APPENDIX E – FLOOD DAMAGE ANALYSIS TECHNICAL MEMORANDUM

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Peterson-Brustad, Inc., April 21, 2011, "Technical Memorandum, Flood Damage Economic Analysis, Wisconsin Pump Station"

Flood Damage Economic Analysis

Wisconsin Pump Station ***April 21, 2011***

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Introduction

The Stockton East Water District is submitting a request for funding from the Integrated Regional Water Management Grant Program for the Calaveras River Integrated Storm Water Management Project. One portion of this project is to replace the existing Wisconsin Storm Water Pump Station and increase its pumping capacity to provide 100-year flood protection in the pump station's drainage area. The purpose of this technical memorandum is to quantify the expected annual benefits from flood damage reduction due to the increased capacity of the Wisconsin Pump Station.

Wisconsin Pump Station

Background

The existing Wisconsin Storm Water Pump Station provides storm drainage pumping for a 450 acre area of central Stockton consisting primarily of single family residences. The area is protected from riverine flooding by levees on the Calaveras River to the north, on the San Joaquin River to the west, and on the Smith Canal to the south. The pump station is needed to pump storm water from the basin over the levees into the Calaveras River. The pump station is operated and maintained by Reclamation District 1614. The existing pump station is 70 years old and consists of a sheet pile sump with a concrete slab / concrete pump house on top. The following paragraph is a summary of the Wisconsin Pump Station condition assessment performed by KSN in 2009.

> The Wisconsin pump station is an old structure that is comprised of a steel sheet pile sump with a concrete slab / concrete pump house on top. The sump has no bottom and therefore is subject to groundwater infiltration. Although the pump house on top is in fair condition, the sheet pile sump itself is in failure mode. The sheet pile sump is reinforced with wood timber whalers that have rotted. The steel sheet piles themselves are bowing inward and have rotted to a point that a person can punch their hand through them. During our inspection the sump was pumped dry it was quite apparent at that time that the steel and timber sump

structure was inadequate and in a failing state. It was decided that any improvements and/or upsizing of the pumping capacity of the pump station would be detrimental to the structural integrity of the sump and that the entire structure should be removed and replaced with a new sump structure.

Wisconsin Pump Station Timbers

Wisconsin Pump Station Sheet Pile

The Wisconsin Pump Station sump's structural integrity has diminished to the point where there is now great concern the pump house is in danger of collapsing into the sump. Therefore, the pump station requires replacement.

Study Methodology

The benefits of the Wisconsin Pump Station Improvement Project are presented in terms of flood damage reduction at various annual exceedance probabilities (100-year, 25-year, and 10-year). San Joaquin County Assessor's office data was used to estimate existing parcel area and structure area by type of land use throughout the Wisconsin Pump Station drainage basin.

Given that functional integrity of the existing pump station has deteriorated to a point where it is essentially in failure mode, flood depths for the 100-year, 25-year, and 10-year storm events were developed assuming the existing pump station has failed and is inoperable. Flood damage was estimated for land, infrastructure, automobiles, structures and structure contents for these flood events. Flood emergency response costs as well as residential displacement and shelter costs were also estimated.

The flood damages for structures and contents were developed using guidance from the USACE *Planning Guidance Notebook*, ER1105-2-100, April 2000. Land damage was estimated at 10% of the land value based on previous work done for the Sacramento Area Flood Control Agency's (SAFCA) *Engineer's Report for SAFCA Operation and Maintenance Assessment*, 1991.

"Without" project benefits are based on the total flood damages at the 100-year, 25-year, and 10-year storm events assuming the pump station is inoperable. Benefits associated with events less frequent than the 100-year event (e.g. 200-year) for both the "Without" and "With" project were assumed to be equal to the damages estimated for the 100-year event. USACE methods were

then used to determine the expected annual damages for both the "Without" and "With" project scenarios. Appendix A presents a summary of the expected annual damage computation procedures.

