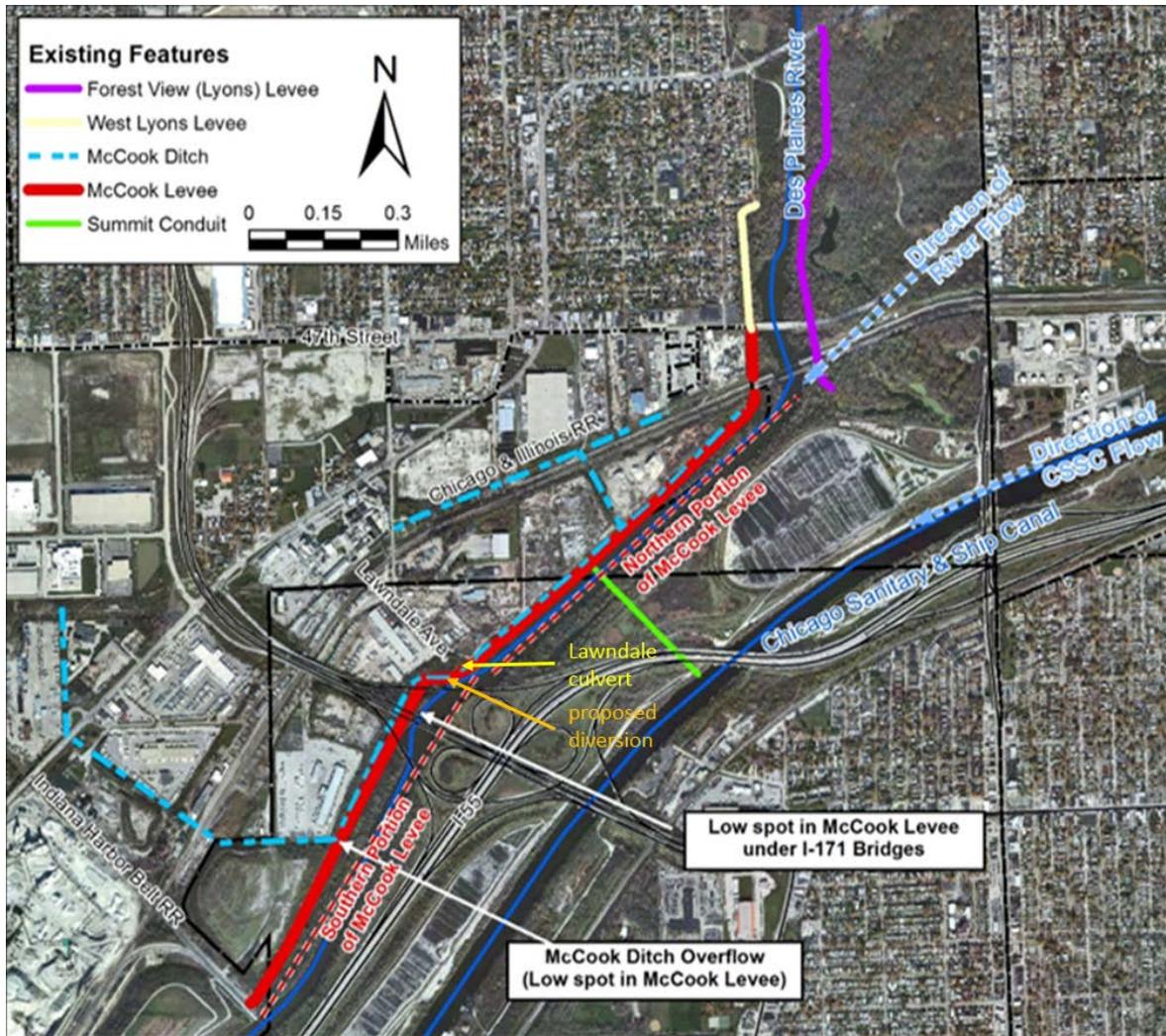


Figure 1 – Existing Features

There are also other overbank connections between McCook Ditch and the Des Plaines River which further complicate the hydraulics. When flows are high enough on the McCook Ditch they can overflow to the Des Plaines. Also, when the Des Plaines River is high, flows can go overbank into McCook Ditch. The later condition adds flow that goes through the Lawndale culvert and subsequently into the Summit Conduit and can cause flooding in the leveed interior area north of Lawndale. The later was the cause of the most extensive flooding in the April 2013 flood event. The original plan of blocking the Lawndale Culvert would reduce this flood risk on the interior, however, further hydraulic analysis showed that diverting all the McCook Ditch flow to the Des Plaines can cause adverse stage impacts. Figure 2 presents a closer look at the hydraulic features between Lawndale Avenue and the Summit Conduit.

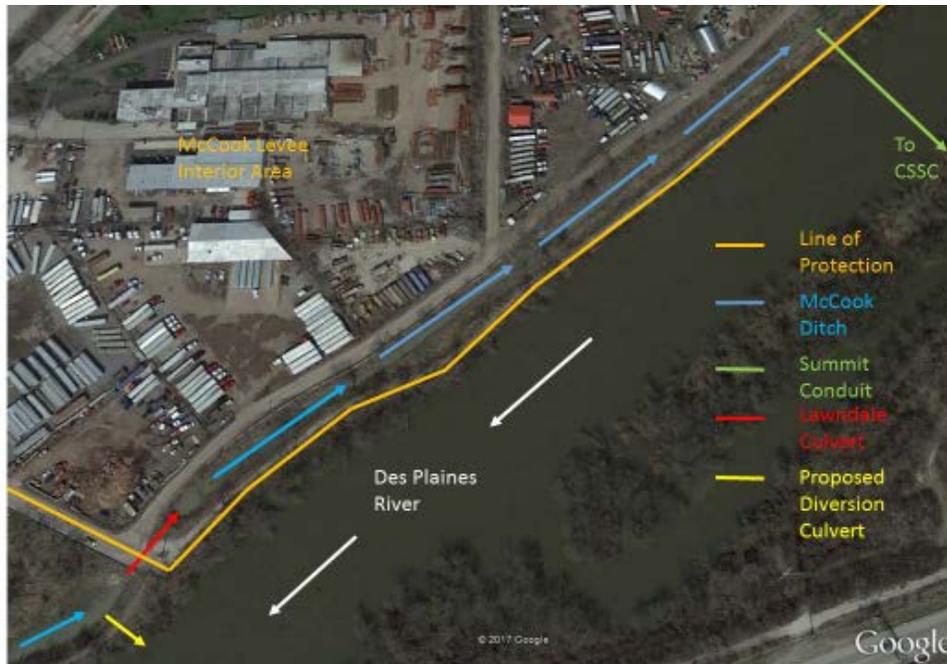


Figure 2 – Hydraulic Features from Lawndale Avenue to Summit Conduit

The modeling for the project was taken from the Lyons Levee project as noted above. The final project modeling was a steady state HEC-RAS model. The inflows were based on a flow frequency analysis. To analyze the stage impacts this model was used but converted to an unsteady flow model with added features that included the Lawndale culvert, the Summit Conduit, the northern and southern McCook Levee interior areas and the connection between the Des Plaines River and McCook Ditch.

For inflow hydrographs, synthetic event flow hydrographs at the Riverside gage location based on the Des Plaines River Phase II modeling were used and prorated to match the peak flows from the previous Lyons Levee study. A simple model of the McCook Ditch/Summit Conduit watershed that was developed for Lake Michigan Diversion was used for inflows for the interior areas.

When comparing the maximum stage profiles of the steady state and unsteady state modeling, the stage differences were around one tenth to two tenths of a foot lower on average with the unsteady model for the areas between Joliet Road and Lemont Road. This seems reasonable for this phase of the study and considering the many changes to the modeling, but should be looked into more closely during the next phase."

When comparing the existing condition model versus the proposed condition model, which included blocking off of the Lawndale culvert and diverting McCook Ditch to the Des Plaines, adverse stage impacts of approximately one tenth of a foot were seen. These stage impacts would not meet the State of Illinois regulatory requirements for approximately eight miles for the 100-year event.

To mitigate the stage impacts, a reduced size Lawndale culvert and a reduced size diversion were modeled until a balance of stage reductions and acceptable interior stages were met. This model included a 3.25 foot diameter reinforced concrete culvert for both the Lawndale and diversion culverts. Headwalls with grooved end of pipe at the upstream ends were assumed. The existing Lawndale culvert is a five foot diameter corrugated metal pipe with a headwall. This eliminated adverse stage impacts for all synthetic events (2, 5, 10, 25, 50 and 100-year). Figure 3 below presents 100 year stage and flow hydrographs near the peak for a location near the McCook overflow (see figure 1 above for location)

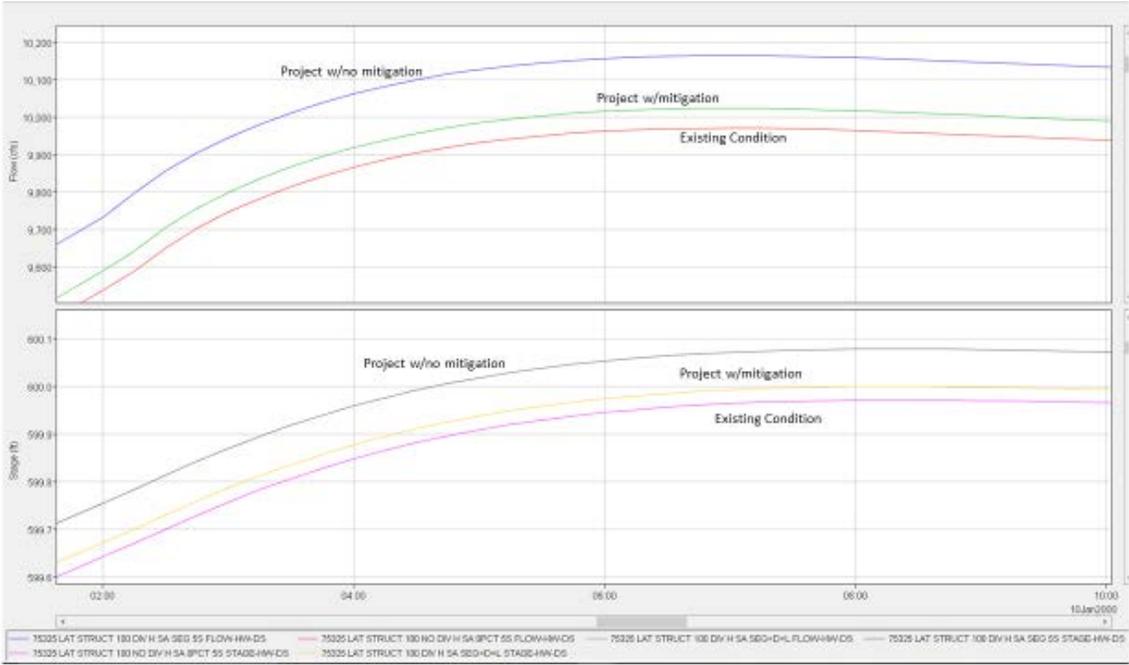


Figure 3 – Peak Stage and Flow near McCook Ditch Overflow

After discussion with the PDT team it was decided adding a sluice gate at Lawndale was the most practical solution. A partially open gate setting will mimic the reduced pipe size of the Lawndale culvert. It should be noted that a flapgate is needed on the diversion culvert to prevent flows from the Des Plaines River continually passing into the interior and into the Summit Conduit. Trash racks are recommended for both culverts. Additional survey information of the overflow areas is expected to be available between now and the plans and specification phase. In addition inflow hydrographs from more detailed modeling of the interior areas maybe be available. The project model will be updated with the best available information at that time if required. This could cause minor changes in pipe sizes/gate openings.

FLOOD WARNING

A recent flood warning plan was developed by the Chicago District for the Village of Forest View in 2014. It includes a new gage at the project location and includes the Riverside gage one and a half miles upstream. Due to the close proximity and similar overtopping

elevations, the flood warning plan and warning levels would also be applicable to the McCook/West Lyons Levee.

EROSION PROTECTION

Modeled velocities are very low on the Des Plaines along the McCook/West Lyons Levee and do not indicate the need for erosion protection, however, there is at least one small isolated eroded area along the existing sheet pile that was noted during the field investigation where erosion protection is recommended.

CLIMATE CHANGE IMPACTS

As outlined in ECB No. 2016-25, an investigation of the trends in the annual maximum flow gage data was performed to qualitatively assess impacts of climate change within the watershed using the USACE Climate Hydrology Assessment Tool. The drainage area for USGS gage 05532500, Des Plaines River at Riverside, IL, is 630 square miles. The gage has a period of record from 1914 to present day for various stream statistics including peak streamflow and daily discharge data.

For the Des Plaines River, [Figure 4](#) below shows the instantaneous peak streamflow obtained from the USGS website for gage closest to the project site. The figures depict a trend towards increasing annual peak streamflow for the period of record, as represented by the gage trendline. However, the p-value for the gage trendline is 0.000899, which is considered statistically significant. [Figure 5](#) displays the projected annual monthly trends from the USACE Climate Hydrology Assessment Tool.

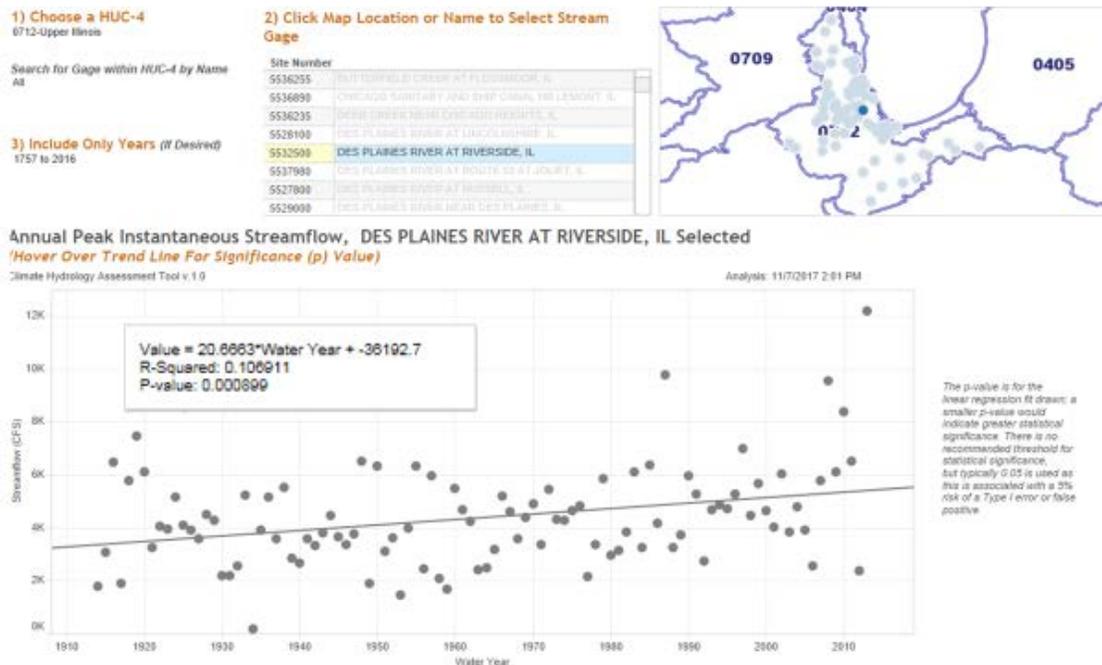


Figure 4. Peak Streamflow for Des Plaines River at Riverside, IL

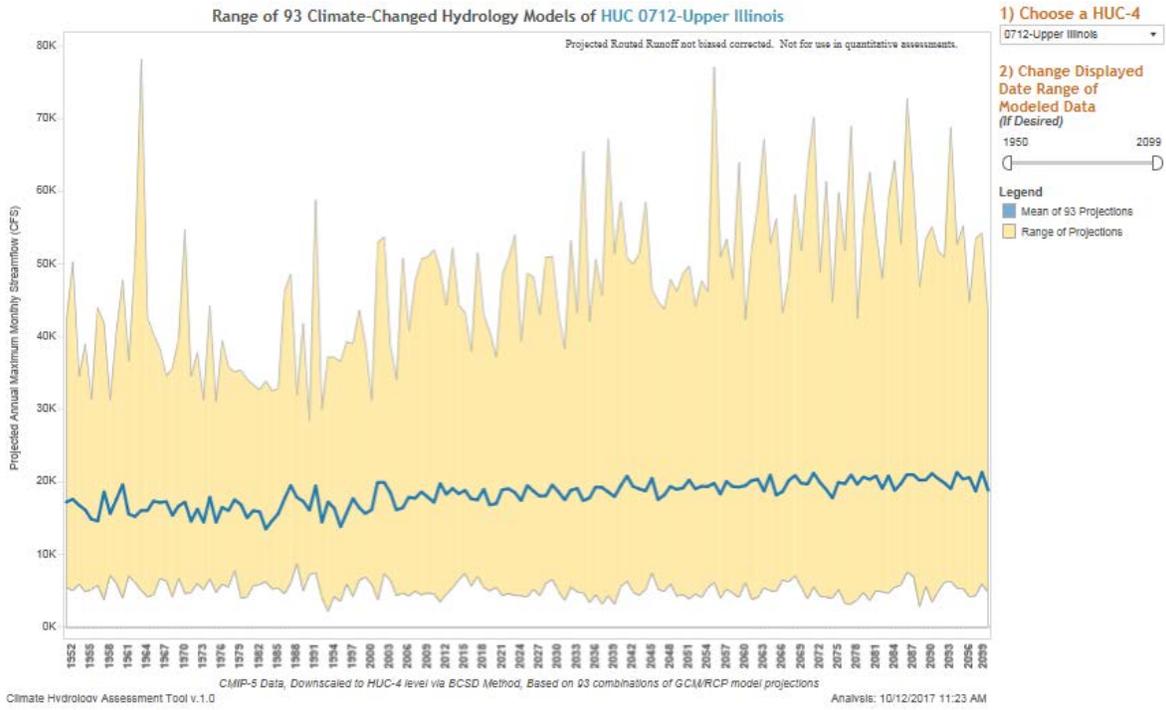


Figure 5. Project Annual Maximum Monthly Streamflow for HUC-4:0712-Upper Illinois

Using the web-based Nonstationary Detection Tool, the stream gage closest to the project site was investigated for non-stationarity (figure 6). For the USGS 05532500, Des Plaines River at Riverside, Illinois gage, several abrupt non-stationarities were detected, as shown in Figure 6. Non-stationarities were detected at three general change points within the period of record: 1920, 1981-1983 and 2006-2007. In 1920, only the Mood test for variance detected a non-stationarity, however, other statistical tests that target segment changes in variance/standard deviation and overall distribution detected a decrease in variance of 3,380,882 cfs squared and a decrease of standard deviation of 894 cfs (-38%). For the 1981-83 non-stationarity, the Lombard Wilcoxon, Pettit, and Mann-Whitney tests all concurred with regard to a general mean change point and the Energy Divisive Method detected a distributional change point, however, out of the other statistical tests that target segment changes in mean, variance/standard deviation and overall distribution, only a change in mean of 1502 cfs (38 % increase) was detected. For the 2006-2007 non-stationarity, the Mood test for variance and both the Kolmogorov-Smirnov and LePage distributional tests detected non-stationarities, in addition, for other statistical tests that target segment changes in variance/standard deviation and overall distribution detected an increase in variance of 9,161,268 cfs squared and an increase of standard deviation of 1,910 cfs (132%). In general these non-stationarities appear to be robust.

This is further supported when assessing monotonic trends within the record, as shown in [figure 7](#) (1914-2013) and figure 8 (1920-2013) which shows statistically significant positive trends in the data. Figure 9 presents the period 1981 to 2013 where no trend was detected. Figure 10 presents the period 2006 to 2013. A positive trend was detected, but was not statistically significant. The dataset shows definite non-stationarities and various statistical trends depending on the time period analyzed, but how much is attributable to urbanization and how much is attributable to climate is uncertain.

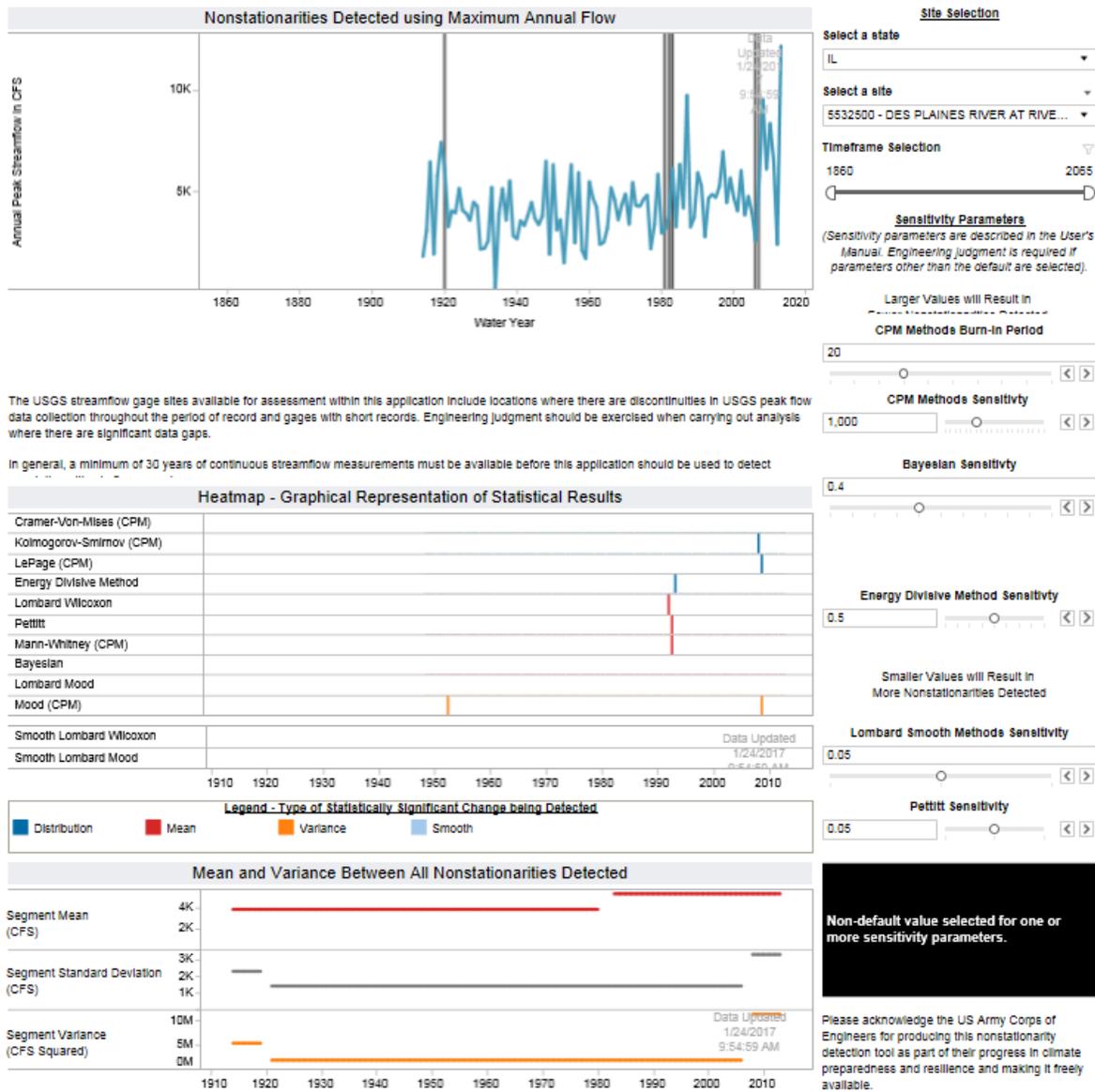
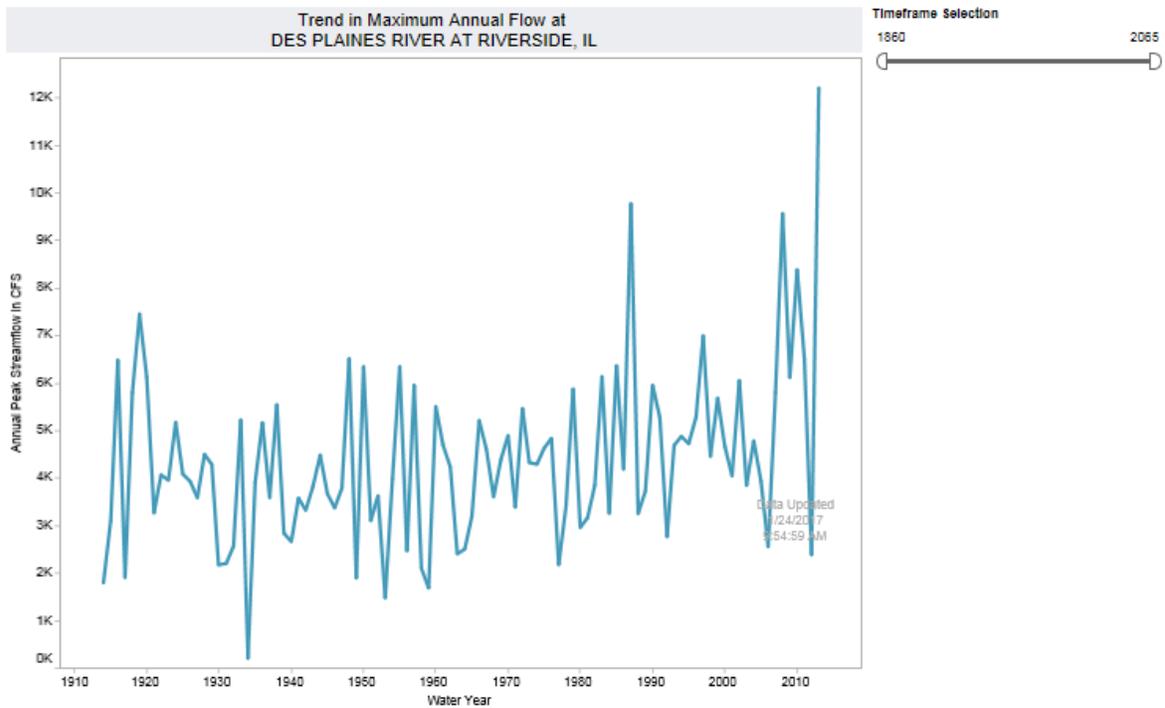


Figure 6. Nonstationary Analysis, Des Plaines River at Riverside, IL (1914)



Monotonic Trend Analysis

Is there a statistically significant trend?

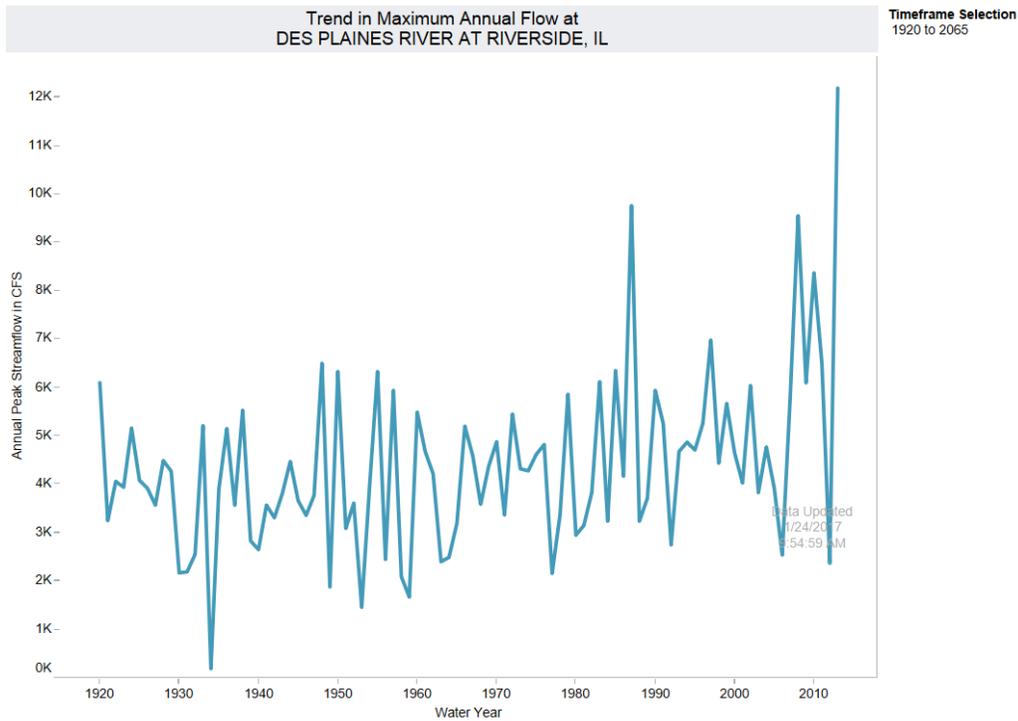
Yes, using the Mann-Kendall Test at the .05 level of significance.
 Yes, using the Spearman Rank Order Test at the .05 level of significance.

What type of trend was detected?

Using parametric statistical methods, a **positive trend** was detected.
 Using robust parametric statistical methods (Sen's Slope), a **positive trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Figure 7. Trend Analysis for Des Plaines River at Riverside, IL (1914-2013)



Monotonic Trend Analysis

Is there a statistically significant trend?

Yes, using the Mann-Kendall Test at the .05 level of significance.

Yes, using the Spearman Rank Order Test at the .05 level of significance.

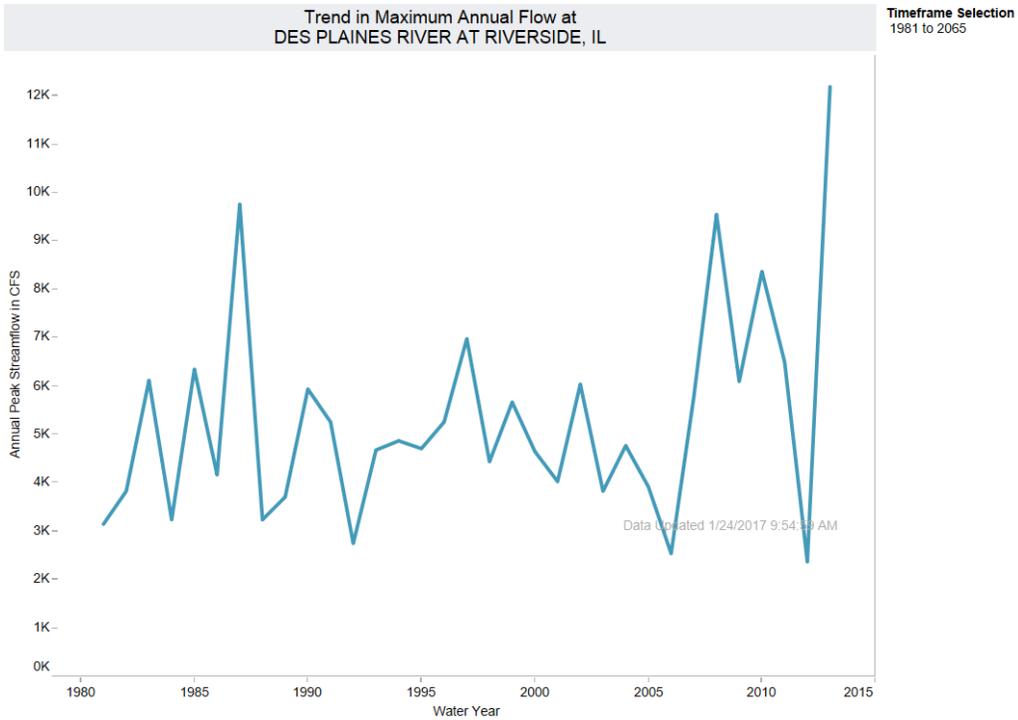
What type of trend was detected?

Using parametric statistical methods, **a positive trend** was detected.

Using robust parametric statistical methods (Sen's Slope), **a positive trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Figure 8. Trend Analysis for Des Plaines River at Riverside, IL (1920-2013)



Monotonic Trend Analysis

Is there a statistically significant trend?

No, using the Mann-Kendall Test at the .05 level of significance.

No, using the Spearman Rank Order Test at the .05 level of significance.

What type of trend was detected?

Using parametric statistical methods, **no trend** was detected.

Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Figure 9. Trend Analysis for Des Plaines River at Riverside, IL (1981-2013)

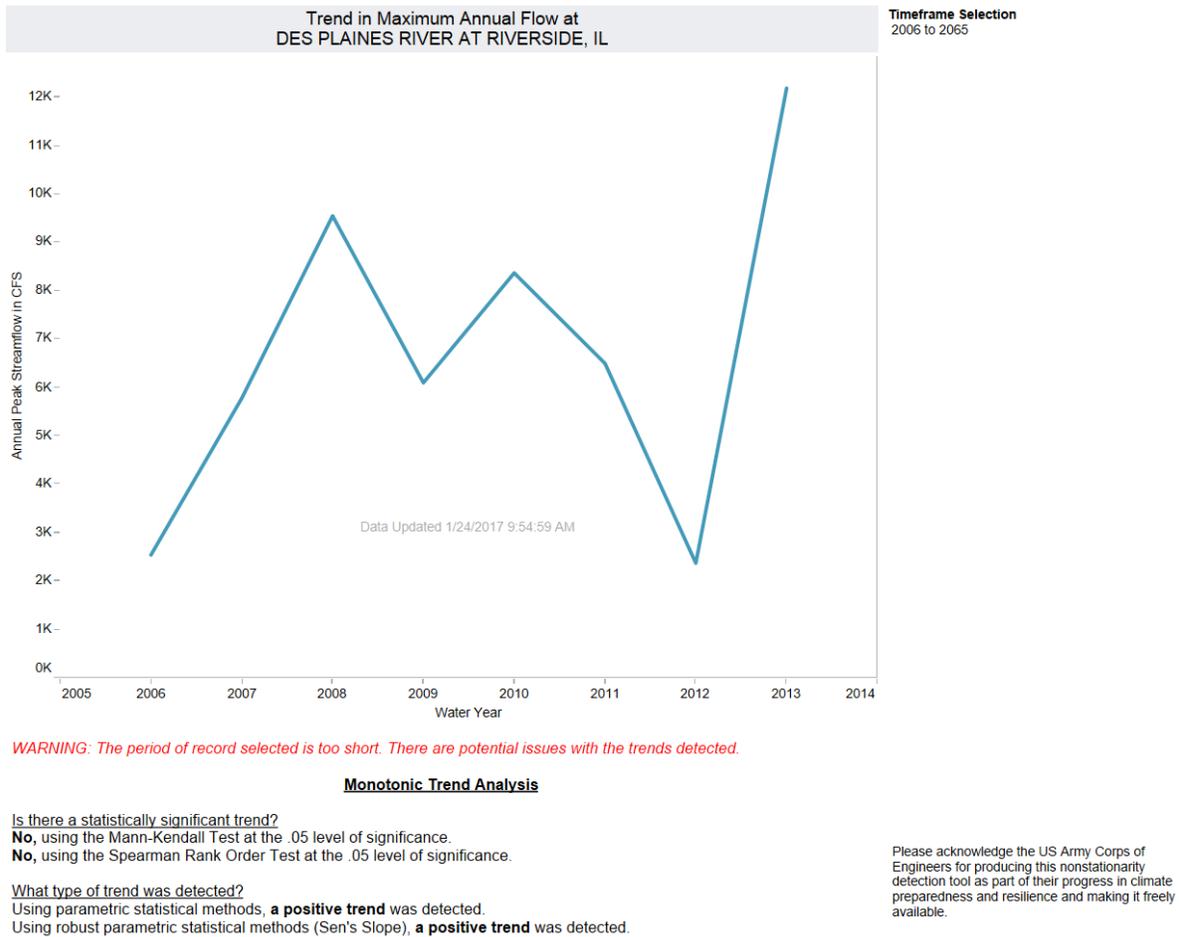


Figure 10. Trend Analysis for Des Plaines River at Riverside, IL (2006-2013)

Finally, the USACE online Vulnerability Assessment Tool was reviewed. For the Flood Risk Reduction business line, the project was not vulnerable to climate change for the Wet 2050 and Wet 2085 scenario/epoch combination within the project HUC-4 region as shown in [Figure 11](#) below. In addition, for the dry scenario there was a 3.82% change and for the wet scenario, an 8.00% change in the WOVA score for the HUC-4 Region with a Flood Risk Reduction business line as shown in [Figure 12](#) and [Figure 13](#) below.

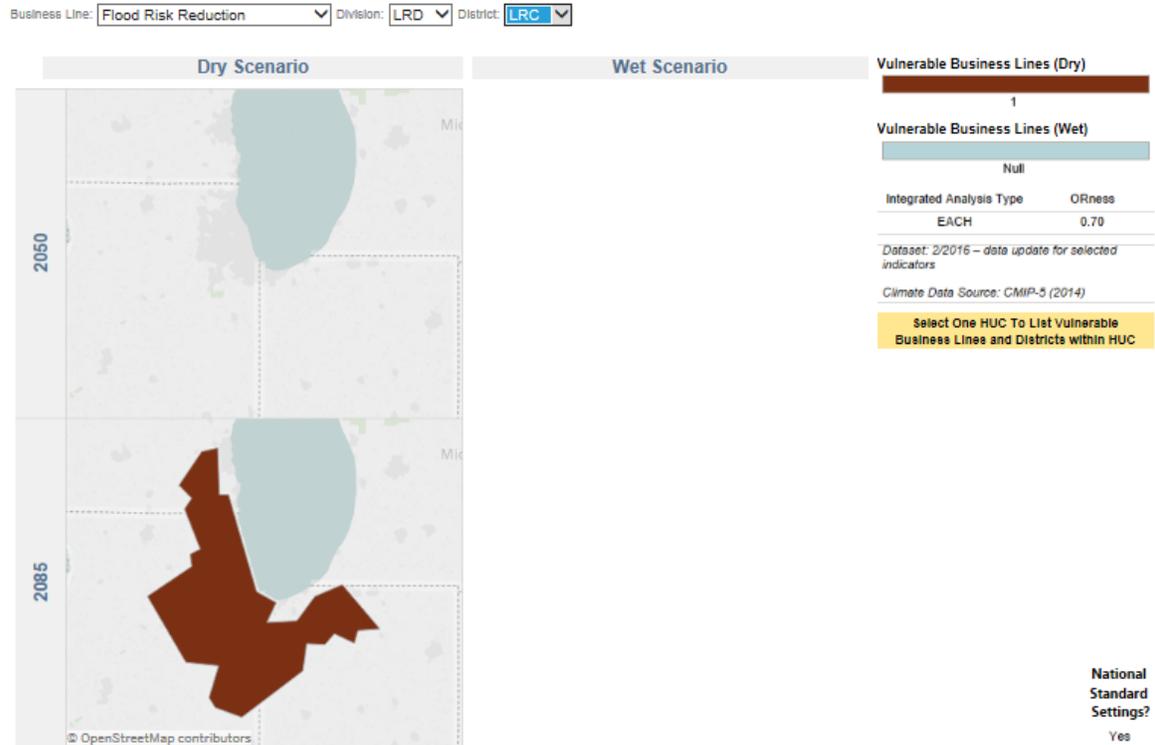


Figure 11. Vulnerability Assessment Tool HUC-4:0712-Upper Illinois

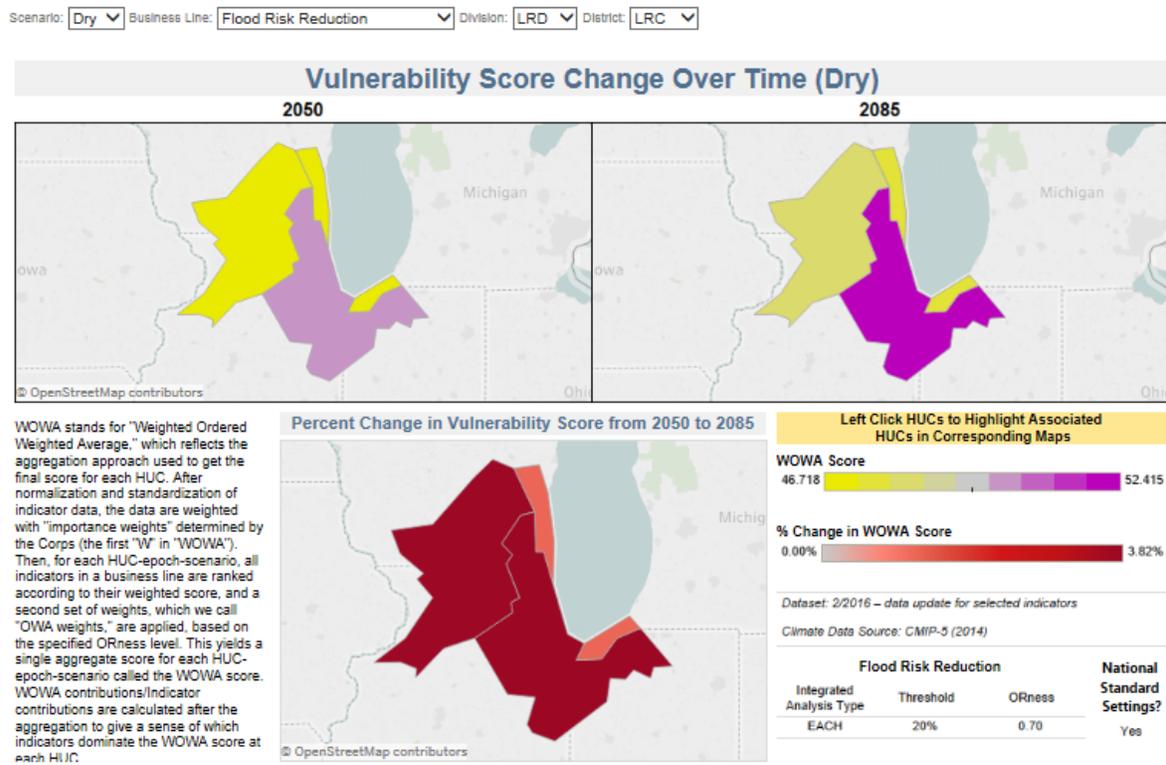


Figure 12. Vulnerability Score, Dry Scenario HUC-4:0712-Upper Illinois

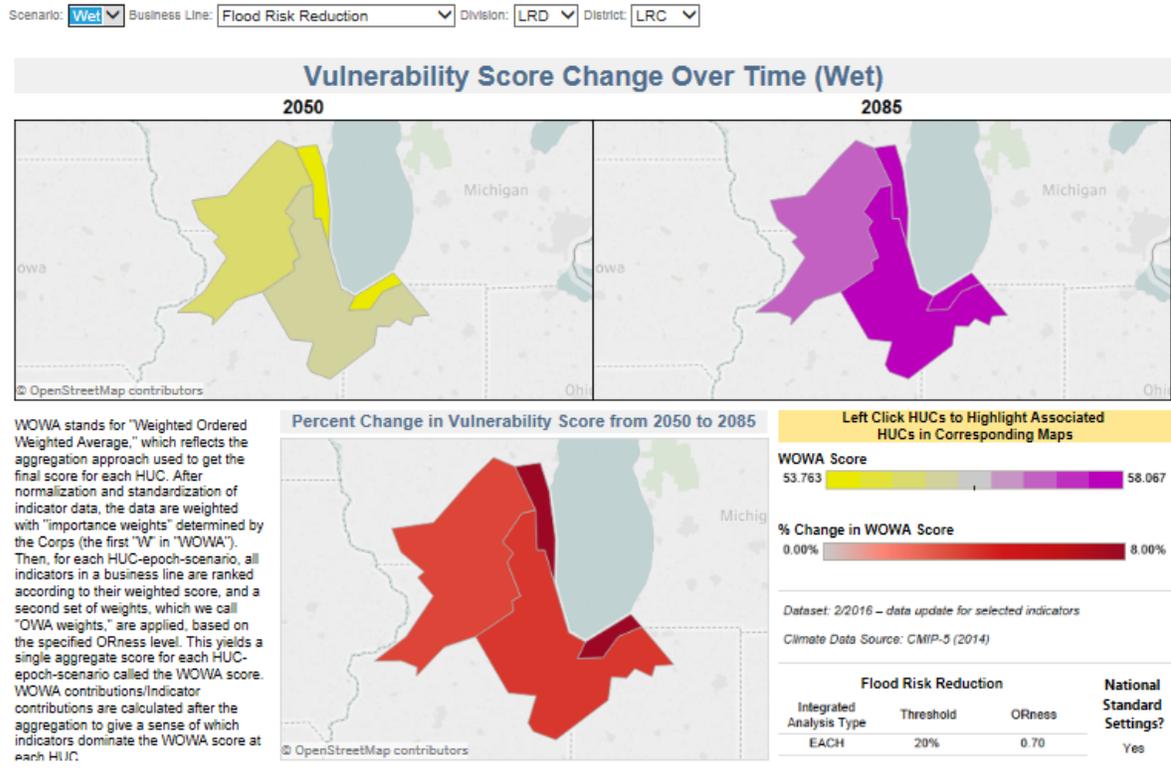


Figure 13. Vulnerability Score, Wet Scenario HUC-4:0712-Upper Illinois

Based on the tools utilized above, it appears that the project area could be significantly impacted by climate change. Since the levee crest elevation is limited to a specific elevation as described above in paragraph two under Superiority Analysis, it is not feasible to raise the levee higher in regard to climate change concerns.

Climate Change Literature Review

USACE is undertaking its climate change preparedness and resilience planning and implementation in consultation with internal and external experts using the best available — and actionable — climate science. As part of this effort, the USACE has developed concise reports summarizing observed and projected climate and hydrological patterns, at a HUC2 watershed scale cited in reputable peer-reviewed literature and authoritative national and regional reports. Trends are characterized in terms of climate threats to USACE business lines. The reports also provide context and linkage to other agency resources for climate resilience planning, such as downscaled climate data for sub-regions, and watershed vulnerability assessment tools.

The USACE literature review report focused on the Great Lakes Region was finalized in April, 2015 (USACE, April 2015) and the USACE literature review focused on the

Upper Mississippi Region was finalized in June, 2015 (USACE, June 2015). The Des Plaines River Watershed is located in the Upper Mississippi Region, but is within 18 miles of the Great Lakes Region, so climatic information from both literature reviews are relevant to the Des Plaines River Watershed. Figure 14, taken from the Great Lakes report, portrays the National Climate Assessment's (NCA) reported summary of the observed change in very heavy precipitation for the U.S., defined as the amount of precipitation falling during the heaviest 1% of all daily events. The NCA results indicate that 37% more precipitation is falling in the Great Lakes Region now as compared with the first half of the 20th century, and that the precipitation is concentrated in larger events.

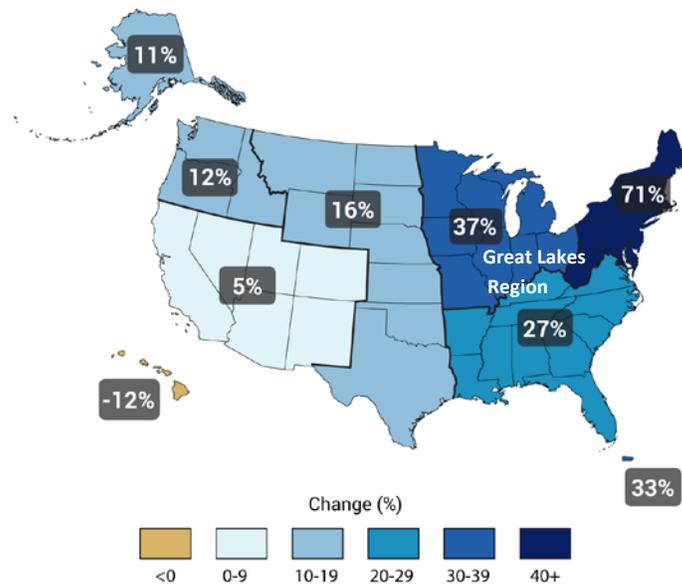


Figure 14 - Percent changes in precipitation falling in the heaviest 1% of events from 1958 to 2012 for each region (Walsh et al., 2014).

