TETRA TECH

MEMO

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Subject:	KC Levee Breach Analysis, Mapping, and Risk Assessment: Economic Inventory Status Memo

1. INTRODUCTION

1.1. PURPOSE

The purpose of this memorandum is to document the status of inventory data gathering and to describe the major datasets, information sources, and references that will be used in components of Subtask 8, Economic Evaluation of Flood Risk. Therefore, this memorandum achieves concurrence among the consultant team and King County, providing the data and information sources that will be relied upon for the risk evaluation. The information documented in this memorandum will provide the basis for development of the economic evaluation approach for each basin that will be documented in a technical memorandum as part of Subtask 8.2, Evaluation Approach.

1.2. CONTEXT FOR INVENTORY DATA COLLECTION

Inventory data in support of the economic analysis includes information that describes the people, property, and infrastructure which are at risk of impacts from flooding. These assets or resources that are at risk are grouped into *impact categories*, with the intent that a specific *evaluation methodology* will be developed for each impact category in future Subtask 8.2 that will detail the modeling methods. As scoped, inventory data is limited to existing and publicly available information. As such, agreement upon the breadth and depth of inventory data that will be relied upon, and manner in which any data gaps will be filled based on publicly available information, will inform the development of the evaluation methodology.

1.3. SCOPE OF WORK

This memorandum provides the deliverable *Inventory Status Memo*, addressing Subtask 8.1 as part of the economic evaluation of flood risk for the Lower Raging, Lower Tolt, and South Fork Snoqualmie River basins (Tasks 300, 400, and 500) of the King County Levee Breach Analysis Mapping and Risk Assessment study (LBAMRA). Table 1 summarizes the relevant scope and notes the sections of this memo which address each scope item.

Table 1 – Scope of Work Reference Table

	Scope Item	*Document Reference*
A	Inventory the floodplain and compile land use information to differentiate land use types and identify roads, utilities, and critical facilities.	Sections 2.0, 3.0, and 4.0 discuss impact categories which characterize land use and the built environment.
B	Compile demographic information and develop estimates of population at risk, vulnerable populations, and identification of other ESJ considerations to supplement the quantitative economic evaluation of flood risk.	Each impact category discussion includes a subsection that describes how that category will be considered in the ESJ analysis. Section 5.0 discusses the ESJ analysis directly.

	Scope Item	*Document Reference*
C	Collect and verify damage function data for specified risk categories. Default damage functions and inventory data obtained from the FEMA Hazus database shall be checked for suitability and used in the analysis if appropriate. Data sources shall be limited to the existing Hazus Level 2 database, publicly available and published industry, and agency reports, previous USACE studies, data provided by King County, and Hazus data.	Each impact category subsection describes damage function data that was collected and verified.
D	Extent of inventory should allow for maximum extent of inundation based upon input from geotechnical and hydraulic elements of the project.	The inventory information for the built environment has been assembled according to the hydraulic model domain for each basin. Relevant sections include 2.0, 3.0, 4.0. Extents will be refined when model outputs are available.
E	The deliverable will be a simple memorandum noting the status of inventory development and bulleting the major datasets that will be incorporated into the Economic evaluation approach memorandum.	This document is the deliverable that satisfies this scope item.

The following impact categories address scope items A through D, from Table 1. Note that not all impact categories may be applicable in all basins. The Evaluation Approach Memo will include inventory data summarization for each basin which identified the final proposed list of impact categories for each basin, selected from that list of impact categories identified in this memorandum.

A total of 19 potential impact categories are discussed in this memorandum. As shown in Table 2, these categories are grouped into 4 summary categories according to the nature of the impact.

Table 2 – Summary of Impact Categories

Direct Physical Damages	*Response and Restoration Costs*	*Other Economic Costs*	*Equity, Social Justice, Public Safety, and Health*
Structures, Contents, and Inventory	Debris Removal	Roadway Detour and Delay*	Equity and Social Justice Indicators
Direct Vehicle	Building Cleanup	Business Disruption	Residential Evacuation, Subsistence, and Reoccupation
Direct Road	Emergency Response	Recreation Loss	Public Services and Critical Facilities
Direct Bridge	Landscape Restoration	Lost Worker Productivity	Utility Loss of Service Impacts
Direct Critical Utilities			Mental Stress and Anxiety
Agricultural Loss			

* Other modes such as rail and air were excluded following preliminary review of the basins, which determined there were not rail or air transportation assets in the floodplain. Should other basins added to the scope through modification, the addition of detour and delay impacts for other transportation modes may occur.

1.4. ORGANIZATION OF THIS MEMORANDUM

This memorandum is organized according to the potential[1] impact categories that will be modeled in the economic evaluation of flood risk. Each of the summary impact categories shown in Table 2 (Direct Physical Damages; Response and Restoration Costs; Other Economic Disruptions; and Equity, Social Justice and Health) is addressed in terms of the data inventory status and the proposed use of the data is summarized. For each summary impact category, the following topics are addressed:

- Definition of the proposed impact category;
- Summary of the inventory data proposed for use;
- Summary of the damage functions proposed for use; and
- Summary of overall inventory status.

Following the impact category summaries, Section 6 documents the QA/QC for the development of this deliverable, and Section 7 lists the proposed data sources.

2. DIRECT PHYSICAL DAMAGES

Direct physical damages include damages to buildings, vehicles, roads, bridges, other facilities, and agriculture. These are directly impacted due to flood waters and are distinct from other economic impacts such as response and restoration, business interruptions and other indirect impacts, and also

[1] The final list of impact categories to be included in the modeling will be defined and coordinated with King County as part of Subtask 8.2, Evaluation Approach Memorandum.

separate from environmental justice impacts although equity considerations are highlighted for each of these subcategories.

2.1. Structure, Contents, and Inventory

This impact category describes the building-related losses associated with direct contact with floodwaters. The types of buildings included are based on occupancy and are outlined in Section 2.1.2. The impact category includes:

- *Structure damage* is an estimated dollar value of damage to structural components of the building, such as foundation, walls, and utilities.
- *Content damage* is an estimated dollar value of damage to non-structural components of the building, such as furniture, fixtures, cabinetry, and other personal property or commercial equipment.
- *Inventory damage* is applicable only to non-residential buildings that contain business inventory and is an estimated dollar value from loss of inventory that is ruined by floodwaters.

These impacts are estimated as a function of the depth of flooding at the building, relative to the building's first finished floor elevation. This depth of flooding is read against a depth-damage function (DDF), which provides the percent loss of structure, content, and inventory value at a given flood depth and a given total building replacement value[2]. Therefore, the economic inventory items needed for evaluation of this impact category include information regarding building attributes sufficient to allow identification and use of an appropriate DDF for each building.

