

ECONOMIC EVALUATION
PROCEDURES, ASSUMPTIONS,
AND METHODOLOGIES FOR THE
PROPOSED FLOOD RETARDING
STRUCTURES IN UPPER DUBLIN
TOWNSHIP, PENNSYLVANIA

Prepared for

URS Corporation
335 Commerce Drive
Fort Washington, PA 19034

June 2010

URS

URS Corporation
200 Orchard Ridge Drive, Suite 101
Gaithersburg, MD 20878
21387516

TABLE OF CONTENTS

SECTION ONE: INTRODUCTION.....	1-1
SECTION TWO: COST-EFFECTIVENESS ANALYSIS.....	2-1
2.1 Structure and Content Damages Due to Overbank Flooding	2-1
2.1.1 Structure Inventory	2-1
2.1.2 Structure Inventory Post Processing	2-3
2.1.3 Structure and Content Damage Analysis	2-5
2.2 Structure Damage Benefit Analysis	2-8
2.3 Transportation Analysis	2-9
2.4 Cost Analysis	2-10
2.5 Cost-Effectiveness Evaluation	2-11
SECTION THREE: IMPACTS ON BUSINESSES	3-1
3.1 Disruption Cost	3-2
3.2 Rental Costs	3-2
3.3 Displacement Costs	3-5
3.4 Loss of Revenue	3-5
3.5 Business Impact Evaluation	3-7
SECTION FOUR: SUMMARY.....	4-1
SECTION FIVE: REFERENCES.....	5-1

Exhibits

Exhibit 1: Depth-Damage Functions Used in the Study Area

Tables

Table 1: Number of Residential and Nonresidential Structures Inventoried	2-3
Table 2: Upper Dublin Township Damage Reaches.....	2-4
Table 3: Summary of Structure Inventory Data Items	2-4
Table 4: Average Annual Damages (AAD) for the Without-Project Alternative (\$1,000's)	2-6
Table 5: Structures Flooded under Without-Project Conditions	2-7
Table 6: AAD for the With- Project Alternative (\$1,000's)	2-7
Table 7: Structures Flooded under With-Project Conditions	2-8
Table 8: Overbank Flooding Benefit Calculations for With-Project Alternative*	2-8
Table 9: Structures Damaged Under With-Project Compared to Without-Project Conditions	2-9

TABLE OF CONTENTS

Table 10: Average Annual Benefits Due to Reduced Road Flooding 2-10

Table 11: Cost Analysis 2-11

Table 12: Comparison of Benefits and Costs (\$1,000's) 2-11

Table 13: Disruption Costs for With- and Without-Project Conditions 3-2

Table 14: Depth of Flooding versus Business Displacement 3-3

Table 15: Total Business Days Lost at Each Flood Event 3-4

Table 16: Rental Costs for With- and Without-Project Conditions 3-4

Table 17: Total Displacement Costs 3-5

Table 18: Revenue per Day by Industry..... 3-6

Table 19: Loss of Revenue 3-7

Table 20: Comparison of Benefits and Costs Including Indirect Benefits (\$1,000's)..... 3-7

SECTION ONE: INTRODUCTION

URS Corporation (URS) conducted an economic analysis for flood retarding structures in Upper Dublin Township, PA. This economic analysis is comprised of two sections—one evaluates the cost effectiveness of the proposed structures and the other reviews the impacts on commercial businesses. The cost-effectiveness evaluation takes into consideration the direct damages that result from flooding, such as damages to commercial and residential structures and road flooding. The business impacts consider lost revenue and displacement to the businesses and property owners that would be indirectly impacted by the flooding.

SECTION TWO: COST-EFFECTIVENESS ANALYSIS

The economic analysis for the Upper Dublin Township Feasibility Study evaluated the cost effectiveness of flood retarding structures on the basis of flood-related costs and damages avoided. Damages and costs considered in the economic evaluation include flood damages to residential and nonresidential structures and increased travel costs associated with road flooding. Damages and costs were considered for two alternatives, the Without-Project and With-Project alternatives.

To determine whether an alternative is economically justified, the average annual benefits were compared to the average annual costs. Annual benefits in this study are defined as reduced structure and content damages and reduced travel costs. Annual costs are the cost of constructing the flood retarding structures and operating and maintaining these structures. If the annual benefits for an alternative exceeded the annual costs, then the alternative was considered cost effective (or economically justified). In such cases, the benefit-to-cost ratio (BCR) was greater than 1.0.

2.1 STRUCTURE AND CONTENT DAMAGES DUE TO OVERBANK FLOODING

Knowledge of existing residential and nonresidential development located in a floodplain is critical to evaluating a flood damage reduction project. Potential flood damages to residential and nonresidential structures in the study area were evaluated through a structure inventory.

2.1.1 Structure Inventory

The purpose of the structure inventory was to collect data on residential and nonresidential structures in the study area. Information collected during the field work was used to evaluate the value of the structure and identify other characteristics to estimate potential flood damages.

a. Field Database. The field database was constructed using a list of structures that had previously experienced damage. The list of structures was provided by representatives of Upper Dublin Township. In addition, a geographic information system (GIS) analysis was conducted to define the full extent of the study area. A graphic representation of the 100-year floodplain downstream of the two flood retarding structures was superimposed upon a tax-parcel map of the area. A 15-meter buffer was added to the floodplain to account for any inaccuracies. As a result, this field database incorporated all the structures in the list, along with several other structures that may not have been listed, but have a flood risk based on their proximity to the floodplain. The final field database contained all residential structures and all nonresidential structures (classified as commercial, exempt, industrial, agricultural land, agricultural dwelling, and other in the tax database) located in the study area.

b. Data Collection. The field work for the structure inventory was conducted in March 2010. One two-person survey team collected information on each structure in the field database. The survey team used addresses and aerial maps to locate the selected structures. All information was collected and recorded from outside of each structure. Structures that no longer exist were deleted from the database. Data were also collected for any new nonresidential structures not contained in the field database.

Residential Structures

The following information was collected or verified for each selected residential structure:

- Address
- Photograph of structure
- Characteristics
 - Type of structure (e.g., single-family)
 - Type of foundation
 - Finished floor area
 - Quality of construction
 - Condition of structure
 - Style of structure (e.g., one-story)
 - Type of exterior wall (e.g., siding)
 - Type of roofing
 - Presence of garage
 - Presence of other outbuildings
 - Presence of fireplaces
 - First floor elevation (FFE) adjustment (height of first floor above adjacent grade)

The finished floor area of each building was estimated using an aerial photograph and tracing tool available on the computer, tax records, and visual observation. The construction quality of each structure was judged by considering the workmanship in relation to the materials used. The appearance and condition of the structure in relation to the effective age determined the physical condition recorded for each of the buildings.

Nonresidential Structures

The following information was collected for each commercial structure:

- Name of business
- Address
- Photograph of structure
- Characteristics
 - General use of structure (e.g., office, barber shop)
 - Total floor area
 - Construction class (e.g., masonry bearing walls)
 - Story height
 - Quality of construction

- Number of stories
- Perimeter shape (e.g., square, rectangular)
- FFE adjustment (height of first floor above adjacent grade)

Use of the commercial structure was determined by the activities conducted in the building as observed during the field survey and based on the company name.

A total of 146 structures were inventoried during the 2010 field work (Table 1).

Table 1: Number of Residential and Nonresidential Structures Inventoried

Structure Type	Number Inventoried
Residential	34
Nonresidential	112
Commercial	95
Industrial	11
Public	6
Total Structures	146

2.1.2 Structure Inventory Post Processing

Structure replacement values were determined for each structure using RSMeans Cost Data (2010). Structure replacement values were based on occupancy type, exterior walls, square footage, and other structural parameters. Structure replacement values were based on 2010 dollars.

Because the survey team did not enter any buildings, a number of structural characteristics normally used by RSMeans—such as the method of heating and cooling, type of plumbing, and the type of interior floor covering—could not be recorded. Default values provided by RSMeans were used for undefined characteristics.

Depth-damage functions (DDFs) were assigned to each structure to represent the potential damage that could occur to the structure and its contents during a flood event. The DDFs used in this analysis were developed by the Federal Emergency Management Agency (FEMA) and the U.S. Army Corps of Engineers (USACE), Institute of Water Resources (IWR) (See Exhibit 1). These DDFs were selected for this analysis because they were developed based on standard structure and content characteristics. The DDFs were assigned to residential structures based on the structure type and presence of a basement. Nonresidential DDFs were assigned based on the use of the commercial structure identified during the structure inventory.

Each structure was assigned a DDF to estimate the damages to the physical structure and to estimate the damages to the contents of the structure. Contents values were estimated based on the DDF assigned to the structure. Each DDF has a content-to-structure value ratio (CSVR), which estimates the value of the contents in relation to the value of the structure. During the damage analysis, the value of the structure is referenced to the structure DDF and the value of the contents is referenced to the content DDF.

Each structure was assigned to a stream and station number. This allows the location of the structure to be indexed along the correct stream and water surface elevation. The station numbers were based on the stations used for the hydrologic and hydraulic (H&H) analysis and assigned using GIS functions. The Upper Dublin Township study area contains four streams: Pine Run, Pine Run Tributary, Rapp Run, and Sandy Run. Pine Run has three Reaches (Upper, Middle, and Lower), and Sandy Run has two (Upper and Lower). However, one reach was assigned to each stream to simplify the analysis (Table 2).

Table 2: Upper Dublin Township Damage Reaches

Stream	Reach
Pine Run	UpMidLow
Pine Tributary	Tributary
Rapp Run	Main Stem
Sandy Run	UpLow

Table 3 summarizes all data items used in the structure inventory and the sources of their values.

Table 3: Summary of Structure Inventory Data Items

Data Item	Nonresidential (Commercial, Industrial, Public) Structures	Residential Structures
Structure ID	Unique ID used to reference specific structures. Assigned automatically in IWR-GeoFIT software and referenced to tax assessor data.	Unique ID used to reference specific structures.
Business Name and Address	Field observation and tax assessor data.	Field observation and tax assessor data.
Approximate Building Square Footage	Field observation.	Field observation.
Type of Construction Material, Effective Age, Number of Stories	Field observation.	Field observation.
Structure Functional Use	Field observation.	Field observation.
Number of Structures on Site	Each structure was recorded individually during inventory.	Data based on primary structure on parcel—garages and other outbuildings were not identified separately and are included with the primary structure.
River Mile (station number, stream name)	Assigned using GIS river station shape file and location of structure (determined from tax assessor and field observation).	Assigned using GIS river station shape file and location of structure (determined from tax assessor and field observation).
Replacement Value of Structure	RSMeans Cost Data.	RSMeans Cost Data.
Content Value (Inventory) and Other Value (Computers, Equipment, Machines, and Misc.)	Based on standard CSVRS associated with DDFs.	Based on standard CSVRS associated with DDFs.

