Guidance for Flood Risk Analysis and Mapping

Levee-Specific Non-Regulatory Flood Risk Datasets

May 2016

FEMA

Requirements for the Federal Emergency Management Agency (FEMA) Risk Mapping, Assessment, and Planning (Risk MAP) Program are specified separately by statute, regulation, or FEMA policy (primarily the Standards for Flood Risk Analysis and Mapping). This document provides guidance to support the requirements and recommends approaches for effective and efficient implementation. Alternate approaches that comply with all requirements are acceptable.

For more information, please visit the FEMA Guidelines and Standards for Flood Risk Analysis and Mapping webpage (www.fema.gov/guidelines-and-standards-flood-risk-analysis-and-mapping). Copies of the Standards for Flood Risk Analysis and Mapping policy, related guidance, technical references, and other information about the guidelines and standards development process are all available here. You can also search directly by document title at www.fema.gov/resource-document-library.

Document History

Affected Section or Subsection	Date	Description
First Publication	May 2016	Initial version of new transformed guidance. The content was derived from the Guidelines and Specifications for Flood Hazard Mapping Partners, Procedure Memoranda, and/or Operating Guidance documents. It has been reorganized and is being published separately from the standards.

Table of Contents

List of Figures

1.0 Definitions

Levee Flood Risk Products have been developed to effectively communicate risk to a broad audience. These products comprise the following datasets: Levee Point Elements, Levee Community-Supplied Breach and Armored Overtopping Locations, Levee Rating Curve Locations, Levee Location (and associated Levee Scenario Lookup Table), Levee Freeboard, and Levee Analysis Impact Area. There are other datasets not discussed here that may be better suited for helping to communicate levee risks. Therefore, this is not intended be an all-inclusive list of the only levee datasets that could or should be produced as part of a Flood Risk Project. References directing individuals towards other existing information which communicates levee risks should be provided in the Flood Risk Report (FRR), rather than duplicating that data within the Flood Risk Database (FRD). These additional resources may include FEMA's Accreditation Status Tracker (FAST), the USACE's National Levee Database (NLD), and FEMA's National Flood Hazard Layer (NFHL) Levees (S_Levees) feature classes. Additional resources that provide guidance for other flood risk datasets that can be produced in levee areas are also available, such as the Flood Depth & Analysis Grids Guidance, Flood Risk Assessment Guidance, Changes Since Last FIRM Guidance, and Areas of Mitigation Interest Guidance.

As with many enhanced risk datasets, decisions to deviate from the products described herein should take into consideration available data and project funding, the desire for and commitment to appropriately use the data by project stakeholders, and community capacity for utilizing this data. If products are developed or datasets are enhanced in ways that are not described herein, the Mapping Partner should provide adequate documentation so that any such supplemental datasets could be beneficial to future Flood Risk Projects.

Regions and Mapping Partners should use discretion when considering whether to produce these levee datasets and where to apply them as part of a Flood Risk Project. Key decision factors are the accessibility of levee analysis modeling information and the ability to identify locations for which the creation of these datasets could be expected to increase the community's risk awareness and/or lead them to mitigation actions. However, the availability of levee modeling information is not the only criteria to use when identifying the Levee Flood Risk Datasets to be funded; another key factor is an awareness of local levee management processes and topographic characteristics. It is, therefore, important that the applicability or benefit to the end user of the data be taken into account when selecting the Levee Flood Risk Datasets to be included in the project.

Additionally, if any of the Levee Flood Risk Products could introduce confusion or unnecessary complication for affected communities, or if any of the levee flood risk data otherwise might not specifically help the community better understand risk and take appropriate mitigation action, it may be best to avoid the use of those datasets. In other words, although it may be possible to create a particular Levee Flood Risk Dataset, the creation, use, and/or distribution of such datasets should be carried out with discretion in terms of usability and efficacy. Details on the appropriate application of each Levee Flood Risk Dataset are included in each dataset's discussion below.

2.0 FRD-Related Guidance

The Levee-Specific Flood Risk Datasets include the following tables in the FRD:

- S_Lev_Elements_Pt: “Levee Element Locations”
- S_Lev_Breach_Pt: “Levee Community-Supplied Breach and Armored Overtopping Locations”
- S_Lev_Rating_Curve_Pt: “Levee Rating Curve Locations” (also includes guidance for L_Lev_Rating_Curve: “Levee Rating Curve Table”)
- S_Levee_Ln: “Levee Locations” (also includes guidance for L_Levee_Scenario: “Levee Scenario Table”)
- S_Lev_Freeboard_Ln: “Levee Freeboard”
- S_Lev_Inundation_Ar: “Levee Analysis Impact Area”

Guidance specific to each of these tables is below.

2.1 Levee Element Locations

2.1.1 Definition and Purpose

This dataset contains point locations and information (such as capacity) for drainage and protection features along the levee not previously inventoried in the USACE’s NLD. These include, but are not limited to, pumps, gravity conduits, sleeves, and closure structures. This information should be used to update the NLD in coordination with the USACE.