2.1.1. Inventory Data

Best available building information is available from the King County Department of Assessment. In order to capture the maximum potential extent of inundation based on future outputs from the geotechnical and hydraulic models, inventory extent was defined based on the hydraulic model domain for each basin. Based on this domain, a request was made for necessary data on 1,211 parcels for the Lower Tolt River, 1,276 parcels for the Lower Raging River, and 6,135 parcels for the South Fork Snoqualmie River. Based on coordination with the Assessor, all necessary building information is available, including attributes that will allow definition of building type/use, size, and replacement value, and is sufficient to assign the appropriate DDF for each building. First floor elevation information, will be sampled as necessary based on existing imagery, including Google Street View, or building imagery available on the King County website. First floor information has also been recently developed for a separate King County study on the Tolt, and it is expected that data from that effort will be available for this study. The resultant building inventory and property characteristics database is also a key input to other impact categories discussed in this memorandum and provides a second data source to identify and describe critical facilities in the study area in addition to the Hazus model database (as discussed in Section 2.5).

2.1.2. Damage Function Data

The use of DDFs to estimate flood inundation impacts is the primary methodology employed by federal agencies such as the USACE and FEMA. Both of these agencies have published a variety of DDFs for many building types. Currently, there are two primary sources of standardized DDFs, one available from each agency. The USACE's Risk Management Center maintains the LifeSim model (USACE 2021), which supports event-based flood damage estimation. The LifeSim model contains a library of 40 standard building *occupancy types*, where each occupancy type has its own associated DDF. The second source is FEMA's Hazus model, which supports FEMA's multi-hazard damage estimation mission. Based on review of these sources, the LifeSim library of standard DDFs includes a complete

[2] Note that the database will support estimation of damages in terms of replacement cost or depreciated replacement value. For general risk characterization, reporting of depreciated values is recommended. This will be finalized in coordination with King County as part of Subtask 8.2, Evaluation Approach Memorandum.

and representative set of residential and non-residential DDFs, and no additions were identified from the Hazus library. USACE DDFs for residential structures are published in EGM 04-01, *Generic Depth-Damage Relationships for Residential Structures*, and are based on a USACE statistical analysis of past studies to generate standardized DDFs. The standard non-residential DDFs in LifeSim reflect a selection of riverine flooding damage curves from past USACE studies or from the FEMA HAZUS model default functions. As such, Table 3 presents the following preliminary list of occupancy types (and DDFs) that reflects the 40 standard occupancy types used in LifeSim.

Table 3 – List of Occupancy Types and DDFs

Occupancy / DDF	*Description*
AGR1	Agriculture facilities and offices
COM1	Retail trade
COM2	Wholesale trade
COM3	Personal and repair services
COM4	Professional and technical services
COM5	Banks
COM6	Hospitals
COM7	Medical office and clinic
COM8	Entertainment and recreation
COM9	Theaters
COM10	Parking garages
IND1	Heavy industrial
IND2	Light industrial
IND3	Food/drugs/chemicals
IND4	Metal/minerals processing
IND5	High technology
IND6	Construction facilities and offices
EDU1	Grade schools and administrative offices
EDU2	Colleges and universities
GOV1	Government – general services
GOV2	Government – emergency response
REL1	Churches and non-profit organizations
RES1-1SNB	Single family residential structure that is 1 story tall with no basement.
RES1-1SWB	Single family residential structure that is 1 story tall and has a basement.
RES1-2SNB	Single family residential structure that is 2 stories tall with no basement.
RES1-2SWB	Single family residential structure that is 2 stories tall and has a basement.
RES1-3SNB	Single family residential structure that is 3 stories tall with no basement.
RES1-3SWB	Single family residential structure that is 3 stories tall and has a basement.
RES1-SLNB	Single family residential structure that is a split-level structure with no basement.
RES1-SLWB	Single family residential structure that is a split-level structure and has a basement.
RES2	Manufactured housing
RES3A	Multi Family Residence – Duplex

Occupancy / DDF	*Description*
RES3B	Multi Family Residence – 3 to 4 units
RES3C	Multi Family Residence – 5 to 9 Units
RES3D	Multi Family Residence – 10 to 19 Units
RES3E	Multi Family Residence – 20 to 49 Units
RES3F	Multi Family Residence – more than 50 Units
RES4	Temporary lodging (e.g., Hotels, motels, or other buildings used for temporary lodging)
RES5	Institutional dormitories
RES6	Nursing Homes

2.1.3. Preliminary Socioeconomic and ESJ Considerations

The structure inventory will serve as the smallest geographic unit of analysis for much of the ESJ analysis proposed for this study. The value and types of structures, as well as ownership rates, can give some insight into household incomes (e.g., mobile homes are lower value than permanent structures). Race and ethnic population data will be reviewed based upon King County American Community Survey (ACS) data and any other information from the King County Assessor's database (e.g., housing tenure as available). For non-residential properties, daytime/workday population will be reviewed based on the types of businesses and general income/race statistics for the industrial code. Also, FEMA HAZUS methodology for selected non-residential occupancies will be reviewed and used if relevant.

2.1.4. Inventory Status Summary

At the time of writing, data from the Assessor has been received and is being processed. Based on preliminary review, the Assessor's data is complete and meets the needs identified in this memo. No inventory issues are anticipated in the use of the Assessor's data to support estimation of impacts to building structure, contents, and inventory.

2.2. Direct Vehicle

This impact category estimates loss in vehicle value due to contact with floodwater. Vehicle impacts are modeled similar to building impacts, using a DDF that related depth of flooding to percent loss of vehicle value.

2.2.1. Inventory Data

A vehicle inventory is created as a function of the building inventory, where an average number of vehicles will be assigned to structures by occupancy type. For residential inventory, the average number of vehicles is obtained from U.S. Census Bureau datasets, such as the American Community Survey program and information from the Bureau of Transportation Statistics (BTS 2019). For non-residential inventory, sampling will be conducted on relevant occupancy types within the study area. Vehicle value will be based upon the latest published information from automotive industry sources, such as the Edmunds Used Vehicle Outlook (Edmunds 2020). For commercial vehicles, industry publications will be used to estimate average value for a typical commercial vehicle.

2.2.2. Damage Function Data

Based on past studies, the USACE has developed a standardized vehicle DDF for personal vehicles by vehicle type (USACE 2009). Recent work on the LifeSim model has resulted in a single aggregated DDF for personal vehicles as well. For commercial vehicles, an adjusted DDF will be developed based on the estimated difference in ground clearance between personal vehicles and a typical commercial vehicle (e.g., a semi-trailer truck).

2.2.3. Preliminary Socioeconomic and ESJ Considerations

While this impact category addresses the monetary value loss from flooded vehicles, the information may inform qualitative description of ESJ impacts to mobility. Such impacts will be considered in the context of the King County Determinants of Equity discussed in Section 5.

2.2.4. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified. The population of the vehicle inventory is pending, as it will be informed primarily by the final building inventory. All necessary data is available, and no inventory issues are expected in the computation of these impacts.