Data Item	Nonresidential (Commercial, Industrial, Public) Structures	Residential Structures
DDF for Structure	Assigned standard DDF based on function of the structure as observed during inventory.	Assigned standard DDF based on residence type as observed during inventory.
DDF for Content and Other	Associated with DDF assigned to structure.	Associated with DDF assigned to structure.
Damage Category (e.g., commercial, public)	Associated with DDF assigned to structure.	Associated with DDF assigned to structure.
First Floor Elevation	The majority of FFEs were determined by professional surveyors, the remaining were estimated based on elevation data and field observation.	The majority of FFEs were determined by professional surveyors, the remaining were estimated based on elevation data and field observation.
Begin Damage Elevation for Structure	Provided by surveyors and the township.	Provided by surveyors and the township.
Begin Damage Elevation for Contents and Other	Associated with DDF assigned to structure.	Associated with DDF assigned to structure.

2.1.3 Structure and Content Damage Analysis

The estimated structure and content damages for the With- and Without-Project alternatives were determined based on the FFEs, structure replacement values, water surface elevation during flood events, and DDFs. When estimating the monetary value of damage of a particular flood event for a residential or nonresidential structure, the amount of inundation is determined for the structure based on the water surface elevation for that event (based on the H&H analysis). The level of inundation is then referenced to the DDF to determine the percent damage to the structure for that flood event. The percent damage is then multiplied by the structure replacement value to determine the value of the damages. For example, a 50-year flood event may result in 1 foot of water in a structure, which would result in 13-percent damage (referenced to DDF). If the structure was valued at \$100,000, damages would be estimated at \$13,000. For nonresidential structures, the DDFs estimate damages based on a one-story commercial structure. To adjust for multiple stories, nonresidential structure replacement values were divided by the number of stories, as recorded during the structure inventory.

To conduct the analysis, data from the structure inventory, DDFs, and H&H analysis were incorporated into the Hydraulic Engineering Center – Flood Damage Analysis (HEC-FDA) program. The USACE developed HEC-FDA to estimate the average annual flood damages. HEC-FDA requires data on eight flood recurrence intervals, which were obtained from the H&H analysis. The eight flood recurrence intervals include the 50-percent-chance event (2-year), 20-percent-chance event (5-year), 10-percent-chance event (10-year), 4-percent-chance event (25-year), 2-percent-chance event (50-year), 1-percent-chance event (100-year), 0.5-percent-chance event (200-year), and 0.2-percent-chance event (500-year). Additional information for the 100-

percent-chance event (1-year) was manually entered when determining the exceedance probability functions.

Following review of the initial HEC-FDA runs, structure input data and DDFs were reviewed to confirm that the results represented flood damages for the study area. For example, the first floor elevation was adjusted to the adjacent grade elevation so that damages to structures with basements were not overestimated. Residential structures with basements were assumed to have a finished basement. The results were also provided to representatives from Upper Dublin Township for review. The results were found to be representative of historical flooding in the study area.

The following subsections provide descriptive analyses of the overbank flood damages for the Without-Project and With-Project alternatives.

1. Without-Project Alternative. The Without-Project alternative is the baseline alternative; it provides a common base of comparison for all other alternatives. This alternative includes features and other conditions that would likely occur in the study area without construction of the With-Project alternative considered in this report.

Table 4 lists average annual overbank flood damage estimates by reach and damage category based on the HEC-FDA output.

Table 4: Average Annual Damages (AAD) for the Without-Project Alternative

Reach	Damage Categories				TOTAL AAD
	Industrial	Commercial	Public	Residential	
Pine Run	\$340,000	\$970,000	\$0	\$0	\$1,310,000
Pine Trib	\$0	\$0	\$0	\$0	\$0
Rapp Run	\$80,000	\$50,000	\$0	\$10,000	\$140,000
Sandy Run	\$240,000	\$2,010,000	\$10,000	\$0	\$2,260,000
TOTAL	\$660,000	\$3,030,000	\$10,000	\$10,000	\$3,710,000

Note:

Damage estimates are based on 2010 dollars.
Values are rounded.

The category receiving the highest damage is Commercial, followed by Industrial, Public, and Residential, respectively. Total Average Annual Damages is approximately \$3,710,000.

In addition to an analysis of monetary damages associated with overbank flooding in Upper Dublin Township, the analysis identified the number of structures damaged for each recurrence interval. Table 5 displays the estimated number of structures that would be flooded above the first floor for the selected flood recurrence intervals for the Without-Project conditions.

Table 5: Structures Flooded under Without-Project Conditions

Flood Event	Number of Structures Flooded
50% (2-year)	3
20% (5-year)	12
10% (10-year)	18
4% (25-year)	25
2% (50-year)	31
1% (100-year)	36
0.5% (200-year)	38
0.2% (500-year)	39

2. With-Project Alternative. The With-Project alternative includes the construction of two flood retarding structures in the study area. The purpose of these structures would be to reduce downstream flooding. The two flood retarding structures would be located on Pine Run and Rapp Run, both in the Sandy Run Watershed. Sandy Run traverses several townships, including Upper Dublin, Abington, Springfield, and Whitemarsh townships, and the analysis below includes damages to Upper Dublin and Whitemarsh Township.

HEC-FDA was used to estimate the damages associated with the With-Project alternative. The HEC-FDA output is summarized below. Table 6 presents the average annual damages for the With-Project alternative by damage category (Industrial, Commercial, Public, and Residential).

Table 6: AAD for the With- Project Alternative

Reach	Damage Categories				TOTAL AAD
	Industrial	Commercial	Public	Residential	
Pine Run	\$80,000	\$260,000	\$0	\$0	\$340,000
Pine Trib	\$0	\$0	\$0	\$0	\$0
Rapp Run	\$20,000	\$10,000	\$0	\$2,000	\$32,000
Sandy Run	\$110,000	\$1,050,000	\$6,000	\$0	\$1,166,000
TOTAL	\$210,000	\$1,320,000	\$6,000	\$2,000	\$1,538,000

Note:

Damage estimates are based on 2010 dollars.

Values are rounded.

The majority of damage would be to Commercial properties, followed by Industrial, Public, and Residential, respectively. Total Average Annual Damages are approximately \$1,538,000.

In addition to an analysis of monetary damages associated with overbank flooding in Upper Dublin Township, the analysis identified the number of structures damaged for each recurrence interval. Table 7 displays the estimated number of structures that would be flooded above the first floor for the selected flood recurrence intervals for the With-Project conditions.

Table 7: Structures Flooded under With-Project Conditions

Flood Event	Number of Structures Flooded
50% (2-year)	1
20% (5-year)	3
10% (10-year)	10
4% (25-year)	14
2% (50-year)	19
1% (100-year)	30
0.5% (200-year)	33
0.2% (500-year)	38

2.2 STRUCTURE DAMAGE BENEFIT ANALYSIS

The flood-damage reduction benefit of a With-Project alternative is the reduction in damages when compared to the Without-Project alternative. Therefore, the average annual benefit to structures for the Upper Dublin Township project was calculated by subtracting the AAD for the With-Project alternative (with the two flood retarding structures in place) from the AAD for the Without-Project alternative. Table 8 provides the Without-Project annual damages, the With-Project annual damages, and the resultant benefits. Overbank flood damages for the With-Project alternative are 58 percent less than damages for the Without-Project alternative, resulting in an estimated annual benefit of \$2,200,000.

Table 8: Overbank Flooding Benefit Calculations for With-Project Alternative*

Without-Project Alternative Damage	With-Project Alternative Damage	Annual Benefit (2010)
\$3,700,000	\$1,500,000	\$2,200,000

*values are rounded

In addition to an analysis of monetary damages associated with overbank flooding along the four streams in Upper Dublin Township, the analysis identified the number of structures damaged for each recurrence interval. Table 9 displays the estimated number of structures that would be damaged for a range of flood events for the With-Project conditions compared to Without-Project conditions.

Table 9: Structures Damaged Under With-Project Compared to Without-Project Conditions

Recurrence Interval	Number of Structures Damaged		Difference
	Without-Project	With-Project	
50% (2-year)	3	1	2
20% (5-year)	12	3	9
10% (10-year)	18	10	8
4% (25-year)	25	14	11
2% (50-year)	31	19	12
1% (100-year)	36	30	6
0.5% (200-year)	38	33	5
0.2% (500-year)	39	38	1

2.3 TRANSPORTATION ANALYSIS

A transportation analysis was performed to evaluate flood damages caused by flooding of roads in Upper Dublin Township. Costs associated with road closures include the cost of extra miles travelled due to road detours and the cost of excess travel time due to road closures. The flood-reduction benefit of the With-Project alternative is the reduction in roads flooded when compared to the Without-Project alternative. Therefore, the average annual benefit for the With-Project alternative was calculated by subtracting the costs of road closures for the With-Project alternative from the costs of road closures for the Without-Project alternative.

For this analysis, the roads that would not flood under the With-Project alternative and the roads that would flood under the Without-Project conditions were identified using output from the H&H analysis. The costs of detours associated with each road closure were calculated for each alternative, and included both costs to the township and costs to travelers. Costs to the township are the costs of township workers barricading and clearing flooded roads. Costs were determined through conversations with the employees of the Upper Dublin Township Public Works. Every flood event requires an average of 8 hours for six township workers to barricade and then clear flooded roads. The average wage of each township worker is \$40.80 per hour, which includes benefits and overhead, and accounts for overtime pay on Saturdays and Sundays. The total costs to the township for each flood event equal the average hourly wage of the six workers multiplied by the 8 hours of the flood event, which comes to approximately \$2,000.

Costs to travelers are the costs of the time it takes to take a detour around the flooding and the cost of the extra gas due to the detour. The costs for travelers’ detours were calculated by multiplying the numbers of hours for the detours times the hourly value of a person’s time times the number of travelers per hour on the road. A value of \$37.21 per hour was used for the value of time due to the detour. This value of time is provided in a FEMA paper entitled “FEMA Benefit-Cost Analysis Re-engineering (BCAR): Factoring Disruption of Life Values into Benefit-Cost Analyses”. The paper uses figures, such as the national average employer cost for employee compensation, updated to the then most current data (2009). The numbers of travelers were obtained from Delaware Valley Regional Planning Commission’s (DVRPC’s) traffic

counts, which adjust for daily variations. Traffic counts were adjusted to reflect “per hour” counts.