2.1.2 Guidance for Creation

The analysis required to produce these points and associated data fields typically involves acquiring locations of drainage and protection features not already in the NLD from communities or drainage districts, digitizing locations using aerial imagery in a Geographic Information System (GIS), digitizing locations based on information found in reports or hard-copy as-built plans, or performing field reconnaissance. Figure 1 shows an example of this dataset. The resulting data should also be coordinated spatially with the NLD.

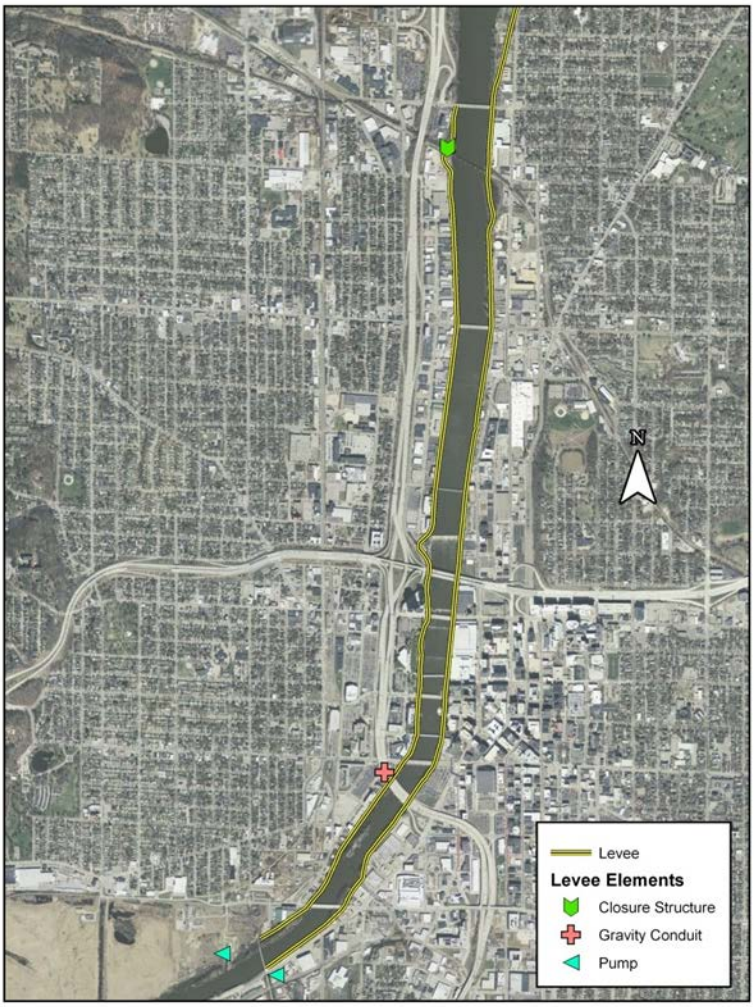
The S_Lev_Elements_Pt spatial table, as detailed in the Flood Risk Database Technical Reference, includes information for the levee elements. The primary data fields include the following: levee elements point type, additional descriptive information, and data origin. Specific domain values have been established for the levee elements point type (D_Levee_Pt_Typ) as detailed in the Domain Tables Technical Reference. These types include over 15 different elements such as levee crossing points, pump station points, and closure structure points.

2.1.3 Guidance for Use

This dataset helps convey to a wide range of levee stakeholders a more complete understanding of all of the elements that influence how a levee is designed, how it functions, and how it may impact flood mapping and risk reduction. While the levee embankment tends to have the primary focus, many of the levee point elements like pump stations, closure structures,

and levee crossing points are essential to the performance of the levee during a flood event. During public meetings, the locations of some of these more critical levee elements should be discussed and used to help explain the expected levee performance during storm events, or to identify underperforming features the community is aware of that may be in need of maintenance or upgrade in the future.

