

South Florida Water Management District Flood Impact Assessment Tool

User Manual



Deltares USA

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1

Introduction

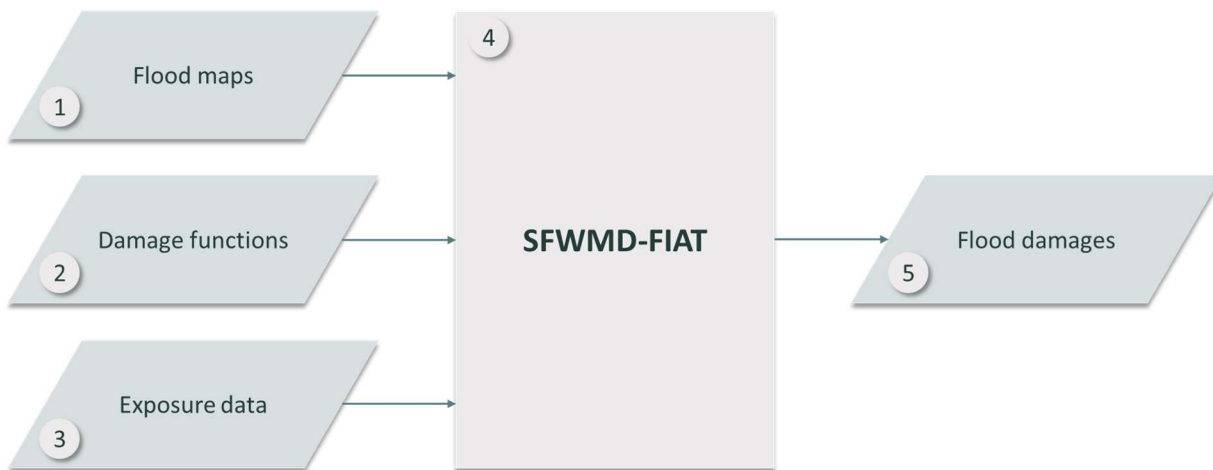
The South Florida Water Management District Flood Impact Assessment Tool (SFWMD-FIAT) was specifically designed for the SFWMD to run quick, consistent, and well-founded flood damage and risk calculations. This functionality will support their Resiliency and Flood Protection Level of Service (FPLOS) Program efforts in deciding on appropriate courses of action and to help underpin the benefits of flood mitigation and adaptation measures when recommending priority infrastructure investments.

The SFWMD-FIAT enables non-modelers to evaluate the damage and risk-reduction benefits of flood mitigation and adaptation measures once the hydrodynamic modeling of these scenarios is completed. It evaluates and outputs damages per building, road segment, and utility, and aggregates to SFWMD-specified aggregation scales.

The SFWMD-FIAT consists of two main components:

- Calculation core: Delft-FIAT is the calculation core of the SFWMD-FIAT; it is a free Deltares-developed fast impact assessment tool that is called by the user interface. Damage calculations with Delft-FIAT typically take about 1 minute to complete.
- User Interface: The user interface enables the user to easily select and run flood damage and risk calculations for an individual event or multiple flood inundation scenarios.

Data requirements for the SFWMD-FIAT are: flood maps, depth-damage functions, and exposure data. The depth-damage functions and exposure data will be set up in advance by the SFWMD, so that the user only needs to select the flood maps for which damages should be evaluated.



1	Flood maps	Selected per damage simulation in user interface
2	Damage functions	Prepared in set-up phase, coupled to exposure types
3	Exposure data	Prepared in set-up phase, developed per area of interest
4	Desktop Damage Tool	User interface and underlying Delft-FIAT damage assessment software
5	Flood damages	Object-level + aggregated tables and (optional) shapefiles of damages

Figure 1 Overview of the SFWMD Flood Impact Assessment Tool.

This user manual begins with a quick-start guide, for users who want to get started with the tool and do not require background information. The manual then describes requirements for installation, the input data, the user interface and operation of the SFWMD-FIAT (in more detail than the quick-start guide), and the output data.

2 Quick-start guide

This section is intended to help the user get started quickly with the SFWMD-FIAT. The main features of the user interface are shown in Figure 4. **Note:** Prior to seeing this screen, the user must select a root directory where the *Database*, *Results*, and *System* sub-folders are found. For a more detailed explanation of the user interface, please refer to Chapter 5. For more detailed information on tool output, please see Chapter 6.

2.1 Folder structure and system start-up

The root directory of the SFWMD-FIAT consists of three folders: (1) the *Database*, which contains the exposure data and damage function input needed for the damage assessment, (2) the *Results*, where the SFWMD-FIAT stores the results from the damage assessment, and (3) the *System*, which contains the executables and other files that are not intended for modification by the user.

To start the tool, double-click the *SFWMD-FIAT.Gui.exe* executable file in the System folder. When the program opens, select the root directory using the button indicated in Figure 3. For SFWMD users, this root directory path will be *C:/FIAT_SFWMD*.

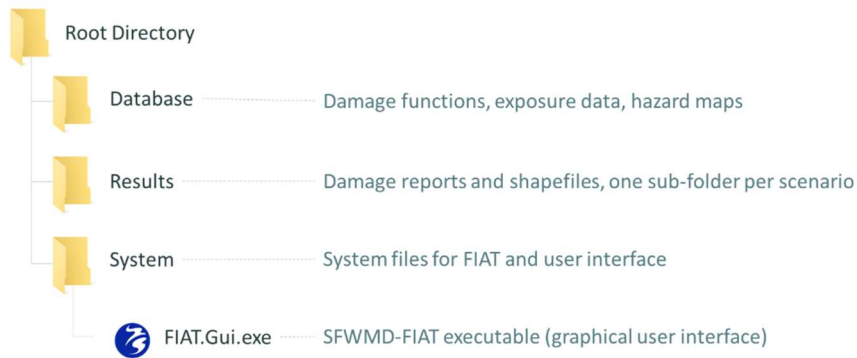


Figure 2 SFWMD-FIAT root directory folder structure and executable location.



Figure 3 Start-up screen of the SFWMD Flood Impact Assessment Tool.

2.2 Operation of the SFWMD Flood Impact Assessment Tool

The user can specify information about the flood scenario they wish to assess via the user interface. There are 15 fields that can be specified, which are described in Figure 4.

The screenshot shows the SFWMD Damage Assessment Tool interface. At the top, it says 'SFWMD Damage Assessment Tool' and features the Florida Water Management District logo. The interface includes several sections for configuring flood scenarios. Callouts 1 through 15 point to specific elements: 1 points to the 'Select Area of Interest' dropdown (set to 'C8'); 2 points to the 'Event' checkbox (checked); 3 points to the 'Scenario name' text input; 4 points to the 'Flood Map Type' dropdown (set to 'Water Depth'); 5 points to the 'Add Scenario' button; 6 points to the 'Risk' checkbox (checked); 7 points to the 'Scenario name' text input for the risk scenario; 8 points to the 'Flood Map Type' dropdown (set to 'Water Depth'); 9 points to the 'Add' button; 10 points to the 'Add Scenario' button; 11 points to the 'Run Damage Assessment' button; 12 points to the 'Save Shapefile' toggle switch; 13 points to the 'Flood map' file selection button; 14 points to the 'Scenario name' text input; and 15 points to the 'Return Period' text input (set to '0').

- 1 Select area of interest – these are the areas for which exposure data has been prepared
- 2 Check this box to evaluate damages for one or more flood events
- 3 Enter a scenario name for the flood event here
- 4 Select flood map type: water depth or water elevation
- 5 Add an event scenario – multiple flood events can be evaluated in a batch run
- 6 Check this box to evaluate flood risk – flood maps must have specified return periods
- 7 Select flood map type – water depth or water elevation
- 8 Select here the return period flood map from your local hard drive
- 9 Add an additional return period flood map
- 10 Add a risk scenario – multiple risk analyses can be evaluated in a batch run
- 11 Once all information is filled in, use this button to run the damage assessment
- 12 Toggle switch to optionally save damage shapefiles
- 13 Select here the event flood map from your local hard drive
- 14 Enter a scenario name for the risk scenario
- 15 Enter the return period of the flood map

Figure 4 Main fields of the SFWMD-FIAT user interface.

3 Installation

For SFWMD users, the SFWMD IT department will have pre-installed the software on the network. For these users, they can find the root directory that contains the tool on their virtual machine or computer at *C:/FIAT_SFWMD*. For installation, they will need to submit an IT service request and provide their virtual desktop or computer name. The depth-damage functions and exposure data will already be populated and placed within the *database/Damage Functions* and *database/Exposure* folders within the root directory.

For non-SFWMD users, the *Database/Damage Functions* and *Database/Exposure* folders will be empty and will need to be populated before running the tool. Please see more details about this process in Section 0.

3.1 Software requirements

The Microsoft .NET framework is required for installation. When opening the software for the first time, the user is directed to the .NET download page. At the time of writing, SFWMD installed the software with .NET version 5.0.4.

3.2 Interface banner

The banner at the top of the SFWMD-FIAT interface can be replaced by any image in PNG format. The location and name of the banner is *System/Styles/Resources/DamageDesktopTool_header.png*. Any (other) PNG that is placed in this folder with this name, will display as a banner at the top of the SFWMD-FIAT interface.

4 Input data

There are three key types of input data for the damage assessment tool: damage functions, exposure data, and hazard maps. The damage functions and exposure data must be prepared prior to running the tool. This preparation requires more expertise than is needed to run the SFWMD-FIAT, as detailed below. In addition to the three key input data, a base configuration file must also be prepared.

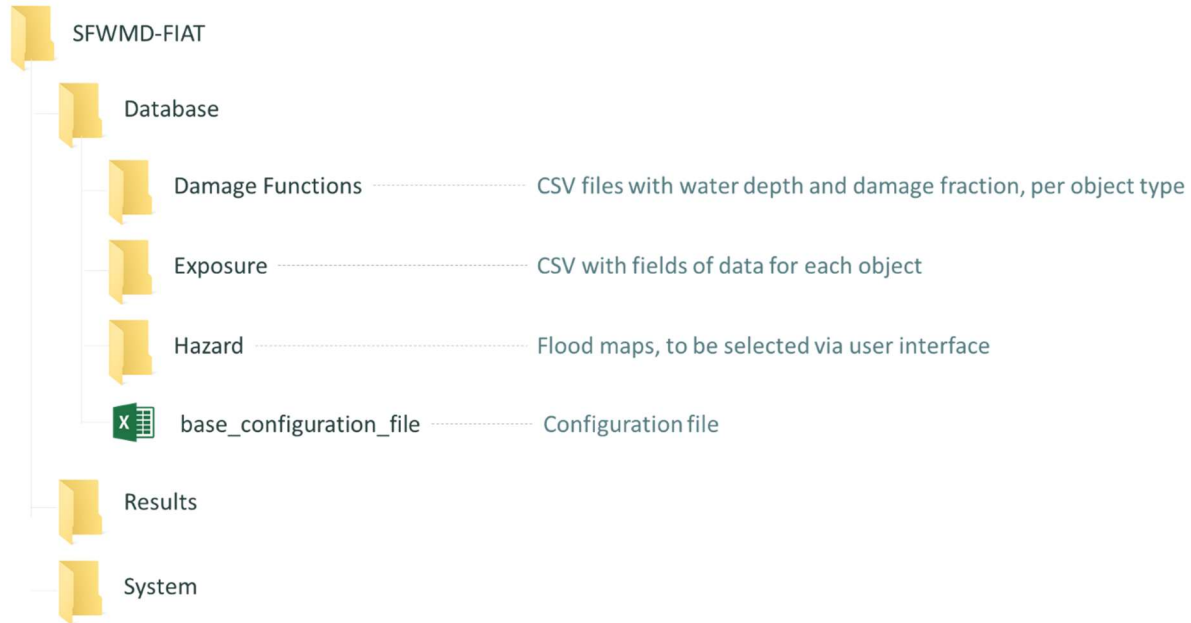


Figure 5 Input data folder structure.

4.1 Damage Functions

Depth-damage functions relate a water depth at an object (like a building or road segment) to a fraction of the maximum potential damage of that object. These functions are specified per object type, such as 'residential 1-story buildings on slab', and for a given water depth return a fraction (a value between 0 and 1), which must be multiplied by the maximum potential damage to obtain a damage value. The value of the maximum potential damage differs per object, and is given in the exposure data.

The damage functions must be given as two-column comma-separated CSV files with the first column containing the water depth in feet, and the second column containing the damage fraction. Water depths may be negative for objects which have damage below the finished floor elevation, and the user is free to choose any water depth increments in the CSV file. A header row is required. The damage function CSV files can have any name the user would like to assign to them. Figure 6 shows an example of a damage function input file (left) and a visual illustration of the damage function (right). The damage functions that were used in the set-up of the SFWMD-FIAT in the current version are described in Appendix B.


```

wd[ft],factor
-4,0.0
-3,0.0
-2,0.0
-1,0.0
0,0.0
1,0.01
2,0.04
3,0.06
4,0.08
5,0.09
6,0.11
7,0.14
8,0.17
9,0.21
10,0.26
11,0.31
12,0.37
13,0.43
14,0.5
15,0.57
16,0.63
17,0.68
18,0.73
19,0.77
20,0.81
21,0.85
22,0.89
23,0.93
24,0.97

```

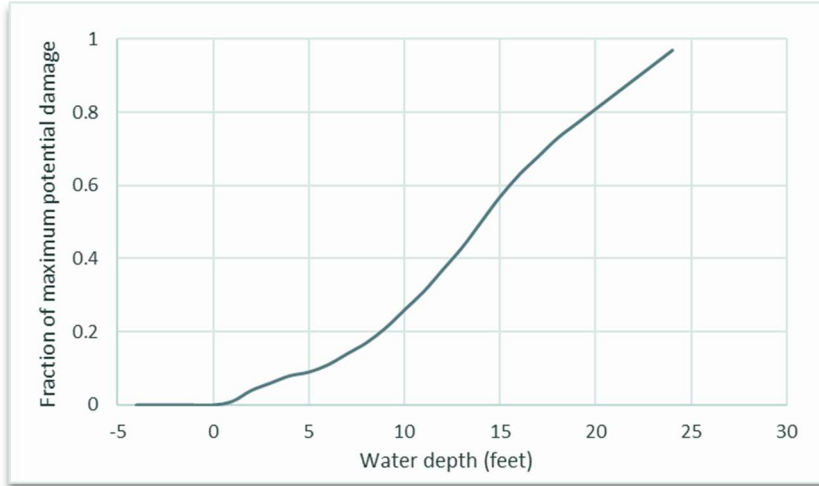


Figure 6 Example of the two-column damage function CSV file (left), and a visual representation of the damage function (right)

4.2 Exposure data

The exposure data folder contains two mandatory files and one optional file. The exposure data CSV file¹, which contains the information about all the objects within the area of interest, and the WKID text file², which contains one line indicating the coordinate reference system (CRS) of the exposure data, are required. A shapefile containing object polygons (such as building footprints) is optional. The exposure data CSV must be located in an area of interest folder, within the *Exposure* sub-folder, named *exposure.csv*; for example, the exposure data for the C9 basin area of interest would have a file path: *Database/Exposure/C9/exposure.csv*.