The cost of the extra gas due to the detour was calculated by taking the miles of the detour divided by the average miles travelled per gallon, times the price of gas, and times the number of travelers (traffic count). The average miles travelled per gallon came from the U.S. Department of Transportation, Federal Highway Administration. The figure includes passenger vehicles, buses, trucks, and motorcycles. The price of gas used was the current price of a gallon of gas for Philadelphia, PA.

Table 10 displays the benefits for transportation at each flood event.

Table 10: Average Annual Benefits Due to Reduced Road Flooding*

Flood Event	Benefit
100% (1-year)	\$19,600
50% (2-year)	\$6,100
20% (5-year)	\$13,800
10% (10-year)	\$12,800
4% (25-year)	\$0
2% (50-year)	\$0
1% (100-year)	\$0
0.5% (200-year)	\$0
0.2% (500-year)	\$0

*values are rounded.

Benefits for the 25-year flood event and higher were insignificant. The benefits at each flood event were multiplied by the respective recurrence interval to arrive at the total average annual benefits associated with the With-Project alternative. The average annual benefit for the With-Project alternative is approximately \$11,000.

2.4 COST ANALYSIS

The cost analysis determined the equivalent annual cost of the With-Project alternative by considering a number of factors; including construction, design, construction management, real estate and easements, and operation and maintenance (O&M) costs (Table 11). The costs were based on 2010 dollars and determined during the engineering analysis. The cost analysis used a period of performance of 50 years and both the USACE water resources discount rate of 4.375 percent and the FEMA discount rate of 7 percent.

Table 11: Cost Analysis*

Item	Cost
Construction	\$10,520,000
Engineering & Design	\$1,400,000
Construction Management and CQA	\$1,260,000
Right of Way Acquisitions	\$1,500,000
Upper Dublin Township Costs	\$100,000
O&M (annual cost)	\$20,000
Equivalent Annual Cost (4.375%)	\$750,000
Equivalent Annual Cost (7%)	\$1,090,000

*Values are rounded.

2.5 COST-EFFECTIVENESS EVALUATION

The two flood retarding structures in the With-Project alternative are intended to reduce downstream flooding. Therefore, the benefits of the project are based on the reduction in damages from the current condition (Without-Project) compared to the condition with the structures in place (With-Project). The benefits being evaluated as part of the cost-effectiveness evaluation are the direct benefits from flooding (e.g., reduced damage to structures and contents, and transportation). The direct damages were estimated following USACE and FEMA guidelines. The BCR for the With-Project alternative was determined using both the USACE discount rate of 4.375 percent and the FEMA discount rate of 7 percent (Table 12).

Table 12: Comparison of Benefits and Costs

Discount Rate	Benefits			Costs	BCR
	Reduction in Structure Damage	Transportation	Total Benefits		
4.375%	\$2,200,000	\$11,000	\$2,211,000	\$750,000	2.9
7%	\$ 2,200,000	\$11,000	\$2,211,000	\$1,090,000	2.0

The BCR is greater than 1.0 for both discount rates, indicating that the flood retarding structures are cost effective.

In the above analysis, direct damages to structures and contents were evaluated using replacement costs for structures. The USACE requires the use of depreciated replacement values of structures instead of replacement values when conducting a flood damage analysis. To confirm the With-Project alternative would be cost effective under USACE guidelines, HEC-FDA was also run with depreciated structure values. Under this scenario, the average annual benefit from the reduction in structure damages due to the flood retarding structures is approximately \$1,900,000. Therefore, the flood retarding structures are cost effective when both depreciated and replacement structure values are used.

SECTION THREE: IMPACTS ON BUSINESSES

In addition to the direct damages, a number of indirect damages (e.g., business disruption/losses) were reviewed to provide insight on the extent of the flooding damages to the business community in Upper Dublin Township and the surrounding area. Although not all of these indirect damages can be monetized, the damages that can be monetized demonstrate that the proposed project will provide positive benefits to the local business community and the region from reduced flooding in Upper Dublin Township. Business losses are not the direct (physical) damages from flooding, but of the indirect damages that are often hard to quantify and that have effects that can last long after the direct damages have been repaired.

Upper Dublin Township is strategically located along Interstate 276 just outside of Philadelphia. With good access, a highly educated population, and an established business park, the Upper Dublin Township area has a lot to offer businesses. However, the township area has not been able to fully capitalize on these advantages because of recurring flooding. The Upper Dublin Township area is a business park that consists of mostly office buildings. The business park located in township is currently underperforming. The businesses that are still located in the flood zone are willing to accept the flooding because the location is good. These businesses may have a threshold for the amount of flooding damage they can incur. Damages from recurring flooding may eventually be higher than the cost of relocating the business out of the area. Even if a business is able to relocate or reopen, it may lose significant revenue during the clean-up and rebuilding process.

Persistent flooding (such as in Upper Dublin Township) can affect building property owners significantly, even after the damage is repaired. Interviews by Urban Partners, LLC, who are working on a separate study of the township, of businesses in the study area revealed that many of the property owners cannot attract the high-end office users. The recurring flooding discourages premium tenants, which precludes higher rents; as a result, property owners end up renting to a lesser quality of tenants. Owners may not be able to lease the building or may have to accept a lower price on the lease to maintain occupancy. Property owners have also stated that some tenants have not been willing or able to make their lease payments due to the flooding.

Reducing the flooding would also benefit the township and its residents. A decrease in flooding could increase property values. Property owners could attract higher-revenue businesses, lease their properties for a higher rent, and potentially have lower vacancy rates, leading to increased tax revenue for Upper Dublin Township. In addition, people who work in the township often live nearby. Providing greater and more stable employment opportunities by reducing flooding would be a direct benefit to the residents of the community.

An increased business and residential population in Upper Dublin Township would increase revenues for the township. Earned income tax is a tax levied as a percent of earned income. The Earned Income Tax in Upper Dublin Township is currently 1 percent of the earned income/net profit for all residents and any non-residents engaged in business or working in the township. Higher property values would also result in higher real estate tax revenues. Increasing and keeping the current businesses and residents in the township would have a positive effect on the tax revenues for the township.

Although the exact impacts on business cannot be easily determined, a business losses analysis was performed utilizing planning level guidance from Federal agencies to estimate the potential

impacts. The following process to calculate displacement costs follows FEMA Benefit-Cost Analysis Version 4.5.5 guidance.

When a natural disaster such as a flood occurs, businesses incur indirect displacement costs, comprised of daily rental costs and a one-time disruption cost, and lost revenue.

3.1 DISRUPTION COST

The disruption cost of a structure is dependent on the total area (square footage) of the structure, and the disruption per square foot cost of the structure. The size of the structures collected during the structure inventory, as discussed previously in this report, were utilized for this analysis. FEMA 2008 standard values for Displacement Costs were used to represent disruption costs. These 2008 values were inflated to 2010 values using the Consumer Price Index (CPI) from the U.S. Bureau of Labor Statistics.

HEC-FDA data output was used to determine which structures would flood at each flood recurrence interval. For nonresidential structures, the FEMA Displacement Costs are dependent on the occupancy class. The occupancy class determined in the structure inventory was used to obtain the corresponding disruption cost for each structure. This disruption cost was then multiplied by the total area of the structure to determine the total disruption cost for each structure. The total disruption costs for all structures were then summed for each flood recurrence interval.

Disruption costs were calculated for both the Without-Project and With-Project conditions. The results are shown in Table 13 below. Benefits at each flood interval due to the flood retarding structures were found by subtracting the total disruption costs for With-Project conditions from total disruption costs for Without-Project conditions. This reduction in disruption costs would be an indirect benefit of the flood retarding structures.

Table 13: Disruption Costs for With- and Without-Project Conditions*

Flood Event	Without-Project Alternative	With-Project Alternative	Benefit of the With-Project Alternative
50% (2-year)	\$183,000	\$143,000	\$41,000
20% (5-year)	\$406,000	\$183,000	\$222,000
10% (10-year)	\$533,000	\$363,000	\$169,000
4% (25-year)	\$913,000	\$417,000	\$496,000
2% (50-year)	\$1,195,000	\$651,000	\$544,000
1% (100-year)	\$1,357,000	\$1,173,000	\$184,000
0.5% (200-year)	\$1,442,000	\$1,307,000	\$135,000
0.2% (500-year)	\$1,565,000	\$1,442,000	\$124,000

*Values are rounded.

3.2 RENTAL COSTS

Daily rental costs are the other element contributing to total displacement costs. The rental costs of a structure are dependent on the structure's total area (square footage), the rental cost of the

structure, and the number of days the structure is displaced. As in the process to calculate disruption costs, total areas collected during the structure inventory were used in this analysis. The number of days of business displacement depends on the depth of flooding for each flood event. FEMA DDFs relate the depth of flooding to the number of days a business is displaced. Table 14 shows the number of days of business displacement for a range of flood depths.

Table 14: Depth of Flooding versus Business Displacement

Depth of Flooding Relative to Structure FFE (feet)	Business Interruption (days)
-2	0
-1	0
0	0
1	45
2	90
3	135
4	180
5	225
6	270
7	315
8	360
9	405
10+	450

The HEC-FDA output identified which structures were flooded at each recurrence interval. The flooding depth for each structure was then used to determine the number of days the business would be displaced. The flooding for each structure was rounded to the nearest foot, to correspond with the DDFs. To show the decrease in business days lost, the days of displacement for each structure were summed for each flood event. This was done for both the Without-Project and With-Project HEC-FDA results. The results are shown in Table 15.

Table 15: Total Business Days Lost at Each Flood Event

Flood Event	Displacement Days Without Project	Displacement Days With Project	Decrease In Displacement Days Due to Project
50% (2-year)	135	45	90
20% (5-year)	720	135	585
10% (10-year)	1,350	540	810
4% (25-year)	2,340	1,035	1,305
2% (50-year)	3,825	1,890	1,935
1% (100-year)	5,490	3,645	2,025
0.5% (200-year)	6,840	5,400	1,440
0.2% (500-year)	7,965	7,020	945

Rental costs came from the FEMA 2008 standard values for Displacement Costs. Like disruption costs, these values were also updated to 2010 dollars using the CPI. For nonresidential structures, the rental costs are dependent on the occupancy class. The occupancy class determined in the structure inventory was used to obtain the corresponding rental cost for each structure. This rental cost was then multiplied by the total structure area to arrive at a total rental cost for each business. FEMA provides the rental cost as a monthly figure. Consequently, each total rental cost was divided by 30 to obtain a daily rental cost.

The daily rental cost was then multiplied by the number of days the business is displaced, at each flood event. Rental costs were calculated for both the Without-Project and With-Project conditions, as shown in Table 16 below.

