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Land Use Interpretation in Flood Damage Estimation

Sharon Michelle Metzler
San Jose State University

LAND USE INTERPRETATION

IN FLOOD DAMAGE ESTIMATION

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Sharon M. Metzler

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Sharon M. Metzler

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Dr. Richard Taketa	Department of Geography
Dr. M. Kathyrn Davis	Department of Geography
Dr. Kristin Byrd	United States Geological Survey

ABSTRACT

LAND USE INTERPRETATION
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by Sharon M. Metzler

This thesis examines the role of geographic land use interpretation in flood damage estimation. Sample flood data were drawn from the 1998 flood event along San Francisquito Creek in northern Santa Clara County, California. Spatial flood data for the event were collected from the Santa Clara Valley Water District (the District); depth-damage factors and the flood damage equations were both collected from US Army Corps of Engineers' (the Corps) publications; and spatial parcel data were collected from the Santa Clara County Tax Assessor's office (the Assessor).

This study computes flood damages per parcel using the Corps' recommended equations. Within that computation process the land use classifications from three different agencies and comprising 9-100 land use categories were interpreted to fulfill the calculations. The Tax Assessor's land uses were generalized into construction land uses in order to identify replacement costs. Construction land use categories were then generalized into the Corps land uses in order to apply depth-damage factors per structure. The flood-affected parcels were then grouped to include the District's designated land uses. The flood risk was then mapped by land use and described in dollars as a means of choosing an appropriate flood protection measure. The computation was performed per parcel and variations in the economic information conveyed by each agency's land uses were reviewed.

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Chapter 1

Introduction

Unlike some natural hazards that are distinguished by the areas they affect, flooding in the United States touches a broad spectrum of landscapes. Whereas New England's *Nor'easter* storms and Southern California's *Santa Ana Winds* are severe and seasonal, they are strongly associated with their localities. Flooding, however, affects all landscapes: inland deserts, coastlines, mountains, river basins, and of course the wide, gentle arc of the floodplain itself. Although flooding is nationally widespread, each flood event is highly localized and sensitive to the perpetually changing built environment- only pieces of which are inundated with each flooding episode (FEMA, 1992). But those pieces of ground are so crucial to human life and enterprise that protection against the hazard inspires regional systems of inter-agency cooperation, federal legislation, and federal funding.

In the United States the physical geography of floodplains attracts most human settlement and commerce, and therefore floodplains are characteristically populated (NRC, 2000). The geology of many floodplains has made them fertile to farm, and the waterways – both costal and river– from which the flood hazard swells, have historically served to transport humans and our saleable goods. Consequently, the nature of the floodplain attracts settlement, which as always begets evermore settlement. Combined with the widespread and continuous nature of flooding, the hazard leads to tremendous costs in lives and dollars (FEMA, 1992). As a result the Federal government has designated flooding a national hazard and thereby made planning for flood protection a civil imperative at all levels of government.

In an effort to minimize flood damages, agencies and individuals within the US government carefully select and implement flood protection measures that are adequate to their jurisdiction's flood risk. The engineers and civil administrators overseeing public flood protection projects are floodplain managers and they work for agencies like the US Army Corps of Engineers (the Corps), the Federal Emergency Management Agency (FEMA), and in the case of Silicon Valley, smaller local resource agencies like the Santa Clara Valley Water District (the District). . Since flood damages are principally the effect of flood waters in contact with people, property, and livelihoods, flood protection is typically a physical structure redirecting and/or containing flood waters: levees, seawalls, cement-lined (channelized) riverbeds, etc. . Beyond the price of engineering design and physical construction, each flood protection measure has an environmental impact and social consequences. . Therefore, floodplain managers prepare cost-benefit analyses to carefully select flood protection that is cost-effective and appropriate to the given flood risks. This study addresses the problem of interpreting land use as a means of assessing flood damages as part of the cost-benefit analysis.

The purpose of this research is to evaluate the role of land use interpretation in the flood damage assessment process at the parcel level. To keep the research realistic, the calculation is performed in accordance with published economic guidance from the US Army Corps of Engineers (USACE, 1996b), and is based on an actual flood event along

San Francisquito Creek in northern Santa Clara County during winter 1998. The computation is performed at the finest scale of uniform land use identification, the parcel.

Chapter 2

Literature review

Spatial Techniques in Flood Damage Assessment

The US Army Corps of Engineers began reviewing the effectiveness of spatial techniques in the computation of flood damages as early as 1978. The Corps' 1978 report on spatial techniques (USACE, Davis and Webb, 1978) describes the methods and results of a 1977 study performed on Rowlett Creek, in Garland, Texas, by Corps engineers and researchers. The methodology relies on the characterization of land uses based on a grid-cell inventory of the flood affected area. Benefits described include the analysis of individual buildings within a flood event, for instance the role of specific structures in the restriction of high-water flows and the impact of flooding on individual structures. Other benefits included the ability to compare a range of protection measures from least to most invasive, and the utilization of quantitative flood heights at specified segments of creek. This study suggests a positive relationship between the number of land use categories and computational accuracy but indicates that 20 categories of land use are likely sufficient for damage estimation.

Depth-to-Damage Computation Curves

Economic research and recommendation for per parcel replacement valuation is regularly published by the Corps. The Corps' 1997 Final Report (USACE 1997) published by the Corps' Louisiana office, gives per-building estimates of replacement value for both fresh and saltwater based on each structure's use. The graphs which indicate the predicted extent of dollar damages in relation to the flood depths, are called depth-to-damage curves. The curves developed from the 1997 Final Report (USACE 1997) are suitable for the San Francisco Bay Area because like, Louisiana, the Bay Area has a coastal geography that is protected from saltwater flooding by levees and also exposed to freshwater flooding from streams, creeks, and rivers. The final report also suggests that even among low-density, low development geographies, revisions to the damage curves are justifiable due to changes and uncertainties in construction costs and technology.

Risk Analysis and Uncertainty in Flood Reduction Studies

When state and local officials petitioned the U. S. Congress regarding the U. S. Army Corps of Engineers' revisions to their risk analysis methods, Congress commissioned the National Research Council to investigate the Corps' revisions. The results of that research (National Research Council, 2000) indicate that the wide range of physical geography across the United States justifies the Corps revisions for varying levels of protection in different communities. The Research Council's report further states that advancements in software technology obligates the Corps to move beyond procedural revisions of their method toward developing software tools that could be adapted for use by any community at risk of flooding.

Factors Influencing Uncertainty in Flood Damage to Buildings

Merz, Kreibich and others (2004) found that damages from actual flood events across nine German counties followed a lognormal distribution and that this was consistent even when the data were grouped by building use and inundation (flood) depth. Their research indicates that damage curves relating depth to predicted damages fail to account for variations among similar buildings types affected by identical depths, and therefore absolute damage curves do not account for the involved uncertainties.

Chapter 3

Methodology

Step 1: Data Acquisition

Parcel data for all of Santa Clara County was requested and collected from the Santa Clara County Tax Assessor's office along with a complete list of the County's parcel-associated land uses. GIS-formatted flood event records for the 1998 San Francisquito Creek flooding were collected from the Santa Clara Valley Water District. Publications related the 1998 flooding and documents explaining the District's most recent damage estimation equation were also collected from the Water District. Economic guidance publications from the Corps of Engineers were reviewed to find appropriate and complete damage calculation recommendations. Post-flood event reports from the Corps of Engineers were reviewed to identify geographic locations with similar inundation and structural exposure profiles to Santa Clara County. Construction costs and real estate information required to fulfill the Corps' procedural recommendations were collected.

Step 2: Data Preparation

Construction and real estate data for each parcel was extracted from local and regional real estate databases. Construction cost values and the Assessor's land use types were interpreted and associated with each parcel. These inputs were then associated with land uses from the Corps' selected report of damage curves acquired in *Step 1*. Parcel and flood event data were cleaned as needed and projected to a State Plane projection in the GIS. To compute per parcel flood damages in accordance with the Corps economic guidance, a GIS script was written, tested and developed using the python scripting language.

Step 3: Flood Damage Calculation

The physical flood event was re-created as spatial GIS polygons describing depth and creek source. The polygons were intersected with the prepared parcel dataset from *Step 2*. The python script was run, utilizing the construction, real estate, and land use information prepared in *Step 2*. The results were then mapped as a distribution of flood-affected parcels, by each agency's land use classification and by the flood depth. The estimated dollar damages were also graphed as a distribution per flooded creek segment.

Chapter 4

Case study

Santa Clara County and San Francisquito Creek

Many floodplains in the United States are susceptible to freshwater (or riverine) flooding, but Santa Clara County's proximity to San Francisco Bay makes it susceptible to both fresh and saltwater flooding. Santa Clara County is the broad, flat valley at the southern end of California's San Francisco Bay, nearly enclosed by the Santa Cruz and Diablo Mountain ranges. To the west, the Santa Cruz Mountains form the steep, green, coastal redwood ranges. They capture mist and cloud cover coming inland off of the Pacific Ocean (McArthur, 1981). The oak and chaparral Diablo Mountains are softer and enclose the valley to the east. Precipitation is naturally channeled down the slopes of both ranges and through a network of creeks and streams. An elaborate stream network crosses the valley's interior, carrying rainfall and collecting ground water and surface run-off on its way north. To the north, the valley meets the expansive salt marshes of South San Francisco Bay. These marshes provide a partial buffer during flooding and tidal activity (USGS, 1998). The marshes also carry brackish and salt water inland from the Bay.

The Santa Clara Valley Water District manages water resources within the Santa Clara Valley. Although the District publicizes its civic role as *"Providing stream stewardship, wholesale water supply, and flood protection for Santa Clara County,"* its management tasks also include conservation planning, the collection and monitoring of groundwater resources, waterway maintenance and restoration, and flood control. The

District is a wholesale water distributor. The District provides treated water to retailers who in turn sell water to residents and businesses. The collection points of surface run-off distinguish the District's five watersheds. San Francisquito Creek is part of the District's Lower Peninsula Watershed in northern Santa Clara County (see Figure 1*).* The creek is a 14-mile long catchment for an area of 45 square miles crossing both Santa Clara County and San Mateo County (USGS, 2008). The creek's upstream sources begin in the Santa Cruz Mountains and travel through five cities en route to the Bay where the creek finally deposits into the Bay at the San Mateo and Santa Clara County boundaries. The creek's centerline is the municipal border for Menlo Park and Palo Alto, Menlo Park and East Palo Alto, and East Palo Alto and Palo Alto.

Figure 1. Santa Clara Valley's Five Watersheds.