2.3. Direct Road

Direct impacts to roads are typically difficult to quantify in a generalized manner for a large floodplain, as the susceptibility of a road to flood damage is largely a function of the road segment's susceptibility to erosion, which is in turn difficult to quantify in aggregate across all roads in a floodplain. As such, there are no standardized values available for road damage from flooding.

For this study, the expected recommended approach in the Evaluation Approach memo (future Subtask 8.2) will be to use the hydraulic modeling results to identify a threshold, based on depth and/or velocity, which is reasonably likely to induce roadway damage. With this approach, the identification of damaged roads would be directly tied to the flood modeling results. The addition of this step acknowledges that not every road segment experiences damage when inundated. To assess the reasonableness of the resultant frequency-damage function, it will be compared to historical damage information available from King County, and/or past federal flood risk studies, as available.

2.3.1. Inventory Data

A roadway inventory will be competed for each basin study area using the USACE LifeSim model, which facilitates generation of a road network based on the OpenStreetMap API (OSM 2021). The resultant GIS dataset will contain road centerlines and attribute information about the roads. This network will be cut into segments (e.g., ½-mile long segments) and a representative damage tabulation point will be assigned along each reach (e.g., the mean elevation along the segment).

2.3.2. Damage Function Data

Following Hurricane Katrina and its associated flooding, the USACE New Orleans District collected and elicited information about damage to roadways and used this information to develop depth-to-dollar damage functions for two types of roads, major/secondary highways, and other streets (USACE 2012). This function will be adjusted for geography and price level and applied to the study areas. Note that King County has provided historical damage information from four recent flood events that contains estimates of roadway damages for the purpose of FEMA Preliminary Damage Assessment reports (King County 2021a). This data will be reviewed in detail and will be used to adjust the standardized values obtained from the reference USACE source.

2.3.3. Preliminary Socioeconomic and ESJ Considerations

While this impact category addresses the monetary value loss from road flooding, the information may inform qualitative description of ESJ impacts to transportation and mobility. Such impacts will be considered in the context of the King County Determinants of Equity discussed in Section 5.

2.3.4. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified. The road network GIS layers for the entire model hydraulic domains have been generated and will be clipped to flood extents once hydraulic outputs become available. The specifics of the depth/velocity thresholds for identification

of damaged roads will be coordinated with the hydraulic element of the consultant team and documented in the Evaluation Approach memo (subsequent Subtask 8.2). No inventory issues are expected in the computation of these impacts.

2.4. Direct Bridge

This impact category addresses the potential for structural damage to bridges from flooding. Because damage to the bridge structure is dependent on velocities as well as depth, no standardized DDF is available for bridges. However, the FEMA Hazus model contains a bridge damage module that can estimate the percent damage on a bridge and the probability of the bridge being functional for a given flood event. This assessment in Hazus is based on failure risk for different magnitude flood events as a function of scour risk. Scour risk for bridges in the USFHWA National Bridge Inventory (FHA 2021) are prepopulated in Hazus and may be leveraged in this analysis. If more recent or refined bridge risk data is available from King County or the hydraulic modeling team, in a format that can be readily applied to the HAZUS methodology, it will be incorporated in this analysis.

2.4.1. Inventory Data

The primary inventory data for this impact category is the National Bridge Inventory, which is prepopulated in the FEMA Hazus database and includes generalized bridge repair cost information for each bridge. The use of the HAZUS methodology to compute bridge risk will also rely on depth outputs from the hydraulic modeling for modeled flood events, which will be coordinated with the hydraulic modeling team.

2.4.2. Damage Function Data

The FEMA HAZUS methodology contains damage functions which estimate the percent damage to a bridge and the probability of the bridge being functional for a given flood event. In combination with a general estimate of total replacement cost, a frequency-damage function may be developed for each modeled bridge. Note that King County has provided historical damage information from four recent flood events that contains some information about damage to bridges for the purpose of FEMA Preliminary Damage Assessment reports (King County 2021a). This data will be reviewed in detail and will be used to adjust the standardized values obtained from the reference USACE source.

2.4.3. Preliminary Socioeconomic and ESJ Considerations

While this impact category addresses the monetary value loss from bridge damage, the information may inform qualitative description of ESJ impacts to transportation and mobility. Such impacts will be considered in the context of the King County Determinants of Equity discussed in Section 5.

2.4.4. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified and no inventory issues are expected in the computation of these impacts.

2.5. Direct Critical Utilities

This impact category addresses direct impact to critical utility infrastructure not already addressed Sections 2.1 (buildings), 2.3 (roads), and 2.4 (bridges). In each basin, there may be other utility infrastructure at risk of damage, such as water treatment plant or electrical substation infrastructure. There may also be utility infrastructure whose location in the floodplain will be mapped but damages will be not computed, such as buried arterial utility lines. In general, utility networks and connections to individual properties will not be inventoried or mapped.

Note that this impact category addresses direct damage to critical utility infrastructure. Loss of service impacts and equity and social justice impacts related to critical facilities are discussed in Section 5. The definition of critical facilities for the KC LBAMRA is presented in Section 5.

2.5.1. Inventory Data

The FEMA Hazus model contains a default database of critical utility infrastructure that provides facility type and value. This dataset will be cross-referenced with the inventory built from the Assessor's database and refined based on available data to ensure that the inventory of critical facilities is complete.

2.5.2. Damage Function Data

The FEMA Hazus model provides DDFs for critical utility infrastructure by facility type. These functions will be used to estimate impacts. Infrastructure valuation will be based upon local data from King County as available, with the option to use the generalized facility cost information available in Hazus where needed. The use of the Hazus methodology to compute impacts is dependent on the availability of hydraulic outputs to provide depths by flood event. Note that King County has provided historical damage information from four recent flood events as collected for the purpose of FEMA Preliminary Damage Assessment reports (King County 2021a). Preliminary review of the data found that some damages to utility facilities was noted. This data will be reviewed in detail and will be used to adjust the standardized values obtained from the reference USACE source.

2.5.3. Preliminary Socioeconomic and ESJ Considerations

While this impact category addresses the monetary value loss from physical damage to critical utility infrastructure, the information may inform qualitative description of ESJ considerations and impacts related to access to critical facilities by providing the inventory of critical facilities for consideration in that evaluation. Such impacts will be considered in the context of the King County Determinants of Equity discussed in Section 5.

2.5.4. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified and no inventory issues are expected in the computation of these impacts.

2.6. Agricultural Loss

Flood risk to agricultural production is typically estimated as a function of crop loss and the associated reduction in income due to flooding of crops and pasture. The USACE provides a standardized methodology (USACE 1987) for such an analysis in the LifeSim model. First, an inventory acreage by crop type is developed. Then, a production budget is entered for each crop. Based on the specified seasonality of flooding, the model computes the impacts to crops, the associated loss in yield and therefore sales, and adjusts for production expenditures that were never realized due to the flooding.