The exposure data CSV file contains information about each object in the area of interest that is needed for the damage calculation. Each row represents an object, such as a building, road segment, or utility, and each column represents an attribute of the object, such as its location, elevation or maximum potential damage value.

¹ The exposure CSV can be comma-separated or semi-colon separated.

² The WKID text file is a one-line file containing the information about the coordinate reference system (CRS) of the exposure data; this one-liner can be obtained from <https://spatialreference.org/> for any standard CRS. Optional formats are: a CRS WKT string; an authority string (i.e. 'epsg:4326'); or an EPSG integer code (i.e. 4326).

The SFWMD has created an exposure data model-building tool that makes use of standardized datasets and produces exposure data following a consistent methodology for all basins in the District. This tool is described in Appendix A.

For users who would want to create their own exposure data, or modify existing exposure data, Table 1 provides a description of the default fields (columns) in the exposure data CSV for the SFWMD-FIAT. The field/column name is given, a description of the field, an indicator of whether it is a required field, and example values for a residential 1-story building with no basement. More details about the exposure data fields are further provided after the table in Section 4.2.1.

Table 1 Description of the default fields (columns) in the exposure data CSV file for the SFWMD Flood Impact Assessment Tool.³

Field	Description	Required	Example
Object ID	Unique numerical identifier of the object	Yes	1
Object Name	Unique name of the object	Yes	fp_1
Primary Object Type	Object type	Yes	RES1-1SNB
Secondary Object Type	More specification about object type	Yes	Res 1, 1 Story no Basement
X Coordinate	X-Coordinate of the object	Yes*	
Y Coordinate	Y-Coordinate of the object	Yes*	
Extraction Method	Method to extract water depth	Yes	centroid
Damage Function: Structure	Damage function for the structure	At least one	g_struct_2
Damage Function: Content	Damage function for the content		g_cont_62
Damage Function: Other	Any other damage function (e.g. road damage)		
First Floor Elevation	Feet elevation of the finished floor above ground level	Yes	1
Ground Elevation	Ground elevation at location of object	Yes	10.11
Max Potential Damage: Structure	Maximum potential structural damage	At least one	594105.25
Max Potential Damage: Content	Maximum potential content damage		312559.66
Max Potential Damage: Other	Maximum potential damage for 'other' type		
Object-Location Shapefile Path	Path to shapefile with object area polygons	No	..\database\Exposure\C8\C8_Spatial.shp
Object-Location Join ID	ID to join the objects to the area shapefile	No	1
Join Attribute Field	Attribute in shapefile to join with Join ID	No	Object_ID
Aggregation Label: Subbasin	Sub-basin label	No	C8-W-7
Aggregation Label: Land use	Land use label	No	Fixed Single Family Units
Aggregation Label: Tax use	Tax use label	No	SINGLE FAMILY
Aggregation Label: Census Tract	Census tract label	No	1205
Aggregation Label: Census Block	Census block label	No	2006
Aggregation Variable: SVI	Social vulnerability index	No	0.1388
Aggregation Label: Poverty	Poverty label	No	0
Aggregation Label: Critical Infrastructure	Critical infrastructure label (yes/no)	No	N

* X- and Y-coordinates are required *except when* there is an Object-Location Shapefile connected to the object

³ Additional fields may be present when the exposure data was generated by the SFWMD exposure data model-builder, but these are not required. Additional fields in the exposure data will not affect the calculation.

4.2.1 Description of the exposure data fields

Table 1 provides descriptions of the exposure data fields. This section provides similar information, but with more detail than was feasible in the table, which can be useful for some fields.

The first fields in the exposure data, the **object ID** and the **object name**, are administrative information. The user is free to choose these but they must be unique for each object.

For the **primary object type** and the **secondary object type**, the developer of the exposure data set is free to interpret the information they input, with one exception. The SFWMD-FIAT requires roads to be assigned a primary object type 'road' in order to summarize the road damages separately from buildings and utilities in the output files. Traditionally, the primary object type describes the category of object (such as residential or commercial), and the **secondary object type** gives more detail (such as single-story home on slab, or grocery store). These fields can help the developer of the exposure data set up an automatic look-up table for assigning damage functions. For exposure data developed using the SFWMD exposure data model-builder tool, this information was already used in the assignment of damage functions and (with the exception of roads) only serves in the exposure file as metadata.

The **X and Y coordinate** give the centroid location of the object. These coordinates are required unless there is an Object-Location Shapefile connected to the object (see description of this shapefile further in this section).

The extraction method refers to which water level or water depth is selected over an object. The options are (1) *centroid*, which selects the water level or depth at the center of the object, or (2) *area*, which considers the water level or depth over the entire polygon and takes either an average or maximum; this latter choice is selected in the configuration file. If selecting the option area, it is mandatory to include an Object-Location Shapefile which contains the areal polygons of the objects (see description of this shapefile further in this section).

There are three **damage function** fields: structure, content, and other. At least one of these must be provided for each object. The value that is entered is the name of the damage function. This name is coupled to the damage function CSV file via the configuration file (see Section 4.4). The 'other' field can be different types for different objects. For example, for a restaurant, the 'other' may refer to inventory. The user is free to use any damage function for the *other* field. It is intended to give an additional option when more than two damage types are required for an object.

The **first-floor elevation** gives the height of the finished floor above ground level. So, if a home is raised by 1 foot above the ground, the first-floor elevation would be 1 foot. The inundation inside a building or utility is calculated by subtracting the first-floor elevation from the water depth at the location of the building or utility. The **ground elevation** is the value of a digital elevation model (DEM) at the location of the object.

The **maximum potential damage** can be entered for three types: structure, content, and other. These correspond to the damage functions that were entered for the same object. For each damage function type that was assigned, a maximum potential damage must also be assigned. These values represent the maximum damage to the structure, content, or other (e.g. inventory). There are methods to derive

these values, based on building type and area of the building, with the Hazus manual being an industry standard in how to derive these values⁴.

Object polygons (such as building/utility footprints or road polygons) can be coupled to the exposure data objects by referencing a shapefile that contains the polygons. When such a shapefile exists, the path can be given in the field **Object-Location Shapefile Path**. There are two advantages of connecting such a shapefile: (1) water levels or depths can be considered over the entire object, if *area* is selected for the extraction method; this can be more appropriate than point estimates for large buildings, and (2) the damage results can be assigned to the object footprints for outputting shapefiles where the objects are colored based on their damages. Without areal information, the output would be point data, which can be harder to visualize. The exposure dataset requires two additional pieces of information to make the connection to the shapefile: the name of the attribute field in the shapefile which contains the join ID (the **Join Attribute Field**), and the value of the join ID for the object (the **Object-Location Join ID**).



The user must manually remove any building or road polygons that fall **partially** outside the flood map extent. The exposure data is automatically filtered based on the extent of the flood map. However, building or road polygons that fall partially outside of the flood map extent are retained in the exposure data. In these cases, the program is unable to find a water depth/water elevation for those objects and returns an error. Future versions will contain an automated correction for this issue.

The damage results are aggregated over any **aggregation label** that the user specifies in the exposure data. There are several default aggregation labels that are included for the SFWMD, and these fields are populated automatically using the SFWMD exposure data model-building tool. These aggregation labels are: sub-basin, land use, tax use, census tract, census block, poverty, and critical infrastructure. For the example of sub-basin, damages to all objects with the same sub-basin label will be combined to return the damages per sub-basin. The same approach is used for any label given in the exposure data. The user can add additional aggregation labels by adding a column and giving a heading that begins with “Aggregation Label:” and then contains the label name; for example, if a user wants to aggregate over zip codes they could include a zip-code column with the header “Aggregation Label: zip code”.

An **aggregation variable** is similar to an aggregation label, except that it can take continuous values instead of discrete labels, and the summation of damages occurs over ‘bins’. For example, the aggregation variable included in the SFWMD default exposure file is the social vulnerability index (SVI). The damages for objects that fall within an SVI class, for example between 0 and 0.2, will be added together to return the damages for different SVI classes. These classes are specified in the configuration file.

4.3 Flood maps

The flood maps are input that the user can easily select via the user interface. This allows the user to evaluate the economic impacts for a variety of flood mitigation and adaptation measures over a range of future climate conditions, as long as flood maps are available for those scenarios.

The flood maps can be either flood elevation or flood depth maps. The user will be asked in the user interface to specify which they are inputting.

⁴ FEMA Hazus Inventory Technical Manual 4.2.3.



The format of the flood depth/elevation maps must be GeoTIFF files.



The flood maps must be in the same coordinate reference system used for the x-y locations of the objects in the exposure data. This warning, and the required coordinate reference system, appear when the program opens, and again when a new area of interest is selected.



If using water elevation maps, the vertical datum of the maps must be NAVD88 in feet, which is the datum used to obtain the ground elevation in the exposure data.



The flood maps must be either uncompressed or compressed using the LZW method⁵.

4.4 Configuration file

The base configuration file is an Excel workbook which contains important information for the damage assessment calculation core Delft-FIAT. Most of the configuration file is filled in automatically via the user interface, but a few fields must be set up in advance.



For SFWMD users, this file will already be populated, and the user should not need to open or modify it.

There are five tabs in the base configuration file: (1) Exposure, (2) Hazard, (3) Damage Functions, (4) Settings, and (5) SVI. Each of these are described below.

The **exposure tab** requires information about the location of the exposure file CSV file, and the coordinate reference system (CRS). These are automatically filled in via the user interface. The user does not explicitly need to indicate the file location; the program relies on the fixed folder structure within the root directory and the user's selection of the area of interest to determine the exposure data file location, and the location of the WKID text file, with the CRS information. See an example of a filled-in exposure tab in Figure 7.

	A	B
1	Exposure File	CRS
2	C:\SFWMD_FIAT\Database\Exposure\C8\exposure.csv	PROJCS["NAD_1983_HARN_StatePlane_Florida_East_FIPS_0901_Feet",G
3		

Figure 7 Example of FIAT configuration file tab 'Exposure'.

The **hazard tab** contains information about the flood map file location, the return period of the flood map (for probabilistic/risk calculations), the CRS of the flood map, and the inundation reference. The flood map file location and return period, and the inundation reference are provided via the user interface. The inundation reference tells the program if the flood map values are relative to DEM (flood depths) or datum (flood elevations). When the user selects a flood map type for their input flood map

⁵ The LZW algorithm is a very common compression technique. This algorithm is typically used in GIF and optionally in PDF and TIFF.

(they can choose water depth or water elevation), this information is used to fill in the inundation reference in the configuration file. When a water elevation map is input, the ground elevation data that is included in the exposure dataset is used to derive the flood depths at the buildings, utilities, and roads. For the CRS, the program relies on the fixed folder structure within the root directory and the user's selection of the area of interest to determine the location of the WKID text file. See an example of a filled-in hazard tab in Figure 8.

	A	B	C	D
1	Hazard File	Return Period	CRS	Inundation Reference
2	C:\SFWMD_FIAT\Database\Hazard\some_event.tif	Event	PROJCS["NAD_	DEM
3				

Figure 8 Example of FIAT configuration file tab 'Hazard'.

The **damage functions tab** must be prepared prior to running SFWMD-FIAT; it is not automatically filled in by the user interface. It contains three columns: (1) Damage Function ID, (2) Damage Function File, and (3) Average or Max Inundation over Areal Objects. The damage function ID is the name that is referenced in the exposure data CSV file. For example, the damage function ID could be 'residential-single-story'. The damage function file is the path to the CSV file that contains the damage function data (water depths and damage fractions, see section 4.1). This helps connect an object in the exposure data CSV file to the damage function that corresponds to that object. The third column informs Delft-FIAT how the water depth or water level should be taken over an areal object. When an object is large, the water levels or depths may fluctuate over the area. The options for which water level or depth to use are 'average' or 'max'. For building, utility, and road damage, generally average is used. See an example of a filled-in damage function tab in Figure 9.

	A	B	C
1	Damage Function ID	Damage Function File	Average or Max Inundation over Areal Objects
2	h_struct_616	..\Database\Damage Functions\h_struct_616.csv	average
3	h_struct_652	..\Database\Damage Functions\h_struct_652.csv	average
4	h_struct_493	..\Database\Damage Functions\h_struct_493.csv	average
5	h_struct_575	..\Database\Damage Functions\h_struct_575.csv	average
6	h_struct_631	..\Database\Damage Functions\h_struct_631.csv	average
7	h_struct_545	..\Database\Damage Functions\h_struct_545.csv	average
8	h_struct_591	..\Database\Damage Functions\h_struct_591.csv	average
9	h_struct_586	..\Database\Damage Functions\h_struct_586.csv	average

Figure 9 Example of FIAT configuration file tab 'Damage Functions'.

The **settings tab** is filled in automatically by the user interface, except for the vertical unit field. This field is metadata that is meant to document the units with which the user is working. The site name will be filled in as the area of interest selected in the user interface, and the scenario name will be given by the user in the user interface. The output CRS is automatically selected to be the same as the input CRS, which the program finds in the WKID text file in the exposure sub-folder within the root directory. See an example of a filled-in settings tab in Figure 10.

	A	B	C	D
1	Site Name	Scenario Name	Output CRS	Vertical Unit
2	C8	Some event	PROJCS["NAD_19	feet
3				

Figure 10 Example of FIAT configuration file tab 'Settings'.

The **SVI tab** (SVI = social vulnerability index) is a special tab for an aggregation variable. It is the only aggregation variable that is included in the default SFWMD exposure data file. Additional aggregation variables would require additional tabs. Aggregation variables are described in the exposure data section; they are used to group damages by value of the variable. The SVI tab (and aggregation variable tabs in general) are intended to tell the Delft-FIAT calculation core what the value 'bins' are; the damages of objects whose values fall within those bins are then aggregated. For the SVI, which ranges from 0 to 1, four bins have been chosen, indicated by upper limits 0.25, 0.50, 0.75, and 1; these limits can be modified by the user. The first column indicates the bin number, the second column gives a bin label, and the third column specifies the bin upper limit. See an example of a filled-in SVI tab in Figure 11.