Reproduced from the Santa Clara Valley Water District's public website: www. valleywater. org/

Since record keeping for floods in the valley began in 1931, San Francisquito Creek has been the source of four major floods (Cushing, 1999). Until 1998 the largest flood event took place during Christmas 1955, inundating approximately 2,600 acres with a measured discharge of 5,560 cubic feet per second (USGS, 1998). By comparison the 1998 flood event inundated 11,000 acres with an estimated discharge of 7,100 cubic feet per second (Cushing, 1999). The footprint of the 1998 flood is very close to the Corps' predicted 100-year (or 1% probability) flood event for San Francisquito Creek. Figure 2 illustrates the flood event by depth, source, and affected parcels. Discharge is a less common measure than acreage, and deserves further explanation. Appendix A describes the relationship between flood frequency and discharge.

Describing the 1998 flooding as discharge and acreage explains the hydraulic aspects of the event. Accounting for the lives affected and the dollars spent for clean-up and recovery is a more tangible description. Following the February 1998 floods, the District performed a post-flood assessment. According to that report, the San Francisquito flooding affected 3,411 households (Cushing, 1999); 60% or 2,027 of those were in Palo Alto; another 1,384 were East Palo Alto and Menlo Park homes and caused $23,707,000 in residential damage. Table 1 provides summary acreage and parcel count information for the flooded location. These numbers are useful for post-event assessment, but because there have been many changes in the landscape along San Francisquito Creek since 1998, the same event today would have a different impact.

Table 1. Summary of Acreage, Parcels and Source of Flooding for the 1998 San Francisquito Creek Flood Event.

1998 San Francisquito Flood Event		
Flood Depth	**Acres**	**Parcel Count**
Less Than 1 Foot	300. 89	1,530
1 Foot	1,061. 90	1938
2 Feet	97. 06	473
Total	1,459. 85	3,941

Flood Damages, Structures and Parcels

Choosing an appropriate flood protection measure for any location involves performing a site-specific cost-benefit analysis. The objective of the analysis is to compare a community's expected dollar damages for a given flood event to the financial and environmental cost of constructing a flood protection mechanism (USACE, 1996). In simplified terms the *cost* of a protection project is compared to the *value of the benefit* offered by the same protection. A floodplain manager's work is to prepare this cost-benefit analysis as accurately as possible. Because flooding is a national hazard, the US Army Corps of Engineers has been meticulous in studying the effect of floodwaters on a variety of building materials (NRC, 2000) and providing economic guidance as a result. The agency regularly performs comprehensive, building-to-building studies following major flood events. Their results are published to inform everyone concerned with developing, insuring, or protecting the inhabited floodplain. The engineers and economists at the US Army Corps of Engineers publish economic guidance, best practices, and detailed equations so that calculating estimated flood damages as part of the cost-benefit analysis can be nationally uniform and current with actual economic and construction circumstances (NRC, 2000).

Overall, flood damage estimation, as recommended by the Corps, is a series of calculations developed to identify multiple levels of damage. There are, for instance, *direct damages* produced by objects in contact with floodwaters, and *indirect damages,* produced as a peripheral consequence of the flooding. The direct damage calculation is the sum of two calculations. The first of these is *structural damage*, or more specifically, the percentage of a structure's *depreciated replacement value* that is attributed to flooding. The second is the value of damages incurred on an affected structure's contents; this is summarized by the Corps as a percentage of the structural damage: the *content-to-structure-value-ratio (CSVR).* Finally, *indirect damages* as a whole are assessed as a percentage of the summed direct damages. For the purpose of this study the sum of these three represent *estimated flood damages*. See Figure 3.

S*tructural* damages amount for the largest portion of dollar damages, followed by *indirect damages* and *contents damages* respectively. Along with an affected structure's size and constituent materials, the cost of structural damage is driven by a well understood relationship between flood water depth and expected dollars damage: deeper flood water implies higher dollar damages. The Corps' publications provide depth-damage curves intended to more accurately describe expected damages per flood depth. "Curve" refers to the shape of the line produced when the table of depth-to-damage figures is graphed. See Table 2 and Figure 4. Because the Corps' finest scale of post-flood event study is building-to-building and since buildings are parcel-level objects these curves are suitable for per parcel analysis. Calculating damages at geographic units larger than the parcel increases any uncertainty inherent to the computation by expanding the aggregation of units (USACE, 1978).

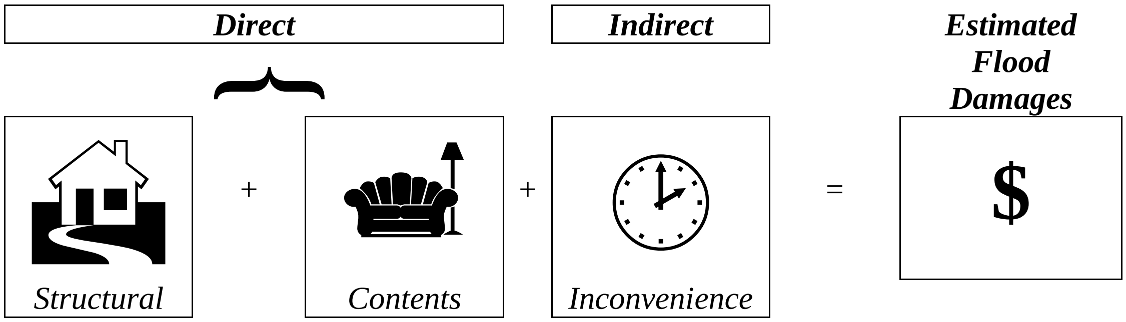

Figure 3. Illustration of Estimated Flood Damages.
As described in the *National Economic Development Procedures Manual – Urban Flood Damage* (USACE, 1988).

Table 2. List of Depth-to-Damage Curves.

Curves for Single-Family Residential Structures	
Flood Depth in Feet	Damage as % Structure Value
0	0. 011
0. 5	0. 224
1	0. 224
2	0. 232
3	0. 280
4	0. 314
5	0. 329
6	0. 479
7	0. 479
8	0. 479

Based on single-family residential structures and freshwater flooding.
(USACE, 1997).

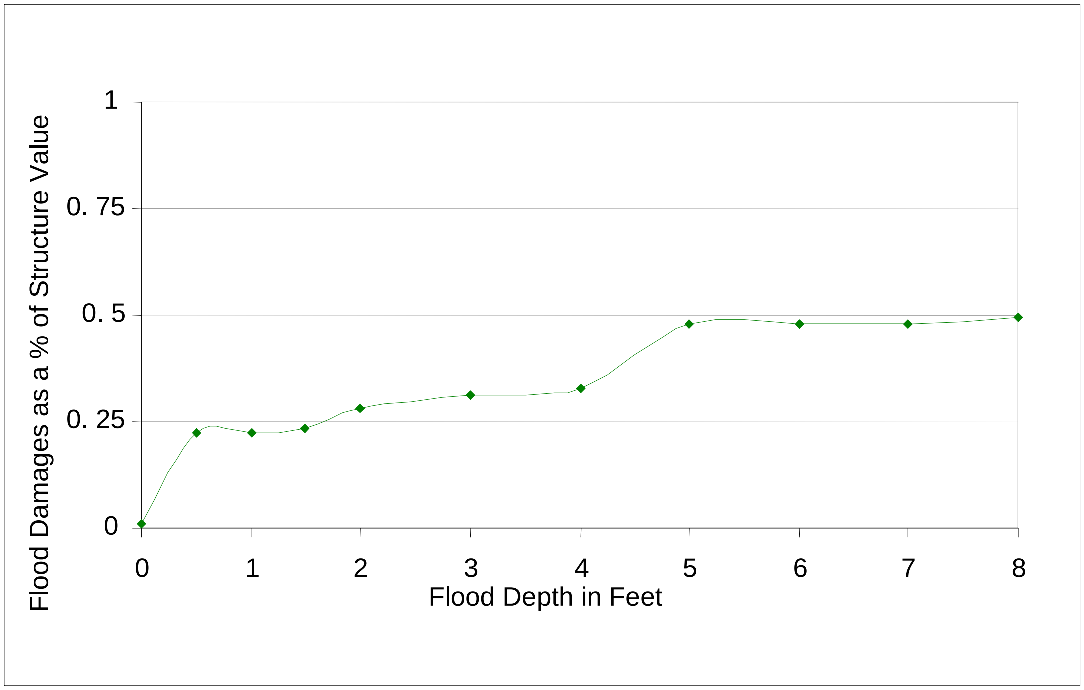

Figure 4. Depth-to-Damage Curves.
Based on single-family residential structures and freshwater flooding.
(USACE, 1997).

Per Parcel Damage Assessment

The effectiveness of any selected flood protection mechanism– seawall, cemented channel or levee – is directly related to the physical geography of the landscape. As the physical features and materials exposed to flood waters change, the surfaces over and across which flood waters travel also change. Whereas smooth, cemented surfaces convey rainfall as run-off, the soil, grass or undeveloped land absorbs it. Conveyed run-off collects in streams, creeks, and low-points on the landscape. An increase in impervious (non-absorbent) surfaces upriver of any waterway predictably increases the total volume of run-off that floodplain managers can expect in a waterway. But since construction and development are parcel-level activities, approved and only somewhat overseen by municipal agencies, floodplain managers are in a peculiar position. They do not control the hydrologic cycle of rainfall, and they do not influence the course of construction and development impacting run-off volume within the floodplain. Nevertheless, floodplain managers are responsible for protecting the lives and businesses within their jurisdiction by testing flood scenarios on the known landscape and selecting the most appropriate protection measure.

For agencies such as the Santa Clara Valley Water District, overseeing rapidly changing urban floodplains that intersect many municipalities, being able to estimate flood damages per parcel allows, if not control of landscape changes, at least a finer scale of estimation, one that captures the unit at which change happens most frequently— the parcel. Although floodplain managers do not control construction permits, they *do* choose computation methods used for evaluating flood damages. Accurate damage estimation involves following economic guidance from the Corps, applying current damage curves, and performing the calculation with landscape information and economic data that are as up-to-date as possible. Before the advent of digitized parcel maps and geographic information software, the pace of economic growth (additional population) and development (additional structures) quickly outdated any agency's paper maps and damage estimates, especially if parcel aggregation was used (USACE, 1978).

Software advances in the last 20 years have made large-scale, per parcel damage estimation feasible for resource protection agencies. Until geographic information system (GIS) software and databases became available for personal computing environments, per parcel flood damage estimation was expensive and time consuming (NRC, 2000). Attempting to keep large scale damage assessments current with rapid construction in an economically flourishing urban landscape and floodplain was previously impractical, because parcel maps were maintained on paper and revised in periodic cycles measurable in years (NRC, 2000). Even after GIS software became available, data format standards and well thought-out inter-agency relationships were necessary in order for agencies with complementary responsibilities to effectively share data (NRC, 2000). Now that many regional agencies have elements of data standardization in place, floodplain managers are in a position to compute damages with data at a scale measurable in meters and current within days of actual changes made in the floodplain.