In addition to crop-related losses, there may be other farm-related losses that would need to be separately evaluated, including cost of restoring fields, farm roads, and equipment to regular operation. For example, some farms incur costs to drain fields or address sedimentation and may experience damage to specialized equipment or infrastructure, such as on-farm roads or irrigation equipment, or may experience adverse livestock impacts. Such losses will be estimated as supported by available historical information, stakeholder input about on-farm assets and risk, or application of an estimate per-acre cost for restoration activities.

2.6.1. Inventory Data

The crop loss approach in LifeSim requires identifying acreages of cropland in the floodplain, by crop type. This step is automated by LifeSim, allowing import of a GIS layer from the USDA Cropland Data Layer that covers the study area. The next requirement is the specification of enterprise crop budgets by crop type (planting and harvest dates, yield, price, monthly production expenditures, and optionally a substitute crop that might be planted if the field floods late in the season). This data is not provided in LifeSim, though is commonly available from previous studies or from the local agricultural extension.

For this study, the database maintained by Washington State University (WSU 2021) will be used unless local budgets are available from stakeholders or King County.

2.6.2. Damage Function Data

In the LifeSim model, impacts are affected flood duration and flood timing (time of year).

Specification of an assumed flood date affects how much production expenditure has occurred at the time of flooding for each crop type, the extent to which the planted crop can recover from the flood without impacting yield, and whether the farmer would have time to replant an alternate crop during the same year to recoup some losses. These adjustments are made by the model based on the monthly production budgets that are specified.

Specification of duration-damage functions by crop may utilize one of three generalized curves in LifeSim, for 1-day, 3-day, and 7-day inundation durations. For this study, the hydraulic outputs will be reviewed to determine which of the generalized curves is most appropriate for the study area.

2.6.3. Preliminary Socioeconomic and ESJ Considerations

This impact category addresses the monetary value loss from physical damage to agricultural properties, and as part of the ESJ analysis, the race/ethnicity of farmworkers will be reviewed (to the extent possible) for differential income impacts to farmworkers. The information may inform qualitative description of ESJ impacts related to economic opportunity and the importance of the King County agricultural economy. The analysis will also describe potential impacts to agricultural small-business enterprises, such as U-Pick berry farms or seasonal agrotourism (e.g., pumpkin patches). Such impacts will be considered in the context of the King County Determinants of Equity discussed in Section 5.

2.6.4. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified. No inventory issues are expected in the estimation of these impacts.

3. RESPONSE AND RESTORATION COSTS

3.1. Debris Removal

Following a major flood event there may be substantial debris requiring cleanup, such as building-related debris and natural debris (vegetation, sediment). The FEMA Hazus model contains a debris tonnage estimation methodology that addresses building debris as a function of building structural components (founding, structure, and finishes), but does not address content, inventory, or natural debris. However, this Hazus methodology represents the best-available debris estimation approach for large inventories. Consideration of building content and interior cleanup is considered separately in Section 3.2. Building Cleanup.

For this debris removal category, impact estimation relies on the depth grids that will be developed by the hydraulics element of the consultant team and the building inventory developed as part of this economics effort. The Hazus methodology will then be used to generate a frequency-to-debris-tonnage relationship. Tonnage may be converted to volume (cubic yards) based on published FEMA Debris Estimating Guides (FEMA 2010) typically employed for disaster recovery field operations. This information may then be converted to a frequency-damage relationship based on average debris removal costs per cubic yard.

3.1.1. Inventory Data

The inventory data required for estimation of these impacts will be finalized building inventory and hydraulic depth grids, both of which are required to implement the Hazus methodology to estimate

debris tonnage. The building inventory is described in Section 2.1. Hydraulic depth grids are being developed by the hydraulic element of the project team under separate subtasks.

3.1.2. Damage Function Data

A 2020 study by the USACE Portland District published a range of costs from a minimum of $8 to a maximum of $46 per cubic yard, with an average of $28 for the cleanup, trucking, and disposal of flood debris (USACE 2020). This source will be adjusted for price level and provides the parameters of a triangular distribution for the estimation of debris removal impacts. Note that King County has provided historical damage information from four recent flood events, some of which contain estimates of damage related to debris removal (King County 2021a). This data will be reviewed in detail and will be used to adjust the standardized values obtained from the reference USACE source as appropriate.

3.1.3. Preliminary Socioeconomic and ESJ Considerations

This impact category addresses the monetary impact of structural debris cleanup following a flood. Recent research suggests that elsewhere in the country, the cleanup workers for these jobs include low wage, marginalized, and sometimes undocumented immigrant employees. Information on this topic will be reviewed and make up a qualitative discussion of this topic in the context of ESJ.

3.1.4. Inventory Status Summary

All of the inventory data needs are accounted for, and no inventory issues are expected in the computation of these impacts.

3.2. Building Cleanup

The building cleanup impact category addresses the cleanup costs that would be incurred at residential buildings and some non-residential buildings for the extraction of floodwaters, drying out of the buildings and contents, and any necessary decontamination treatments such as mold and mildew abatement (these impacts are separate from the debris removal impacts discussed previously in Section 3.1). Building cleanup costs will be applied to those buildings whose occupancies indicate there would be a need for such cleanup activities, such as residential buildings, commercial buildings, and public buildings, where engagement with the public is generally expected. Building cleanup impacts will not be estimated for occupancies such as warehouses and industrial buildings, where such incremental cleanup costs may not be applicable due to differences in building materials, contents, and public accessibility.

3.2.1. Inventory Data

The inventory data necessary for cleanup costs is contained in the building inventory. Cleanup costs will be applied to building whose occupancies indicate there would be a need for such cleanup activities, such as residential, commercial retail, and public buildings. Cleanup costs will be calculated by structure based on a cleanup unit cost per square foot for the building's first floor square footage. Estimated cleanup unit costs are available from previous USACE studies, and generally are around $10 per square foot (USACE 2020a) of finished first floor area.

3.2.2. Damage Function Data

Recent studies by the USACE have developed a DDF for cleanup costs, assigning 100% of cleanup cost impacts for flood depths greater than 3 feet, and interpolating impacts at lesser depths. This function will be modified for application to study area occupancies and foundation types.

3.2.3. Preliminary Socioeconomic and ESJ Considerations

This impact category addresses the monetary impact of building cleanup following a flood. Recent research suggests that elsewhere in the country, the cleanup workforce for these jobs include low wage, marginalized, and sometimes undocumented immigrant employees. Information on this topic will be reviewed and make up a qualitative discussion of this topic in the context of ESJ.

3.2.4. Inventory Status Summary

All of the inventory data needs are accounted for, and no inventory issues are expected in the computation of these impacts.