Annual project benefits were determined from the difference between expected annual damage for the "Without" project and the "With" project scenarios. Annual project costs were developed from the project's capital construction and estimated annual maintenance cost. The construction cost of the project was evaluated over 50 years at a discount rate of 6%.

Wisconsin Pump Station Drainage Basin

To determine the flood damages for the basin, the values of the land, structures, structure contents, and automobiles within the basin must be determined. Since damages will be determined by flood depth, the Wisconsin Pump Station Drainage Basin was divided into 5 areas (A through E) based on ground surface elevation. The following discussion presents the assumptions used for determining the value for the items potentially damaged by flood water. At the end of the discussion, the values for land, structures, structure contents, and automobiles are summarized by area within the drainage basin.

Land Value

For the purposes of this study, it was assumed that the land value for residential property within the study area is $75,000 per lot. Land values for commercial, public, and vacant land were taken directly from the San Joaquin County Tax Assessor's records. There is no industrial or agricultural land use within the Wisconsin Pump Station Drainage Area.

Structure and Content Value

San Joaquin County Tax Assessor's records include land use, structure value and living area data for each parcel within the study area. Structure values for commercial and public land use were taken directly from the County data. Residential structure values were determined using USACE data developed in connection with the USACE Draft Economic Reevaluation Report, American River Watershed Project, 2007. Content values for all land use types were determined using the same USACE data. Table 1 presents the structure and content values for each land use type used in this damage assessment.

Table 1. Structure and Content Values based on Land Use

Land Use	Structure Value ($/SF)	Content Value (% of structure value)
Residential	60	50%
Commercial	Per County Data	107%
Public	Per County Data	107%
Vacant	--	--

Automobile Value

The number of automobiles in the Wisconsin Pump Station Drainage Basin is based on the 2008 US Census Bureau data that assigns 1.45 automobiles per residential structure. The 2009 National Auto Dealer Association estimates the average depreciated replacement value at $15,200 per automobile. The total value of automobiles within the drainage basin is based on these two values. However, the automobile value used in this damage assessment estimates that 50% of the automobiles will be removed from the damage areas during flood events and will avoid damage.

Drainage Basin Value Summary

Table 2 presents a summary of the land, structure, contents, and automobile values for each of the areas (differentiated by ground surface elevation) within the Wisconsin Pump Station Drainage Basin.

Table 2. Drainage Basin Values for Damage Assessment

Wisconsin Pump Station Drainage Area	Total Area (ac)	Number of Parcels	Land Value ($1,000)	Structure Value ($1,000)	Content Value ($1,000)	Auto Value ($1,000)
Area A (Elev = -2 ft)	2.2	11	825	804	402	121
Area B (Elev = -1 ft)	23.3	70	5,142	4,600	2,306	727
Area C (Elev = 0 ft)	47.0	188	13,978	15,649	7,825	2,050
Area D (Elev = +1 ft)	243.5	462	34,581	44,333	27,168	4,992
Area E (Elev = +2 ft)	139.0	460	33,634	47,885	24,637	4,816
TOTAL	**455.1**	**1,191**	**88,160**	**113,272**	**62,338**	**12,706**

Flood Damage Assessment

This analysis of the flood damage reduction benefit for the Wisconsin Pump Station drainage basin is based on the avoidance of damage to structures, to the contents of the structures, to automobiles, to infrastructure, and to land. Other benefits that were considered were avoidance of flood emergency response costs as well as residential displacement and shelter costs. Most of these damages are dependent upon the depth of the flood water. The flood damage assessment below addresses the "Without" project conditions.

Flood Depth

The "Without" project flood elevation was determined for the 100-year, 25-year, and 10-year storm events (KSN, Erik Almaas). To determine the flood depth, the Wisconsin Pump Station drainage basin was divided into 5 areas (A through E) based on the parcel's ground surface elevation. Table 3 presents the flood depth for each area for each of the annual exceedance events. Note that negative flood depths reflect the height above the flood water elevation for the

drainage area. These flood depths, rounded to the nearest foot, were used in the depth-damage relationships for each type of damage.