In Santa Clara County the County Tax Assessor's office maintains digitized parcel maps for the purpose of accurate tax collection. FEMA and the Santa Clara Valley

Water District maintain flood maps for regulatory and emergency planning purposes. Through a Memorandum of Understanding, the County provides the District with spatial data files describing the County's parcels. Since the District uses ESRI's ArcView GIS software and has access to the County's spatial parcel file, per parcel flood damage computation is possible. This study was *only* possible because GIS software, data sharing, programmatic computation methods, and the Corps' economic guidance were available to perform per parcel damage estimation. With these elements in-place, Floodplain Managers in Santa Clara County can test flood scenarios, damage curves and economic assumptions in order to improve the cost-benefit analyses that are essential for selecting the most appropriate flood protection measures.

Table 3 lists the steps followed and data used in this study. The central work of this study was properly implementing the Corps' economic guidance (USACE, 1988). On Table 3 the "Steps" and "Information Needed" columns are the Corps' recommendations; the 'Source' and 'Format' columns describe where the data came from and how it was provided. Appendix B articulates the value of all variables used in each Corps' land use class. Appendix C explains the depreciation equation as recommended by the US Army Corps of Engineers New Orleans Office, from which the depth-damage curves were selected. Appendix D explains each variable and computational implementation in accordance with the Corps' economic guidance (USACE, 1996b). Appendices D-3, D-4, and D-5 illustrate the computation on the 3 primary forms of flood damage: *direct structural damage*, *direct contents damages*, and *indirect damages*.

Appendix D-6 lists the cost multipliers used per zip code in this calculation to account for variations in construction quality within Santa Clara County.

Table 3. Calculating Estimated Flood Damages Per parcel: Method, Input Data, Data Formats & Sources. The ‘Steps’ and ‘Information Needed’ columns are based on the *National Economic Development Procedures Manual – Urban Flood Damage*, (USACE, 1988).

Steps		**Information Needed**	**Source**	**Format**
1	**Identify Flooded Area**	Flood Location	SCVWD & FEMA Flood Maps	Digital
		Flood Depth	SCVWD & FEMA Flood Maps	Digital
2	**Identify Affected Properties**	Parcel Location & Land Use Type	County Assessor Parcel Map	Digital
3	**Estimate Value of Affected Properties**			
3a	Depreciate Replacement Value of Structure	Land Use Type	County Assessor Parcel Map	Digital
		Construction Costs	*BNi Construction Costbook 2005*	Printed → Digital
		Sub-Regional Cost Index	*BNi Construction Costbook 2005*	Digital
		Structure Square Footage	MetroScan® Software	Digital
		Building Age	MetroScan® Software	Digital
		Content-to-Structure-Value-Ratio	US Army Corps of Engineers, 1997	Printed → Digital
3b	Estimate Value of Contents	Land Use Type	County Assessor Parcel Map	Digital
		Content-to-Structure-Value-Ratio	US Army Corps of Engineers, 1997	Printed → Digital
4	**Estimate Damages per Affected Property**			
4a	Structural Flood Damages	Depreciated Replacement Value of Structure	US Army Corps of Engineers, 1997	Printed → Digital
		Depth-to-Damage Factor: Structures		
4b	Contents Flood Damages	Estimated Value of Contents		
		Depth-to-Damage Factor: Contents	US Army Corps of Engineers, 1997	Printed → Digital
4c	Indirect Flood Damages	Land Use Type	County Assessor Parcel Map	Digital
		Indirect Damage Factor	Santa Clara Valley Water District,1981	Printed → Digital
5	**Sum Flood Area Damages**	Results of Step 4.		

Chapter 5

Research Goals

In this research, I evaluated the extent of land use classification across agencies and the how the variation might influence per parcel flood damage assessment. In order to properly perform the Corps' recommended flood damage calculation following the 5 steps (see *Table 3*) recommended in the Corps' *National Economic Development Procedures Manual – Urban Flood Damage* (USACE, 1988), I needed to procedurally apply land use categories developed by 4 separate agencies. First, the Santa Clara County Tax Assessor's office with 100 land uses, see Table 5; second, the *BNi Construction Costbook* (BNi Building News, 2005), with 49 construction land uses, see column 5 on *Table 4A*; third, the US Army Corps of Engineers, with 9 damage curve land use descriptions (USACE, 1997); and fourth the Santa Clara Valley Water District, with 4 cost factors for undeveloped/non-construction, land uses. *Tables 4A* and *4B* illustrate the exact conversion across the four agency land use categories.

In this study, the Assessor's land use codes infer replacement value by indicating the type structure allowed by the County to be built on the parcel: 01 Single Family, 06 Condominium or Townhouse, etc. The Assessor's land use codes were reinterpreted to construction land uses based on the *BNi Construction Costbook* (BNi Building News, 2005). The *Costbook* provided per-square foot costs for replacing a structure. Information on the actual structure sizes on each parcel was imported to the parcel data file from the MetroScan® real estate software provided by the District. Because there are

100 Assessor land use codes and only 49 construction land uses, descriptive land use information is reduced by half at this re-interpretation step.

Table 4A. Interpreted Land Uses Across Agencies with Reconstruction Costs.					
District Land Use	*FLE* [a]	*Assessor's Use Code* [b]	*Corps' Land Use* [c]	*BNi Construction Costbook Land Use* [d]	*Cost/ SqFt* [e]
Commercial	60 yrs	61	Groceries & Gas Stations	Public: Auto Dealer	$ 113. 95
		52	Groceries & Gas Stations	Mall/Plaza	$ 70. 54
		14	Professional Business	Research & Dev.	$ 183. 78
		39, 59	Professional Business	Offices	$ 153. 04
		50, 51	Retail & Personal Services	Mall/Plaza	$ 70. 54
		53, 54, 55, 56	Retail & Personal Services	Business Center	$ 55. 75
		58, 68	Retail & Personal Services	Retail Store	$ 128. 97
		18	Professional Business	Offices	$ 153. 04
Industrial	60 yrs	10, 11, 12, 13, 15, 16, 17, 19, 90	Warehouse & Contractor Services	Warehouse w/Office	$ 50. 74
		20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31*, 32, 33, 34, 35, 36, 37, 38, 40	Warehouse & Contractor Services	Manufacturing	$ 93. 50
		99	Warehouse & Contractor Services	Research Dev.	$ 183. 48
Mobile Home	30 yrs	8, 67	Mobile Home	Mobile Home	$ 40. 00
Multi-Family	50 yrs	2, 3, 4, 5, 7, 9	Multi-Family Residences	Apartments	$ 93. 37
		6	Multi-Family Residences	Condo/Town Home	$ 104. 72
Public/Quasi	60 yrs	64	Eating & Recreation	Health Center	$ 106. 18
		65, 83	Eating & Recreation	Recreation Center	$ 142. 11
		41, 42, 43, 44, 45, 46, 47	Public & Semi-Public	Transportation	$ 204. 46
		60	Public & Semi-Public	Parking Garage	$ 41. 88
		62	Public & Semi-Public	Elementary School	$ 126. 32
		63, 75	Public & Semi-Public	Nursing Home	$ 218. 12
		70	Public & Semi-Public	College Facility	$ 402. 25
		71, 72	Public & Semi-Public	High School	$ 132. 24
		73	Public & Semi-Public	Hospital	$ 247. 85
		74	Public & Semi-Public	Government Bldg	$ 164. 30
		76	Public & Semi-Public	Church	$ 139. 77
		77	Public & Semi-Public	Museums	$ 187. 25
		78, 79	Public & Semi-Public	Arena	$ 186. 27
Single-Family Residence	55 yrs	1	Single-Family Residences	Single-Family Homes	$ 123. 89

[a] Functional Life Expectancy of Structure. See Appendix C.
[b] Table 5, "Land Use Codes of Santa Clara County Tax Assessor. "
[c] US Army Corps of Engineers, New Orleans District Office, May 1997.
[d] BNi Building News, 2005. Appendix E. "Square Foot Tables and Subcategories".
[e] Value derived as an average based on all project sizes for the selected "Square Foot Table".
[f] Santa Clara Valley Water District Waterways Study, 2000.
[g] Based on clean-up costs reported by the City of Palo Alto after the 1998 San Francisquito flood event.
[*] Dollar damages for this land use do not include damages to contents, since the structure is vacant.

Table 4B. Agricultural Land Use Groupings Across Agencies and Reconstruction Costs.					
District Land Use	*FLE* [a]	*Assessor's Use Code* [b]	*Corps' Land Use* [c]	*BNi Construction Costbook Land Use* [d]	*Cost/ SqFt* [e]
Agriculture	N/A	92, 97	Annual	N/A	$ 65. 00 [f]
		93	Grazing	N/A	$ 6. 00 [f]
		91, 94	Perennial	N/A	$ 35. 00 [f]
Insufficient Information	N/A	none		N/A	$ 0. 00
Not Counted	N/A	0, 69, 95, 96, 98		N/A	$ 0. 00
Open Improved	N/A	66, 81, 82, 84, 85, 86, 87, 88, 89		N/A	$ 200. 00 [g]

[a] Functional Life Expectancy of Structure. See Appendix C.
[b] Table 5, "Land Use Codes of Santa Clara County Tax Assessor. "
[c] US Army Corps of Engineers, New Orleans District Office, May 1997.
[d] BNi Building News, 2005. Appendix E. "Square Foot Tables and Subcategories".
[e] Value derived as an average based on all project sizes for the selected "Square Foot Table".
[f] Santa Clara Valley Water District Waterways Study, 2000.
[g] Based on clean-up costs reported by the City of Palo Alto after the 1998 San Francisquito flood event.
[*] Dollar damages for this land use do not include damages to contents, since the structure is vacant.

Chapter 6

Results

When flooding from the 1998 San Francisquito Creek event was recreated in the GIS, not every available land use category was represented among the flood-affected parcels. For instance, there are no Assessor Code “13 Grain Storage, Stockyard, Packing Services” in the affected area. Only 27 of the Assessor’s 100 land uses are affected; only 19 the 49 construction land uses are affected; only 7 of the Corps’ 13 land uses are affected; and only 3 of the District’s 4 undeveloped land uses are affected. The most substantial loss of economic landscape information occurs when construction land uses are re-interpreted to Corps’ damage curve land uses in order to apply the damage curve factors. The transition results in a 47% reduction in landscape information. Figure 5 illustrates how the percentage decrease in land use information was computed. A total of 19 flood affected construction types are re-interpreted to 7 Corps damage curve land uses plus 3 District descriptions of undeveloped land.

The majority of the 3,941 parcels impacted by the San Francisquito Creek flood event are residential. But each agency’s land use classification accounts for different levels of detail, even within the residential category. Figure 6 illustrates the counts and residential subcategories represented. Of the affected parcels, the Assessor’s classification represents 7 residential land uses. The *BNi Construction Costbook* classification represents 4 residential land uses. The Corps’ classification represents 2 residential land uses. Five parcels described as “Convalescent Hospital” or “Residential Care” are absent from the Corps’ residential subcategories altogether, because they fit best into the Corps' "Public & Semi-Public" land use classification (see Table 4A, column "Assessor's Use Code", codes 63 and 75).

$$\frac{\textit{Count of Applied Construction Land Uses} - \textit{Count of Final Land Uses Applied}}{\textit{Count of Applied Construction Land}} = \textit{Reduction in Land Use Information}$$

$$\frac{19 - 10}{19} = 0.$$

Figure 5. Calculation to Determine the Decrease in Land Use Information.