Figure 1: Levee Element Locations Dataset



2.2 Levee Community-Supplied Breach and Armored Overtopping Locations

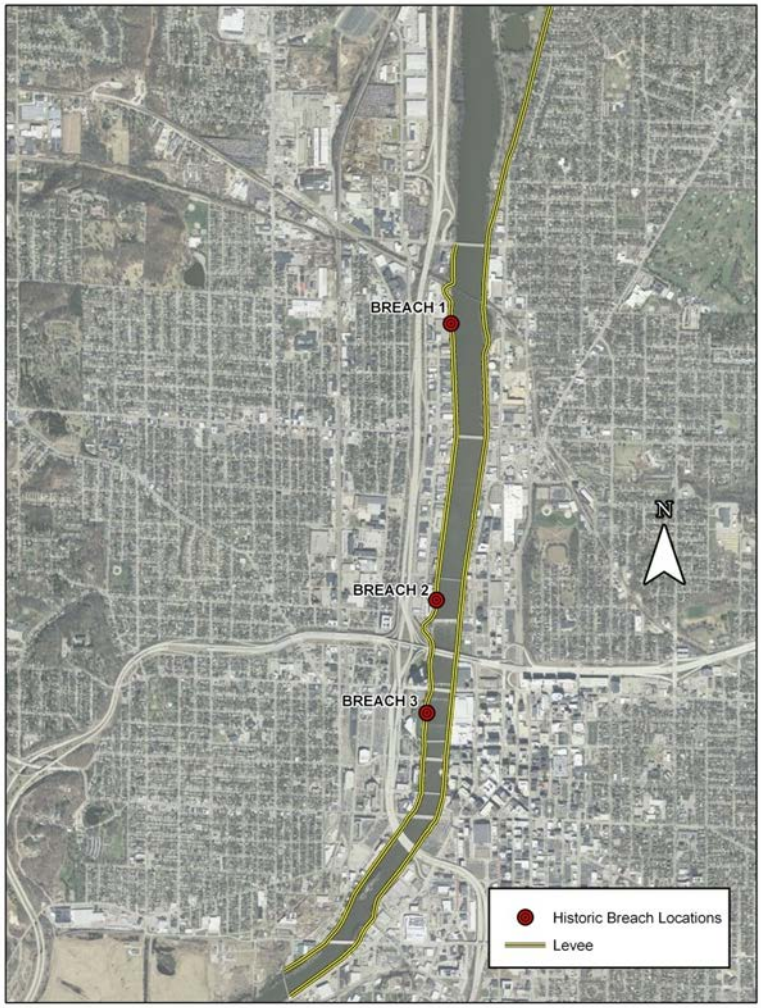
2.2.1 Definition and Purpose

This dataset contains point locations of community-supplied potential levee breach locations and armored overtopping locations. A potential structural-based breach location should be discussed with the community as a high-risk factor along the levee. Attributes for each location will identify the data sources. This effort should support the activities listed in the new Levee Analysis and Mapping Procedure (LAMP) processes.

2.2.2 Guidance for Creation

In addition to digital data provided by the community, these features can manually be identified if their locations are known. The analysis to produce these points and associated data fields can be done by digitizing locations using aerial imagery in GIS, digitizing locations based on information found in reports or hard-copy as-built plans, or performing field reconnaissance. Figure 2 shows an example map of these locations. These locations should be spatially coordinated with the NLD.

Figure 2: Community-Supplied Breach and Armored Overtopping Locations Dataset



The S_Lev_Breach_Pt spatial table includes information for these points. The primary data fields include the following: levee breach type, data origin, date of historic breach or overtopping, height and width information of breach or overtopping, time of day for breach or overtopping, and levee scenario. Specific domain values have been established for the levee breach point type (D_Breach_Pt_Typ), indicating if the breach was community supplied, historical or potential, or an armored overtopping location. The Levee Scenario is defined by the Levee Scenario Table (L_Levee_Scenario) and will be described in more detail in the Levee Locations dataset.

2.2.3 Guidance for Use

This dataset provides the community a way to identify and store locations of concern for future levee failure within the FRD. Locations along the levee with either historical breaches or armored overtopping will be places in which public and private stakeholders may have an interest, both from a historical perspective, and in discussing efforts the community has made, or will be making, to improve performance in the future. Visualizing these locations geospatially, along with other infrastructure nearby, will also help in emergency response planning and discussions. It may also be worthwhile to know these locations during Local Levee Partnership Team (LLPT) meetings, and as levee modeling and mapping approaches are discussed with the community. Much of this information may also be available in the NLD, including past inspection data and flood fighting information.

2.3 Levee Rating Curve Locations

2.3.1 Definition and Purpose

This dataset contains point locations along the levee where a rating curve of flows and associated water surface elevations (WSELs) were generated, which can be compared to levee toe and crest heights at the same location. The rating curve table associated with each point can be used to help communicate the severity of levee height deficiency (e.g. if not providing 1% annual chance protection, etc.) The rating curve may include information for a range of levee performance scenarios and the use of fragility curves.