3.3. Emergency Response

Emergency costs include those expenses resulting from a flood that would not otherwise be incurred. For example, the costs of flood fighting, increased costs of normal operations during the flood, and increased costs of police or fire service.

3.3.1. Inventory Data

The building inventory discussed in Section 2.1 will be used to calibrate estimated emergency costs from previous studies or other published information for use in the study areas.

3.3.2. Damage Function Data

Two USACE sources provide good information about estimating emergency costs associated with flooding.

The first is a report developed by the USACE New Orleans District (USACE 2012) which developed unit cost estimates and DDFs for several types of emergency costs, including emergency response roadway clearing, incremental hospital operating costs, police emergency operations per affected household, and fire emergency operations per affected household. The report also provides an estimate of relocation costs for stations that experienced substantial flooding.

The second is a recent USACE Portland District study on Columbia River (USACE 2020), which included elicitation of emergency operating costs for the Multnomah County Drainage District. This study provides activity-level cost information for flood fighting, inspections, road closures, and other operations in terms of labor, materials, and equipment. These costs will be leveraged to estimate local flood response costs for different size flood events to build a frequency-damage function.

Note that King County has provided historical damage information from four recent flood events that contains estimates of multiple types of damage for the purpose of FEMA Preliminary Damage Assessment reports (King County 2021a). This data will be reviewed in detail and will be used to adjust the standardized values obtained from the reference USACE source as applicable.

3.3.3. Preliminary Socioeconomic and ESJ Considerations

This impact category addresses the monetary impact of emergency flood response. The methodology for this category relies on identification of affected properties, which is addressed by the building inventory in Section 2.1. In addition to property, ESJ considerations related to emergency response include health and safety risk to people experiencing homelessness that may be within the floodplain, which will be considered qualitatively.

3.3.4. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified. No inventory issues are expected in the estimation of these impacts.

3.4. Landscape Restoration

Landscaping impacts are estimated based on a repair/re-landscaping cost proxy, where flooded facilities, such as parks, golf courses, and schoolyards, would incur landscape restoration costs.

3.4.1. Inventory Data

GIS analysis will be used to identify properties requiring substantial landscape restoration. A point inventory of such areas will be developed and attributed with the ground elevation at the facility centroid and the total size of the area in acres.

3.4.2. Damage Function Data

A recent USACE Portland District study developed an average landscaping restoration cost per acre of $28,000 (USACE 2020) and developed an accompanying DDF. This source facilitates computation of landscape restoration impacts in the economic model in the same manner that building impacts are calculated. Note that King County has provided some historical flood damage information that included damages at parks and recreation facilities (2021a). This information will be reviewed in detail and used to adjust the standardized value from the USACE source as appropriate.

3.4.3. Preliminary Socioeconomic and ESJ Considerations

This impact category addresses the monetary impact of repairing landscaped areas following a flood. Because major landscaped areas include parks, golf courses, and potentially other public or community spaces, the results of this analysis may be leveraged in the ESJ evaluation to qualitatively describe impacts to access to parks and natural areas, consistent with the King County Determinants of Equity.

3.4.4. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified. The population of the landscape area inventory is pending, as it will be informed by the final building inventory and related Assessor's data to identify parcels with major landscaping requirements. All necessary data is available, and no inventory issues are expected in the computation of these impacts.

4. OTHER ECONOMIC COSTS

4.1. Roadway Detour and Delay

When roads are flooded and impassable, vehicle occupants experience health and safety risks, as well as adverse economic impacts in the form of lost time due to detours and added vehicle operating costs on those detours. By estimating the volume of traffic affected by flooding in a given event, and estimating the necessary detour, the adverse economic impact can be calculated. Health and safety risk from flooded roadways will be characterized through GIS mapping, showing the nature and extent of roadway flooding for various hydraulic scenarios.

4.1.1. Inventory Data

A roadway inventory will be completed for each basin study area using the USACE LifeSim model, which facilitates generation of a road network based on the OpenStreetMap API (OSM 2021). The resultant GIS dataset will contain road centerlines and attribute information about the roads. Traffic counts are available from King County (2021) as well as from WSDOT (2021) and will be used to attribute flooded roads with estimated traffic volume and affected population. Necessary detours will be estimated based on a map analysis to identify reasonable detours for highways and major arterials for key flood events. Impacts to traffic on small local roads will not be analyzed, as it is typically assumed that trips experiencing significant detour and delay are accounted for by consideration of highways and major arterials.

4.1.2. Damage Function Data

The value of lost time for vehicle occupants can be estimated based on a USACE methodology for value of time saved. This methodology estimates an hourly value of time as a function of median hourly income, adjusted by the vehicle trip purpose (work trip versus recreation trip). This dollar value can be applied to the affected vehicle volume based on the duration of detour.

Increased vehicle operating costs are based on variable operating cost per mile, applied to the incremental mileage required for the detour. Variable operating costs per mile can be readily obtained from industry sources such as AAA (2020).

4.1.3. Preliminary Socioeconomic and ESJ Considerations

This impact category addresses the monetary impact of traffic detours and delays. Part of this analysis requires estimation of affected vehicle trips along relevant roadways. This information may be leveraged in the ESJ analysis to describe the population whose access to transportation and mobility may be affected. Such impacts will be considered in the context of the King County Determinants of Equity discussed in Section 5.

4.1.4. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified. The road network GIS layers for the entire model hydraulic domains have been generated and will be clipped to flood extents once hydraulic outputs become available. The specifics of the depth/velocity thresholds for identification of damaged roads will be coordinated with the hydraulic element of the consultant team and documented in the Evaluation Approach memo (subsequent Subtask 8.2). No inventory issues are expected in the estimation of these impacts.

4.2. Business Disruption (Regional Economic Impacts)

Inundation of non-residential properties can result in temporary closure of businesses while owners restore the functionality of the property. During this period of closure, businesses would experience loss in sales and revenue. Estimates of these direct revenue losses will be based upon estimated annual revenue per square foot by occupancy type. In addition to these direct impacts, the IMPLAN input-output model will be used to estimate indirect and induced employment and income impacts on the regional economy[3].

4.2.1. Inventory Data

The non-residential inventory will be identified based on the building inventory dataset that is being developed and is discussed in Section 2.1. For relevant structures, estimated annual sales (revenue) will be estimated based on information provided by King County Assessor (as available), and supplemented as necessary with generalized values for major occupancy types which are contained in the FEMA Hazus model database.

4.2.2. Damage Function Data

The duration of business closure drives the potential magnitude of direct revenue losses. The closure period would include the period of inundation, as well as a restoration period after flood water has receded. The FEMA Hazus model provides estimates of restoration as a function of flood depth for common non-residential occupancy types. The direct loss estimates will be segregated by major industry for use as inputs to the IMPLAN model. This industry segregation will be based on information provided by the King County Assessor in the building inventory discussed in Section 2.1.