	A	B
1	Bin upper limit	Bin label
2	0.25	low
3	0.5	medium-low
4	0.75	medium-high
5	1	high
6		

Figure 11 Example of FIAT configuration file tab 'SVI'.

4.5 Input modifications

Modifications to the exposure data, damage functions, or configuration file are expected to occur infrequently, but it can happen that changes periodically occur and warrant an update of some of these values. The best way for SFWMD staff to make changes is to re-run the SFWMD-developed exposure-data model-building tool, which will implement changes in all relevant files.

For those who wish to make changes manually, this section describes the modifications that require changes to multiple files. Changes that can be made without any dependency between files are not included here. For example, changing the maximum potential structure damage of objects in the exposure data or adding an aggregation label column to the exposure data can be done without any modifications to other files.

There are two modifications that involve dependency between files: (1) new damage functions, (2) and (2) new aggregation variable.



When making changes to the exposure CSV file, the user is encouraged to use a text editing program like Notepad or TextPad. The user is discouraged from using Excel to make changes. Excel modifies the delimiters of the file automatically, making it unreadable by the SFWMD-FIAT user interface. If using Excel, the user is encouraged to check and correct any changed delimiters in a text editor afterwards.

4.5.1 Damage functions

This section focuses on the inclusion of a new damage function file. If the user only wants to update an existing damage function, this can be done simply by changing the values in the existing damage

function file; no other changes would need to be implemented. The following steps are required to add a new damage function:

Step 1 – Create the new damage function CSV and place it in the damage function folder within the database folder under the root directory.

Step 2 – Open the base configuration file and go to the tab ‘Damage Functions’. Add a new row with the damage function ID (this is the value that will be referenced in the exposure data file) and the path to the damage function CSV file. Indicate how the water depth will be selected over areal objects (see Section 4.4 for more information on the damage functions tab in the configuration file).

Step 3 – In the exposure data file, update or add the damage function information with the new damage function name for all objects where the new damage function should be used.

4.5.2 Aggregation variable

To add a new aggregation variable, two files need to be modified using the following steps:

Step 1 – Add the new aggregation variable as a new tab to the configuration file. The tab will contain two columns: (1) the upper limit of each of the bins (for example: 0.25, 0.50, 0.75, 1), and (2) the label of the bins (for example: low, medium-low, medium-high, high).

Step 2 – Add to the exposure data file a new column that starts with “Aggregation Variable:” and then contains the name of the variable. This name must correspond with the name of the tab that was created in the configuration file in Step 1.

5 User Interface

The quick-start guide in Section 0 explains how to open and get started in the user interface. It also provided an overview of the button functionality in the user interface. This section will provide more details on how to use the interface.

Once the root directory has been selected, the program will read the areas of interest for which there is exposure data. Each area of interest has its own sub-folder in the *Exposure* folder. Figure 12 shows the example for which exposure data for basins C8 and C9 have been completed and stored within the *Exposure* folder. If an additional area of interest is added to the *Exposure* folder, it will automatically appear in the drop-down list and can be selected via the user interface.

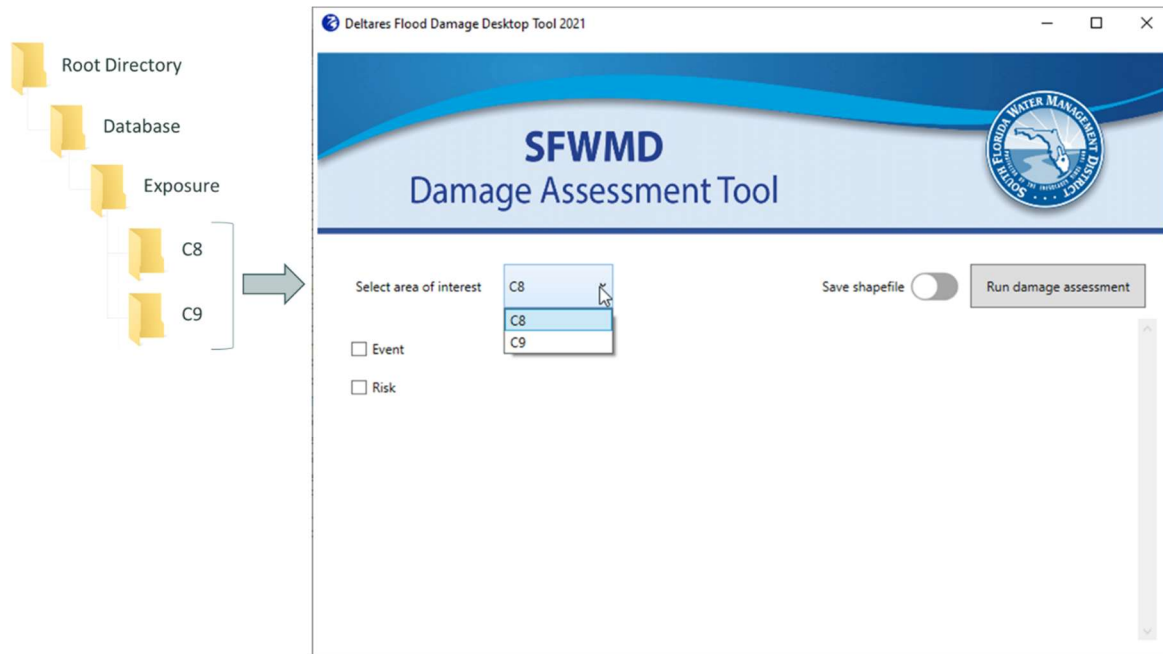


Figure 12 Exposure data folder structure which links to the area of interests available in the SFWMD-FIAT.

When the SFWMD-FIAT opens, it will select by default one of the pre-loaded exposure data areas of interest. When the program is opened to the default area of interest, or when a new area of interest is selected, a warning will appear that all input flood maps must be in the same coordinate reference system (CRS) as the exposure data for that area of interest; the CRS is indicated in the warning. See an example in Figure 13.

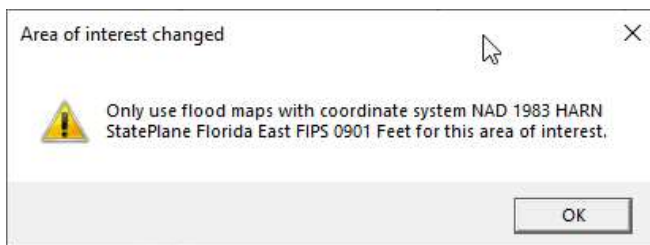


Figure 13 Pop-up warning to remind the user to input flood maps with the correct coordinate reference system..

There are two modes of operation of the SFWMD-FIAT: an event mode and a risk mode. The **event mode** is intended to evaluate the flood damages for a single event that has occurred or might occur in the future. An example of an application of the event mode would be to evaluate how a proposed flood mitigation or adaptation measure would have reduced damages from a historic event, such as Hurricane Irma.

Figure 14 shows the event mode selection in the user interface. The user must enter a scenario name for each scenario they want to evaluate. They must select the flood map type, which is either water depth or water elevation, and they must specify the location of the flood map on their hard drive⁶. Once the scenarios have been entered, the user should click the “Run damage assessment” button to start the calculations.

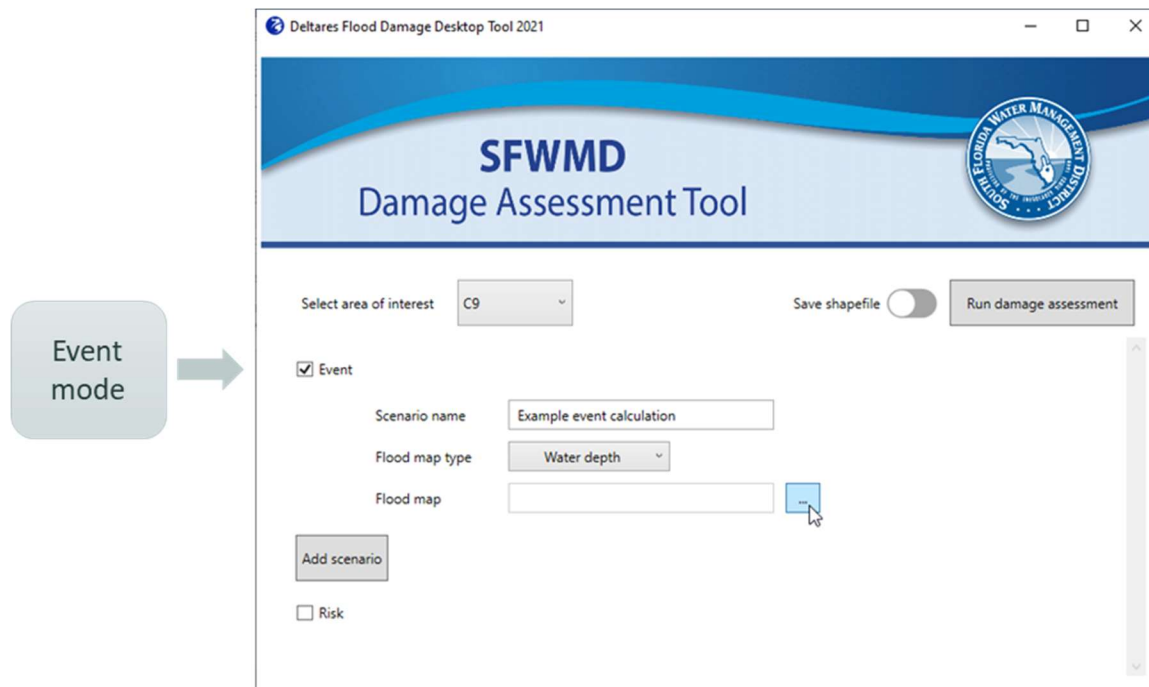


Figure 14 SFWMD-FIAT example in event mode.

The **risk mode** is intended to evaluate return-period damages and expected annual damages. An example of an application of the risk mode is to assess the risk-reduction benefits of a proposed flood mitigation or adaptation measure. The risk mode requires flood maps with specified return periods, sometimes referred to as return-period flood maps or probabilistic flood maps.

Figure 15 shows the risk mode selection in the user interface. The user must enter a scenario name for each risk scenario they want to evaluate. They must select whether the flood maps they are inputting are water depth or water elevation maps, and they must specify the location of the flood maps on their hard drive. For the risk mode, the user must indicate the return period of each of the input flood maps. A minimum of two return period maps is required to perform the risk calculation. For a description of the risk calculation, see the damage assessment methodology appendix (Appendix C). Once the

⁶ The flood map must be a GeoTIFF file and the vertical datum must be NAVD88 (see Section 4.3).

scenarios have been entered, the user should click the “Run damage assessment” button to start the calculations.

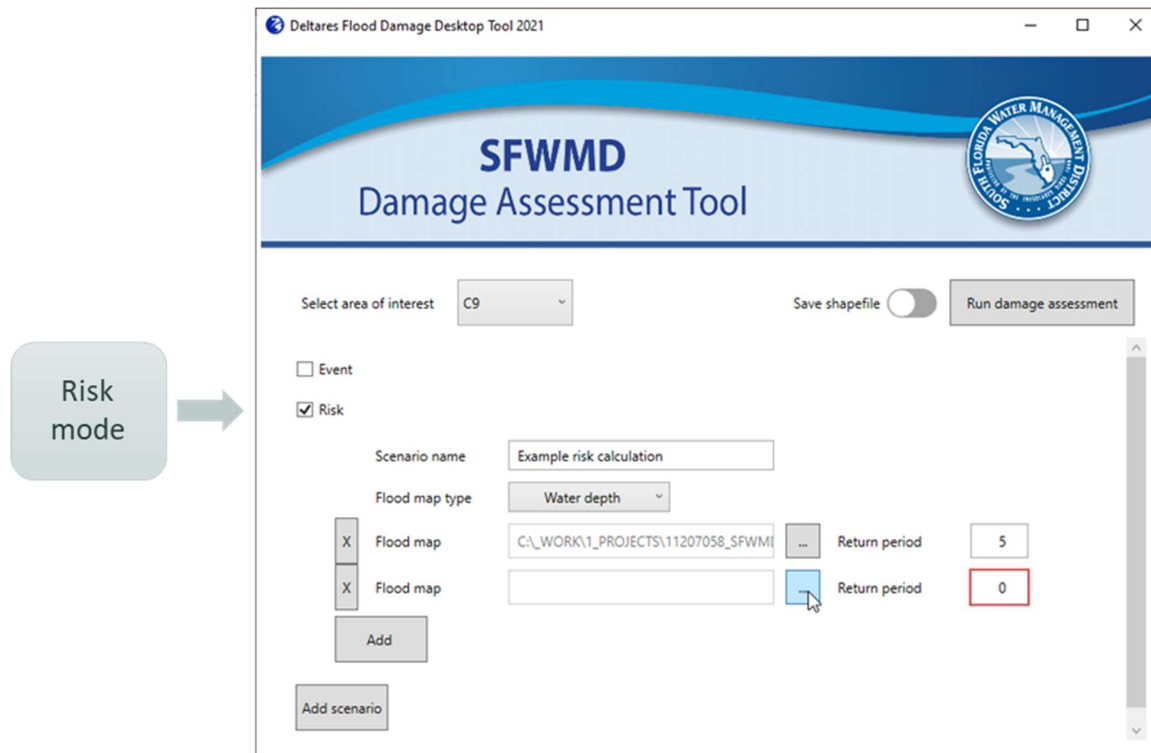


Figure 15 SFWMD-FIAT example in risk mode.

The program features are the same for both event and risk modes. The user can input multiple scenarios and run these at one time as a batch run, reducing the manual labor required of the user. The user can also select ‘Save shapefile’ at the top of the window to output shapefiles of the damage and/or risk results for easy visualization in GIS programs.

Each scenario takes about 1-5 minutes to run, depending on the size of the area, the resolution of the flood map, the number of flood maps, whether a shapefile is saved, and the speed of the computer. Once all the calculations are finished, the user will see a window pop up indicating that the run has been completed. See example of the finished run notification in Figure 16.

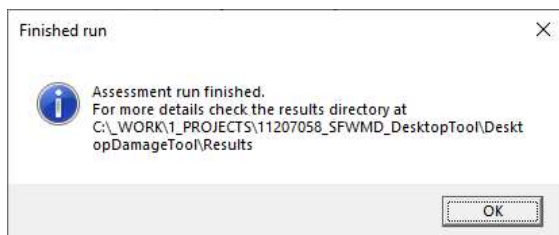


Figure 16 Pop-up window when the assessment run has finished.