2.3.2 Guidance for Creation

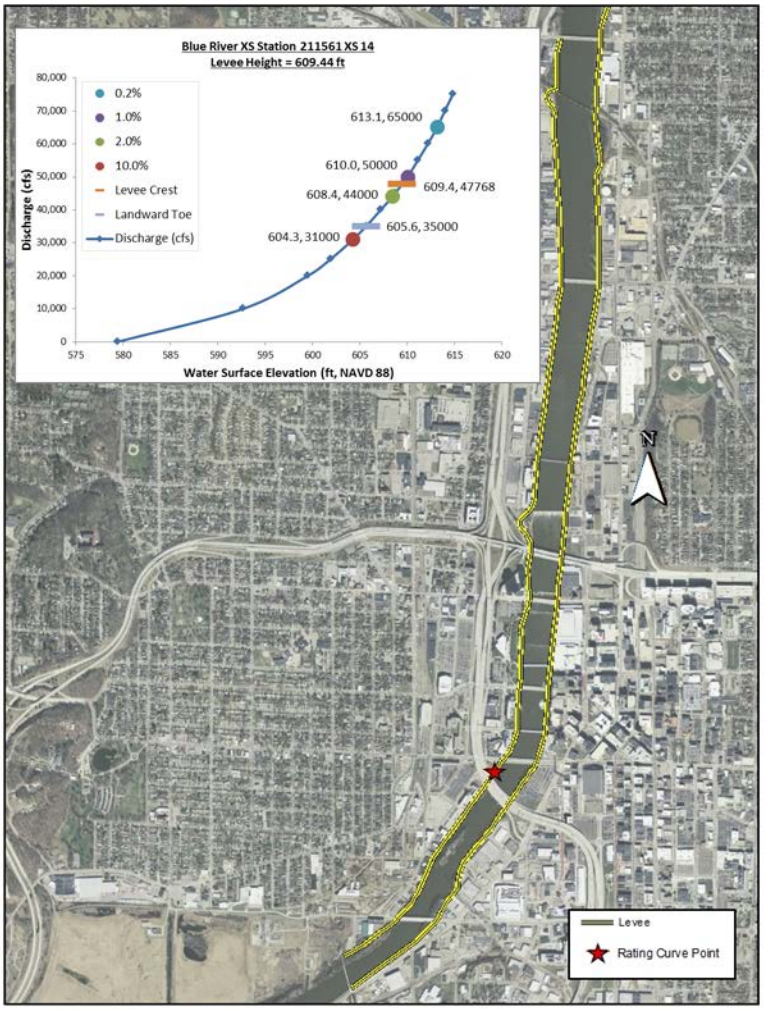
The analysis required to produce these points typically involves digitizing locations using aerial imagery in GIS and compared with the NLD. The decision process by which these locations are identified can be based on community input, or based on locations deemed to be of interest through the inspection of information found in reports or hard-copy as-built plans, or in performing field reconnaissance. Likewise, the associated rating curve table and data fields are populated by reviewing available levee models and reports to determine the WSELs and discharges for different scenarios, as shown on Figure 3. Detailed, multi-scenario levee analysis data will be required to produce this dataset, following levee analysis guidance procedures described in guidance available through the FEMA website (www.fema.gov/final-levee-analysis-and-mapping-approach).

The S_Lev_Rating_Curve_Pt spatial table includes basic information for these points, including the ID number for the associated rating curve table and descriptive information. The L_Lev_Rating_Curve data table contains the data used to produce the actual rating curve, where the x coordinate represents the WSEL and the y coordinate represents the discharge value. Additional data fields for each point include levee scenario (described in more detail in the Levee Locations dataset) and levee event type. Specific domain values for the levee event type (D_Levee_Event) include a range of percent-annual chance events, historical event, overtopping, levee crest, and levee toe.

2.3.3 Guidance for Use

These rating curve datasets should be used in conjunction with other levee datasets to provide detailed levee model results for specific locations of concern. These rating curve datasets show the relative elevations of levee elements like the levee toe or levee crest and how these elevations compare to calculated flood elevations. These rating curves provide ways to show how the same storm event may be several feet below the levee crest in one location, but overtopping in another, and to identify the discharges that could potentially threaten levee stability or overtopping. When used in conjunction with stream gage data and the levee breach points, the rating curves help explain why a certain location may be of greater concern than other locations. In the future, these rating curves may also be critical for the potential creation and use of levee fragility curves for risk analyses.

Figure 3: Levee Rating Curve Locations and Table Datasets



2.4 Levee Locations and Levee Scenarios

2.4.1 Definition and Purpose

This dataset contains the location of the levee as a line feature along the top of the levee. This section also includes a description of the Levee Scenario Table, which describes scenarios that can be modeled for the levee. The scenario is defined as the unique combination of the flooding event, levee accreditation status, and the source of the flooding event. The user should also consult with the LAMP guidance document to make best use of data to provide multiple products.

2.4.2 Guidance for Creation

The analysis required to produce these lines, as shown in Figure 4, and associated table and data fields typically involves acquiring a certified crest survey from the community or organization responsible for levee maintenance. However, in discussions with the FEMA Regional Project Officer and community, other methods to identify the levee crest may be utilized if deemed appropriate.

Figure 4: Levee Location Dataset

The survey can take many forms, including but not limited to:

- Site plan drawings, especially as-built plans
- Spatially referenced survey data
- Station referenced levee cross sections

Specific sources may include FEMA's Mid-term Levee Inventory (MLI) and FEMA's Accreditation Status Tracker (FAST), USACE's National Levee Database (NLD), and FEMA's National Flood Hazard Layer (NFHL) Levees (S_Levee) feature classes for locations of levee center lines. If multiple sources are available, preference should typically be given to the most recent dataset and then to spatially referenced data. If using spatially referenced survey points, the data can be converted to a line using GIS software for attribution. If a spatial survey is not available, nationally maintained levee databases, including the NLD or MLI, should be consulted for a line representing the levee location. If neither of these are available, then a line should be derived from a georeferenced site plan drawing. If none of these survey resources are available, a levee crest elevation can be extracted from LiDAR datasets. However, it is recommended that mapping partners utilize GIS software to implement a search buffer along the levee location line to find the highest crest elevations across the entire length of the levee.