Table 3. Flood Depths

Wisconsin Pump Station Drainage Area	Flood Depths (ft) for Annual Exceedance Probability		
	100-year (Flood Elev = 0.1 ft)	**25-year** (Flood Elev = -0.4 ft)	**10-year** (Flood Elev = -1.1 ft)
Area A (Elev = -2 ft)	2.1	1.6	0.9
Area B (Elev = -1 ft)	1.1	0.6	-0.1
Area C (Elev = 0 ft)	0.1	-0.4	-1.1
Area D (Elev = +1 ft)	-0.9	-1.4	-2.1
Area E (Elev = +2 ft)	-1.9	-2.4	-3.1

Land Damage

There are a number of factors that contribute to the flood damage to land, both vacant and improved. These include, but are not limited to, physical damage to the land during a flood, increased cost of development, and reduction of land values. Based on the determination in Sutter Butte Flood Control Agency's *Feather River West Levee Strengthening EIP Project Preliminary Benefit-Cost Analysis*, 1991, all parcels in that basin would be subject to a ten-percent land damage factor regardless of flood depth. This assumption was used to determine the land damage for each of the annual exceedance events. Table 4 presents the estimated land damage for each area within the drainage basin for the 100-year, 25-year, and 10-year events.

Table 4. Flood Land Damage

Wisconsin Pump Station Drainage Area	Flood Damage to Land ($)		
	100-year Event	**25-year Event**	**10-year Event**
Area A	$ 82,500	$ 82,500	$ 82,500
Area B	$ 514,186	$ 514,186	--
Area C	--	--	--
Area D	--	--	--
Area E	--	--	--
TOTAL	**$ 596,686**	**$ 596,686**	**$ 82,500**

Structure and Content Damage

USACE defines potential flood damages to structures and contents by land use category:

- Commercial and Public - structure value and content value including equipment and furniture, supplies, merchandise, and other items used in the conduct of business.
- Residential - physical damages to dwelling units (single-family and multi-family) and to residential contents including household items and personal property.

The structure and content damage was determined as a function of the flood depth and based on a percentage of the structure and content value. The structure and content damage percentages used are based on the USACE *American River Watershed Common Features Project, Appendix H – Economics*, 2010. Table 5 presents the structure and content percent damage as a function of flood depth for each of the four land use types within the drainage basin.

Table 5. Structure and Content Damage by Flood Depth

Land Use	Structure Damage (% of Structure Value)				Content Damage (% of Content Value)			
	Flood Depth 2 ft	Flood Depth 1 ft	Flood Depth 0 ft	Flood Depth -1 ft	Flood Depth 2 ft	Flood Depth 1 ft	Flood Depth 0 ft	Flood Depth -1 ft
Residential, One Story	32%	23%	13%	3%	18%	13%	8%	2%
Residential, Two Stories	21%	15%	9%	3%	13%	9%	5%	1%
Commercial	27%	22%	7%	0%	96%	91%	0%	0%
Public	27%	22%	7%	0%	98%	97%	0%	0%
Vacant	--	--	--	--	--	--	--	--

Table 6 presents the estimated structure and contents damage for each area within the drainage basin for the 100-year, 25-year, and 10-year events.