The USACE literature review document summarizes and consolidates several studies which have attempted to project future changes in hydrology. Based on a review of four studies, the projected total annual precipitation is expected to have a small increase when compared to the historic record and the precipitation extremes are projected to see a large increase. It is noted that consensus between the studies is low, and although most studies indicate an overall increase in observed average precipitation, there is variation in how these trends manifest both seasonally and geographically. Figures 15 and 16, taken from the USACE Climate Change and Hydrology Literature Reviews, summarizes observed and projected trends for various variables reviewed.

For both the Upper Mississippi and Great Lakes Regions, increase in temperatures have been observed and additional increases in temperature are predicted for the future. For the Great Lakes Region, “nearly all studies note an upward trend in average temperatures, but generally the observed change is small. Some studies note seasonal differences with possible cooling trends in fall or winter.” For the Upper Mississippi Region, increasing trends were more uniformly reported by multiple studies. There is a strong consensus within the literature that temperatures are projected to continue to increase over the next century.

Increases in streamflow have been observed and projections for streamflow rates are variable. For the Great Lakes region, trends in low and annual streamflow were variable, with slight increases observed at some gages but other gages showing no significant changes. “Significant uncertainty exists in projected runoff and streamflow, with some models projecting increases and other decreases. Changes in runoff and streamflow may also vary by season. Projections of water levels in the Great Lakes also have considerable uncertainty, but overall lake levels are expected to drop over the next century.” For the Upper Mississippi Region, “a strong consensus was found showing an upward trend in mean, low, and peak streamflow in the study region.” There is no clear consensus on projected streamflow trends, “with some studies projecting an increase in future streamflow (as a result of increased precipitation) in the study region, while others project a decrease in flows (a result of increased evapotranspiration).” In general, projections suggest increased flows are expected in the winter and spring and decreased flows expected in the summer.

PRIMARY VARIABLE	OBSERVED		PROJECTED	
	Trend	Literature Consensus (n)	Trend	Literature Consensus (n)
Temperature	↑	(7)	↑	(4)
Temperature MINIMUMS	↑	(1)	↑	(1)
Temperature MAXIMUMS	—	(1)	↑	(5)
Precipitation	↕	(7)	↑	(4)
Precipitation EXTREMES	↑	(5)	↑↑	(4)
Hydrology/ Streamflow	↑	(7)	↕	(3)

NOTE: Although most studies indicate an overall increase in observed average precipitation, there is variation both seasonally and geographically. There is considerable uncertainty in projected streamflows, with no clear consensus between studies

TREND SCALE

= Large Increase
 = Small Increase
 = No Change
 = Variable
 = Large Decrease
 = Small Decrease
 = No Literature

LITERATURE CONSENSUS SCALE

= All literature report similar trend
 = Low consensus
 = Majority report similar trends
 = No peer-reviewed literature available for review
(n) = number of relevant literature studies reviewed

Figure 15 – Great Lakes Region - Summary matrix of observed and projected climate trends and literary consensus. (USACE, 2015)

PRIMARY VARIABLE	OBSERVED		PROJECTED	
	Trend	Literature Consensus (n)	Trend	Literature Consensus (n)
 Temperature	↑	 (7)	↑↑	 (14)
 Temperature MINIMUMS	↑	 (3)	↑↑	 (4)
 Temperature MAXIMUMS	↓	 (3)	↑↑	 (6)
 Precipitation	↑↑	 (12)	↑	 (15)
 Precipitation EXTREMES	↑	 (2)	↑	 (10)
 Hydrology/ Streamflow	↑	 (10)	↕↑	 (15)

TREND SCALE

 = Large Increase
  = Small Increase
  = No Change
  = Variable
 = Large Decrease
  = Small Decrease
  = No Literature

LITERATURE CONSENSUS SCALE

 = All literature report similar trend
  = Low consensus
 = Majority report similar trends
  = No peer-reviewed literature available for review
(n) = number of relevant literature studies reviewed

Figure 16 – Upper Mississippi Region - Summary matrix of observed and projected climate trends and literary consensus. (USACE, 2015)

Based on the tools utilized above, it appears that the project area could be significantly impacted by climate change, however, since the levee crest elevation is limited to a specific elevation for the reasons described above in paragraph two under Superiority Analysis, it is not feasible at this time to raise the levee higher in regard to climate change concerns.

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1. EM 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies , Department of the Army, U.S. Army Corps of Engineers, 1 August 1996
2. EC 1110-2-6067 , USACE Process for the National Flood Insurance Program (NFIP) Levee System Evaluation , Department of the Army, U.S. Army Corps of Engineers, 31 August 2010
3. ETL 1110-2-299 "Overtopping of Flood Control Levees and Floodwalls" Department of the Army, U.S. Army Corps of Engineers, 22 August 1986
4. ECB No. 2017-15 "Managed Overtopping of Levee Systems" 14 July 2017
5. ECB No. 2016-25 "Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects" 16 September 2016

Attachment 1

LYONS LEVEE IMPROVEMENT PROJECT Hydrology & Hydraulics Technical Memorandum

Prepared for

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Submitted by:



MC Consulting Inc.

1301 West 22nd Street | Suite 215
Oak Brook, IL 60559

P 630.990.0922 | **F** 630.990.0927

www.mcconsultinginc.com

In Association with:

AECOM

AECOM Technical Services, Inc.

2IM Group ● Environmental Design International

Program Director:

Majid A. Chaudhry, Ph.D., P.E.

Project Manager/Lead Principal Engineer:

William J. Weaver, P.E.

River and Drainage Engineer:

John Morgan, P.E.

MC Consulting Inc.

AECOM Technical Services, Inc.

ZIM Group



William J. Weaver



Majid A. Chaudhry



MC Consulting Inc.
1301 West 22nd Street | Suite 215
Oak Brook, IL 60559
P 630.990.0922 | F 630.990.0927
www.mcconsultinginc.com

In Association with:

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- Appendix B – H&H Computer Model Input and Output Files

1. Introduction and Background

Lyons levee has been providing protection for the Village of Forest View against Des Plaines River flooding for the better part of the last 100 years. The levee is located beginning 250 feet downstream of Joliet Road on the east side of the river, and parallels the river for a distance of 3,900 feet to the south ending at the Metropolitan Water Reclamation District (MWRDGC) HASMA facility. The original levee construction began in 1892. The work was completed in stages and was completed in 1908. Figure 1-1 is a project vicinity map. Figure 1-2 illustrates the location of the levee on an aerial photograph.

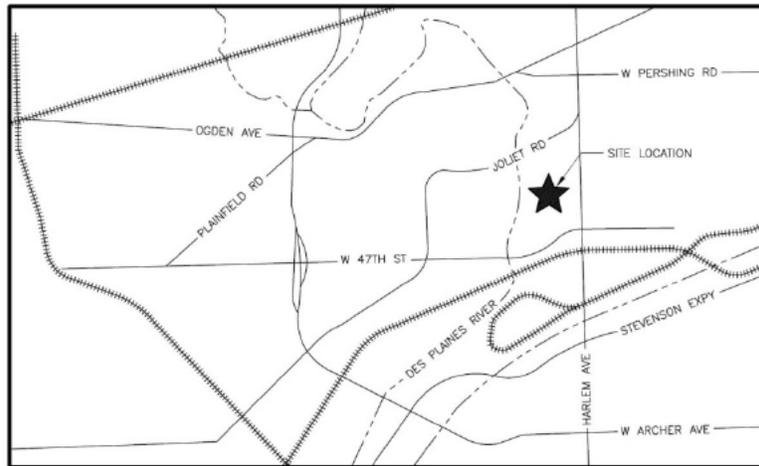


Figure 1-1 – Project Vicinity Map

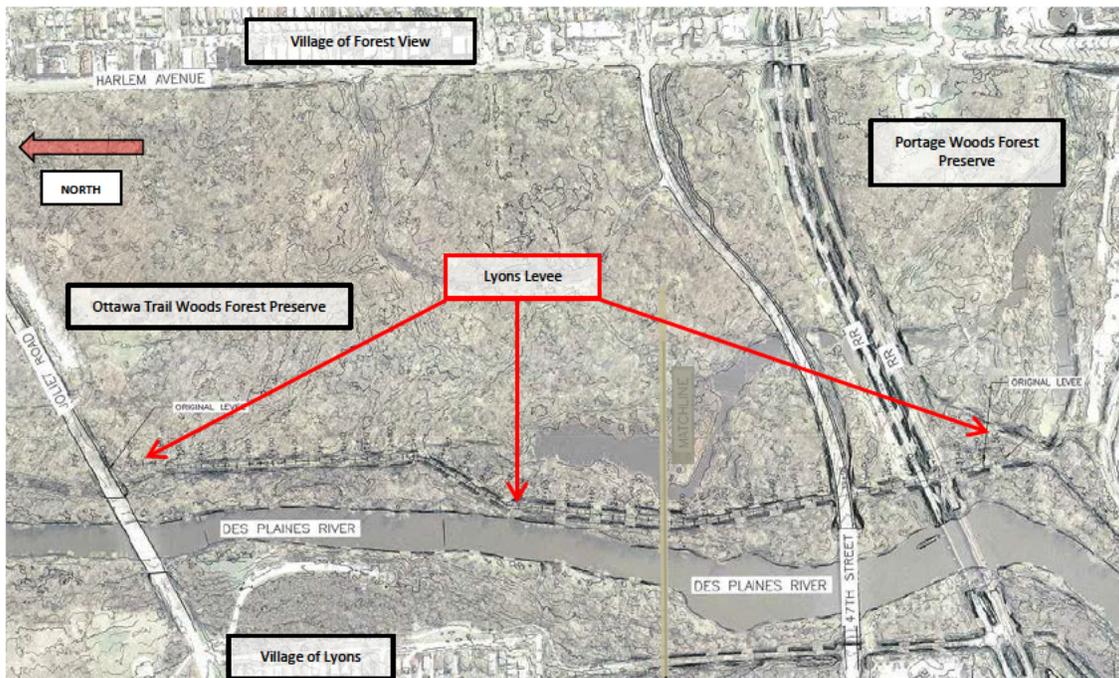


Figure 1-2 – Lyons Levee Location Map

The original levee was reported to have been constructed at elevation 602.0 at the downstream project limits and gradually increasing to 605.0 at the upstream limits at Joliet Road. Over the years, levee settlement, erosion, and foot traffic created low spots in the crest resulting in a minimum crest elevation of approximately 601.0 in several locations.

During April 2013, a flood event that produced the largest Des Plaines River flood discharge for the last 100 years as recorded at the Riverside flow gage caused overtopping of the levee. This event is estimated to have exceeded a flood recurrence interval of 100 years, and overtopped the levee by approximately 0.5 feet at three levee low spots. While some minor levee crest erosion occurred on the upland side, overall the levee survived the event in good shape. Figure 1-3 is a photograph of the levee during summer.



Figure 1-3 – Lyons Levee Crest

The Lyons Levee improvement project will upgrade the levee to improve flood protection. The design basis includes an evaluation of the April 2013 flood event to help in the understanding of flood risk and frequency at this location. The levee improvements will help reduce the future risk of flooding in the Village of Forest View.

This Hydrology and Hydraulics Technical Memorandum is prepared to summarize the Des Plaines River Hydrology and Hydraulics studies and Lyons Levee interior drainage studies completed to support the design basis analysis for the proposed levee improvements. This memorandum includes the following information prepared at the request of the U.S. Army Corps of Engineers – Chicago District:

- Evaluation of Des Plaines River flood elevations and flood frequency.
- Evaluate the various river flood models that have been developed for the Des Plaines River and assess the April 2013 flood event frequency. This assessment utilized high water data provided by MWRDGC, Forest View and Hancock Engineering.
- Assess the interior drainage system capacity and potential deficiencies upland of the existing levee.

Field surveys were completed to provide information needed to support the flood study. Land survey field work and archive searches were completed to develop base map information for the project. The field survey efforts included the following tasks:

- Establish horizontal and vertical control.
- General Site Topography –The base mapping relies on the existing Cook County LIDAR survey, topographic mapping and parcel shape files used to correlate existing parcel and right-of-way lines as obtained from the Cook County GIS. This data was obtained, reviewed for obvious discrepancies

and converted for use in AutoCad Civil 3D. Additional survey data collected by MWRDGC and the project team was used to enhance the LIDAR survey. This information forms the basis for enhancing the existing river hydraulic models used for the study and to support the interior drainage study.

- Existing levee survey - A centerline profile of the top of east levee was surveyed at a minimum of 100-foot intervals. Cross-sections of the levee were not surveyed in the field. The survey information supports the technical evaluations of levee improvement options. MWRDGC completed a survey of the east levee crest.
- River Cross sections – A hydrographic survey of the Des Plaines River in the project area was performed to develop cross sections of the river for use in updating hydraulic models.
- Interior drainage –localized hydraulic structure and other survey information needed to support the Interior Drainage evaluation has been completed. The survey includes information needed for the Harlem Ave underpass evaluation.
- Integrated base mapping incorporating all information obtained has been prepared.

2. Des Plaines River Flood Evaluation

The work described in this section was performed to evaluate the effectiveness/level of protection of the current levee and the levee profile required to protect Forest View from flooding during large flood events on the Des Plaines River. The scope of the project included evaluating the April 2013 flood event using the existing models. Hydrologic modeling of the Des Plaines River was not included in the scope of work. The existing DWP hydrology would be used when needed. In addition, a statistical analysis of the historical river flow records for the Riverside gage was completed to enhance the understanding of flood frequency for this site.

The existing hydraulic models were updated to include the additional detail required to prepare a preliminary design of the levee improvements. After completion of the initial model updates and modeling the April 2013 flood event, it was determined that additional calibration of the hydraulic model was needed to adequately represent this flood event.

2.1 Existing Des Plaines River Flood Profiles.

There are four previous studies of the Des Plaines River flood profiles in the vicinity of the Lyons Levee. A summary of the flood profiles and discharges for the 1% exceedance chance (100-yr) flood are presented in the following sections.

2.1.1 MWRDGC Lower Des Plaines River Detailed Watershed Plan (DWP). The DWP was prepared in February 2011 by Christopher B. Burke Engineering, Ltd. for MWRDGC. The DWP used HEC-HMS for the hydrologic modeling and unsteady flow HEC-RAS for the hydraulic modeling of the Des Plaines River and its tributaries in Cook County. The 1% exceedance chance flood stages at the Joliet Road and 47th Street bridges are approximately 603.1 and 602.7 feet NAVD88, respectively. The 1% exceedance chance discharges at Hoffman Dam and 47th Street Bridge are 9,670 and 9,600 cfs, respectively.

2.1.2 FEMA Flood Insurance Study. The FEMA Flood Insurance Study (FIS) for Cook County, IL dated August 2008 shows the 1% exceedance chance flood elevations at the Joliet Road and 47th Street Bridge are approximately 598.8 and 597.6 feet NAVD88, respectively. The 1% exceedance chance flood discharges at Hoffman Dam and 47th Street Bridge are 7,706 and 7,900 cfs, respectively. The flood profiles and discharges in the FEMA Flood Insurance Study are based on the Illinois Department of Transportation – Division of Water Resources Des Plaines River flood plain maps prepared in 1978. These maps were prepared using the TR-20 hydrologic model and WSP-2 hydraulic model developed by the NRCS for the Lower Des Plaines River flood control study performed in the 1970's.

2.1.3 U.S. Army Corps of Engineers Studies

2.1.3.1 Upper Des Plaines River Feasibility Study. The Chicago District Corps of Engineers released a draft report in September 2013 on the Flood Control Plan for the Upper Des Plaines River and its tributaries. This report does not cover the Lyons Levee

project area. The study ends upstream of Hoffman Dam. The study does publish discharges on the Des Plaines River from a discharge frequency analysis performed in January 2008. The 1% exceedance chance discharge at the USGS Riverside stream gage is 9,068 cfs.

2.1.3.2 Lyons Levee Assessment. The Corps of Engineers published a levee assessment of the Lyons Levee in June 2012. The 1% exceedance chance flood elevation at River Mile 42.3 according to this study is 601.58 feet NAVD88. This is near the 47th Street Bridge. The discharges used in this study were not published in the report. The Corps of Engineers estimated that the Lyons Levee would be overtopped during a 5% exceedance chance (20-yr) flood.

2.2 Updated Hydrologic Analysis

The Des Plaines River hydrology was updated for this study to establish a “Project Design Flood” that serves as the levee design basis for this project. This was done due to the large variance in the published flows for this site and the number of flood events where the discharge measured at the USGS Riverside stream gage exceeded flows published in the FEMA Flood Insurance Study (FIS) for the 1% exceedance chance discharge since 1978.

The annual peak discharges for the USGS Des Plaines River at Riverside stream gage were obtained from the USGS web site. The published data covers the period from WY 1914 to WY 2013. This record includes the April 2013 flood event that overtopped the Lyons Levee and flooded Forest View. The April 2013 flood discharge at Riverside was 12,200 cfs according to the USGS. A discharge frequency analysis of the annual peak discharges was performed using the Corps of Engineers software package HEC-SSP 2.0. A regional skew and the regional skew mean square error parameters used by the Corps of Engineers in their January 2008 discharge frequency analysis were used in this analysis. The regional skew was -0.16 and the regional skew MSE was 0.2. The results of this analysis are shown in Table 2-1 and Figure 2-1. This analysis provides the 100-year Project Design Flood (Design Flood) for the Lyons Levee improvement project.

Table 2-1 – Riverside Discharge Frequency Analysis

% Chance Exceedance	Computed Flow (cfs)	Expected Probability Flow (cfs)	5% Confidence Limit (cfs)	95% Confidence Limit (cfs)
0.2 (500-yr)	11,760	12,090	13,740	10,360
0.5 (200-yr)	10,620	10,850	12,260	9,440
1.0 (100-yr)	9,750	9,920	11,140	8,730
2.0 (50-yr)	8,870	8,980	10,030	8,010
5.0 (20-yr)	7,670	7,730	8,540	7,010
10.0 (10-yr)	6,720	6,760	7,390	6,200
20.0 (5-yr)	5,710	5,730	6,190	5,320
50.0 (2-yr)	4,130	4,130	4,420	3,870

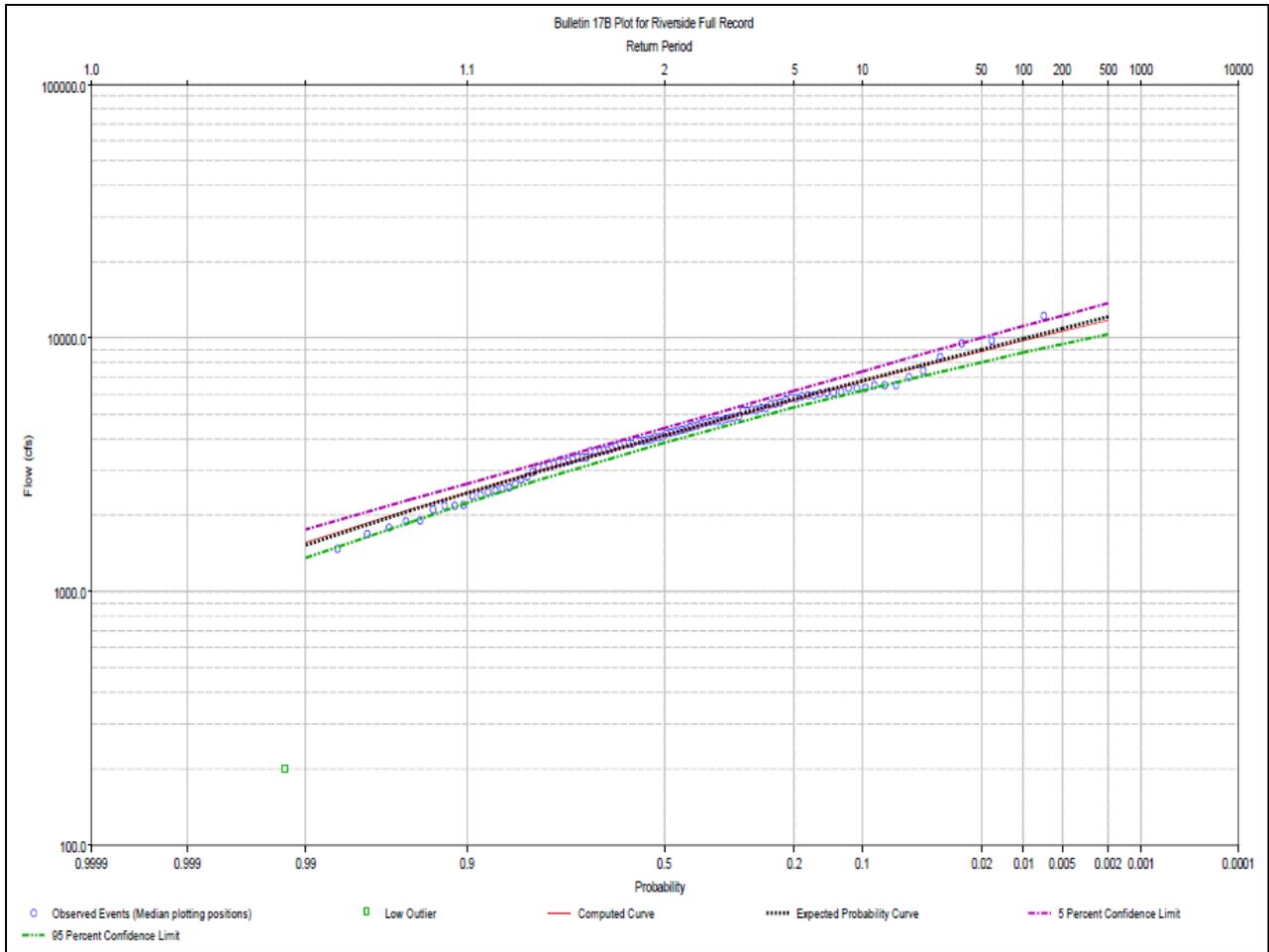


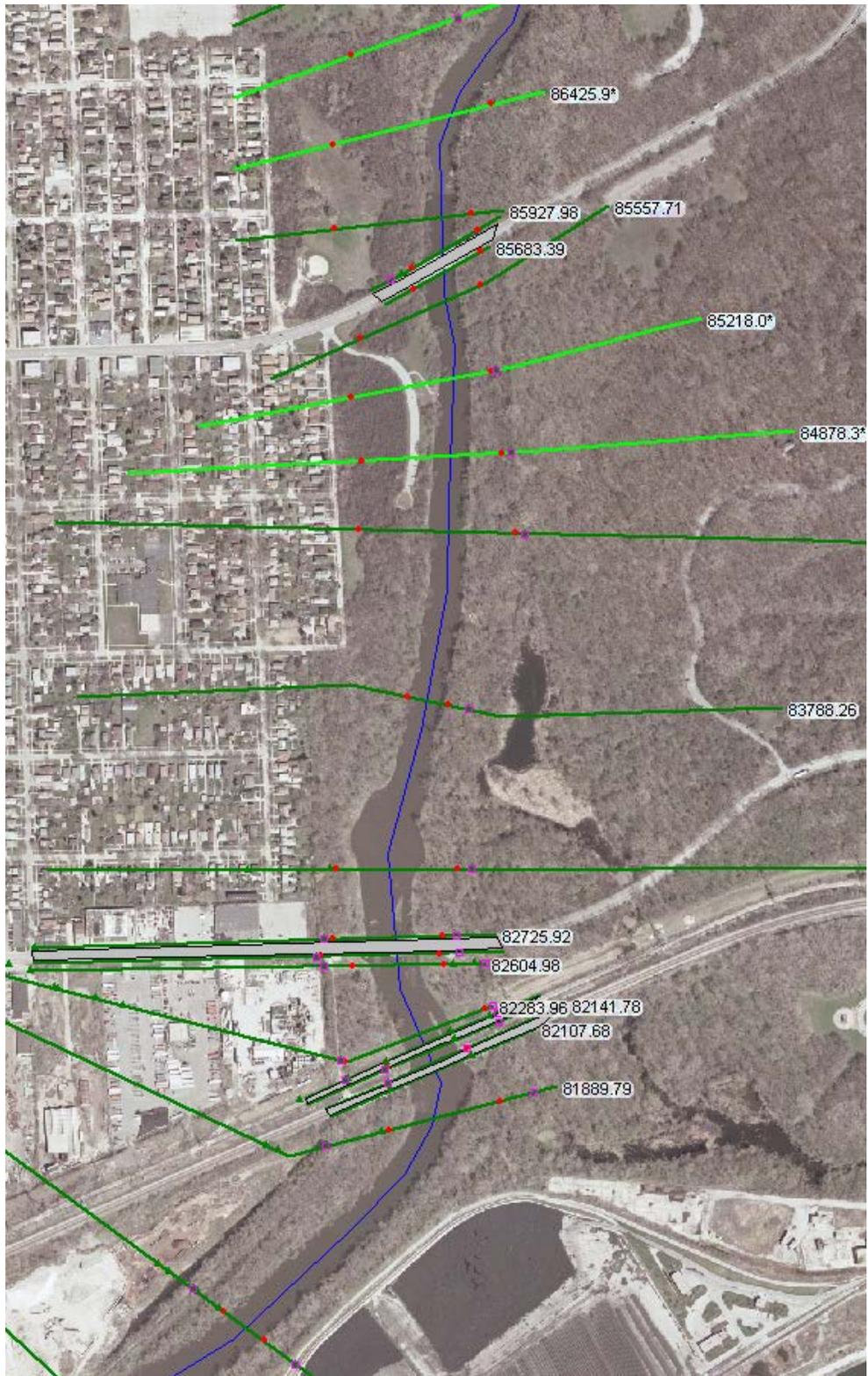
Figure 2-1 – Riverside Discharge Frequency Analysis

The 100-year Project Design Flood resulting from this analysis is based on a statistical analysis of 100 years of river gage records, which included a variety of watershed conditions that occurred between 1914 and 2013. The proposed levee improvements will incorporate a freeboard above the 100-year Project Design Flood. A readme file is provided for the HEC-SSP computer model in Appendix A. Computer model input and output for this analysis is provided in Appendix B in a file named: "DesPlainesRiver_SSP_Files".

2.3 Hydraulic Analysis

The DWP HEC-RAS model was modified for this study. The DWP model was truncated to represent the Des Plaines River from Hoffman Dam at the upstream boundary to the downstream boundary at the Cook County line.

2.3.1 Updates to the HEC-RAS Model. The unsteady flow HEC-RAS model developed for the Lower Des Plaines Detailed Watershed Plan was used as the base model for this study. The cross section locations for this HEC-RAS model are shown in Figure 2-2. The sections that have an asterisk (*) by the section numbers are interpolated and are illustrated in light green color.



Note: Section Numbers with an Asterisk (*) are interpolated.

Figure 2-2 – Lower Des Plaines River Detailed Watershed Plan Cross Section Locations

The DWP HEC-RAS model was updated with additional levee details and Des Plaines River geometry needed for the preliminary design. Additional cross sections were added to the model to replace interpolated cross sections in the vicinity of Lyons Levee. Cross sections were added to the model near Lyons Levee to better reflect where changes in the river and levee geometry occur. These new cross sections were developed using the Cook County bare earth LIDAR data and a bathymetric survey of the Des Plaines River performed for this study. The cross sections within the levee limits were truncated at the crest of the Lyons Levee.

Lateral structures were added to the model within the project limits to represent potential levee overtopping. The levee profile used for these lateral structures is based on a detailed levee profile surveyed for this project. The lateral structures in the model allow water overtopping of the levee if the river flood stage exceeds the levee crest. If this were to occur, the water is extracted from the river system causing a reduction in river flow downstream of Lyons Levee.

Lateral structures were also added to the model downstream of Willow Springs. These structures represent inter-basin flow that can occur between the Des Plaines River and Sanitary and Ship Canal during extreme river levels. These lateral structures were obtained from a model developed by the Corps of Engineers for the Great Lakes and Mississippi River Interbasin Study (GLMRIS). The GLMRIS HEC-RAS model was used in the Lyons Levee assessment report prepared by the Corps of Engineers. The updated cross section geometry for the updated model near Lyons Levee is shown in Figure 2-3.

A readme file is provided for the HEC-RAS computer model in Appendix A. Computer model input and output for this analysis is provided in Appendix B in a file named: "DesPlainesRiver_RAS_Files".

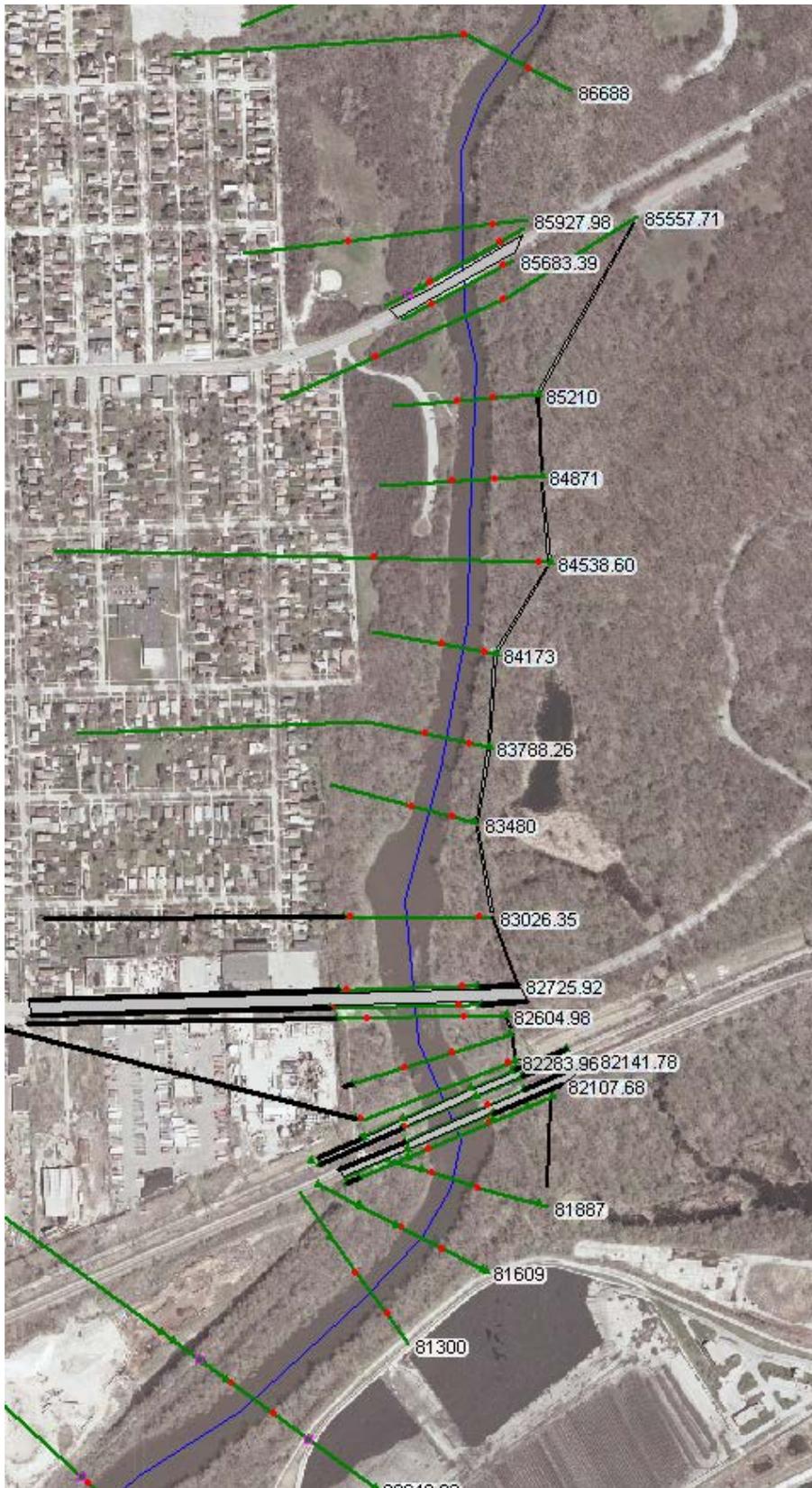


Figure 2-3 – Final Cross Section and Lateral Structure Locations

2.3.2 HEC-RAS Model Calibration. The HEC-RAS model developed for this project was run to simulate the April 2013 flood event to evaluate how well the model represents observed flood conditions during that event. The observed high water elevation at the USGS Riverside stream gage was 605.65 feet NAVD88. The Des Plaines River flood elevation near 47th Street was estimated based on the overtopping photos taken during the event and the existing levee profile survey, and observed high water locations reported by Brian Levy of the MWRDGC. The high water marks near 47th Street were estimated to be 601.70 feet NAVD88. The initial HECRAS model run for the April 2013 flood event produced elevations of 606.36 and 602.44 feet NAVD88 at Riverside and 47th Street, respectively. These elevations were significantly higher than the observed high water marks. We performed a calibration analysis to improve how the HEC-RAS model represents the larger event floods.

The calibration process included an update to the existing levee profile as described in Section 2.3.1. The primary calibration tool used included adjustments to the channel and overbank Manning’s n-values. The initial channel and overbank n-values ranged from 0.038 – 0.050 and 0.070 – 0.090, respectively.

The HEC-RAS calibration was performed using six recent historic storms from September 2008 to July 2014 using the unsteady flow option. A summary of the peak flows and observed high water marks for these events is provided in Table 2-2. The July 2014 flood event was included because of the recent addition of a USGS stage gage at this location. Three of the other five events have flows greater than the published FEMA FIS 1% exceedance flood.

Table 2-2 – Calibration Events

Event	Flow at Riverside (cfs)	Observed High Water Elevation at Riverside (ft NAVD88)	Observed High Water Elevation at 47 th Street (ft NAVD88)
September 2008	9,560	604.25	n/a
December 2008	6,110	602.30	n/a
July 2010	8,380	603.61	n/a
July 2011	6,510	602.84	n/a
April 2013	12,200	605.65	601.70
July 2014	3,920	600.97	596.13

In addition to the 47th Street high water elevation for the April 2013 flood event, the overtopping volume was estimated using the high water mark near the Forest View City Hall. The overtopping volume was estimated at 614 ac-ft below elevation 593.3 feet NAVD88.

The calibration process for the Des Plaines River HEC-RAS model included the adjustment of channel and overbank n-values to bring the computed stages closer to the observed stages. The channel and overbank n-values for the calibration runs downstream of 47th Street are 0.033 and

0.056, respectively. The final channel and overbank n values between 47th Street and the USGS Riverside stream gage are therefore also selected to be 0.045 and 0.056, respectively.

A summary of the calibration results is provided in Table 2-3. The HEC-RAS model estimates a total overtopping volume of 667.9 ac-ft compared to an approximate observed volume of 614.0 ac-ft. Based on the elevation differences in Table 2-3 and the differences in the overflow volumes, the model is considered to provide a reasonable calibration.

Table 2-3 – Calibration Results

Event	47 th Street Observed (ft NAVD)	47 th Street Computed (ft NAVD)	Difference (ft)	Riverside Observed (ft NAVD)	Riverside Computed (ft NAVD)	Difference (ft)
September 2008	n/a			604.25	604.74	0.49
December 2008	n/a			602.30	602.62	0.32
July 2010	n/a			603.61	604.09	0.48
July 2011	n/a			602.84	602.90	0.06
April 2013	601.70	601.67	-0.03	605.65	605.81	0.16
July 2014	596.13	595.85	-0.28	600.97	600.57	-0.40

2.3.3 Design Storm Profiles. The Project Design Flood profiles were computed using the calibrated HEC-RAS model in steady flow mode, and the “expected probability flows” developed as described in Section 2.2. We are unable to use the unsteady flow model for these events since we only have a hydrograph for the historic event from April 2013. Water surface profiles for the 10, 5, 2, and 1% exceedance events (10-, 20-, 50-, and 100yr recurrence intervals) were computed. In addition, the published FEMA FIS 1% exceedance chance flow of 7,900 cfs was used to estimate the flood profile using the calibrated HEC-RAS model. For the design storm profiles, overtopping of the levee was not included in the modeling. A summary of the design water surface profiles at Riverside, Joliet Road, 47th Street, Canadian National Railroad, BNSF Railroad, and the downstream end of the Lyons Levee are provided in Table 2-4. The water surface profiles are shown in Figure 2-4.

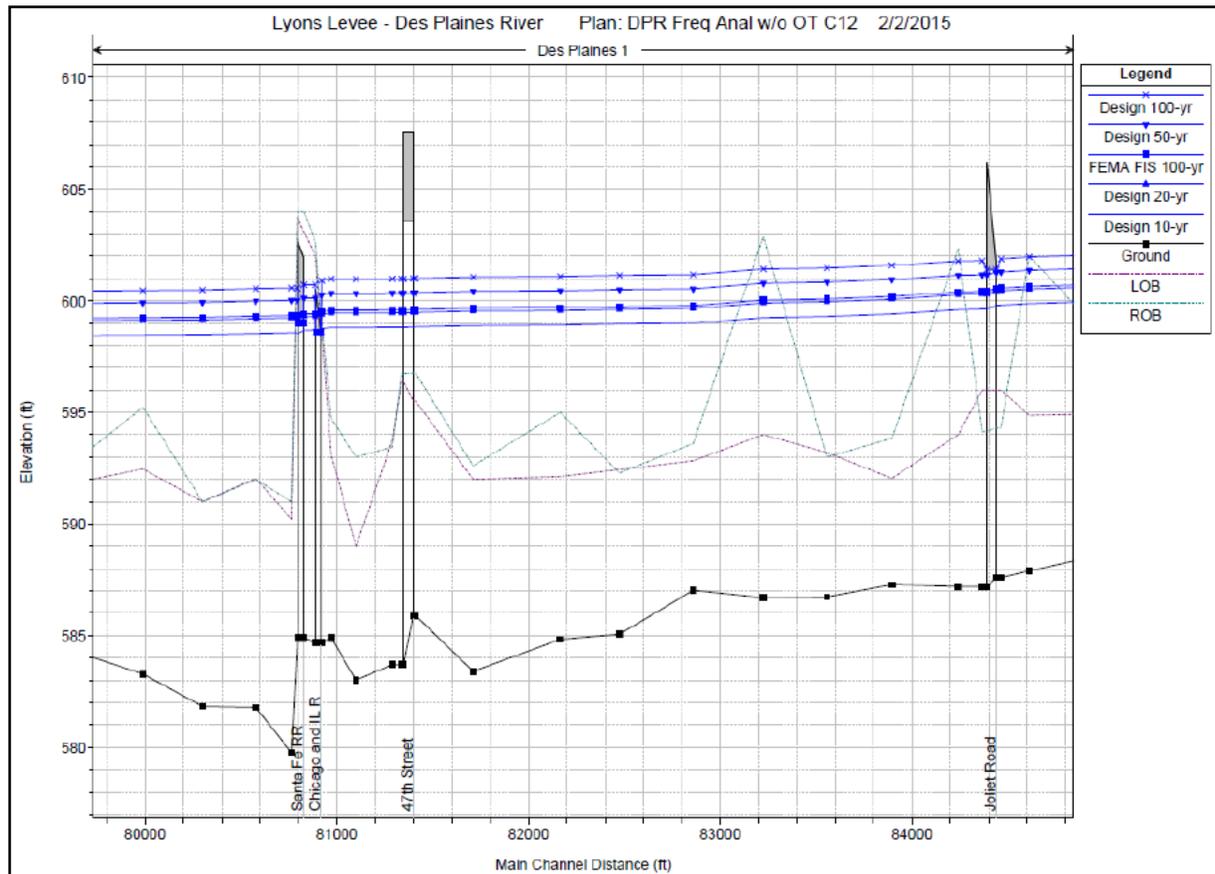
The calibrated HEC-RAS model with the FEMA FIS discharges produces higher water surface elevation estimates than the published FEMA flood profile. This is due in part to the change in computer models. The FEMA study used the WSP2 computer program. Furthermore, the FEMA model downstream boundary at 47th Street appears to be set too low as confirmed in the calibration analysis completed for the April 2013 event for this project. The HEC-RAS computed profile is approximately 1.8 feet higher at Joliet Road and 2 feet higher at 47th Street.

Table 2-4 –Water Surface Profile Summary

Location	Flood Elevations using HECRAS Model Calibrated to April 2013 Flood Event				
	% Exceedance (in any given year)				**FEMA FIS 100-yr event
	10 % (10-yr event)	5 % (20-yr event)	2 % (50-yr event)	*1% (100-yr event)	
Downstream Levee Limit	598.53	599.20	599.99	600.55	599.31
BNSF RR	598.68	599.30	600.12	600.72	599.41
Canadian National RR	598.75	599.39	600.27	600.91	599.52
47 th Street	598.81	599.46	600.35	600.98	599.59
Joliet Road	599.80	600.45	601.29	601.88	600.57
USGS Riverside Stream Gage	602.86	603.45	604.14	604.62	603.55

*100-year Project Design Flood

**100-year Profile using FEMA Discharge in HECRAS model.



1 in Horiz. = 700 ft 1 in Vert. = 6 ft

*The 100 year Project Design Flood is defined in Section 2.2.
 LOB and ROB refer to left river overbank and right river overbank, respectively.

Figure 2-4 – Design Storm Water Surface Profiles

2.3.4 Urbanization Impact on Project Design Flood. The 100 –year Project Design Flood discharge developed as the design basis for Lyons levee improvements is based on an analysis of a 100 year river gage record as summarized in Section 2.2. In most respects, having such a long gage record is ideal and helps to reduce uncertainties that can result from analyses of shorter records. However, it is possible that a long gage record could potentially mask the effects of urbanization on flood peaks. In some cases urbanization can cause changes in rainfall frequency and watershed rainfall-runoff characteristics among other unknown factors on Des Plaines River discharges. Factors that can offset the influences of urbanization include stormwater and floodway regulations that have been implemented in recent decades and flood control project implementation by government entities.

A sensitivity analysis was performed to evaluate this phenomenon as it may apply to the Des Plaines River flood study presented in this report. The analysis includes a flood discharge frequency evaluation for a shorter and more recent time period at the Riverside gage than the 100 year record used to develop the 100-year Project Design Flood discharge. This analysis used the HEC-SSP computer program to analyze a 40 year gage record extending from 1974 through 2013. The results are compared with the 100 year gage record analysis to see if there has been a discernable change in the discharge frequency on the Des Plaines River at Riverside.

Results of this analysis for two gage record time periods is summarized in the following table. The 1% chance exceedance flow at Riverside is 9,920 cfs for the entire 100 year period of record, and 11,500 cfs for a record that excludes all data except for the last 40 years.

Expected Flow at Des Plaines River at Riverside								
Period	50%	20%	10%	5%	2%	1%	0.5%	0.2%
Period of Record 1914 to 2013	4,130	5,730	6,760	7,730	8,980	9,920	10,850	12,090
1974 to 2013	4,770	6,580	7,770	8,900	10,380	11,500	12,640	14,200

The shorter record requires more extrapolation to estimate the 100-yr flow than the 100 year record. Furthermore, one or more large flood events can significantly skew the magnitude of the 1% flow, when a shorter period of record is considered. There are a number of factors that come into play regarding differences in the discharge frequency curves. These can include a short record that can contain abnormally high measured flows, urbanization, increased rainfall due to climate change, flood control improvements upstream, and other issues.

The results of this analysis indicate that while the differences in flood discharges for a given gage record period can result in different flows, the approach taken to establish project design

conditions for the Lyons levee project are reasonable. The larger 100 year flow for the arbitrarily shorter gage record analysis reflects a 15% increase compared to the Project Design Flood which is based on a 100 year record. The proposed levee design will include significant freeboard above the Project Design Flood with the new levee crest above the flood profile for both of the gage period analyses summarized above. Furthermore, the proposed levee crest will be constructed above the flood of record at this gage which occurred during 2013.

3. Interior Drainage Evaluation

The existing drainage system located between Lyons Levee and Harlem Avenue was investigated to evaluate if this system has caused flood damages. The existing drainage system is bounded by Harlem Avenue on the east, the Lyons Levee on the west, Joliet Road on the north, and the MWRDGC Harlem Avenue Solids Management Area (HASMA) on the south. The general direction of the flow is from Harlem Avenue and Joliet Road to the south and west to a series of culverts under 47th Street and the Canadian National and BNSF Railroads. After passing through the railroad culverts the flow turns to the south and east to two small culverts under Harlem Avenue near the HASMA site. The discharge from these culverts is intercepted by the Harlem Avenue storm sewer and conveyed to the Sanitary and Ship Canal. See Figure 3-1 for a general overview of the interior drainage system.

The only known drainage problem related to the drainage system behind the levee is the periodic flooding that has occurred at the Harlem Avenue underpass south of 47th Street. The Illinois Department of Transportation investigated the flooding problems at the Harlem Avenue underpass under the Canadian National and BNSF Railroad tracks. The Location Drainage Technical Memorandum describing the existing problems and several alternative solutions was prepared by Hampton, Lenzini and Renwick, Inc. in November 2013. Alternative 3A was recommended in the report. This alternative consists of replacing the existing 30" and 36" sewers with new sewers with 42" and 48" sizes.



Figure 3-1 – Interior Drainage System Overview

3.1 Existing Interior Drainage System

To evaluate the existing interior drainage system, a HEC-HMS and HEC-RAS models were developed. The hydrology was modeled using HEC-HMS. An unsteady flow HEC-RAS model was developed to model the major components of the interior drainage system.

3.2 HEC-HMS Hydrologic Model Development

The interior drainage system was subdivided into 4 sub-basins shown in Figure 3-1. These correspond to the major drainage features in the interior drainage system. Sub-basin 47th West is tributary to the culvert under 47th Street. Sub-basin 47th East is the area tributary to the ditches along Harlem Avenue and 47th Street. The Railroad sub-basin is the area tributary to the culverts between 47th Street and the Railroad culverts. Sub-basin Harlem represents the area between the railroads and Harlem Avenue that drains to the culverts under Harlem Avenue. The primary land use within the interior drainage area is forest that belongs to the Forest Preserve District of Cook County. A summary of the drainage basin parameters is shown in Table 3-1. The total interior drainage area is 152.3 acres.

Table 3-1 – Summary of Subbasin Parameters

Subbasin	Area (ac)	Curve Number	Time of Concentration (min)
47 th East	27.49	75	70
47 th West	78.18	71	107
Railroad	21.24	82	59
Harlem	25.39	83	41

The NRCS curve number and unit hydrograph methods were used in modeling the runoff from these sub-basins. The interior drainage area was modeled using a critical duration storm methodology. The model was run for the 99, 50, 20, 10, 4, 2, and 1% exceedance frequencies (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr recurrence intervals, respectively) and the 1-, 2-, 3-, 6-, 12-, and 24 hour duration storms. The HEC-HMS model was used to generate the runoff hydrographs that would be input to the unsteady flow HEC-RAS model.

A readme file is provided for the HEC-HMS computer model in Appendix A. Computer model input and output for this analysis is provided in Appendix B in a file named: "LyonsLevee_HMS_Files".

3.3 HEC-RAS Hydraulic Model Development

HEC-RAS was selected for modeling the interior drainage system to be compatible with the Des Plaines River system so that the two models could be combined if necessary to model the impacts of any overtopping flows on the interior drainage system. The unsteady flow option of HEC-RAS was used to capture the impact of the existing ponds and restrictive culverts on the interior drainage flood elevations.

The HEC-RAS model consists of three storage areas representing the existing ponds in the system and three river reaches connecting the ponds and representing the downstream outlet channel. Within the three river reaches there are four culverts representing the roadway crossings under 47th Street, CN Railroad, BNSF Railroad, and Harlem Avenue. In addition there are two inline structures representing existing beaver dams within the Forest Preserve. The beaver dams are in the downstream reach just upstream of Harlem Avenue. See Figure 3-2 for the HEC-RAS model extents.