Regardless of the levee location source, the line should be checked against aerial imagery and available topography sets for reasonableness, and any discrepancies should be rectified through discussion with the community or maintenance organization. Special attention should be given if the survey pre-dates available imagery or topography, so that any changes made to the levee alignment can be captured. Information on the levee design, including levee geometry, design, and maintenance details can usually be found in design documents, as-built plans, or in the operation and maintenance manual. If the information is based on design documents for levee sections with planned constructions or repairs, a note indicating such should be made in the description field.

The S_Levee_Ln spatial table stores the levee location dataset. Primary data fields in this table include the levee name, ID in the NLD, owner, levee descriptive information (length, height, width, year built), design freeboard, levee scenario, Emergency Action Plan (EAP) information (status, maintaining organization), and construction type. The domain table for construction type (D_Const_typ) includes over 10 options including earth-fill, rock-fill, clay, and asphalt-concrete.

The L_Levee_Scenario table, as detailed in the Flood Risk Database Technical Reference, provides details on the naming conventions to describe the unique combination of the flooding event, levee accreditation status, and the source of the flooding event. The flooding event is defined by the D_Levee_Event domain type. The levee accreditation status is defined by the D_Levee_Accreditation domain table and contains values for accredited, provisionally accredited, and non-accredited. The flooding source is defined by the D_Flooding_Source domain table with values for riverine, coastal, and dams. All levee Flood Risk Datasets that represent results from a levee analysis will have an associated levee scenario or multiple scenarios.

The L_Levee_Scenarios table also includes information on the types of levee analysis performed for each scenario. This includes a data field for levee analysis type, as defined by the D_Levee_Analysis domain table. Defined values for the analysis type include accredited levee, natural valley, overtopping, freeboard deficient, sound reach, and structural-based inundation. The levee scenarios table also includes a data field to link to information on the models used for the analysis (FRD_Model_Info data table).

2.4.3 Guidance for Use

The levee location dataset provides the primary spatial feature in the FRD for which detailed information about a levee system is stored. In communities where historic levee information may only be found in design reports or model output files, this levee location dataset can serve as a digital archive for detailed data describing the levee design and performance. It also provides a means to define the extent of the levee and to provide a concise resource summarizing the latest construction and maintenance details. The levee location also serves as indication of the levee study extent and a baseline for the analysis performed. In addition to providing a levee data archive, the levee location and associated data also provide valuable background information for public meetings addressing levee issues.

Additional guidance for levee public meetings is available from levee guidance available through the FEMA website at www.fema.gov/final-levee-analysis-and-mapping-approach.

2.5 Levee Freeboard

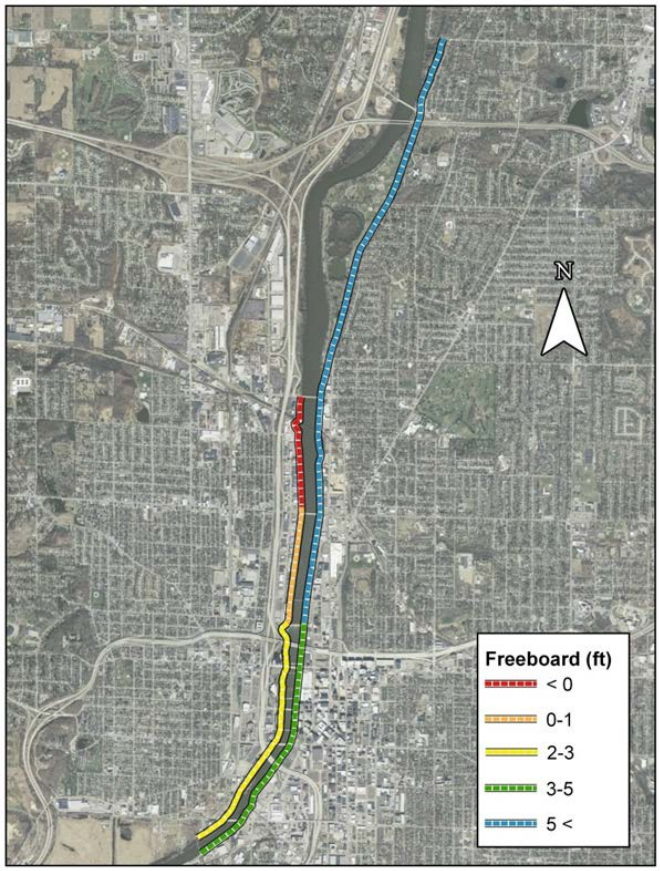
2.5.1 Definition and Purpose

This dataset contains freeboard information along the levee for different scenarios. For each scenario, a different set of freeboard line segments can be defined, where each segment is related to a particular range of freeboard values, such as 0 to 1 foot, 1 to 2 feet, etc.

2.5.2 Guidance for Creation

If the Levee Location dataset has been produced, its geometry can be used in the creation of the Levee Freeboard dataset. Otherwise, the creation process for this dataset is essentially the same as that of the Levee Location dataset. The line features representing the levee are then split based on freeboard ranges. Figure 5 shows an example of the levee freeboard dataset, where each segment is defined based on a range of whole foot values.