6 Output data

Once a run is completed, the user can access the damage assessment results on their hard drive for each scenario they evaluated. For each scenario, the results include raw data output, processed tabulated data, a shapefile (if the user selected this option in the user interface), the configuration file for the scenario, and a log file with details about the simulation.

The results are stored in sub-folders within the *Results* folder under the root directory. Figure 17 illustrates the structure of the *Results* folder for an example where the C9 basin was selected as the area of interest, and the user ran a risk scenario named 'example risk calculation' and an event scenario named 'example event calculation'. Within the results folder, the SFWMD-FIAT creates a sub-folder for the area of interest that the user selected. Within this folder, the user can find sub-folders for each scenario that has been run. The naming convention of the scenario sub-folders is a concatenation of the scenario name that the user provided in the user interface and the time stamp that the run was completed. The time stamp format is YYYYMMDDHHMMSS.

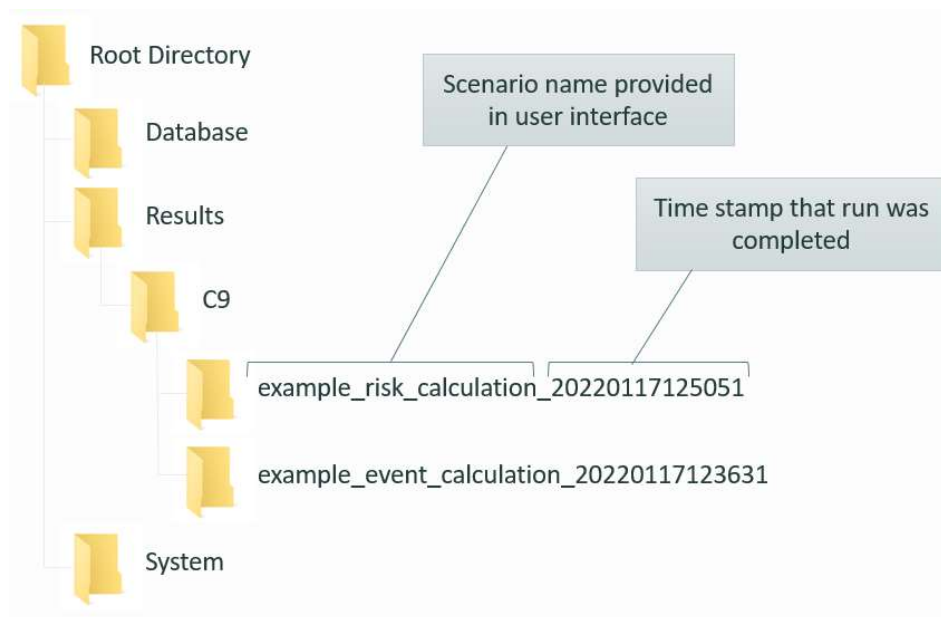
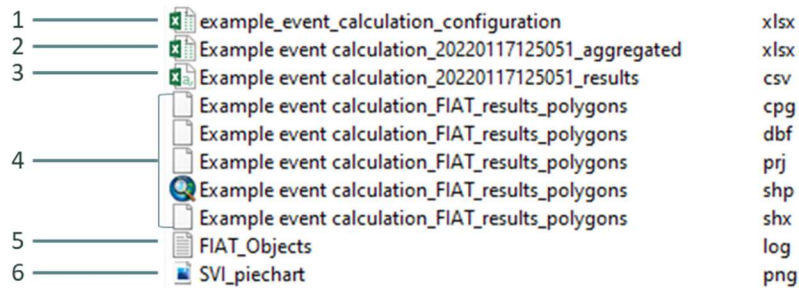


Figure 17 Results folder structure.

Within each scenario folder are six types of output. Figure 18 shows an example for the 'Example event calculation' scenario. The figure identifies each type of output. The list below describes each of these outputs in more detail.



- 1 The configuration file for the scenario
- 2 Aggregated, post-processed damage results for reporting and planning purposes
- 3 Raw data per object; includes exposure data (input) and damage assessment output per object
- 4 Shapefile of damages and associated GIS files; this output is optional, if selected in the user interface
- 5 Log file containing details of the simulation, and any warning messages
- 6 Social vulnerability pie chart showing damage distribution over social vulnerability indicator classes

Figure 18 Screenshot and description of the SFWMD-FIAT output files

The log file contains warnings or error messages related to the damage calculations. If the run did not complete properly, and incomplete results are found in the *Results* folder, the user should open the log file to gain insight into what caused the calculation to terminate. Chapter 7 explains the warning and error messages that could show up in the log file.

The results that the user is most likely interested in are the aggregated, post-processed damage results, and the shapefile of damages. The aggregated tabulated results were designed together with the SFWMD to reduce manual labor in the further use of the damage assessment results for grant applications and planning. For each aggregation level in the Excel workbook there are two tabs, an *Overview* and a *Details* tab. The overview gives total damages (and risk if running a risk calculation) for buildings and utilities (together) and roads (separately). The details tab separates the damages into the source of the building/utility damage, such as structural, content, or other (e.g. inventory) damage. The results are aggregated by several fields: global (these are the total damages for the area of interest), sub-basin, land use, tax use, census tract, census block, poverty, and critical infrastructure type. In addition to these, the results are aggregated over social vulnerability index (SVI) classes. The SVI ranges from 0 to 1, with 1 being the most vulnerable.

The shapefile of damages contains a wealth of information about the objects, coupled to their footprints. Figure 19 shows shapefile output for an example scenario run with the SFWMD-FIAT. The attribute table of the objects contains many fields, which are described in [Error! Reference source not found. Table 2.](#)



Figure 19 Example shapefile output for a scenario run with the SFWMD-FIAT (legend omitted for privacy). Each object can be clicked to obtain a wealth of exposure data information and damage assessment results.

Table 2 Description of the fields in the damage results shapefile attribute table; data type indicates if the data is input (exposure data) or damage output.

Data type	Attribute	Full name
Exposure data input	ObjectID	Object ID
	PriObjType	Primary object type
	SecObjType	Secondary object type
	X	X Coordinate
	Y	Y Coordinate
	ExctrMeth	Extraction method
	DamFunStr	Damage Function: Structure
	DamFunCon	Damage Function: Content
	DamFunOth	Damage Function: Other
	FFE	First Floor Elevation
	GroundElev	Ground Elevation
	PotDamStr	Max Potential Damage: Structure
	PotDamCon	Max Potential Damage: Content
	PotDamOth	Max Potential Damage: Other
	ShpPath	Object-Location Shapefile Path
	JoinID	Object-Location Join ID
	JoinField	Join Attribute Field
	Subbasin	Aggregation Label: Subbasin
	LandUse	Aggregation Label: Land Use
	TaxUse	Aggregation Label: Tax Use
	CensusTrac	Aggregation Label: Census Tract
CensusBloc	Aggregation Label: Census Block	
SVI	Aggregation Variable: SVI	
Poverty	Aggregation Label: Poverty	
CriticalIn	Aggregation Label: Critical Infrastructure	
Damage output	ID_#_RP	Inundation depth inside building, return period of # years
	RF_#_RP	Reduction factor, return period of # years
	SD_#_RP	Structure damage, return period of # years
	CD_#_RP	Content damage, return period of # years
	OD_#_RP	Other damage, return period of # years
	TD_#_RP	Total damage, return period of # years
	EAD	Expected annual damages (risk)

7 Warnings and error messages

The simulation log file (see Figure 18) contains warning and error messages that can help the user troubleshoot when simulations do not complete. Similarly, the user can consult the log file to make sure there were not any program warnings that need attention. With a warning, the SFWMD-FIAT continues the simulation. An error stops the SFWMD-FIAT simulation and results in incomplete output files. The warning and error messages that can be found in the log file are explained in this section. For each message, the message text that would be found in the log file is provided and the explanation is given below it in italicized font.

7.1 Warnings



The hazard data is in Coordinate System [CRS found] while the following was specified for this dataset: [CRS required]. The hazard data Coordinate System must be correctly defined in the configuration file.

This is a warning about the coordinate reference system that is supplied in the WKID.txt and the coordinate reference system that is read from the hazard maps. Note that even if the coordinate reference system is the same but the naming is different, the program will give a warning.



fiona.ogrext - INFO - Failed to auto identify EPSG

This warning can be ignored. This warning is generated by open-source Python packages used by Delft-FIAT, which are not able to automatically identify the EPSG coordinate reference system. This does not cause any issues, because the program identifies the CRS using the WKID.txt.



fiona._env - WARNING - Normalized/launched field name

This warning can be ignored. It arises when the field name of an attribute has more than 10 characters. A shapefile field name can only handle a maximum of 10 characters, so anything more than that is cut off.



The inundation depth exceeded the limits of the damage function for the objects with the following Object IDs

This warning informs the user that the inundation depth of the objects with the Object IDs indicated are exceeding the upper limit of the damage function that is used for those objects. It could indicate unexpected inundation.



fiona._env - WARNING - Value [value] of field [field name] of feature [feature number] not successfully written. Possibly due to too larger number with respect to field width

This warning indicates that a [value] of a [field name] of feature with [feature number] is truncated because the value contains more digits than is allowed in that field of the shapefile attribute. The user can always check the value in the CSV output, where it is fully written.



Check the [Site Name/Scenario Name/Vertical Unit] in the configuration file [path to configuration file]. This should be a string but was entered as [data type].

This warning arises when (one of) the Site Name/Scenario Name/Vertical Unit values in the configuration file is not a string datatype.



Invalid input, please write 'True' to save results to shapefile or 'False' to not save results to shapefile.

This is a Delft-FIAT warning when the command to save the results to a shapefile is incorrectly given. In the SFWMD-FIAT program, this is automatically correctly filled in using the 'save shapefile' on/off state in the user interface.



Cannot find an appropriate damage fraction for a water depth of [water depth] for Object ID [Object ID].

Delft-FIAT cannot determine the appropriate damage fraction for object [Object ID]. Check the damage function and water depth relevant to that object.



There are objects that contain a [structure/content/other] damage function but not a max potential structure damage, or vice versa. Please check your exposure input file [path to exposure modification file]

The exposure data CSV is missing information on damage functions and/or potential damage for certain objects. The user can solve this warning by adding the missing values to the exposure data CSV. The SFWMD-FIAT will continue to run and will not assign any [structure/content/other] damage to the objects that are missing information.

7.2 Errors



Invalid path to configuration file: [path to configuration file]
Please try again to enter a path to an existing configuration file

This is a Delft-FIAT error message that an invalid configuration file path has been given. In the SFWMD-FIAT program, the location of the configuration file is automatically obtained from the folder structure. If this error is seen, it indicates that the folder structure has been altered. To solve this error, restore the original folder structure (see Chapter 4).



The Exposure File does not exist. Check the location and name of the file in the configuration file.

The Delft-FIAT program cannot find the specified exposure file. This error should not occur for the SFWMD-FIAT program, because the exposure data location is automatically passed to Delft-FIAT using the user-interface. If it does occur, restore the original folder structure to solve the error (see Chapter 4).



[key] is a missing value. Check the configuration file: [path to configuration file]

This is a Delft-FIAT error when the configuration file is missing a key. This error should not occur for the SFWMD-FIAT program, because the correct base configuration file was delivered with the program. If it does occur, the user can set up their own (base) configuration file (see Section 4.4).



[key] is empty. Check the configuration file: [path to configuration file]

This is a Delft-FIAT error when a value in the configuration file is missing. In the SFWMD-FIAT program, this error should not occur, because the configuration file is automatically correctly filled. If it does occur, the user can fill in the missing values in the configuration file (see Section 4.4.).



The Exposure Modification File does not exist. Check the location and name of the file [path to exposure modification data CSV file] in the configuration file: [path to configuration file]

This is a Delft-FIAT error when an exposure modification file is entered, but the path to the file does not exist. In the SFWMD-FIAT program, no exposure modification files are currently used, so this error should not occur.



One of the Hazard Files does not exist. Check the location and name of the file/folder [name of hazard file] in the configuration file: [path to configuration file]

The indicated hazard file does not exist. The user should check whether the selected hazard file exists in the location entered in the SFWMD-FIAT. In the SFWMD-FIAT program, this warning will only occur if the user deletes (a) hazard file(s) after selecting them in the user interface, and then starts the simulation.



The file names of the Hazard Files are not unique. Rename the files so that they are unique and change this accordingly in the configuration file: [path to configuration file]

The file names of the hazard files are not unique. The SFWMD-FIAT requires unique hazard file names when running a risk calculation. The user should manually change the hazard file names and reselect the renamed hazard files.



Inundation Reference for the hazards in the configuration file [path to configuration file] must be either DEM or DATUM.

This is a Delft-FIAT error when the inundation reference in the configuration file is set to something else besides DEM or DATUM. In the SFWMD-FIAT program, this is automatically correctly filled in using the 'flood map type' dropdown menu in the user interface.



Not all Damage Functions have a corresponding Damage Function ID attribute. Please check the configuration file: [path to configuration file]

This error arises when (one of) the damage function(s) defined in the configuration file does not have a corresponding Damage Function ID. The user must check the base configuration file tab 'Damage Functions' and fill in the empty Damage Function IDs to fix this error.



One of the Damage Function Files does not exist. Check the location and name of the file [path to damage function file] in the configuration file: [path to configuration file]

This error arises when (one of) the damage function(s) files does not exist. The user must check the base configuration file tab 'Damage Functions' and check whether the path to the relevant damage function file is correct.



Not all Damage Functions have a corresponding 'Average or Max Inundation over Areal Objects' attribute. Please check the configuration file: [path to configuration file]

This error arises when (one of) the damage function(s) defined in the configuration file does not have a corresponding Average or Max Inundation over Areal Objects attribute (i.e. the field is empty/blank). The user must check the base configuration file tab 'Damage Functions' and fill in the empty Water Depth Over Aerial Objects attribute(s) to fix this error.



The 'Average or Max Inundation over Areal Objects' field for the damage functions must be either AVERAGE or MAX. Please check the configuration file: [path to configuration file]

This error arises when (one of) the damage function(s) Average or Max Inundation over Areal Objects attribute is something else besides AVERAGE or MAX. The user should correct the value of this attribute to either AVERAGE or MAX.



Only one event can be used as input. Please configure the configuration file [path to configuration file] to only input one event.

This is a Delft-FIAT error when more than one hazard file is used to calculate damages in the Event mode. In the SFWMD-FIAT program, this will not occur since the user interface only allows one hazard file input in the Event mode.