	Santa Clara County Tax Assessor		BNi Construction Costbook 2005		US Army Corps of Engineers	
	3,615	Single-Family	3,615	Single-Family Home	3,615	Single-Family
	69	Five or More Family	157	Apartment	159	Multi-Family
	58	Two-Family	4	Nursing Home		
	29	Three and Four Family	2	Condo/Town Home		
	2	Convalescent Hospital				
	2	Condominium, Townhouse				
	2	Residential Care Facilities				
	1	Fraternity, Sorority, Boarding, Rooming House				
Σ	7	Residential Land Uses	4	Residential Land Uses	2	Residential Land Uses
	3,778	Residential Parcels of	3,778	Residential Parcels of	3,774	Residential Parcels of
	3,941	Flood Affected Parcels	3,941	Flood Affected Parcels	3,941	Flood Affected Parcels

Figure 6. Residential Subcategories and Parcel Counts for the Replicated 1998 San Francisquito Creek Flood Event.

The Assessor's categories contain the greatest variety of descriptive land use. But the Assessor's categories don't convey economic information directly to the flood damage computation. Instead they infer value by indicating the likely construction type for each parcel (see Step 2 in Table 3). The *BNi Construction Costbook* categories provide precise dollar value multipliers for per-square-foot construction costs (see Table 4A) but less land use variation than the Assessor's classifications. The Corps' land use categories are the briefest of the three classifications. Within the damage calculation, the Corps' land uses rely heavily on each parcel's assigned construction classes (see Step 3 in Table 3), because flood damages are estimated as only a percentage of a structure's depreciated replacement value.

There is a sharp drop in the value of land use information in the transition from construction land use to the Corps' land use. In this study, the information lost in the transition from construction to Corps' land use is insignificant. If the flood-affected properties were more diverse, instead of so heavily single-family residential, the drop could be more significant. For example, both the Assessor and the *BNi Construction Costbook* classify 95. 864% of the parcels as residential. The Corps' classification identifies 95. 762% of the parcels as residential. This is a difference of only 0. 00102%, meaning that across the three classifications, the Corps' land use assignment would conflict with the *BNi Construction Costbook* land use assignment approximately once of every thousand parcels. Figures 7, 8 and 9 map the affected parcels by each agency's land use.

If a flood event of similar size struck a densely populated, highly mixed use area, like Guadalupe Creek in downtown San Jose, there would certainly be many more discrepancies in land use assignments. In that case the estimated dollar damages from flooding would likely be more inaccurate as a result of larger discrepancies in land use classifications across the various agencies. This finding is consistent with a 2004 German research paper, “Factors Influencing Uncertainty in Flood Damage to Buildings” (Merz, 2004). The research indicated that damage curves relating depth to predicted damages fail to account for variations among similar buildings types affected by identical depths, and therefore absolute damage curves do not account for the involved uncertainties.

While methodological, predictive tools to improve upon damage curves are being developed, the Corps’ existing damage curves would be improved if they were more closely aligned with the construction industry’s categories. The *BNi Construction Costbook* is published annually. Its categories reflect the types of structures being built, the required materials, and labor employed in the process. Producing depth-damage curves aligned with the construction industry’s building categories would enhance the flood damage estimation process by smoothing the transition of interpreted land uses, see Steps 3 and 4, on Table 3. Future investigation on this topic might include: determining rates of land use change typified by floodplain geographies of various sizes and population densities. Another future investigation might include determining the ideal composition of landscape diversity in the most flood-prone areas of the developed floodplain.

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Appendix A Understanding Flood Frequency and Discharge

Discharge is a key element in determining flood-frequency (how often a flood event is likely to occur), and although flooding is most tangibly described in terms of lives and dollars, flood-frequency is essential to assessing a hazard's associated risk and damage potential. For the purposes of hydraulic analysis, discharge refers to the rate and volume of water flow at a given point on a waterway[1]. Not surprisingly, its equation incorporates both area and velocity. To determine discharge, stream gauges (vertical rulers) within referenced sections of a waterway are read and recorded for water surface height (stage). Discharge is then calculated as the area of the waterway's *cross-section* at the gauge location multiplied by the water's velocity. Since the relationship between stage and velocity is consistent[2], continuously measuring velocity within a waterway is unnecessary. As an example: water moving at 5 feet per second in a 50 square foot section of creek generates 250 cubic feet per second of discharge.

Hydrologists use stage and discharge to determine flood-frequencies, or how often a segment of waterway is likely to flood. Even though historical logs of discharge flows are relatively recent, certainly younger than 100-years, each flood event theoretically improves the predictive basis for any flood-frequency analysis by increasing the population of observations upon which the prediction is made. The mathematics for flood frequency analysis is straight-forward: For every year of record, the highest flow (Q) is recorded; this listing is ranked (highest being 1), and the frequency (T) is derived as:

$$T = (n + 1) / m$$

where m represents the ranking, and n represents the count of elements in the listing. For instance, for a Q of 321, among 30 years of observations, the frequency is computed as

$$T = (30 + 1) / 20 \quad = 21 /30 \quad = 1.\ 550 \text{ years}$$

Because the events are selected from 1 year periods (365 days), T can be multiplied by 365 to describe the interval of days between discharge events of the same size. In this case, (1. 033 * 365) = 565. 75 days. *See Figure A1*.

Q	**T**	**Q**	**T**	**Q**	**T**
61	1. 033	*321*	1. 550	*590*	3. 100
85	1. 069	*365*	1. 632	*592*	3. 444
194	1. 107	*371*	1. 722	*616*	3. 875
207	1. 148	*381*	1. 824	*620*	4. 429
256	1. 192	*418*	1. 938	*633*	5. 167
261	1. 240	*473*	2. 067	*652*	6. 200
266	1. 292	*529*	2. 214	*693*	7. 750
275	1. 348	*538*	2. 385	*705*	10. 333
292	1. 409	*546*	2. 583	*738*	15. 500
316	1. 476	*554*	2. 818	*797*	31. 000

Figure A1. Example of 30-years peak discharge data for a hypothetical waterway.

Flood-frequency analysis enables the depiction of inundation risk as either a function of time (years) or as a probability. Time is the most convenient and familiar term: 30-year flood event, a 50-year flood event, a 100-year flood event, etc. Unfortunately, temporal description implies non-recurrence within the named period, which is misleading. Each year's weather cycle is not truly independent from the last and so 100-year flood events can occur in succession. For this reason, describing flood events as probabilities is more precise. A 100-year flood event is one that has a 1% likelihood of recurring in any given year.

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[1] Don M. Corbett and others, Stream-Gauge Procedure: A Manual Describing Methods and Practices of the Geological Survey, USGS Water Supply Paper No. 888 (Washington, DC, 1943) 13-108.

[2] E. J. Kennedy, "Discharge Ratings at Gaging Stations," Techniques of Water-Resource Investigations of the United States Geological Survey, chap. A10 of book 3, Applications of Hydraulics (Washington, DC. ,1984).

Appendix B Input Variables Listed by Corps Land Use Category

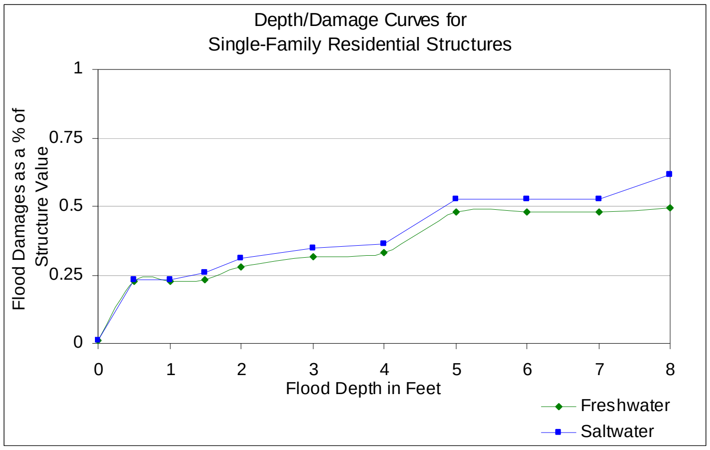
Corps Land Use Category	Appendix Document
Single Family Residences	B1
Multi-Family Residences	B2
Mobile Homes	B3
Eating & Recreation	B4
Groceries & Gas Stations	B5
Professional Businesses	B6
Public & Semi-Public	B7
Retail & Personal Services	B8
Warehouse & Contractor Services	B9

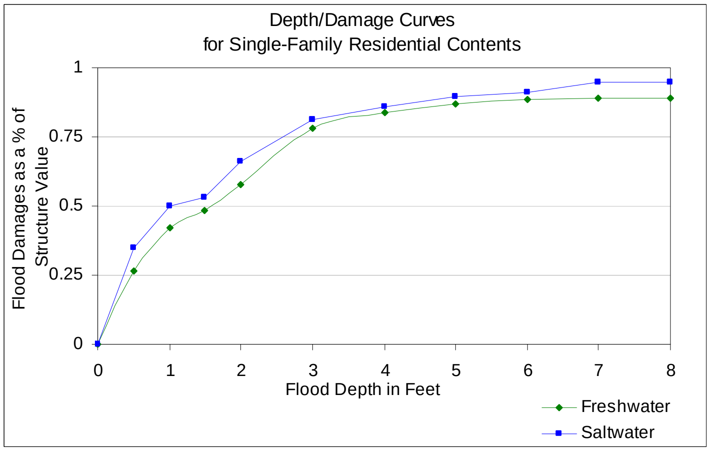
Sources for Variables Listed in Documents

Input Variable	Source
Depth-to-Damage Curves	US Army Corps of Engineers, New Orleans District Office, May 1997.
Assessor Land Use Codes	Santa Clara County Tax Assessor. See also Figure 6 in this study.
BNi Construction Cost Book	BNi Construction Cost Book, 2005
Content-Structure-Value Ratio	US Army Corps of Engineers, New Orleans District Office, May 1997.
Building Life Expectancy	US Army Corps of Engineers, New Orleans District Office, May 1997.
Effective Age Factor	US Army Corps of Engineers, New Orleans District Office, May 1997.
Indirect Damages	Santa Clara Valley Water District, Waterways Planning Study, 1981.