Figure 5: Levee Freeboard Dataset



To calculate the freeboard, the elevation of the levee crest must be obtained or calculated. Potential sources of this elevation data include:

- Site plan drawings
- Spatially referenced survey data
- Station referenced levee cross sections
- LiDAR data

If multiple resources are available, consideration should be given to the date and quality of the various survey resources. Typically, the most recent information should be used, except in special circumstances. Preference should also be given to spatially referenced survey information. If none of these survey resources are available, a levee crest elevation can be extracted from LiDAR datasets with preference to the bare earth points instead of a DEM. However, it is recommended that Mapping Partners utilize GIS software to implement a search buffer along the levee location line to find the highest crest elevations across the entire length of the levee. The USGS National Elevation Dataset does not have the precision to capture the top of levee elevation, thus it should not be used for this analysis.

After establishing the levee crest information, the data should be compared to the flood event elevation data. For each flood event, the freeboard for historical events can be found by

subtracting the local flood event elevation from the levee crest elevation, at each survey point. However, it must be made clear that for the purposes of 44 CFR 65.10 requirements the Flood Insurance Rate Map (FIRM) elevations determined for the 1% annual chance flood must be used, not an historical event.

For a coastal event, the Mapping Partner should consider the elevation of the BFE, as opposed to just the stillwater elevation, since the two can differ due to contributions from waves or wave runup. The Mapping Partner should evaluate if the levee is vulnerable to waves or wave runup hazards. If waves or wave runup are expected, the freeboard calculation should be based on the surge elevation plus waves or wave runup contributions. Again, the requirements of 44 CFR 65.10 are used for certification/accreditation purposes.

The S_Lev_Freeboard_Ln spatial table stores the levee freeboard data. Primary data fields include levee scenario, freeboard value in one foot increments, and additional descriptive information. Consult the Flood Risk Database Technical Reference for the standards to use for freeboard ranges.

2.5.3 Guidance for Use

This dataset can be used by communities to highlight levee segments that may be more vulnerable during various flood events. The Levee Freeboard dataset relates freeboard to events of varying magnitude and from differing flood sources. Therefore, community planners and emergency management officials can evaluate which sections of levee might need remediation. Communities can also use the data to anticipate which sections might be vulnerable to approaching storms and can effectively deploy temporary flood mitigation techniques.

2.6 Levee Analysis Impact Area

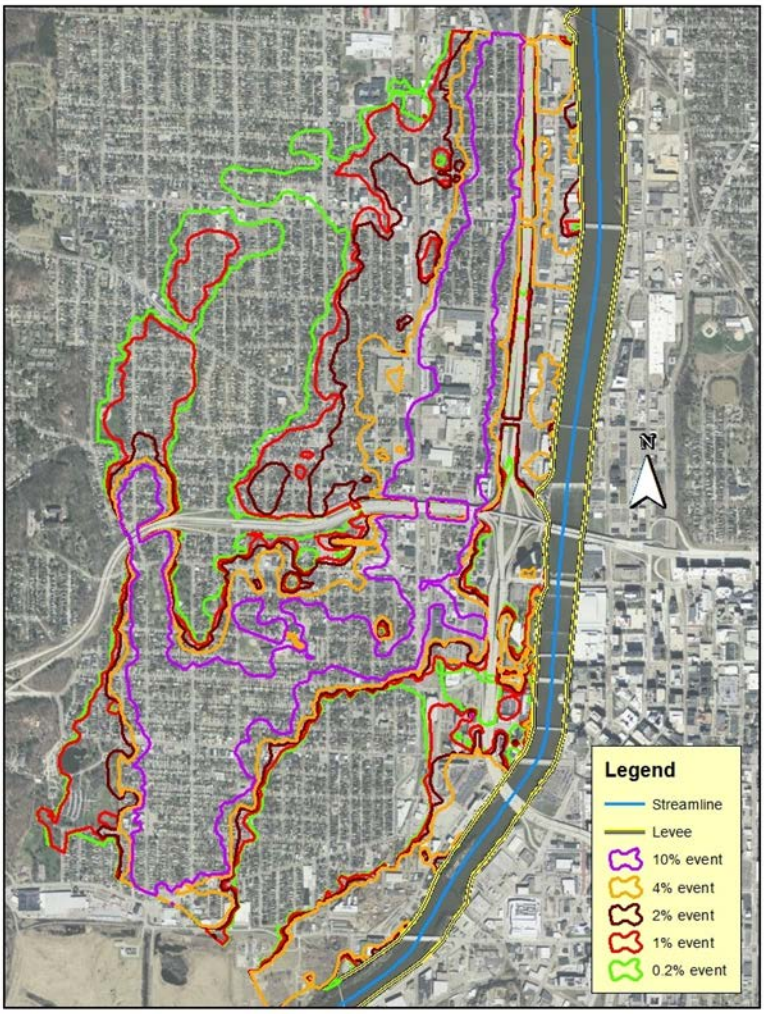
2.6.1 Definition and Purpose

This dataset contains polygons showing the extents of flooding behind a levee for various scenarios. This includes the Levee Shadow scenario, which represent the extents of the impacted area behind a levee based on levee crest elevation. Multiple flood frequencies can exist within the feature class for each flow scenario, and as such, the polygons stored in this dataset will be attributed in such a way that users of the data can compare/contrast different scenarios.