Table 6. Flood Structure and Contents Damage

Wisconsin Pump Station Drainage Area	Flood Damage to Structures ($)			Flood Damage to Contents ($)		
	100-year Event	25-year Event	10-year Event	100-year Event	25-year Event	10-year Event
Area A	$ 257,318	$ 257,318	$ 184,948	$ 72,371	$ 72,371	$ 52,268
Area B	$ 1,057,996	$ 1,057,996	$ 597,403	$ 308,970	$ 308,970	$ 183,581
Area C	$ 1,979,084	$ 1,979,084	$ 469,475	$ 605,226	$ 605,226	$ 149,578
Area D	$ 1,066,736	$ 1,066,736	$ -	$ 347,886	$ 347,886	$ -
Area E	$ -	$ -	$ -	$ -	$ -	$ -
TOTAL	**$ 4,361,135**	**$ 4,361,135**	**$ 1,251,826**	**$ 1,334,453**	**$ 1,334,453**	**$ 385,427**

Automobile Damage

The damages to automobiles were determined based on the values estimated previously along with the flood depth for each area of the drainage basin. The automobile damage percentages used are based on the USACE *Generic Depth-Damage Relationships for Vehicles*, 2009. Table 7 presents the automobile percent damage as a function of flood depth.

Table 7. Automobile Damage by Flood Depth

Flood Depth (ft)	Automobile Damage (% of Value)
2	57%
1	41%
0	22%
-1	0%

Table 8 presents the estimated automobile damage for each area within the basin for the 100-year, 25-year, and 10-year events.

Table 8. Automobile Flood Damage

Wisconsin Pump Station Drainage Area	Flood Damage to Automobiles ($)		
	100-year Event	25-year Event	10-year Event
Area A	$ 69,095	$ 69,095	$ 49,700
Area B	$ 298,201	$ 298,201	$ 160,010
Area C	$ 450,938	$ 450,938	$ -
Area D	$ -	$ -	$ -
Area E	$ -	$ -	$ -
TOTAL	**$ 818,235**	**$ 818,235**	**$ 209,711**

Infrastructure Damage

Infrastructure damage within the Wisconsin Pump Station Drainage Basin will mainly consist of road damage. Road repair damages were estimated at an average $1 per square foot of paved area in the flooded areas only. Table 9 presents the estimated infrastructure damage for each area within the basin for the 100-year, 25-year, and 10-year events.

Table 9. Infrastructure Flood Damage

Wisconsin Pump Station Drainage Area	Flood Damage to Infrastructure ($)		
	100-year Event	25-year Event	10-year Event
Area A	$ 14,421	$ 14,421	$ 14,421
Area B	$ 152,425	$ 152,425	$ -
Area C	$ -	$ -	$ -
Area D	$ -	$ -	$ -
Area E	$ -	$ -	$ -
TOTAL	**$ 166,846**	**$ 166,846**	**$ 14,421**

Displacement Costs

Displacement of residents during a flood event represents costs other than the property damage described previously. This is a consequence of the time residents are displaced due to flood damage. For this project, FEMA's method for estimating typical displacement times and costs were used based on the FEMA software for *Benefit-Cost Analysis for Flood Mitigation Projects*, 2009. Typical displacement times are based on flood depth:

- Less than 1 ft flood depth: no displacement time
- 1 ft flood depth: 45 days displacement
- Greater than 1 ft flood depth: 45 additional days of displacement for each foot above 1 ft up to a maximum of 720 days

Table 10 presents a depth-damage function for the four land use types in the drainage basin based on computations performed in the *Smith Canal Closure Structure Inundation-Reduction Benefit Analysis*, 2010 (David Ford Consulting).

Table 10. Displacement Costs by Flood Depth

Flood Depth (ft)	Displacement Costs (% of Structure Value)
2	8.0%
1	4.2%
0	0%
-1	0%

Table 11 presents the estimated displacement costs for each area within the basin for the 100-year, 25-year, and 10-year events.

Table 11. Displacement Costs associated with Flood Damage

Wisconsin Pump Station Drainage Area	Displacement Costs ($)		
	100-year Event	25-year Event	10-year Event
Area A	$ 64,330	$ 64,330	$ 33,773
Area B	$ 193,219	$ 193,219	$ -
Area C	$ -	$ -	$ -
Area D	$ -	$ -	$ -
Area E	$ -	$ -	$ -
TOTAL	$ 257,549	$ 257,549	$ 33,773

Emergency Response Costs

Emergency response costs within the Wisconsin Pump Station Drainage Basin that were considered include the following costs:

- Evacuation
- Security

- Debris Removal
- Cleanup

Emergency repair costs were estimated at an average $25,000 per acre of flooded area. Table 12 presents the estimated emergency response costs for each area within the basin for the 100-year, 25-year, and 10-year events.