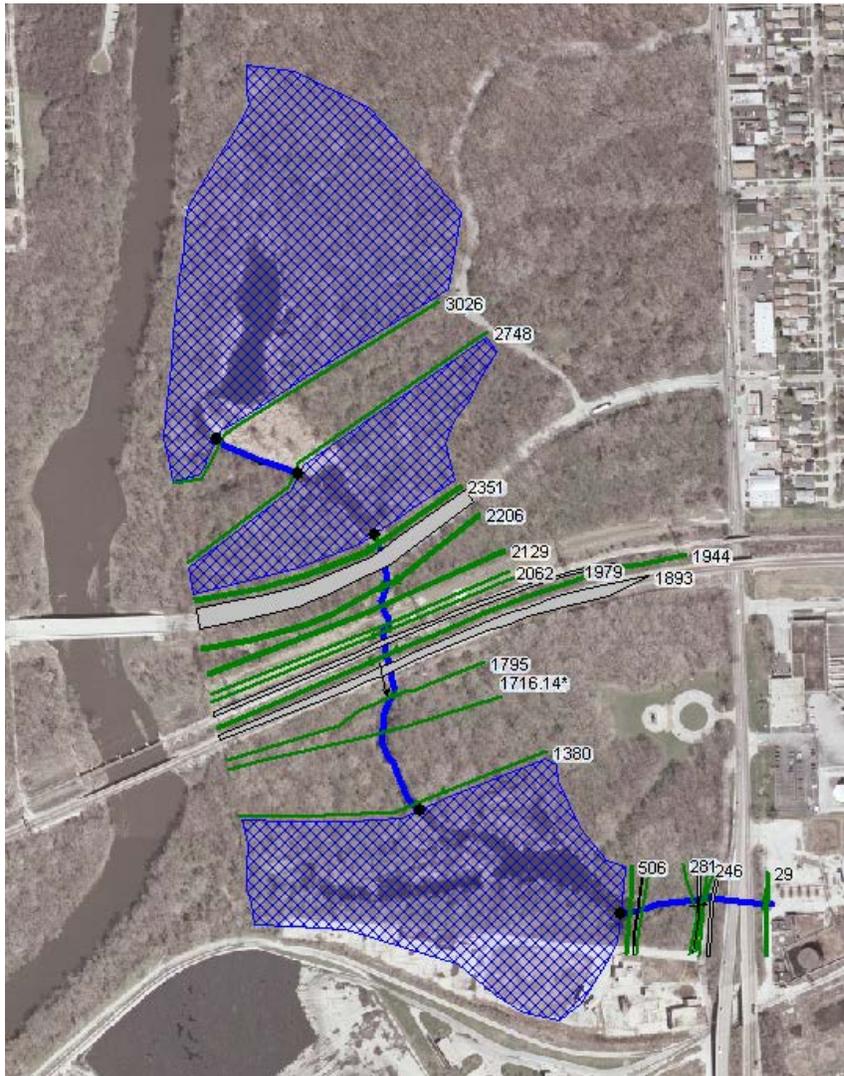


Figure 3-2 – HEC-RAS Model Extents

The input data for the 23 cross sections, 4 culverts, 2 in-line structures, and 3 ponds were developed using HEC-GeoRAS. The data sources were field survey conducted for this study and the Cook County bare earth LIDAR point data provided by MWRDGC. The survey data was used to define the channel portion of each cross section while the overbank portions of the cross sections were based on the LIDAR data.

Historic high water information was not available for calibration. The model inputs representing land cover in the channel and overbank were developed based on engineering references and experience with similar sites. Interpolated cross sections were used in portions of the model to improve model stability. The downstream discharge from the interior drainage system compared favorably with the flows developed by IDOT in evaluating the Harlem Avenue storm sewer improvements to alleviate flooding in the Harlem Avenue underpass at the railroad tracks. The 2% exceedance chance critical duration flow from the interior drainage analysis was 42 cfs. The IDOT report used two methods to determine the flow from this area. The flows in the IDOT report were 58 cfs using the StreamStats computer program, and 43 cfs using the NRCS methods for the 2% exceedance chance 1-hr duration storm.

3.4 Existing Conditions Results

The HEC-RAS model results do not identify any flood problems within the interior drainage system. The flooding identified by the modeling is contained within the Forest Preserve District of Cook County property. The flood elevations do not cause impact to the roads within the interior drainage boundaries.

The critical duration analysis identified the 6-hour duration storm as generally providing the highest flood levels within the interior drainage area. A summary of the peak high water levels at 47th Street, the CN Railroad, the pond in the Forest Preserve District south of the Railroad Tracks and upstream of Harlem Avenue are shown in Table 3-2.

Table 3-2 – Summary of Interior Drainage Flood Levels

Location	10% Exceedance Chance (ft NAVD)	2% Exceedance Chance (ft NAVD)	1% Exceedance Chance (ft NAVD)
47 th Street (upstream face)	588.8	589.7	590.3
CN Railroad (upstream face)	588.5	589.6	590.2
Pond	587.1	588.2	588.7
Harlem Avenue (upstream face)	587.0	588.2	588.7

The lowest pavement elevations outside of the underpass which would be impacted by the interior drainage flooding were in the vicinity of the 47th Street and Harlem Avenue intersection. The pavement elevations in this area are between 591 and 592 ft NAVD based on the contour mapping. The interior drainage high water levels near 47th Street can back up into this area via a storm sewer and roadside ditches along the south side of 47th Street. A readme file is provided for the interior drainage HEC-RAS computer model in Appendix A. Computer model input and output for this analysis is provided in Appendix B in a file named: "LyonsLevee_RAS_Files".

Based on the interior drainage analysis, the existing interior drainage system is capable of handling the local runoff behind the levee without causing flood damages or highway delays due to water on the pavement.

4. Proposed Levee Improvement Plan

The Lyons Levee Improvement project seeks to reduce the Des Plaines River flooding risk in the Forest View area. The recommended flood risk reduction measure would provide flood protection for events up to the 100-year flood and meet Federal, State and local design requirements. The limits of levee improvements under consideration begin just south of Joliet Road and extend downstream for a distance of approximately 1,050 feet south of 47th Street, a total distance of 4,327 feet. This Section summarizes the design basis for the selected option.

The proposed plan includes a reconstruction of the existing levee. The plan includes the following features:

- The levee restoration will build on the existing levee footprint and is located within the same corridor for its entire length. The levee crest will be raised at key locations and the slopes will be widened where necessary to provide improved levee geometry that will enhance stability and seepage control. Reconstruction of the existing levee will be accomplished in accordance with design standards generally in accordance with the requirements of the United States Army Corps of Engineers engineering manual titled “Design and Construction of Levees” (EM 1110-2-1913) published April 30, 2000.
- All trees present on the levee crest and slope will be removed including roots down to a half inch root diameter. Tree removal will extend for a distance of 15 feet beyond the proposed toe of levee slope.
- The project includes the placement of compacted earth on top of the existing grade to increase the levee height as follows:
 - Add fill to the levee to extend the existing crest to two feet above the 100-year Project Design Flood profile in all areas except as noted below. This flood event is described in Section 2.2.
 - Limit the levee height increase where necessary such that the proposed levee crest is no higher than 0.5 feet below the levee elevation on the opposite (west) side of the Des Plaines River. If the east levee crest is higher than this design rule, the east levee crest shall remain at its existing elevation.
 - The east levee crest elevation changes will be constructed 0.1 feet higher than the above stated design criteria to accommodate future anticipated settlement of the levee that will occur due to the proposed fill.
 - Upgrade the 500 foot reach of levee from Station 13+00 to Station 17+50 where an old buried spillway exists to improve stability and seepage control. The improvements in this reach include levee widening, a crest increase, and placement of a steel sheet pile seepage cutoff wall.
 - Construct a 10-foot wide gravel maintenance road on the levee crest and re-vegetate the levee and adjacent areas with suitable vegetation. All fill material will be placed on the land side of the existing levee; no new fill will be placed within the floodway of the Des Plaines River.

The levee will tie into existing high ground near Joliet Road on the north and at the MWRDGC HASMA facility to the south.

The following general design criteria were developed to comply with design requirements and provide a consistent approach:

- 100-year Project Design Flood – The Des Plaines River flood profile published in the FEMA Flood Insurance Study serves as the base flood from a regulatory perspective. However, for this project, an updated analysis was performed for the project design basis. The updated interpretation of the base flood condition is called: “100-year Project Design Flood”. A definition for this flood is provided in Section 2.2. The project seeks to establish flood protection for the 100 year flood with freeboard, to the extent that is practical and feasible.
- Levee Crest Elevation / Freeboard –
 - The top of levee (crest) elevation is set to be at least 2 feet above the 100-year Project Design Flood Profile except in areas where such a levee crest increase would result in the east levee crest being higher than 0.5 feet below the west levee at the same river location.
 - When the planned east levee crest criterion of “2 feet above the 100-year Project Design Flood Profile” would result in a crest that is higher than 6 inches below the west levee crest, the east levee crest is limited to be no higher than 0.5 feet below the west levee crest elevation. One exception to this rule is that the proposed levee crest shall not be lower than the existing levee crest elevation. Following is a summary of locations where the proposed levee crest elevation is lower than the planned levee crest elevation of “2 feet above the 100-year Project Design Flood”:
 - Station 18+13 to 18+48
 - Station 24+00 to 31+20
 - Station 32+68 to 35+22
 - Station 35+45 to 35+95
 - Station 36+50 to 36+82
 - In all locations, the proposed east levee crest will provide freeboard above the 100-year Project Design Flood as defined in Section 2.2. The proposed levee will also be constructed higher initially to anticipate expected levee crest settlement as described in Section 2.1.
 - Where the existing levee elevation is greater than the 100-year Project Design Flood plus 2.0 feet, the levee is to be left at the existing elevation.
 - In addition to creating a proposed levee crest that provides freeboard above the 100-year Project Design Flood, the proposed levee crest would provide protection from a flood that is comparable to the April 2013 flood event of 12,200 cfs.
- Settlement allowance – The placement of additional fill on the existing levee is anticipated to induce less than approximately one-inch of settlement due to the limited amount of fill to be placed and considerations that most, if not all, of the consolidation related settlement for this levee has already occurred during its lifetime. Settlement due to fill placement at the old buried spillway is estimated to be up to four inches due to the greater amount of fill in this area. The levee will be overbuilt by the amount of anticipated future settlement to accommodate the amount of consolidation related settlement while maintaining adequate levee freeboard. The balance of construction involves placement of a steel sheet pile wall that is not expected to experience significant settlement. Any

required levee overbuild is included in the construction quantities for areas of levee where the crest will be raised. The drawings illustrate the higher amount of fill that will be placed during construction to anticipate future settlement.

- Levee crest width – a minimum 12 feet crest width at the top of levee will be created. Where the existing levee top width is wider than this minimum, the wider geometry will be maintained.
- A 10 foot wide gravel service road will be included on the levee crest. Two gravel turnouts will be constructed wider than the base road width to provide for safe maintenance access.
- Existing Levee Clearing and Grubbing / Tree clear zone – Trees will be removed for a minimum 15 feet from the toe of the proposed levee on both river and land side. The contractor will clear the surface of the existing levee (including tree clear zone). This includes removal of all trees and roots within 15 feet of the toe of the levee. Remove all roots that are greater than ½ inch in diameter and the associated root ball and all organic material. Backfill with suitable fill material (typically matching levee fill). The Forest Preserve District of Cook County (FPDCC) has requested that certain trees be provided to the FPDCC for recycling. FPDCC will identify and tag these trees and develop a specification for how these are to be handled and transported to the designated site.
- Levee side slopes – minimum 3H:1V to allow for maintenance and inspection as well as overall levee stability.
- Seepage control measures - Based on the results of field explorations, analysis, and observations from prior inspections, the following are design measures that will be employed to manage seepage:
 - The use of relatively flat 3H:1V side slopes.
 - Replacement of clay soils on the levee side slopes to be coordinated with the planned tree and other woody vegetation removal from the slopes
 - A Steel sheet pile wall will be installed to limit seepage exit gradients and piping erosion potential at the old buried spillway at station 13+00 to 18+60.
- Levee materials – Additional fill placed for reconfiguration and/or raising of the levees will be cohesive (i.e., clay) material, free of topsoil, debris, and other deleterious material. The maximum particle size will be one inch and contain at least 25% by weight of particles finer than the #200 U.S. sieve size. The material will have a specified permeability of 1.0×10^{-7} cm/s or less. Soil placed as part of the Temporary Flood Protection Measures, as described in Section 4, will be reworked into the proposed final design.
- Compaction requirements – Material placed for reconfiguration and/or raising of the levee will be placed in maximum 9-inch thick loose lifts and compacted with a sheepsfoot roller or other suitable equipment. The material should be maintained within a range from 1% to 3% above the optimum moisture content and compaction of at least 95% of the maximum dry density per standard proctor test (ASTM D698).
- Vegetation types on levee and within clear zone – vegetation on the levee and generally within 15 feet of the toe of the levee will be limited to perennial grasses that are resistant to both drought and periodic inundation. Native species appropriate for the levee setting are recommended. A 6-inch thick topsoil layer is included for the entire levee surface and levee clear zone that extends 15-feet from toe of levee.

- Utility penetrations through levee / flood wall – Reduce to maximum extent possible. Provide positive cutoff for storm and sanitary sewers. The levee owner should carefully monitor any proposed future levee utility penetrations to minimize possible failure due to utility collapse, poorly compacted trench backfill or other utility related issues. This may require some form of easement or other agreement with the existing railroads to ensure the integrity of the levee.
- Exploration Trench – An exploration trench is usually utilized to expose potential undesirable underground features such as old drain tile, utilities, pockets of unsuitable material or other debris or obstructions. Based on the site history, no exploration trench will be required.
- Sheet pile criteria – Steel sheet pile penetration depths have generally been set to provide added seepage resistance in the existing levee at the old buried spillway area.
- Seismic – The Lyons levee project is located within “Seismic zone 1” based on the Uniform Building Code Seismic Zone map located within the current version of USACE’s ER 1110-2-1806 (“Earthquake Design and Evaluation for Civil Works Project”). As documented by USACE in the Levee Condition Report: “No recent earthquakes or fault activity have been documented in the area; therefore the need for seismic design analysis is not required and not considered necessary. “
- Permanent inspection and maintenance access – a 10’ wide, 12-inch thick gravel wearing surface is located on the levee crest for inspection and maintenance. Access to the levee is planned from the north and south sides of 47th Street, from the south side of Joliet Road and from the MWRDGC HASMA site. This will require modification to the existing guard rails on either side of 47th Street to enable vehicle access. Vehicle turnouts are included at two locations for the section of levee between 47th Street and Joliet Road. These features will allow two vehicles to pass when travelling in opposite directions, or one vehicle to turnaround.
- Erosion protection – Based on the relatively low velocities in the Des Plaines River in the overbank areas and the setback of the levee from the river, no significant permanent erosion control features are required. Existing riprap in the vicinity of the bridges appears to be generally adequate. Establishment and maintenance of grassed vegetation on the side slopes of the levee will be critical for long term stability and erosion control. This will require erosion control blanket for the entire levee surface until vegetation establishment. Inspection and re-establishment of good vegetative cover and removal of woody vegetation, particularly in the first few years, will be an important maintenance item. Scour protection in the vicinity of the bridges appears to be adequate. No additional riprap in these areas is recommended.
- Railroad closure – Where the railroads cross the levee, the top of the railroad ballast generally exists at or near the proposed top of levee elevation. The thickness of the ballast zone is approximately two feet thick and is porous. We recommend that the porous ballast zone should be replaced with a concrete keyed into the underlying soil on top of the levee. Additional coordination with the railroads regarding ballast zone sealing is recommended.
- Existing Spillway Structure – The buried spillway structure that exists between station numbers 13+00 and 18+00 will require a different design approach than the balance of the levee. The design will address seepage and potential future structural degradation of the old concrete and stone spillway that could otherwise cause problems for the levee in the future. The design also recognizes the difficulty that a removal of the old spillway would cause including deep excavations, extensive

wetland impacts, dewatering issues that would likely require extensive cofferdams, and unknown subsurface conditions. The levee upgrade design will limit the amount of disturbance to the existing spillway by focusing levee improvements on its east side. It will take advantage of the existing levee as a buttress, but will not count on it for seepage control. A new steel sheet pile wall would be driven at the landside toe of the existing levee, and a levee extension would be constructed on the landward side using 3H:1V side slopes. This would result in a relatively wide levee section at this area, but would not require the costly removal or excavation of the existing spillway. The existing buried abutments would need to be partially removed to allow for the installation of sheet piles to tie into the levee to the north and south of the buried spillway. Additional explorations in the form of test pits and soil borings are proposed in this area to evaluate the horizontal limits of the spillway and the abutments in order to evaluate the potential for obstructions during the driving of sheet piling and to refine the geometry of the proposed construction in this area.

- An unidentified concrete structure located at approximately station 21+00 would need to be demolished and removed.
- Three wooden power poles located at approximately station 34+00 on the levee crest and riverside side slope. These should be relocated outside of the levee footprint.
- Forest Preserve District Fence Relocation – an existing Forest Preserve District fence located at approximately station 38+00 to 41+50 will be removed and replaced in a new location. A 100 foot length of the existing gravel trail will be reconstructed in a new location to accommodate the new fence location and levee service road. A more detailed survey of this area will be performed in final design to minimize the disruption in this area.
- Interior drainage – The only known interior drainage problem is the Harlem Avenue underpass under the railroad tracks. IDOT is developing a drainage improvement project to address this issue. Existing roadside ditches are poorly defined and have not been actively maintained. This causes the sheet flow of storm water from the road right of way into the Forest Preserve. It does not appear that this condition causes flood damage in the Forest Preserve. The rest of the interior drainage system appears to be adequate from a flood damage perspective. Section 3 provides detailed information for the interior drainage system.
- The recently completed earthwork for Temporary Flood Protection Measures, as described in Section 4, will be reworked into the permanent levee restoration. The permanent crest will be wider in places. This option includes the construction of an access road on top. Earth placed as part of the temporary measures project will be reworked and incorporated into the final design.

4.1 Proposed Levee Evaluation

The proposed levee profile was modeled in HEC-RAS for the 10-, 20-, 50-, and 100-yr flood events, and using the expected probability Flow rates as summarized in Table 2-1. These runs show that the Des Plaines River water surface profiles for all of these events will not exceed the proposed levee crest. The April 2013 (flood of record) storm was modeled in HEC-RAS using the unsteady flow option. The April 2013 flood does not overtop the proposed levee profile. The maximum water surface elevation for this flood is less than 0.1 feet below the levee crest profile at the lowest point in the proposed levee profile upstream of 47th Street.

Appendix A
Computer Model Readme Files

**Des Plaines River HEC-RAS Model (Lyons Levee - Des Plaines River)
(Lyons_Levee.prj)**

HEC-RAS Report Files

The HEC-RAS report text files for each run are named based on the Steady/Unsteady Plan files with .rep as an extension.

The HEC-RAS report PDF files for each run are named based on the Steady/Unsteady Plan files with .pdf as an extension.

HEC-RAS Input Files

Steady Flow Input Files

Freq Anal w/2013(Lyons_Levee.f03)

Frequency Analysis Computed Flows (10-, 20-, 50-, and 100-yr), FIS 100-yr, and Historic Storm Peak Flows at Riverside (Sep 2008, Dec 2008, Jul 2010, Jul 2011, Apr 2013, and Jul 2014), and 12,000 cfs

Diversion Evaluation(Lyons_Levee.f04)

Flows for an evaluation of diversion alternatives to CAWS

OrdinaryHighWaterMark Flows(Lyons_Levee.fo5)

Flows used to estimate the Ordinary Highwater Mark for USACE Permitting

CorpsRequestedProfiles(Lyons_Levee.fo6)

The 10 profiles from the 1- to 500-yr flows for Corps Damage Analysis (1-, 2-, 5-, 10-, 20-, 25-, 50-, 100-, 200-, and 500-yr)

Unsteady Flow Input Files

2013 USGS Flows(Lyons_Levee.u15)

Historic USGS flow hydrographs at Riverside for 2006, September 2008, December 2008, July 2010, July 2011, April 2013, and July 2015

100-yr 2013 Ratio(Lyons_Levee.u01)

April 2013 flood event hydrograph ratioed to provide a hydrograph with the 100-yr peak flow rate

12k 2013 Ratio(Lyons_Levee.u10)

April 2013 flood event hydrograph ratioed to provide a hydrograph with a 12,000 cfs peak flow rate

Geometry Input Files

Proposed Levee(Lyons_Levee.g05)

This is the Lyons Levee Improvement Plan profile described in the report. Profile provided by AECOM.

DPR Updated Levee 08062014 C12(Lyons_Levee.g33)

Existing Levee Profile updated with field survey on 8/6/2014. This was the 12th and final Calibration Run. This included updated river cross sections between Joliet Road and railroad bridges. Overflows between CAWS and the Des Plaines River were included downstream.

Scenario 100-yr plus 1 Levee(Lyons_Levee.g02)

Scenario 1 Levee Profile for Evaluating Overtopping of Alternative Levee Profiles upstream of 47th Street. Scenario 1 includes a section of the levee with a reduced 1 foot of freeboard above the 100-yr storm north of 47th Street.

Scenario 2 100-yr plus 1.5 Levee(Lyons_Levee.go4)

Scenario 2 Levee Profile for Evaluating Overtopping of Alternative Levee Profiles upstream of 47th Street. Scenario 2 includes a section of the levee with a reduced 1.5 foot of freeboard above the 100-yr storm north of 47th Street.

Scenario 100-yr plus 2 Levee(Lyons_Levee.go3)

Scenario 3 Levee Profile for Evaluating Overtopping of Alternative Levee Profiles upstream of 47th Street. Scenario 3 includes a section of the levee with a reduced 2 foot of freeboard above the 100-yr storm north of 47th Street.

Steady Flow Plan Files

DPR Freq Analysis w/OT C12(Lyons_Levee.p63)

Existing Levee Profile with f03 and g33 with overtopping of the Lyons Levee calculated

DPR Freq Anal w/o OT C12(Lyons_Levee.p64)

Existing Levee Profile with f03 and g33 without overtopping of the Lyons Levee calculated

DPR Diversion Evaluation(Lyons_Levee.p66)

Existing Levee Profile with f04 and g33 to evaluate several diversion alternatives

Ordinary Highwater Mark(Lyons_Levee.p67)

Existing Levee Profile with f05 and g33 to determine ordinary highwater mark profile for USACE Permit

Proposed Levee(Lyons_Levee.p76)

Proposed Levee Profile with f03 and g05 to evaluate the proposed levee water surface profile.

Corps Requested Proposed Profiles(Lyons_Levee.p80)

Proposed Levee Profile with f06 and g05 for Corps Damage Evaluation

Corps Requested Existing Profiles(Lyons_Levee.p90)
Existing Levee Profile with f06 and g33 for Corps Damage
Evaluation

Unsteady Flow Plan Files

DPR Updated Levee 2013 C12(Lyons_Levee.p56)
Existing Levee Profile with g33 and u15 Calibration to April
2013 event

DPR Updated Levee 2014 C12(Lyons_Levee.p57)
Existing Levee Profile with g33 and u15 Calibration to July
2014 event

DPR Updated Levee 2011 C12(Lyons_Levee.p58)
Existing Levee Profile with g33 and u15 Calibration to July
2011 event

DPR Updated Levee 2010 C12(Lyons_Levee.p59)
Existing Levee Profile with g33 and u15 Calibration to July
2010 event

DPR Updated Levee 2008D C12(Lyons_Levee.p60)
Existing Levee Profile with g33 and u15 Calibration to
December 2008 event

DPR Updated Levee 2008S C12(Lyons_Levee.p61)
Existing Levee Profile with g33 and u15 Calibration to
September 2008 event

DPR Updated Levee 2006 C12(Lyons_Levee.p62)
Existing Levee Profile with g33 and u15 Calibration to
October 2006 event

100-yr Scenario 1 100+1(Lyons_Levee.p68)
Scenario Levee 1 profile with u01 and g02 to evaluate
effectiveness of Scenario 1 for the 100-yr

12k Scenario 1 100+1(Lyons_Levee.p73)
Scenario Levee 1 profile with u10 and g02 to evaluate
effectiveness of Scenario 1 for 12000 cfs

100-yr Scenario 2 100+1.5(Lyons_Levee.p72)
Scenario Levee 2 profile with u01 and g04 to evaluate
effectiveness of Scenario 2 for the 100-yr

12k Scenario 2 100+1.5(Lyons_Levee.p71)
Scenario Levee 2 profile with u10 and g04 to evaluate
effectiveness of Scenario 2 for 12000 cfs

100-yr Scenario 3 100+2(Lyons_Levee.p69)
Scenario Levee 3 profile with u01 and g03 to evaluate
effectiveness of Scenario 3 for the 100-yr

12k Scenario 3 100+2(Lyons_Levee.p70)

Scenario Levee 3 profile with u10 and g03 to evaluate effectiveness of Scenario 3 for 12000 cfs

April 2013 without Lateral Structures(Lyons_Levee.p74)

April 2013 storm with existing Levee Profile with u15 and g33 to evaluate the impact of no lateral structures on the water surface profile

April 2013 with Proposed Levee(Lyons_Levee.p79)

April 2013 storm with the proposed levee profile with g05 and u15.

**Des Plaines River SSP Input/Output Description (Frequency Analysis)
(Lyons_Levee.ssp)**

Frequency Analyses using Bulleting 17b Methods (input file name and description)

Riverside_1974_-_2013.17b
Des Plaines River at Riverside for Water Year 1974 to 2013

Riverside_1984_-_2013.17b
Des Plaines River at Riverside for Water Year 1984 to 2013

Riverside_1990_-_2013.17b
Des Plaines River at Riverside for Water Year 1990 to 2013

Riverside_1994_-_2013.17b
Des Plaines River at Riverside for Water Year 1994 to 2013

Riverside_Full_Record.17b
Des Plaines River at Riverside for Water Year 1914 to 2013

Des_Plaines_1990_-_2013.17b
Des Plaines River at Des Plaines for Water Year 1990 to 2013

Des_Plaines_Period_of_Record.17b
Des Plaines River at Des Plaines for Water Year 1938 to 2013

Output (Gage location and period analyzed)

Riverside_1974_-_2013.pdf
Riverside_1984_-_2013.pdf
Riverside_1990_-_2013.pdf
Riverside_1994_-_2013.pdf
Riverside_Full_Record.pdf
Des_Plaines_1990_-_2013.pdf
Des_Plaines_Period_of_Record.pdf

Plots (Gage location and period analyzed)

Plot_Riverside_1974_-_2013.pdf
Plot_Riverside_1984_-_2013.pdf
Plot_Riverside_1990_-_2013.pdf
Plot_Riverside_1994_-_2013.pdf
Plot_Riverside_Full_Record.pdf
Plot_Des_Plaines_1990_-_2013.pdf
Plot_Des_Plaines_Period_of_Record.pdf

Interior Drainage HEC-HMS Input/Output Descriptions (LyonsLevee_IntDrain.hms)

HEC-HMS Hydrograph Plots

Plots contain all of the frequency analyzed (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr)

basinname_XXhr.pdf

basinname - subbasin ID (47thStreet_East, 47thStreet_West, Harlem, and Railroad)
XX - storm duration in hours (1-, 2-, 3-, 6-, 12-, and 24-hr duration)

HEC-HMS Input Listings

Subbasin Schematic.pdf

Picture of Subbasin boundaries and the HEC-HMS schematic.

Subbasin Area.pdf

Listing of the drainage area, curve number, and time of concentration for each subbasin

HMS Input Component Naming Convention

Basin Models

LyonsLeveeID

The interior drainage schematic and input (drainage area, curve number, time of concentration, etc.) for the Lyons Levee subbasins behind the levee.

Meteorologic Models - Assign rainfall hyetographs to basin models and subbasins.

XXhour

XX - Storm duration in hours

Control Specifications (sets computational time window and time step for the run)

LyonsLevee

Time-Series Data (Precipitation Gages)

xxHyQ Bulletin 70 rainfall distributions for the various storm durations

xx - storm duration in hours

y - Bulletin 70 quartile rainfall distribution

HMS Compute/Results Naming Convention

LLxxYzzH

xx - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

zz - storm duration in hours (1, 2, 3, 6, 12, and 24 hours)

Lyons Levee Interior Drainage HEC-RAS Model (LyonsLeveeID.prj)

Report Files - These are pdf listings of the RAS report files generated for the critical duration 6 hour storm for the various frequencies modeled.

REPORT xxxYR 6HR EXISTING.PDF

xxx - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

Profile Plots - These are pdf's of the critical duration 6 hour storm.

PROFILE xxxYR 6HR EXISTING.PDF

xxx - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

HEC-RAS input files

Geometry Files

Existing Conditions (LyonsLeveeID.g03)

The geometry input for existing conditions along the interior drainage flow path to Harlem Avenue

Unsteady Flow Files

XXXyZZh Existing (LyonsLeveeID.u**)

XXX - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

ZZ - storm duration in hours (1, 2, 3, 6, 12, and 24 hour duration storms)

Generate Hot Start

base flow model used to generate a starting water surface profile to reduce instabilities in the model at start up.

Unsteady Flow Plan Files

XXXyZZh Existing (LyonsLeveeID.p**)

XXX - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

ZZ - storm duration in hours (1, 2, 3, 6, 12, and 24 hour duration storms)

Hot Start

base flow model used to generate a starting water surface profile to reduce instabilities in the model at start up.

Appendix B

Computer Model Input & Output
Files:

- DesPlainesRiver_SSP_Files
- DesPlainesRiver_RAS_Files
- LyonsLevee_HMS_Files
- LyonsLevee_RAS_Files

MCCOOK, IL SECTION 205

APPENDIX D: HYDROLOGY AND HYDRAULIC ANALYSIS

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ATTACHMENTS

ATTACHMENT 1: "Lyons Levee Improvement Project, Hydrology and Hydraulics Technical Memorandum" dated December 2015.

APPENDIX D: HYDROLOGIC AND HYDRAULIC ANALYSIS
MCCOOK, IL
SECTION 205 FLOOD RISK MANAGEMENT

INTRODUCTION

The Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) has performed a Hydrologic and Hydraulics (H & H) analysis in regards to their proposed Lyons Levee Improvement Project, which has been documented in the report "Lyons Levee Improvement Project, Hydrology and Hydraulics Technical Memorandum" dated December 2015. This analysis is also applicable to the McCook Levee Project which is located across the Des Plaines River from the Lyons Levee Project, however, sections specific to the Lyons Levee project will not apply to the McCook Levee project.

The report covers much of the H & H analysis that is normally required by the U.S. Army Corps of Engineers (USACE) for feasibility studies. The report is attached and will be considered as the main portion of the H & H Appendix, in addition to the supplemental analyses below that include additional items normally covered in a USACE Flood Risk Management (FRM) levee project. This supplemental appendix provides additional information to address such items as: risk and uncertainty analysis, superiority analysis, project impacts, and flood warning.

RISK AND UNCERTAINTY

The MWRDGC report includes a very comprehensive documentation of the H & H data available for the study reach. The associated analysis also includes a very recently updated model, which includes close calibrations for six recent historic flood events, three of which have peak flows exceeding the published FEMA 1% chance exceedance flood. Updated flow frequency analyses for the USGS gage on the Des Plaines River at Riverside, Illinois, located one and a half miles upstream of the project are also included.

USACE policy requires that flood risk management projects be designed using a risk-based analysis rather than designing to a level of protection.

A risk and uncertainty analysis was performed using data from the MWRDGC report and the associated hydraulic modeling. At the imminent overtopping location of the levee system, the levee crest is 1.5 feet above the one percent chance exceedance design water surface. Due to the 100 year period of record at the gage, and very close comparisons between the observed and computed stages for the calibration runs, the FDA analysis computed a 95.4% chance that the one percent chance exceedance flood event would not overtop the levee. Current USACE guidance (EC 1110-2-6067) requires a minimum of two feet of freeboard, even when there is a greater than 95% confidence level that the one percent flood will not exceed the crest elevation.

SUPERIORITY ANALYSIS

The existing West Lyons Levee includes a low area that would be the location of imminent overtopping of the McCook levee system. The West Lyons Levee is basically a continuation of the McCook Levee along the west side of the Des Plaines River north of 47th Street. The water surface profiles indicate that overtopping will occur at this location first and not in other areas where the levee is relatively higher.

In the development, design and coordination between the State of Illinois and MWRDGC for the Lyons Levee project on the east side of the Des Plaines River, it was decided that the levee heights on the east levee would remain six inches below the West Lyons Levee as has historically been the case. For the design of the McCook/West Lyons levee the USACE is accepting the agreements that have been previously made regarding the levee heights of the Lyons and West Lyons Levees. Any raising of these levees would need to be coordinated with these entities and would need to consider the impacts on both sides of the river.

With regard to the recently released guidance, ECB 2017-15 “Managed Overtopping of Levee Systems”, the overtopping location for the McCook/West Lyons Levee is not ideal. The location is along the back yards of a residential area. While the first floors of the homes are at or near the 100 year flood level, there is a low area in the back yards with a greater than an eight foot depth which brings up concerns of possible loss of life. The new guidance also recommends armoring the overtopping location. The top of the existing levee includes a paved bike, but no armoring on the back side of the levee.

For this instance, the volume in the interior is small north of 47th Street and would fill up rapidly whether it overtops or fails. There is a natural area that provides a secondary tieback for the McCook Levee with a minimum elevation of 602.0, so a failure of the West Lyons levee would have much less of an impact to the McCook levee interior than it would without this high ground. Flood warning would also decrease the risk. With consideration of these factors, the risk appears to be reasonably manageable.

PROJECT IMPACTS

There are no project induced stage impacts due to fill or storage on the Des Plaines River, however, the proposed diverting of flows from McCook Ditch into the Des Plaines River can cause increased stages.

The original project plan was to block off the culvert at Lawndale Avenue and add a diversion from McCook Ditch just south of Lawndale to the Des Plaines River. Currently all flow from McCook Ditch passes through the Lawndale culvert and then outlets to the Chicago Sanitary and Ship Canal through the Summit Conduit. The Summit Conduit is also the only outlet for the interior drainage of the project. See Figure 1 below for existing condition features. The project interior is located to the northern portion of the McCook Levee on the figure with Lawndale being the dividing line.

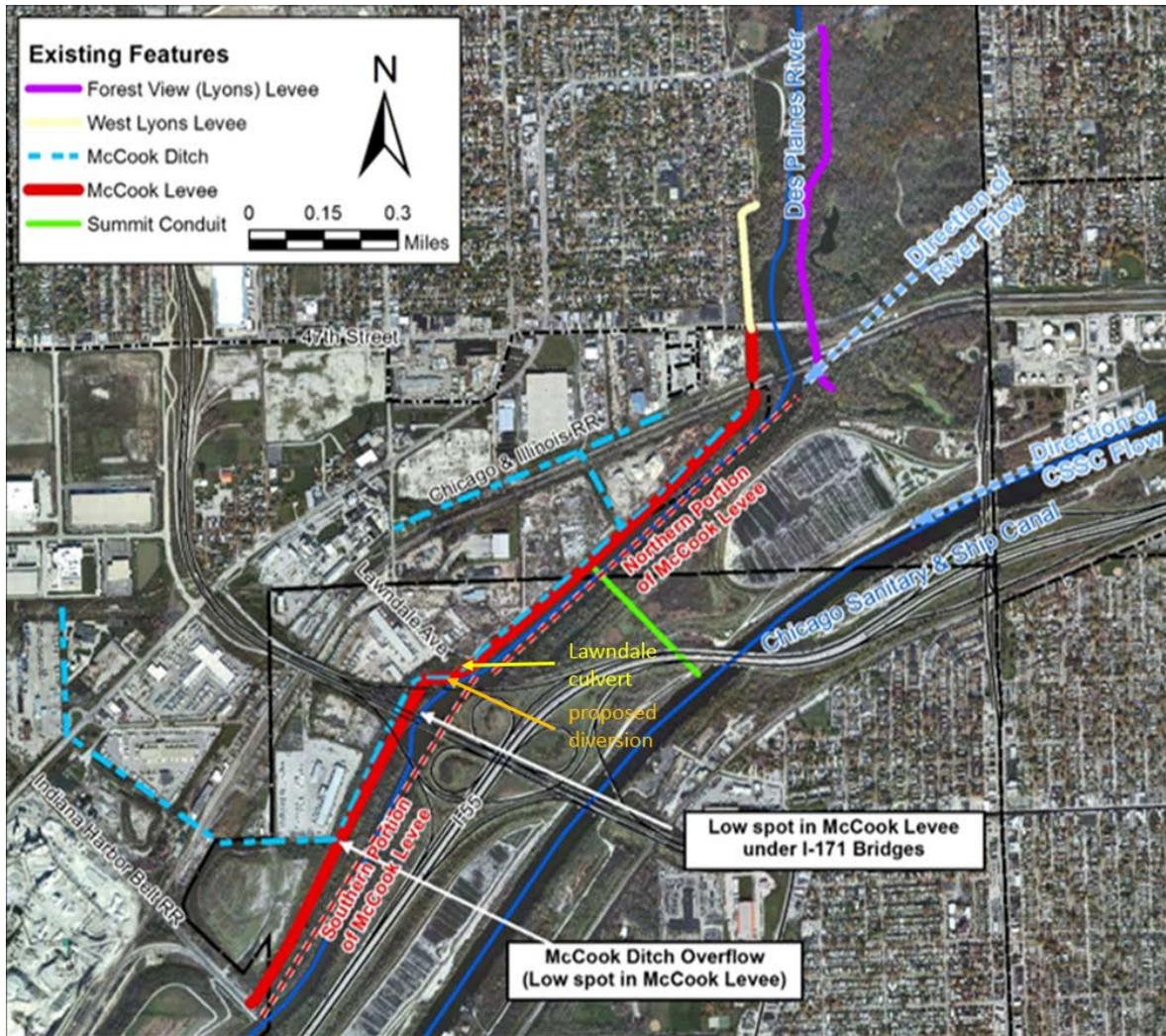


Figure 1 – Existing Features

There are also other overbank connections between McCook Ditch and the Des Plaines River which further complicate the hydraulics. When flows are high enough on the McCook Ditch they can overflow to the Des Plaines. Also, when the Des Plaines River is high, flows can go overbank into McCook Ditch. The later condition adds flow that goes through the Lawndale culvert and subsequently into the Summit Conduit and can cause flooding in the leveed interior area north of Lawndale. The later was the cause of the most extensive flooding in the April 2013 flood event. The original plan of blocking the Lawndale Culvert would reduce this flood risk on the interior, however, further hydraulic analysis showed that diverting all the McCook Ditch flow to the Des Plaines can cause adverse stage impacts. Figure 2 presents a closer look at the hydraulic features between Lawndale Avenue and the Summit Conduit.

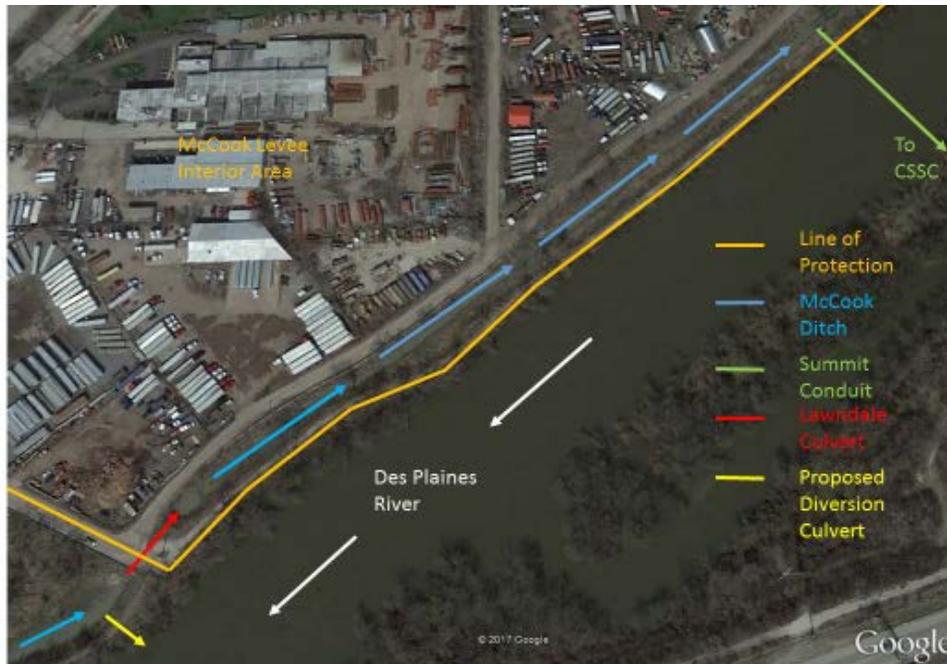


Figure 2 – Hydraulic Features from Lawndale Avenue to Summit Conduit

The modeling for the project was taken from the Lyons Levee project as noted above. The final project modeling was a steady state HEC-RAS model. The inflows were based on a flow frequency analysis. To analyze the stage impacts this model was used but converted to an unsteady flow model with added features that included the Lawndale culvert, the Summit Conduit, the northern and southern McCook Levee interior areas and the connection between the Des Plaines River and McCook Ditch.

For inflow hydrographs, synthetic event flow hydrographs at the Riverside gage location based on the Des Plaines River Phase II modeling were used and prorated to match the peak flows from the previous Lyons Levee study. A simple model of the McCook Ditch/Summit Conduit watershed that was developed for Lake Michigan Diversion was used for inflows for the interior areas.

When comparing the maximum stage profiles of the steady state and unsteady state modeling, the stage differences were around one tenth to two tenths of a foot lower on average with the unsteady model for the areas between Joliet Road and Lemont Road. This seems reasonable for this phase of the study and considering the many changes to the modeling, but should be looked into more closely during the next phase."

When comparing the existing condition model versus the proposed condition model, which included blocking off of the Lawndale culvert and diverting McCook Ditch to the Des Plaines, adverse stage impacts of approximately one tenth of a foot were seen. These stage impacts would not meet the State of Illinois regulatory requirements for approximately eight miles for the 100-year event.

To mitigate the stage impacts, a reduced size Lawndale culvert and a reduced size diversion were modeled until a balance of stage reductions and acceptable interior stages were met. This model included a 3.25 foot diameter reinforced concrete culvert for both the Lawndale and diversion culverts. Headwalls with grooved end of pipe at the upstream ends were assumed. The existing Lawndale culvert is a five foot diameter corrugated metal pipe with a headwall. This eliminated adverse stage impacts for all synthetic events (2, 5, 10, 25, 50 and 100-year). Figure 3 below presents 100 year stage and flow hydrographs near the peak for a location near the McCook overflow (see figure 1 above for location)

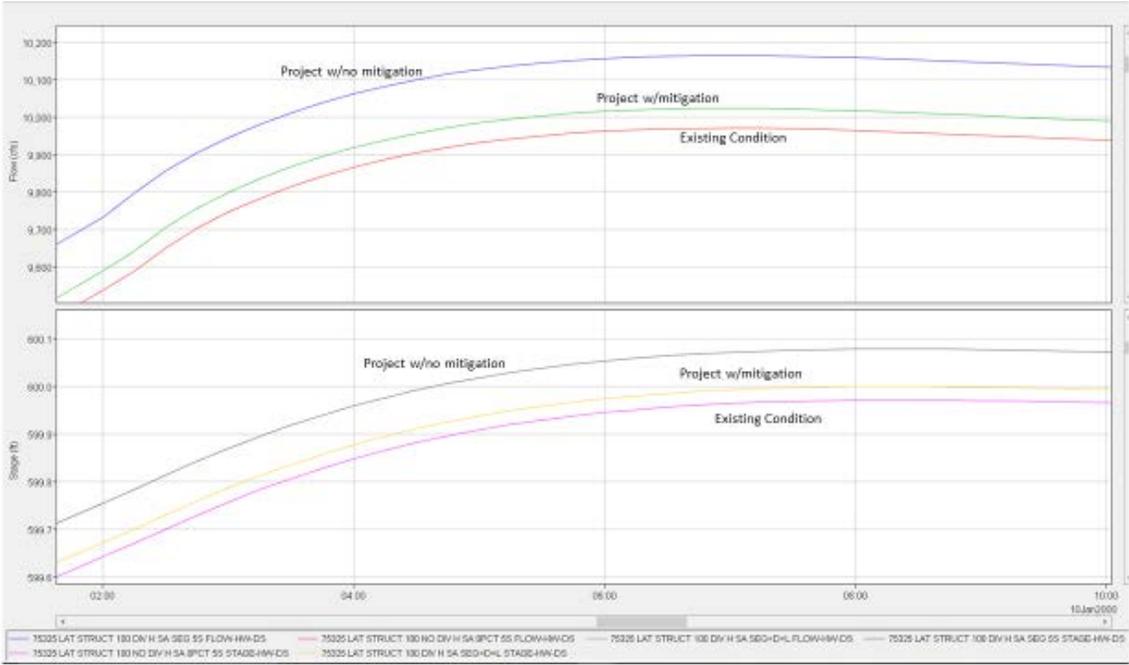


Figure 3 – Peak Stage and Flow near McCook Ditch Overflow

After discussion with the PDT team it was decided adding a sluice gate at Lawndale was the most practical solution. A partially open gate setting will mimic the reduced pipe size of the Lawndale culvert. It should be noted that a flapgate is needed on the diversion culvert to prevent flows from the Des Plaines River continually passing into the interior and into the Summit Conduit. Trash racks are recommended for both culverts. Additional survey information of the overflow areas is expected to be available between now and the plans and specification phase. In addition inflow hydrographs from more detailed modeling of the interior areas maybe be available. The project model will be updated with the best available information at that time if required. This could cause minor changes in pipe sizes/gate openings.

FLOOD WARNING

A recent flood warning plan was developed by the Chicago District for the Village of Forest View in 2014. It includes a new gage at the project location and includes the Riverside gage one and a half miles upstream. Due to the close proximity and similar overtopping

elevations, the flood warning plan and warning levels would also be applicable to the McCook/West Lyons Levee.

EROSION PROTECTION

Modeled velocities are very low on the Des Plaines along the McCook/West Lyons Levee and do not indicate the need for erosion protection, however, there is at least one small isolated eroded area along the existing sheet pile that was noted during the field investigation where erosion protection is recommended.

CLIMATE CHANGE IMPACTS

As outlined in ECB No. 2016-25, an investigation of the trends in the annual maximum flow gage data was performed to qualitatively assess impacts of climate change within the watershed using the USACE Climate Hydrology Assessment Tool. The drainage area for USGS gage 05532500, Des Plaines River at Riverside, IL, is 630 square miles. The gage has a period of record from 1914 to present day for various stream statistics including peak streamflow and daily discharge data.

For the Des Plaines River, [Figure 4](#) below shows the instantaneous peak streamflow obtained from the USGS website for gage closest to the project site. The figures depict a trend towards increasing annual peak streamflow for the period of record, as represented by the gage trendline. However, the p-value for the gage trendline is 0.000899, which is considered statistically significant. [Figure 5](#) displays the projected annual monthly trends from the USACE Climate Hydrology Assessment Tool.