The Coordinate Reference System (CRS) of the [Hazard Files/Output CRS] is not correctly assigned. Please add a valid CRS as EPSG/ESRI code (e.g. EPSG:4326) or a WKT in the configuration file [path to configuration file]

The Coordinate Reference System is not correctly assigned in the configuration file. In the SFWMD-FIAT, the CRS is automatically copied from the WKID.txt file in the relevant exposure folder. To solve the error, check and revise the CRS in this file to an existing EPSG or ESRI code, or a WKT. To check the validity of a CRS, <https://spatialreference.org/> can be consulted.



The following columns are missing from the exposure data: [list of missing columns]. Please add those to the exposure data CSV file: [path to exposure data CSV file]

The exposure data CSV is missing required column names. Check Chapter 4.2 which column names are required and add those to the exposure data CSV. In the workflow for the SFWMD-FIAT, this should not happen since the exposure data model builder is configured to add and fill all required columns in the exposure data CSV.



Not all damage functions that are in the exposure input file [path to exposure data CSV file] are defined in the configuration file [path to configuration file]. Please add the damage functions [missing damage functions] in the configuration file.

The exposure data CSV contains damage functions that are not defined in the (base) configuration file. To solve the error, these damage function (files) must be defined correctly in the (base) configuration file.



The Object IDs must be unique. Check the exposure input file [path to exposure data CSV file]

The exposure data column 'Object ID' is not unique. This can be solved by giving a unique (integer) ID to each object in the exposure data CSV. For the SFWMD-FIAT, this is unlikely to happen since the exposure data model builder gives a unique ID to all objects.



The exposure shapefile [name of shapefile] contains a Z-coordinate. Please supply a shapefile with only XY coordinates.

Delft-FIAT can currently only handle shapefiles with XY coordinates, therefore, only those shapefiles are allowed.



An exposure modification file is submitted but contains no data (except for the header). Please check your exposure modification data [path to exposure modification data CSV file]

The supplied exposure modification file contains no objects/data. For the SFWMD-FIAT, no exposure modification files are used so this error should not occur.



The number of X and Y coordinates are not aligned. Please check the X and Y coordinates in the exposure input file [path to exposure data CSV file]

This error arises when XY coordinates in the exposure data CSV are used to locate the objects within Delft-FIAT, instead of using a shapefile, and the number of X coordinates is less than the number of Y coordinates, or vice versa. This should be fixed in the exposure data CSV by adding the missing X and/or Y coordinates.



Column [required column name] is required and missing from the exposure input file [path to exposure data CSV file]

The exposure data CSV is missing required column names. Check Chapter 4.2 which column names are required and add those to the exposure data CSV. In the workflow for the SFWMD-FIAT, this should not happen since the exposure data model builder is configured to add and fill all required columns in the exposure data CSV.



There may only be one type of inundation reference for the flood maps. Please check your configuration file [path to configuration file]

This is a Delft-FIAT error that arises when there is inconsistency in the inundation references for the flood maps, which occurs when one or more flood maps are provided as water depth maps, and one or more are provided as water level maps. In the SFWMD-FIAT program, this cannot occur because the configuration file is automatically filled in correctly by the program, according to what is chosen in the user interface.



None of the exposure objects are within the flood map extent.

This error arises when no exposure objects are found within the flood map extent. This could be caused by an inconsistency in coordinate systems between the exposure data and flood maps. The user can visually check this error by opening the exposure data and flood map(s) in any GIS software.

Appendix A Exposure data model builder

The exposure data requirements are described in Section 4.2 of the User Manual. This appendix describes the SFWMD exposure data model-builder tool that uses standardized data sets to create the required exposure data for all the basins within the SFWMD.

The exposure data builder uses Esri ModelBuilder, a visual programming language that documents and automates geoprocessing workflows. A series of models were compiled to *attribute* buildings and utilities footprints and create and *attribute* road segments. The process of attributing footprints and segments refers to assigning exposure data, such as elevation and maximum potential damages, to them.

Exposure features are created from building footprints, user-defined water control structure and pump station footprints, electric facility land use polygons, and roads. Exposure features are attributed with the required exposure data fields using normalized parcel tax use codes, land use categories, 2020 Census Blocks and Tracts, CDC SVI overall ranking, and hydrologic sub-basins. Elevation statistics are calculated within the geometry of each exposure feature using NAVD99 topo-bathymetric data.

Three geoprocessing workflows were compiled: road processing, building and utility processing, and exposure data export to the SFWMD-FIAT required format. The feature-processing workflows:

- Compile features at a regional level, i.e. Miami-Dade and Broward County combined, to create continuous, non-redundant features;
- Join feature and aggregation attribution based on coincident location;
- Calculate elevation zonal statistics;
- Populate damage function and value fields using lookup tables;
- Subset regional data into areas of interest (AOI) for use in the SFWMD-FIAT;
- Export features into the exposure data template.

The workflows start with the correct ArcGIS Pro project and folder structure. The next steps are road processing, building and utility processing, and finally exposure data export, see Figure 20. The processing steps go from 1 (in the *road processing* section) to 21 (in the *exposure data export* section) and are required to be followed in this order for a successful completion.

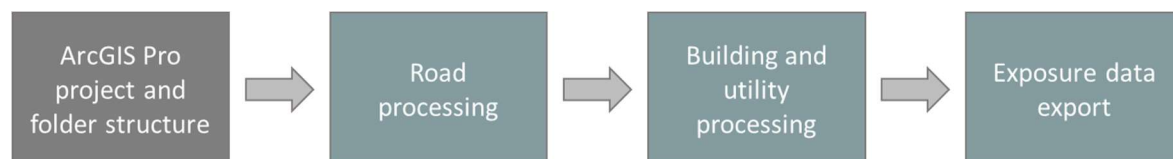


Figure 20 The exposure data builder overall workflow.

For the following sections, it is useful to note two acronyms are used frequently. **AOI** is used for *area of interest*, and **Fp** is used for *footprint*.

A.1 Data sources

This section describes the data sources that are used in the development of the exposure data for the SFWMD Flood Impact Assessment Tool. Newer or updated data sources may be included in the future.

The following list contains datasets that are maintained by SFWMD and used by the ModelBuilder tools during processing of the exposure data.

- NavTeq / HERE Streets
- NavTeq / HERE Admin3 / County boundaries
- SFWMD Enterprise Topo-Bathymetric Mosaic for Broward and Miami-Dade Counties
- SFWMD Enterprise Land Use / Land Cover
- SFWMD Enterprise Normalized Parcels
- Florida 2020 Census Blocks and Tracts
- Centers for Disease Control and Prevention (CDC) 2018 Social Vulnerability Index (SVI) by Census Tract

The following additional data sources were also used:

- Miami-Dade and Broward County Building Footprints
- User-supplied Miami-Dade hydrologic model sub-basins
- User-supplied water control structure and pump station footprints
- User-supplied area of interest boundary file

All data sources are projected to the **NAD 1983 HARN StatePlane Florida East FIPS 0901 (US Feet), WKID 2881, ESPG coordinate system**. Vertical data are in **North American Vertical Datum (NAVD) 1988 units feet**.

A.2 ArcGIS Pro project set up

This section gives an overview of the ArcGIS software, project, components, and data configuration that are required to run the exposure data builder.

Software: ArcGIS Pro version 2.8, Esri ModelBuilder

Project name: ExposureDataProcessing_V3.aprx

A.2.1 Data preparation

Besides geospatial data from pre-existing sources, a table is required to link each occupancy type in the exposure data to damage functions and maximum potential damage values⁷. The name of this lookup table is: *HAZUS_DMGFUNC_REPVALUE_LOOKUP*. The required columns and information in the lookup table are described in Table 3.

Table 3 Description of the required columns and information in the *HAZUS_DMGFUNC_REPVALUE_LOOKUP* look-up table

Column name	Description	Linked column in exposure data
DF_STRUC	Name of the structure damage function	Damage Function: Structure
DF_CONT	Name of the content damage function	Damage Function: Content
DF_OTHER	Name of the other damage function	Damage Function: Other
STRUC_REP_VALUE	For all building categories: per-square-foot structure damage values. For all utility categories: per-object structure damage values.	Max Potential Damage: Structure
CONT_REP_VALUE	For all building categories: per-square-foot content damage values. For all utility categories: per-object content damage values.	Max Potential Damage: Content
OTHER_REP_VALUE	For all building categories: per-square-foot other damage values. For all utility categories: per-object other damage values.	Max Potential Damage: Other
CRIT_INFRA	Indicator if critical infrastructure (Y/N)	Aggregation Label: Critical Infrastructure

⁷ For buildings, the maximum potential damages in the lookup table are given per square foot. The ModelBuilder multiplies these per-square-foot maximum damage values with the area of each building to obtain the per-building maximum potential damage; for utilities, the maximum potential damages are given per utility type.

A.2.2 Project file geodatabases

There are several geodatabase files that are needed to process the exposure data input for SFWMD-FIAT (see project folder structure in Figure 21). Each of the geodatabases is described below.

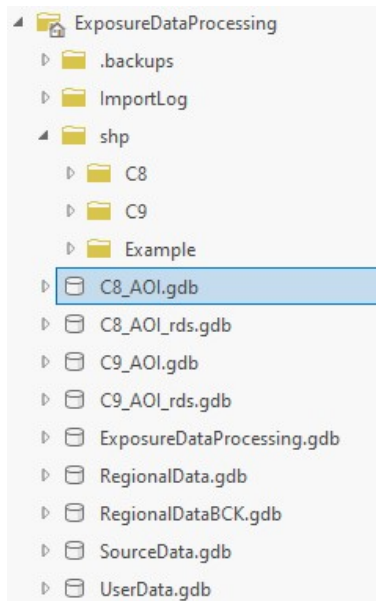


Figure 21 ArcGIS Pro project folder structure.

Area of Interest footprint geodatabase: %AOI%_AOI.gdb

File geodatabase for area of interest (AOI) footprint feature class processing. This is connected to the user-supplied area of interest boundary file. An example name would be C9_AOI.gdb.

Area of Interest roads geodatabase: %AOI%_AOI_rds.gdb

File geodatabase for area of interest (AOI) road feature class processing. This is connected to the NavTeq / HERE Streets input data. An example name would be C9_AOI_rds.gdb.

Regional data geodatabase: RegionalData.gdb

File geodatabase containing regional subsets of enterprise data generated during model processing, i.e. regional roads and footprints.

Regional data backup geodatabase: RegionalDataBCK.gdb

File geodatabase containing a backup version of some regional subsets of enterprise data generated during model processing, i.e. regional roads and footprints.

Source data geodatabase: SourceData.gdb

File geodatabase containing building footprint source data, processing template feature classes (*ExposureDataTable*, *Input Schema*), and Damage Function and Value lookup tables⁸ (*HAZUS_DMGFUNC_REPVALUE_LOOKUP*, *HAZUS_DMGFUNC_LANDUSE_FIAT*, *HAZUS_DMGFUNC_TAXUSE_FIAT*). These user-prepared look-up tables are described in Section A.2.1.

⁸ The master lookup table *HAZUS_DMGFUNC_REPVALUE_LOOKUP* contains 2021 USD damage values. The values are updated from their original years.

User data geodatabase: *UserData.gdb*

User provided polygon feature classes, i.e. Sub-Basins, model domains, AOI boundaries, aggregation areas, utility / Water Control Structure / Pump Station area footprints.

A.2.3 Data configuration requirements

Due to the size of the **SFWMD Enterprise Normalized Parcels** feature class and processing limitations across the SFWMD network, a copy of the normalized parcel feature class must be made on a local drive then clipped to the regional boundary and added to the RegionalData.gdb for inclusion and use in spatial joins.

The SFWMD-FIAT presents model results both at the overall level and at subdivisions called aggregation levels. Several aggregation labels are included by default in the modelbuilder: sub-basin, land use, tax use, census tract, census block, poverty, critical infrastructure, and SVI. To exclude certain aggregation labels from ModelBuilder processing, the fields specified for each feature class were made visible using the design fields tool. Fields that are not marked to be visible will be excluded from spatial joins / processing. **Please note:** Read Only fields are required fields and must remain visible. The feature class fields that are used as aggregation labels are provided in Table 3.

The following are the SFWMD selected attribution for aggregation included in ModelBuilder processing.

Table 4 Feature class, and field within the feature class, used for each aggregation label

Aggregation label	Feature Class	Field
Tax Use	SFWMD Enterprise Normalized Parcels	PARUSEDESC
Land Use	SFWMD Enterprise Land Cover and Use	LANDUSE_DESCRIPTION
Census Block	Florida 2020 Census Blocks and Tracts	BLOCKCE20
Census Tract	Florida 2020 Census Blocks and Tracts	TRACTCE20
Poverty	CDC 2018 SVI	POV
SVI	CDC 2018 SVI	RPL_THEMES

A.2.4 Variables

The following variables were established for use in the model builder tools.

- *path*: Network path to location of ArcGIS Pro Project and file geodatabases
- *AOI*: Name of Area of Interest, i.e. C9
- *AOI_gdb*: Name of AOI file geodatabase including reference to the path variable, i.e. %path%\%AOI%_AOI.gdb, %path%\C9_AOI.gdb
- *AOI_rds*: Name of roads AOI file geodatabase including reference to the path variable, i.e. %path%\%AOI%_AOI_rds.gdb, %path%\C9_AOI_rds.gdb
- *SourceData*: Name of source data file geodatabase including reference to the path variable, i.e. %path%\SourceData.gdb
- *RegionalData*: Name of regional data file geodatabase including reference to the path variable, i.e. %path%\RegionalData.gdb
- *UserData*: Name of user data file geodatabase including reference to the path variable, i.e. %path%\UserData.gdb
- *Region*: Abbreviation for the regional area being processed

- *RegStreets*: HERE streets line feature class clipped to regional area
- *RegMajRds*: HERE major roads line feature class clipped to regional area
- *InputStreets*: Regional road segments polygon feature class
- *InputMajRds*: Regional major road segments polygon feature class
- *AOI_Streets*: Regional road segments polygon feature class clipped to area of interest
- *AOI_MajRds*: Regional major road segments polygon feature class clipped to area of interest
- *Shapefile*: Relative path and name within the SFWMD Damage Assessment tool database for the required shapefile. i.e. “..\database\Exposure\C8\C8_Spatial.shp”
- *ShapefilePath*: Location to export shapefile within ArcGIS Pro Project folder structure

A.2.5 ToolBox

Thirteen processing models were developed to compile and format road and footprint exposure data for the SFWMD Damage Assessment tool. Each is a processing module. Figure 22 depicts the tool box. Each model is discussed in more detail in the road, building and utility processing sections below.