Table 16: Rental Costs for With- and Without-Project Conditions*

Flood Event	Without-Project Alternative	With-Project Alternative	Benefit of the With-Project Alternative
50% (2-year)	\$607,000	\$533,000	\$74,000
20% (5-year)	\$2,155,000	\$607,000	\$1,549,000
10% (10-year)	\$3,392,000	\$1,527,000	\$1,865,000
4% (25-year)	\$5,052,000	\$3,056,000	\$1,996,000
2% (50-year)	\$8,334,000	\$4,518,000	\$3,816,000
1% (100-year)	\$11,871,000	\$7,807,000	\$4,064,000
0.5% (200-year)	\$14,622,000	\$11,934,000	\$2,688,000
0.2% (500-year)	\$16,703,000	\$15,093,000	\$1,610,000

*Values are rounded.

The benefits of the flood retarding structures at each recurrence interval were found by subtracting the total rental costs for the With-Project conditions from total rental costs for Without-Project conditions. This reduction in rental costs would be an indirect benefit of the flood retarding structures.

3.3 DISPLACEMENT COSTS

Total displacement costs are a sum of total disruption costs and total rental costs. The total indirect benefits associated with the flood retarding structures are the reduction in displacement costs due to the With-Project conditions. The results are displayed in Table 17.

Table 17: Total Displacement Costs

Flood Event	Without-Project Alternative	With-Project Alternative	Benefit of the With-Project Alternative
50% (2-year)	\$790,000	\$676,000	\$114,000
20% (5-year)	\$2,561,000	\$790,000	\$1,771,000
10% (10-year)	\$3,925,000	\$1,891,000	\$2,034,000
4% (25-year)	\$5,966,000	\$3,473,000	\$2,493,000
2% (50-year)	\$9,530,000	\$5,169,000	\$4,361,000
1% (100-year)	\$13,228,000	\$8,980,000	\$4,248,000
0.5% (200-year)	\$16,064,000	\$13,240,000	\$2,824,000
0.2% (500-year)	\$18,268,000	\$16,535,000	\$1,733,000

The benefits at each flood event were multiplied by the respective recurrence interval to arrive at the total average annual benefits associated with the With-Project alternative. The average annual benefit for the With-Project alternative is approximately \$745,000.

3.4 LOSS OF REVENUE

The business revenue losses from potential flooding were calculated using data from the U.S. Bureau of the Census, 2007 Economic Census. All values were updated to 2010 dollars using the CPI. The 2007 Census provides selected statistics by economic sector. The data classifies businesses according to the North American Industry Classification System (NAICS), which is the standard for federal statistical agencies. Data was used from Pennsylvania averages collected from the Bureau. To correspond with this data, it was determined which NAICS code would be most appropriate for the businesses occupying the structures in the study area. The Census reports “sales, shipments, receipts, or revenue” (revenue) for each NAICS code, and includes the number of establishments in each code for the State of Pennsylvania. To get a “per establishment” value, the total revenue for the code was divided by the number of establishments; representing an average yearly revenue for each business. Average revenue per day generated by each business was found by dividing the yearly value by 365. Table 18 displays the revenue per establishment per day for the NAICS codes.

Table 18: Revenue per Day by Industry

NAICS Code	Industry	Revenue per Establishment per Day
21	Mining, quarrying, and oil and gas extraction	\$26,500
31-33	Manufacturing	\$43,900
42	Wholesale trade	\$42,700
44-45	Retail trade	\$10,300
51	Information	N
53	Real estate and rental and leasing	\$4,000
54	Professional, scientific, and technical services	\$4,500
56	Administrative and support and waste management and remediation services	\$3,800
61	Educational services	\$2,600
62	Healthcare and social assistance	\$6,700
71	Arts, entertainment, and recreation	\$4,200
72	Accommodation and food services	\$2,100
81	Other services (except public administration)	\$2,000
23	Construction	\$6,000

N: Not available or not comparable

It should be noted these revenues per day values are approximate estimates of the revenues generated by the businesses in Upper Dublin Township. These are average values from the Census Bureau, and do not account for the size of the business. These values could be underestimating the revenues in the township because the businesses in the study area are fairly large, and may therefore produce more revenue than the average business. Without interviewing every business in the township, this analysis is a conservative estimate, to be used for planning level purposes only.

Revenues lost were calculated for the selected flood events and for both the With-Project and Without-Project conditions. The estimates of average revenue per day for each structure were multiplied by the number of days the business is disrupted, as determined previously in the lost business days. Lost business days were capped at 45 days. This was based on the assumption that after 45 days, businesses were likely to have found another location or means of operating the business, even if the original location was not repaired fully yet. The lost revenues were summed for all structures flooded at each flood event, for With-Project and Without-Project. The results are shown in Table 19.

Table 19: Loss of Revenue*

Flood Event	Lost Revenue-Without Project	Lost Revenue-With Project	Benefit
2 Year	\$435,000	\$95,000	\$340,000
5 Year	\$2,480,000	\$435,000	\$2,045,000
10 Year	\$5,897,000	\$1,845,000	\$4,051,000
25 Year	\$7,896,000	\$3,410,000	\$4,486,000
50 Year	\$8,715,000	\$6,656,000	\$2,059,000
100 Year	\$9,566,000	\$8,544,000	\$1,021,000
200 Year	\$9,831,000	\$9,055,000	\$775,000
500 Year	\$10,001,000	\$9,831,000	\$170,000

*Values are rounded.

The difference between the With-Project and Without-Project loss revenues is the benefit attributed to the flood retarding structures. Total average annual benefits are \$1,006,000.

3.5 BUSINESS IMPACT EVALUATION

The impacts on businesses in the study area from flooding can be significant. The economic analysis reviewed indirect impacts (e.g., business disruption/losses) from flooding to gain insight on the extent of the flooding damages to the business community in Upper Dublin Township and the surrounding area. This conceptual level analysis monetized these impacts.

Although the direct damage evaluation estimated that the two flood retarding structures were cost effective, business impacts were analyzed for a conceptual estimate of the benefit that reduced flooding would have on the study area. Section 2 of this report showed a conservative estimate of benefits that supports the flood retarding structures. Table 20 compares both direct and indirect benefits and costs for the flood retarding structures at both a 4.375 percent and 7 percent discount rate.

Table 20: Comparison of Benefits and Costs Including Indirect Benefits

Discount Rate	Benefits				Total Benefits	Total Costs	BCR
	Reduction in Structure Damage	Transportation	Disruption Benefits	Business Impact Benefits			
4.375%	\$2,200,000	\$11,000	\$745,000	\$1,006,000	\$3,962,000	\$750,000	5.2
7%	\$2,200,000	\$11,000	\$745,000	\$1,006,000	\$3,962,000	\$1,090,000	3.6

SECTION FOUR: SUMMARY

The two flood retarding structures proposed in the With-Project alternative are designed to reduce downstream flooding. Therefore, the benefits of the project are based on the reduction in damages from the current condition (Without-Project) compared to the condition with the structures in place (With-Project). The benefits evaluated as part of the cost-effectiveness evaluation are the direct benefits from flooding (e.g., reduced damage to structures and contents, and transportation). The project was found to be cost effective based on the direct damages to structures, contents, and transportation.

The economic analysis also reviewed the indirect impacts (e.g., business disruption/losses) from flooding to gain insight on the extent of flood damage to the business community in Upper Dublin Township and the surrounding area. The impacts on businesses in the study area from flooding can be significant, including lower rent for property owners, business disruption and relocation, and reduced tax to the township. Although not all of these indirect damages can be monetized, the damages that can be monetized demonstrate that the proposed project will provide additional positive benefits to the local business community and the region from reduced flooding in Upper Dublin Township.

SECTION FIVE: REFERENCES

- American Automobile Association. *Fuel Gauge Report*. 2010.
<http://www.fuelgaugereport.com/PAmetro.asp>. Accessed 5 April 2010.
- Delaware Valley Regional Planning Commission. Traffic Counts. Accessed 5 April 2010.
- Federal Emergency Management Agency. 2007. *Benefit-Cost Analysis Re-engineering (BCAR): Factoring Disruption of Life Values into Benefit-Cost Analyses*. November 28, 2007.
- Federal Emergency Management Agency, BCA Tool Kit, Version 4.5.5. for the Hazard Mitigation Assistance program. <http://www.bchelpline.com>. Accessed June 2010.
- Federal Emergency Management Agency, HAZUS-MH MR3 Flood Technical Manual, Table 14.10, 2006.
- RSMeans CostWorks, 2010*. R.S. Means Company, Inc., Kingston, MA, 2008.
- U.S. Army Corps of Engineers. 2000. *Planning Guidance Notebook: Engineer Regulation 1105-2-100*. 22 April 2000.
- U.S. Bureau of Labor Statistics. 2009. *Employer Costs for Employee Compensation Economic News Release*. December 2009. <http://www.bls.gov/news.release/ecec.nr0.htm>. Accessed 30 March 2010.
- U.S. Bureau of Labor Statistics, *Historical CPI Data*.. www.bls.gov. Accessed June 2010
- U.S. Bureau of the Census, *2007 Economic Census*. <http://factfinder.census.gov>. Accessed June 2010.
- U.S. Department of Transportation. 2006. *Impact of Fuel Consumption*. National Household Travel Survey: NHTS Brief. June.
http://nhts.ornl.gov/2001/pub/Impact_of_Fuel_Costs.pdf. Accessed 1 April 2010.
- U.S. Department of Transportation. 2007. *Economic Analysis Primer: Benefit Cost Analysis*. Federal Highway Administration,
<http://www.fhwa.dot.gov/infrastructure/asstmgmt/primer05.cfm>. Accessed 1 April 2010.