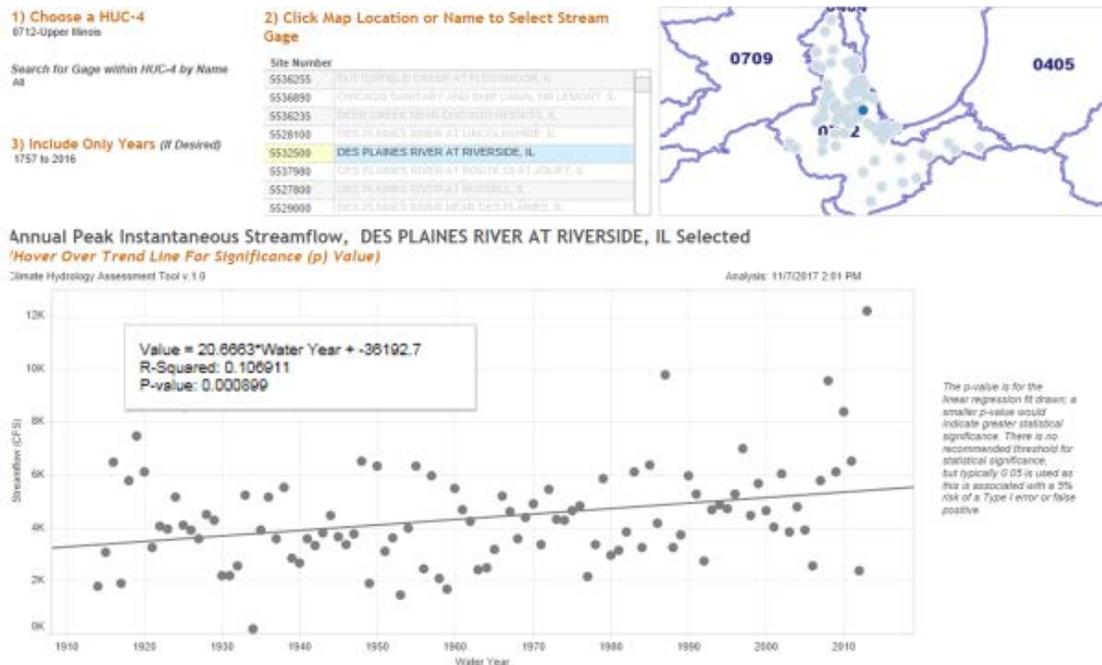


Figure 4. Peak Streamflow for Des Plaines River at Riverside, IL

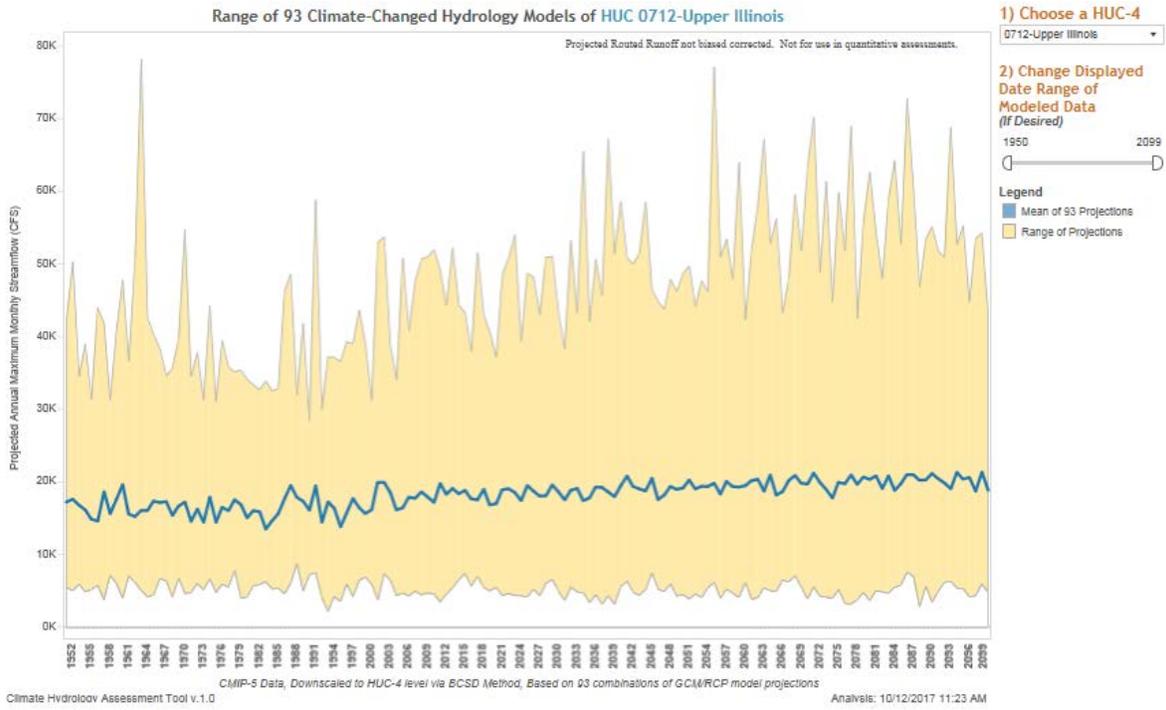


Figure 5. Project Annual Maximum Monthly Streamflow for HUC-4:0712-Upper Illinois

Using the web-based Nonstationary Detection Tool, the stream gage closest to the project site was investigated for non-stationarity (figure 6). For the USGS 05532500, Des Plaines River at Riverside, Illinois gage, several abrupt non-stationarities were detected, as shown in Figure 6. Non-stationarities were detected at three general change points within the period of record: 1920, 1981-1983 and 2006-2007. In 1920, only the Mood test for variance detected a non-stationarity, however, other statistical tests that target segment changes in variance/standard deviation and overall distribution detected a decrease in variance of 3,380,882 cfs squared and a decrease of standard deviation of 894 cfs (-38%). For the 1981-83 non-stationarity, the Lombard Wilcoxon, Pettit, and Mann-Whitney tests all concurred with regard to a general mean change point and the Energy Divisive Method detected a distributional change point, however, out of the other statistical tests that target segment changes in mean, variance/standard deviation and overall distribution, only a change in mean of 1502 cfs (38 % increase) was detected. For the 2006-2007 non-stationarity, the Mood test for variance and both the Kolmogorov-Smirnov and LePage distributional tests detected non-stationarities, in addition, for other statistical tests that target segment changes in variance/standard deviation and overall distribution detected an increase in variance of 9,161,268 cfs squared and an increase of standard deviation of 1,910 cfs (132%). In general these non-stationarities appear to be robust.

This is further supported when assessing monotonic trends within the record, as shown in [figure 7](#) (1914-2013) and figure 8 (1920-2013) which shows statistically significant positive trends in the data. Figure 9 presents the period 1981 to 2013 where no trend was detected. Figure 10 presents the period 2006 to 2013. A positive trend was detected, but was not statistically significant. The dataset shows definite non-stationarities and various statistical trends depending on the time period analyzed, but how much is attributable to urbanization and how much is attributable to climate is uncertain.

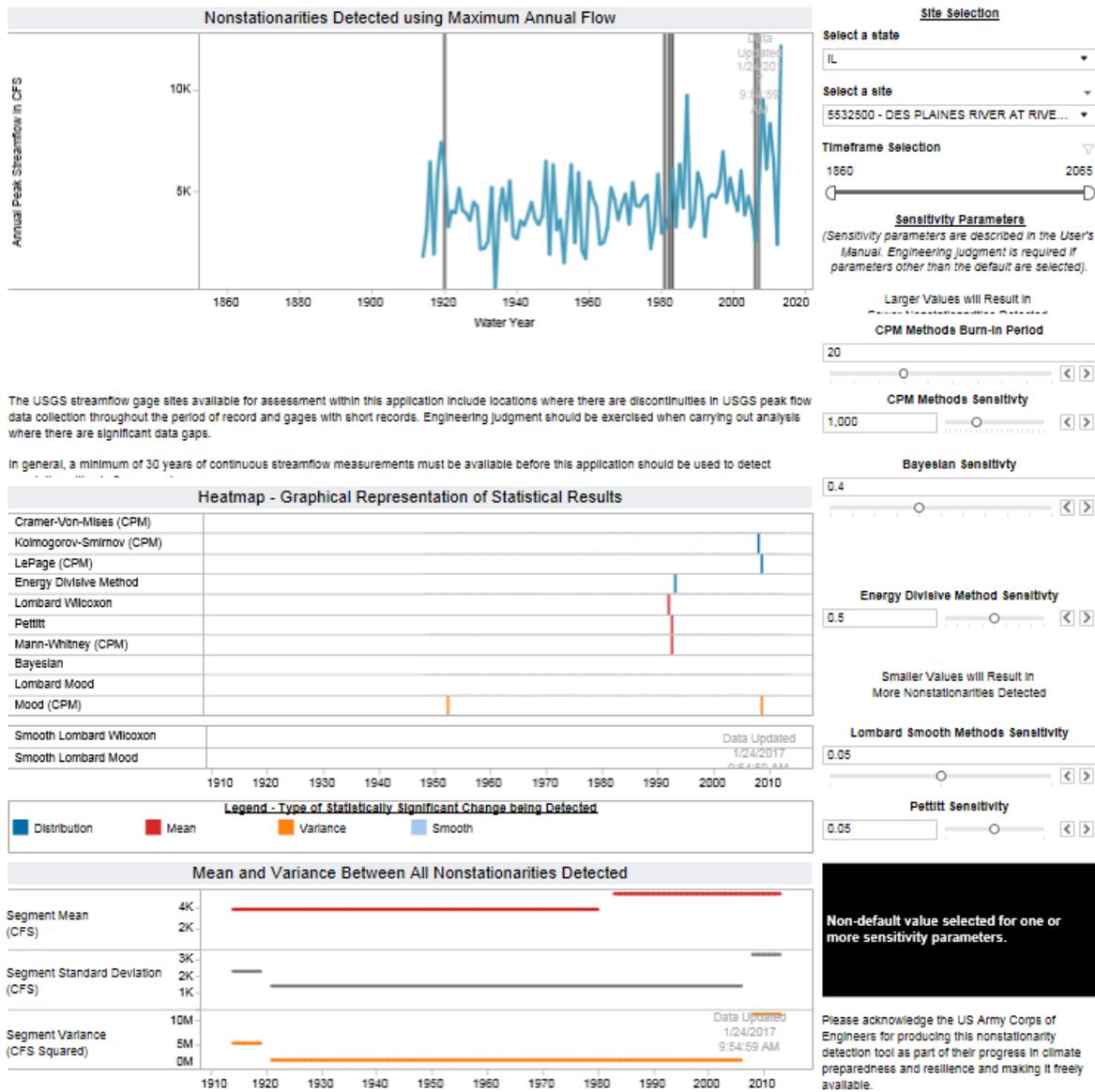
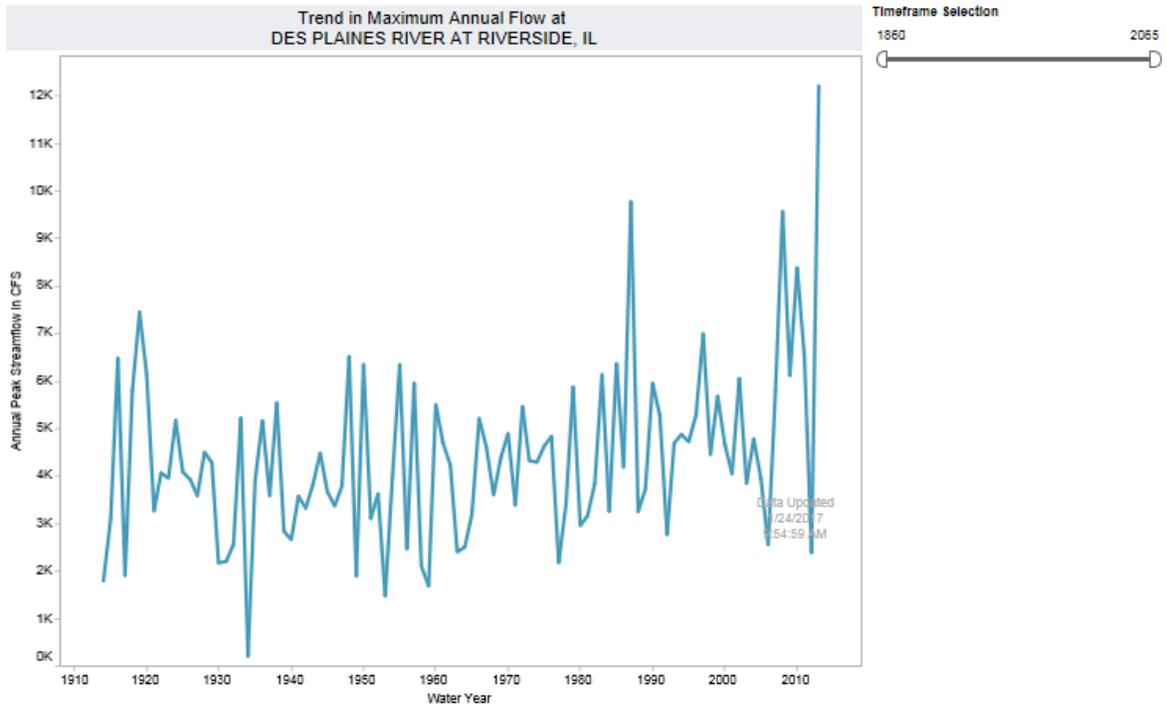


Figure 6. Nonstationary Analysis, Des Plaines River at Riverside, IL (1914)



Monotonic Trend Analysis

Is there a statistically significant trend?

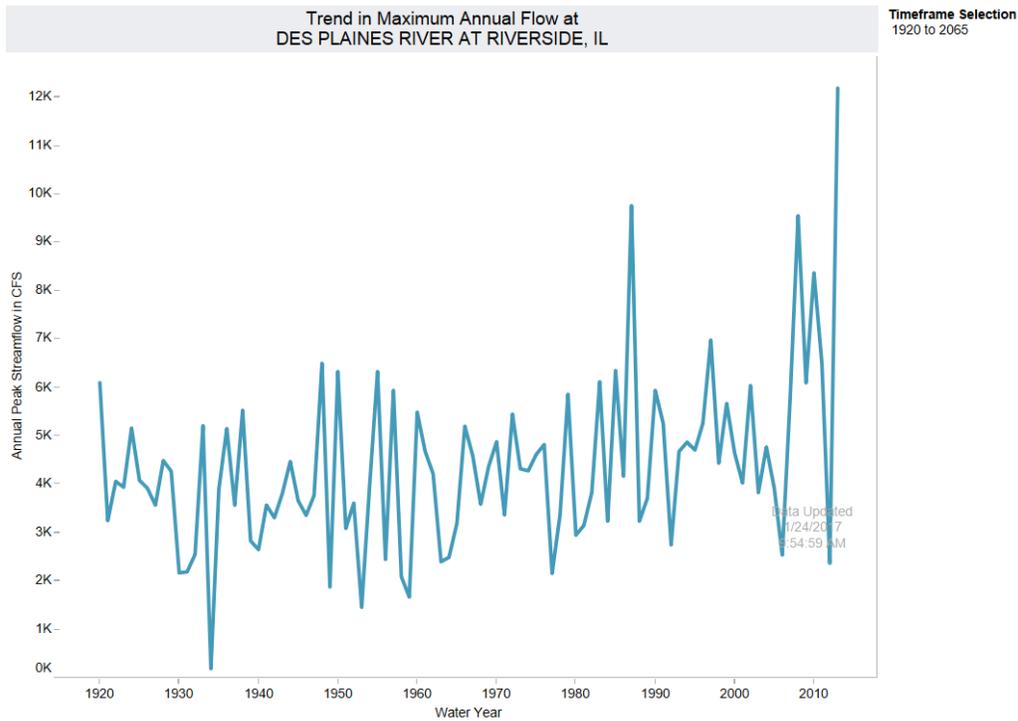
Yes, using the Mann-Kendall Test at the .05 level of significance.
 Yes, using the Spearman Rank Order Test at the .05 level of significance.

What type of trend was detected?

Using parametric statistical methods, a **positive trend** was detected.
 Using robust parametric statistical methods (Sen's Slope), a **positive trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Figure 7. Trend Analysis for Des Plaines River at Riverside, IL (1914-2013)



Monotonic Trend Analysis

Is there a statistically significant trend?

Yes, using the Mann-Kendall Test at the .05 level of significance.

Yes, using the Spearman Rank Order Test at the .05 level of significance.

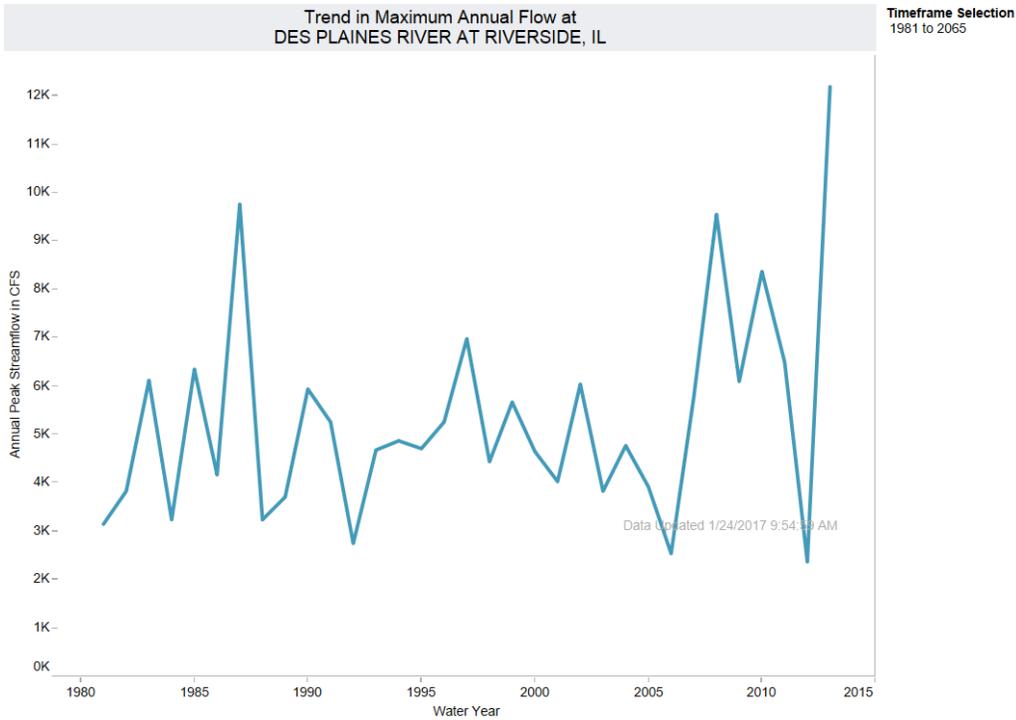
What type of trend was detected?

Using parametric statistical methods, **a positive trend** was detected.

Using robust parametric statistical methods (Sen's Slope), **a positive trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Figure 8. Trend Analysis for Des Plaines River at Riverside, IL (1920-2013)



Monotonic Trend Analysis

Is there a statistically significant trend?

No, using the Mann-Kendall Test at the .05 level of significance.

No, using the Spearman Rank Order Test at the .05 level of significance.

What type of trend was detected?

Using parametric statistical methods, **no trend** was detected.

Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Figure 9. Trend Analysis for Des Plaines River at Riverside, IL (1981-2013)

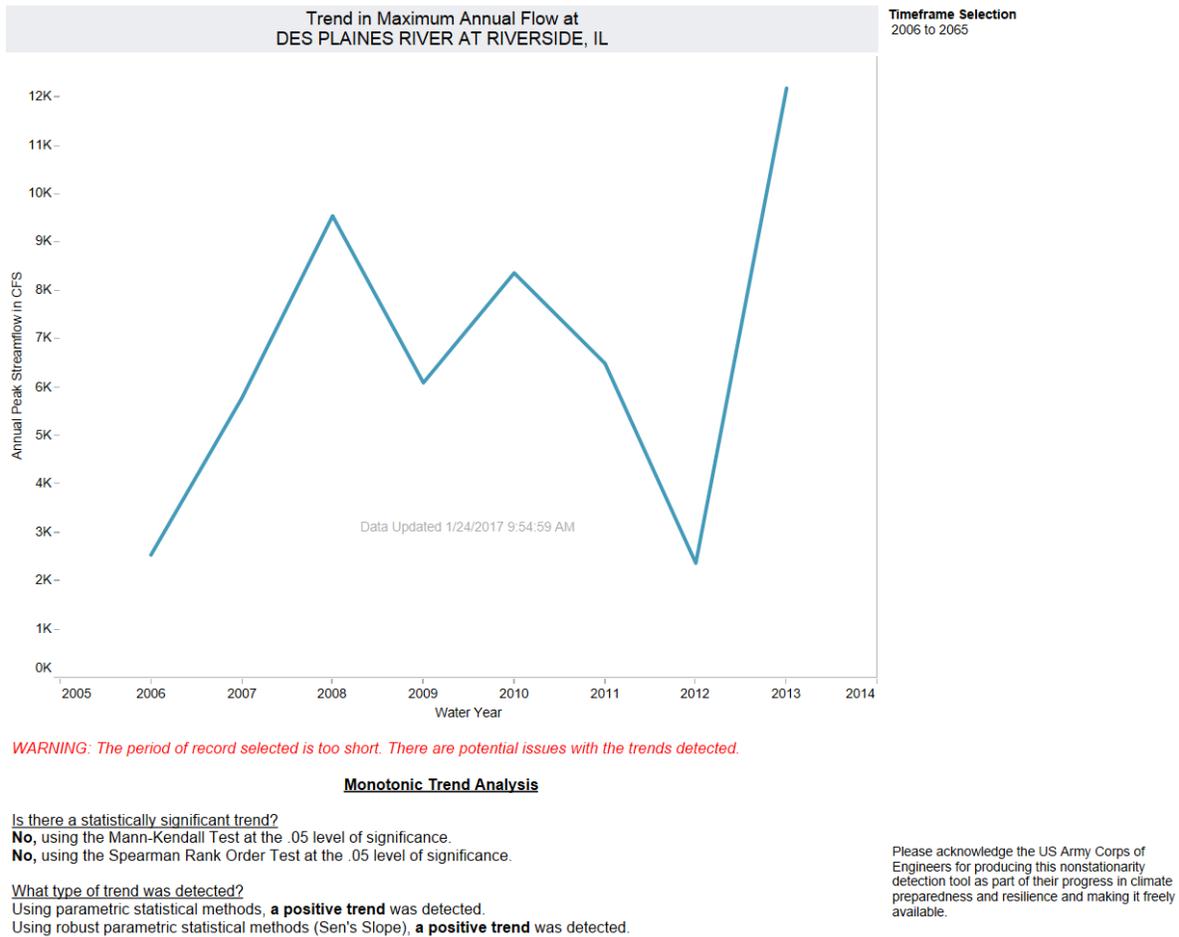


Figure 10. Trend Analysis for Des Plaines River at Riverside, IL (2006-2013)

Finally, the USACE online Vulnerability Assessment Tool was reviewed. For the Flood Risk Reduction business line, the project was not vulnerable to climate change for the Wet 2050 and Wet 2085 scenario/epoch combination within the project HUC-4 region as shown in [Figure 11](#) below. In addition, for the dry scenario there was a 3.82% change and for the wet scenario, an 8.00% change in the WOVA score for the HUC-4 Region with a Flood Risk Reduction business line as shown in [Figure 12](#) and [Figure 13](#) below.

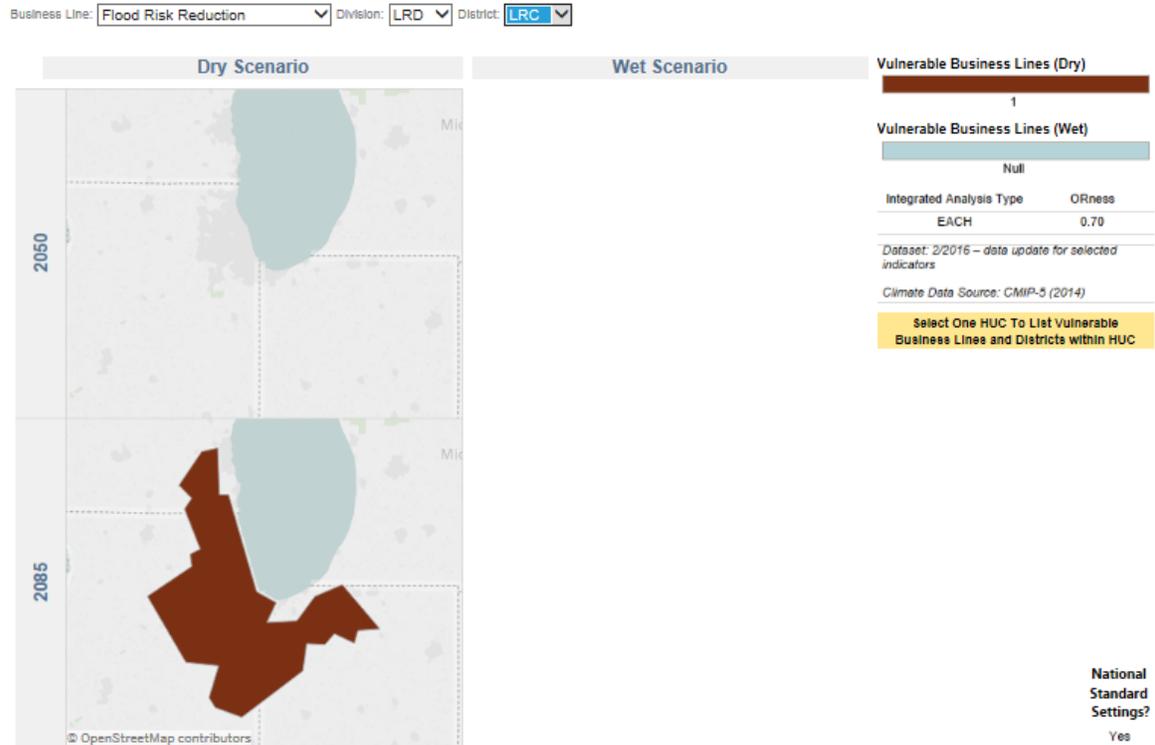


Figure 11. Vulnerability Assessment Tool HUC-4:0712-Upper Illinois

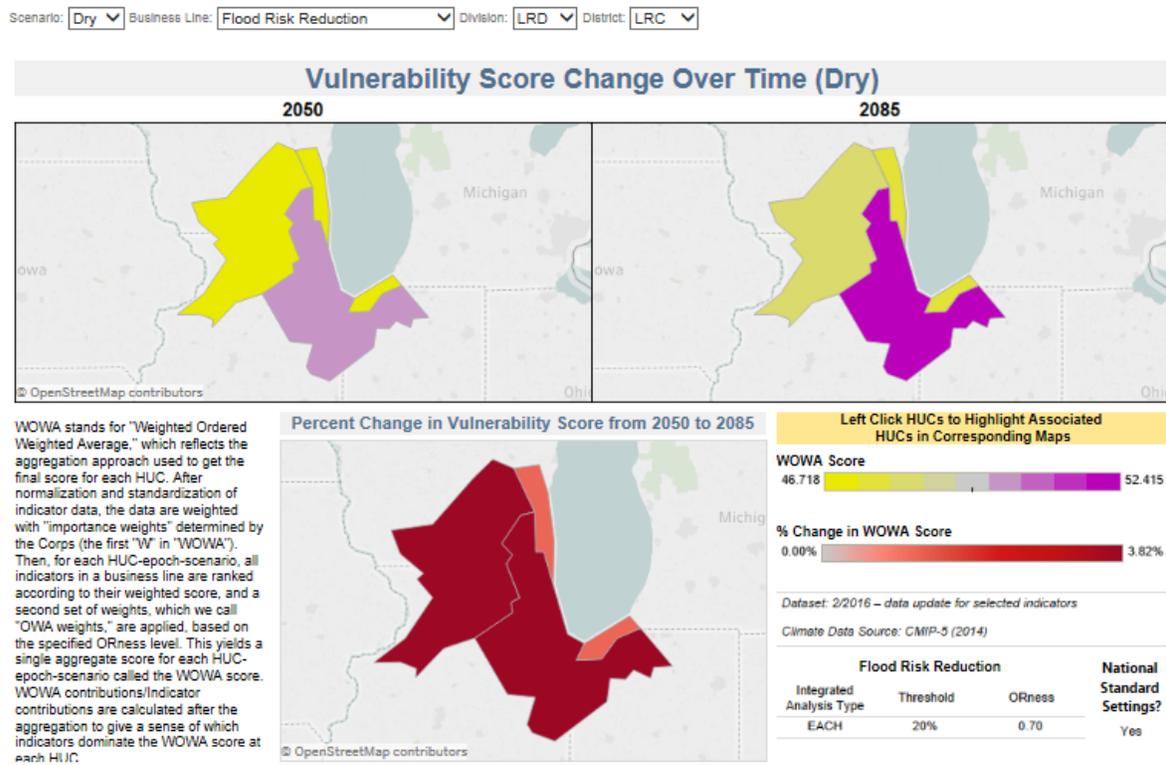


Figure 12. Vulnerability Score, Dry Scenario HUC-4:0712-Upper Illinois

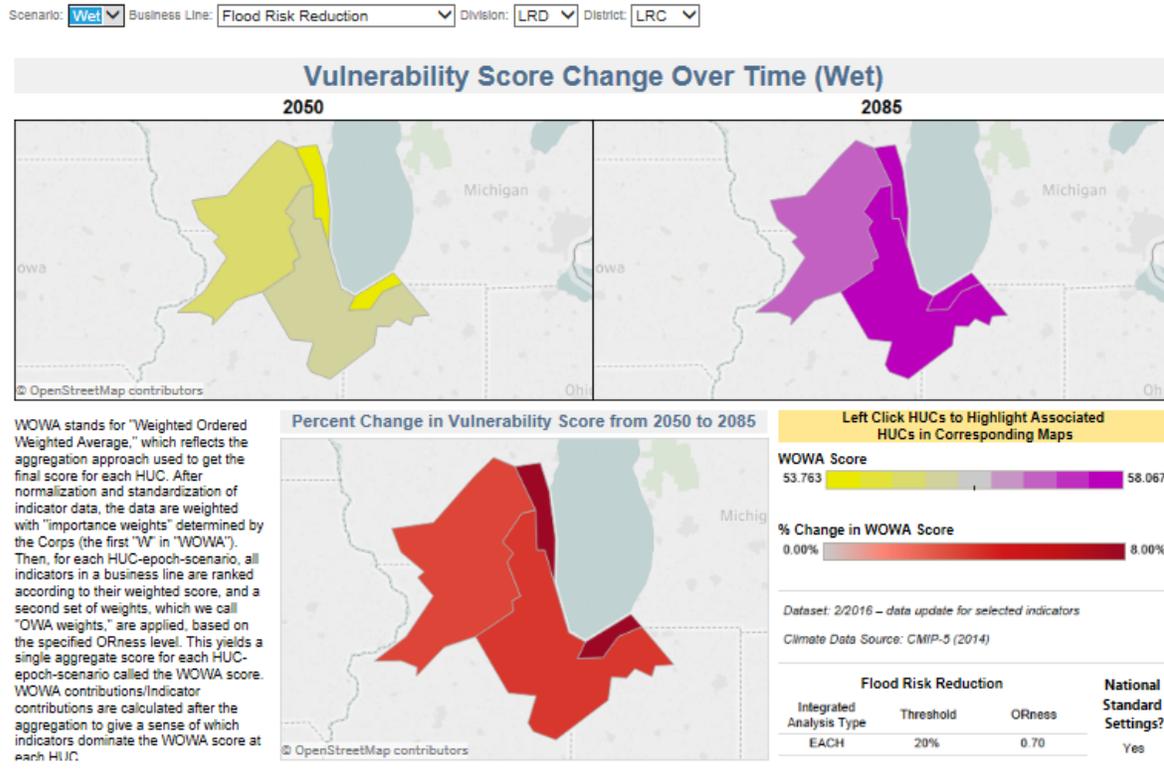


Figure 13. Vulnerability Score, Wet Scenario HUC-4:0712-Upper Illinois

Based on the tools utilized above, it appears that the project area could be significantly impacted by climate change. Since the levee crest elevation is limited to a specific elevation as described above in paragraph two under Superiority Analysis, it is not feasible to raise the levee higher in regard to climate change concerns.

Climate Change Literature Review

USACE is undertaking its climate change preparedness and resilience planning and implementation in consultation with internal and external experts using the best available — and actionable — climate science. As part of this effort, the USACE has developed concise reports summarizing observed and projected climate and hydrological patterns, at a HUC2 watershed scale cited in reputable peer-reviewed literature and authoritative national and regional reports. Trends are characterized in terms of climate threats to USACE business lines. The reports also provide context and linkage to other agency resources for climate resilience planning, such as downscaled climate data for sub-regions, and watershed vulnerability assessment tools.

The USACE literature review report focused on the Great Lakes Region was finalized in April, 2015 (USACE, April 2015) and the USACE literature review focused on the

For both the Upper Mississippi and Great Lakes Regions, increase in temperatures have been observed and additional increases in temperature are predicted for the future. For the Great Lakes Region, “nearly all studies note an upward trend in average temperatures, but generally the observed change is small. Some studies note seasonal differences with possible cooling trends in fall or winter.” For the Upper Mississippi Region, increasing trends were more uniformly reported by multiple studies. There is a strong consensus within the literature that temperatures are projected to continue to increase over the next century.

Increases in streamflow have been observed and projections for streamflow rates are variable. For the Great Lakes region, trends in low and annual streamflow were variable, with slight increases observed at some gages but other gages showing no significant changes. “Significant uncertainty exists in projected runoff and streamflow, with some models projecting increases and other decreases. Changes in runoff and streamflow may also vary by season. Projections of water levels in the Great Lakes also have considerable uncertainty, but overall lake levels are expected to drop over the next century.” For the Upper Mississippi Region, “a strong consensus was found showing an upward trend in mean, low, and peak streamflow in the study region.” There is no clear consensus on projected streamflow trends, “with some studies projecting an increase in future streamflow (as a result of increased precipitation) in the study region, while others project a decrease in flows (a result of increased evapotranspiration).” In general, projections suggest increased flows are expected in the winter and spring and decreased flows expected in the summer.

PRIMARY VARIABLE	OBSERVED		PROJECTED	
	Trend	Literature Consensus (n)	Trend	Literature Consensus (n)
Temperature	↑	(7)	↑	(4)
Temperature MINIMUMS	↑	(1)	↑	(1)
Temperature MAXIMUMS	—	(1)	↑	(5)
Precipitation	↕	(7)	↑	(4)
Precipitation EXTREMES	↑	(5)	↑↑	(4)
Hydrology/ Streamflow	↑	(7)	↕	(3)

NOTE: Although most studies indicate an overall increase in observed average precipitation, there is variation both seasonally and geographically. There is considerable uncertainty in projected streamflows, with no clear consensus between studies

TREND SCALE

= Large Increase
 = Small Increase
 = No Change
 = Variable
 = Large Decrease
 = Small Decrease
 = No Literature

LITERATURE CONSENSUS SCALE

= All literature report similar trend
 = Low consensus
 = Majority report similar trends
 = No peer-reviewed literature available for review
(n) = number of relevant literature studies reviewed

Figure 15 – Great Lakes Region - Summary matrix of observed and projected climate trends and literary consensus. (USACE, 2015)

PRIMARY VARIABLE	OBSERVED		PROJECTED	
	Trend	Literature Consensus (n)	Trend	Literature Consensus (n)
 Temperature	↑	 (7)	↑↑	 (14)
 Temperature MINIMUMS	↑	 (3)	↑↑	 (4)
 Temperature MAXIMUMS	↓	 (3)	↑↑	 (6)
 Precipitation	↑↑	 (12)	↑	 (15)
 Precipitation EXTREMES	↑	 (2)	↑	 (10)
 Hydrology/ Streamflow	↑	 (10)	↕↑	 (15)

TREND SCALE

 = Large Increase
 = Small Increase
 = No Change
 = Variable
 = Large Decrease
 = Small Decrease
 = No Literature

LITERATURE CONSENSUS SCALE

 = All literature report similar trend
 = Low consensus
 = Majority report similar trends
 = No peer-reviewed literature available for review
(n) = number of relevant literature studies reviewed

Figure 16 – Upper Mississippi Region - Summary matrix of observed and projected climate trends and literary consensus. (USACE, 2015)

Based on the tools utilized above, it appears that the project area could be significantly impacted by climate change, however, since the levee crest elevation is limited to a specific elevation for the reasons described above in paragraph two under Superiority Analysis, it is not feasible at this time to raise the levee higher in regard to climate change concerns.

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1. EM 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies , Department of the Army, U.S. Army Corps of Engineers, 1 August 1996
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3. ETL 1110-2-299 "Overtopping of Flood Control Levees and Floodwalls" Department of the Army, U.S. Army Corps of Engineers, 22 August 1986
4. ECB No. 2017-15 "Managed Overtopping of Levee Systems" 14 July 2017
5. ECB No. 2016-25 "Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects" 16 September 2016

Attachment 1

LYONS LEVEE IMPROVEMENT PROJECT Hydrology & Hydraulics Technical Memorandum

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Submitted by:



MC Consulting Inc.

1301 West 22nd Street | Suite 215

Oak Brook, IL 60559

P 630.990.0922 | **F** 630.990.0927

www.mcconsultinginc.com

In Association with:

AECOM

AECOM Technical Services, Inc.

2IM Group ● Environmental Design International

Program Director:

Majid A. Chaudhry, Ph.D., P.E.

Project Manager/Lead Principal Engineer:

William J. Weaver, P.E.

River and Drainage Engineer:

John Morgan, P.E.

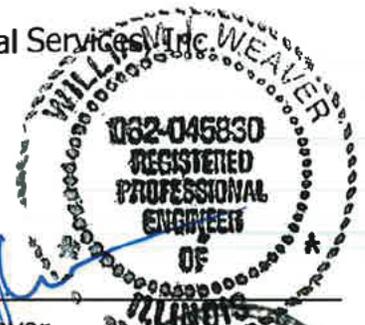
MC Consulting Inc.

AECOM Technical Services, Inc.

ZIM Group



William J. Weaver



Majid A. Chaudhry



MC Consulting Inc.
1301 West 22nd Street | Suite 215
Oak Brook, IL 60559
P 630.990.0922 | F 630.990.0927
www.mcconsultinginc.com

In Association with:

AECOM

AECOM Technical Services, Inc.

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1. Introduction and Background

Lyons levee has been providing protection for the Village of Forest View against Des Plaines River flooding for the better part of the last 100 years. The levee is located beginning 250 feet downstream of Joliet Road on the east side of the river, and parallels the river for a distance of 3,900 feet to the south ending at the Metropolitan Water Reclamation District (MWRDGC) HASMA facility. The original levee construction began in 1892. The work was completed in stages and was completed in 1908. Figure 1-1 is a project vicinity map. Figure 1-2 illustrates the location of the levee on an aerial photograph.

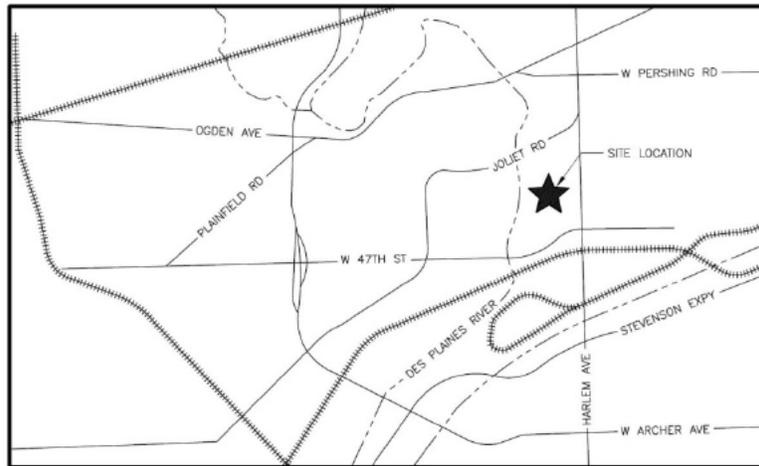


Figure 1-1 – Project Vicinity Map

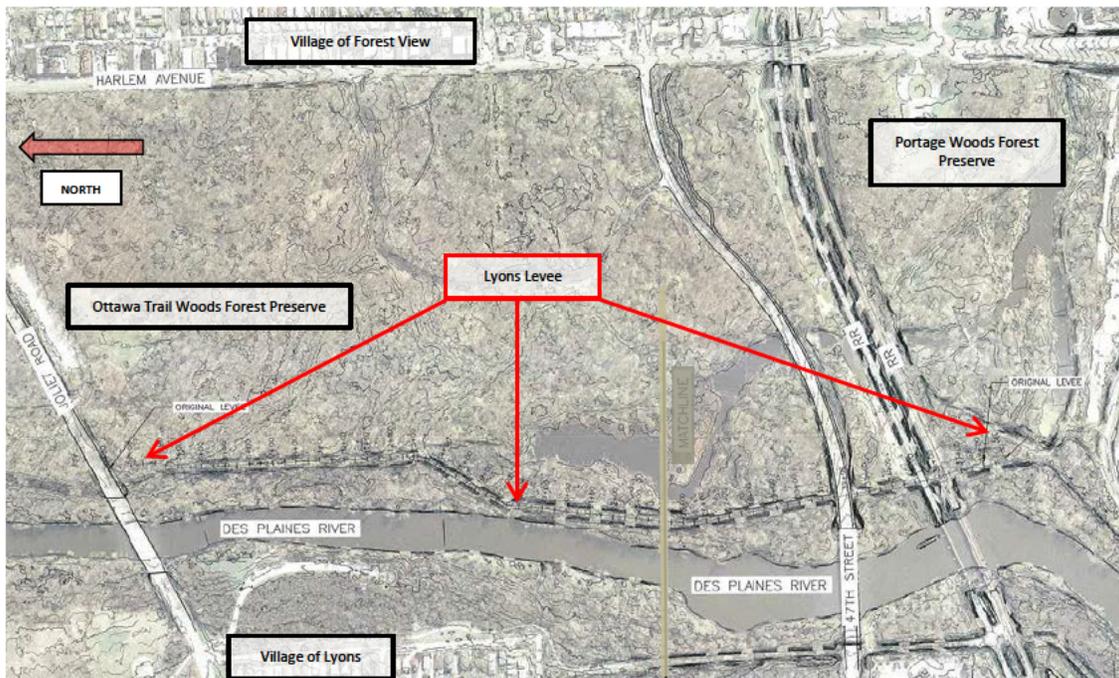


Figure 1-2 – Lyons Levee Location Map

The original levee was reported to have been constructed at elevation 602.0 at the downstream project limits and gradually increasing to 605.0 at the upstream limits at Joliet Road. Over the years, levee settlement, erosion, and foot traffic created low spots in the crest resulting in a minimum crest elevation of approximately 601.0 in several locations.

During April 2013, a flood event that produced the largest Des Plaines River flood discharge for the last 100 years as recorded at the Riverside flow gage caused overtopping of the levee. This event is estimated to have exceeded a flood recurrence interval of 100 years, and overtopped the levee by approximately 0.5 feet at three levee low spots. While some minor levee crest erosion occurred on the upland side, overall the levee survived the event in good shape. Figure 1-3 is a photograph of the levee during summer.



Figure 1-3 – Lyons Levee Crest

Levee maintenance completed as part of temporary flood control measures implemented during 2014 has raised the minimum crest elevation to 602.0.

The Lyons Levee improvement project will upgrade the levee to improve flood protection. The design basis includes an evaluation of the April 2013 flood event to help in the understanding of flood risk and frequency at this location. The levee improvements will help reduce the future risk of flooding in the Village of Forest View.

This Hydrology and Hydraulics Technical Memorandum is prepared to summarize the Des Plaines River Hydrology and Hydraulics studies and Lyons Levee interior drainage studies completed to support the design basis analysis for the proposed levee improvements. This memorandum includes the following information prepared at the request of the U.S. Army Corps of Engineers – Chicago District:

- Evaluation of Des Plaines River flood elevations and flood frequency.
- Evaluate the various river flood models that have been developed for the Des Plaines River and assess the April 2013 flood event frequency. This assessment utilized high water data provided by MWRDGC, Forest View and Hancock Engineering.
- Assess the interior drainage system capacity and potential deficiencies upland of the existing levee.

Field surveys were completed to provide information needed to support the flood study. Land survey field work and archive searches were completed to develop base map information for the project. The field survey efforts included the following tasks:

- Establish horizontal and vertical control.
- General Site Topography –The base mapping relies on the existing Cook County LIDAR survey, topographic mapping and parcel shape files used to correlate existing parcel and right-of-way lines as obtained from the Cook County GIS. This data was obtained, reviewed for obvious discrepancies

and converted for use in AutoCad Civil 3D. Additional survey data collected by MWRDGC and the project team was used to enhance the LIDAR survey. This information forms the basis for enhancing the existing river hydraulic models used for the study and to support the interior drainage study.

- Existing levee survey - A centerline profile of the top of east levee was surveyed at a minimum of 100-foot intervals. Cross-sections of the levee were not surveyed in the field. The survey information supports the technical evaluations of levee improvement options. MWRDGC completed a survey of the east levee crest.
- River Cross sections – A hydrographic survey of the Des Plaines River in the project area was performed to develop cross sections of the river for use in updating hydraulic models.
- Interior drainage –localized hydraulic structure and other survey information needed to support the Interior Drainage evaluation has been completed. The survey includes information needed for the Harlem Ave underpass evaluation.
- Integrated base mapping incorporating all information obtained has been prepared.

2. Des Plaines River Flood Evaluation

The work described in this section was performed to evaluate the effectiveness/level of protection of the current levee and the levee profile required to protect Forest View from flooding during large flood events on the Des Plaines River. The scope of the project included evaluating the April 2013 flood event using the existing models. Hydrologic modeling of the Des Plaines River was not included in the scope of work. The existing DWP hydrology would be used when needed. In addition, a statistical analysis of the historical river flow records for the Riverside gage was completed to enhance the understanding of flood frequency for this site.

The existing hydraulic models were updated to include the additional detail required to prepare a preliminary design of the levee improvements. After completion of the initial model updates and modeling the April 2013 flood event, it was determined that additional calibration of the hydraulic model was needed to adequately represent this flood event.

2.1 Existing Des Plaines River Flood Profiles.

There are four previous studies of the Des Plaines River flood profiles in the vicinity of the Lyons Levee. A summary of the flood profiles and discharges for the 1% exceedance chance (100-yr) flood are presented in the following sections.

2.1.1 MWRDGC Lower Des Plaines River Detailed Watershed Plan (DWP). The DWP was prepared in February 2011 by Christopher B. Burke Engineering, Ltd. for MWRDGC. The DWP used HEC-HMS for the hydrologic modeling and unsteady flow HEC-RAS for the hydraulic modeling of the Des Plaines River and its tributaries in Cook County. The 1% exceedance chance flood stages at the Joliet Road and 47th Street bridges are approximately 603.1 and 602.7 feet NAVD88, respectively. The 1% exceedance chance discharges at Hoffman Dam and 47th Street Bridge are 9,670 and 9,600 cfs, respectively.

2.1.2 FEMA Flood Insurance Study. The FEMA Flood Insurance Study (FIS) for Cook County, IL dated August 2008 shows the 1% exceedance chance flood elevations at the Joliet Road and 47th Street Bridge are approximately 598.8 and 597.6 feet NAVD88, respectively. The 1% exceedance chance flood discharges at Hoffman Dam and 47th Street Bridge are 7,706 and 7,900 cfs, respectively. The flood profiles and discharges in the FEMA Flood Insurance Study are based on the Illinois Department of Transportation – Division of Water Resources Des Plaines River flood plain maps prepared in 1978. These maps were prepared using the TR-20 hydrologic model and WSP-2 hydraulic model developed by the NRCS for the Lower Des Plaines River flood control study performed in the 1970's.

2.1.3 U.S. Army Corps of Engineers Studies

2.1.3.1 Upper Des Plaines River Feasibility Study. The Chicago District Corps of Engineers released a draft report in September 2013 on the Flood Control Plan for the Upper Des Plaines River and its tributaries. This report does not cover the Lyons Levee

project area. The study ends upstream of Hoffman Dam. The study does publish discharges on the Des Plaines River from a discharge frequency analysis performed in January 2008. The 1% exceedance chance discharge at the USGS Riverside stream gage is 9,068 cfs.

2.1.3.2 Lyons Levee Assessment. The Corps of Engineers published a levee assessment of the Lyons Levee in June 2012. The 1% exceedance chance flood elevation at River Mile 42.3 according to this study is 601.58 feet NAVD88. This is near the 47th Street Bridge. The discharges used in this study were not published in the report. The Corps of Engineers estimated that the Lyons Levee would be overtopped during a 5% exceedance chance (20-yr) flood.