Appendix B-1 “Single Family Residences”
Variables Used for Damage Calculation

Depth-to-Damage Curves





Computation Inputs

Assessor Land Use Codes

01

BNi Construction Cost Book

Square Foot Tables

Residential

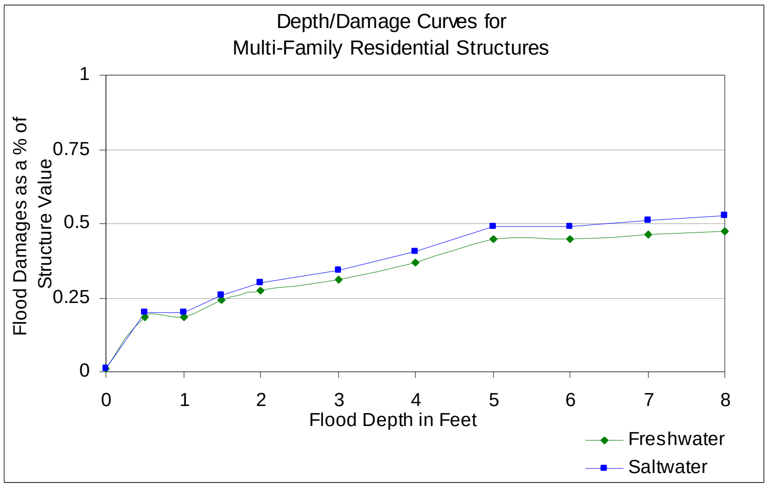
Subcategory / Use Codes	$/Sq Ft
Single Family Home 01	$123.89

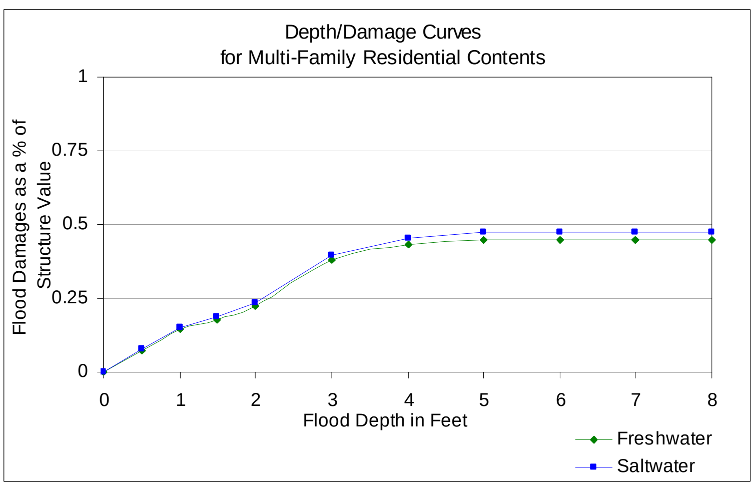
US Army Corps of Engineers

Content-to-Structure Value Ratio	0. 46
Bldg Life Expectancy	55-yrs
Effective Age Factor	0. 25
Indirect Damage	0. 15

Appendix B-2 “Multi-Family Residences”
Variables Used for Damage Calculation

Depth-to-Damage Curves





Computation Inputs

Assessor Land Use Codes

02, 03, 04, 05, 06, 07, 09

BNi Construction Cost Book

Square Foot Tables

Residential

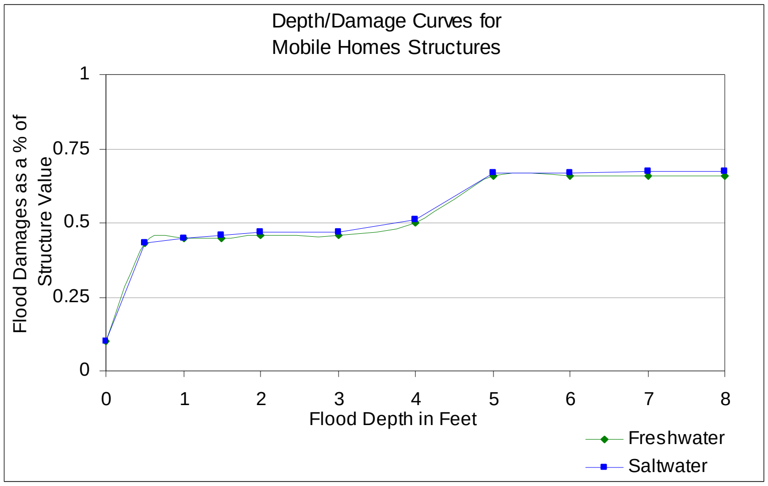
Subcategory /Use Codes	$/SqFt
Apartments 02-05, 07,09	$93. 37
Condo/Town Home 06	$104. 72

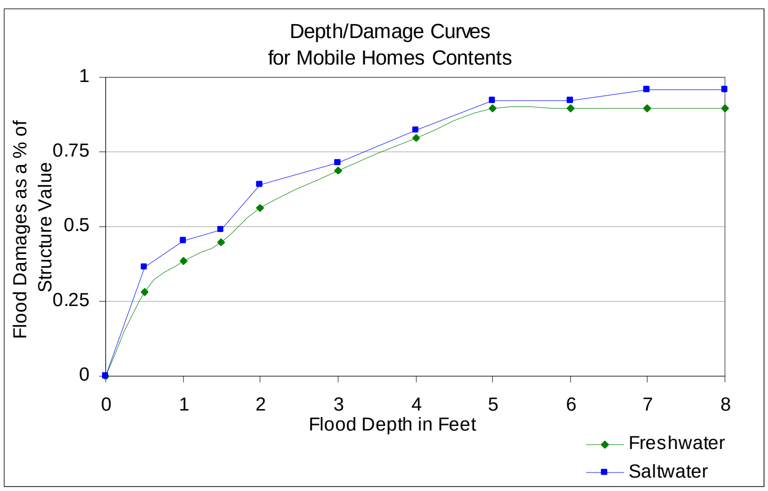
US Army Corps of Engineers

Content-to-Structure Value Ratio	0. 22
Bldg Life Expectancy	55-yrs
Effective Age Factor	0. 25
Indirect Damage	0. 15

Appendix B-3 “Mobile Homes”
Variables Used for Damage Calculation

Depth-to-Damage Curves





Computation Inputs

Assessor Land Use Codes

08, 67

BNi Construction Cost Book

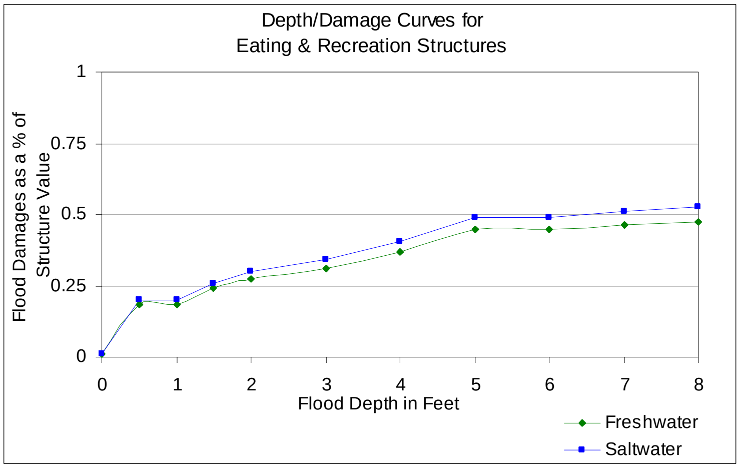
Use Codes	$/Sq Ft
08, 67	$40. 00

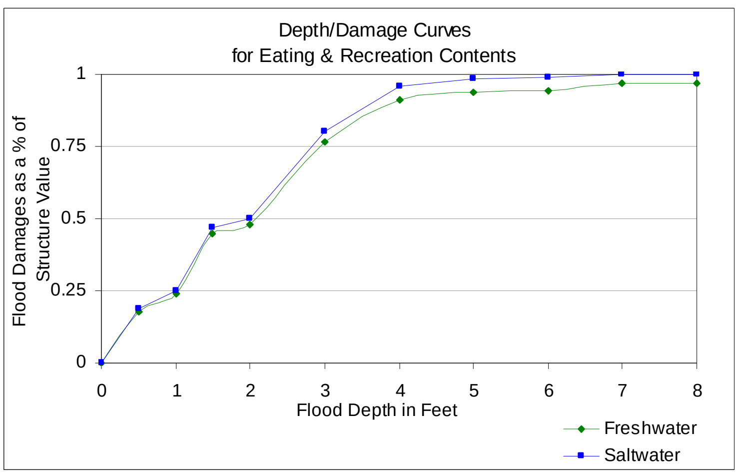
US Army Corps of Engineers

Content-to-Structure Value Ratio	0. 64
Bldg Life Expectancy	55-yrs
Effective Age Factor [e]	0. 25
Indirect Damage [f]	0. 15

Appendix B-4 "Eating & Recreation"
Variables Used for Damage Calculation

Depth-to-Damage Curves





Computation Inputs

Assessor Land Use Codes

64, 65, 83

BNi Construction Cost Book

Square Foot Tables

Recreation

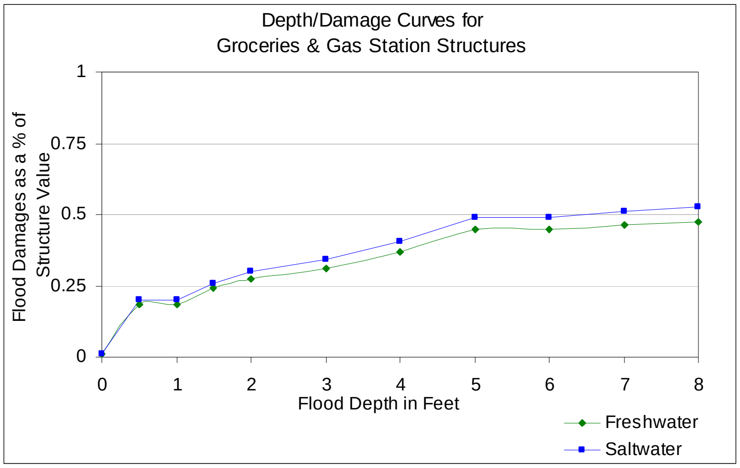
Subcategory / Use Code	$ / Sq Ft
Health Center 64	$106. 18
Recreation Center 65, 83	$142. 11

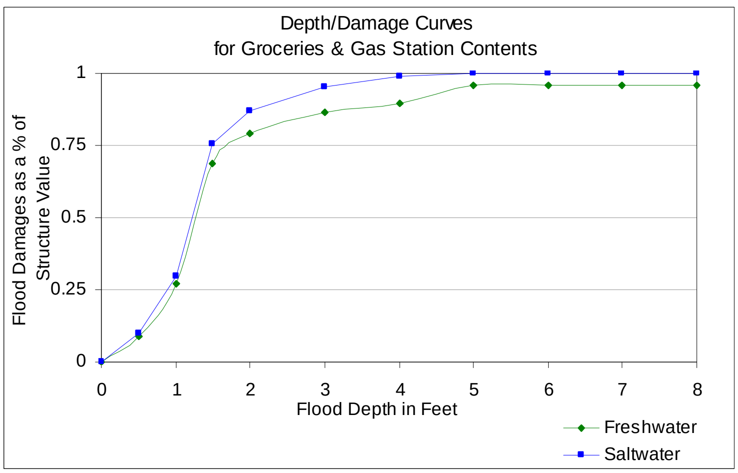
US Army Corps of Engineers

Content-to-Structure Value Ratio	0. 64
Bldg Life Expectancy	60-yrs
Effective Age Factor	0. 25
Indirect Damage	0. 35