EXHIBIT 1
Depth-Damage Functions Used in the Study Area

EXHIBIT 1
Depth-Damage Functions Used in the Study Area

Occ_Name	Occ_Description	Cat_Name	Parameter	Start_Data																
APT_P	Apartment-preengineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0	0	0	4.5	6.9	9.7	14.6	19.6	25.8	27.8	33.6	34.8	38	39.8	41
		COM	S		0	0.5	0.5	1	8.5	12.5	16.1	20.4	25.9	31.7	33.5	37.5	39.4	42.2	45.1	46.6
		COM	STU		0	1.1	1.3	3.3	14.8	17.5	22.9	28.7	33.2	39.3	40.1	44	46.6	50	53.5	55.5
		COM	CTL		0	0	0	0	9.4	16.7	19.7	23.4	31.4	38	43.3	48.6	52.1	55.7	57.3	58.6
		COM	C		0	0	0	0	14.3	21.7	26.6	30.4	39	45	47.9	51.9	55.7	59.3	60.6	63.4
		COM	CTU		0	0	0	0	19.6	29.3	34.3	37.7	45.4	50.7	52.7	55.4	60.1	61.7	64.9	67.7
		COM	Struct	N																
APT_E	Apartment-engineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0	0	0	4.4	6.3	8.5	12.3	16	21.4	24.8	28.7	30.4	31.9	33.3	34.9
		COM	S		0	0	0	0	7.9	11	13.6	17.4	21.3	26.2	29.6	32.1	34.1	37.2	38.9	41.1
		COM	STU		0	0.6	0.8	1.6	14.2	17.1	20.1	25.1	28.1	32.9	36.9	39.8	41.6	46	48.6	50.9
		COM	CTL		0	0	0	0	9.4	16.7	19.7	23.4	31.4	38	43.3	48.6	52.1	55.7	57.3	58.6
		COM	C		0	0	0	0	14.3	21.7	26.6	30.4	39	45	47.9	51.9	55.7	59.3	60.6	63.4
		COM	CTU		0	0	0	0	19.6	29.3	34.3	37.7	45.4	50.7	52.7	55.4	60.1	61.7	64.9	67.7
		COM	Struct	N																
GROC_P	grocery-preengineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0	0	0	4.1	5.6	8.2	12.4	17.7	22.9	25.3	31.8	33.9	39.3	41.8	42.9
		COM	S		0	0.5	0.5	1.3	7.6	11.6	15.7	19.5	25.9	32.9	35.3	41.1	44.6	48.1	51.4	52.9
		COM	STU		0	1.4	1.4	3.2	13.7	16.8	23	29.6	35.9	43.4	45.9	50.6	55.6	58.7	61.5	63.3
		COM	CTL		0	0	0	0	17.9	23.9	30.7	36.4	45.3	53.9	67.1	77.1	92.3	94.1	95	95
		COM	C		0	0	0	0	24	30.7	36.8	40.9	52.9	64	75.4	87.3	98.9	100	100	100
		COM	CTU		0	0	0	0.2	26.8	35.9	42.1	48.6	63.3	74	87.6	94.7	99.4	100	100	100
		COM	Struct	N																
GROC_E	grocery-engineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0	0	0	4.1	5	6.9	9.7	13.3	17.8	21.9	25.8	28.4	31.4	33.3	35
		COM	S		0	0	0	0.1	7.1	10.1	13	16.4	20.8	26.7	30.6	34.4	37.8	41.5	43.3	45.5
		COM	STU		0	0.8	0.8	1.5	13.4	16.5	20.1	25.6	30	35.8	41.2	44.7	48.3	52.6	54.6	56.7
		COM	CTL		0	0	0	0	17.9	23.9	30.7	36.4	45.3	53.9	67.1	77.1	92.3	94.1	95	95
		COM	C		0	0	0	0	24	30.7	36.8	40.9	52.9	64	75.4	87.3	98.9	100	100	100
		COM	CTU		0	0	0	0.2	26.8	35.9	42.1	48.6	63.3	74	87.6	94.7	99.4	100	100	100
		COM	Struct	N																
CONV_P	convenience-preengineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0	0	0	6.2	9.3	12.7	17	24.1	31.2	34.4	41.7	44.6	50.9	53.3	54.5
		COM	S		0	0.4	0.4	1.1	11.1	16	21.6	25.3	34.1	41.9	45.4	51.4	57	60.6	62.8	63.6
		COM	STU		0	1.3	1.3	2.7	17.6	22.1	29.2	34.2	42	49.8	52.5	60	63.8	66.4	68.5	69.5
		COM	CTL		0	-0.1	-0.1	0	6.5	15.1	21.6	28.4	37.6	55.6	65.7	71.6	78.1	80.4	81.3	81.4
		COM	C		0	0	0	0	11.6	23.1	32.1	39.9	52.9	70.7	79.3	88	94.1	95.7	97.1	98.6
		COM	CTU		0	0	0	0	18.6	30.4	40.1	50	64	78.6	87.9	94.4	97.7	98.6	100	100
		COM	Struct	N																
CONV_E	convenience-engineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0	0	0	6	8.4	11.2	14.4	20	26.3	30.7	35.9	39.1	43.4	45.4	46.9
		COM	S		0	0	0	0.3	10.2	14.1	18.5	21.9	28.7	35.5	40	44.4	49.5	53.3	54.5	56

EXHIBIT 1
Depth-Damage Functions Used in the Study Area

Occ_Name	Occ_Description	Cat_Name	Parameter	Start_Data															
		COM	STU	0	0.8	0.8	1.3	16.5	20.8	25.4	29.8	35.7	41.9	47.2	53	55.9	59.5	61.1	62.5
		COM	CTL	0	-0.1	-0.1	0	6.5	15.1	21.6	28.4	37.6	55.6	65.7	71.6	78.1	80.4	81.3	81.4
		COM	C	0	0	0	0	11.6	23.1	32.1	39.9	52.9	70.7	79.3	88	94.1	95.7	97.1	98.6
		COM	CTU	0	0	0	0	18.6	30.4	40.1	50	64	78.6	87.9	94.4	97.7	98.6	100	100
		COM	Struct	N									34						
HTL_P	hotel-preengineered	COM	Stage	-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL	0	0	0	0	3.9	5.2	7.2	10.7	15.2	19.8	20.8	25.7	26.9	30.9	32.9	34
		COM	S	0	0.5	0.7	1.3	8.2	11.7	15.1	18.1	23.9	29.1	31.8	35.3	38.1	40.8	44.4	45.7
		COM	STU	0	1.4	1.6	3.3	14.5	16.9	22.1	27.6	32.1	38.5	41	44	47.7	51.3	55.1	56.8
		COM	CTL	0	0	0	0	6.8	10.3	13.6	18.3	23.9	30.3	37.9	41.1	47.1	49.4	51.1	52.9
		COM	C	0	0	0	0	11.8	16.1	18.6	26.3	34.1	39.7	48.7	52.4	58.4	61.3	63.1	64.9
		COM	CTU	0	0	0	0	16.6	22.3	25.6	34.7	41.4	53	62.4	67.4	68.7	71.3	72.6	73.7
		COM	Struct	N									32						
HTL_E	hotel-engineered	COM	Stage	-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL	0	0	0	0	3.9	4.6	5.9	8.1	10.9	14.7	17.8	20.2	22	23.6	25.1	26.7
		COM	S	0	0	0.1	0.1	7.6	10.2	12.5	15.3	19.2	23.6	27.8	29.8	32.5	35.6	37.7	39.8
		COM	STU	0	0.8	1	1.6	14	16.6	19.5	24	27.1	32	37.5	39.6	42.3	46.9	49.7	51.7
		COM	CTL	0	0	0	0	6.8	10.3	13.6	18.3	23.9	30.3	37.9	41.1	47.1	49.4	51.1	52.9
		COM	C	0	0	0	0	11.8	16.1	18.6	26.3	34.1	39.7	48.7	52.4	58.4	61.3	63.1	64.9
		COM	CTU	0	0	0	0	16.6	22.3	25.6	34.7	41.4	53	62.4	67.4	68.7	71.3	72.6	73.7
		COM	Struct	N									26						
MED_P	medical-preengineered	COM	Stage	-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL	0	0	0	0	4.7	7.2	9.7	14.5	19.3	27.2	31.5	39.6	45.1	52.6	56.1	59.3
		COM	S	0	0.3	0.7	1.3	8.4	12.8	16.3	21	27.9	37.2	40.9	51.9	56.6	61.7	66	67.8
		COM	STU	0	1.1	1.4	2.9	14.4	17.9	22.9	28.8	36.3	44.8	49.9	58.8	63.5	68.7	71.3	73.4
		COM	CTL	0	0	0	0	5.6	10.3	15	21.9	32.8	46.8	59.1	66.3	73.8	83.8	91.9	92.5
		COM	C	0	0	0	0	9	14.3	18.4	26.9	40.4	57.1	67.3	75.4	82.3	91.3	96.3	96.9
		COM	CTU	0	0	0	0	13.9	21.3	26.9	42.5	52.6	63.3	75	82.3	86.9	94.1	98.1	99.4
		COM	Struct	N									70						
MED_E	medical-engineered	COM	Stage	-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL	0	0	0	0	4.7	6.7	8.8	12.8	16.6	23.8	28.9	35.4	40.9	46.8	49.9	53.2
		COM	S	0	0	0.3	0.6	8	11.7	14.5	18.9	24.4	32.7	37.2	46.3	50.7	55.8	58.9	61.2
		COM	STU	0	0.7	1	1.8	14.1	17.5	20.8	26.1	32	39.1	45.9	53.2	56.9	62.6	64.6	67
		COM	CTL	0	0	0	0	5.6	10.3	15	21.9	32.8	46.8	59.1	66.3	73.8	83.8	91.9	92.5
		COM	C	0	0	0	0	9	14.3	18.4	26.9	40.4	57.1	67.3	75.4	82.3	91.3	96.3	96.9
		COM	CTU	0	0	0	0	13.9	21.3	26.9	42.5	52.6	63.3	75	82.3	86.9	94.1	98.1	99.4
		COM	Struct	N									61						
HOSP_P	hospital-preengineered	COM	Stage	-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL	0	0	0	0.5	4.7	8.5	11.3	16.2	24.6	34.4	42.2	52.8	58.9	66.4	71.9	74
		COM	S	0	0.2	0.6	1.3	9	14.1	18.2	24.7	34.5	44.6	51.4	61.7	67.8	75.5	79.6	81.3
		COM	STU	0	0.9	1.4	2.9	16.5	21.2	26.6	35.2	45.3	53.2	62.2	71.5	76.5	82.1	83.9	85.2
		COM	CTL	0	0	0	0	6.9	10.4	13.9	21.3	29.3	43	53.6	65	73.6	82.9	88.6	90
		COM	C	0	0	0	0	10.3	14.6	18.4	27	37	53.4	70	79.1	85.6	92.5	95.6	96.3
		COM	CTU	0	0	0	0	15.7	20.3	23.7	35.6	47.1	61.4	75.7	85.7	91.4	95	97.1	97.9
		COM	Struct	N									48						