2.2 Updated Hydrologic Analysis

The Des Plaines River hydrology was updated for this study to establish a “Project Design Flood” that serves as the levee design basis for this project. This was done due to the large variance in the published flows for this site and the number of flood events where the discharge measured at the USGS Riverside stream gage exceeded flows published in the FEMA Flood Insurance Study (FIS) for the 1% exceedance chance discharge since 1978.

The annual peak discharges for the USGS Des Plaines River at Riverside stream gage were obtained from the USGS web site. The published data covers the period from WY 1914 to WY 2013. This record includes the April 2013 flood event that overtopped the Lyons Levee and flooded Forest View. The April 2013 flood discharge at Riverside was 12,200 cfs according to the USGS. A discharge frequency analysis of the annual peak discharges was performed using the Corps of Engineers software package HEC-SSP 2.0. A regional skew and the regional skew mean square error parameters used by the Corps of Engineers in their January 2008 discharge frequency analysis were used in this analysis. The regional skew was -0.16 and the regional skew MSE was 0.2. The results of this analysis are shown in Table 2-1 and Figure 2-1. This analysis provides the 100-year Project Design Flood (Design Flood) for the Lyons Levee improvement project.

Table 2-1 – Riverside Discharge Frequency Analysis

% Chance Exceedance	Computed Flow (cfs)	Expected Probability Flow (cfs)	5% Confidence Limit (cfs)	95% Confidence Limit (cfs)
0.2 (500-yr)	11,760	12,090	13,740	10,360
0.5 (200-yr)	10,620	10,850	12,260	9,440
1.0 (100-yr)	9,750	9,920	11,140	8,730
2.0 (50-yr)	8,870	8,980	10,030	8,010
5.0 (20-yr)	7,670	7,730	8,540	7,010
10.0 (10-yr)	6,720	6,760	7,390	6,200
20.0 (5-yr)	5,710	5,730	6,190	5,320
50.0 (2-yr)	4,130	4,130	4,420	3,870

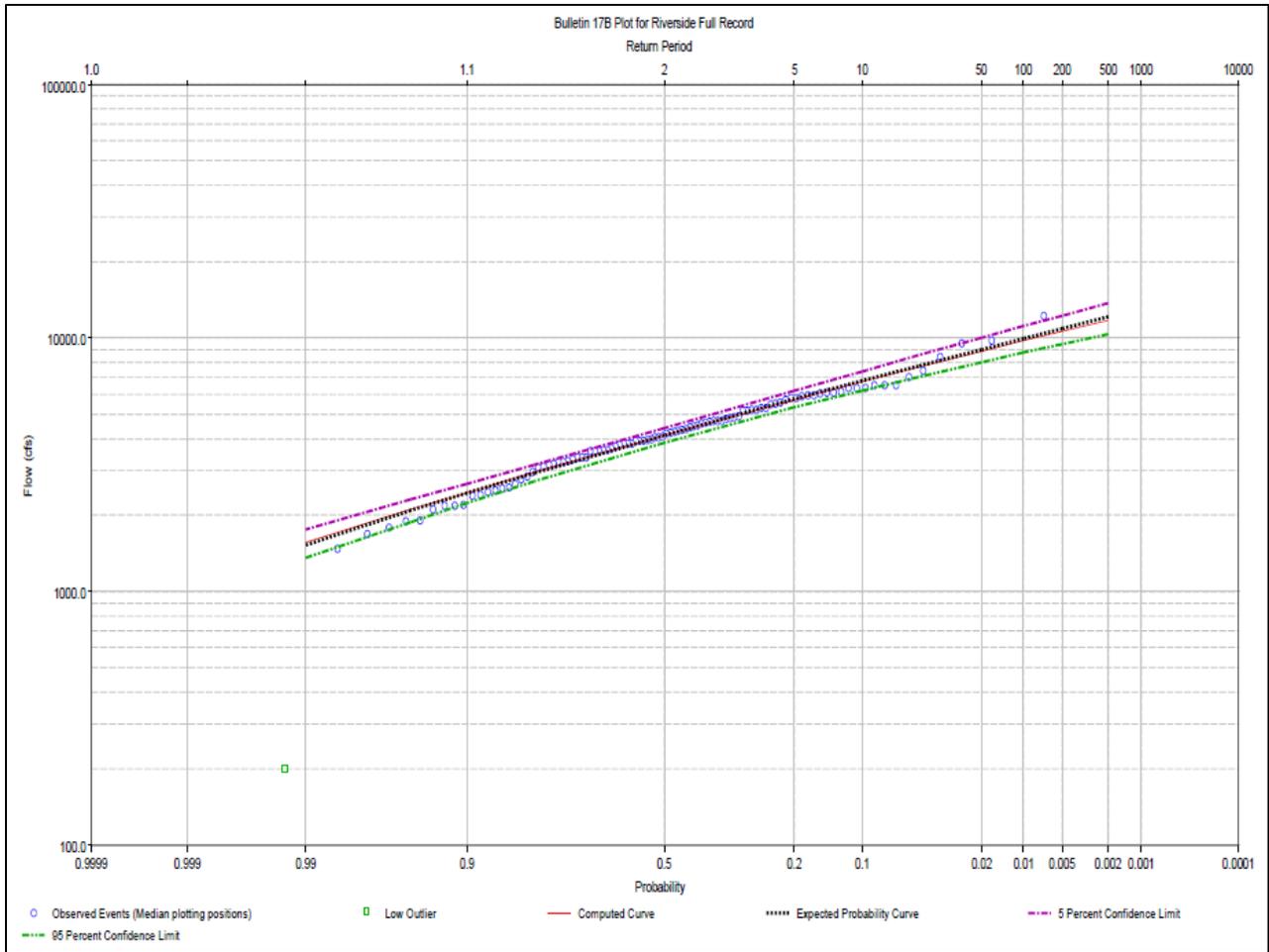


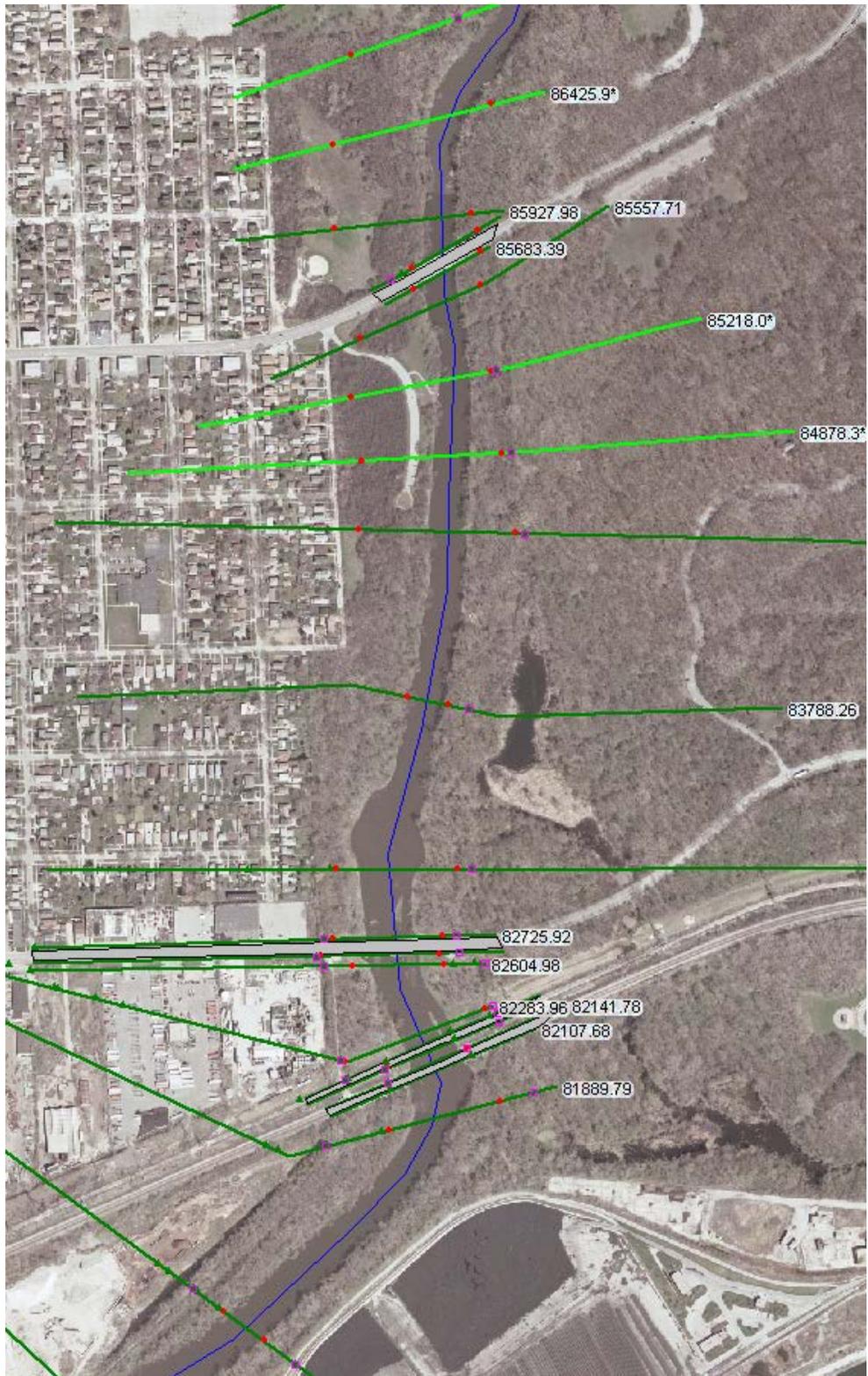
Figure 2-1 – Riverside Discharge Frequency Analysis

The 100-year Project Design Flood resulting from this analysis is based on a statistical analysis of 100 years of river gage records, which included a variety of watershed conditions that occurred between 1914 and 2013. The proposed levee improvements will incorporate a freeboard above the 100-year Project Design Flood. A readme file is provided for the HEC-SSP computer model in Appendix A. Computer model input and output for this analysis is provided in Appendix B in a file named: "DesPlainesRiver_SSP_Files".

2.3 Hydraulic Analysis

The DWP HEC-RAS model was modified for this study. The DWP model was truncated to represent the Des Plaines River from Hoffman Dam at the upstream boundary to the downstream boundary at the Cook County line.

2.3.1 Updates to the HEC-RAS Model. The unsteady flow HEC-RAS model developed for the Lower Des Plaines Detailed Watershed Plan was used as the base model for this study. The cross section locations for this HEC-RAS model are shown in Figure 2-2. The sections that have an asterisk (*) by the section numbers are interpolated and are illustrated in light green color.



Note: Section Numbers with an Asterisk (*) are interpolated.

Figure 2-2 – Lower Des Plaines River Detailed Watershed Plan Cross Section Locations

The DWP HEC-RAS model was updated with additional levee details and Des Plaines River geometry needed for the preliminary design. Additional cross sections were added to the model to replace interpolated cross sections in the vicinity of Lyons Levee. Cross sections were added to the model near Lyons Levee to better reflect where changes in the river and levee geometry occur. These new cross sections were developed using the Cook County bare earth LIDAR data and a bathymetric survey of the Des Plaines River performed for this study. The cross sections within the levee limits were truncated at the crest of the Lyons Levee.

Lateral structures were added to the model within the project limits to represent potential levee overtopping. The levee profile used for these lateral structures is based on a detailed levee profile surveyed for this project. The lateral structures in the model allow water overtopping of the levee if the river flood stage exceeds the levee crest. If this were to occur, the water is extracted from the river system causing a reduction in river flow downstream of Lyons Levee.

Lateral structures were also added to the model downstream of Willow Springs. These structures represent inter-basin flow that can occur between the Des Plaines River and Sanitary and Ship Canal during extreme river levels. These lateral structures were obtained from a model developed by the Corps of Engineers for the Great Lakes and Mississippi River Interbasin Study (GLMRIS). The GLMRIS HEC-RAS model was used in the Lyons Levee assessment report prepared by the Corps of Engineers. The updated cross section geometry for the updated model near Lyons Levee is shown in Figure 2-3.

A readme file is provided for the HEC-RAS computer model in Appendix A. Computer model input and output for this analysis is provided in Appendix B in a file named: "DesPlainesRiver_RAS_Files".

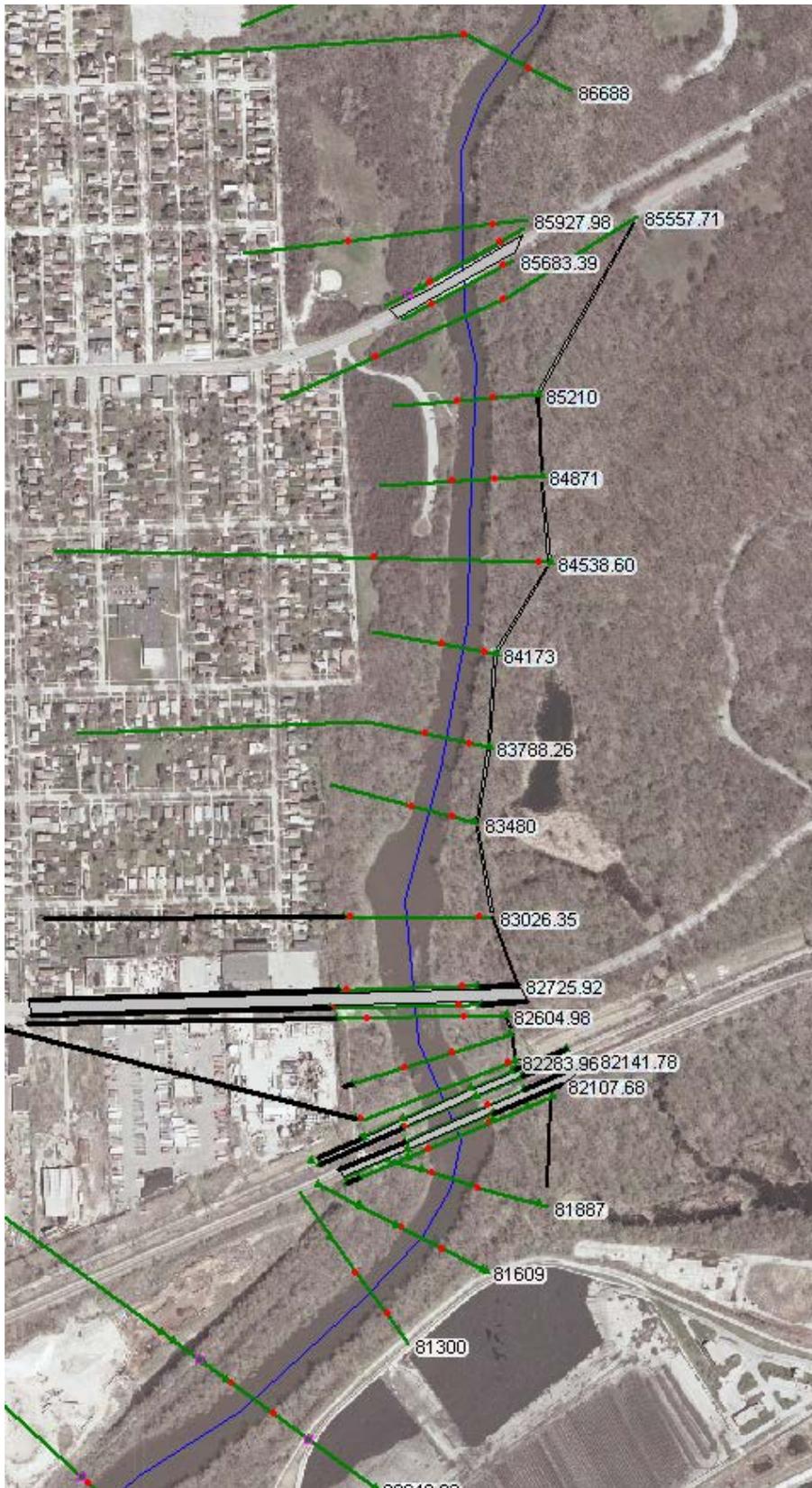


Figure 2-3 – Final Cross Section and Lateral Structure Locations

2.3.2 HEC-RAS Model Calibration. The HEC-RAS model developed for this project was run to simulate the April 2013 flood event to evaluate how well the model represents observed flood conditions during that event. The observed high water elevation at the USGS Riverside stream gage was 605.65 feet NAVD88. The Des Plaines River flood elevation near 47th Street was estimated based on the overtopping photos taken during the event and the existing levee profile survey, and observed high water locations reported by Brian Levy of the MWRDGC. The high water marks near 47th Street were estimated to be 601.70 feet NAVD88. The initial HECRAS model run for the April 2013 flood event produced elevations of 606.36 and 602.44 feet NAVD88 at Riverside and 47th Street, respectively. These elevations were significantly higher than the observed high water marks. We performed a calibration analysis to improve how the HEC-RAS model represents the larger event floods.

The calibration process included an update to the existing levee profile as described in Section 2.3.1. The primary calibration tool used included adjustments to the channel and overbank Manning’s n-values. The initial channel and overbank n-values ranged from 0.038 – 0.050 and 0.070 – 0.090, respectively.

The HEC-RAS calibration was performed using six recent historic storms from September 2008 to July 2014 using the unsteady flow option. A summary of the peak flows and observed high water marks for these events is provided in Table 2-2. The July 2014 flood event was included because of the recent addition of a USGS stage gage at this location. Three of the other five events have flows greater than the published FEMA FIS 1% exceedance flood.

Table 2-2 – Calibration Events

Event	Flow at Riverside (cfs)	Observed High Water Elevation at Riverside (ft NAVD88)	Observed High Water Elevation at 47 th Street (ft NAVD88)
September 2008	9,560	604.25	n/a
December 2008	6,110	602.30	n/a
July 2010	8,380	603.61	n/a
July 2011	6,510	602.84	n/a
April 2013	12,200	605.65	601.70
July 2014	3,920	600.97	596.13

In addition to the 47th Street high water elevation for the April 2013 flood event, the overtopping volume was estimated using the high water mark near the Forest View City Hall. The overtopping volume was estimated at 614 ac-ft below elevation 593.3 feet NAVD88.

The calibration process for the Des Plaines River HEC-RAS model included the adjustment of channel and overbank n-values to bring the computed stages closer to the observed stages. The channel and overbank n-values for the calibration runs downstream of 47th Street are 0.033 and

0.056, respectively. The final channel and overbank n values between 47th Street and the USGS Riverside stream gage are therefore also selected to be 0.045 and 0.056, respectively.

A summary of the calibration results is provided in Table 2-3. The HEC-RAS model estimates a total overtopping volume of 667.9 ac-ft compared to an approximate observed volume of 614.0 ac-ft. Based on the elevation differences in Table 2-3 and the differences in the overflow volumes, the model is considered to provide a reasonable calibration.

Table 2-3 – Calibration Results

Event	47 th Street Observed (ft NAVD)	47 th Street Computed (ft NAVD)	Difference (ft)	Riverside Observed (ft NAVD)	Riverside Computed (ft NAVD)	Difference (ft)
September 2008	n/a			604.25	604.74	0.49
December 2008	n/a			602.30	602.62	0.32
July 2010	n/a			603.61	604.09	0.48
July 2011	n/a			602.84	602.90	0.06
April 2013	601.70	601.67	-0.03	605.65	605.81	0.16
July 2014	596.13	595.85	-0.28	600.97	600.57	-0.40

2.3.3 Design Storm Profiles. The Project Design Flood profiles were computed using the calibrated HEC-RAS model in steady flow mode, and the “expected probability flows” developed as described in Section 2.2. We are unable to use the unsteady flow model for these events since we only have a hydrograph for the historic event from April 2013. Water surface profiles for the 10, 5, 2, and 1% exceedance events (10-, 20-, 50-, and 100yr recurrence intervals) were computed. In addition, the published FEMA FIS 1% exceedance chance flow of 7,900 cfs was used to estimate the flood profile using the calibrated HEC-RAS model. For the design storm profiles, overtopping of the levee was not included in the modeling. A summary of the design water surface profiles at Riverside, Joliet Road, 47th Street, Canadian National Railroad, BNSF Railroad, and the downstream end of the Lyons Levee are provided in Table 2-4. The water surface profiles are shown in Figure 2-4.

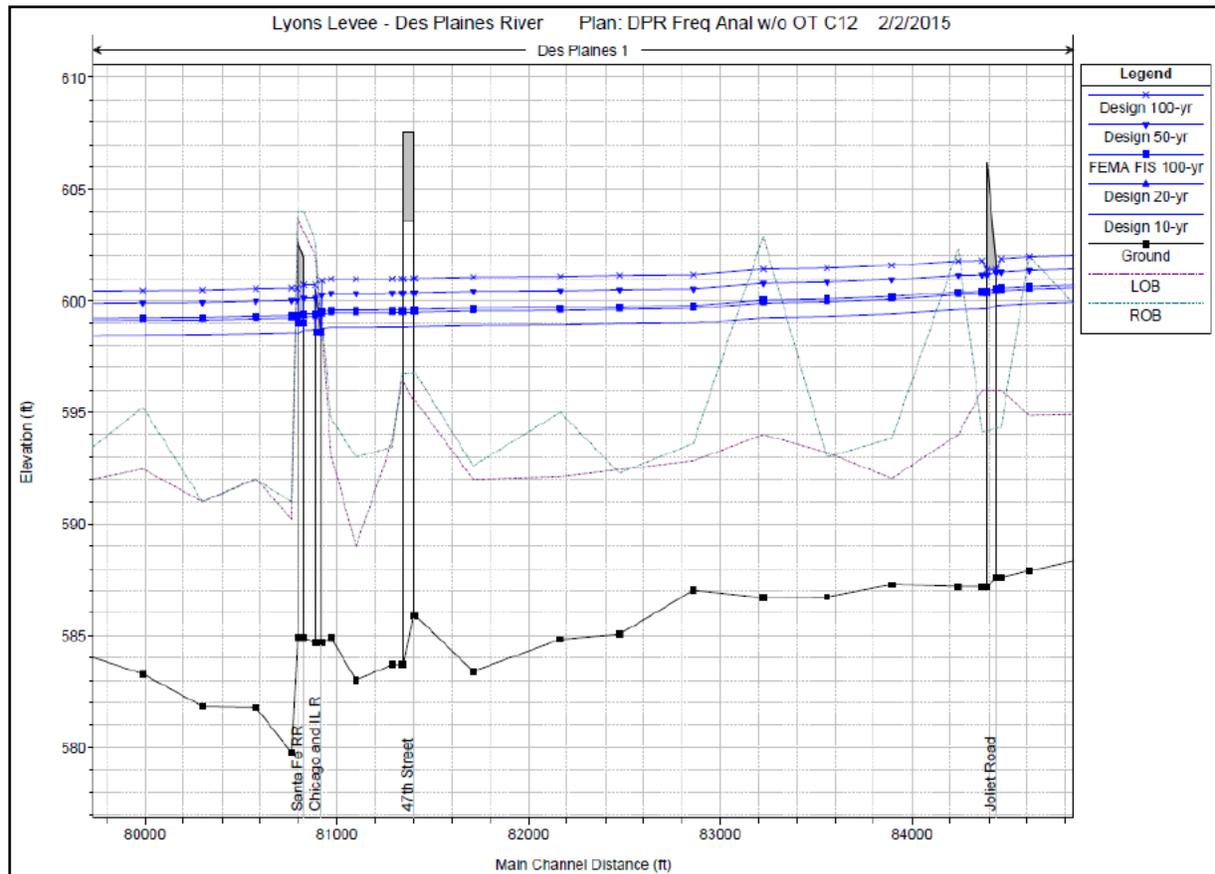
The calibrated HEC-RAS model with the FEMA FIS discharges produces higher water surface elevation estimates than the published FEMA flood profile. This is due in part to the change in computer models. The FEMA study used the WSP2 computer program. Furthermore, the FEMA model downstream boundary at 47th Street appears to be set too low as confirmed in the calibration analysis completed for the April 2013 event for this project. The HEC-RAS computed profile is approximately 1.8 feet higher at Joliet Road and 2 feet higher at 47th Street.

Table 2-4 –Water Surface Profile Summary

Location	Flood Elevations using HECRAS Model Calibrated to April 2013 Flood Event				
	% Exceedance (in any given year)				**FEMA FIS 100-yr event
	10 % (10-yr event)	5 % (20-yr event)	2 % (50-yr event)	*1% (100-yr event)	
Downstream Levee Limit	598.53	599.20	599.99	600.55	599.31
BNSF RR	598.68	599.30	600.12	600.72	599.41
Canadian National RR	598.75	599.39	600.27	600.91	599.52
47 th Street	598.81	599.46	600.35	600.98	599.59
Joliet Road	599.80	600.45	601.29	601.88	600.57
USGS Riverside Stream Gage	602.86	603.45	604.14	604.62	603.55

*100-year Project Design Flood

**100-year Profile using FEMA Discharge in HECRAS model.



*The 100 year Project Design Flood is defined in Section 2.2.
 LOB and ROB refer to left river overbank and right river overbank, respectively.

Figure 2-4 – Design Storm Water Surface Profiles

2.3.4 Urbanization Impact on Project Design Flood. The 100 –year Project Design Flood discharge developed as the design basis for Lyons levee improvements is based on an analysis of a 100 year river gage record as summarized in Section 2.2. In most respects, having such a long gage record is ideal and helps to reduce uncertainties that can result from analyses of shorter records. However, it is possible that a long gage record could potentially mask the effects of urbanization on flood peaks. In some cases urbanization can cause changes in rainfall frequency and watershed rainfall-runoff characteristics among other unknown factors on Des Plaines River discharges. Factors that can offset the influences of urbanization include stormwater and floodway regulations that have been implemented in recent decades and flood control project implementation by government entities.

A sensitivity analysis was performed to evaluate this phenomenon as it may apply to the Des Plaines River flood study presented in this report. The analysis includes a flood discharge frequency evaluation for a shorter and more recent time period at the Riverside gage than the 100 year record used to develop the 100-year Project Design Flood discharge. This analysis used the HEC-SSP computer program to analyze a 40 year gage record extending from 1974 through 2013. The results are compared with the 100 year gage record analysis to see if there has been a discernable change in the discharge frequency on the Des Plaines River at Riverside.

Results of this analysis for two gage record time periods is summarized in the following table. The 1% chance exceedance flow at Riverside is 9,920 cfs for the entire 100 year period of record, and 11,500 cfs for a record that excludes all data except for the last 40 years.

Expected Flow at Des Plaines River at Riverside								
Period	50%	20%	10%	5%	2%	1%	0.5%	0.2%
Period of Record 1914 to 2013	4,130	5,730	6,760	7,730	8,980	9,920	10,850	12,090
1974 to 2013	4,770	6,580	7,770	8,900	10,380	11,500	12,640	14,200

The shorter record requires more extrapolation to estimate the 100-yr flow than the 100 year record. Furthermore, one or more large flood events can significantly skew the magnitude of the 1% flow, when a shorter period of record is considered. There are a number of factors that come into play regarding differences in the discharge frequency curves. These can include a short record that can contain abnormally high measured flows, urbanization, increased rainfall due to climate change, flood control improvements upstream, and other issues.

The results of this analysis indicate that while the differences in flood discharges for a given gage record period can result in different flows, the approach taken to establish project design

conditions for the Lyons levee project are reasonable. The larger 100 year flow for the arbitrarily shorter gage record analysis reflects a 15% increase compared to the Project Design Flood which is based on a 100 year record. The proposed levee design will include significant freeboard above the Project Design Flood with the new levee crest above the flood profile for both of the gage period analyses summarized above. Furthermore, the proposed levee crest will be constructed above the flood of record at this gage which occurred during 2013.

3. Interior Drainage Evaluation

The existing drainage system located between Lyons Levee and Harlem Avenue was investigated to evaluate if this system has caused flood damages. The existing drainage system is bounded by Harlem Avenue on the east, the Lyons Levee on the west, Joliet Road on the north, and the MWRDGC Harlem Avenue Solids Management Area (HASMA) on the south. The general direction of the flow is from Harlem Avenue and Joliet Road to the south and west to a series of culverts under 47th Street and the Canadian National and BNSF Railroads. After passing through the railroad culverts the flow turns to the south and east to two small culverts under Harlem Avenue near the HASMA site. The discharge from these culverts is intercepted by the Harlem Avenue storm sewer and conveyed to the Sanitary and Ship Canal. See Figure 3-1 for a general overview of the interior drainage system.

The only known drainage problem related to the drainage system behind the levee is the periodic flooding that has occurred at the Harlem Avenue underpass south of 47th Street. The Illinois Department of Transportation investigated the flooding problems at the Harlem Avenue underpass under the Canadian National and BNSF Railroad tracks. The Location Drainage Technical Memorandum describing the existing problems and several alternative solutions was prepared by Hampton, Lenzini and Renwick, Inc. in November 2013. Alternative 3A was recommended in the report. This alternative consists of replacing the existing 30" and 36" sewers with new sewers with 42" and 48" sizes.



Figure 3-1 – Interior Drainage System Overview

3.1 Existing Interior Drainage System

To evaluate the existing interior drainage system, a HEC-HMS and HEC-RAS models were developed. The hydrology was modeled using HEC-HMS. An unsteady flow HEC-RAS model was developed to model the major components of the interior drainage system.

3.2 HEC-HMS Hydrologic Model Development

The interior drainage system was subdivided into 4 sub-basins shown in Figure 3-1. These correspond to the major drainage features in the interior drainage system. Sub-basin 47th West is tributary to the culvert under 47th Street. Sub-basin 47th East is the area tributary to the ditches along Harlem Avenue and 47th Street. The Railroad sub-basin is the area tributary to the culverts between 47th Street and the Railroad culverts. Sub-basin Harlem represents the area between the railroads and Harlem Avenue that drains to the culverts under Harlem Avenue. The primary land use within the interior drainage area is forest that belongs to the Forest Preserve District of Cook County. A summary of the drainage basin parameters is shown in Table 3-1. The total interior drainage area is 152.3 acres.

Table 3-1 – Summary of Subbasin Parameters

Subbasin	Area (ac)	Curve Number	Time of Concentration (min)
47 th East	27.49	75	70
47 th West	78.18	71	107
Railroad	21.24	82	59
Harlem	25.39	83	41

The NRCS curve number and unit hydrograph methods were used in modeling the runoff from these sub-basins. The interior drainage area was modeled using a critical duration storm methodology. The model was run for the 99, 50, 20, 10, 4, 2, and 1% exceedance frequencies (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr recurrence intervals, respectively) and the 1-, 2-, 3-, 6-, 12-, and 24 hour duration storms. The HEC-HMS model was used to generate the runoff hydrographs that would be input to the unsteady flow HEC-RAS model.

A readme file is provided for the HEC-HMS computer model in Appendix A. Computer model input and output for this analysis is provided in Appendix B in a file named: "LyonsLevee_HMS_Files".

3.3 HEC-RAS Hydraulic Model Development

HEC-RAS was selected for modeling the interior drainage system to be compatible with the Des Plaines River system so that the two models could be combined if necessary to model the impacts of any overtopping flows on the interior drainage system. The unsteady flow option of HEC-RAS was used to capture the impact of the existing ponds and restrictive culverts on the interior drainage flood elevations.

The HEC-RAS model consists of three storage areas representing the existing ponds in the system and three river reaches connecting the ponds and representing the downstream outlet channel. Within the three river reaches there are four culverts representing the roadway crossings under 47th Street, CN Railroad, BNSF Railroad, and Harlem Avenue. In addition there are two inline structures representing existing beaver dams within the Forest Preserve. The beaver dams are in the downstream reach just upstream of Harlem Avenue. See Figure 3-2 for the HEC-RAS model extents.

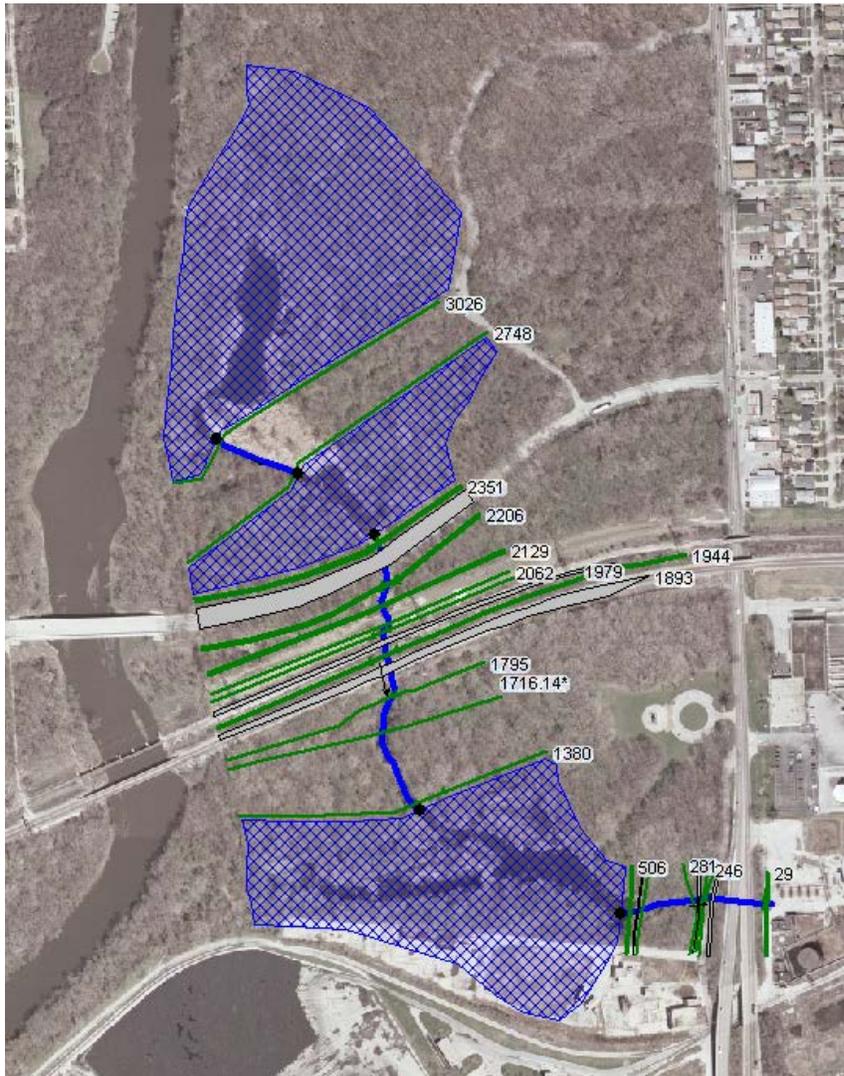


Figure 3-2 – HEC-RAS Model Extents

The input data for the 23 cross sections, 4 culverts, 2 in-line structures, and 3 ponds were developed using HEC-GeoRAS. The data sources were field survey conducted for this study and the Cook County bare earth LIDAR point data provided by MWRDGC. The survey data was used to define the channel portion of each cross section while the overbank portions of the cross sections were based on the LIDAR data.

Historic high water information was not available for calibration. The model inputs representing land cover in the channel and overbank were developed based on engineering references and experience with similar sites. Interpolated cross sections were used in portions of the model to improve model stability. The downstream discharge from the interior drainage system compared favorably with the flows developed by IDOT in evaluating the Harlem Avenue storm sewer improvements to alleviate flooding in the Harlem Avenue underpass at the railroad tracks. The 2% exceedance chance critical duration flow from the interior drainage analysis was 42 cfs. The IDOT report used two methods to determine the flow from this area. The flows in the IDOT report were 58 cfs using the StreamStats computer program, and 43 cfs using the NRCS methods for the 2% exceedance chance 1-hr duration storm.

3.4 Existing Conditions Results

The HEC-RAS model results do not identify any flood problems within the interior drainage system. The flooding identified by the modeling is contained within the Forest Preserve District of Cook County property. The flood elevations do not cause impact to the roads within the interior drainage boundaries.

The critical duration analysis identified the 6-hour duration storm as generally providing the highest flood levels within the interior drainage area. A summary of the peak high water levels at 47th Street, the CN Railroad, the pond in the Forest Preserve District south of the Railroad Tracks and upstream of Harlem Avenue are shown in Table 3-2.

Table 3-2 – Summary of Interior Drainage Flood Levels

Location	10% Exceedance Chance (ft NAVD)	2% Exceedance Chance (ft NAVD)	1% Exceedance Chance (ft NAVD)
47 th Street (upstream face)	588.8	589.7	590.3
CN Railroad (upstream face)	588.5	589.6	590.2
Pond	587.1	588.2	588.7
Harlem Avenue (upstream face)	587.0	588.2	588.7

The lowest pavement elevations outside of the underpass which would be impacted by the interior drainage flooding were in the vicinity of the 47th Street and Harlem Avenue intersection. The pavement elevations in this area are between 591 and 592 ft NAVD based on the contour mapping. The interior drainage high water levels near 47th Street can back up into this area via a storm sewer and roadside ditches along the south side of 47th Street. A readme file is provided for the interior drainage HEC-RAS computer model in Appendix A. Computer model input and output for this analysis is provided in Appendix B in a file named: "LyonsLevee_RAS_Files".

Based on the interior drainage analysis, the existing interior drainage system is capable of handling the local runoff behind the levee without causing flood damages or highway delays due to water on the pavement.

4. Proposed Levee Improvement Plan

The Lyons Levee Improvement project seeks to reduce the Des Plaines River flooding risk in the Forest View area. The recommended flood risk reduction measure would provide flood protection for events up to the 100-year flood and meet Federal, State and local design requirements. The limits of levee improvements under consideration begin just south of Joliet Road and extend downstream for a distance of approximately 1,050 feet south of 47th Street, a total distance of 4,327 feet. This Section summarizes the design basis for the selected option.

The proposed plan includes a reconstruction of the existing levee. The plan includes the following features:

- The levee restoration will build on the existing levee footprint and is located within the same corridor for its entire length. The levee crest will be raised at key locations and the slopes will be widened where necessary to provide improved levee geometry that will enhance stability and seepage control. Reconstruction of the existing levee will be accomplished in accordance with design standards generally in accordance with the requirements of the United States Army Corps of Engineers engineering manual titled “Design and Construction of Levees” (EM 1110-2-1913) published April 30, 2000.
- All trees present on the levee crest and slope will be removed including roots down to a half inch root diameter. Tree removal will extend for a distance of 15 feet beyond the proposed toe of levee slope.
- The project includes the placement of compacted earth on top of the existing grade to increase the levee height as follows:
 - Add fill to the levee to extend the existing crest to two feet above the 100-year Project Design Flood profile in all areas except as noted below. This flood event is described in Section 2.2.
 - Limit the levee height increase where necessary such that the proposed levee crest is no higher than 0.5 feet below the levee elevation on the opposite (west) side of the Des Plaines River. If the east levee crest is higher than this design rule, the east levee crest shall remain at its existing elevation.
 - The east levee crest elevation changes will be constructed 0.1 feet higher than the above stated design criteria to accommodate future anticipated settlement of the levee that will occur due to the proposed fill.
 - Upgrade the 500 foot reach of levee from Station 13+00 to Station 17+50 where an old buried spillway exists to improve stability and seepage control. The improvements in this reach include levee widening, a crest increase, and placement of a steel sheet pile seepage cutoff wall.
 - Construct a 10-foot wide gravel maintenance road on the levee crest and re-vegetate the levee and adjacent areas with suitable vegetation. All fill material will be placed on the land side of the existing levee; no new fill will be placed within the floodway of the Des Plaines River.

The levee will tie into existing high ground near Joliet Road on the north and at the MWRDGC HASMA facility to the south.

The following general design criteria were developed to comply with design requirements and provide a consistent approach:

- 100-year Project Design Flood – The Des Plaines River flood profile published in the FEMA Flood Insurance Study serves as the base flood from a regulatory perspective. However, for this project, an updated analysis was performed for the project design basis. The updated interpretation of the base flood condition is called: “100-year Project Design Flood”. A definition for this flood is provided in Section 2.2. The project seeks to establish flood protection for the 100 year flood with freeboard, to the extent that is practical and feasible.
- Levee Crest Elevation / Freeboard –
 - The top of levee (crest) elevation is set to be at least 2 feet above the 100-year Project Design Flood Profile except in areas where such a levee crest increase would result in the east levee crest being higher than 0.5 feet below the west levee at the same river location.
 - When the planned east levee crest criterion of “2 feet above the 100-year Project Design Flood Profile” would result in a crest that is higher than 6 inches below the west levee crest, the east levee crest is limited to be no higher than 0.5 feet below the west levee crest elevation. One exception to this rule is that the proposed levee crest shall not be lower than the existing levee crest elevation. Following is a summary of locations where the proposed levee crest elevation is lower than the planned levee crest elevation of “2 feet above the 100-year Project Design Flood”:
 - Station 18+13 to 18+48
 - Station 24+00 to 31+20
 - Station 32+68 to 35+22
 - Station 35+45 to 35+95
 - Station 36+50 to 36+82
 - In all locations, the proposed east levee crest will provide freeboard above the 100-year Project Design Flood as defined in Section 2.2. The proposed levee will also be constructed higher initially to anticipate expected levee crest settlement as described in Section 2.1.
 - Where the existing levee elevation is greater than the 100-year Project Design Flood plus 2.0 feet, the levee is to be left at the existing elevation.
 - In addition to creating a proposed levee crest that provides freeboard above the 100-year Project Design Flood, the proposed levee crest would provide protection from a flood that is comparable to the April 2013 flood event of 12,200 cfs.
- Settlement allowance – The placement of additional fill on the existing levee is anticipated to induce less than approximately one-inch of settlement due to the limited amount of fill to be placed and considerations that most, if not all, of the consolidation related settlement for this levee has already occurred during its lifetime. Settlement due to fill placement at the old buried spillway is estimated to be up to four inches due to the greater amount of fill in this area. The levee will be overbuilt by the amount of anticipated future settlement to accommodate the amount of consolidation related settlement while maintaining adequate levee freeboard. The balance of construction involves placement of a steel sheet pile wall that is not expected to experience significant settlement. Any

required levee overbuild is included in the construction quantities for areas of levee where the crest will be raised. The drawings illustrate the higher amount of fill that will be placed during construction to anticipate future settlement.

- Levee crest width – a minimum 12 feet crest width at the top of levee will be created. Where the existing levee top width is wider than this minimum, the wider geometry will be maintained.
- A 10 foot wide gravel service road will be included on the levee crest. Two gravel turnouts will be constructed wider than the base road width to provide for safe maintenance access.
- Existing Levee Clearing and Grubbing / Tree clear zone – Trees will be removed for a minimum 15 feet from the toe of the proposed levee on both river and land side. The contractor will clear the surface of the existing levee (including tree clear zone). This includes removal of all trees and roots within 15 feet of the toe of the levee. Remove all roots that are greater than ½ inch in diameter and the associated root ball and all organic material. Backfill with suitable fill material (typically matching levee fill). The Forest Preserve District of Cook County (FPDCC) has requested that certain trees be provided to the FDPCC for recycling. FDPCC will identify and tag these trees and develop a specification for how these are to be handled and transported to the designated site.
- Levee side slopes – minimum 3H:1V to allow for maintenance and inspection as well as overall levee stability.
- Seepage control measures - Based on the results of field explorations, analysis, and observations from prior inspections, the following are design measures that will be employed to manage seepage:
 - The use of relatively flat 3H:1V side slopes.
 - Replacement of clay soils on the levee side slopes to be coordinated with the planned tree and other woody vegetation removal from the slopes
 - A Steel sheet pile wall will be installed to limit seepage exit gradients and piping erosion potential at the old buried spillway at station 13+00 to 18+60.
- Levee materials – Additional fill placed for reconfiguration and/or raising of the levees will be cohesive (i.e., clay) material, free of topsoil, debris, and other deleterious material. The maximum particle size will be one inch and contain at least 25% by weight of particles finer than the #200 U.S. sieve size. The material will have a specified permeability of 1.0×10^{-7} cm/s or less. Soil placed as part of the Temporary Flood Protection Measures, as described in Section 4, will be reworked into the proposed final design.
- Compaction requirements – Material placed for reconfiguration and/or raising of the levee will be placed in maximum 9-inch thick loose lifts and compacted with a sheepsfoot roller or other suitable equipment. The material should be maintained within a range from 1% to 3% above the optimum moisture content and compaction of at least 95% of the maximum dry density per standard proctor test (ASTM D698).
- Vegetation types on levee and within clear zone – vegetation on the levee and generally within 15 feet of the toe of the levee will be limited to perennial grasses that are resistant to both drought and periodic inundation. Native species appropriate for the levee setting are recommended. A 6-inch thick topsoil layer is included for the entire levee surface and levee clear zone that extends 15-feet from toe of levee.

- Utility penetrations through levee / flood wall – Reduce to maximum extent possible. Provide positive cutoff for storm and sanitary sewers. The levee owner should carefully monitor any proposed future levee utility penetrations to minimize possible failure due to utility collapse, poorly compacted trench backfill or other utility related issues. This may require some form of easement or other agreement with the existing railroads to ensure the integrity of the levee.
- Exploration Trench – An exploration trench is usually utilized to expose potential undesirable underground features such as old drain tile, utilities, pockets of unsuitable material or other debris or obstructions. Based on the site history, no exploration trench will be required.
- Sheet pile criteria – Steel sheet pile penetration depths have generally been set to provide added seepage resistance in the existing levee at the old buried spillway area.
- Seismic – The Lyons levee project is located within “Seismic zone 1” based on the Uniform Building Code Seismic Zone map located within the current version of USACE’s ER 1110-2-1806 (“Earthquake Design and Evaluation for Civil Works Project”). As documented by USACE in the Levee Condition Report: “No recent earthquakes or fault activity have been documented in the area; therefore the need for seismic design analysis is not required and not considered necessary. “
- Permanent inspection and maintenance access – a 10’ wide, 12-inch thick gravel wearing surface is located on the levee crest for inspection and maintenance. Access to the levee is planned from the north and south sides of 47th Street, from the south side of Joliet Road and from the MWRDGC HASMA site. This will require modification to the existing guard rails on either side of 47th Street to enable vehicle access. Vehicle turnouts are included at two locations for the section of levee between 47th Street and Joliet Road. These features will allow two vehicles to pass when travelling in opposite directions, or one vehicle to turnaround.
- Erosion protection – Based on the relatively low velocities in the Des Plaines River in the overbank areas and the setback of the levee from the river, no significant permanent erosion control features are required. Existing riprap in the vicinity of the bridges appears to be generally adequate. Establishment and maintenance of grassed vegetation on the side slopes of the levee will be critical for long term stability and erosion control. This will require erosion control blanket for the entire levee surface until vegetation establishment. Inspection and re-establishment of good vegetative cover and removal of woody vegetation, particularly in the first few years, will be an important maintenance item. Scour protection in the vicinity of the bridges appears to be adequate. No additional riprap in these areas is recommended.
- Railroad closure – Where the railroads cross the levee, the top of the railroad ballast generally exists at or near the proposed top of levee elevation. The thickness of the ballast zone is approximately two feet thick and is porous. We recommend that the porous ballast zone should be replaced with a concrete keyed into the underlying soil on top of the levee. Additional coordination with the railroads regarding ballast zone sealing is recommended.
- Existing Spillway Structure – The buried spillway structure that exists between station numbers 13+00 and 18+00 will require a different design approach than the balance of the levee. The design will address seepage and potential future structural degradation of the old concrete and stone spillway that could otherwise cause problems for the levee in the future. The design also recognizes the difficulty that a removal of the old spillway would cause including deep excavations, extensive

wetland impacts, dewatering issues that would likely require extensive cofferdams, and unknown subsurface conditions. The levee upgrade design will limit the amount of disturbance to the existing spillway by focusing levee improvements on its east side. It will take advantage of the existing levee as a buttress, but will not count on it for seepage control. A new steel sheet pile wall would be driven at the landside toe of the existing levee, and a levee extension would be constructed on the landward side using 3H:1V side slopes. This would result in a relatively wide levee section at this area, but would not require the costly removal or excavation of the existing spillway. The existing buried abutments would need to be partially removed to allow for the installation of sheet piles to tie into the levee to the north and south of the buried spillway. Additional explorations in the form of test pits and soil borings are proposed in this area to evaluate the horizontal limits of the spillway and the abutments in order to evaluate the potential for obstructions during the driving of sheet piling and to refine the geometry of the proposed construction in this area.