Table 12. Emergency Response Costs associated with Flood Damage

Wisconsin Pump Station Drainage Area	Emergency Response Costs ($)		
	100-year Event	25-year Event	10-year Event
Area A	$ 55,175	$ 55,175	$ 55,175
Area B	$ 583,200	$ 583,200	$ -
Area C	$ -	$ -	$ -
Area D	$ -	$ -	$ -
Area E	$ -	$ -	$ -
TOTAL	**$ 638,375**	**$ 638,375**	**$ 55,175**

Damage Assessment Summary

Table 13 presents a summary of the "Without" project flood damages and costs categories within the basin for the 100-year, 25-year, and 10-year events.

Table 13. "Without" Project Damage Assessment Summary

Damage/Cost	Flood Damages and Costs ($)		
	100-year Event	25-year Event	10-year Event
Land Damage	$ 596,686	$ 596,686	$ 82,500
Structure Damage	$ 4,361,135	$ 4,361,135	$ 1,251,826
Contents Damage	$ 1,334,453	$ 1,334,453	$ 385,427
Automobile Damage	$ 818,235	$ 818,235	$ 209,711
Infrastructure Damage	$ 166,846	$ 166,846	$ 14,421
Displacement Costs	$ 257,549	$ 257,549	$ 33,773
Emergency Response Costs	**$ 638,375**	**$ 638,375**	**$ 55,175**
TOTAL	**$ 8,173,279**	**$ 8,173,279**	**$ 2,032,832**

Expected Annual Project Benefits

The expected annual project benefits were determined using the 100-year, 25-year, and 10-year exceedance probabilities. The difference between the "Without" project and "With" project flood damages and costs represents the project benefits.

Expected Annual Damages

The expected flood damage was determined using the methodology in the USACE's *Expected Annual Flood Damage Computation User's Manual*, 1989, for both the "Without" project and "With" project scenarios. The "Without" project expected flood damage and costs were taken from Table 13 above. The "With" project expected flood damage and costs were assumed to be for event less frequent that the 100-year event. For the purposes of this analysis, it was assumed that the "With" project damage equals the 100-year event damage. Figure 1 presents the damage-frequency curve for both "Without" project and "With" project scenarios. The area beneath the damage-frequency curve represents the expected annual damage for each scenario. Table 15 presents the expected annual flood damage for the two project scenarios. The difference between the two expected annual flood damage scenarios is considered the Annual Damage Reduction or Project Benefit. The Annual Project Benefit is also presented in Table 14.