EXHIBIT 1
Depth-Damage Functions Used in the Study Area

Occ_Name	Occ_Description	Cat_Name	Parameter	Start_Data	-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
HOSP_E	hospital-engineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0	0	0.4	4.7	8.1	10.6	15	22.6	31.9	40.1	49.5	55.6	62.1	67.3	69.5
		COM	S		0	0	0.4	0.9	8.7	13.3	16.9	23	31.8	41.2	48.3	57.4	63.2	70.7	74.1	76.1
		COM	STU		0	0.7	1.1	2.2	16.1	20.6	25.1	33.1	42	49.2	58.8	67.2	71.6	77.4	79	80.5
		COM	CTL		0	0	0	0	6.9	10.4	13.9	21.3	29.3	43	53.6	65	73.6	82.9	88.6	90
		COM	C		0	0	0	0	10.3	14.6	18.4	27	37	53.4	70	79.1	85.6	92.5	95.6	96.3
		COM	CTU		0	0	0	0	15.7	20.3	23.7	35.6	47.1	61.4	75.7	85.7	91.4	95	97.1	97.9
		COM	Struct	N				0.8							44					
OFF_P	office-preengineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0.3	0.3	0.4	5.2	7.5	10.3	13.4	18.3	22	24.2	29.1	34.4	39.8	43.7	44.7
		COM	S		0	0.8	0.8	1.6	9.9	13.5	16.8	19.4	25.4	30.5	33.5	38.6	45.7	51.1	55	59.1
		COM	STU		0	1.5	1.5	3.2	14.4	18.4	23.6	27.8	34	39.9	43.8	47.6	55.1	62.4	65.7	70.1
		COM	CTL		0	0	0.3	0.5	7.3	13.6	17.9	23.7	34.3	43.6	51.9	59.7	64.4	73.6	79.3	81.9
		COM	C		0	0.2	0.7	0.7	14.3	20	26	34.3	45.4	55	63.9	73.3	76.4	83.4	89.3	91.4
		COM	CTU		0	0.5	1.2	1.3	22.1	29.3	33.6	41.4	54.6	63.6	71.4	79.6	82.9	85.7	92.1	96.4
		COM	Struct	N				0.8							21					
OFF_E	office-engineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0.3	0.3	0.4	5.1	6.9	9.2	11.6	15.4	18.7	22	25.4	30.7	34.5	37.9	39.3
		COM	S		0	0.4	0.4	0.9	9.3	12.3	14.9	17.5	22.2	26.8	30.7	34.7	41.2	46.5	49.4	53.6
		COM	STU		0	1.1	1.1	2	14	18	21.6	25.4	30.3	35.3	41	44.1	50.3	57.7	60.4	64.6
		COM	CTL		0	0	0.3	0.5	7.3	13.6	17.9	23.7	34.3	43.6	51.9	59.7	64.4	73.6	79.3	81.9
		COM	C		0	0.2	0.7	0.7	14.3	20	26	34.3	45.4	55	63.9	73.3	76.4	83.4	89.3	91.4
		COM	CTU		0	0.5	1.2	1.3	22.1	29.3	33.6	41.4	54.6	63.6	71.4	79.6	82.9	85.7	92.1	96.4
		COM	Struct	N				0.8							19					
REST_P	restaurant-preengineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0	0	0.5	8.9	13.1	18.1	24.8	33	40.3	47	55.6	59.6	64.4	66.3	67
		COM	S		0	0.3	0.3	1.9	14.8	19.4	25.3	32.4	41	49.6	56.3	63.9	67.2	71.3	72.7	73.5
		COM	STU		0	1.7	1.7	3.6	21.7	26.4	35.5	42.1	49.9	58.4	64.9	71.4	76	77.4	79.1	79.7
		COM	CTL		0	0	0	0	10.7	20.4	27.9	37.3	45.6	63.3	72.1	78.3	86.3	90	90.9	91.4
		COM	C		0	0	0	0	17.1	27.7	35.9	48.9	57.3	71.9	79.7	84.9	92.9	93.4	94.3	94.3
		COM	CTU		0	0	0	0	22.9	34.6	42.9	52.1	63.7	78.4	86.6	90	96.3	97.1	97.1	97.1
		COM	Struct	N				0.8							26					
REST_E	restaurant-engineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0	0	0.5	8.5	12.2	16.7	22.4	29.5	36.3	43.6	50.7	54.8	58.4	60	61
		COM	S		0	0	0	1.2	13.7	17.7	22.7	29.1	36.4	44.1	51.2	57.5	60.7	64.9	65.7	67
		COM	STU		0	1.3	1.3	2.6	20.5	24.9	32.2	38.1	44.7	52	59.7	65.2	69.1	71.3	72.8	73.7
		COM	CTL		0	0	0	0	10.7	20.4	27.9	37.3	45.6	63.3	72.1	78.3	86.3	90	90.9	91.4
		COM	C		0	0	0	0	17.1	27.7	35.9	48.9	57.3	71.9	79.7	84.9	92.9	93.4	94.3	94.3
		COM	CTU		0	0	0	0	22.9	34.6	42.9	52.1	63.7	78.4	86.6	90	96.3	97.1	97.1	97.1
		COM	Struct	N				0.8							23					
FFR_P	fastfood-preengineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0	0	0	6.1	9.3	13.9	20.9	26.9	37.5	44	50.9	54.6	59.7	64.2	64.9
		COM	S		0	0.3	0.3	0.6	11.1	15.9	22.5	28.7	37.4	47.3	52.1	58.3	63.5	67	70.9	72.2
		COM	STU		0	1.1	1.1	2.1	18.6	23.9	32	42.4	48.9	58.1	61.9	67.4	73.5	76.6	79	79.6
		COM	CTL		0	0	0	0	5	15	21.4	28.7	39.9	49.4	65.4	72.9	82.9	88	94.3	94.3

EXHIBIT 1
Depth-Damage Functions Used in the Study Area

Occ_Name	Occ_Description	Cat_Name	Parameter	Start_Data																	
FFR_E	fastfood-engineered	COM	C	0	0	0	0	10.6	21.3	29.4	38.6	52.7	62.6	73	79.3	88.3	94.9	98.6	98.6		
		COM	CTU	0	0	0	0	16.4	31.3	38.4	51.4	62.3	72.7	79.6	83.6	95.7	98	98.6	98.6		
		COM	Struct	N																32	
		COM	Stage	-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10		
		COM	STL	0	0	0	0	6	8.6	12.6	18.7	23.5	33.3	40.4	45.8	49.6	53.3	57.4	58.4		
		COM	S	0	0	0	0	10.4	14.4	19.9	25.6	32.8	41.6	47.1	52	56.9	60.5	63.4	65.1		
		COM	STU	0	0.8	0.8	1.2	17.7	22.7	28.9	38.1	43.4	51.3	56.8	61.4	66.4	70.2	72.2	73.2		
		COM	CTL	0	0	0	0	5	15	21.4	28.7	39.9	49.4	65.4	72.9	82.9	88	94.3	94.3		
		COM	C	0	0	0	0	10.6	21.3	29.4	38.6	52.7	62.6	73	79.3	88.3	94.9	98.6	98.6		
		COM	CTU	0	0	0	0	16.4	31.3	38.4	51.4	62.3	72.7	79.6	83.6	95.7	98	98.6	98.6		
ELEC_P	electronics-preengineered	COM	Struct	N															28		
		COM	Stage	-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10		
		COM	STL	0	0	0	0	4.6	6.5	9	13	18.3	23.5	26.6	31.9	34.2	39.3	41.9	43.3		
		COM	S	0	0.5	0.5	1.1	8.7	12.9	16.8	20.4	26.8	33.2	36.5	40.3	43.9	48.3	51.5	52.6		
		COM	STU	0	1.2	1.4	3.1	15.7	18.9	24.6	30.7	36.8	44	46.3	49.6	55.1	59	61.6	62.8		
		COM	CTL	0	0	0	0	7.3	16.9	22.9	27.6	33.4	56.4	68.9	77.6	85.4	90.6	91.4	93.4		
		COM	C	0	0	0	0	10.9	23	28.7	34.1	44.3	67	77.7	86.7	95.4	97.4	98.6	98.6		
		COM	CTU	0	0	0	0	16.7	29.9	37.9	45.6	58	75.7	85.4	95	97.7	100	100	100		
		COM	Struct	N																82	
		ELEC_E	electronics-engineered	COM	Stage	-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
COM	STL			0	0	0	0	4.6	5.7	7.5	10.3	13.8	18.3	23	25.9	28.7	31.4	33.4	35.3		
COM	S			0	0	0	0	8	11.2	13.9	17.1	21.6	26.9	31.6	33.8	37.1	41.7	43.4	45.3		
COM	STU			0	0.6	0.8	1.4	14.9	18.1	21.4	26.4	30.7	36.3	41.6	43.9	48	52.8	54.7	56.3		
COM	CTL			0	0	0	0	7.3	16.9	22.9	27.6	33.4	56.4	68.9	77.6	85.4	90.6	91.4	93.4		
COM	C			0	0	0	0	10.9	23	28.7	34.1	44.3	67	77.7	86.7	95.4	97.4	98.6	98.6		
COM	CTU			0	0	0	0	16.7	29.9	37.9	45.6	58	75.7	85.4	95	97.7	100	100	100		
COM	Struct			N																65	
FURN_P	furniture-preengineered			COM	Stage	-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
				COM	STL	0	0	0	0	3.7	5.7	8	11.8	16.8	22.3	24.8	30.8	32.8	38.3	41	42.9
		COM	S	0	0.5	0.5	1.1	7.9	11.8	15.1	18.7	25.2	32.1	35	39.5	42.7	47.1	51.3	52.5		
		COM	STU	0	1.2	1.4	3.2	14.1	17.2	23	29.4	36	42.7	45.4	49.4	54.3	58.9	61.9	63.1		
		COM	CTL	0	0	0	0	31.1	38.4	44.3	50.7	55.7	65.3	73.9	80.4	90.6	94.9	95.7	95.7		
		COM	C	0	0	0	0	39.9	46.9	53.3	61.9	68.1	79.1	85.7	90.7	97.1	99.3	99.3	99.3		
		COM	CTU	0	0	0	0	45	53.3	60.3	67.4	74.3	85.7	92.9	96.4	98.6	100	100	100		
		COM	Struct	N																46	
		FURN_E	furniture-engineered	COM	Stage	-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
				COM	STL	0	0	0	0	3.8	5.1	6.7	9.2	12.5	17.3	21.4	24.9	27.5	30.5	32.7	34.9
COM	S			0	0	0	0	7.3	10.3	12.5	15.7	20.3	26	30.4	33.1	36.2	40.7	43.2	45.2		
COM	STU			0	0.6	0.8	1.5	13.7	16.8	20.1	25.4	30.1	35.3	40.9	43.8	47.3	52.7	54.8	56.6		
COM	CTL			0	0	0	0	31.1	38.4	44.3	50.7	55.7	65.3	73.9	80.4	90.6	94.9	95.7	95.7		
COM	C			0	0	0	0	39.9	46.9	53.3	61.9	68.1	79.1	85.7	90.7	97.1	99.3	99.3	99.3		
COM	CTU			0	0	0	0	45	53.3	60.3	67.4	74.3	85.7	92.9	96.4	98.6	100	100	100		
COM	Struct			N																37	