2.6.2 Guidance for Creation

The spatial analysis used to create these polygons may involve mapping the WSEL associated with each levee scenario being produced (1% annual chance flood, levee shadow, natural valley, etc.). The S_Lev_Inundation_Ar spatial table stores this dataset, with primary data fields including levee scenario, area of inundation, and community. Figure 6 shows an example of this dataset for a range of levee scenarios.

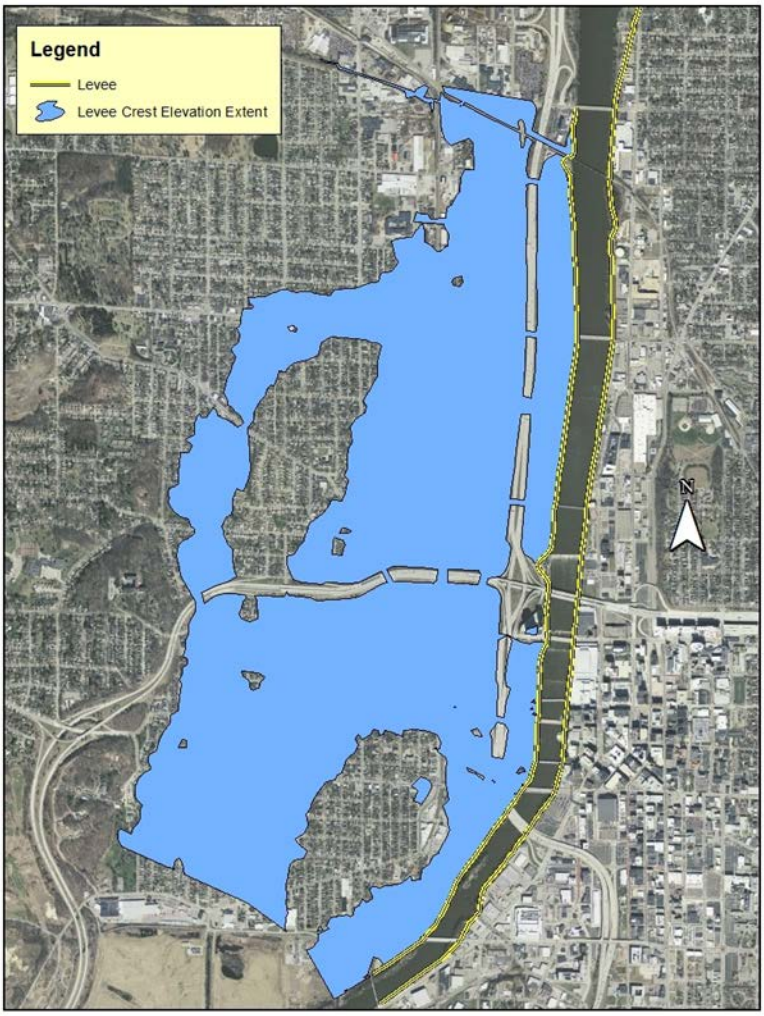
Figure 6: Example of Levee Analysis Impact Area Dataset for Percent Annual Chance Events



If the flood event data is available as a set of cross-sections or point elevations, the data will first need to be converted into a raster dataset. If the flood event data is available as a grid or raster dataset, the topographic dataset can be directly subtracted to produce a floodplain polygon. This is similar to the process used for typical riverine floodplain boundary mapping.

For specialized levee scenarios, such as the Levee Shadow (shown in Figure 7) where the modeling determines the extents of impacted area behind a levee based on levee crest elevation, developers should make sure to properly document in the Levee Scenario Table the assumptions used to create this polygon. The Levee Shadow may also be based on a "protected area" analysis from the USACE that projects the top of levee (as opposed to a specific frequency) back until it intersects with ground elevations.

Figure 7: Example of Levee Analysis Impact Area Dataset for Levee Shadow



If evaluating a coastal event based on data produced from a regional two-dimensional surge study, Mapping Partners will need to evaluate how the levee was represented in the model. If the levee isn't represented in the surge model, then Mapping Partners should consider using the stillwater surfaces developed for overland modeling of the area. When some or all of the levee is represented in the surge model, the Mapping Partner will need to extrapolate the surge data from the water side of the levee to cover the extent of the floodplain.

2.6.3 Guidance for Use

The Levee Analysis Impact Area provides the expected levee inundation for different flood events. These data are essential to inform the public that levees are only designed for certain storm events and that land areas on the landward side of the levee can be flooded for certain events. Local emergency management and evacuation plans can use this information to identify at-risk populations. This dataset is also clipped based on the upstream and downstream extent of the levee analysis, so it can show where analysis has been performed.