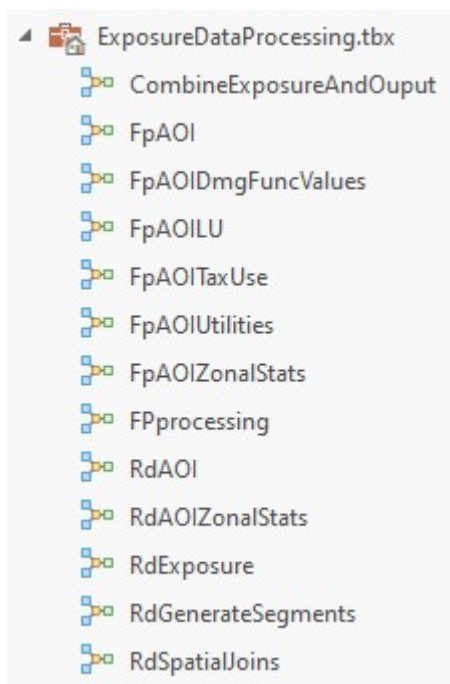


Figure 22 Exposure data processing toolbox in ArcGIS Pro.

A.3 Road processing

This section describes the input sources, input requirements and processing steps for the road exposure data.

A.3.1 Input Sources

Of the datasets described in the Data Sources section, the following are used in the road processing.

- StatePlane SFWMD Enterprise NavTeq / HERE Streets feature class;
- StatePlane SFWMD Enterprise NavTeq / HERE Admin3 / County Feature class;

- StatePlane SFWMD Enterprise Topo-Bathymetric Mosaic;
- StatePlane SFWMD Enterprise Land Use / Land Cover feature class;
- StatePlane Enterprise CENSUS Block and Tract feature class;
- StatePlane Enterprise CDC Social Vulnerability feature class;
- StatePlane AOI boundary(s);
- StatePlane User Sub-Basins;

The user-prepared damage function and value lookup tables (see Section A.2.1) are also used in the road processing.

A.3.2 Input Source Configuration Requirements

The NavTeq / HERE Streets feature class is subdivided into a major road layer and a street layer using the following definition queries:

- For major roads, create a definition query selecting roads where functional class is not equal to "5" (FUNC_CLASS <> '5')
- For streets, create a definition query selecting roads where functional class is equal to 5 and Speed Class is not equal to 8 (FUNC_CLASS = '5' And SPEED_CAT <> '8')

To reduce the number of attribution fields, the following attributes are selected to be visible. All other fields will be dropped when roads are clipped to the regional extent.

- LINK_ID
- ST_NAME
- FEAT_ID
- FUNC_CLASS
- SPEED_CAT
- BRIDGE
- TUNNEL
- RAMP
- ROUNDABOUT
- INTERINTER
- URBAN
- PHYS_LANES

The NavTeq / HERE Admin 3 County Boundaries feature class is used to create regional areas from groups of counties. To produce a new county-based region, create a definition query that selects one or many counties by names using the POLYGON_NM field, i.e. POLYGON_NM = 'BROWARD' Or POLYGON_NM = 'MIAMI-DADE'.

A.3.3 Processing steps

An overview of the road data and processing steps is provided in Figure 23.

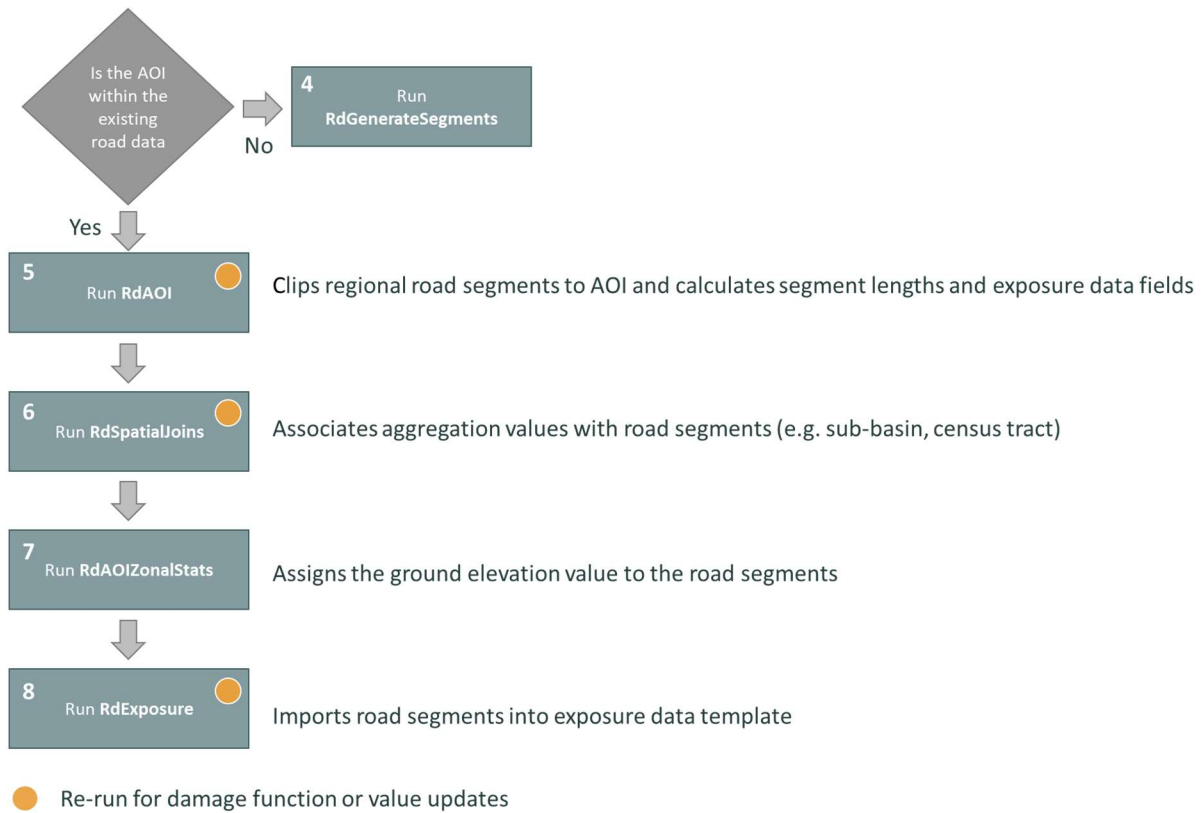


Figure 23 Roads exposure data workflow.

The exposure data builder workflow starts here:

1. Open ArcGIS Pro and navigate to and open the exposure data processing project in the Admin Data Tools Directory.
2. Create an AOI.gdb named %AOI%_AOI.gdb and an AOI_rds.gdb named %AOI%_AOI_rds.gdb.
3. Open the Roads Map and the ExposureProcessing toolbox. Select edit for each of the following models to open them in model builder:
 - **RdGenerateSegments**: Clips statewide major roads and streets layer to regional area, creates road segments, and associates major roads and street attribution.
 - **RdAOI**: Clips regional road and street segments to Area of Interest (AOI) and calculates road segment lengths and exposure data fields with the following steps:
 - Cleans data (eliminates / merges small segments, performs multipart to single part, repairs geometry);
 - Calculates values for OBJ_NUM, OBJ_NAME, OCCUPANCY, OCC_DESC_TYPE, LANES, DMG_FUNC_NAME;
 - Intersects with regional roads to assign road segment polygon OBJ_NAMES to intersected road segments;
 - Runs frequency on OBJ_NAME and summarizes length of road within each segment;
 - Adds join between road segment and frequency result and calculates road segment SEG_LENGTH;
 - Selects road segments where SEG_LENGTH is null (buffered road segment result does not intersect with regional road layer) and deletes these segments;
 - Add join with HAZUS_DMGFUNC_REPVALUE_LOOKUP and calculates MAXIMUM_POTENTIAL_DAMAGE_STRUCTURE and CRIT_INFRA. Damage functions and values are assigned to the road and street segments based on its length and number of lanes.
 - **RdSpatialJoins**⁹: Performs spatial joins to associate aggregation values with road segments.
 - **RdAOIZonalStatistics**¹⁰: Calculates elevation zonal statistics and uses mean to assign ground elevation to road segments with the following steps:
 - Performs zonal statistics as table;
 - Joins results with road segments;
 - Calculates Found Elevation field from desired statistic.
 - **RdExposure**: Imports road segments into exposure data template.
4. Determine if the AOI to be processed is within the extent of the existing regional roads feature classes. If yes, skip running the **RdGenerateSegments** model. If no, navigate to the **RdGenerateSegments** model; use the same region of interest boundary; verify or update model variables; validate model; run model; verify output, and delete intermediate data.
5. Navigate to the **RdAOI** model; verify or update model variables; validate model; run model; verify output, and delete intermediate data.
6. Navigate to the **RdSpatialJoins** model; verify or update model variables; validate model; run model; verify output, and delete intermediate data.

⁹ Road segments are attributed using intersect in the spatial joins.

¹⁰ The value associated with the feature is calculated using zonal statistics. The mean, median, max, min, std, 90th percentile elevations within the feature area are all available for use. C8 and C9 use mean elevation within the road polygon. No elevations outside the polygon area are considered.

7. Navigate to the **RdAOIZonalStats** model; verify or update model variables; validate model; run model; verify output, and delete intermediate data.
8. Navigate to the **RdExposure** model; verify or update model variables; validate model; run model; verify output, and delete intermediate data.

A.4 Building and utility processing

This section describes the input sources, input requirements and processing steps for the building and utility exposure data.

A.4.1 Input Sources

- StatePlane building footprint source
- StatePlane SFWMD Enterprise Topo-Bathymetric Mosaic
- StatePlane SFWMD Enterprise Land Use / Land Cover feature class
- StatePlane SFWMD Enterprise Normalized Parcels feature class
- StatePlane Enterprise CENSUS Block and Tract feature class
- StatePlane Enterprise CDC Social Vulnerability feature class
- StatePlane AOI boundary(s)
- StatePlane User Sub-Basins
- StatePlane User water control structure and pump station footprints
- Damage Function / Feature Value Look Up table

A.4.2 Input Source Configuration Requirements

A definition query is required to create the electrical facility footprints from the StatePlane SFWMD Enterprise Land Use / Land Cover feature class. The definition query to apply is LANDUSE_ CODE equal "8310", Electrical Power Facility (LANDUSE_ CODE = '8310').

There is no source for water control structure footprints. Partial structure footprints are captured in the footprint feature classes. Because water control structure and pump station footprints should be represented as a single footprint and not multiple footprints, a user supplied boundary of water control features needs to be compiled for each area of interest. The AHED Watershed field should be updated to reflect the area of interest name because this attribute is used to select that footprint instead of using a clip since water control feature footprint tend to be on the edge of the watershed area and should not be clipped out using a spatial operation.

A.4.3 Processing steps

An overview of the steps in the building and utility processing is provided by Figure 24 .

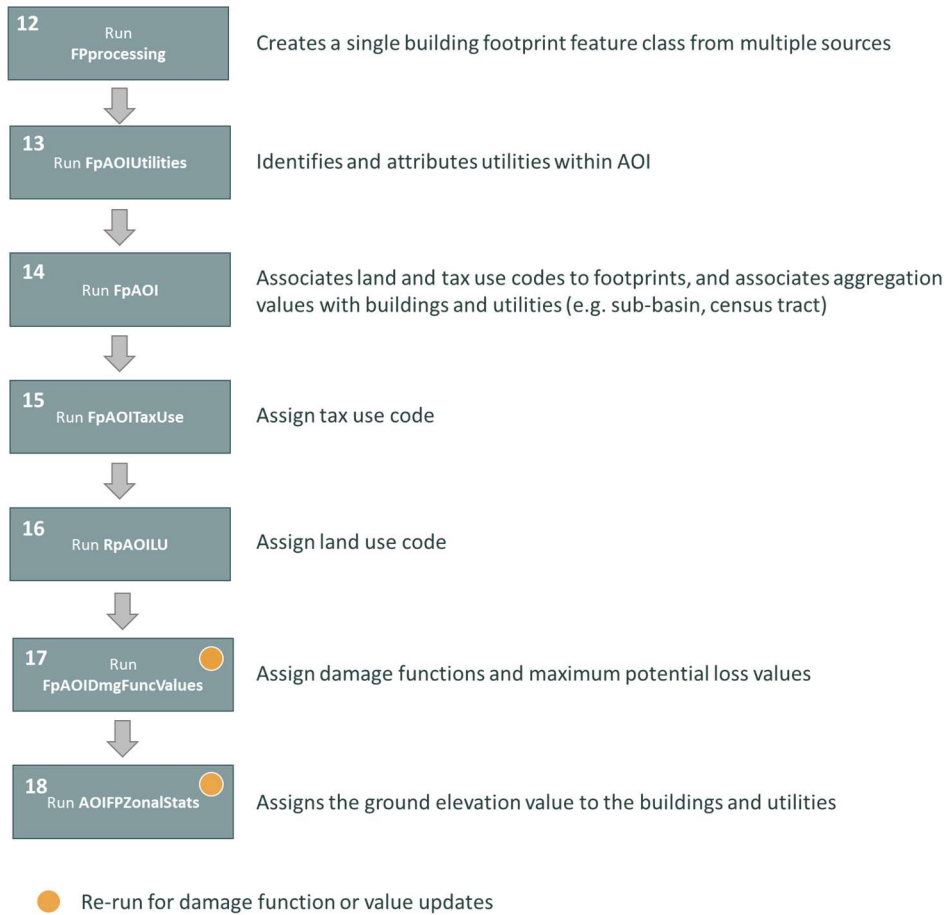


Figure 24 Building and utility exposure data workflow.