Figure 1. Damage-Frequency Curves

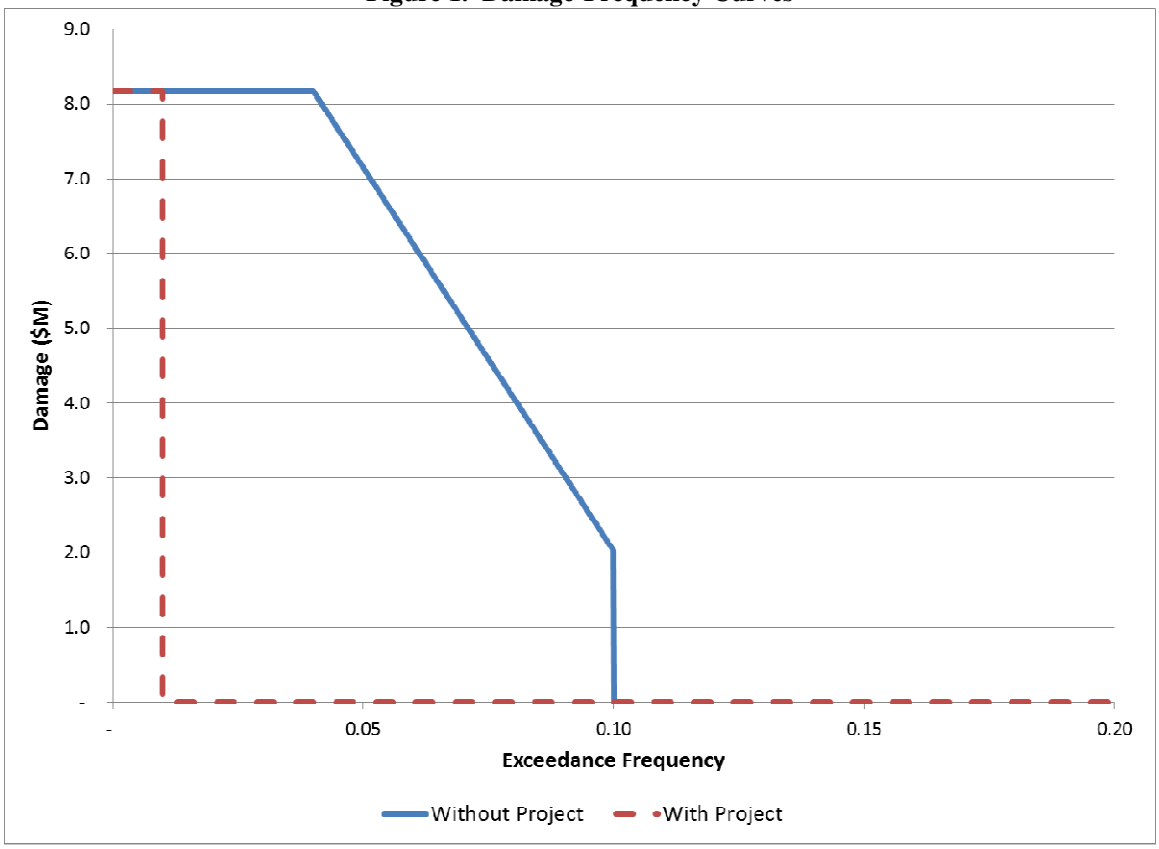

Table 14. Expected Annual Flood Damage and Costs

Project Scenario	Expected annual Flood Damage ($1,000/yr)
"Without" Project	633
"With" Project	82
Expected Annual Project Benefit	**551**

Benefit-Cost Analysis

The project costs for implementation of the new Wisconsin Pump Station are estimated to be $1.5 million. In addition to the Wisconsin Pump Station replacement, the project includes a new diversion from the Calaveras River and recharge ponds for the Stockton East Water District (project cost $8.0M). Using a discount rate of 6% over 50 years gives an annual cost for the pump station replacement of $95,000/yr. Annual operating costs for the pump station are estimated at $11,000/yr. Therefore, the total estimated annual project costs are $106,000/yr.

The ratio of the Expected Annual Project Benefits ($551,000/yr) to the Annual Project Costs ($106,000/yr) results in a Benefit-Cost Ratio of 5.2 for the Wisconsin Pump Station replacement.

Attachment 1. Expected annual damage computation procedure

Theoretical background

In mathematical terms, if X represents the value of annual flood damage, then the expected value of annual damage, $E[X]$, is computed as

$$E[X] = \int_{-\infty}^{\infty} x f_X(x)\,dx \tag{1}$$

in which x represents the random value of annual damage that occurs with probability $f_X(x)dx$. With this, all the information about the probability of occurrence of various magnitudes of damage is condensed into a single number by summing the products of all possible damage values and the likelihood of their occurrence.