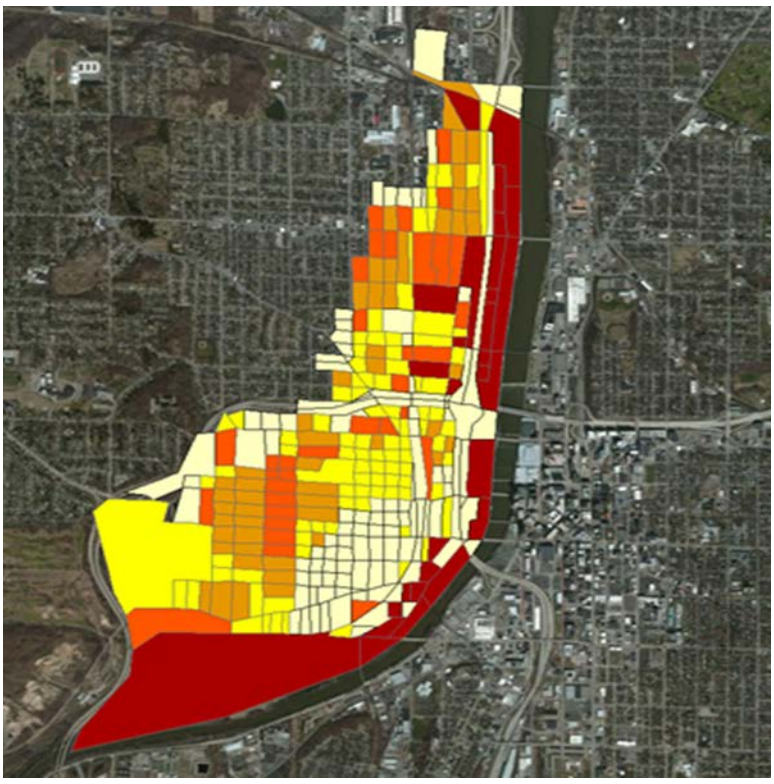
2.7 Other Levee-Related Flood Risk Datasets

In addition to the levee-related datasets detailed earlier, there are a number of additional Flood Risk Datasets that can be developed for levees.

Critical facilities, especially those at risk from flooding from certain levee scenarios, can be mapped as point data within a Flood Risk Project. Guidance on the development of at-risk essential (or critical) facilities can be found in the Areas of Mitigation Interest (AOMI) Guidance. Two spatial datasets associated with critical facilities are the S_AOMI_Pt and S_Cr_Fac_Pt spatial tables. The Flood Risk Database Technical Reference has additional information on the data fields for each of these datasets.

Flood risk assessment analyses can also be conducted based on levee flood depth grids. Guidance on the development of flood risk assessment datasets for both polygon areas and individual structures (user-defined facilities or UDF) can be found in the Flood Risk Assessment Guidance. Both the L_RA_Results and the L_RA_UDF_Results data tables contain data fields to allow levee scenario-specific loss results to be stored. These data can used to show relative risk to structures as shown in Figure 8.

Figure 8: Example of Levee Flood Risk Assessment for Census Blocks



Many raster datasets can be developed for levee scenarios such as water surface elevation, flood depth, velocity, and severity grids. Guidance on the development of these grids can be found in the Flood Depth and Analysis Grids Guidance. Naming conventions for levee scenarios to use for each of the raster dataset types can be found in the Flood Risk Database Technical Reference.

3.0 Levee Flood Risk Information on the Flood Risk Map

Levee Flood Risk information should be shown on the Flood Risk Map (FRM) as appropriate. The FRM may cover the geographic footprint of the Flood Risk Project or focus on specific areas of particular interest to the community. Multiple FRMs may be created that focus on smaller subsections of the Project with levee influences if doing so would improve the usability of the product with the community. The FRM Guidance provides additional information related to how this information may be depicted.

4.0 Levee Flood Risk Information in the Flood Risk Report

Levee Flood Risk information should be included in the FRR. The FRR Guidance provides additional information related to how this information is reported. Although a template exists for the FRR that can be used, the content of the FRR is flexible and can be customized to meet the needs of the stakeholders within the Flood Risk Project area.

The type of additional levee-specific information that should be taken into consideration to be added into the FRR, if available, includes the following:

- Photographs that call attention to specific risks or areas at risk (local photos, field reconnaissance photos, historic flood photos, etc.)
- Graphic visualizations that show the potential impacts of flooding on certain areas within the project footprint
- Links to other data and resources that provide information on levee-specific hazards

5.0 Dataset Spatial Extents

The levee-specific Flood Risk datasets should only be produced within the extents defined by the project footprint (S_FRD_Proj_Ar in the FRD). Within this Flood Risk Project area, they may be produced for single or multiple stream or river reaches, depending on applicability and data availability. The data delivered should not extend beyond S_FRD_Proj_Ar.

6.0 Data Delivery Timeline

The Flood Risk Database Guidance provides recommendations as to when the Levee Flood Risk datasets should generally be provided to communities during the life of a Flood Risk Project, and the conditions under which they should be updated after their initial delivery.