The exposure data builder workflow continues here:

9. Open ArcGIS Pro and navigate to and open the exposure data processing project in the Admin Data Tools Directory.
10. Verify that there is an AOI.gdb named %AOI%_AOI.gdb.
11. Open the Footprints Map and the ExposureDataProcessing toolbox. Select edit for each of the following models to open them in model builder:
 - **FpProcessing¹¹**: Creates a single building footprint feature class from multiple sources, dissolves multipart footprints into single footprints, and removes redundant / overlapping footprints between sources using county or other extents.
 - **FpAOIUtilities¹²**: Identifies and attributes electrical facilities and water control structures / pump stations for inclusion as utilities within the area of interest with the following steps:
 - Clips reselected LCLU feature class to AOI and adds OBJ_NUM, OBJ_NAME, OCCUPANCY, OCC_DESC_TYPE, DMG_FUNC_NAME and calculated values for each;
 - Reselects User Supplied Utilities for the identified AOI and copies them into an AOI_Utilities feature class and calculates values for OBJ_NUM and OBJ_NAME;
 - Appends electric facility footprints to user supplied AOI_Utilities feature class.
 - **FpAOIFP**: Clips building footprints to area of interest, erases building footprints within electrical facility and water control structure / pump station footprints, and performs spatial joins¹³ to associate land and tax use codes to footprints as well as other aggregation attribution with the following steps:
 - Clips building footprints to AOI;
 - Cleans data (performs multipart to single part, repairs geometry);
 - Calculates OBJ_NUM and OBJ_NAME;
 - Performs select by location on AOI building footprints using the AOI_Utilities feature class and removes/deletes selected footprint records (eliminates overlapping building footprints for utilities where we are using an area in place of a building footprint);
 - Appends AOI_Utility footprints to building footprints;
 - Performs spatial joins with aggregation layers.
 - **FpAOITaxUse**: Uses tax use code and tax use look up table to assign damage function names with the following step:
 - Joins HAZUS_DMGFUNC_TAXUSE_FIAT to building footprints and calculates values for OCCUPANCY, OCC_TYPE_DESC, DMG_FUNC.
 - **FpAOILU**: Uses land use code and land use look up table to assign damage function names with the following steps:

¹¹ This model will need to be customized based on the nature of the building footprint geometry. For Broward County (BR), each building was a single polygon. For Miami-Dade (MD), each roof elevation within the building footprint was a polygon. Footprints in MD were dissolved to create a single footprint per building. There were also overlapping footprints between these two sources. This model performs a spatial join on County boundary and then appends only those footprints within the correct county into the footprint Input Schema.

¹² Uses a reselected SFWMD Land Cover feature class as source for Electric Facility footprints (LC_CODE = 8300) and user supplied Utility footprints. The User Supplied Utility footprints must identify which AOI it belongs to. These cannot be clipped because utilities like water control structures are possibly on AOI boundaries.

¹³ Building footprints are attributed using the centroid in the spatial joins.

- Joins HAZUS_DMGFUNC_LANDUSE_FIAT to building footprints, selects where OCCUPANCY is null and calculates values for OCCUPANCY, OCC_TYPE_DESC, DMG_FUNC;
 - Removes join and selects where OCCUPANCY is null and LANDUSE_DESCRIPTION is Reservoirs or Channelized Waterways, canals and deletes selected rows¹⁴.
 - **FpAOIDmgFuncValues**: Joins footprints to damage function look up table and assigns damage functions, values, and maximum potential loss values with the following steps:
 - Joins HAZUS_DMGFUNC_REPVALUE_LOOKUP to footprints and calculates damage function and replacement cost fields from lookup table;
 - Performs reselects on OCCUPANCY to perform maximum potential damage calculations for utilities, structures, content, and other.
 - **FpAOIZonalStats**¹⁵: Calculates elevation zonal statistics for areas within footprints and uses mean to assign ground elevation to building footprints with the following steps:
 - Performs zonal statistics as table;
 - Joins results with footprints;
 - Calculates Ground Elevation field from desired measure.
12. Navigate to the **FPprocessing** model, verify or update the AOI_gdb, Source_gdb, and AOI model variables; validate model; run model; verify output, and delete intermediate data.
 13. Navigate to the **FpAOIUtilities** model, verify or update the AOI_gdb, Source_gdb, and AOI model variables; validate model; run model; verify output, and delete intermediate data.
 14. Navigate to the **FpAOI** model, verify or update the AOI_gdb, Source_gdb, and AOI model variables; validate model; run model; verify output, and delete intermediate data.
 15. Navigate to the **FpAOITaxUse** model, verify or update the AOI_gdb, Source_gdb, and AOI model variables; validate model; run model; and verify output.
 16. Navigate to the **FpAOILU** model, verify or update the AOI_gdb, Source_gdb, and AOI model variables; validate model; run model; and verify output.
 17. Navigate to the **FpAOIDmgFuncValues** model, verify or update the AOI_gdb, Source_gdb, and AOI model variables; validate model; run model; and verify output.
 18. Navigate to the **AOIFPZonalStats** model, verify or update the AOI_gdb, Source_gdb, and AOI model variables; validate model; run model; and verify output.

A.5 Exposure data export

The exposure data export workflow assigns unique feature identifiers and exports features and unique identifiers to a shapefile and related attribution to SFWMD-FIAT required .csv file. The resulting files are the files to be copied to the *Exposure* folder (see User Manual).



¹⁴ Removes boat houses and road decks that cross streams that were delineated as building footprints.

¹⁵ The value associated with the feature is calculated using zonal statistics. The mean, median, max, min, std, 90th percentile elevations within the feature area are all available for use. C8 and C9 uses median elevation within the footprint polygon. No elevations outside the polygon area are considered.

Figure 25 Exposure data export workflow.

The CombineExposureAndOutput model (see Section A.5.1) assigns a first-floor elevation¹⁶ to all of the buildings and utilities.

A.5.1 Processing steps

The exposure data builder workflow continues here, and these are the final steps:

19. Open the Footprints Map and the ExposureDataProcessing toolbox. Select edit for each of the following model to open them in model builder:
 - **CombineExposureAndOutput:** Appends road exposure data to footprint exposure data and export to FIAT Exposure Shapefile and Data Table with the following steps:
 - Appends footprints and road segments into the Exposure data Template;
 - Calculates Object_ID, FinishedFloorElevation, ObjectLocationJoinID, JoinAttributeField, ObjectLocationShapefilePath;
 - Appends geometry and Object_ID into shapefile export template;
 - Exports exposure data template to .csv.
20. Navigate to the **CombineExposureAndOutput** model, verify or update the AOI_gdb, Source_gdb, and AOI model variables; validate model; run model; and verify output.
21. Open the exported .csv and the exported_example.csv in Excel, delete the OID field from the exported.csv, copy the column name headers from the exported_example.csv, insert the copied headers into exported.csv and save exported.csv.
22. Open the %AOI%_Spatial.prj file in the resulting output. Copy all contents of this file. Create a new .txt file "WKID.txt" in the folder of the AOI exposure data, paste the contents, and save this file. This allows the SFWMD-FIAT to identify the coordinate system that is used for the exposure data and hazard maps in this AOI.

¹⁶ The first-floor elevation is set to 1 ft at the moment of writing.

A.6 Maximum potential damages

This section describes the maximum potential damages used for content, structure, and inventory for the buildings, roads, and utilities. These are the values used in the exposure database at the moment of writing, but can be updated in the future if required; see Section A.2.1 and the required processing steps in Sections A.3.3, A.4.3, and A.5.1.

A.6.1 Update values to 2021 price year

All values were updated to 2021 price year using the inflation rates shown in Table 5. The text box below explains how this is done.

Table 5 Inflation rate used to convert damage values to 2021 dollars (source: <https://www.minneapolisfed.org/about-us/monetary-policy/inflation-calculator/consumer-price-index-1913->).

Year	Annual inflation rate	Year	Annual inflation rate
2002	1.6%	2012	2.1%
2003	2.3%	2013	1.5%
2004	2.7%	2014	1.6%
2005	3.4%	2015	0.1%
2006	3.2%	2016	1.3%
2007	2.9%	2017	2.1%
2008	3.8%	2018	2.4%
2009	-0.4%	2019	1.8%
2010	1.6%	2020	1.2%
2011	3.2%	2021	4.8%

Increasing values based on inflation rates

The formula to calculate the increase in value between year T_0 and year T_n is shown below, where V_0 is the value in year T_0 , V_n is the value in T_n , n is the number of years between T_0 and T_n , r_t is the inflation rate for year t , and \prod is the product operator.

$$V_n = V_0 \times \prod_{t=1}^n \left(1 + \frac{r_t}{100}\right)$$

So, for example, a value of $V_0 = \$120$ in 2018 would be translated to a value in 2021 as follows:

$$V_{2021} = V_{2018} \times \left(1 + \frac{r_{2019}}{100}\right) \times \left(1 + \frac{r_{2020}}{100}\right) \times \left(1 + \frac{r_{2021}}{100}\right)$$

Plugging in the numbers from Table 5, that becomes:

$$V_{2021} = \$120 \times \left(1 + \frac{1.8}{100}\right) \times \left(1 + \frac{1.2}{100}\right) \times \left(1 + \frac{4.8}{100}\right) = \$129.56$$

A.6.2 Structural maximum damages - Buildings

For buildings, values of structural damages per square foot were available per occupancy type from the FEMA HAZUS manual (see Table 6). The values were translated from a 2018 price year to a 2021 price year using the annual inflation rates in Table 5.

*Table 6 Original (2018) and updated (2021) structure damage costs per occupancy type. Source 2018 values: FEMA Hazus Inventory Technical Manual 4.2.3. *Based on Census Bureau 2016 Manufactured Housing Survey Annual Data.*

Occupancy type	Maximum structure damage [\$/sq.ft] (2018)	Maximum structure damage [\$/sq.ft] (2021)
RES1-1SNB	116.66	125.95
RES1-2SNB	122.75	132.53
RES1-3SNB	127.94	138.13
RES2	45.51*	51.37
RES3A	124.25	134.15
RES3B	109.66	118.40
RES3C	201.33	217.37
RES3D	187.75	202.71
RES3E	188.48	203.50
RES3F	174.53	188.43
RES4	182.28	196.80
RES5	199.63	215.53
RES6	215.91	233.11
COM1	114.47	123.59
COM2	120.00	129.56
COM3	139.88	151.02
COM4	176.29	190.33
COM5	261.33	282.15
COM6	302.35	326.44
COM7	266.54	287.77
COM8	227.53	245.66
COM9	190.95	206.16
COM10	80.59	87.01
IND1	133.03	143.63
IND2	120.00	129.56
IND3	180.47	194.85
IND4	180.47	194.85
IND5	180.47	194.85
IND6	120.00	129.56
AGR1	120.00	129.56
REL1	190.53	205.71
GOV1	149.83	161.77
GOV2	254.23	274.48
EDU1	201.63	217.69
EDU2	171.05	184.68

A.6.3 Structural maximum damages – Utilities

Table 7 shows the structural damage values for medium-sized water treatment plants, waste-water treatment plants and medium voltage substations, which were taken from the FEMA HAZUS manual¹⁷. Table 8 gives the structural damage value for water control structures, which was provided by the SFWMD¹⁸.

Note that these damage values are per utility building, in contrast to the per square foot damages for buildings.

Table 7 Structure damage value per utility for medium water and waste-water treatment plants updated to 2021 values.

Utility type	Damage value year	Structure damage in damage value year	Structure damage (2021)
Medium Water Treatment Plant (50-200 MGD)	2001	\$100,000,000	\$153,119,245
Medium Waste Water Treatment Plant (50-200 MGD)	2019	\$110,965,000	\$117,686,816
Medium Voltage Sub-station (230 KV)	2010	\$20,000,000*	\$24,874,478

Table 8 Damage value for SFWMD water control structures (2015 and 2021 values).

Utility Type	Damage per unit (2015)	Damage per unit (2021)
Water control structure	\$1,704,764	\$1,949,346

¹⁷ Values for medium-sized water and waste-water treatment plants were taken from FEMA HAZUS technical manual 4.2.3; values for medium voltage substations were taken from FEMA HAZUS technical manual 2.1.

¹⁸ Source: WCSReplacementCost_Train.xlsx. The damage value is the average of replacement value for all structures with a 'Structure Type' (filtered out blanks and '#').

A.6.4 Content, equipment, and inventory maximum damages

The content damage is estimated as a percentage of the structure damage value of the same occupancy type (see Table 9). Equipment damage values are assumed to be the same percentages of the structure damage values as the content damage values. Inventory damage values are assumed to be the business inventory percentage of the annual sales. Table 10 presents the original (2017) and inflation-corrected (2021) annual sales values.

Table 9 Maximum content damage as a percentage of maximum structure damage, per occupancy type. Source: FEMA HAZUS Inventory Technical Manual 4.2.3.

Occupancy type	Maximum content damages [% of maximum structural damages]
RES1	50
RES2	50
RES3A-F	50
RES4	50
RES5	50
RES6	50
COM1	100
COM2	100
COM3	100
COM4	100
COM5	100
COM6	150
COM7	150
COM8	100
COM9	100
COM10	50
IND1	150
IND2	150
IND3	150
IND4	150
IND5	150
IND6	100
AGR1	100
REL1	100
GOV1	100
GOV2	150
EDU1	100
EDU2	150

Table 10 Annual sales values and business inventory percentages. Inventory damages are the business inventory percentage of the annual sales. Source: FEMA HAZUS Inventory Technical Manual 4.2.3.

Occupancy Type	Annual sales [\$ /sq.ft] (2017)	Annual sales [\$ /sq.ft] (2021)	Business inventory [% of annual sales]
AGR1	156.00	172.47	8%
COM1	56.00	61.91	13%
COM2	81.00	89.55	10%

IND1	750.00	829.18	5%
IND3	733.00	810.39	5%
IND4	690.00	762.85	3%
IND5	459.00	507.46	4%

A.6.5 Road maximum damages

Error! Reference source not found. shows the 2017 and 2021-corrected damage values for road segments per number of lanes. These values were taken from the 2017 Deltares report “Assessment of alternative flood mitigation strategies for the C-7 Basin in Miami, Florida”.

Table 11 Damage values for road segments (2017 and 2021 values). *Extrapolated from report values.

Number of lanes per road segment	Damage cost estimate [\$ /ft] (2017)	Damage cost estimate [\$ /ft] (2021)
0	120*	132.67
1	120*	132.67
2	240	265.34
3	360	398.01
4	480	530.68
5	600*	663.35
6	720	796.02
7	840*	928.69
8	960*	1,061.36
9	1,080*	1,194.02
10	1,200*	1,326.69

Appendix B Damage functions

The SFWMD and Deltares curated a set of damage functions to be used throughout the district basins. The assignment of damage functions for different occupancy types and the sources of the damage functions are documented in this appendix. These damage functions can be modified at any time, which is described in Section 4.5.1 of the user manual.

For single family residential buildings (RES1) up to two stories, we used damage functions developed by USACE-IWR. These functions are approved damage functions including uncertainty estimates. These are referred to as ‘generic curves’ and are recommended when no site-specific damage functions are available.

USACE-IWR and FEMA expert elicitation curves¹⁹ were used for the occupancy types in Table 12. These curves do not have an approved status but have been used in several USACE feasibility studies.