EXHIBIT 1
Depth-Damage Functions Used in the Study Area

Occ_Name	Occ_Description	Cat_Name	Parameter	Start_Data	-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
CLOTH_P	clothing-preengineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0	0	0	4.9	6.8	9.3	13.4	18.4	23.3	26.7	32.2	34.4	39.5	41.7	43.1
		COM	S		0	0.5	0.5	1.1	9.1	13.2	16.9	20.5	26.6	33.3	36.4	41	43.9	47.7	51.3	52.4
		COM	STU		0	1.2	1.4	3.1	15.8	19.1	24.5	30.9	37	44.5	47	50.7	54.9	58.9	62	63.2
		COM	CTL		0	0	0	0	8.1	19.1	31	40	47	61.4	69.3	81.4	86.4	92.6	95.6	96.4
		COM	C		0	0	0	0	12.3	29	38.4	46.3	55.4	70	79	89	95.7	97.9	97.9	99.3
		COM	CTU		0	0	0	0	17.4	37.4	46.7	54.9	65	80	85.6	95	96.4	97.9	99.3	99.3
		COM	Struct	N				0.8							57					
CLOTH_E	clothing-engineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0	0	0	4.8	6	7.8	10.6	13.9	18.1	23.1	26.2	28.8	31.6	33.3	35.1
		COM	S		0	0	0	0	8.3	11.4	13.9	17.2	21.4	26.9	31.5	34.3	37.2	41.2	43.2	45.1
		COM	STU		0	0.6	0.8	1.4	14.9	18.3	21.3	26.6	30.8	36.7	42.1	44.8	47.8	52.7	55	56.6
		COM	CTL		0	0	0	0	8.1	19.1	31	40	47	61.4	69.3	81.4	86.4	92.6	95.6	96.4
		COM	C		0	0	0	0	12.3	29	38.4	46.3	55.4	70	79	89	95.7	97.9	97.9	99.3
		COM	CTU		0	0	0	0	17.4	37.4	46.7	54.9	65	80	85.6	95	96.4	97.9	99.3	99.3
		COM	Struct	N				0.8							45					
SERV_P	servicerelated-preengineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0	0	0	3.7	5.1	7.4	10.9	15.2	20	21.1	27	29.3	33.7	35.6	36.7
		COM	S		0	0.5	0.5	1.2	7.5	11.1	15	18.1	23.5	29.5	31.9	36.8	40.9	45.1	48.3	49.7
		COM	STU		0	1.2	1.4	3.4	13.2	15.9	22	26.2	32.4	39.8	42.1	46	52.2	57.1	59.8	61.1
		COM	CTL		0	0	0	0	7.2	11.6	15.7	23.7	32.9	44.4	50.7	58.4	70.6	74.3	76.4	77.9
		COM	C		0	0	0	0.4	11.7	16.4	21.9	28.9	40.9	57.7	63.3	70.7	79.3	84.3	87.1	87.1
		COM	CTU		0	0	0	0.7	16.2	21.6	29.1	35.7	50.9	67	74.3	78.3	84	88	90	90
		COM	Struct	N				0.8							83					
SERV_E	servicerelated-engineered	COM	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		COM	STL		0	0	0	0	3.8	4.4	6	8.3	10.9	15	18	21.3	24	26	27.4	29.1
		COM	S		0	0	0	0.1	7	9.7	12.4	15.3	18.9	24	27.9	31	34.8	39.1	40.8	43
		COM	STU		0	0.6	0.8	1.7	12.9	15.8	19.4	23	27.3	33.1	38.4	41.2	45.8	51.3	53.2	55
		COM	CTL		0	0	0	0	7.2	11.6	15.7	23.7	32.9	44.4	50.7	58.4	70.6	74.3	76.4	77.9
		COM	C		0	0	0	0.4	11.7	16.4	21.9	28.9	40.9	57.7	63.3	70.7	79.3	84.3	87.1	87.1
		COM	CTU		0	0	0	0.7	16.2	21.6	29.1	35.7	50.9	67	74.3	78.3	84	88	90	90
		COM	Struct	N				0.8							66					
LT_P	lightmanufacturing-preengineered	IND	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		IND	STL		0	0	0	0	3.5	5.6	8.4	12.3	16.8	22.2	23.4	29.6	31.5	37.7	40.6	42.2
		IND	S		0	0.5	0.5	1	7.8	11.9	16.1	19.8	25.7	31.6	34.4	39.9	43.2	47.7	52.6	53.9
		IND	STU		0	1.1	1.3	3.3	14	17.2	23.1	28.7	34.3	42.9	45.4	51.2	54.3	59.6	62.2	64.1
		IND	CTL		0	0	0	0	6.6	12.4	18.6	23.3	33.6	41.1	52.1	60.4	73.4	81.7	84.9	89.3
		IND	C		0	0	0	0	12.1	19.3	26.6	31	42.3	52.3	60.7	72	82.1	90.7	94.3	95
		IND	CTU		0	0	0	0	18.6	26.4	34.9	41.3	55.9	65.4	77	82.9	90.6	94.7	96.4	97.1
		IND	Struct	N				0.8							48					

EXHIBIT 1
Depth-Damage Functions Used in the Study Area

Occ_Name	Occ_Description	Cat_Name	Parameter	Start_Data																
LT_E	lightmanufacturing-engineered	IND	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		IND	STL		0	0	0	0	3.6	4.9	7	9.6	12.6	17.2	20.2	23.9	26.3	30	32.3	34.3
		IND	S		0	0	0	0	7.3	10.4	13.4	16.8	20.9	25.9	30.1	33.8	37	41.5	44.6	46.7
		IND	STU		0	0.6	0.8	1.6	13.6	16.9	20.3	25.1	29	35.7	41.1	45.4	47.6	53.5	55.4	57.6
		IND	CTL		0	0	0	0	6.6	12.4	18.6	23.3	33.6	41.1	52.1	60.4	73.4	81.7	84.9	89.3
		IND	C		0	0	0	0	12.1	19.3	26.6	31	42.3	52.3	60.7	72	82.1	90.7	94.3	95
		IND	CTU		0	0	0	0	18.6	26.4	34.9	41.3	55.9	65.4	77	82.9	90.6	94.7	96.4	97.1
		IND	Struct	N				0.8												
WHR_P	warehouse refrigerated-preengineered	IND	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		IND	STL		0	0	0	0	4	6.5	9.4	13.9	20.2	26.2	29.5	35.1	39.5	45.1	49.5	51.3
		IND	S		0	0.4	0.4	0.9	8.2	13	16.9	21.5	29.1	36.7	40.2	46.2	49.9	54.3	58.9	60.9
		IND	STU		0	1	1	2.4	14.7	18.1	23.6	29.5	38.3	45.9	50	54.3	59.2	64.5	67.1	68.3
		IND	CTL		0	0	0	0	14.4	21.7	29.3	40	51.4	58.6	62.9	74.3	77.9	82.9	89.3	89.3
		IND	C		0	0	0	0	20.7	29.7	37.6	48	59.1	65.7	74.3	79.7	84	89.9	93.6	93.6
		IND	CTU		0	0	0	0	30.7	36.9	44.4	54.9	65.7	76.6	78.7	84	89.3	95	95	95
		IND	Struct	N				0.8												
WHR_E	warehouse refrigerated-engineered	IND	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		IND	STL		0	0	0	0	4	5.8	8.2	11.5	16.3	21.5	26.1	29.8	34.3	37.8	41.6	43.8
		IND	S		0	0	0	0	7.7	11.5	14.5	18.6	24.3	30.9	35.5	39.8	43.3	47.8	50.9	53.4
		IND	STU		0	0.6	0.6	1.1	14.2	17.6	21	26	32.7	38.8	45.2	48.4	52.2	58	59.9	61.6
		IND	CTL		0	0	0	0	14.4	21.7	29.3	40	51.4	58.6	62.9	74.3	77.9	82.9	89.3	89.3
		IND	C		0	0	0	0	20.7	29.7	37.6	48	59.1	65.7	74.3	79.7	84	89.9	93.6	93.6
		IND	CTU		0	0	0	0	30.7	36.9	44.4	54.9	65.7	76.6	78.7	84	89.3	95	95	95
		IND	Struct	N				0.8												
WH_P	warehouse-preengineered	IND	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		IND	STL		0	0	0	0	3.5	5.1	7.6	11.7	16.4	21.2	22.3	28.3	29.9	34.5	37.6	38.7
		IND	S		0	0.5	0.5	1.1	7.6	11.8	16.1	19.9	25.4	31.4	34.2	39	41.8	45.7	50.4	51.7
		IND	STU		0	1.2	1.4	3.3	14	17.4	23.6	28.8	34.2	42.5	44.7	48.9	52.7	56.9	60.6	62.2
		IND	CTL		0	0	0	0	7.1	12.3	19.3	25.4	35.7	48.3	57.3	65.9	74.9	81.4	84.1	88.1
		IND	C		0	0	0	0	13.4	20.7	27.6	33.7	47.4	56.9	65.6	73.6	81.3	88.4	91.6	93.6
		IND	CTU		0	0	0	0	21.1	28	35.6	45.6	57	67.7	76	82.4	89.7	94.1	98.3	99.3
		IND	Struct	N				0.8												
WH_E	warehouse-engineered	IND	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		IND	STL		0	0	0	0	3.6	4.5	6.2	8.9	11.9	15.9	19	22.4	24.6	26.7	29.2	30.8
		IND	S		0	0	0	0	7.1	10.2	13.3	16.7	20.4	25.5	29.7	32.8	35.5	39.6	42.5	44.5
		IND	STU		0	0.6	0.8	1.6	13.6	17	20.6	25	28.7	35.1	40.4	43.3	46.2	51.2	53.9	55.9
		IND	CTL		0	0	0	0	7.1	12.3	19.3	25.4	35.7	48.3	57.3	65.9	74.9	81.4	84.1	88.1
		IND	C		0	0	0	0	13.4	20.7	27.6	33.7	47.4	56.9	65.6	73.6	81.3	88.4	91.6	93.6
		IND	CTU		0	0	0	0	21.1	28	35.6	45.6	57	67.7	76	82.4	89.7	94.1	98.3	99.3
		IND	Struct	N				0.8												