[3] Direct revenue losses for flooded businesses are imported into IMPLAN to estimate the effects of sales and revenues loss on relationships with other industries and spending patterns in the economy (generating indirect and induced output losses). The Subtask 8.2 memorandum will contain more information about display and interpretation of results from the IMPLAN model.

4.2.3. Preliminary Socioeconomic and ESJ Considerations

This impact category addresses disruption of business activity from flooding. Results from the IMPLAN analysis will include job impacts. These job impact results may be used in the ESJ analysis to support characterization of ESJ impacts from flooding. Low-income workers may be more sensitive to even temporary income loss, and hence this could be more costly to those communities. Such impacts will be considered in the context of the King County Determinants of Equity discussed in Section 5.

4.2.4. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified. No inventory issues are expected in the estimation of these impacts.

4.3. Recreation and Natural Lands Access Losses

This impact category estimates the economic impact of flooding on affected recreation, and other natural land resources. For this impact category, the quantitative focus is on public outdoor recreation resources. Impacts associated with private or fee-based recreation facilities (e.g., museums, golf courses) are considered to be addressed by the business interruption analysis discussed in Section 4.2. For public recreation resources, the recreation value being evaluated is user willingness to pay for the resource, regardless of whether use fees are actually charged. For this purpose, the USACE provides the Unit Day Value methodology (USACE 2020b) which uses a scoring rubric to estimate the willingness to pay for recreation resources in the floodplain based on the context of other resources available locally and regionally. The methodology provides annually updated unit costs that can be applied to visitation counts to estimate resource value.

In addition to use value, there may be impacts from physical damage to recreation trails or related facilities.

4.3.1. Inventory Data

Recreation visitation data for public and free recreation areas, such as trails and parks, is not often available. However, if representative data is available from King County, it will be used to develop generalized use rates for different recreation areas or facility types. If local site-specific data is not available, existing published information from past studies or based on other existing published data for outdoor recreation within the study areas will be used to estimate use density, such as based on published visitation volumes for State parks (WSP 2021).

4.3.2. Damage Function Data

Losses will be estimated based on an estimated duration of closure for recreational facilities following flooding. The basis for these estimates will be inundation duration information that will be available from the hydraulic modeling and will be adjusted to account for reasonable inspection and restoration of facilities. Note that King County has provided some historical flood damage information that included damages at parks and recreation facilities (2021a). This information will be reviewed in detail and used to adjust the standardized value from the USACE source as appropriate.

4.3.3. Preliminary Socioeconomic and ESJ Considerations

This impact category addresses the monetary economic impact from reduction in quality and/or quantity of available recreation resources. Information about the type and location of recreation resources in the study area may inform characterization of ESJ conditions with regard to access to parks and natural areas. For example, different cultural groups might be more or less dependent on such resources. Also, subsistence fishing and hunting curtailments may be relevant to low-income as well as racial and ethnic populations. Finally, homeless populations could be more affected by loss of access to parks and other natural public properties. Such impacts will be considered in the context of the King County Determinants of Equity discussed in Section 5.

4.3.4. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified. No inventory issues are expected in the estimation of these impacts.

4.4. Lost worker Productivity

This impact category is intended to characterize worker productivity impacts that may arise due to adverse human health impacts following a flood, such as from extreme stress and anxiety. The FEMA BCA Methodology for the Hazard Mitigation Assistance grant program establishes a standardized dollar value per affected resident of the floodplain that represents the long-term decrease in productivity (i.e., income) associated with the aforementioned mental health impacts. Because these effects are a function of individual trauma and are an estimate of effects up to 30 months after the flood event, they are not considered duplicative of the business disruption impacts addressed in Section 4.2.

4.4.1. Inventory Data

This impact category is applicable to the affected residential building inventory. The relevant population will be identified for each flood event based upon hydraulic modeling outputs, the residential building inventory discussed in Section 2.1, and the average household size for King County from the best available U.S. Census data.

4.4.2. Damage Function Data

The FEMA BCA Toolkit version 6.0 contains the most recent standard values per affected resident. Based upon the FEMA literature, the standard values already incorporate a distribution of flood impact severity. As such, the standard loss value may be applied to all residences experiencing flood damage. Note, however, that the monetary results of this analysis are secondary to the qualitative characterization of human health impacts as it relates to the ESJ analysis.

4.4.3. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified. No inventory issues are expected in the estimation of these impacts.

5. EQUITY, SOCIAL JUSTICE, AND HEALTH

Equity, social justice, and health impacts are an essential component of understanding flood risk in a community. In addition to monetized expected annual damage, the analysis shall qualitatively consider other demographic and socio-economic considerations to inform and characterize flood risk. This shall include identification of critical facilities, populations at risk, vulnerable populations and ESJ considerations. For the following categories, impacts will be generally qualitative, and will include a spatial analysis of indicators of equity, social, and health within the study area population, overlaid with results of the flood risk modeling outputs.

5.1. Equity and Social Justice Impact Indicators

King County's Equity[4] and Social Justice[5] (ESJ) Strategic Plan provides a foundation for pro-equity investment decision making. Where there are disparities in the Determinants of Equity[6] within a region, equity and social justice is not achieved. The Strategic Plan lists 8 key Determinants of Equity, including 1) access to child and youth development, 2) economic development and jobs, 3)

[4] "Equity is the full and equal access to opportunities, power and resources so that all people achieve their full potential and thrive. Equity is an ardent journey toward well-being as defined by those most negatively affected." (King County 2016)
[5] "All aspects of justice—including legal, political, economic and environmental—and requires the fair distribution of and access to public goods, institutional resources and life opportunities for all people." (King County 2016)
[6] "The social, economic, geographic, political and physical environments and conditions in which people live. Full and equal access to the Determinants of Equity is necessary to have equity for all people regardless of race, class, gender, language spoken and geography." (King County 2016)

environment and climate, 4) health and human services, 5) housing, 6) information and technology, 7) justice system, and 8) transportation and mobility. Within the context of the LBAMRA study, the goal of the ESJ analysis is to understand the extent to which socially and economically vulnerable populations in floodplains are at a higher risk of being disproportionately negatively impacted by levee breaches. Such risk can be related to several of the Determinants of Equity through impacts to educational and park facilities, impacts to businesses providing local jobs, impacts to medical facilities, and impacts to transportation systems which enable access to the aforementioned community resources. The ESJ evaluation will assess the extent to which flooding impacts these determinants through a combination of mapping and quantitative metrics.

This impact category identifies the socially and economically vulnerable populations in the affected areas. Demographic and economic data will facilitate identifying the locations of concentrated racial/ethnic groups and other communities of color (black, indigenous, and other people of color–BIPOC), low-income communities, senior populations, disabled populations, housing-related indicators, and other groups identified as vulnerable. This characterization of population will be based upon existing published information from the U.S. Census Bureau, King County, and other local and state agencies, as described in the next section.