- An unidentified concrete structure located at approximately station 21+00 would need to be demolished and removed.
- Three wooden power poles located at approximately station 34+00 on the levee crest and riverside side slope. These should be relocated outside of the levee footprint.
- Forest Preserve District Fence Relocation – an existing Forest Preserve District fence located at approximately station 38+00 to 41+50 will be removed and replaced in a new location. A 100 foot length of the existing gravel trail will be reconstructed in a new location to accommodate the new fence location and levee service road. A more detailed survey of this area will be performed in final design to minimize the disruption in this area.
- Interior drainage – The only known interior drainage problem is the Harlem Avenue underpass under the railroad tracks. IDOT is developing a drainage improvement project to address this issue. Existing roadside ditches are poorly defined and have not been actively maintained. This causes the sheet flow of storm water from the road right of way into the Forest Preserve. It does not appear that this condition causes flood damage in the Forest Preserve. The rest of the interior drainage system appears to be adequate from a flood damage perspective. Section 3 provides detailed information for the interior drainage system.
- The recently completed earthwork for Temporary Flood Protection Measures, as described in Section 4, will be reworked into the permanent levee restoration. The permanent crest will be wider in places. This option includes the construction of an access road on top. Earth placed as part of the temporary measures project will be reworked and incorporated into the final design.

4.1 Proposed Levee Evaluation

The proposed levee profile was modeled in HEC-RAS for the 10-, 20-, 50-, and 100-yr flood events, and using the expected probability Flow rates as summarized in Table 2-1. These runs show that the Des Plaines River water surface profiles for all of these events will not exceed the proposed levee crest. The April 2013 (flood of record) storm was modeled in HEC-RAS using the unsteady flow option. The April 2013 flood does not overtop the proposed levee profile. The maximum water surface elevation for this flood is less than 0.1 feet below the levee crest profile at the lowest point in the proposed levee profile upstream of 47th Street.

Appendix A
Computer Model Readme Files

**Des Plaines River HEC-RAS Model (Lyons Levee - Des Plaines River)
(Lyons_Levee.prj)**

HEC-RAS Report Files

The HEC-RAS report text files for each run are named based on the Steady/Unsteady Plan files with .rep as an extension.

The HEC-RAS report PDF files for each run are named based on the Steady/Unsteady Plan files with .pdf as an extension.

HEC-RAS Input Files

Steady Flow Input Files

Freq Anal w/2013(Lyons_Levee.f03)

Frequency Analysis Computed Flows (10-, 20-, 50-, and 100-yr), FIS 100-yr, and Historic Storm Peak Flows at Riverside (Sep 2008, Dec 2008, Jul 2010, Jul 2011, Apr 2013, and Jul 2014), and 12,000 cfs

Diversion Evaluation(Lyons_Levee.f04)

Flows for an evaluation of diversion alternatives to CAWS

OrdinaryHighWaterMark Flows(Lyons_Levee.fo5)

Flows used to estimate the Ordinary Highwater Mark for USACE Permitting

CorpsRequestedProfiles(Lyons_Levee.fo6)

The 10 profiles from the 1- to 500-yr flows for Corps Damage Analysis (1-, 2-, 5-, 10-, 20-, 25-, 50-, 100-, 200-, and 500-yr)

Unsteady Flow Input Files

2013 USGS Flows(Lyons_Levee.u15)

Historic USGS flow hydrographs at Riverside for 2006, September 2008, December 2008, July 2010, July 2011, April 2013, and July 2015

100-yr 2013 Ratio(Lyons_Levee.u01)

April 2013 flood event hydrograph ratioed to provide a hydrograph with the 100-yr peak flow rate

12k 2013 Ratio(Lyons_Levee.u10)

April 2013 flood event hydrograph ratioed to provide a hydrograph with a 12,000 cfs peak flow rate

Geometry Input Files

Proposed Levee(Lyons_Levee.g05)

This is the Lyons Levee Improvement Plan profile described in the report. Profile provided by AECOM.

DPR Updated Levee 08062014 C12(Lyons_Levee.g33)

Existing Levee Profile updated with field survey on 8/6/2014. This was the 12th and final Calibration Run. This included updated river cross sections between Joliet Road and railroad bridges. Overflows between CAWS and the Des Plaines River were included downstream.

Scenario 100-yr plus 1 Levee(Lyons_Levee.g02)

Scenario 1 Levee Profile for Evaluating Overtopping of Alternative Levee Profiles upstream of 47th Street. Scenario 1 includes a section of the levee with a reduced 1 foot of freeboard above the 100-yr storm north of 47th Street.

Scenario 2 100-yr plus 1.5 Levee(Lyons_Levee.go4)

Scenario 2 Levee Profile for Evaluating Overtopping of Alternative Levee Profiles upstream of 47th Street. Scenario 2 includes a section of the levee with a reduced 1.5 foot of freeboard above the 100-yr storm north of 47th Street.

Scenario 100-yr plus 2 Levee(Lyons_Levee.go3)

Scenario 3 Levee Profile for Evaluating Overtopping of Alternative Levee Profiles upstream of 47th Street. Scenario 3 includes a section of the levee with a reduced 2 foot of freeboard above the 100-yr storm north of 47th Street.

Steady Flow Plan Files

DPR Freq Analysis w/OT C12(Lyons_Levee.p63)

Existing Levee Profile with f03 and g33 with overtopping of the Lyons Levee calculated

DPR Freq Anal w/o OT C12(Lyons_Levee.p64)

Existing Levee Profile with f03 and g33 without overtopping of the Lyons Levee calculated

DPR Diversion Evaluation(Lyons_Levee.p66)

Existing Levee Profile with f04 and g33 to evaluate several diversion alternatives

Ordinary Highwater Mark(Lyons_Levee.p67)

Existing Levee Profile with f05 and g33 to determine ordinary highwater mark profile for USACE Permit

Proposed Levee(Lyons_Levee.p76)

Proposed Levee Profile with f03 and g05 to evaluate the proposed levee water surface profile.

Corps Requested Proposed Profiles(Lyons_Levee.p80)

Proposed Levee Profile with f06 and g05 for Corps Damage Evaluation

Corps Requested Existing Profiles(Lyons_Levee.p90)
Existing Levee Profile with f06 and g33 for Corps Damage
Evaluation

Unsteady Flow Plan Files

DPR Updated Levee 2013 C12(Lyons_Levee.p56)
Existing Levee Profile with g33 and u15 Calibration to April
2013 event

DPR Updated Levee 2014 C12(Lyons_Levee.p57)
Existing Levee Profile with g33 and u15 Calibration to July
2014 event

DPR Updated Levee 2011 C12(Lyons_Levee.p58)
Existing Levee Profile with g33 and u15 Calibration to July
2011 event

DPR Updated Levee 2010 C12(Lyons_Levee.p59)
Existing Levee Profile with g33 and u15 Calibration to July
2010 event

DPR Updated Levee 2008D C12(Lyons_Levee.p60)
Existing Levee Profile with g33 and u15 Calibration to
December 2008 event

DPR Updated Levee 2008S C12(Lyons_Levee.p61)
Existing Levee Profile with g33 and u15 Calibration to
September 2008 event

DPR Updated Levee 2006 C12(Lyons_Levee.p62)
Existing Levee Profile with g33 and u15 Calibration to
October 2006 event

100-yr Scenario 1 100+1(Lyons_Levee.p68)
Scenario Levee 1 profile with u01 and g02 to evaluate
effectiveness of Scenario 1 for the 100-yr

12k Scenario 1 100+1(Lyons_Levee.p73)
Scenario Levee 1 profile with u10 and g02 to evaluate
effectiveness of Scenario 1 for 12000 cfs

100-yr Scenario 2 100+1.5(Lyons_Levee.p72)
Scenario Levee 2 profile with u01 and g04 to evaluate
effectiveness of Scenario 2 for the 100-yr

12k Scenario 2 100+1.5(Lyons_Levee.p71)
Scenario Levee 2 profile with u10 and g04 to evaluate
effectiveness of Scenario 2 for 12000 cfs

100-yr Scenario 3 100+2(Lyons_Levee.p69)
Scenario Levee 3 profile with u01 and g03 to evaluate
effectiveness of Scenario 3 for the 100-yr

12k Scenario 3 100+2(Lyons_Levee.p70)

Scenario Levee 3 profile with u10 and g03 to evaluate effectiveness of Scenario 3 for 12000 cfs

April 2013 without Lateral Structures(Lyons_Levee.p74)

April 2013 storm with existing Levee Profile with u15 and g33 to evaluate the impact of no lateral structures on the water surface profile

April 2013 with Proposed Levee(Lyons_Levee.p79)

April 2013 storm with the proposed levee profile with g05 and u15.

**Des Plaines River SSP Input/Output Description (Frequency Analysis)
(Lyons_Levee.ssp)**

Frequency Analyses using Bulleting 17b Methods (input file name and description)

Riverside_1974_-_2013.17b
Des Plaines River at Riverside for Water Year 1974 to 2013

Riverside_1984_-_2013.17b
Des Plaines River at Riverside for Water Year 1984 to 2013

Riverside_1990_-_2013.17b
Des Plaines River at Riverside for Water Year 1990 to 2013

Riverside_1994_-_2013.17b
Des Plaines River at Riverside for Water Year 1994 to 2013

Riverside_Full_Record.17b
Des Plaines River at Riverside for Water Year 1914 to 2013

Des_Plaines_1990_-_2013.17b
Des Plaines River at Des Plaines for Water Year 1990 to 2013

Des_Plaines_Period_of_Record.17b
Des Plaines River at Des Plaines for Water Year 1938 to 2013

Output (Gage location and period analyzed)

Riverside_1974_-_2013.pdf
Riverside_1984_-_2013.pdf
Riverside_1990_-_2013.pdf
Riverside_1994_-_2013.pdf
Riverside_Full_Record.pdf
Des_Plaines_1990_-_2013.pdf
Des_Plaines_Period_of_Record.pdf

Plots (Gage location and period analyzed)

Plot_Riverside_1974_-_2013.pdf
Plot_Riverside_1984_-_2013.pdf
Plot_Riverside_1990_-_2013.pdf
Plot_Riverside_1994_-_2013.pdf
Plot_Riverside_Full_Record.pdf
Plot_Des_Plaines_1990_-_2013.pdf
Plot_Des_Plaines_Period_of_Record.pdf

Interior Drainage HEC-HMS Input/Output Descriptions (LyonsLevee_IntDrain.hms)

HEC-HMS Hydrograph Plots

Plots contain all of the frequency analyzed (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr)

basinname_XXhr.pdf

basinname - subbasin ID (47thStreet_East, 47thStreet_West, Harlem, and Railroad)
XX - storm duration in hours (1-, 2-, 3-, 6-, 12-, and 24-hr duration)

HEC-HMS Input Listings

Subbasin Schematic.pdf

Picture of Subbasin boundaries and the HEC-HMS schematic.

Subbasin Area.pdf

Listing of the drainage area, curve number, and time of concentration for each subbasin

HMS Input Component Naming Convention

Basin Models

LyonsLeveeID

The interior drainage schematic and input (drainage area, curve number, time of concentration, etc.) for the Lyons Levee subbasins behind the levee.

Meteorologic Models - Assign rainfall hyetographs to basin models and subbasins.

XXhour

XX - Storm duration in hours

Control Specifications (sets computational time window and time step for the run)

LyonsLevee

Time-Series Data (Precipitation Gages)

xxHyQ Bulletin 70 rainfall distributions for the various storm durations

xx - storm duration in hours

y - Bulletin 70 quartile rainfall distribution

HMS Compute/Results Naming Convention

LLxxYzzH

xx - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

zz - storm duration in hours (1, 2, 3, 6, 12, and 24 hours)

Lyons Levee Interior Drainage HEC-RAS Model (LyonsLeveeID.prj)

Report Files - These are pdf listings of the RAS report files generated for the critical duration 6 hour storm for the various frequencies modeled.

REPORT xxxYR 6HR EXISTING.PDF

xxx - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

Profile Plots - These are pdf's of the critical duration 6 hour storm.

PROFILE xxxYR 6HR EXISTING.PDF

xxx - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

HEC-RAS input files

Geometry Files

Existing Conditions (LyonsLeveeID.g03)

The geometry input for existing conditions along the interior drainage flow path to Harlem Avenue

Unsteady Flow Files

XXXyZZh Existing (LyonsLeveeID.u**)

XXX - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

ZZ - storm duration in hours (1, 2, 3, 6, 12, and 24 hour duration storms)

Generate Hot Start

base flow model used to generate a starting water surface profile to reduce instabilities in the model at start up.

Unsteady Flow Plan Files

XXXyZZh Existing (LyonsLeveeID.p**)

XXX - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

ZZ - storm duration in hours (1, 2, 3, 6, 12, and 24 hour duration storms)

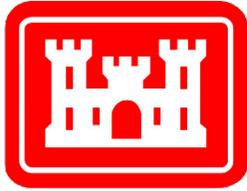
Hot Start

base flow model used to generate a starting water surface profile to reduce instabilities in the model at start up.

Appendix B

Computer Model Input & Output
Files:

- DesPlainesRiver_SSP_Files
- DesPlainesRiver_RAS_Files
- LyonsLevee_HMS_Files
- LyonsLevee_RAS_Files



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Appendix C: Hydrology and Hydraulic Analysis

02 February 2018

MCCOOK, IL SECTION 205

APPENDIX D: HYDROLOGY AND HYDRAULIC ANALYSIS

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Figure 16. Upper Mississippi Region - *Summary matrix of observed and projected climate trends and literary consensus. (USACE, 2015)*

ATTACHMENTS

ATTACHMENT 1: "Lyons Levee Improvement Project, Hydrology and Hydraulics Technical Memorandum" dated December 2015.

APPENDIX D: HYDROLOGIC AND HYDRAULIC ANALYSIS
MCCOOK, IL
SECTION 205 FLOOD RISK MANAGEMENT

INTRODUCTION

The Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) has performed a Hydrologic and Hydraulics (H & H) analysis in regards to their proposed Lyons Levee Improvement Project, which has been documented in the report "Lyons Levee Improvement Project, Hydrology and Hydraulics Technical Memorandum" dated December 2015. This analysis is also applicable to the McCook Levee Project which is located across the Des Plaines River from the Lyons Levee Project, however, sections specific to the Lyons Levee project will not apply to the McCook Levee project.

The report covers much of the H & H analysis that is normally required by the U.S. Army Corps of Engineers (USACE) for feasibility studies. The report is attached and will be considered as the main portion of the H & H Appendix, in addition to the supplemental analyses below that include additional items normally covered in a USACE Flood Risk Management (FRM) levee project. This supplemental appendix provides additional information to address such items as: risk and uncertainty analysis, superiority analysis, project impacts, and flood warning.

RISK AND UNCERTAINTY

The MWRDGC report includes a very comprehensive documentation of the H & H data available for the study reach. The associated analysis also includes a very recently updated model, which includes close calibrations for six recent historic flood events, three of which have peak flows exceeding the published FEMA 1% chance exceedance flood. Updated flow frequency analyses for the USGS gage on the Des Plaines River at Riverside, Illinois, located one and a half miles upstream of the project are also included.

USACE policy requires that flood risk management projects be designed using a risk-based analysis rather than designing to a level of protection.

A risk and uncertainty analysis was performed using data from the MWRDGC report and the associated hydraulic modeling. At the imminent overtopping location of the levee system, the levee crest is 1.5 feet above the one percent chance exceedance design water surface. Due to the 100 year period of record at the gage, and very close comparisons between the observed and computed stages for the calibration runs, the FDA analysis computed a 95.4% chance that the one percent chance exceedance flood event would not overtop the levee. Current USACE guidance (EC 1110-2-6067) requires a minimum of two feet of freeboard, even when there is a greater than 95% confidence level that the one percent flood will not exceed the crest elevation.

SUPERIORITY ANALYSIS

The existing West Lyons Levee includes a low area that would be the location of imminent overtopping of the McCook levee system. The West Lyons Levee is basically a continuation of the McCook Levee along the west side of the Des Plaines River north of 47th Street. The water surface profiles indicate that overtopping will occur at this location first and not in other areas where the levee is relatively higher.

In the development, design and coordination between the State of Illinois and MWRDGC for the Lyons Levee project on the east side of the Des Plaines River, it was decided that the levee heights on the east levee would remain six inches below the West Lyons Levee as has historically been the case. For the design of the McCook/West Lyons levee the USACE is accepting the agreements that have been previously made regarding the levee heights of the Lyons and West Lyons Levees. Any raising of these levees would need to be coordinated with these entities and would need to consider the impacts on both sides of the river.

With regard to the recently released guidance, ECB 2017-15 “Managed Overtopping of Levee Systems”, the overtopping location for the McCook/West Lyons Levee is not ideal. The location is along the back yards of a residential area. While the first floors of the homes are at or near the 100 year flood level, there is a low area in the back yards with a greater than an eight foot depth which brings up concerns of possible loss of life. The new guidance also recommends armoring the overtopping location. The top of the existing levee includes a paved bike, but no armoring on the back side of the levee.

For this instance, the volume in the interior is small north of 47th Street and would fill up rapidly whether it overtops or fails. There is a natural area that provides a secondary tieback for the McCook Levee with a minimum elevation of 602.0, so a failure of the West Lyons levee would have much less of an impact to the McCook levee interior than it would without this high ground. Flood warning would also decrease the risk. With consideration of these factors, the risk appears to be reasonably manageable.

PROJECT IMPACTS

There are no project induced stage impacts due to fill or storage on the Des Plaines River, however, the proposed diverting of flows from McCook Ditch into the Des Plaines River can cause increased stages.

The original project plan was to block off the culvert at Lawndale Avenue and add a diversion from McCook Ditch just south of Lawndale to the Des Plaines River. Currently all flow from McCook Ditch passes through the Lawndale culvert and then outlets to the Chicago Sanitary and Ship Canal through the Summit Conduit. The Summit Conduit is also the only outlet for the interior drainage of the project. See Figure 1 below for existing condition features. The project interior is located to the northern portion of the McCook Levee on the figure with Lawndale being the dividing line.

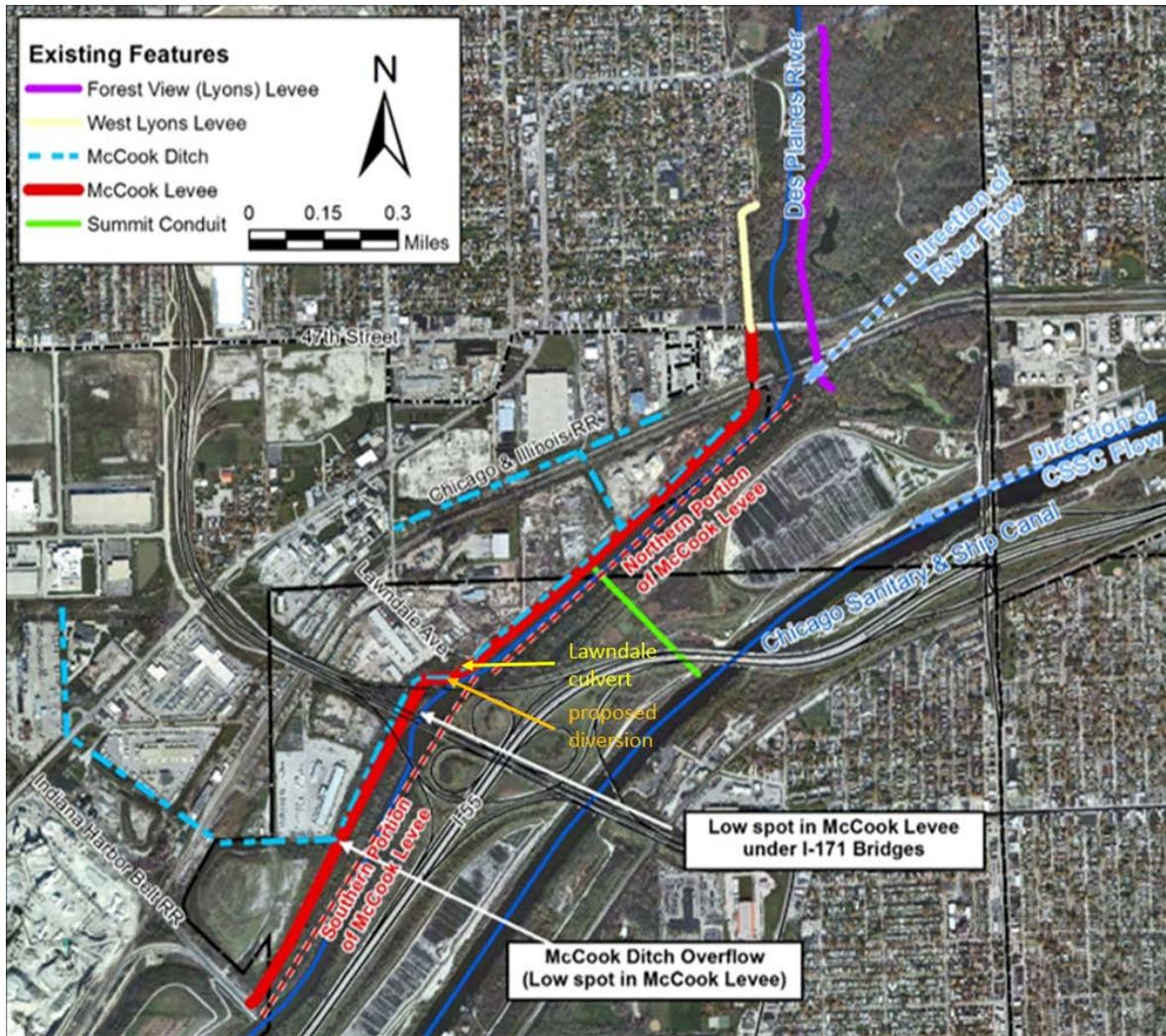


Figure 1 – Existing Features

There are also other overbank connections between McCook Ditch and the Des Plaines River which further complicate the hydraulics. When flows are high enough on the McCook Ditch they can overflow to the Des Plaines. Also, when the Des Plaines River is high, flows can go overbank into McCook Ditch. The later condition adds flow that goes through the Lawndale culvert and subsequently into the Summit Conduit and can cause flooding in the leveed interior area north of Lawndale. The later was the cause of the most extensive flooding in the April 2013 flood event. The original plan of blocking the Lawndale Culvert would reduce this flood risk on the interior, however, further hydraulic analysis showed that diverting all the McCook Ditch flow to the Des Plaines can cause adverse stage impacts. Figure 2 presents a closer look at the hydraulic features between Lawndale Avenue and the Summit Conduit.

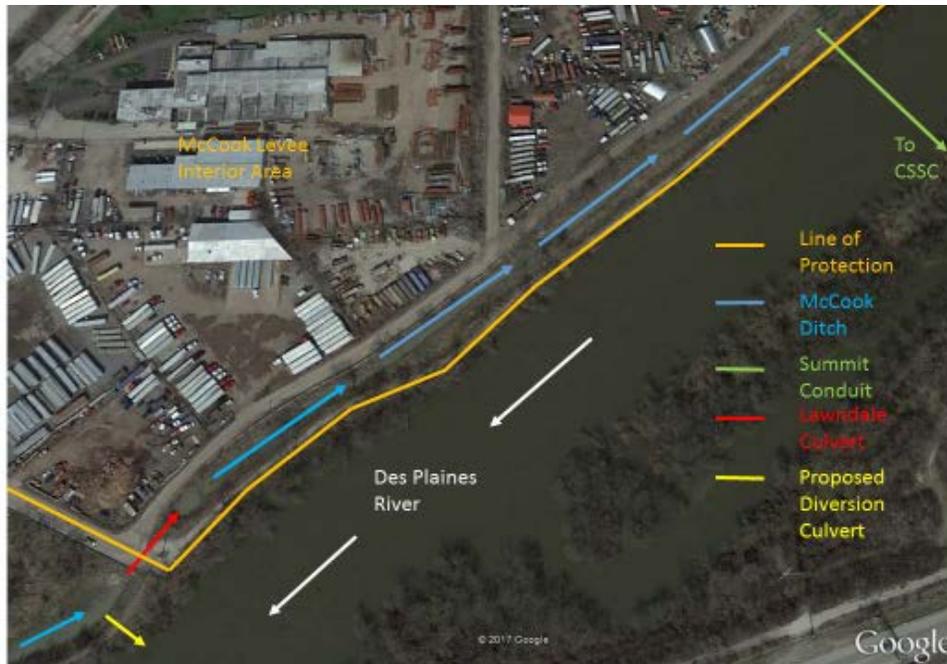


Figure 2 – Hydraulic Features from Lawndale Avenue to Summit Conduit

The modeling for the project was taken from the Lyons Levee project as noted above. The final project modeling was a steady state HEC-RAS model. The inflows were based on a flow frequency analysis. To analyze the stage impacts this model was used but converted to an unsteady flow model with added features that included the Lawndale culvert, the Summit Conduit, the northern and southern McCook Levee interior areas and the connection between the Des Plaines River and McCook Ditch.

For inflow hydrographs, synthetic event flow hydrographs at the Riverside gage location based on the Des Plaines River Phase II modeling were used and prorated to match the peak flows from the previous Lyons Levee study. A simple model of the McCook Ditch/Summit Conduit watershed that was developed for Lake Michigan Diversion was used for inflows for the interior areas.

When comparing the maximum stage profiles of the steady state and unsteady state modeling, the stage differences were around one tenth to two tenths of a foot lower on average with the unsteady model for the areas between Joliet Road and Lemont Road. This seems reasonable for this phase of the study and considering the many changes to the modeling, but should be looked into more closely during the next phase."

When comparing the existing condition model versus the proposed condition model, which included blocking off of the Lawndale culvert and diverting McCook Ditch to the Des Plaines, adverse stage impacts of approximately one tenth of a foot were seen. These stage impacts would not meet the State of Illinois regulatory requirements for approximately eight miles for the 100-year event.

To mitigate the stage impacts, a reduced size Lawndale culvert and a reduced size diversion were modeled until a balance of stage reductions and acceptable interior stages were met. This model included a 3.25 foot diameter reinforced concrete culvert for both the Lawndale and diversion culverts. Headwalls with grooved end of pipe at the upstream ends were assumed. The existing Lawndale culvert is a five foot diameter corrugated metal pipe with a headwall. This eliminated adverse stage impacts for all synthetic events (2, 5, 10, 25, 50 and 100-year). Figure 3 below presents 100 year stage and flow hydrographs near the peak for a location near the McCook overflow (see figure 1 above for location)

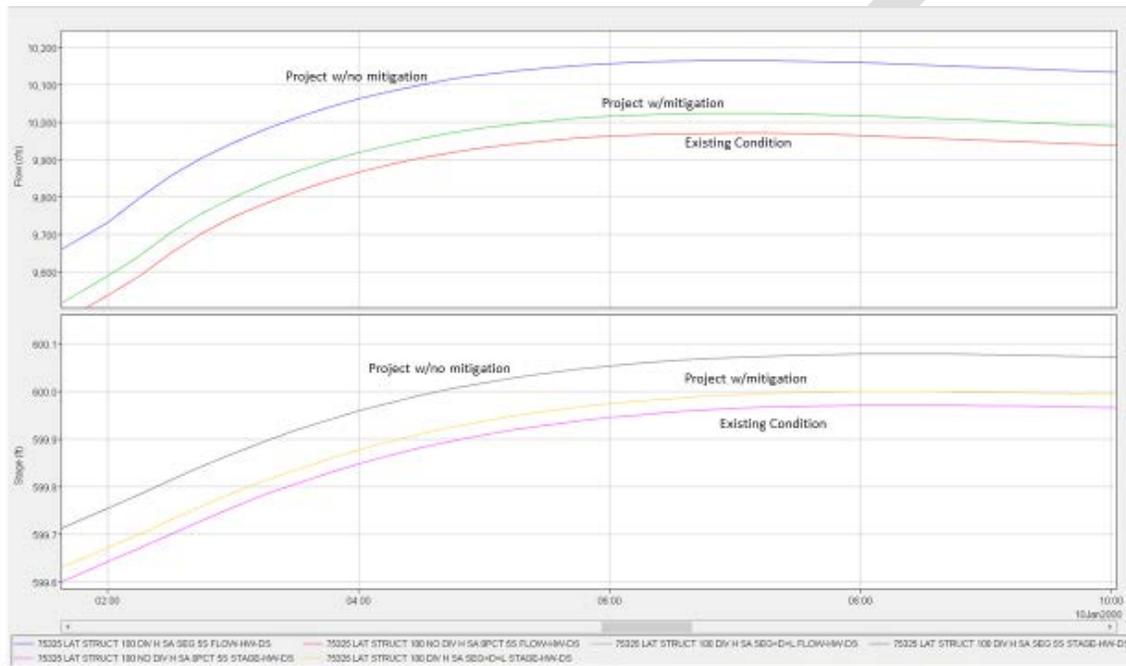


Figure 3 – Peak Stage and Flow near McCook Ditch Overflow

After discussion with the PDT team it was decided adding a sluice gate at Lawndale was the most practical solution. A partially open gate setting will mimic the reduced pipe size of the Lawndale culvert. It should be noted that a flapgate is needed on the diversion culvert to prevent flows from the Des Plaines River continually passing into the interior and into the Summit Conduit. Trash racks are recommended for both culverts. Additional survey information of the overflow areas is expected to be available between now and the plans and specification phase. In addition inflow hydrographs from more detailed modeling of the interior areas maybe be available. The project model will be updated with the best available information at that time if required. This could cause minor changes in pipe sizes/gate openings.

FLOOD WARNING

A recent flood warning plan was developed by the Chicago District for the Village of Forest View in 2014. It includes a new gage at the project location and includes the Riverside gage one and a half miles upstream. Due to the close proximity and similar overtopping

elevations, the flood warning plan and warning levels would also be applicable to the McCook/West Lyons Levee.

EROSION PROTECTION

Modeled velocities are very low on the Des Plaines along the McCook/West Lyons Levee and do not indicate the need for erosion protection, however, there is at least one small isolated eroded area along the existing sheet pile that was noted during the field investigation where erosion protection is recommended.

CLIMATE CHANGE IMPACTS

As outlined in ECB No. 2016-25, an investigation of the trends in the annual maximum flow gage data was performed to qualitatively assess impacts of climate change within the watershed using the USACE Climate Hydrology Assessment Tool. The drainage area for USGS gage 05532500, Des Plaines River at Riverside, IL, is 630 square miles. The gage has a period of record from 1914 to present day for various stream statistics including peak streamflow and daily discharge data.

For the Des Plaines River, [Figure 4](#) below shows the instantaneous peak streamflow obtained from the USGS website for gage closest to the project site. The figures depict a trend towards increasing annual peak streamflow for the period of record, as represented by the gage trendline. However, the p-value for the gage trendline is 0.000899, which is considered statistically significant. [Figure 5](#) displays the projected annual monthly trends from the USACE Climate Hydrology Assessment Tool.

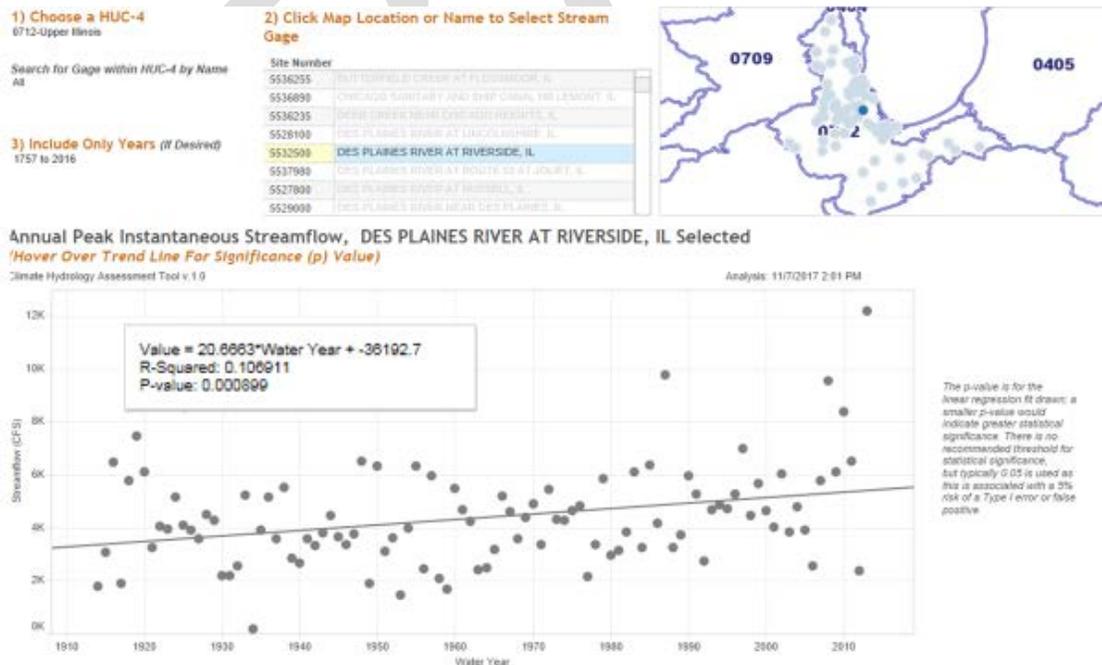


Figure 4. Peak Streamflow for Des Plaines River at Riverside, IL

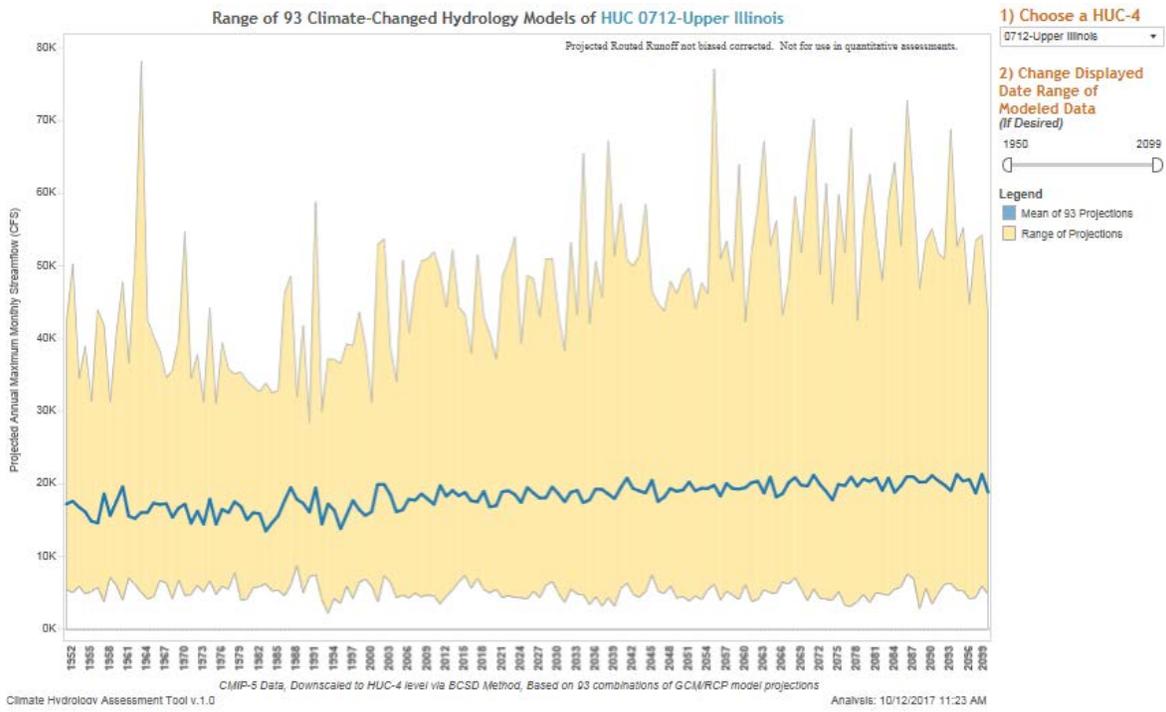


Figure 5. Project Annual Maximum Monthly Streamflow for HUC-4:0712-Upper Illinois

Using the web-based Nonstationary Detection Tool, the stream gage closest to the project site was investigated for non-stationarity (figure 6). For the USGS 05532500, Des Plaines River at Riverside, Illinois gage, several abrupt non-stationarities were detected, as shown in Figure 6. Non-stationarities were detected at three general change points within the period of record: 1920, 1981-1983 and 2006-2007. In 1920, only the Mood test for variance detected a non-stationarity, however, other statistical tests that target segment changes in variance/standard deviation and overall distribution detected a decrease in variance of 3,380,882 cfs squared and a decrease of standard deviation of 894 cfs (-38%). For the 1981-83 non-stationarity, the Lombard Wilcoxon, Pettit, and Mann-Whitney tests all concurred with regard to a general mean change point and the Energy Divisive Method detected a distributional change point, however, out of the other statistical tests that target segment changes in mean, variance/standard deviation and overall distribution, only a change in mean of 1502 cfs (38 % increase) was detected. For the 2006-2007 non-stationarity, the Mood test for variance and both the Kolmogorov-Smirnov and LePage distributional tests detected non-stationarities, in addition, for other statistical tests that target segment changes in variance/standard deviation and overall distribution detected an increase in variance of 9,161,268 cfs squared and an increase of standard deviation of 1,910 cfs (132%). In general these non-stationarities appear to be robust.

This is further supported when assessing monotonic trends within the record, as shown in [figure 7](#) (1914-2013) and [figure 8](#) (1920-2013) which shows statistically significant positive trends in the data. [Figure 9](#) presents the period 1981 to 2013 where no trend was detected. [Figure 10](#) presents the period 2006 to 2013. A positive trend was detected, but was not statistically significant. The dataset shows definite non-stationarities and various statistical trends depending on the time period analyzed, but how much is attributable to urbanization and how much is attributable to climate is uncertain.

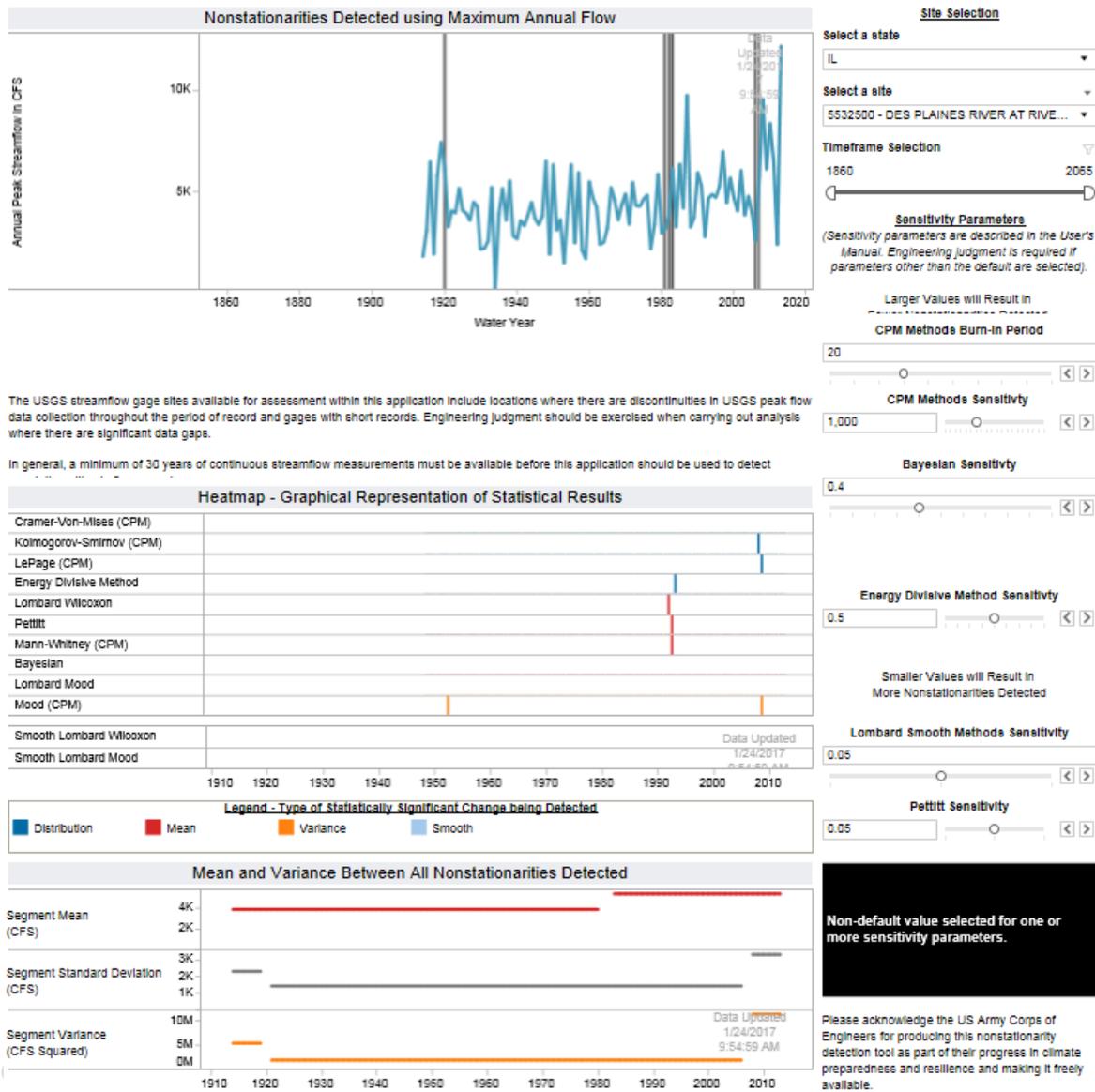
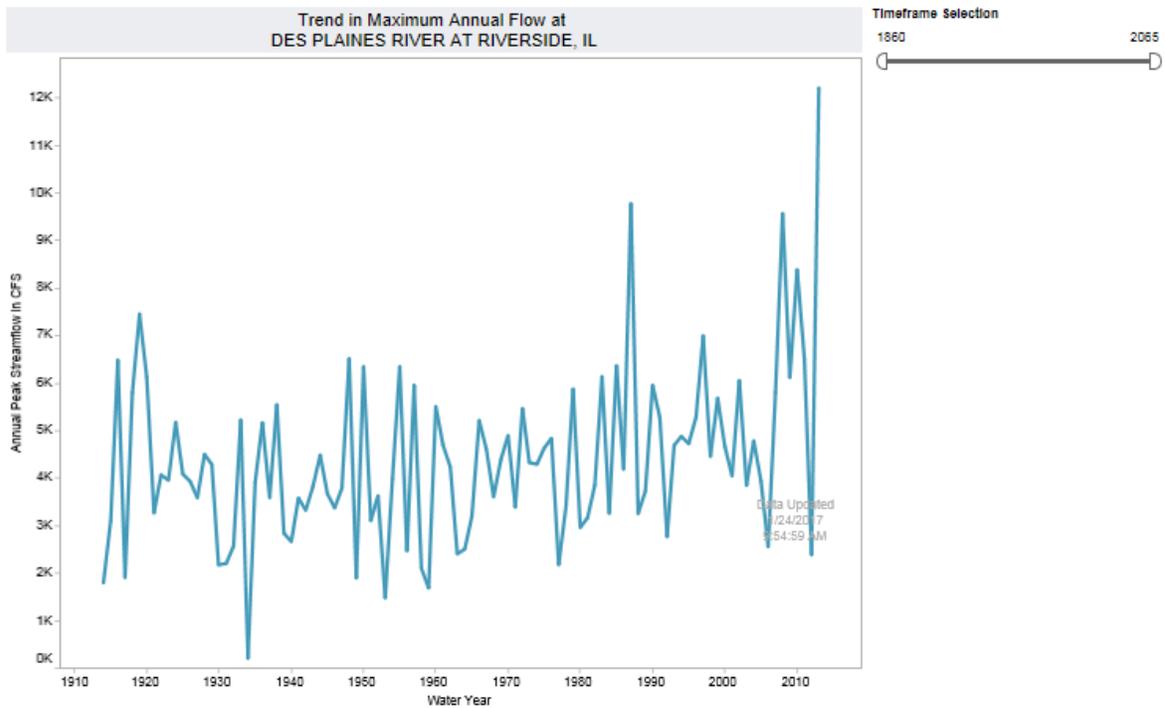


Figure 6. Nonstationary Analysis, Des Plaines River at Riverside, IL (1914)



Monotonic Trend Analysis

Is there a statistically significant trend?

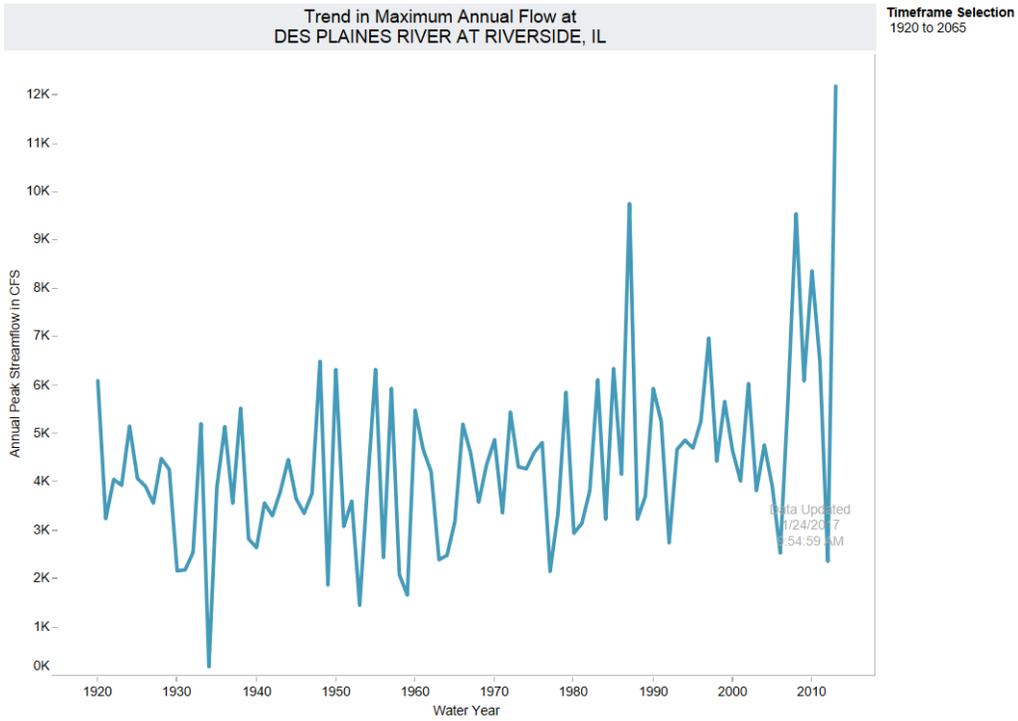
Yes, using the Mann-Kendall Test at the .05 level of significance.
 Yes, using the Spearman Rank Order Test at the .05 level of significance.

What type of trend was detected?

Using parametric statistical methods, a **positive trend** was detected.
 Using robust parametric statistical methods (Sen's Slope), a **positive trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Figure 7. Trend Analysis for Des Plaines River at Riverside, IL (1914-2013)



Monotonic Trend Analysis

Is there a statistically significant trend?

Yes, using the Mann-Kendall Test at the .05 level of significance.

Yes, using the Spearman Rank Order Test at the .05 level of significance.