In the equation, $f_X(x)$ is what statisticians refer to as the *probability density function* (PDF). In hydrologic engineering, an alternative representation of the same information, the so-called *cumulative distribution function* (CDF), is more commonly used. This is defined as

$$F_X[x] = \int_{-\infty}^{x} f_X(u)du \tag{2}$$

This probability distribution function, also known as a *frequency function*, defines the probability that annual maximum damage will not exceed a specified value X. Alternately, by exchanging the limits of integration, the CDF could define the probability that the damage will exceed a specified value. In either case, the CDF and PDF are related as

$$\frac{dF_X[x]}{dx} = f_X(x) \tag{3}$$

so the expected value of annual damage can be computed as

$$E[X] = \int_{-\infty}^{\infty} x \frac{dF_X(x)}{dx} dx \tag{4}$$

Method of computation

Mechanically, then, finding the expected value of annual damage is equivalent to integrating the annual damage cumulative frequency function. The function could be integrated analytically if it were written as an equation. This approach is of little practical value because analytical forms commonly are not available. In fact, the damage-frequency function required for expected-annual-damage computation commonly is not available in any form. Theoretically, the function could be derived by collecting annual damage data over time and fitting a statistical model. In most cases, such damage data are not available or are very sparse for existing conditions, and they *never* are available for modified conditions.

Instead, the damage-frequency function is derived commonly via transformation of available hydrologic, hydraulic, and economic information, as illustrated in Figure 5. A stage-frequency function (Figure 5*a*) is developed using principles of hydrology and hydraulics. An elevation-damage function (Figure 5*b*) is developed from information about location and value of damageable property in the floodplain. With this, the stage-frequency function can be transformed to yield the required damage-frequency function (Figure 5*c*). Finally, to compute the expected damage, the resulting damage-frequency function can be integrated.

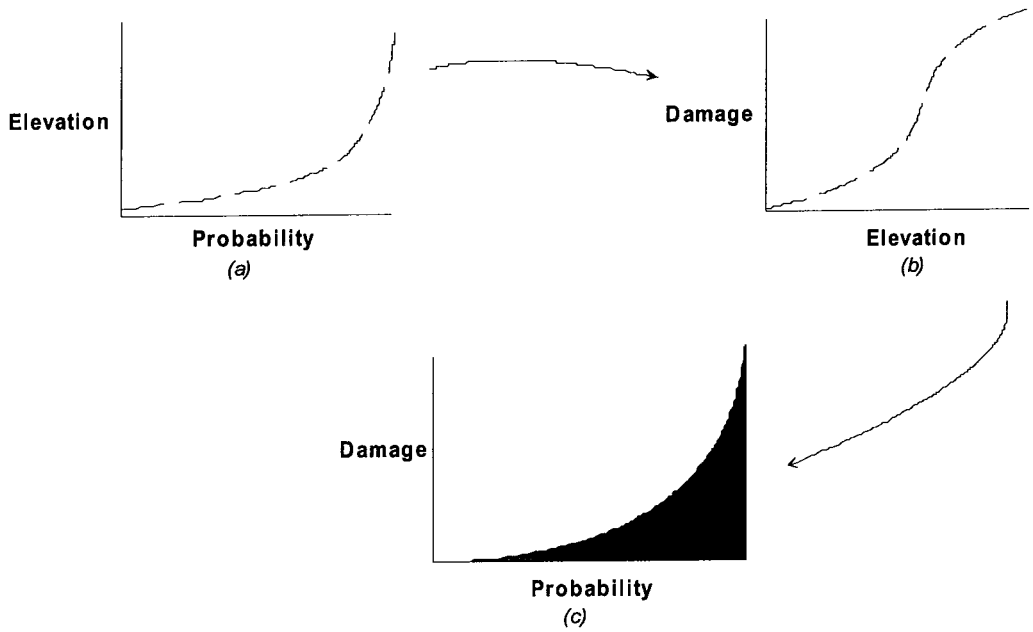

Figure 5. EAD computed by transformation and integration