Overlays with other socioeconomic and geographic factors, and the outputs of the hydraulic modeling will serve to inform the analysis. The analysis will use GIS tools and maps to provide a clearer visual interpretation of risks and impacts. Comparison with other nearby locations, such as adjacent census units, will also help demonstrate how populations differ.

5.1.1. Inventory Data

Data from the U.S. Census Bureau, such as the Census 2020 and American Community Survey (ACS) 5-Year estimates will provide the necessary inventory data for this impact category. The U.S. Census Bureau continue to publish additional datasets from the 2020 Census. Best available geographic resolution will be obtained and utilized following the finalization of the Evaluation Approach Memorandum (Subtask 8.2). Other sources of demographic and economic data to supplement the analysis include Washington State Office of Financial Management (OFM), King County Office of Economic and Financial Analysis, and Washington Employment Security Department (ESD). In addition, the analysis will be informed by the Washington Environmental Health Disparities Mapping Tool (WEHD), the EPA Social Vulnerability Index (SVI), and other vulnerability indices. These published indices will provide tract-level information that may be used to generate more detailed estimates at the block group or block level. Specifics of the approach will be detailed in Subtask 8.2, Evaluation Approach Memorandum.

While the U.S. Census Bureau does not provide population projections, it is considered the best source of latest population estimates/data at the census tract level broken down by race, ethnicity, sex, and age groups. If needed, population growth rates for racial and ethnic groups (including BIPOC), gender identity, and different age groups may be estimated based on State-level projections by OFM and applied to ACS population estimates to develop population projections for relevant areas.

Population and demographic information will be compiled and integrated with the final building inventory discussed previously in Section 2.1. This will support estimation of population exposed to flooding as well as support this ESJ evaluation.

5.1.2. Damage Function Data

The identification of vulnerable communities will provide information on geographic pockets where such communities are concentrated. Impacts from the other categories (e.g., structure impacts, roads, utilities, agriculture) will be evaluated for the vulnerable populations and compared with impacts for the less vulnerable populations.

5.1.3. Inventory Status Summary

For this impact category, inventory and data sources have been identified. No inventory issues are expected in the estimation of these impacts.

5.2. Residential Evacuation, Subsistence, and Reoccupation

This impact category addresses the potential need for residents to evacuate their homes, subsist following evacuation (food, lodging, etc.), and reoccupation[7]. Relevant population at risk will be identified based upon flood modeling results and the inventory data identified in Section 2.1. This will include identification of total population at risk, as well as the population in buildings with sufficient depth that evacuation is required. This population will be characterized according to the equity and social justice indicators discussed in Section 5.1. To the extent possible, potentially affected homeless populations will also be identified in terms of temporary public outdoor spaces. This category will also qualitatively characterize the flooding of arterial roadways that may affect the viability of evacuation and may result in public safety impacts based on the nature and extent of roadway flooding for various hydraulic scenarios.

5.2.1. Inventory Data

The residential building inventory discussed in Section 2.1 will provide the necessary inventory data for this impact category.

5.2.2. Damage Function Data

Based upon past USACE studies (USACE 2012), evacuation is likely to begin where flood depths exceed 2 feet of water. This criterion will be applied to the flood model results to identify relevant properties and populations.

5.2.3. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified. No inventory issues are expected in the estimation of these impacts.

5.3. Public Services and Critical Facilities

There are many public services and critical facilities that benefit the community and may be subject to impact from flooding, such as schools, libraries, and community centers. In addition to the direct damage to these buildings (see Sections 2.1 and 2.5) or cost of emergency response (Section 3.3), adverse impacts may additionally include loss of service impacts to local residents (e.g., school closures). This impact category considers the extent to which loss of critical facility services would differentially affect local population local ESJ populations and the King County Determinants of Equity.

For the purpose of this study, critical facilities will be defined consistent with the 2020-2025 King County Regional Hazard Mitigation Plan (King County 2020), which lists the following critical facilities: schools, hospitals, nursing homes, hazardous materials storage facilities, wastewater and stormwater management facilities, animal waste storage facilities. Additional facilities that will be considered critical include assisted living facilities, police and fire stations, facilities with designated emergency management purposes (storage, operations center, shelter, etc.), major sports venues (i.e., stadiums), and jail/correctional facilities. Buildings identified as critical facilities will be flagged in the database. Identification of critical facilities will be based upon existing published data from King County, including GIS datasets and the Regional Hazard Mitigation Plan. Designation as a critical facility will not affect computed structure, content, or inventory damages, but the presence and type of critical facilities in the floodplain may inform the evaluation for other impact categories.

[7] Following Hurricane Katrina and its associated flooding, the USACE New Orleans District collected and elicited information for this impact category and developed an estimate of up to $5,500 (2010 prices) per affected household (USACE 2012).

5.3.1. Inventory Data

The building inventory discussed in Section 2.1 and the critical utilities facilities analysis discussed in Section 2.5 will provide the necessary inventory data for this impact category. Relevant critical facilities will be mapped in combination with inundation information from the hydraulic modeling outputs.

5.3.2. Damage Function Data

Relevant public buildings experiencing loss of service will be estimated based upon the hydraulic modeling outputs and outage probability information available from past USACE expert elicitation reports (USACE 2012). It is anticipated that these outage probabilities will be used to adjust the FEMA standard values such that they can be applied to all relevant damaged buildings. Based on these sources, the potential duration of service loss can be characterized and used to describe the magnitude of this impact in a qualitative manner.

5.3.3. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified. No inventory issues are expected in the estimation of these impacts.

5.4. Utility Loss of Service Impacts (Electric, Water, Wastewater)

Reliable utility service is critical to the daily lives of floodplain residents. This impact category evaluates the potential for interruption of utility service. Risk of utility outage will be used to characterize the potential affected population for each flood event.

5.4.1. Inventory Data

The building inventory discussed in Section 2.1 will serve as the inventory for this impact category. Buildings experiencing outage will be estimated based upon the hydraulic modeling outputs and outage probability information available from past USACE expert elicitation reports (USACE 2012).

5.4.2. Damage Function Data

Buildings experiencing outage will be estimated based upon the hydraulic modeling outputs and outage probability information available from past USACE expert elicitation reports (USACE 2012). Affected buildings will be used in conjunction with population information to characterize the potential for utility service disruption and the affected population. Duration of disruption will be estimated based upon the FEMA benefit-cost analysis methodology, which estimates the need for approximately 45 days of restoration time per foot of flood depth relative to the first floor.

5.4.3. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified. No inventory issues are expected in the estimation of these impacts.