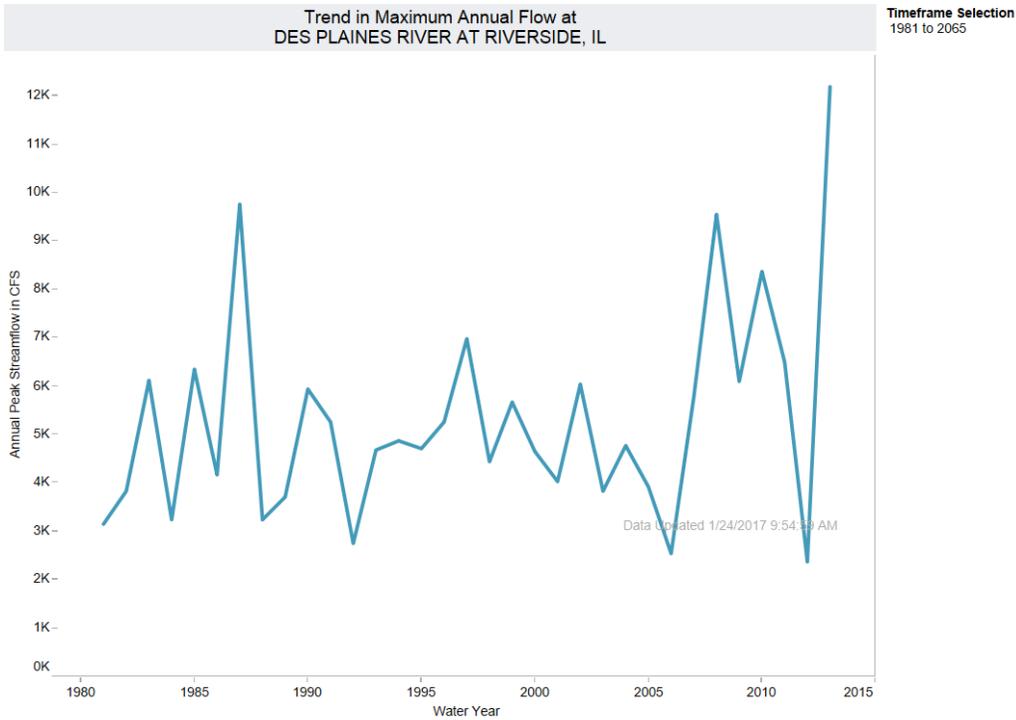
What type of trend was detected?

Using parametric statistical methods, **a positive trend** was detected.

Using robust parametric statistical methods (Sen's Slope), **a positive trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Figure 8. Trend Analysis for Des Plaines River at Riverside, IL (1920-2013)



Monotonic Trend Analysis

Is there a statistically significant trend?

No, using the Mann-Kendall Test at the .05 level of significance.

No, using the Spearman Rank Order Test at the .05 level of significance.

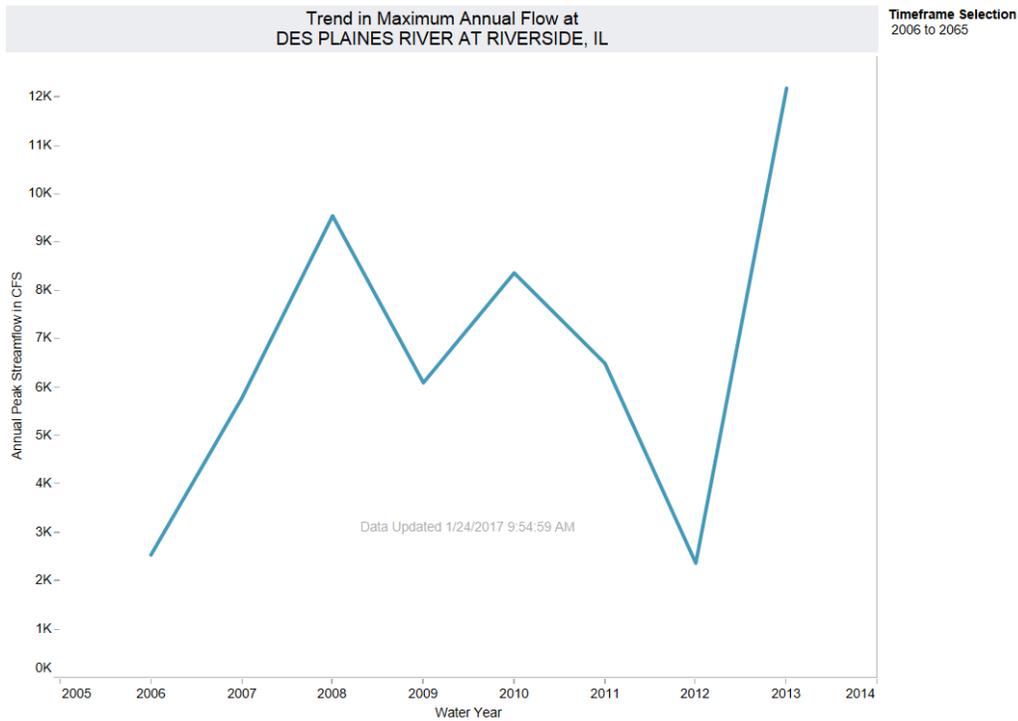
What type of trend was detected?

Using parametric statistical methods, **no trend** was detected.

Using robust parametric statistical methods (Sen's Slope), **no trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Figure 9. Trend Analysis for Des Plaines River at Riverside, IL (1981-2013)



WARNING: The period of record selected is too short. There are potential issues with the trends detected.

Monotonic Trend Analysis

Is there a statistically significant trend?

No, using the Mann-Kendall Test at the .05 level of significance.

No, using the Spearman Rank Order Test at the .05 level of significance.

What type of trend was detected?

Using parametric statistical methods, **a positive trend** was detected.

Using robust parametric statistical methods (Sen's Slope), **a positive trend** was detected.

Please acknowledge the US Army Corps of Engineers for producing this nonstationarity detection tool as part of their progress in climate preparedness and resilience and making it freely available.

Figure 10. Trend Analysis for Des Plaines River at Riverside, IL (2006-2013)

Finally, the USACE online Vulnerability Assessment Tool was reviewed. For the Flood Risk Reduction business line, the project was not vulnerable to climate change for the Wet 2050 and Wet 2085 scenario/epoch combination within the project HUC-4 region as shown in [Figure 11](#) below. In addition, for the dry scenario there was a 3.82% change and for the wet scenario, an 8.00% change in the WOVA score for the HUC-4 Region with a Flood Risk Reduction business line as shown in [Figure 12](#) and [Figure 13](#) below.

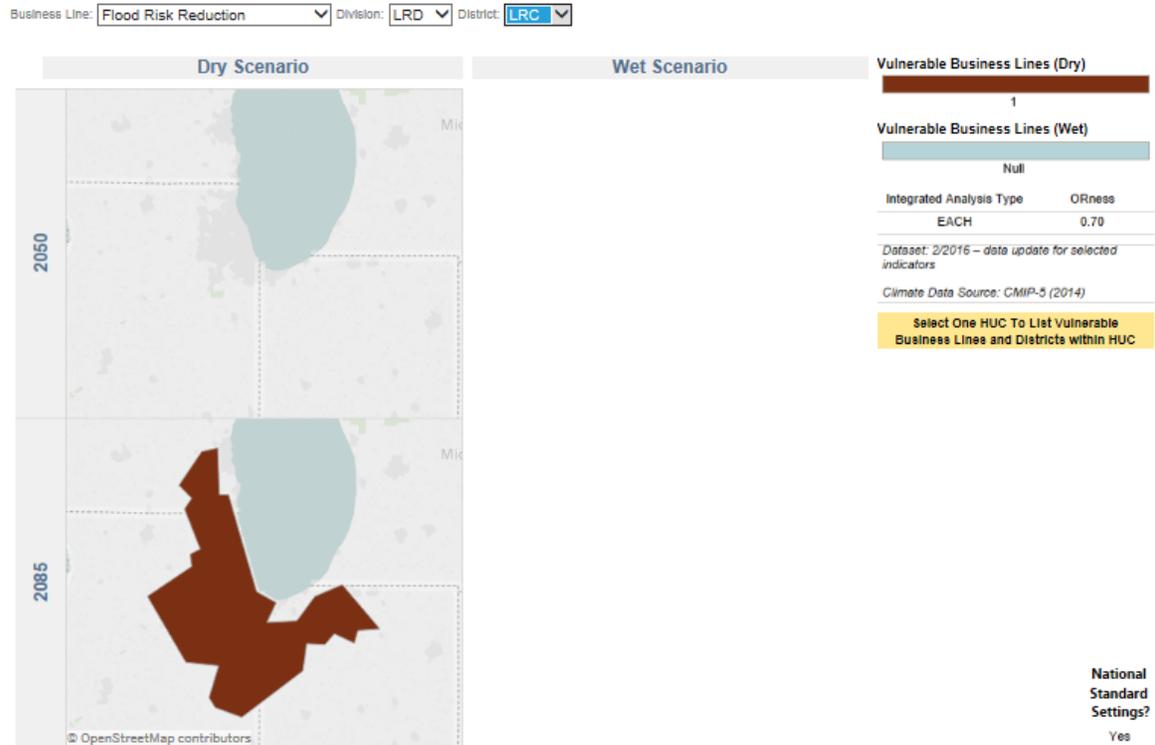


Figure 11. Vulnerability Assessment Tool HUC-4:0712-Upper Illinois

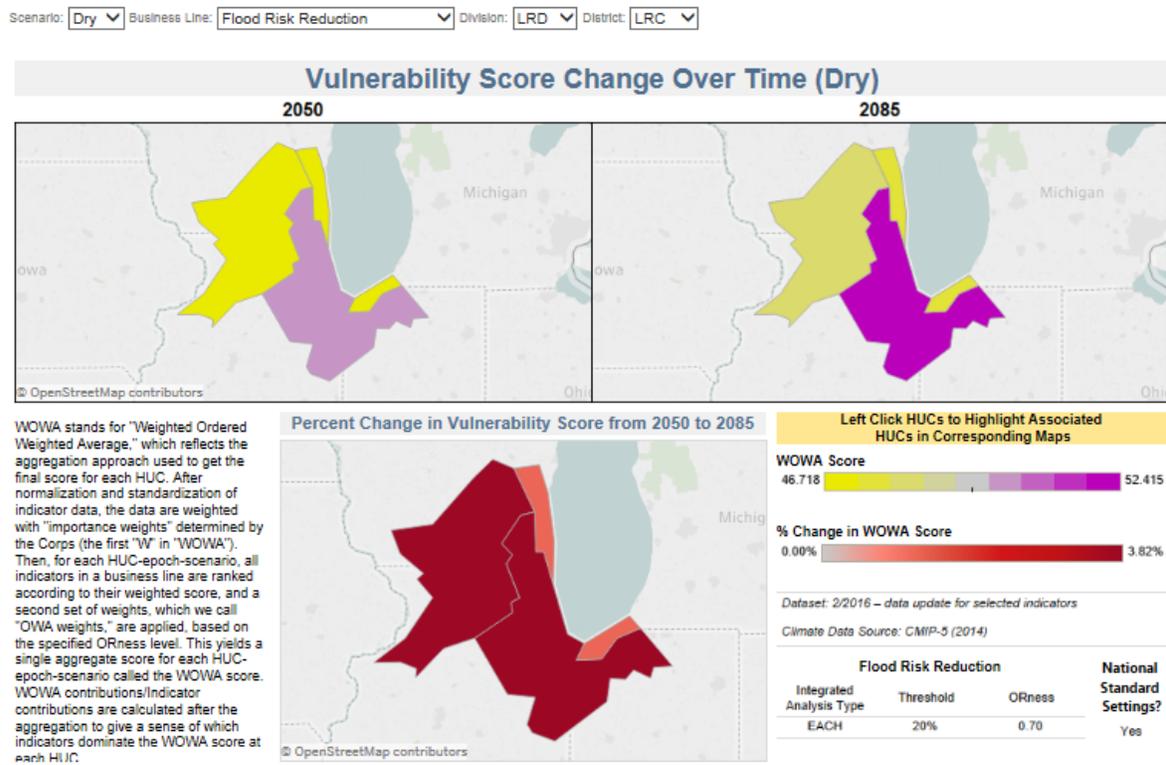


Figure 12. Vulnerability Score, Dry Scenario HUC-4:0712-Upper Illinois

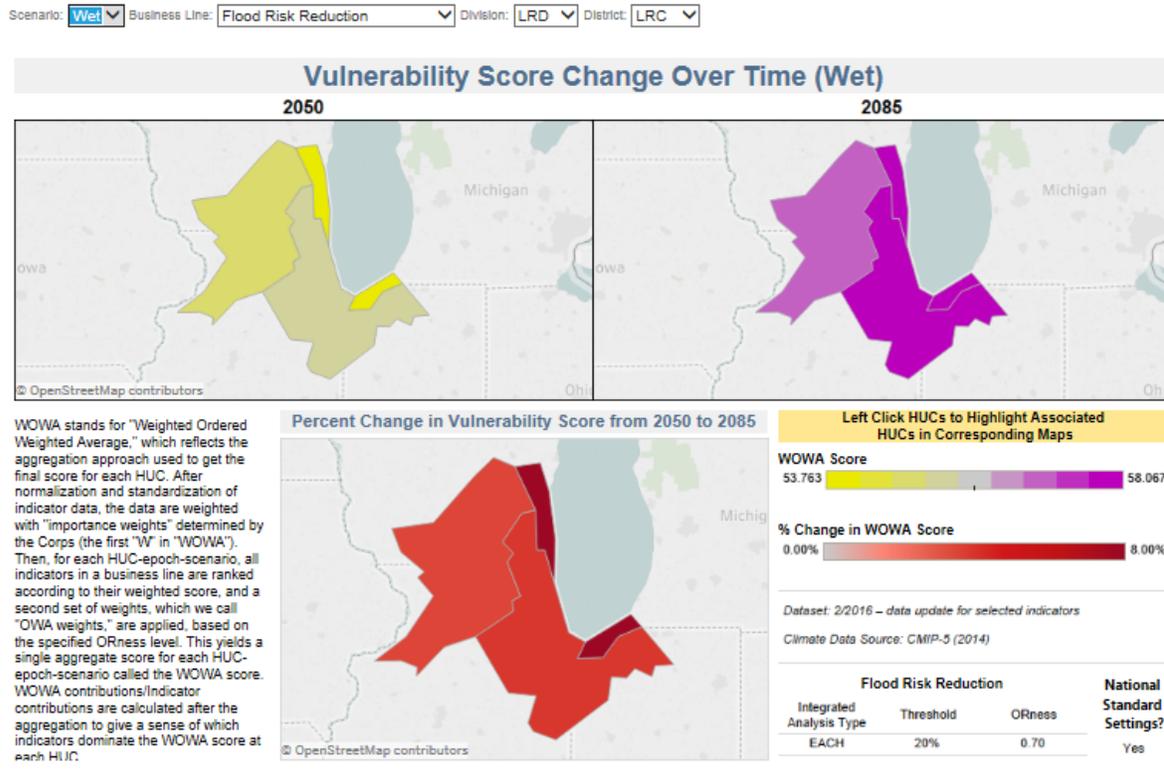


Figure 13. Vulnerability Score, Wet Scenario HUC-4:0712-Upper Illinois

Based on the tools utilized above, it appears that the project area could be significantly impacted by climate change. Since the levee crest elevation is limited to a specific elevation as described above in paragraph two under Superiority Analysis, it is not feasible to raise the levee higher in regard to climate change concerns.

Climate Change Literature Review

USACE is undertaking its climate change preparedness and resilience planning and implementation in consultation with internal and external experts using the best available — and actionable — climate science. As part of this effort, the USACE has developed concise reports summarizing observed and projected climate and hydrological patterns, at a HUC2 watershed scale cited in reputable peer-reviewed literature and authoritative national and regional reports. Trends are characterized in terms of climate threats to USACE business lines. The reports also provide context and linkage to other agency resources for climate resilience planning, such as downscaled climate data for sub-regions, and watershed vulnerability assessment tools.

The USACE literature review report focused on the Great Lakes Region was finalized in April, 2015 (USACE, April 2015) and the USACE literature review focused on the

Upper Mississippi Region was finalized in June, 2015 (USACE, June 2015). The Des Plaines River Watershed is located in the Upper Mississippi Region, but is within 18 miles of the Great Lakes Region, so climatic information from both literature reviews are relevant to the Des Plaines River Watershed. Figure 14, taken from the Great Lakes report, portrays the National Climate Assessment’s (NCA) reported summary of the observed change in very heavy precipitation for the U.S., defined as the amount of precipitation falling during the heaviest 1% of all daily events. The NCA results indicate that 37% more precipitation is falling in the Great Lakes Region now as compared with the first half of the 20th century, and that the precipitation is concentrated in larger events.

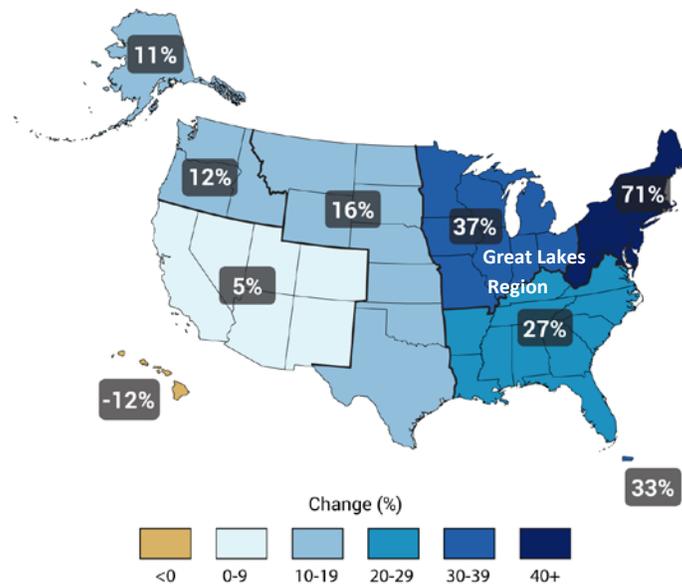


Figure 14 - Percent changes in precipitation falling in the heaviest 1% of events from 1958 to 2012 for each region (Walsh et al., 2014).

The USACE literature review document summarizes and consolidates several studies which have attempted to project future changes in hydrology. Based on a review of four studies, the projected total annual precipitation is expected to have a small increase when compared to the historic record and the precipitation extremes are projected to see a large increase. It is noted that consensus between the studies is low, and although most studies indicate an overall increase in observed average precipitation, there is variation in how these trends manifest both seasonally and geographically. Figures 15 and 16, taken from the USACE Climate Change and Hydrology Literature Reviews, summarizes observed and projected trends for various variables reviewed.

For both the Upper Mississippi and Great Lakes Regions, increase in temperatures have been observed and additional increases in temperature are predicted for the future. For the Great Lakes Region, “nearly all studies note an upward trend in average temperatures, but generally the observed change is small. Some studies note seasonal differences with possible cooling trends in fall or winter.” For the Upper Mississippi Region, increasing trends were more uniformly reported by multiple studies. There is a strong consensus within the literature that temperatures are projected to continue to increase over the next century.

Increases in streamflow have been observed and projections for streamflow rates are variable. For the Great Lakes region, trends in low and annual streamflow were variable, with slight increases observed at some gages but other gages showing no significant changes. “Significant uncertainty exists in projected runoff and streamflow, with some models projecting increases and other decreases. Changes in runoff and streamflow may also vary by season. Projections of water levels in the Great Lakes also have considerable uncertainty, but overall lake levels are expected to drop over the next century.” For the Upper Mississippi Region, “a strong consensus was found showing an upward trend in mean, low, and peak streamflow in the study region.” There is no clear consensus on projected streamflow trends, “with some studies projecting an increase in future streamflow (as a result of increased precipitation) in the study region, while others project a decrease in flows (a result of increased evapotranspiration).” In general, projections suggest increased flows are expected in the winter and spring and decreased flows expected in the summer.

PRIMARY VARIABLE	OBSERVED		PROJECTED	
	Trend	Literature Consensus (n)	Trend	Literature Consensus (n)
Temperature	↑	(7)	↑	(4)
Temperature MINIMUMS	↑	(1)	↑	(1)
Temperature MAXIMUMS	—	(1)	↑	(5)
Precipitation	↕	(7)	↑	(4)
Precipitation EXTREMES	↑	(5)	↑↑	(4)
Hydrology/ Streamflow	↑	(7)	↕	(3)

NOTE: Although most studies indicate an overall increase in observed average precipitation, there is variation both seasonally and geographically. There is considerable uncertainty in projected streamflows, with no clear consensus between studies

TREND SCALE

= Large Increase
 = Small Increase
 = No Change
 = Variable
 = Large Decrease
 = Small Decrease
 = No Literature

LITERATURE CONSENSUS SCALE

= All literature report similar trend
 = Low consensus
 = Majority report similar trends
 = No peer-reviewed literature available for review
(n) = number of relevant literature studies reviewed

Figure 15 – Great Lakes Region - Summary matrix of observed and projected climate trends and literary consensus. (USACE, 2015)

PRIMARY VARIABLE	OBSERVED		PROJECTED	
	Trend	Literature Consensus (n)	Trend	Literature Consensus (n)
 Temperature	↑	 ⁽⁷⁾	↑↑	 ⁽¹⁴⁾
 Temperature MINIMUMS	↑	 ⁽³⁾	↑↑	 ⁽⁴⁾
 Temperature MAXIMUMS	↓	 ⁽³⁾	↑↑	 ⁽⁶⁾
 Precipitation	↑↑	 ⁽¹²⁾	↑	 ⁽¹⁵⁾
 Precipitation EXTREMES	↑	 ⁽²⁾	↑	 ⁽¹⁰⁾
 Hydrology/ Streamflow	↑	 ⁽¹⁰⁾	↕	 ⁽¹⁵⁾

TREND SCALE

 = Large Increase
  = Small Increase
  = No Change
  = Variable
 = Large Decrease
  = Small Decrease
  = No Literature

LITERATURE CONSENSUS SCALE

 = All literature report similar trend
  = Low consensus
 = Majority report similar trends
  = No peer-reviewed literature available for review
(n) = number of relevant literature studies reviewed

Figure 16 – Upper Mississippi Region - Summary matrix of observed and projected climate trends and literary consensus. (USACE, 2015)

Based on the tools utilized above, it appears that the project area could be significantly impacted by climate change, however, since the levee crest elevation is limited to a specific elevation for the reasons described above in paragraph two under Superiority Analysis, it is not feasible at this time to raise the levee higher in regard to climate change concerns.

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1. EM 1110-2-1619, Risk-Based Analysis for Flood Damage Reduction Studies , Department of the Army, U.S. Army Corps of Engineers, 1 August 1996
2. EC 1110-2-6067 , USACE Process for the National Flood Insurance Program (NFIP) Levee System Evaluation , Department of the Army, U.S. Army Corps of Engineers, 31 August 2010
3. ETL 1110-2-299 "Overtopping of Flood Control Levees and Floodwalls" Department of the Army, U.S. Army Corps of Engineers, 22 August 1986
4. ECB No. 2017-15 "Managed Overtopping of Levee Systems" 14 July 2017
5. ECB No. 2016-25 "Guidance for Incorporating Climate Change Impacts to Inland Hydrology in Civil Works Studies, Designs, and Projects" 16 September 2016

Attachment 1

LYONS LEVEE IMPROVEMENT PROJECT Hydrology & Hydraulics Technical Memorandum

Prepared for

**Metropolitan Water Reclamation District
of Greater Chicago (MWRDGC)
100 East Erie Street, Chicago, IL 60611-3154**

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Submitted by:



2 MC Consulting Inc.

1301 West 22nd Street | Suite 215
Oak Brook, IL 60559

P 630.990.0922 | **F** 630.990.0927

www.mcconsultinginc.com

In Association with:

AECOM

AECOM Technical Services, Inc.

2IM Group ● Environmental Design International

Program Director:

Majid A. Chaudhry, Ph.D., P.E.

Project Manager/Lead Principal Engineer:

William J. Weaver, P.E.

River and Drainage Engineer:

John Morgan, P.E.

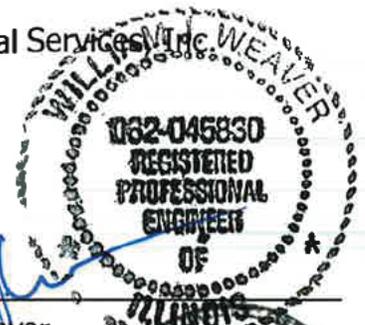
MC Consulting Inc.

AECOM Technical Services, Inc.

ZIM Group



William J. Weaver



Majid A. Chaudhry



MC Consulting Inc.
1301 West 22nd Street | Suite 215
Oak Brook, IL 60559
P 630.990.0922 | F 630.990.0927
www.mcconsultinginc.com

In Association with:

AECOM

AECOM Technical Services, Inc.

ZIM Group • Environmental Design International

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1. Introduction and Background

Lyons levee has been providing protection for the Village of Forest View against Des Plaines River flooding for the better part of the last 100 years. The levee is located beginning 250 feet downstream of Joliet Road on the east side of the river, and parallels the river for a distance of 3,900 feet to the south ending at the Metropolitan Water Reclamation District (MWRDGC) HASMA facility. The original levee construction began in 1892. The work was completed in stages and was completed in 1908. Figure 1-1 is a project vicinity map. Figure 1-2 illustrates the location of the levee on an aerial photograph.

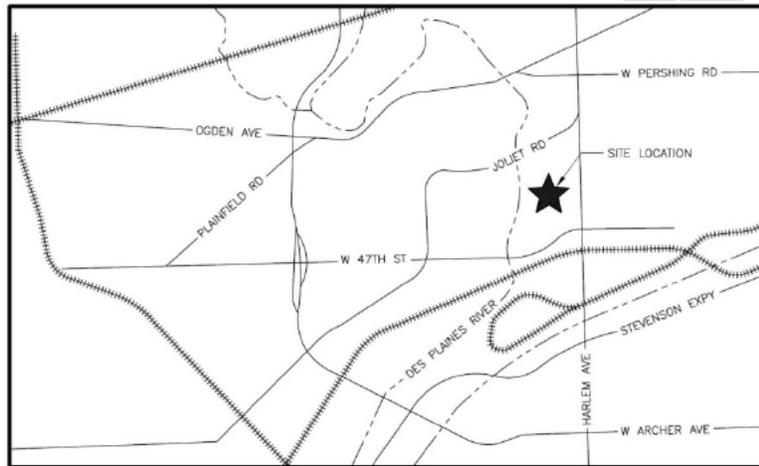


Figure 1-1 – Project Vicinity Map

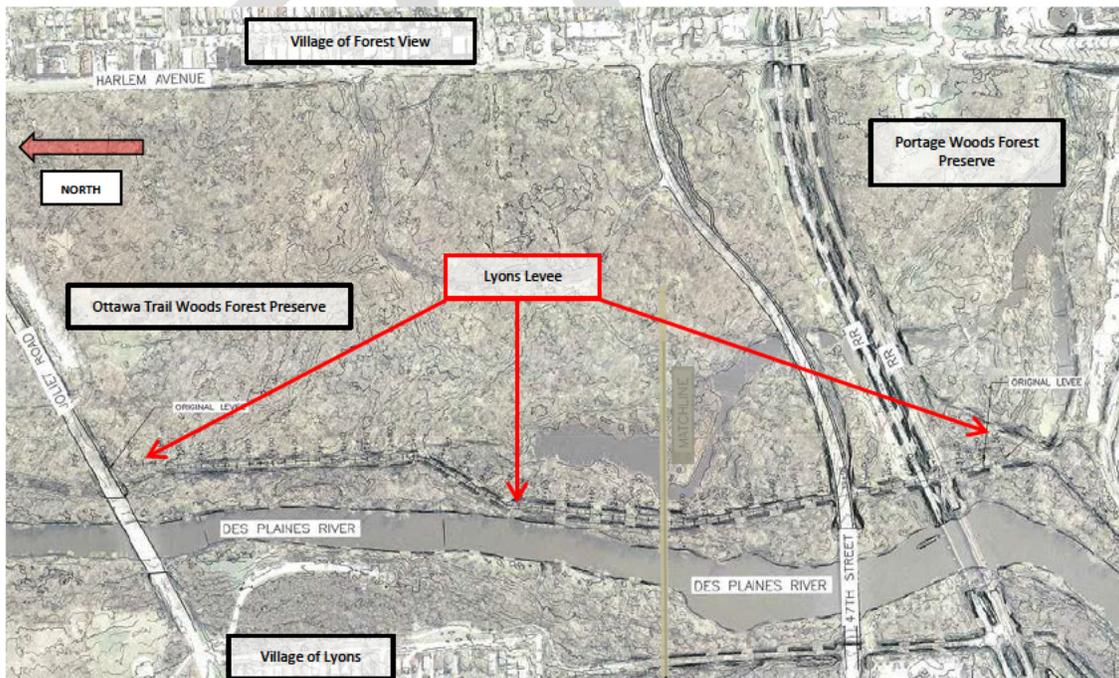


Figure 1-2 – Lyons Levee Location Map

The original levee was reported to have been constructed at elevation 602.0 at the downstream project limits and gradually increasing to 605.0 at the upstream limits at Joliet Road. Over the years, levee settlement, erosion, and foot traffic created low spots in the crest resulting in a minimum crest elevation of approximately 601.0 in several locations.

During April 2013, a flood event that produced the largest Des Plaines River flood discharge for the last 100 years as recorded at the Riverside flow gage caused overtopping of the levee. This event is estimated to have exceeded a flood recurrence interval of 100 years, and overtopped the levee by approximately 0.5 feet at three levee low spots. While some minor levee crest erosion occurred on the upland side, overall the levee survived the event in good shape. Figure 1-3 is a photograph of the levee during summer.



Figure 1-3 – Lyons Levee Crest

Levee maintenance completed as part of temporary flood control measures implemented during 2014 has raised the minimum crest elevation to 602.0.

The Lyons Levee improvement project will upgrade the levee to improve flood protection. The design basis includes an evaluation of the April 2013 flood event to help in the understanding of flood risk and frequency at this location. The levee improvements will help reduce the future risk of flooding in the Village of Forest View.

This Hydrology and Hydraulics Technical Memorandum is prepared to summarize the Des Plaines River Hydrology and Hydraulics studies and Lyons Levee interior drainage studies completed to support the design basis analysis for the proposed levee improvements. This memorandum includes the following information prepared at the request of the U.S. Army Corps of Engineers – Chicago District:

- Evaluation of Des Plaines River flood elevations and flood frequency.
- Evaluate the various river flood models that have been developed for the Des Plaines River and assess the April 2013 flood event frequency. This assessment utilized high water data provided by MWRDGC, Forest View and Hancock Engineering.
- Assess the interior drainage system capacity and potential deficiencies upland of the existing levee.

Field surveys were completed to provide information needed to support the flood study. Land survey field work and archive searches were completed to develop base map information for the project. The field survey efforts included the following tasks:

- Establish horizontal and vertical control.
- General Site Topography –The base mapping relies on the existing Cook County LIDAR survey, topographic mapping and parcel shape files used to correlate existing parcel and right-of-way lines as obtained from the Cook County GIS. This data was obtained, reviewed for obvious discrepancies

and converted for use in AutoCad Civil 3D. Additional survey data collected by MWRDGC and the project team was used to enhance the LIDAR survey. This information forms the basis for enhancing the existing river hydraulic models used for the study and to support the interior drainage study.

- Existing levee survey - A centerline profile of the top of east levee was surveyed at a minimum of 100-foot intervals. Cross-sections of the levee were not surveyed in the field. The survey information supports the technical evaluations of levee improvement options. MWRDGC completed a survey of the east levee crest.
- River Cross sections – A hydrographic survey of the Des Plaines River in the project area was performed to develop cross sections of the river for use in updating hydraulic models.
- Interior drainage –localized hydraulic structure and other survey information needed to support the Interior Drainage evaluation has been completed. The survey includes information needed for the Harlem Ave underpass evaluation.
- Integrated base mapping incorporating all information obtained has been prepared.

2. Des Plaines River Flood Evaluation

The work described in this section was performed to evaluate the effectiveness/level of protection of the current levee and the levee profile required to protect Forest View from flooding during large flood events on the Des Plaines River. The scope of the project included evaluating the April 2013 flood event using the existing models. Hydrologic modeling of the Des Plaines River was not included in the scope of work. The existing DWP hydrology would be used when needed. In addition, a statistical analysis of the historical river flow records for the Riverside gage was completed to enhance the understanding of flood frequency for this site.

The existing hydraulic models were updated to include the additional detail required to prepare a preliminary design of the levee improvements. After completion of the initial model updates and modeling the April 2013 flood event, it was determined that additional calibration of the hydraulic model was needed to adequately represent this flood event.

2.1 Existing Des Plaines River Flood Profiles.

There are four previous studies of the Des Plaines River flood profiles in the vicinity of the Lyons Levee. A summary of the flood profiles and discharges for the 1% exceedance chance (100-yr) flood are presented in the following sections.

2.1.1 MWRDGC Lower Des Plaines River Detailed Watershed Plan (DWP). The DWP was prepared in February 2011 by Christopher B. Burke Engineering, Ltd. for MWRDGC. The DWP used HEC-HMS for the hydrologic modeling and unsteady flow HEC-RAS for the hydraulic modeling of the Des Plaines River and its tributaries in Cook County. The 1% exceedance chance flood stages at the Joliet Road and 47th Street bridges are approximately 603.1 and 602.7 feet NAVD88, respectively. The 1% exceedance chance discharges at Hoffman Dam and 47th Street Bridge are 9,670 and 9,600 cfs, respectively.

2.1.2 FEMA Flood Insurance Study. The FEMA Flood Insurance Study (FIS) for Cook County, IL dated August 2008 shows the 1% exceedance chance flood elevations at the Joliet Road and 47th Street Bridge are approximately 598.8 and 597.6 feet NAVD88, respectively. The 1% exceedance chance flood discharges at Hoffman Dam and 47th Street Bridge are 7,706 and 7,900 cfs, respectively. The flood profiles and discharges in the FEMA Flood Insurance Study are based on the Illinois Department of Transportation – Division of Water Resources Des Plaines River flood plain maps prepared in 1978. These maps were prepared using the TR-20 hydrologic model and WSP-2 hydraulic model developed by the NRCS for the Lower Des Plaines River flood control study performed in the 1970's.

2.1.3 U.S. Army Corps of Engineers Studies

2.1.3.1 Upper Des Plaines River Feasibility Study. The Chicago District Corps of Engineers released a draft report in September 2013 on the Flood Control Plan for the Upper Des Plaines River and its tributaries. This report does not cover the Lyons Levee

project area. The study ends upstream of Hoffman Dam. The study does publish discharges on the Des Plaines River from a discharge frequency analysis performed in January 2008. The 1% exceedance chance discharge at the USGS Riverside stream gage is 9,068 cfs.

2.1.3.2 Lyons Levee Assessment. The Corps of Engineers published a levee assessment of the Lyons Levee in June 2012. The 1% exceedance chance flood elevation at River Mile 42.3 according to this study is 601.58 feet NAVD88. This is near the 47th Street Bridge. The discharges used in this study were not published in the report. The Corps of Engineers estimated that the Lyons Levee would be overtopped during a 5% exceedance chance (20-yr) flood.

2.2 Updated Hydrologic Analysis

The Des Plaines River hydrology was updated for this study to establish a “Project Design Flood” that serves as the levee design basis for this project. This was done due to the large variance in the published flows for this site and the number of flood events where the discharge measured at the USGS Riverside stream gage exceeded flows published in the FEMA Flood Insurance Study (FIS) for the 1% exceedance chance discharge since 1978.

The annual peak discharges for the USGS Des Plaines River at Riverside stream gage were obtained from the USGS web site. The published data covers the period from WY 1914 to WY 2013. This record includes the April 2013 flood event that overtopped the Lyons Levee and flooded Forest View. The April 2013 flood discharge at Riverside was 12,200 cfs according to the USGS. A discharge frequency analysis of the annual peak discharges was performed using the Corps of Engineers software package HEC-SSP 2.0. A regional skew and the regional skew mean square error parameters used by the Corps of Engineers in their January 2008 discharge frequency analysis were used in this analysis. The regional skew was -0.16 and the regional skew MSE was 0.2. The results of this analysis are shown in Table 2-1 and Figure 2-1. This analysis provides the 100-year Project Design Flood (Design Flood) for the Lyons Levee improvement project.

Table 2-1 – Riverside Discharge Frequency Analysis

% Chance Exceedance	Computed Flow (cfs)	Expected Probability Flow (cfs)	5% Confidence Limit (cfs)	95% Confidence Limit (cfs)
0.2 (500-yr)	11,760	12,090	13,740	10,360
0.5 (200-yr)	10,620	10,850	12,260	9,440
1.0 (100-yr)	9,750	9,920	11,140	8,730
2.0 (50-yr)	8,870	8,980	10,030	8,010
5.0 (20-yr)	7,670	7,730	8,540	7,010
10.0 (10-yr)	6,720	6,760	7,390	6,200
20.0 (5-yr)	5,710	5,730	6,190	5,320
50.0 (2-yr)	4,130	4,130	4,420	3,870

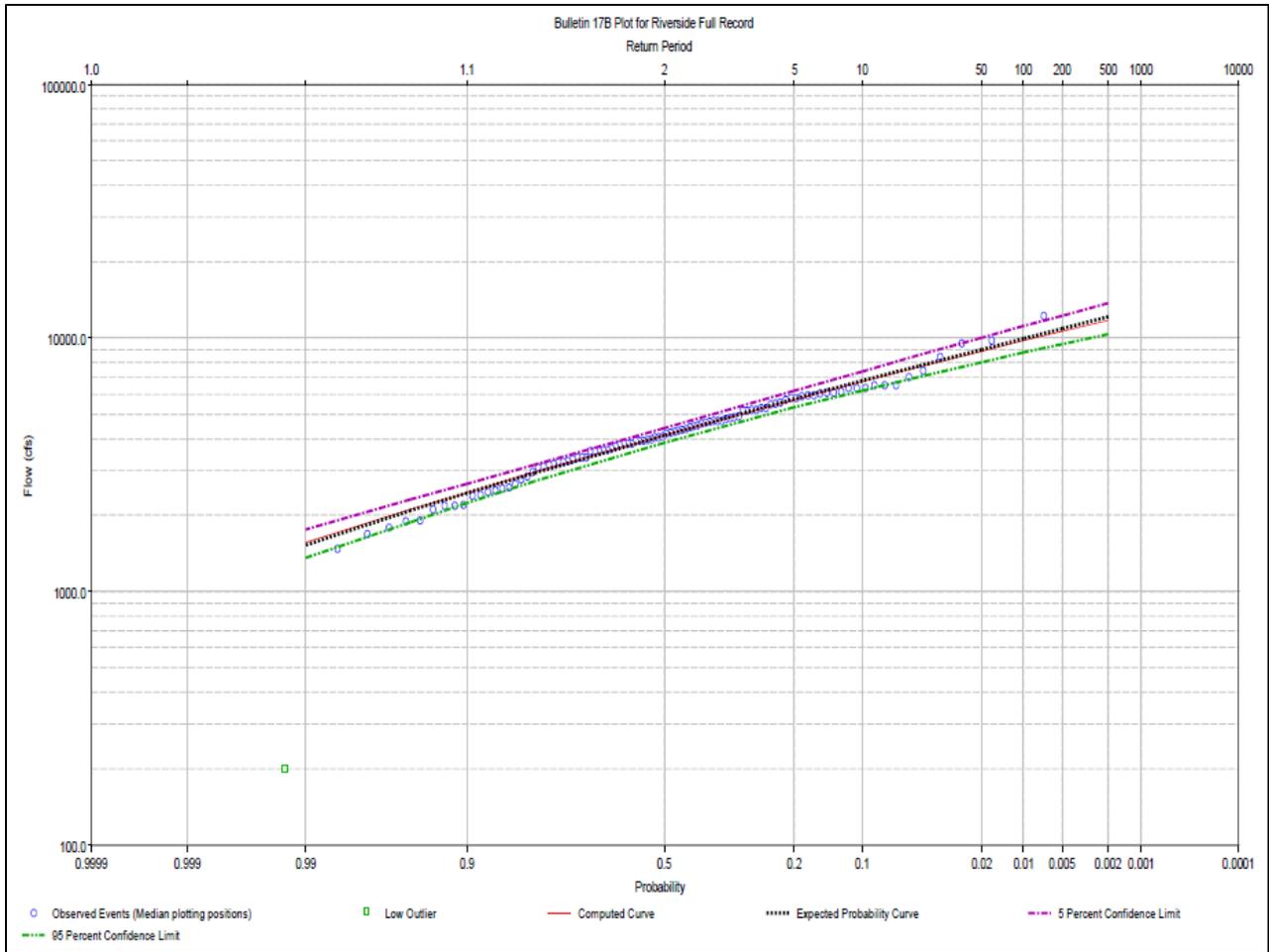


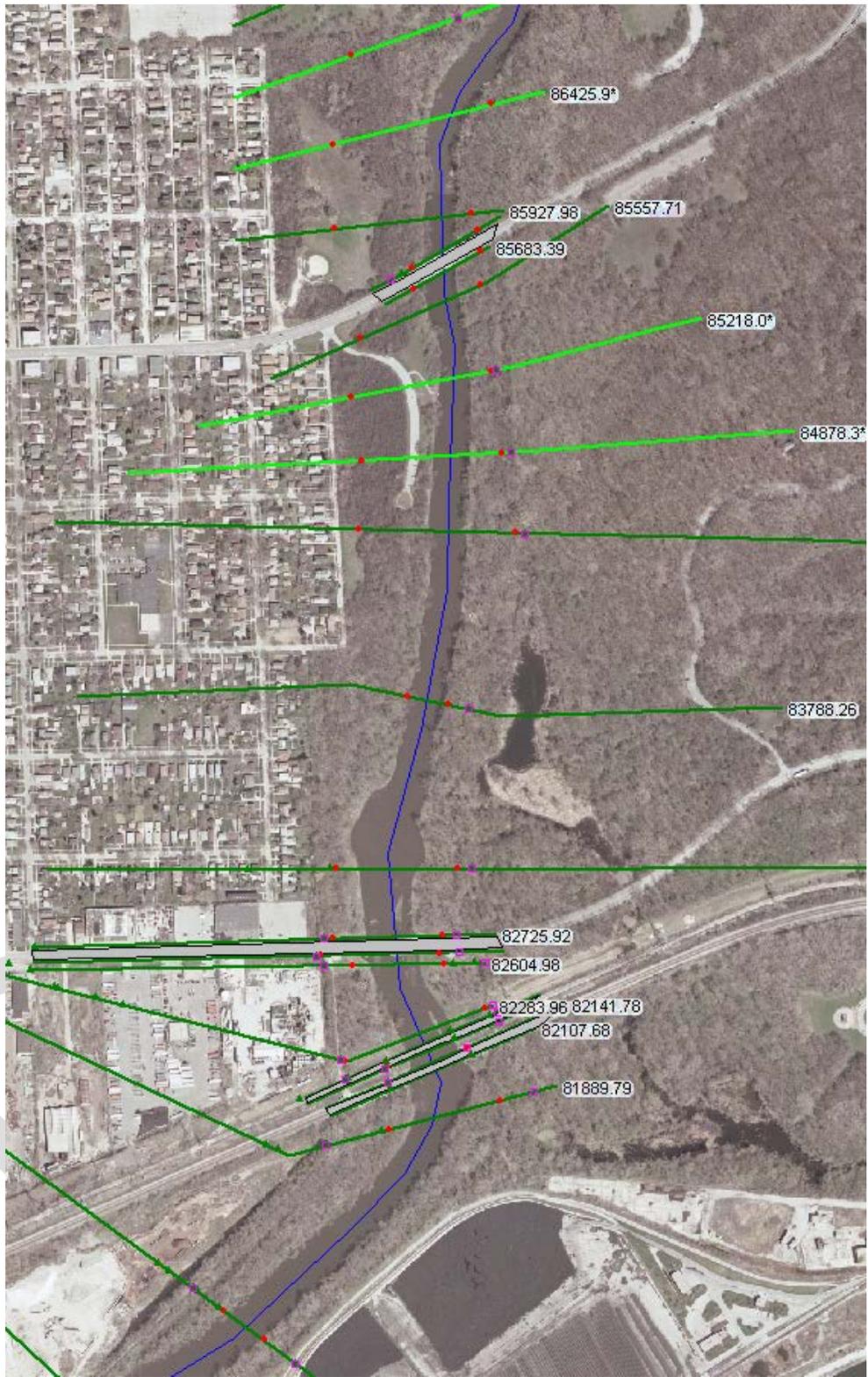
Figure 2-1 – Riverside Discharge Frequency Analysis

The 100-year Project Design Flood resulting from this analysis is based on a statistical analysis of 100 years of river gage records, which included a variety of watershed conditions that occurred between 1914 and 2013. The proposed levee improvements will incorporate a freeboard above the 100-year Project Design Flood. A readme file is provided for the HEC-SSP computer model in Appendix A. Computer model input and output for this analysis is provided in Appendix B in a file named: "DesPlainesRiver_SSP_Files".

2.3 Hydraulic Analysis

The DWP HEC-RAS model was modified for this study. The DWP model was truncated to represent the Des Plaines River from Hoffman Dam at the upstream boundary to the downstream boundary at the Cook County line.

2.3.1 Updates to the HEC-RAS Model. The unsteady flow HEC-RAS model developed for the Lower Des Plaines Detailed Watershed Plan was used as the base model for this study. The cross section locations for this HEC-RAS model are shown in Figure 2-2. The sections that have an asterisk (*) by the section numbers are interpolated and are illustrated in light green color.



Note: Section Numbers with an Asterisk (*) are interpolated.

Figure 2-2 – Lower Des Plaines River Detailed Watershed Plan Cross Section Locations

The DWP HEC-RAS model was updated with additional levee details and Des Plaines River geometry needed for the preliminary design. Additional cross sections were added to the model to replace interpolated cross sections in the vicinity of Lyons Levee. Cross sections were added to the model near Lyons Levee to better reflect where changes in the river and levee geometry occur. These new cross sections were developed using the Cook County bare earth LIDAR data and a bathymetric survey of the Des Plaines River performed for this study. The cross sections within the levee limits were truncated at the crest of the Lyons Levee.

Lateral structures were added to the model within the project limits to represent potential levee overtopping. The levee profile used for these lateral structures is based on a detailed levee profile surveyed for this project. The lateral structures in the model allow water overtopping of the levee if the river flood stage exceeds the levee crest. If this were to occur, the water is extracted from the river system causing a reduction in river flow downstream of Lyons Levee.

Lateral structures were also added to the model downstream of Willow Springs. These structures represent inter-basin flow that can occur between the Des Plaines River and Sanitary and Ship Canal during extreme river levels. These lateral structures were obtained from a model developed by the Corps of Engineers for the Great Lakes and Mississippi River Interbasin Study (GLMRIS). The GLMRIS HEC-RAS model was used in the Lyons Levee assessment report prepared by the Corps of Engineers. The updated cross section geometry for the updated model near Lyons Levee is shown in Figure 2-3.

A readme file is provided for the HEC-RAS computer model in Appendix A. Computer model input and output for this analysis is provided in Appendix B in a file named: "DesPlainesRiver_RAS_Files".