Appendix B-5 "Groceries & Gas Stations"
Variables Used for Damage Calculation

Depth-to-Damage Curves





Computation Iinputs

Assessors Land Use Codes

52, 61

BNi Construction Cost Book

Square Foot Tables

Commercial

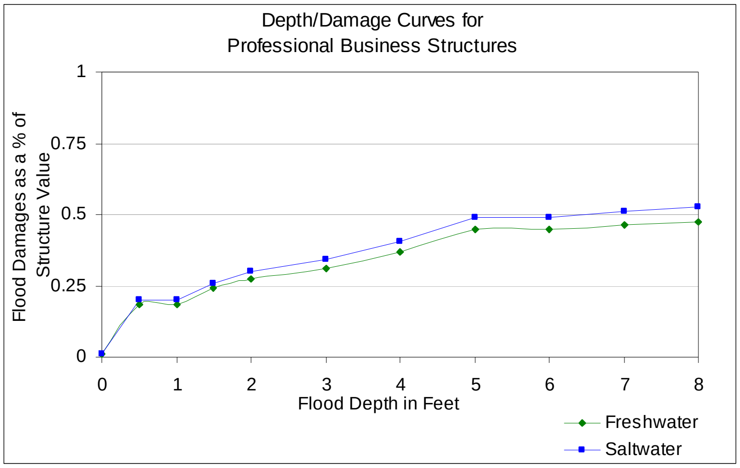
Subcategory /Use Codes	$/Sq Ft
Mall/Plaza 52	$113. 95
Auto Dealership	$70. 54

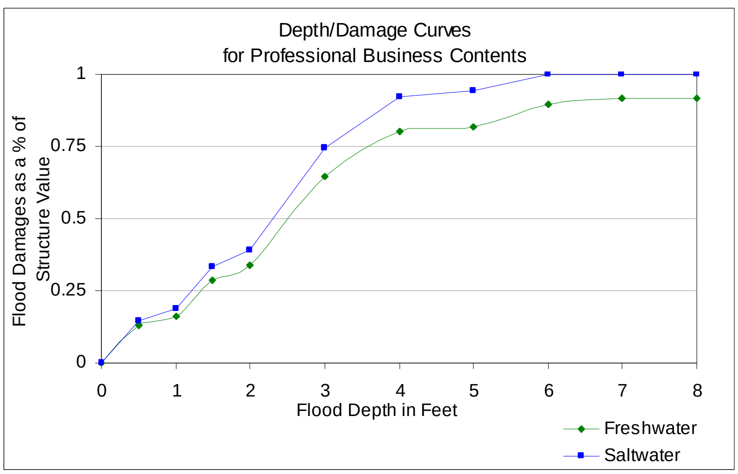
US Army Corps of Engineers

Content-to-Structure Value Ratio	0. 64
Bldg Life Expectancy	60-yrs
Effective Age Factor	0. 25
Indirect Damage	0. 35

Appendix B-6 "Professional Businesses"
Variables Used for Damage Calculation

Depth-to-Damage Curves





Computation Inputs

Assessors Land Use Codes

14, 39, 59

BNi Construction Cost Book

Square Foot Tables

Commercial

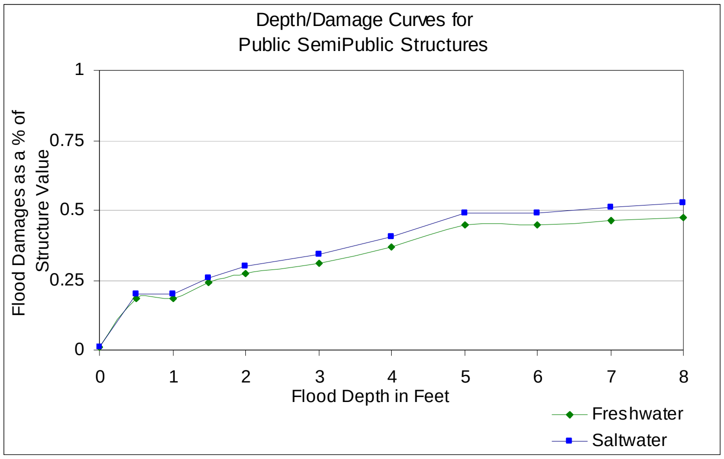
Subcategory / Use Codes	$/Sq Ft
Research & Devel 14	$183. 78
Offices 39, 59	$153. 04

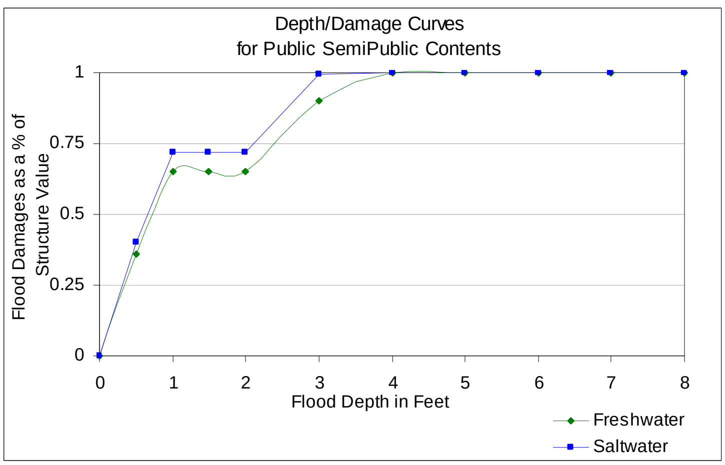
US Army Corps of Engineers

Content-to-Structure Value Ratio	0. 91
Bldg Life Expectancy	60-yrs
Effective Age Factor	0. 25
Indirect Damage	0. 35

Appendix B-7 “Public & Semi-Public”
Variables Used for Damage Calculation

Depth-to-Damage Curves [a]





Computation Inputs

Assessor Land Use Codes

41-47, 60, 62, 63, 70-79

BNi Construction Cost Book

Square Foot Tables

Public, Recreation, Medical, Education, Religious

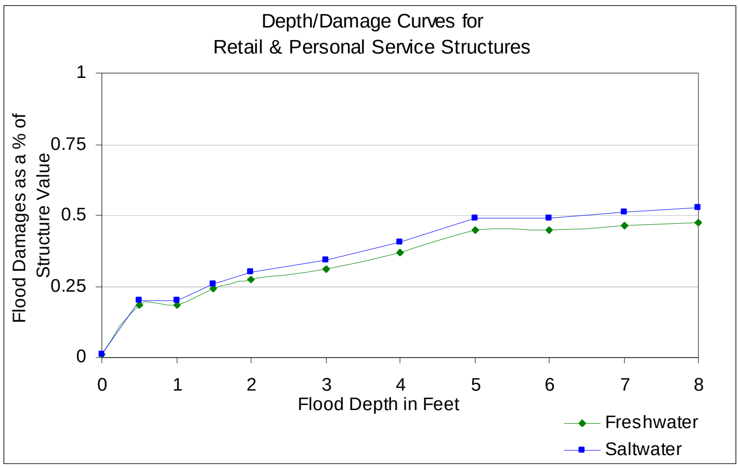
Subcategory /	Use Codes	$/Sq Ft
Transportation	41-47	$204.46
Parking Garage	60	$41. 88
Elementary School	62	$126.32
Nursing Home	63, 75	$218.12
College Facility	70	$402.25
High School	71,72	$132.24
Hospital	73	$247.85
Govt Bldg	74	$164.30
Church	76	$139.77
Museums	77	$187.25
Arena	78, 79	$186.27

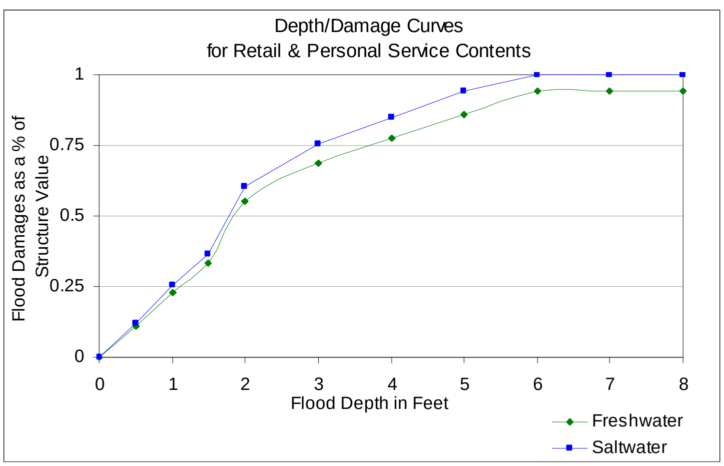
US Army Corps of Engineers

Content-to-Structure Value Ratio	0. 37
Bldg Life Expectancy	60-yrs
Effective Age Factor	0. 25
Indirect Damage	0. 34

Appendix B-8 "Retail & Personal Services"
Variables Used for Damage Calculation

Depth-to-Damage Curves





Computation Inputs

Assessor Land Use Codes

50, 51, 53-56, 58,68

BNi Construction Cost Book

Square Foot Tables

Commercial

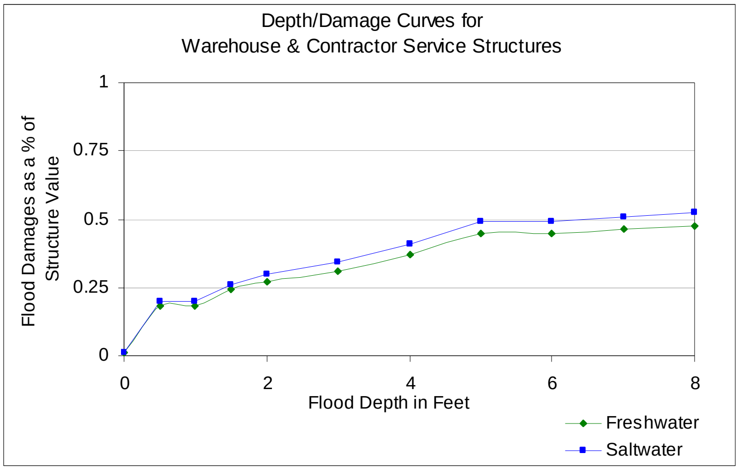
Subcategory / Use Codes		$/Sq Ft
Mall/Plaza	50,51	$70. 54
Business Center	53-56	$55. 75
Retail Store	58,68	$128. 97