For the remaining building occupancy types, we use the most recent HAZUS damage functions from the HAZUS 4.0 SQL database.

Table 12 Occupancy Types of which damage functions from IWR and FEMA expert elicitation are available.

Occupancy Type	Description
RES2	Mobile Home
RES3	Multi-Family Dwelling
RES4	Temporary Lodging
RES5	Institutional Dormitory
COM1 – Restaurant*	Retail Trade – Restaurant
COM3	Personal and Repair Services
COM4	Business/Professional/Technical Services
COM6	Hospital
IND2	Light Industrial
REL1	Church/Membership Organizations
EDU1	Schools/Libraries

* Remaining COM1 (retail) categories were assigned the HAZUS COM1 average damage function

For **roads**, the same approach is used as in the 2017 report ‘Assessment of alternative flood mitigation strategies for the C-7 Basin in Miami, Florida’. In that project, Miami-Dade County staff indicated that roads inundated for more than 48 hours must be rebuilt due to damage to the base materials. Based on a conservative recession rate of 0.3 feet per day, the study concluded that damages occur when the flood depth on roads exceeds 0.6 feet. We therefore constructed a damage step function with 100% damage at 0.6 ft flood depth and higher.

¹⁹ The source of these curves is the Draft Report Nonresidential Flood Depth-Damage Functions Derived from Expert Elicitation, April 2009, Revised 2013. FEMA Contract Number HSFHQ-06-D-0162. Task Order HSFHQ-08-J-0014. Not for distribution, but data shared by USACE.

Appendix C Damage assessment methodology

The flood SFWMD Flood Impact Assessment Tool has as its damage calculation core the Deltares-developed tool Delft Fast Impact Assessment Tool (Delft-FIAT). This appendix describes Delft-FIAT and the damage assessment methodology built into it.

C1. About Delft-FIAT

Delft-FIAT is a fast, free Python-based flood impact assessment tool developed and continuously improved by Deltares, that rapidly assesses the direct economic impacts to buildings, utilities, and roads for input flood depth maps. Fast impact modeling removes bottlenecks in climate adaptation planning, allowing for the large numbers of calculations needed to understand the effectiveness of adaptation options and the changes in damage and risk as climate and socio-economic conditions change.

Delft-FIAT works with an easy format for exposed assets, consisting of information on the location, exposed value, finished floor elevation, ground elevation, and associated depth-damage function. A simple configuration file specifies the location of depth-damage functions and flood maps, as well as return periods of flood maps if calculating risk.

Delft-FIAT is flexible, which means the exposure data, damage functions, and flood maps can be modified by the user. It also means the tool can be connected to other software, such as flood modeling or GIS software, and that the program can be called many times, to assess uncertainty in damage estimates, or to run for many flood scenarios.

Delft-FIAT can be tailored to accommodate user needs, outputting metrics important to communities such as the number of homes affected by the 10-year flood event, or aggregating damage and risk over social vulnerability classes to assess equity in adaptation planning. The exposure dataset for Delft-FIAT contains important information for each object in the area of interest. This includes the type of object, location, first floor elevation, maximum potential damage, and associated damage function.

C2. How Delft-FIAT works

Delft-FIAT combines exposure data and flood maps with damage curves to calculate the flood damages and risk per object, where an object can be a building, a road segment, or a utility.

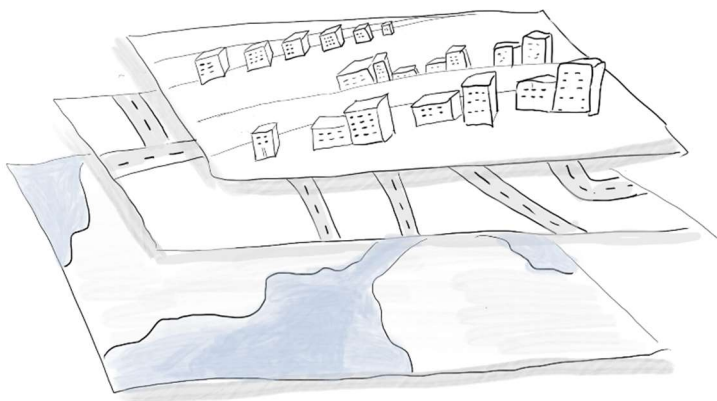


Figure 26 Conceptual impression of Delft-FIAT. Flood maps are overlaid on building, utility, and road data (and combined with damage functions) to determine damages.

The main workflow of Delft-FIAT is illustrated in Figure 27. For each object specified in the exposure dataset, where the object can be a building, a utility, or a road segment, the water level or water depth is extracted. When the water level is extracted, the ground elevation of the object, given in the exposure dataset, is subtracted to derive the water depth. The water depth inside the building is obtained by subtracting from the water depth the *first floor elevation*, which is the height of the object above ground level. This water depth is then used with the damage function assigned to the object in the exposure dataset to determine the fraction of total damage. The maximum damage for the object, also given in the exposure dataset is then multiplied with the damage fraction to determine the damage to the object. Damages can be calculated separately for structure, content, and any third type of damage (such as inventory) which the user is free to define. When the user inputs multiple return-period flood maps, Delft-FIAT will – in addition to calculating return period damages – also automatically calculate expected annual damages, a common metric for risk.

Each of the steps in the workflow are elaborated below.

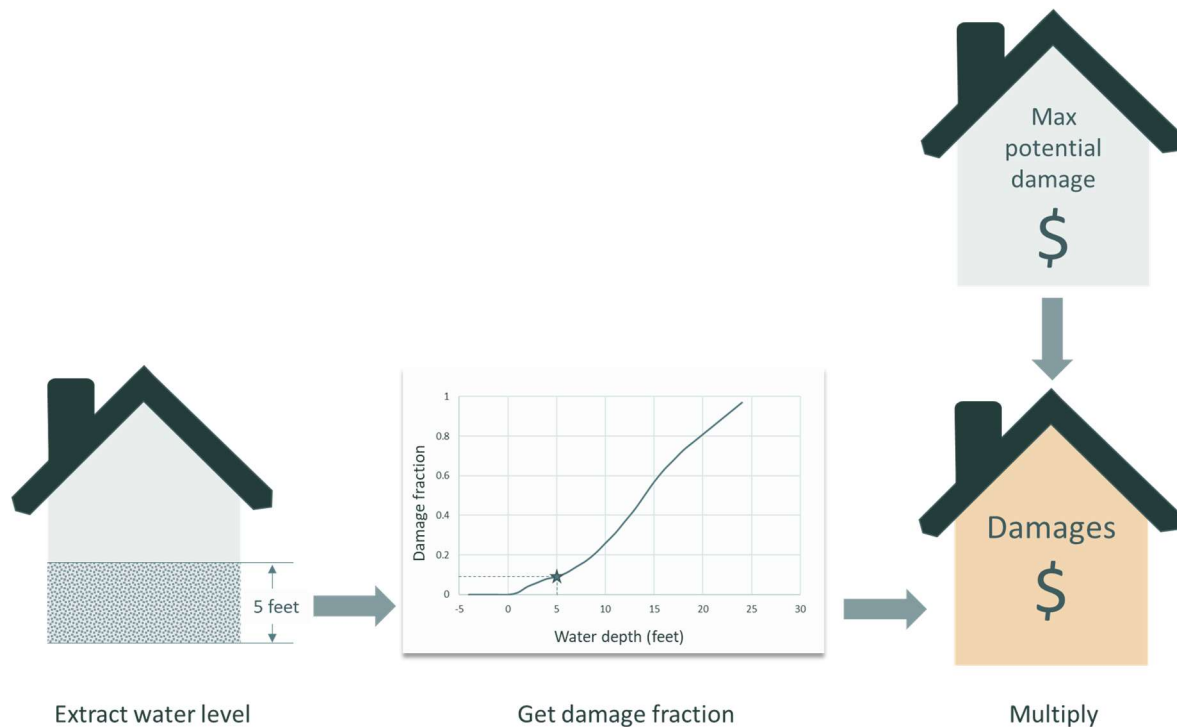


Figure 27 High-level workflow of Delft-FIAT. For each object, the water level is extracted within the building or on the road, the damage fraction is determined using damage functions, and the combination of the damage fraction and the maximum potential damages returns the damage to the building or road.

C.1.1 Extracting the water depth at object locations

Delft-FIAT extracts the water depth or water level from the flood map at the location of each of the objects in the exposure dataset. When the user has specified an object polygon shapefile in the exposure dataset (see Section 4.2), there is an option to extract the water level at the center point, or over the entire object area, and use either the maximum or average value for the damage calculation (this option is in the configuration file; see Section 4.4). When the user chooses an areal water depth extraction, Delft-FIAT retains information on the fraction of the area that was inundated, and will

correct the damage using this fraction. For example, if 80% of a building is flooded, Delft-FIAT will use the water depth over the flooded portion in the damage calculation, but will later reduce the damages to 80% to compensate for the non-flooded area of the building. If the user has input a water elevation map, Delft-FIAT will subtract the ground elevation at the location of the object to derive the water depth. For each building, the first-floor elevation is subtracted from the water depth to derive the inundation water depth (above the first floor). This step is omitted for roads.

C.1.2 Determining the fraction of total damage

For each object, Delft-FIAT makes use of its associated damage function that was assigned in the exposure dataset. The inundation water depth of the object is used to determine from the damage function the fraction of total damage (see Section 4.1 for a description and example of damage functions).

Delft-FIAT offers the option of three types of damages per object: structural, content, and 'other'. The 'other' type is a catch-all for any damage type besides structural or content. This can be used, for example, for commercial building inventory damage. Delft-FIAT calculates a damage fraction for each damage type for which a damage function was assigned in the exposure dataset.

C.1.3 Calculating damages

Per object, Delft-FIAT multiplies the damage fraction obtained with the inundation water depth and the damage function by the maximum potential damage. In the exposure data, each damage type for which a damage function was assigned must also contain a value for the maximum potential damage. This multiplication gives the damage value per damage type. Delft-FIAT then sums the damages over the different damage types to derive a value of total damage for the object (for example structural damage and content damage).

C.1.4 Calculating risk

When a user inputs multiple return period flood maps, Delft-FIAT will calculate the damages for each return period and will also integrate the damages to calculate the expected annual damage, a metric for risk. Figure 28 illustrates how the expected annual damage is calculated using the return period damages. The figure shows an annual frequency of exceedance on the horizontal axis; that is the inverse of the return period (so the 100-year return period damages are the same as the damages with an annual frequency of 1/100). The corresponding return periods for the example in Figure 28 are 5, 10, 25, and 100 years in one case, and 5 and 100 years in a second case. The figure shows a linear interpolation between calculated damages. In the Delft-FIAT program, log-linear interpolation is used, which is more accurate when the spacing between damage frequencies is non-linear. When integrating damages to calculate risk, Delft-FIAT must make an assumption about the damages that occur for (1) less frequent events than the least frequent event calculated (in the example, this is 1/100-year event), and (2) more frequent events than the most frequent event calculated (in the example, this is the 1/5-year event). Delft-FIAT assumes damages remain constant for more extreme, less frequent events than the least frequent event assessed, and that there are no damages for more minor, high frequent events than the most frequent event assessed.

Delft-FIAT will calculate risk if there are at least two return period events entered. However, the accuracy of the expected annual damages (EAD) reduces with fewer return periods. This is illustrated in Figure 28. In the figure, the EAD calculated with two return frequencies is a large overestimate

compared with the case of using four return frequencies. The non-linearity of the damage-frequency curve will determine how many return frequencies are required. It is recommended to use at least four.

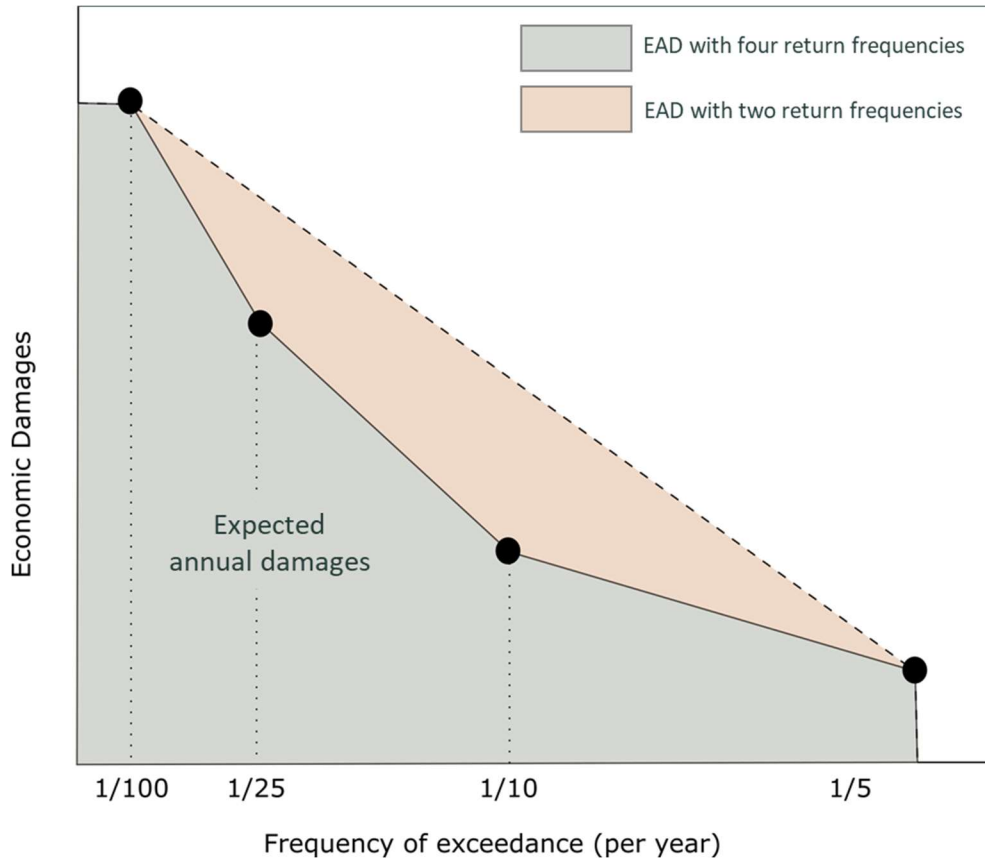


Figure 28 Illustration of the risk calculation in Delft-FIAT for the case of two and four evaluated return frequency events. Damages are interpolated (log-linearly in Delft-FIAT) between return frequencies, and the area beneath the damage-return frequency curve is the estimate of EAD.