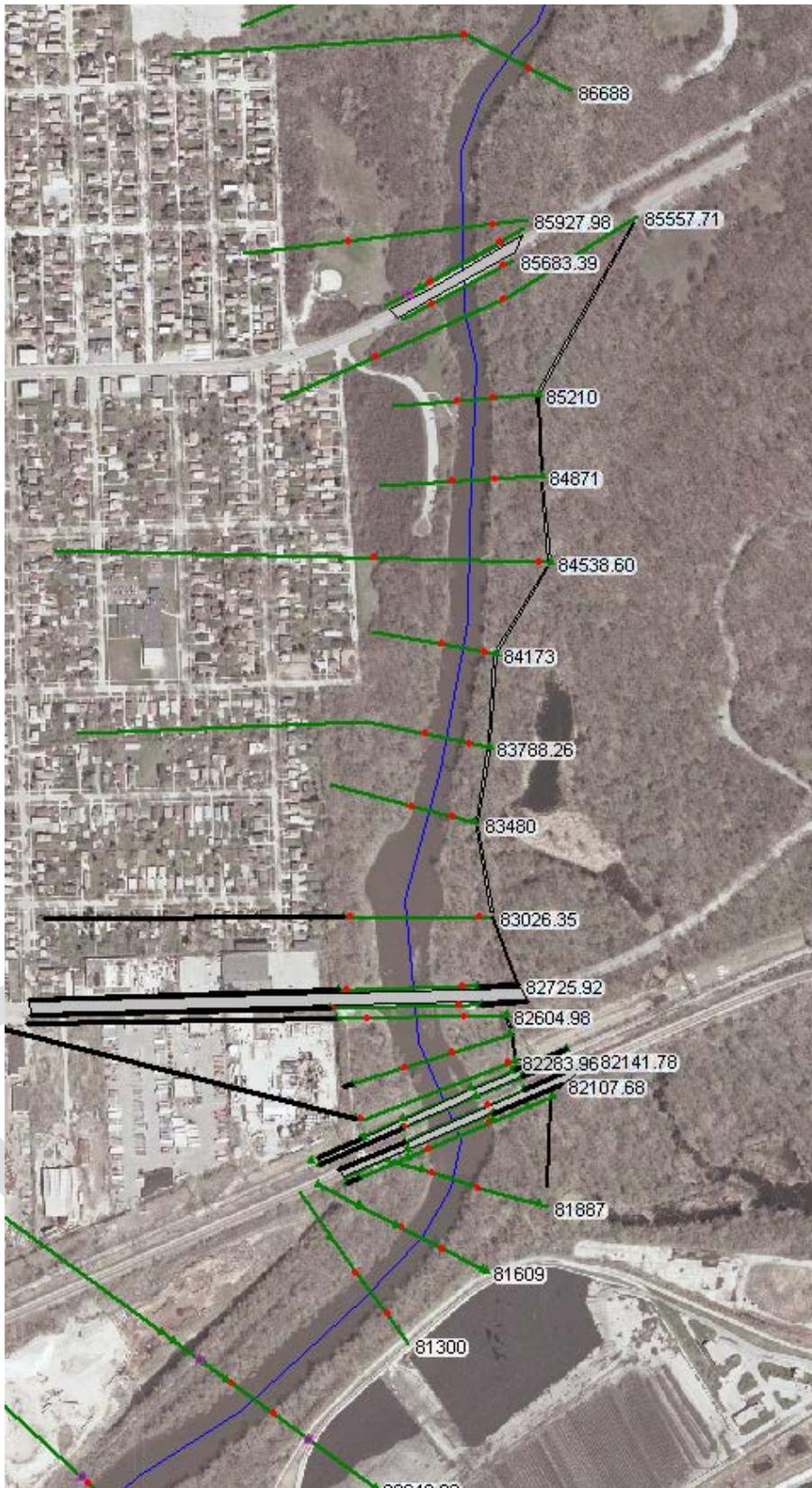


Figure 2-3 – Final Cross Section and Lateral Structure Locations

2.3.2 HEC-RAS Model Calibration. The HEC-RAS model developed for this project was run to simulate the April 2013 flood event to evaluate how well the model represents observed flood conditions during that event. The observed high water elevation at the USGS Riverside stream gage was 605.65 feet NAVD88. The Des Plaines River flood elevation near 47th Street was estimated based on the overtopping photos taken during the event and the existing levee profile survey, and observed high water locations reported by Brian Levy of the MWRDGC. The high water marks near 47th Street were estimated to be 601.70 feet NAVD88. The initial HECRAS model run for the April 2013 flood event produced elevations of 606.36 and 602.44 feet NAVD88 at Riverside and 47th Street, respectively. These elevations were significantly higher than the observed high water marks. We performed a calibration analysis to improve how the HEC-RAS model represents the larger event floods.

The calibration process included an update to the existing levee profile as described in Section 2.3.1. The primary calibration tool used included adjustments to the channel and overbank Manning’s n-values. The initial channel and overbank n-values ranged from 0.038 – 0.050 and 0.070 – 0.090, respectively.

The HEC-RAS calibration was performed using six recent historic storms from September 2008 to July 2014 using the unsteady flow option. A summary of the peak flows and observed high water marks for these events is provided in Table 2-2. The July 2014 flood event was included because of the recent addition of a USGS stage gage at this location. Three of the other five events have flows greater than the published FEMA FIS 1% exceedance flood.

Table 2-2 – Calibration Events

Event	Flow at Riverside (cfs)	Observed High Water Elevation at Riverside (ft NAVD88)	Observed High Water Elevation at 47 th Street (ft NAVD88)
September 2008	9,560	604.25	n/a
December 2008	6,110	602.30	n/a
July 2010	8,380	603.61	n/a
July 2011	6,510	602.84	n/a
April 2013	12,200	605.65	601.70
July 2014	3,920	600.97	596.13

In addition to the 47th Street high water elevation for the April 2013 flood event, the overtopping volume was estimated using the high water mark near the Forest View City Hall. The overtopping volume was estimated at 614 ac-ft below elevation 593.3 feet NAVD88.

The calibration process for the Des Plaines River HEC-RAS model included the adjustment of channel and overbank n-values to bring the computed stages closer to the observed stages. The channel and overbank n-values for the calibration runs downstream of 47th Street are 0.033 and

0.056, respectively. The final channel and overbank n values between 47th Street and the USGS Riverside stream gage are therefore also selected to be 0.045 and 0.056, respectively.

A summary of the calibration results is provided in Table 2-3. The HEC-RAS model estimates a total overtopping volume of 667.9 ac-ft compared to an approximate observed volume of 614.0 ac-ft. Based on the elevation differences in Table 2-3 and the differences in the overflow volumes, the model is considered to provide a reasonable calibration.

Table 2-3 – Calibration Results

Event	47 th Street Observed (ft NAVD)	47 th Street Computed (ft NAVD)	Difference (ft)	Riverside Observed (ft NAVD)	Riverside Computed (ft NAVD)	Difference (ft)
September 2008	n/a			604.25	604.74	0.49
December 2008	n/a			602.30	602.62	0.32
July 2010	n/a			603.61	604.09	0.48
July 2011	n/a			602.84	602.90	0.06
April 2013	601.70	601.67	-0.03	605.65	605.81	0.16
July 2014	596.13	595.85	-0.28	600.97	600.57	-0.40

2.3.3 Design Storm Profiles. The Project Design Flood profiles were computed using the calibrated HEC-RAS model in steady flow mode, and the “expected probability flows” developed as described in Section 2.2. We are unable to use the unsteady flow model for these events since we only have a hydrograph for the historic event from April 2013. Water surface profiles for the 10, 5, 2, and 1% exceedance events (10-, 20-, 50-, and 100yr recurrence intervals) were computed. In addition, the published FEMA FIS 1% exceedance chance flow of 7,900 cfs was used to estimate the flood profile using the calibrated HEC-RAS model. For the design storm profiles, overtopping of the levee was not included in the modeling. A summary of the design water surface profiles at Riverside, Joliet Road, 47th Street, Canadian National Railroad, BNSF Railroad, and the downstream end of the Lyons Levee are provided in Table 2-4. The water surface profiles are shown in Figure 2-4.

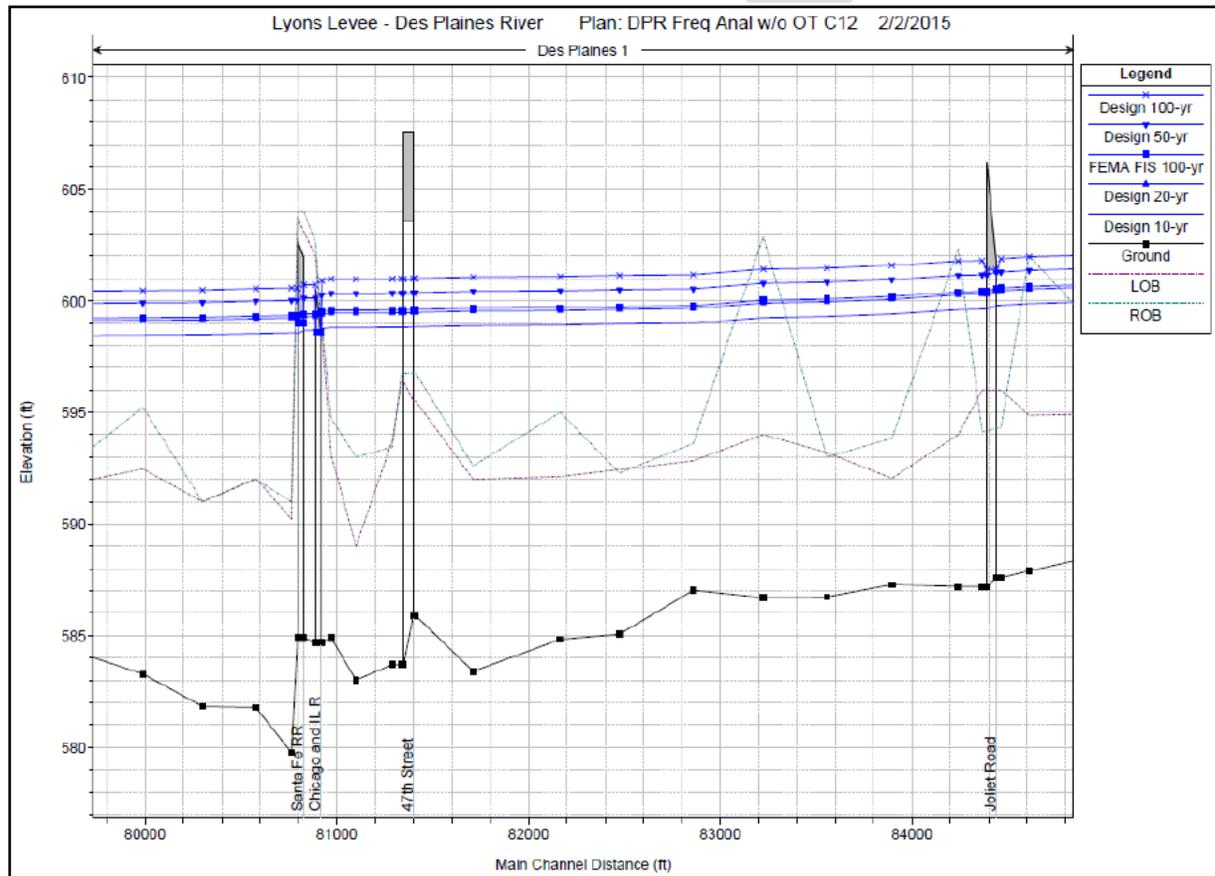
The calibrated HEC-RAS model with the FEMA FIS discharges produces higher water surface elevation estimates than the published FEMA flood profile. This is due in part to the change in computer models. The FEMA study used the WSP2 computer program. Furthermore, the FEMA model downstream boundary at 47th Street appears to be set too low as confirmed in the calibration analysis completed for the April 2013 event for this project. The HEC-RAS computed profile is approximately 1.8 feet higher at Joliet Road and 2 feet higher at 47th Street.

Table 2-4 –Water Surface Profile Summary

Location	Flood Elevations using HECRAS Model Calibrated to April 2013 Flood Event				
	% Exceedance (in any given year)				**FEMA FIS 100-yr event
	10 % (10-yr event)	5 % (20-yr event)	2 % (50-yr event)	*1% (100-yr event)	
Downstream Levee Limit	598.53	599.20	599.99	600.55	599.31
BNSF RR	598.68	599.30	600.12	600.72	599.41
Canadian National RR	598.75	599.39	600.27	600.91	599.52
47 th Street	598.81	599.46	600.35	600.98	599.59
Joliet Road	599.80	600.45	601.29	601.88	600.57
USGS Riverside Stream Gage	602.86	603.45	604.14	604.62	603.55

*100-year Project Design Flood

**100-year Profile using FEMA Discharge in HECRAS model.



*The 100 year Project Design Flood is defined in Section 2.2.
 LOB and ROB refer to left river overbank and right river overbank, respectively.

Figure 2-4 – Design Storm Water Surface Profiles

2.3.4 Urbanization Impact on Project Design Flood. The 100 –year Project Design Flood discharge developed as the design basis for Lyons levee improvements is based on an analysis of a 100 year river gage record as summarized in Section 2.2. In most respects, having such a long gage record is ideal and helps to reduce uncertainties that can result from analyses of shorter records. However, it is possible that a long gage record could potentially mask the effects of urbanization on flood peaks. In some cases urbanization can cause changes in rainfall frequency and watershed rainfall-runoff characteristics among other unknown factors on Des Plaines River discharges. Factors that can offset the influences of urbanization include stormwater and floodway regulations that have been implemented in recent decades and flood control project implementation by government entities.

A sensitivity analysis was performed to evaluate this phenomenon as it may apply to the Des Plaines River flood study presented in this report. The analysis includes a flood discharge frequency evaluation for a shorter and more recent time period at the Riverside gage than the 100 year record used to develop the 100-year Project Design Flood discharge. This analysis used the HEC-SSP computer program to analyze a 40 year gage record extending from 1974 through 2013. The results are compared with the 100 year gage record analysis to see if there has been a discernable change in the discharge frequency on the Des Plaines River at Riverside.

Results of this analysis for two gage record time periods is summarized in the following table. The 1% chance exceedance flow at Riverside is 9,920 cfs for the entire 100 year period of record, and 11,500 cfs for a record that excludes all data except for the last 40 years.

Expected Flow at Des Plaines River at Riverside								
Period	50%	20%	10%	5%	2%	1%	0.5%	0.2%
Period of Record 1914 to 2013	4,130	5,730	6,760	7,730	8,980	9,920	10,850	12,090
1974 to 2013	4,770	6,580	7,770	8,900	10,380	11,500	12,640	14,200

The shorter record requires more extrapolation to estimate the 100-yr flow than the 100 year record. Furthermore, one or more large flood events can significantly skew the magnitude of the 1% flow, when a shorter period of record is considered. There are a number of factors that come into play regarding differences in the discharge frequency curves. These can include a short record that can contain abnormally high measured flows, urbanization, increased rainfall due to climate change, flood control improvements upstream, and other issues.

The results of this analysis indicate that while the differences in flood discharges for a given gage record period can result in different flows, the approach taken to establish project design

conditions for the Lyons levee project are reasonable. The larger 100 year flow for the arbitrarily shorter gage record analysis reflects a 15% increase compared to the Project Design Flood which is based on a 100 year record. The proposed levee design will include significant freeboard above the Project Design Flood with the new levee crest above the flood profile for both of the gage period analyses summarized above. Furthermore, the proposed levee crest will be constructed above the flood of record at this gage which occurred during 2013.

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3. Interior Drainage Evaluation

The existing drainage system located between Lyons Levee and Harlem Avenue was investigated to evaluate if this system has caused flood damages. The existing drainage system is bounded by Harlem Avenue on the east, the Lyons Levee on the west, Joliet Road on the north, and the MWRDGC Harlem Avenue Solids Management Area (HASMA) on the south. The general direction of the flow is from Harlem Avenue and Joliet Road to the south and west to a series of culverts under 47th Street and the Canadian National and BNSF Railroads. After passing through the railroad culverts the flow turns to the south and east to two small culverts under Harlem Avenue near the HASMA site. The discharge from these culverts is intercepted by the Harlem Avenue storm sewer and conveyed to the Sanitary and Ship Canal. See Figure 3-1 for a general overview of the interior drainage system.

The only known drainage problem related to the drainage system behind the levee is the periodic flooding that has occurred at the Harlem Avenue underpass south of 47th Street. The Illinois Department of Transportation investigated the flooding problems at the Harlem Avenue underpass under the Canadian National and BNSF Railroad tracks. The Location Drainage Technical Memorandum describing the existing problems and several alternative solutions was prepared by Hampton, Lenzini and Renwick, Inc. in November 2013. Alternative 3A was recommended in the report. This alternative consists of replacing the existing 30" and 36" sewers with new sewers with 42" and 48" sizes.



Figure 3-1 – Interior Drainage System Overview

3.1 Existing Interior Drainage System

To evaluate the existing interior drainage system, a HEC-HMS and HEC-RAS models were developed. The hydrology was modeled using HEC-HMS. An unsteady flow HEC-RAS model was developed to model the major components of the interior drainage system.

3.2 HEC-HMS Hydrologic Model Development

The interior drainage system was subdivided into 4 sub-basins shown in Figure 3-1. These correspond to the major drainage features in the interior drainage system. Sub-basin 47th West is tributary to the culvert under 47th Street. Sub-basin 47th East is the area tributary to the ditches along Harlem Avenue and 47th Street. The Railroad sub-basin is the area tributary to the culverts between 47th Street and the Railroad culverts. Sub-basin Harlem represents the area between the railroads and Harlem Avenue that drains to the culverts under Harlem Avenue. The primary land use within the interior drainage area is forest that belongs to the Forest Preserve District of Cook County. A summary of the drainage basin parameters is shown in Table 3-1. The total interior drainage area is 152.3 acres.

Table 3-1 – Summary of Subbasin Parameters

Subbasin	Area (ac)	Curve Number	Time of Concentration (min)
47 th East	27.49	75	70
47 th West	78.18	71	107
Railroad	21.24	82	59
Harlem	25.39	83	41

The NRCS curve number and unit hydrograph methods were used in modeling the runoff from these sub-basins. The interior drainage area was modeled using a critical duration storm methodology. The model was run for the 99, 50, 20, 10, 4, 2, and 1% exceedance frequencies (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr recurrence intervals, respectively) and the 1-, 2-, 3-, 6-, 12-, and 24 hour duration storms. The HEC-HMS model was used to generate the runoff hydrographs that would be input to the unsteady flow HEC-RAS model.

A readme file is provided for the HEC-HMS computer model in Appendix A. Computer model input and output for this analysis is provided in Appendix B in a file named: "LyonsLevee_HMS_Files".

3.3 HEC-RAS Hydraulic Model Development

HEC-RAS was selected for modeling the interior drainage system to be compatible with the Des Plaines River system so that the two models could be combined if necessary to model the impacts of any overtopping flows on the interior drainage system. The unsteady flow option of HEC-RAS was used to capture the impact of the existing ponds and restrictive culverts on the interior drainage flood elevations.

The HEC-RAS model consists of three storage areas representing the existing ponds in the system and three river reaches connecting the ponds and representing the downstream outlet channel. Within the three river reaches there are four culverts representing the roadway crossings under 47th Street, CN Railroad, BNSF Railroad, and Harlem Avenue. In addition there are two inline structures representing existing beaver dams within the Forest Preserve. The beaver dams are in the downstream reach just upstream of Harlem Avenue. See Figure 3-2 for the HEC-RAS model extents.

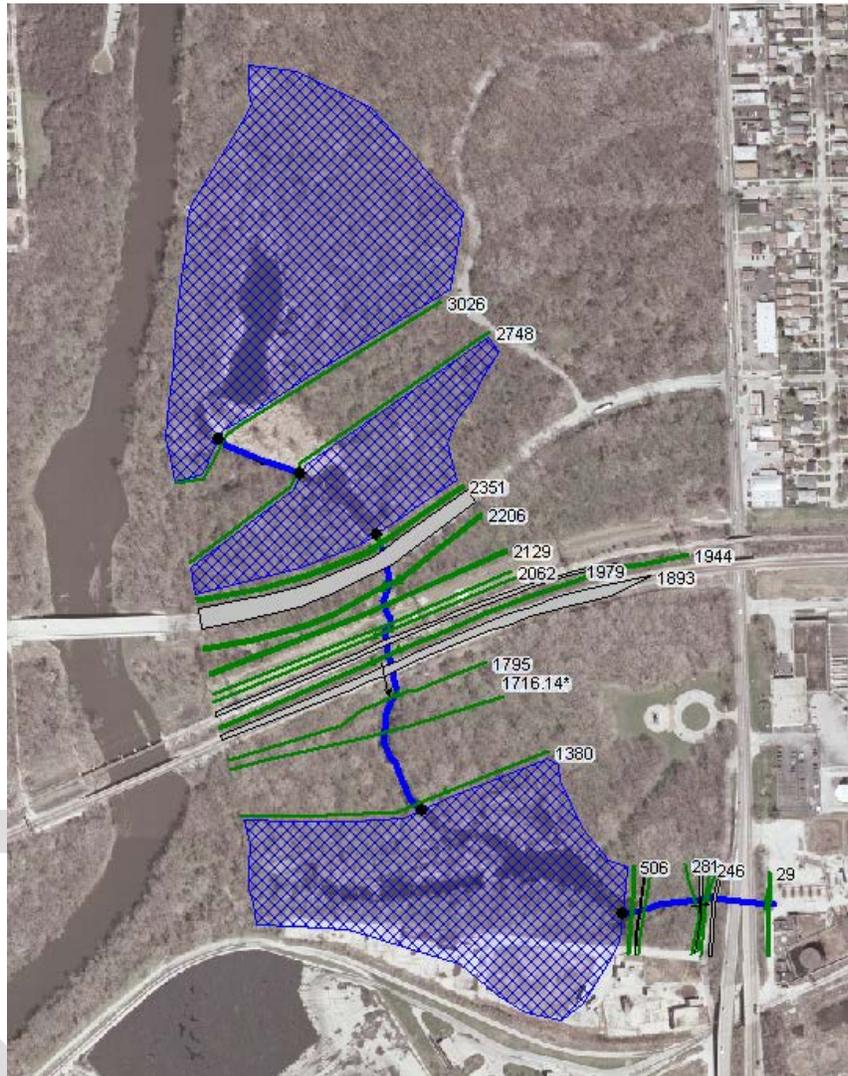


Figure 3-2 – HEC-RAS Model Extents

The input data for the 23 cross sections, 4 culverts, 2 in-line structures, and 3 ponds were developed using HEC-GeoRAS. The data sources were field survey conducted for this study and the Cook County bare earth LIDAR point data provided by MWRDGC. The survey data was used to define the channel portion of each cross section while the overbank portions of the cross sections were based on the LIDAR data.

Historic high water information was not available for calibration. The model inputs representing land cover in the channel and overbank were developed based on engineering references and experience with similar sites. Interpolated cross sections were used in portions of the model to improve model stability. The downstream discharge from the interior drainage system compared favorably with the flows developed by IDOT in evaluating the Harlem Avenue storm sewer improvements to alleviate flooding in the Harlem Avenue underpass at the railroad tracks. The 2% exceedance chance critical duration flow from the interior drainage analysis was 42 cfs. The IDOT report used two methods to determine the flow from this area. The flows in the IDOT report were 58 cfs using the StreamStats computer program, and 43 cfs using the NRCS methods for the 2% exceedance chance 1-hr duration storm.

3.4 Existing Conditions Results

The HEC-RAS model results do not identify any flood problems within the interior drainage system. The flooding identified by the modeling is contained within the Forest Preserve District of Cook County property. The flood elevations do not cause impact to the roads within the interior drainage boundaries.

The critical duration analysis identified the 6-hour duration storm as generally providing the highest flood levels within the interior drainage area. A summary of the peak high water levels at 47th Street, the CN Railroad, the pond in the Forest Preserve District south of the Railroad Tracks and upstream of Harlem Avenue are shown in Table 3-2.

Table 3-2 – Summary of Interior Drainage Flood Levels

Location	10% Exceedance Chance (ft NAVD)	2% Exceedance Chance (ft NAVD)	1% Exceedance Chance (ft NAVD)
47 th Street (upstream face)	588.8	589.7	590.3
CN Railroad (upstream face)	588.5	589.6	590.2
Pond	587.1	588.2	588.7
Harlem Avenue (upstream face)	587.0	588.2	588.7

The lowest pavement elevations outside of the underpass which would be impacted by the interior drainage flooding were in the vicinity of the 47th Street and Harlem Avenue intersection. The pavement elevations in this area are between 591 and 592 ft NAVD based on the contour mapping. The interior drainage high water levels near 47th Street can back up into this area via a storm sewer and roadside ditches along the south side of 47th Street. A readme file is provided for the interior drainage HEC-RAS computer model in Appendix A. Computer model input and output for this analysis is provided in Appendix B in a file named: "LyonsLevee_RAS_Files".

Based on the interior drainage analysis, the existing interior drainage system is capable of handling the local runoff behind the levee without causing flood damages or highway delays due to water on the pavement.

4. Proposed Levee Improvement Plan

The Lyons Levee Improvement project seeks to reduce the Des Plaines River flooding risk in the Forest View area. The recommended flood risk reduction measure would provide flood protection for events up to the 100-year flood and meet Federal, State and local design requirements. The limits of levee improvements under consideration begin just south of Joliet Road and extend downstream for a distance of approximately 1,050 feet south of 47th Street, a total distance of 4,327 feet. This Section summarizes the design basis for the selected option.

The proposed plan includes a reconstruction of the existing levee. The plan includes the following features:

- The levee restoration will build on the existing levee footprint and is located within the same corridor for its entire length. The levee crest will be raised at key locations and the slopes will be widened where necessary to provide improved levee geometry that will enhance stability and seepage control. Reconstruction of the existing levee will be accomplished in accordance with design standards generally in accordance with the requirements of the United States Army Corps of Engineers engineering manual titled “Design and Construction of Levees” (EM 1110-2-1913) published April 30, 2000.
- All trees present on the levee crest and slope will be removed including roots down to a half inch root diameter. Tree removal will extend for a distance of 15 feet beyond the proposed toe of levee slope.
- The project includes the placement of compacted earth on top of the existing grade to increase the levee height as follows:
 - Add fill to the levee to extend the existing crest to two feet above the 100-year Project Design Flood profile in all areas except as noted below. This flood event is described in Section 2.2.
 - Limit the levee height increase where necessary such that the proposed levee crest is no higher than 0.5 feet below the levee elevation on the opposite (west) side of the Des Plaines River. If the east levee crest is higher than this design rule, the east levee crest shall remain at its existing elevation.
 - The east levee crest elevation changes will be constructed 0.1 feet higher than the above stated design criteria to accommodate future anticipated settlement of the levee that will occur due to the proposed fill.
 - Upgrade the 500 foot reach of levee from Station 13+00 to Station 17+50 where an old buried spillway exists to improve stability and seepage control. The improvements in this reach include levee widening, a crest increase, and placement of a steel sheet pile seepage cutoff wall.
 - Construct a 10-foot wide gravel maintenance road on the levee crest and re-vegetate the levee and adjacent areas with suitable vegetation. All fill material will be placed on the land side of the existing levee; no new fill will be placed within the floodway of the Des Plaines River.

The levee will tie into existing high ground near Joliet Road on the north and at the MWRDGC HASMA facility to the south.

The following general design criteria were developed to comply with design requirements and provide a consistent approach:

- 100-year Project Design Flood – The Des Plaines River flood profile published in the FEMA Flood Insurance Study serves as the base flood from a regulatory perspective. However, for this project, an updated analysis was performed for the project design basis. The updated interpretation of the base flood condition is called: “100-year Project Design Flood”. A definition for this flood is provided in Section 2.2. The project seeks to establish flood protection for the 100 year flood with freeboard, to the extent that is practical and feasible.
- Levee Crest Elevation / Freeboard –
 - The top of levee (crest) elevation is set to be at least 2 feet above the 100-year Project Design Flood Profile except in areas where such a levee crest increase would result in the east levee crest being higher than 0.5 feet below the west levee at the same river location.
 - When the planned east levee crest criterion of “2 feet above the 100-year Project Design Flood Profile” would result in a crest that is higher than 6 inches below the west levee crest, the east levee crest is limited to be no higher than 0.5 feet below the west levee crest elevation. One exception to this rule is that the proposed levee crest shall not be lower than the existing levee crest elevation. Following is a summary of locations where the proposed levee crest elevation is lower than the planned levee crest elevation of “2 feet above the 100-year Project Design Flood”:
 - Station 18+13 to 18+48
 - Station 24+00 to 31+20
 - Station 32+68 to 35+22
 - Station 35+45 to 35+95
 - Station 36+50 to 36+82
 - In all locations, the proposed east levee crest will provide freeboard above the 100-year Project Design Flood as defined in Section 2.2. The proposed levee will also be constructed higher initially to anticipate expected levee crest settlement as described in Section 2.1.
 - Where the existing levee elevation is greater than the 100-year Project Design Flood plus 2.0 feet, the levee is to be left at the existing elevation.
 - In addition to creating a proposed levee crest that provides freeboard above the 100-year Project Design Flood, the proposed levee crest would provide protection from a flood that is comparable to the April 2013 flood event of 12,200 cfs.
- Settlement allowance – The placement of additional fill on the existing levee is anticipated to induce less than approximately one-inch of settlement due to the limited amount of fill to be placed and considerations that most, if not all, of the consolidation related settlement for this levee has already occurred during its lifetime. Settlement due to fill placement at the old buried spillway is estimated to be up to four inches due to the greater amount of fill in this area. The levee will be overbuilt by the amount of anticipated future settlement to accommodate the amount of consolidation related settlement while maintaining adequate levee freeboard. The balance of construction involves placement of a steel sheet pile wall that is not expected to experience significant settlement. Any

required levee overbuild is included in the construction quantities for areas of levee where the crest will be raised. The drawings illustrate the higher amount of fill that will be placed during construction to anticipate future settlement.

- Levee crest width – a minimum 12 feet crest width at the top of levee will be created. Where the existing levee top width is wider than this minimum, the wider geometry will be maintained.
- A 10 foot wide gravel service road will be included on the levee crest. Two gravel turnouts will be constructed wider than the base road width to provide for safe maintenance access.
- Existing Levee Clearing and Grubbing / Tree clear zone – Trees will be removed for a minimum 15 feet from the toe of the proposed levee on both river and land side. The contractor will clear the surface of the existing levee (including tree clear zone). This includes removal of all trees and roots within 15 feet of the toe of the levee. Remove all roots that are greater than ½ inch in diameter and the associated root ball and all organic material. Backfill with suitable fill material (typically matching levee fill). The Forest Preserve District of Cook County (FPDCC) has requested that certain trees be provided to the FPDCC for recycling. FPDCC will identify and tag these trees and develop a specification for how these are to be handled and transported to the designated site.
- Levee side slopes – minimum 3H:1V to allow for maintenance and inspection as well as overall levee stability.
- Seepage control measures - Based on the results of field explorations, analysis, and observations from prior inspections, the following are design measures that will be employed to manage seepage:
 - The use of relatively flat 3H:1V side slopes.
 - Replacement of clay soils on the levee side slopes to be coordinated with the planned tree and other woody vegetation removal from the slopes
 - A Steel sheet pile wall will be installed to limit seepage exit gradients and piping erosion potential at the old buried spillway at station 13+00 to 18+60.
- Levee materials – Additional fill placed for reconfiguration and/or raising of the levees will be cohesive (i.e., clay) material, free of topsoil, debris, and other deleterious material. The maximum particle size will be one inch and contain at least 25% by weight of particles finer than the #200 U.S. sieve size. The material will have a specified permeability of 1.0×10^{-7} cm/s or less. Soil placed as part of the Temporary Flood Protection Measures, as described in Section 4, will be reworked into the proposed final design.
- Compaction requirements – Material placed for reconfiguration and/or raising of the levee will be placed in maximum 9-inch thick loose lifts and compacted with a sheepsfoot roller or other suitable equipment. The material should be maintained within a range from 1% to 3% above the optimum moisture content and compaction of at least 95% of the maximum dry density per standard proctor test (ASTM D698).
- Vegetation types on levee and within clear zone – vegetation on the levee and generally within 15 feet of the toe of the levee will be limited to perennial grasses that are resistant to both drought and periodic inundation. Native species appropriate for the levee setting are recommended. A 6-inch thick topsoil layer is included for the entire levee surface and levee clear zone that extends 15-feet from toe of levee.

- Utility penetrations through levee / flood wall – Reduce to maximum extent possible. Provide positive cutoff for storm and sanitary sewers. The levee owner should carefully monitor any proposed future levee utility penetrations to minimize possible failure due to utility collapse, poorly compacted trench backfill or other utility related issues. This may require some form of easement or other agreement with the existing railroads to ensure the integrity of the levee.
- Exploration Trench – An exploration trench is usually utilized to expose potential undesirable underground features such as old drain tile, utilities, pockets of unsuitable material or other debris or obstructions. Based on the site history, no exploration trench will be required.
- Sheet pile criteria – Steel sheet pile penetration depths have generally been set to provide added seepage resistance in the existing levee at the old buried spillway area.
- Seismic – The Lyons levee project is located within “Seismic zone 1” based on the Uniform Building Code Seismic Zone map located within the current version of USACE’s ER 1110-2-1806 (“Earthquake Design and Evaluation for Civil Works Project”). As documented by USACE in the Levee Condition Report: “No recent earthquakes or fault activity have been documented in the area; therefore the need for seismic design analysis is not required and not considered necessary. “
- Permanent inspection and maintenance access – a 10’ wide, 12-inch thick gravel wearing surface is located on the levee crest for inspection and maintenance. Access to the levee is planned from the north and south sides of 47th Street, from the south side of Joliet Road and from the MWRDGC HASMA site. This will require modification to the existing guard rails on either side of 47th Street to enable vehicle access. Vehicle turnouts are included at two locations for the section of levee between 47th Street and Joliet Road. These features will allow two vehicles to pass when travelling in opposite directions, or one vehicle to turnaround.
- Erosion protection – Based on the relatively low velocities in the Des Plaines River in the overbank areas and the setback of the levee from the river, no significant permanent erosion control features are required. Existing riprap in the vicinity of the bridges appears to be generally adequate. Establishment and maintenance of grassed vegetation on the side slopes of the levee will be critical for long term stability and erosion control. This will require erosion control blanket for the entire levee surface until vegetation establishment. Inspection and re-establishment of good vegetative cover and removal of woody vegetation, particularly in the first few years, will be an important maintenance item. Scour protection in the vicinity of the bridges appears to be adequate. No additional riprap in these areas is recommended.
- Railroad closure – Where the railroads cross the levee, the top of the railroad ballast generally exists at or near the proposed top of levee elevation. The thickness of the ballast zone is approximately two feet thick and is porous. We recommend that the porous ballast zone should be replaced with a concrete keyed into the underlying soil on top of the levee. Additional coordination with the railroads regarding ballast zone sealing is recommended.
- Existing Spillway Structure – The buried spillway structure that exists between station numbers 13+00 and 18+00 will require a different design approach than the balance of the levee. The design will address seepage and potential future structural degradation of the old concrete and stone spillway that could otherwise cause problems for the levee in the future. The design also recognizes the difficulty that a removal of the old spillway would cause including deep excavations, extensive

wetland impacts, dewatering issues that would likely require extensive cofferdams, and unknown subsurface conditions. The levee upgrade design will limit the amount of disturbance to the existing spillway by focusing levee improvements on its east side. It will take advantage of the existing levee as a buttress, but will not count on it for seepage control. A new steel sheet pile wall would be driven at the landside toe of the existing levee, and a levee extension would be constructed on the landward side using 3H:1V side slopes. This would result in a relatively wide levee section at this area, but would not require the costly removal or excavation of the existing spillway. The existing buried abutments would need to be partially removed to allow for the installation of sheet piles to tie into the levee to the north and south of the buried spillway. Additional explorations in the form of test pits and soil borings are proposed in this area to evaluate the horizontal limits of the spillway and the abutments in order to evaluate the potential for obstructions during the driving of sheet piling and to refine the geometry of the proposed construction in this area.

- An unidentified concrete structure located at approximately station 21+00 would need to be demolished and removed.
- Three wooden power poles located at approximately station 34+00 on the levee crest and riverside side slope. These should be relocated outside of the levee footprint.
- Forest Preserve District Fence Relocation – an existing Forest Preserve District fence located at approximately station 38+00 to 41+50 will be removed and replaced in a new location. A 100 foot length of the existing gravel trail will be reconstructed in a new location to accommodate the new fence location and levee service road. A more detailed survey of this area will be performed in final design to minimize the disruption in this area.
- Interior drainage – The only known interior drainage problem is the Harlem Avenue underpass under the railroad tracks. IDOT is developing a drainage improvement project to address this issue. Existing roadside ditches are poorly defined and have not been actively maintained. This causes the sheet flow of storm water from the road right of way into the Forest Preserve. It does not appear that this condition causes flood damage in the Forest Preserve. The rest of the interior drainage system appears to be adequate from a flood damage perspective. Section 3 provides detailed information for the interior drainage system.
- The recently completed earthwork for Temporary Flood Protection Measures, as described in Section 4, will be reworked into the permanent levee restoration. The permanent crest will be wider in places. This option includes the construction of an access road on top. Earth placed as part of the temporary measures project will be reworked and incorporated into the final design.

4.1 Proposed Levee Evaluation

The proposed levee profile was modeled in HEC-RAS for the 10-, 20-, 50-, and 100-yr flood events, and using the expected probability Flow rates as summarized in Table 2-1. These runs show that the Des Plaines River water surface profiles for all of these events will not exceed the proposed levee crest. The April 2013 (flood of record) storm was modeled in HEC-RAS using the unsteady flow option. The April 2013 flood does not overtop the proposed levee profile. The maximum water surface elevation for this flood is less than 0.1 feet below the levee crest profile at the lowest point in the proposed levee profile upstream of 47th Street.

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Appendix A
Computer Model Readme Files

**Des Plaines River HEC-RAS Model (Lyons Levee - Des Plaines River)
(Lyons_Levee.prj)**

HEC-RAS Report Files

The HEC-RAS report text files for each run are named based on the Steady/Unsteady Plan files with .rep as an extension.

The HEC-RAS report PDF files for each run are named based on the Steady/Unsteady Plan files with .pdf as an extension.

HEC-RAS Input Files

Steady Flow Input Files

Freq Anal w/2013(Lyons_Levee.f03)

Frequency Analysis Computed Flows (10-, 20-, 50-, and 100-yr), FIS 100-yr, and Historic Storm Peak Flows at Riverside (Sep 2008, Dec 2008, Jul 2010, Jul 2011, Apr 2013, and Jul 2014), and 12,000 cfs

Diversion Evaluation(Lyons_Levee.f04)

Flows for an evaluation of diversion alternatives to CAWS

OrdinaryHighWaterMark Flows(Lyons_Levee.fo5)

Flows used to estimate the Ordinary Highwater Mark for USACE Permitting

CorpsRequestedProfiles(Lyons_Levee.fo6)

The 10 profiles from the 1- to 500-yr flows for Corps Damage Analysis (1-, 2-, 5-, 10-, 20-, 25-, 50-, 100-, 200-, and 500-yr)

Unsteady Flow Input Files

2013 USGS Flows(Lyons_Levee.u15)

Historic USGS flow hydrographs at Riverside for 2006, September 2008, December 2008, July 2010, July 2011, April 2013, and July 2015

100-yr 2013 Ratio(Lyons_Levee.u01)

April 2013 flood event hydrograph ratioed to provide a hydrograph with the 100-yr peak flow rate

12k 2013 Ratio(Lyons_Levee.u10)

April 2013 flood event hydrograph ratioed to provide a hydrograph with a 12,000 cfs peak flow rate

Geometry Input Files

Proposed Levee(Lyons_Levee.g05)

This is the Lyons Levee Improvement Plan profile described in the report. Profile provided by AECOM.

DPR Updated Levee 08062014 C12(Lyons_Levee.g33)

Existing Levee Profile updated with field survey on 8/6/2014. This was the 12th and final Calibration Run. This included updated river cross sections between Joliet Road and railroad bridges. Overflows between CAWS and the Des Plaines River were included downstream.

Scenario 100-yr plus 1 Levee(Lyons_Levee.g02)

Scenario 1 Levee Profile for Evaluating Overtopping of Alternative Levee Profiles upstream of 47th Street. Scenario 1 includes a section of the levee with a reduced 1 foot of freeboard above the 100-yr storm north of 47th Street.

Scenario 2 100-yr plus 1.5 Levee(Lyons_Levee.go4)

Scenario 2 Levee Profile for Evaluating Overtopping of Alternative Levee Profiles upstream of 47th Street. Scenario 2 includes a section of the levee with a reduced 1.5 foot of freeboard above the 100-yr storm north of 47th Street.

Scenario 100-yr plus 2 Levee(Lyons_Levee.go3)

Scenario 3 Levee Profile for Evaluating Overtopping of Alternative Levee Profiles upstream of 47th Street. Scenario 3 includes a section of the levee with a reduced 2 foot of freeboard above the 100-yr storm north of 47th Street.

Steady Flow Plan Files

DPR Freq Analysis w/OT C12(Lyons_Levee.p63)

Existing Levee Profile with f03 and g33 with overtopping of the Lyons Levee calculated

DPR Freq Anal w/o OT C12(Lyons_Levee.p64)

Existing Levee Profile with f03 and g33 without overtopping of the Lyons Levee calculated

DPR Diversion Evaluation(Lyons_Levee.p66)

Existing Levee Profile with f04 and g33 to evaluate several diversion alternatives

Ordinary Highwater Mark(Lyons_Levee.p67)

Existing Levee Profile with f05 and g33 to determine ordinary highwater mark profile for USACE Permit

Proposed Levee(Lyons_Levee.p76)

Proposed Levee Profile with f03 and g05 to evaluate the proposed levee water surface profile.

Corps Requested Proposed Profiles(Lyons_Levee.p80)

Proposed Levee Profile with f06 and g05 for Corps Damage Evaluation

Corps Requested Existing Profiles(Lyons_Levee.p90)
Existing Levee Profile with f06 and g33 for Corps Damage
Evaluation

Unsteady Flow Plan Files

DPR Updated Levee 2013 C12(Lyons_Levee.p56)
Existing Levee Profile with g33 and u15 Calibration to April
2013 event

DPR Updated Levee 2014 C12(Lyons_Levee.p57)
Existing Levee Profile with g33 and u15 Calibration to July
2014 event

DPR Updated Levee 2011 C12(Lyons_Levee.p58)
Existing Levee Profile with g33 and u15 Calibration to July
2011 event

DPR Updated Levee 2010 C12(Lyons_Levee.p59)
Existing Levee Profile with g33 and u15 Calibration to July
2010 event

DPR Updated Levee 2008D C12(Lyons_Levee.p60)
Existing Levee Profile with g33 and u15 Calibration to
December 2008 event

DPR Updated Levee 2008S C12(Lyons_Levee.p61)
Existing Levee Profile with g33 and u15 Calibration to
September 2008 event

DPR Updated Levee 2006 C12(Lyons_Levee.p62)
Existing Levee Profile with g33 and u15 Calibration to
October 2006 event

100-yr Scenario 1 100+1(Lyons_Levee.p68)
Scenario Levee 1 profile with u01 and g02 to evaluate
effectiveness of Scenario 1 for the 100-yr

12k Scenario 1 100+1(Lyons_Levee.p73)
Scenario Levee 1 profile with u10 and g02 to evaluate
effectiveness of Scenario 1 for 12000 cfs

100-yr Scenario 2 100+1.5(Lyons_Levee.p72)
Scenario Levee 2 profile with u01 and g04 to evaluate
effectiveness of Scenario 2 for the 100-yr

12k Scenario 2 100+1.5(Lyons_Levee.p71)
Scenario Levee 2 profile with u10 and g04 to evaluate
effectiveness of Scenario 2 for 12000 cfs

100-yr Scenario 3 100+2(Lyons_Levee.p69)
Scenario Levee 3 profile with u01 and g03 to evaluate
effectiveness of Scenario 3 for the 100-yr

12k Scenario 3 100+2(Lyons_Levee.p70)

Scenario Levee 3 profile with u10 and g03 to evaluate effectiveness of Scenario 3 for 12000 cfs

April 2013 without Lateral Structures(Lyons_Levee.p74)

April 2013 storm with existing Levee Profile with u15 and g33 to evaluate the impact of no lateral structures on the water surface profile

April 2013 with Proposed Levee(Lyons_Levee.p79)

April 2013 storm with the proposed levee profile with g05 and u15.

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**Des Plaines River SSP Input/Output Description (Frequency Analysis)
(Lyons_Levee.ssp)**

Frequency Analyses using Bulleting 17b Methods (input file name and description)

Riverside_1974_-_2013.17b
Des Plaines River at Riverside for Water Year 1974 to 2013

Riverside_1984_-_2013.17b
Des Plaines River at Riverside for Water Year 1984 to 2013

Riverside_1990_-_2013.17b
Des Plaines River at Riverside for Water Year 1990 to 2013

Riverside_1994_-_2013.17b
Des Plaines River at Riverside for Water Year 1994 to 2013

Riverside_Full_Record.17b
Des Plaines River at Riverside for Water Year 1914 to 2013

Des_Plaines_1990_-_2013.17b
Des Plaines River at Des Plaines for Water Year 1990 to 2013

Des_Plaines_Period_of_Record.17b
Des Plaines River at Des Plaines for Water Year 1938 to 2013

Output (Gage location and period analyzed)

Riverside_1974_-_2013.pdf
Riverside_1984_-_2013.pdf
Riverside_1990_-_2013.pdf
Riverside_1994_-_2013.pdf
Riverside_Full_Record.pdf
Des_Plaines_1990_-_2013.pdf
Des_Plaines_Period_of_Record.pdf

Plots (Gage location and period analyzed)

Plot_Riverside_1974_-_2013.pdf
Plot_Riverside_1984_-_2013.pdf
Plot_Riverside_1990_-_2013.pdf
Plot_Riverside_1994_-_2013.pdf
Plot_Riverside_Full_Record.pdf
Plot_Des_Plaines_1990_-_2013.pdf
Plot_Des_Plaines_Period_of_Record.pdf

**Interior Drainage HEC-HMS Input/Output Descriptions
(LyonsLevee_IntDrain.hms)**

HEC-HMS Hydrograph Plots

Plots contain all of the frequency analyzed (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr)

basinname_XXhr.pdf

basinname - subbasin ID (47thStreet_East, 47thStreet_West, Harlem, and Railroad)
XX - storm duration in hours (1-, 2-, 3-, 6-, 12-, and 24-hr duration)

HEC-HMS Input Listings

Subbasin Schematic.pdf

Picture of Subbasin boundaries and the HEC-HMS schematic.

Subbasin Area.pdf

Listing of the drainage area, curve number, and time of concentration for each subbasin

HMS Input Component Naming Convention

Basin Models

LyonsLeveeID

The interior drainage schematic and input (drainage area, curve number, time of concentration, etc.) for the Lyons Levee subbasins behind the levee.

Meteorologic Models - Assign rainfall hyetographs to basin models and subbasins.

XXhour

XX - Storm duration in hours

Control Specifications (sets computational time window and time step for the run)

LyonsLevee

Time-Series Data (Precipitation Gages)

xxHyQ Bulletin 70 rainfall distributions for the various storm durations

xx - storm duration in hours

y - Bulletin 70 quartile rainfall distribution

HMS Compute/Results Naming Convention

LLxxYzzH

xx - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

zz - storm duration in hours (1, 2, 3, 6, 12, and 24 hours)

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Lyons Levee Interior Drainage HEC-RAS Model (LyonsLeveeID.prj)

Report Files - These are pdf listings of the RAS report files generated for the critical duration 6 hour storm for the various frequencies modeled.

REPORT xxxYR 6HR EXISTING.PDF

xxx - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

Profile Plots - These are pdf's of the critical duration 6 hour storm.

PROFILE xxxYR 6HR EXISTING.PDF

xxx - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

HEC-RAS input files

Geometry Files

Existing Conditions (LyonsLeveeID.g03)

The geometry input for existing conditions along the interior drainage flow path to Harlem Avenue

Unsteady Flow Files

XXXyZZh Existing (LyonsLeveeID.u**)

XXX - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

ZZ - storm duration in hours (1, 2, 3, 6, 12, and 24 hour duration storms)

Generate Hot Start

base flow model used to generate a starting water surface profile to reduce instabilities in the model at start up.

Unsteady Flow Plan Files

XXXyZZh Existing (LyonsLeveeID.p**)

XXX - storm frequency in years (1-, 2-, 5-, 10-, 25-, 50-, and 100-yr storms)

ZZ - storm duration in hours (1, 2, 3, 6, 12, and 24 hour duration storms)

Hot Start

base flow model used to generate a starting water surface profile to reduce instabilities in the model at start up.

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Appendix B

Computer Model Input & Output Files:

- DesPlainesRiver_SSP_Files
- DesPlainesRiver_RAS_Files
- LyonsLevee_HMS_Files
- LyonsLevee_RAS_Files