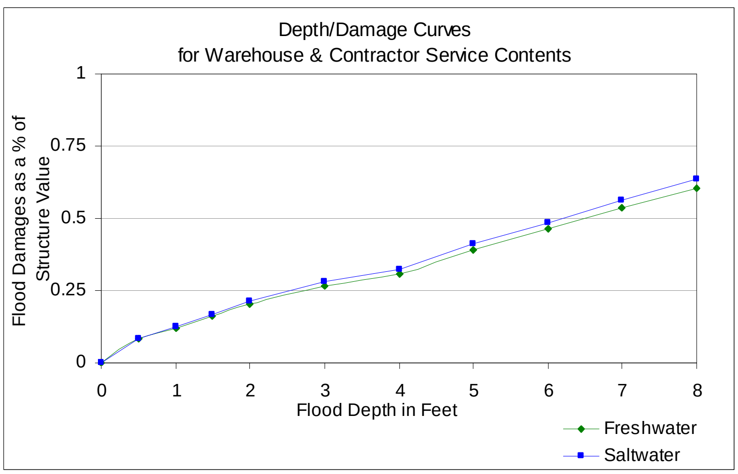
US Army Corps of Engineers

Content-to-Structure Value Ratio	1. 71
Bldg Life Expectancy	60-yrs
Effective Age Factor	0. 25
Indirect Damage	0. 35

Appendix B-9 "Warehouse & Contractor Services"
Variables Used for Damages Calculation

Depth-to-Damage Curves





Computation Inputs

Assessor Land Use Codes

10-13, 15-17, 19-38, 40, 90, 99

BNi Construction Cost Book

Square Foot Tables

Industrial

Subcategory / Use Codes	$/Sq Ft
Warehouse w/Office 10-13,15-17, 19, 90	$50. 74
Manufacturing 20-38, 40	$93. 50
Research & Dev. 99	$183. 48

US Army Corps of Engineers

Content-to-Structure Value Ratio	0. 68
Bldg Life Expectancy	60-yrs
Effective Age Factor	0. 25
Indirect Damage	0. 45

Appendix C — Document on "Building Life Expectancy"

provided as guidance for this study by the US Army Corps of Engineers, New Orleans District Office, by Economist Toni Baldini

Life Expectancy

The typical life expectancy of Residential properties is based upon the type and quality of construction. The values are shown in Table 3. 4 below.

Table 3. 4 Life Expectancy

	Single-Family Residences		**Low-Rise Multiples, Town Houses, Duplexes**	
Quality	Frame	Masonry	Frame	Masonry
Low	45	50	--	--
Fair	50	55	45	50
Average	55	60	50	55
Good	55	60	50	55
Very Good	60	60	55	60
Excellent	60	65	55	60

Effective Age

The effective age of a property is its age in years as compared with other properties performing like functions. It is the actual age less the age that has been taken off by face-lifting, structural reconstruction, removal of functional inadequacies, etc. Effective age is used in the depreciated value calculations. The effective age must be less than or equal to the typical life.

To establish an Effective Age, when no age information is available, simply multiply the typical building life expectancy by the factors below Table 2. 5. Enter the table by choosing the factor based on the overall exterior appearance of the property and the local neighborhood or community.

Example: Assume that the building in question has a typical life expectancy of 50 years and that the structure (exterior view only) is in average condition in a high demand area. To calculate the Effective Age, multiply 50 x . 25 = 12. 5 years as the Effective Age of this property.

General condition ratings can be assigned to the improvement to assist in the development of an appropriate effective age based on observed condition, utility and age. The better the overall condition, the younger or lower the effective age, which lowers the percentage and amount of depreciation. Condition is an integral part in measuring the degree at which items subject to depreciation have been maintained. Applying any additional condition modifier once the effective age has been established based on condition would be redundant.

Table 3. 5 Effective Age

	High Demand/Appreciating Modernization Common	**Stable Area** Some Updating/Appreciation	**Declining Area** Basic Maintenance/Neglect
Newer Properties/ Total Remodel	0. 05	0. 10	0. 15
Above Average Well Maintained	0. 15	0. 25	0. 35
Average Condition Norm for the Area	0. 25	0. 40	0. 55
Below Average	0. 40	0. 60	0. 80

Appendix D Detailing of the Flood Damage Computation

This Appendix explains the method, assumptions, and variables used to calculate flood damages. Flood damages are estimated based on the depreciated replacement value of structures on flood affected properties. The information needed to compute flood damages using the revised method includes: A) the area flooded; B) the depth of flooding; C) the land uses of affected properties; D) the estimated value of structures and E) contents; F) direct depth-to-damage factors; and G) indirect damage factors. This appendix describes how this information was collected and applied.

Appendices D-3, D-4, and D5 are expansions of on Table 2, which gives an overview of the computation.

Appendix D-2 lists definitions for all variables used in the computation.

A. Area Flooded

In 1978 George S. Nolte and Associates, working for the Federal Insurance Administration (FIA), completed a study identifing areas within the five watersheds that are subject to greater than a foot of flooding during a one percent flood event. From the study, a set of paper maps was created to show flooded areas, the water depths or the water surface elevations. The FIA adopted these maps as “Flood Insurance Rate Maps” (FIRMs) and developed codes, which designate the potential flood hazard of a given area. The codes are used to determine insurance rates. They are based on flood depth, flow velocities of floodwaters, and frequency of flooding.

Nolte also provided the District with flood maps describing areas, which flood to a depth of less than one foot. Originally, the flooding was depicted on base maps from the County of Santa Clara’s 500-scale Cadastral maps, dated 1977. In the 1990’s District staff converted the flood maps to digital format for use in the District’s geographic information system.

B. Depth of Flooding

Potential damage to flood affected properties is a function of floodwater depth. The study commissioned by FIA and conducted by Nolte, determined flood depths using land and water surface elevations. In locations where Nolte specified the water depth, the damages caused by flooding were determined directly using the specified depth. In other locations, where Nolte instead specified the water surface elevation, depths were determined by subtracting the land elevation from the water surface elevation. Land elevation information came from the US Geological Survey’s 2000-scale topographic maps.

C. Land Uses of Affected Properties

In this methodology flood damages are a function of the depreciated replacement value of the affected structures. Land use codes provided by the Santa Clara County Assessor's office are used to estimate the type of structures on a flood-affected property, or parcel. The County Assessors Office recognizes 100 land uses- each described by a two-digit code. For the purpose of computing flood damages, the 100 land use codes are generalized into 10 "District" land uses.

Figures 9A and 9B illustrate District land use groupings and the associated Santa Clara County land use codes. The figures also list the damage curve, construction type and estimated cost per square foot associated with each land use. Figure 8 lists all 100 County Land Use Codes as defined by the County of Santa Clara Tax Assessor.

Estimated Value of Structures

Flood damages for an affected property are based on the depreciated replacement value of affected structures. Because flood damage calculations assume a percentage of the value of a structure is lost at various depths of flooding, obtaining a reasonable estimate of a structure's depreciated replacement value is essential. The method used to determine the depreciated replacement value is described below.

DRVS Depreciated Replacement Value of Structure

DRVS = RV – (DF * RV)

The depreciated replacement value of a structure (DRVS) is the structure's replacement value (RV) minus the product of the depreciation factor (DF) and the structure's replacement value (RV). See Figure 2. 2 as an example.

1) RV Replacement Value

RV = CSF * RCCM * SSF * SRCI

Replacement value is estimated based on the type of structure; construction costs per square foot; structural square footage; and a cost index reflecting the estimated quality of construction.

CSF Cost per Square Foot

For each District land use category, the construction cost per square foot is determined using a published construction guide (BNi Construction Costbook, 2005).

RCCM Regional Construction Cost Modifier

This factor adjusts construction costs to reflect regional economic trends (BNi Construction Costbook, 2005). In 2005, the RCCM for the San Jose area was 1. 09. See Appendix E "Square Foot Tables and Subcategories".

SSF Structural Square Footage

Construction costs are bid and estimated by the square footage being constructed. MetroScan® real estate software is used to collect the first floor square footage for flood affected parcels.

SRCI Sub-Regional Cost Index

This index is derived per zip code using the average value per square foot of structure. The index used in this computation method is based on May 2005 real estate data collected from the DataQuick News service. Appendix D-5 lists the indices used for all zip codes within the District's jurisdiction.

2) DF Depreciation Factor

The depreciation factor for a structure is the ratio of its effective age (EA) to its functional life expectancy (FLE). Economist Toni Baldini of the US Army Corps of Engineers New Orleans District provided the method used here. See Appendix C.

DF = EA / FLE

FLE Functional Life Expectancy

The number of years a structure is expected to be useful is its Functional Life Expectancy. See Figures 9A & B and Appendix C. For structures older than the assumed life expectancy, the life span is reduced by 10 years. For instance, a single-family residence older than 55 years is assumed to have an adjusted life expectancy of 45 years. Each parcel's year built information is collected in order to establish each structure's actual age using MetroScan® data.

EA Effective Age

A structure's effective age is its actual age adjusted for the quality of maintenance. Effective age reflects a structure's condition relative to structures of similar use type. Effective age is usually less than actual age and is estimated as a percentage of actual age. See Appendix C. For Santa Clara County, structures are assumed to be in a "High Demand/Appreciating" location and of "Average Condition", making the Effective Age multiplier 0. 25.

D. EVC Estimated Value of Contents

EVC = CSVR * DRVS

1) CSVR Content-to-Structure-Value-Ratio

The Corps of Engineers has developed a factor for estimating the value of a structure's contents. The factor varies by land use and is based on the structure's depreciated replacement value. Appendix D-3 is an example computation for Estimated Value of Contents.

2) DRVS Depreciated Replacement Value of Structure

See above.

E. Direct Depth-to-Damage Factors

Damages caused by floodwaters are a function of floodwater depth and structure type, as indicated by land use. Resource agencies, like the Army Corps of Engineers, and the Institute for Water Resources, have conducted studies to determine how much damage to structures and the contents of structures, results at various depths of flooding. The curves used here are taken from a study (US Army Corps of Engineers, 1997), which expresses the relationship between depth and damage as a percentage of the structure's depreciated replacement value (DRVS). Grouped by land use category, these percentages are commonly called "damage curves". The methodology used here relies on both "Freshwater" and "Saltwater" damage curves, for flooding of one-day duration. (US Army Corps of Engineers, 1997).

Figures 2. 4 through 2. 12 display damage curves used in this computation. Because damage estimation relies on land use, construction cost, and flood depth information, each figure displays the related County use codes; the associated construction costs; functional life expectancy; and the indirect damage factor needed to compute damages for each land use associated with the given curve.

1) SFD Structural Flood Damages

SFD = DDS * DRVS

DDS Structural Depth-to-Damage Factor

This factor represents the percentage of structural damages expected for a given land use, at a given flood depth. See Appendix B. The depth of flooding on the damage curve refers to the depth of water that enters the structure. Flood maps used for this study indicate the depth of floodwater above the ground surface.