EXHIBIT 1
Depth-Damage Functions Used in the Study Area

Occ_Name	Occ_Description	Cat_Name	Parameter	Start_Data																
CF_P	correctionalfacility-preengineered	PUB	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		PUB	STL		0	0	0	0	3	6.2	8.3	13.3	18.2	25.7	27.9	34.2	40.3	47.4	50	51.8
		PUB	S		0	0.6	0.6	0.8	6.8	10.8	14	20	24.8	34	36.5	43.2	49.6	56.3	59.5	62.3
		PUB	STU		0	1.4	1.4	2.4	12.1	16.1	20.5	26.9	31.6	40.7	43	49.1	55.8	63	65.9	68.3
		PUB	CTL		0	0	0	0	3.9	7.8	9.9	13.9	21.5	30.8	40.5	50	57.6	67.8	77.3	80.6
		PUB	C		0	0	0	0	6.3	13.1	14.6	21.3	31	44.1	53	62.3	69.5	77.5	83.8	87.5
		PUB	CTU		0	0	0	0	11.6	18.1	20.6	27.9	41.1	52.9	63.8	71.3	76.3	76.3	91.3	94.4
		PUB	Struct	N																
CF_E	correctionalfacility-engineered	PUB	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		PUB	STL		0	0	0	0	3.1	6	7.9	12.3	16.6	23.8	26.5	31.9	38	44.1	46.6	48.6
		PUB	S		0	0.4	0.4	0.4	6.6	10.3	13	18.6	22.8	31.2	34.4	40.2	46.2	52.8	55.4	58.4
		PUB	STU		0	1.1	1.1	1.4	12.1	16.1	19	24.8	28.6	36.4	40.5	45.7	51.3	58.6	61	63.5
		PUB	CTL		0	0	0	0	3.9	7.8	9.9	13.9	21.5	30.8	40.5	50	57.6	67.8	77.3	80.6
		PUB	C		0	0	0	0	6.3	13.1	14.6	21.3	31	44.1	53	62.3	69.5	77.5	83.8	87.5
		PUB	CTU		0	0	0	0	11.6	18.1	20.6	27.9	41.1	52.9	63.8	71.3	76.3	76.3	91.3	94.4
		PUB	Struct	N																
PS_P	protectiveservices-preengineered	PUB	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		PUB	STL		0	0	0	0	3.5	4.9	6.9	10.8	15.1	19.6	22	27.1	30.3	35.1	37	38.6
		PUB	S		0	0.6	0.6	1.1	7.1	10.5	14	17.3	22.3	28.2	32.1	35.5	38.9	42.7	45.7	47.1
		PUB	STU		0	1.2	1.4	3.3	12.9	15.9	21	25.9	31	38.5	42.6	45.7	50.5	54.4	57.1	58.6
		PUB	CTL		0	0	0	0	5	7	10	15	30	44	50	50	70	80	80	86
		PUB	C		0	0	0	0	5	15	20	25	40	50	58	65	78	90	90	92
		PUB	CTU		0	0	0	0	10	25	30	35	50	60	72	80	90	100	100	100
		PUB	Struct	N																
PS_E	protectiveservices-engineered	PUB	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		PUB	STL		0	0	0	0	3.6	4.4	5.7	8.4	11.1	14.9	19	21.7	25.2	27.7	29.2	31.2
		PUB	S		0	0	0	0	6.7	9.2	11.5	14.5	17.7	22.6	27.9	29.7	32.9	36.8	38.4	40.5
		PUB	STU		0	0.7	0.8	1.5	12.7	15.8	18.5	22.7	26	31.8	38.6	40.8	44.2	49	51	52.9
		PUB	CTL		0	0	0	0	5	7	10	15	30	44	50	50	70	80	80	86
		PUB	C		0	0	0	0	5	15	20	25	40	50	58	65	78	90	90	92
		PUB	CTU		0	0	0	0	10	25	30	35	50	60	72	80	90	100	100	100
		PUB	Struct	N																
REC_P	recreation-preengineered	PUB	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10
		PUB	STL		0	0	0	0	4	6.5	9.9	14.4	21.2	28.5	31.8	38	40.3	45.8	47.8	49.5
		PUB	S		0	0.5	0.5	0.9	8.8	13.5	18.2	23.6	31.3	38.6	42.1	47.6	50.3	54.2	57.5	59.1
		PUB	STU		0	1	1.3	3.1	15	19.1	25	32	40.8	48.2	50.8	56.3	59.5	63.6	66	67.4
		PUB	CTL		0	0	0	0	9.1	17.9	24.4	33.1	50	66	71.3	77.9	85.7	88.6	90.9	91.4
		PUB	C		0	0	0	0	16.9	25.7	31.4	43.7	62.7	72.9	80	84	91.1	95	95	95
		PUB	CTU		0	0	0	0	22.4	32.7	44.1	54.3	71.6	81.6	86.1	89.9	95.3	95.9	97.9	97.9
		PUB	Struct	N																

EXHIBIT 1
Depth-Damage Functions Used in the Study Area

Occ_Name	Occ_Description	Cat_Name	Parameter	Start_Data																			
REC_E	recreation-engineered	PUB	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10			
		PUB	STL		0	0	0	0	4	5.8	8.5	11.8	16.9	23.3	28	32	34.7	38	39.7	41.7			
		PUB	S		0	0	0	0	8.1	11.9	15.4	20.2	26	32.2	36.8	40.7	43.4	47.4	49.4	51.6			
		PUB	STU		0	0.6	0.8	1.6	14.4	18.4	22	27.9	34.5	40.4	45.6	49.8	52.2	57.1	58.9	60.6			
		PUB	CTL		0	0	0	0	9.1	17.9	24.4	33.1	50	66	71.3	77.9	85.7	88.6	90.9	91.4			
		PUB	C		0	0	0	0	16.9	25.7	31.4	43.7	62.7	72.9	80	84	91.1	95	95	95			
		PUB	CTU		0	0	0	0	22.4	32.7	44.1	54.3	71.6	81.6	86.1	89.9	95.3	95.9	97.9	97.9			
		PUB	Struct	N				0.8						25									
RF_P	religious-preengineered	PUB	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10			
		PUB	STL		0	0	0	0	5.4	9	13.6	20.1	27.5	33.8	39.1	46.1	50.4	55.2	58.4	59.6			
		PUB	S		0	0.4	0.4	0.7	10.2	16.4	22.1	28.3	35.9	42.9	48.4	54.2	58.1	62.1	65.3	66.1			
		PUB	STU		0	0.8	1.2	2.7	16.7	22.3	30.6	37.4	45.5	54.3	59.1	62.7	67.6	70.5	73.3	74.4			
		PUB	CTL		0	0	0	0	13	20.1	29.3	37.3	46.3	56.4	65.7	72.9	80.9	87.7	91.4	92.7			
		PUB	C		0	0	0	0	19.7	29.3	41.3	48.4	60	69.3	76.4	81.4	88.4	94.3	97.1	97.1			
		PUB	CTU		0	0	0	0	29.1	41.9	50.1	58.6	66.1	75.4	81.9	86.9	95	97.7	98.6	98.6			
		PUB	Struct	N				0.8						8									
RF_E	religious-engineered	PUB	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10			
		PUB	STL		0	0	0	0	5.3	8.2	12.2	17.6	23.7	29.3	35.5	40.8	45.1	48.3	51.1	52.6			
		PUB	S		0	0	0	0	9.5	14.7	19.3	24.8	30.9	37	43.2	47.6	51.3	55.4	57.5	59			
		PUB	STU		0	0.5	0.8	1.6	16	21.2	27.3	33.2	39.7	47	53.5	56.5	60.4	64.1	66.3	67.8			
		PUB	CTL		0	0	0	0	13	20.1	29.3	37.3	46.3	56.4	65.7	72.9	80.9	87.7	91.4	92.7			
		PUB	C		0	0	0	0	19.7	29.3	41.3	48.4	60	69.3	76.4	81.4	88.4	94.3	97.1	97.1			
		PUB	CTU		0	0	0	0	29.1	41.9	50.1	58.6	66.1	75.4	81.9	86.9	95	97.7	98.6	98.6			
		PUB	Struct	N				0.8						7									
SCH_P	school-preengineered	PUB	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10			
		PUB	STL		0	0	0	0	5	8.1	11.4	16.9	22.5	29.8	32.6	39	40.5	43.2	45	46.4			
		PUB	S		0	0.3	0.3	0.6	9.9	14.2	18.1	23.9	30.2	36.9	39.4	43.9	45.8	48.4	51.1	52.8			
		PUB	STU		0	0.6	1	2.3	16.3	20	25.7	32.9	38.2	44.7	46	51.3	52.9	56.3	60	62.4			
		PUB	CTL		0	0	0	0	9.4	16.7	19.7	23.4	31.4	38	43.3	48.6	52.1	55.7	57.3	58.6			
		PUB	C		0	0	0	0	14.3	21.7	26.6	30.4	39	45	47.9	51.9	55.7	59.3	60.6	63.4			
		PUB	CTU		0	0	0	0	19.6	29.3	34.3	37.7	45.4	50.7	52.7	55.4	60.1	61.7	64.9	67.7			
		PUB	Struct	N				0.8						8									
SCH_E	school-engineered	PUB	Stage		-2	-1	-0.5	0	0.5	1	1.5	2	3	4	5	6	7	8	9	10			
		PUB	STL		0	0	0	0	5	7.6	10.4	15.1	19.7	26.4	30.2	35.1	36.9	38.5	40.1	41.7			
		PUB	S		0	0	0	0	9.3	13	16.2	21.5	26.7	32.7	36.2	39.7	41.6	44.5	46.4	48.5			
		PUB	STU		0	0.3	0.8	1.5	15.8	19.5	23.8	30.3	34.7	40.4	43.4	48	49.3	53.2	56.4	59			
		PUB	CTL		0	0	0	0	9.4	16.7	19.7	23.4	31.4	38	43.3	48.6	52.1	55.7	57.3	58.6			
		PUB	C		0	0	0	0	14.3	21.7	26.6	30.4	39	45	47.9	51.9	55.7	59.3	60.6	63.4			
		PUB	CTU		0	0	0	0	19.6	29.3	34.3	37.7	45.4	50.7	52.7	55.4	60.1	61.7	64.9	67.7			
		PUB	Struct	N				0.8						7									
1ST-NB	one story, no basement	RES	Stage		-2	-1	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1ST-NB		RES	S		0	2.5	13.4	23.3	32.1	40.1	47.1	53.2	58.6	63.2	67.2	70.5	73.2	75.4	77.2	78.5	79.5	80.2	80.7
1ST-NB		RES	SN		0	2.7	2	1.6	1.6	1.8	1.9	2	2.1	2.2	2.3	2.4	2.7	3	3.3	3.7	4.1	4.5	4.9
1ST-NB		RES	C		0	2.4	8.1	13.3	17.9	22	25.7	28.8	31.5	33.8	35.7	37.2	38.4	39.2	39.7	40	40	40	40
1ST-NB		RES	CN		0	2.1	1.5	1.2	1.2	1.4	1.5	1.6	1.6	1.7	1.8	1.9	2.1	2.3	2.6	2.9	3.2	3.5	3.8