5.5. Mental Stress, Anxiety

This impact category is intended to characterize human health impacts following a flood that may result in a decreased quality of life through adverse impacts on mental health. For example, the FEMA BCA Methodology for the Hazard Mitigation Assistance grant program establishes a standardized dollar value per affected resident of the floodplain that represents the costs of mental health treatment following a flood. For this analysis, this risk of human health impact will be considered in the ESJ evaluation to understand whether there would likely be differential human health impacts from flooding that may affect the evaluation of flood risk.

5.5.1. Inventory Data

This impact category is applicable to the affected residential building inventory. The relevant population will be identified for each flood event based upon hydraulic modeling outputs, the residential building inventory discussed in Section 2.1, and the average household size for King County from the best available U.S. Census data.

5.5.2. Damage Function Data

The FEMA BCA Toolkit version 6.0 contains the most recent standard values per affected resident. Based upon the FEMA literature, the standard values already incorporate a distribution of flood impact severity. As such, the standard loss value may be applied to all residences experiencing flood damage. Note, however, that the monetary results of this analysis are secondary to the qualitative characterization of human health impacts as it relates to the ESJ analysis.

5.5.3. Inventory Status Summary

For this impact category, inventory and DDF data sources have been identified. No inventory issues are expected in the estimation of these impacts.

6. QUALITY CONTROL

A quality control review of this memorandum was completed by a senior economist not directly involved with the development of the memorandum. A separate review was performed by a technical editor.

Additional quality control information will be documented as part of the Evaluation Approach Memorandum that will be prepared as part of Subtask 8.2 in a future phase of study.

7. LIST OF DATA SOURCES

(AAA) American Automobile Association. 2020. Your Driving Costs 2020, Annual Report. Available online: https://newsroom.aaa.com/wp-content/uploads/2020/12/2020-Your-Driving-Costs-Brochure-Interactive-FINAL-12-9-20.pdf

(BTS) Bureau of Transportation Statistics. 2019. Average Age of Automobiles and Trucks in Operation in the United States, National Transportation Statistics Database. United States Department of Transportation. Available online: https://www.bts.gov/content/average-age-automobiles-and-trucks-operation-united-states

(FEMA) Federal Emergency Management Agency. 2016. Benefit-Cost Sustainment and Enhancements, Baseline Standard Economic Value Methodology Report. Department of Homeland Security. Available online: https://www.caloes.ca.gov/RecoverySite/Documents/Benefit%20Cost%20Sustainment.pdf

(FEMA) Federal Emergency Management Agency. September 2010. Debris Estimating Field Guide. FEMA Report 329. Available online: https://www.fema.gov/sites/default/files/2020-07/fema_329_debris-estimating_field-guide_9-1-2010.pdf

(FHA) Federal Highway Administration. 2021. National Bridge Inventory Database. U.S. Department of Transportation. Available online: https://www.fhwa.dot.gov/bridge/nbi.cfm

(OSM) Open Street Map. 2021. Application Programming Interface (API). Documentation online at: https://wiki.openstreetmap.org/wiki/API

(USACE) U.S. Army Corps of Engineers, Risk Management Institute. 2021. LifeSim model. Documentation online at: https://www.rmc.usace.army.mil/Software/LifeSim/

(USACE) U.S. Army Corps of Engineers Institute for Water Resources. October 1987. IWR Report 87-R-10, National Economic Development Procedures Manual – Agricultural Flood Damage. U.S. Army Corps of Engineers Institute for Water Resources. Report available online: https://www.iwr.usace.army.mil/Portals/70/docs/iwrreports/87-R-10.pdf

(USACE) U.S. Army Corps of Engineers. 2009. Economic Guidance Memorandum 09-04, Generic Depth Damage Relationships for Vehicles. CECW-CP, Department of the Army. Available online: https://tinyurl.com/3swfnedd

(USACE) U.S. Army Corps of Engineers. 2020. Portland Metro Levee System Feasibility Study. Portland District U.S. Army Corps of Engineers. Report available online: https://www.nwp.usace.army.mil/Missions/Projects-and-Plans/Portland-Metro-Levee-System/

(USACE) U.S. Army Corps of Engineers. 2020a. Westminster East Garden Grove Feasibility Study. Sacramento District U.S. Army Corps of Engineers. Report available online: https://www.lrc.usace.army.mil/Portals/36/docs/projects/Westminster/2020/App%20E%20-%20Economics.pdf

(USACE) U.S. Army Corps of Engineers. 2020b. Economic Guidance Memorandum, 21-02, Unit Day Value for Recreation for Fiscal Year 2021. U.S. Army Corps of Engineers CECW-P. Available online: https://planning.erdc.dren.mil/toolbox/library/EGMs/EGM21-02.pdf

(USACE) U.S. Army Corps of Engineers. March 2012. Development of Depth-Emergency Cost and Infrastructure Damage Relationships for Selected South Louisiana Parishes. Prepared for U.S. Army Corps of Engineers New Orleans District. Provided electronically via personal communication with USACE Portland District.

(WSDOT) Washington State Department of Transportation. 2021. WSDOT Traffic GeoPortal, 2020 Counts (web application). Maintained and published by the Washington State Department of Transportation. Available online: https://www.wsdot.wa.gov/data/tools/geoportal/?config=traffic

(WSP) Washington State Parks. 2021. Visitation Reports, 2014-2020. Available online: https://parks.state.wa.us/1165/Visitation-reports

(WSU) Washington State University. 2021. Crop Enterprise Budgets, Online Database. Maintained and published by the School of Economics, College of Agricultural, Human, and Natural Resource Sciences, Washington State University. Available online: http://ses.wsu.edu/enterprise_budgets/

Edmunds. April 2020. CY 2019 Used Vehicle Report. Edmunds.com. Available online: https://static.ed.edmunds-media.com/unversioned/img/industry-center/insights/2019-used-vehicle-report.pdf

King County. 2016. Equity and Social Justice Strategic Plan, 2016-2022. Published by King County Office of Equity and Social Justice, Office of the King County Executive. Available online: https://aqua.kingcounty.gov/dnrp/library/dnrp-directors-office/equity-social-justice/201609-ESJ-SP-FULL.pdf

King County. 2021a. Preliminary Damage Assessment Data for 2006, 2009, 2015, and 2020 King County Floods. Provided via email by King County. Assembled and provided by Ken Zweig, King County WLRD.

King County. 2021. Traffic Counts Web Application, 2020 Counts. Maintained and published by King County Department of Transportation. Available online: https://gismaps.kingcounty.gov/trafficcounts/

King County. 2020. 2020-2025 King County Regional Hazard Mitigation Plan. Available online at: https://kingcounty.gov/~/media/depts/emergency-management/documents/plans/hazard-mitigation/kcrhmp-draft-20200721.ashx?la=en

(WEHD 2021) Washington Environmental Health Disparities Map. Published online by Washington State Department of Health, at: https://www.doh.wa.gov/DataandStatisticalReports/WashingtonTrackingNetworkWTN/InformationbyLocation/WashingtonEnvironmentalHealthDisparitiesMap