For Santa Clara County, the depth of flooding is adjusted down by 12 inches to accommodate for the predominance of raised slab construction in the county. For instance, for a single-family residence assumed to be in a two-foot flood plain, the Structural Depth-to-Damage Factor used would be for one-foot of flooding. Saltwater flood depths are adjusted by the mean elevation for the given watershed, as recorded on District floodplain maps.

DRVS Depreciated Replacement Value of Structure

See above.

2) CFD Contents Flood Damages

CDF = DDC * EVC

DDC Contents Depth-to-Damage Factor

This factor represents the percentage of contents value lost due to flooding. The factors are specific to structure type and flood depth.

For Santa Clara County, the depth of flooding is adjusted down by 12 inches to accommodate for the predominance of raised slab construction in the county. See above. Item F. 1) in this outline.

EVC Estimated Value of Contents

See above. Item E. in this outline

F. IFD Indirect Flood Damage

The indirect damage factor (IDF) describes damages that are not physical, but incurred as a result of flooding. These costs include income lost to time not working and other inconveniences suffered as a result of flooding. Indirect damages are a function of land use and total direct damages (structure plus content damages).

IFD = IDF * (SFD + CFD)

1) IDF Indirect Damage Factor

Indirect damages are a function of land use and are independent of flood depth. The factors used here are taken directly from the Waterways Planning Study (Santa Clara Valley Water District, 1981), which was provided by the US Army Corps of Engineers. Appendix D-4 gives an example of the indirect damage computation. Appendix B lists the indirect factor used with each associated damage curve.

2) SDF Structural Flood Damages

See above, Item F. 1) in this outline.

3) CFD Contents Flood Damages

See above, Item F. 2) in this outline.

G. Other Damages

In the case of flooding on properties without structures, damages are due to destruction of landscaping, crops, etc. These damages reflect clean-up costs, and are assessed per acre. They are relatively independent of depth and are computed on two categories of open land: Open Improved, Agricultural. Vacant land is assumed to incur no damages from flooding.

1) OIFD Open Improved Flood Damages

OIFD = Acreage * CCA

CCA Clean-Up Cost per Acre

Land uses designated "Open Improved" for the purposes of this assessment are typically parks and quasi-public open land, but the category also includes landfills. Using the 1998 San Francisquito flood event, District staff has estimated a $200 per acre clean-up cost based on the City Of Palo Alto's post-flood clean-up of their municipal golf course.

2) Agricultural Land

The value of damages to agricultural land is based on the value of crops lost to flooding plus clean-up costs. Agricultural land is divided into three sub-categories based on the relative values of their constituent crops: annual, perennial and grazing. County land use codes identify these three subcategories. To estimate damages for agricultural land, Clean-Up Cost per Acre (CCA) is added to the value of lost crops. See above, Item H. 1)

AAFD Annual Agriculture Flood Damages

AAFD = (Acreage * CCA) + (Acres * $65)

Annual crops are the most valuable of the three agricultural sub-categories. Sixty-five dollars per acre represents the value of annual crops lost to flooding (Santa Clara Valle Water District, 1981).

PAFD Perennial Agriculture Flood Damages

PAFD = (Acreage * CCA) + (Acres * $35)

Perennial agriculture is typically orchard land. Thirty-five dollars per acre is used to estimate the value of crops lost to flooding on perennial agricultural land (Santa Clara Valle Water District, 1981).

GAFD Grazing Agriculture Flood Damages

GAFD = (Acreage * CCA) + (Acres * $6)

Grazing agriculture is typically pastureland on the outskirts of the county. This is the least valuable of the three agricultural sub-categories. The value per acre is estimated as six-dollars per acre (Santa Clara Valley Water District, 1981).

Appendix D-2 List of Computation Acronyms Used in Appendices D

Acronym	Name	Description	Units
AAFD	Annual Agriculture Flood Damages	Flood damages incurred on land used for producing annual crops	Dollars/Acre
CCA	Clean-Up Cost per Acre	Estimated cost per acre of flood clean-up on open land	Dollars/Acre
CFD	Contents Flood Damages	Damages incurred to contents of structures affected by flooding	Dollars/Acre
CSF	Cost per Square Foot	Structural construction cost per square foot	Dollars/Sq Ft
CSRV	Content to Structure Value Ratio	Factor to help estimate the value of a structure's contents	Ratio
DDC	Content Depth to Damage Factor	Factor used to estimate damages incurred to the contents of structures as a result of flooding	N/A
DDS	Structural Depth to Damage Factor	Factor used to estimate damages incurred to structures as a result of flooding	N/A
DF	Depreciation Factor	Ratio of a structure's effective age (EA) to its functional life expectancy (FLE)	N/A
DRVS	Depreciated Replacement Value of Structure	A structure's replacement cost minus the product of the depreciation factor (DF) and the structure's replacement value (RV).	Dollars
EA	Effective Age	A structure's effective age is its actual age adjusted for the quality of maintenance that has been performed	Years
EVC	Estimated Value of Contents	Estimated value of structure contents.	Dollars
GAFD	Grazing Agriculture Flood Damages	Flood damages incurred on land used for grazing livestock.	Dollars
FLE	Functional Life Expectancy	Age at which a structure is assumed to no longer be functional	Years
IDF	Indirect Damage Factor	Factor used to estimate non-physical flood damages	N/A
IFD	Indirect Flood Damages	Non-physical damages incurred as a result of flooding	Dollars
OIFD	Open Improved Flood Damages	Flood damages incurred on land with minimal structures, such as parks.	Dollars
PAFD	Perennial Agriculture Flood Damages	Flood damages incurred on land used for producing perennial crops	Dollars
RCCM	Regional Construction Cost Modifier	Factor used to adjust construction costs to reflect regional economic trends	N/A
RV	Replacement Value	Estimated cost of building a structure	Dollars
SRCI	Sub Regional Cost Index	Factor used to adjust construction costs to reflect real estate values throughout the county	N/A
SSF	Structural Square Footage	Square footage of a structure	Sq Ft
SFD	Structural Flood Damages	Damages incurred to structures affected by flooding	Dollars

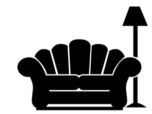
Appendix D-3 Structural Flood Damages

This table explains the computations used to estimate Structural Replacement Value. Steps 3a & 4a, expanded from Figure 6. The example describes a one-story, single-family residence in Campbell, California, built in 1982, with a first-floor square footage of 2400. Life Expectancy is based on "Average" construction quality and wood frame construction. The depreciation factor is based on "Average Condition", in a "High Demand/Appreciating" area. In this example, the adjusted flood depth is assumed to be 1 foot.

Steps / Information Needed	Equation	Example Computation
3a Depreciated Replacement Value of Structure		
i. Replacement Value of Structure • Cost per Square Foot • Regional Construction Cost Modifier • Structural Square Footage: 1^{st} Floor • Sub-Regional Cost Index	[CSF] * [RCCM] * [SSF] * [SRCI]	$123. 89 * 1. 09 * 2400 * 0. 93 = $301,409
ii. Effective Age of Structure • Year Built • Effective Age Factor	([Current Year] - [YB]) * [EAF]	(2005 – 1982) = 23 years 23 years * 0. 25 = 5. 75 years
iii. Depreciation Factor • Functional Life Expectancy • Effective Age	[EA] / FLE]	(1/ 55 years * 5. 75) (0. 01818$^{\alpha}$ * 5. 75) = 0. 10454 [a]
iv. Depreciated Replacement Value of Structure • Depreciation Factor • Replacement Value	RV - (DF * RV)	$301,409 - (0. 104535 * $301,409) $301,409- $31,507 = $269,902
4a **Structural Flood Damages** • Depth-to-Damage Factor: Structures • Depreciated Replacement Value of Structure	[DDS] * [DRVS]	0. 224 * $269,902 **= $60,458**

[a] Although rounded here, the computation does not round or truncate terms at run-time.

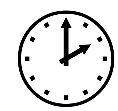
Appendix D-4 Content Flood Damages



This table explains the computations used to estimate Structural Replacement Value. Steps 3a & 4a, expanded from Figure 6.

Steps / Information Needed		Figure/Appendix	Equation	Example Computation	
3b	**Estimated Value of Structure's Contents**				
i	• Contents-to-Structure Value Ratio • Depreciated Replacement Value		[CSRV] * [DRVS]	0. 46 * $269,902	= $124,155
4b	**Contents Flood Damage**				
	• Depth-to-Damage Factor • Estimated Value of Contents	Ap. B	[DDC] * [EVC]	0. 423 * $124,155	= $52,517

Appendix D-5 Indirect Flood Damages



This table explains the computations used to estimate Indirect Flood Damages. Step 4 expanded from Figure 6.

Steps / Information Needed		Equation	Example Computation
4c	**Indirect Flood Damages**		
i.	Estimate Total Damages • Structural Flood Damages • Contents Flood Damages	[SFD] + [CFD]	$60,458 + $52,517 = $112,975
ii.	Estimated Value of Indirect Damages • Indirect Damage Factor • Estimated Total Damages	[IDF] * ([SFD] + [CFD])	0. 15 * $112,975 **= $16,946**

Appendix D-6 **Sub-Regional Cost Indices**

Based on May 2005 DataQuick News Service residential price per square foot.

City	Zip Code	Cost Index	City	Zip Code	Cost Index
Alviso	95002	0. 727	San Jose	95123	0. 855
Campbell	95008	0. 940	San Jose	95124	0. 997
Cupertino	95014	1. 148	San Jose	95125	1. 027
Gilroy	95020	0. 771	San Jose	95126	1. 007
Los Altos	94022	1. 034	San Jose	95127	0. 846
Los Altos	94024	1. 543	San Jose	95128	0. 951
Los Gatos	95030	1. 636	San Jose	95129	1. 062
Los Gatos	95032	1. 333	San Jose	95130	1. 034
Los Gatos	95033	1. 129	San Jose	95131	0. 849
Milpitas	95035	1. 277	San Jose	95132	0. 827
Morgan Hill	95037	0. 898	San Jose	95133	0. 791
Mountain View	94040	0. 761	San Jose	95134	0. 940
Mountain View	94041	1. 105	San Jose	95135	0. 783
Mountain View	94043	1. 133	San Jose	95136	0. 849
Palo Alto	94301	1. 009	San Jose	95138	0. 932
Palo Alto	94306	1. 306	San Jose	95139	0. 807
San Jose	95110	1. 575	San Jose	95148	0. 861
San Jose	95111	0. 931	San Martin	95046	0. 893
San Jose	95112	0. 780	Santa Clara	95050	1. 027
San Jose	95116	0. 959	Santa Clara	95051	0. 945
San Jose	95117	0. 838	Santa Clara	95054	0. 940
San Jose	95118	0. 920	Saratoga	95070	1. 396
San Jose	95119	0. 926	Sunnyvale	94085	0. 993
San Jose	95120	0. 852	Sunnyvale	94086	0. 988
San Jose	95121	0. 999	Sunnyvale	94087	1. 142
San Jose	95122	0. 830	Sunnyvale	94089	1. 066