First to Fifth Creek Damages Report

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Synopsis :	This report documents the methodology and results from the damages assessment undertaken on the First to Fifth Creek system in South Australia.

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1 INTRODUCTION

Tonkin Consulting was engaged by the Torrens Catchment Water Management Board to undertake a floodplain mapping study of the Torrens Creeks (First to Fifth Creeks). WBM was part of the study team and was responsible for the floodplain mapping of three creek systems and conducting the damages assessment for all 5 creeks. This report documents the findings of the flood damages assessment.

The focus of the study was on the series of creeks known as First, Second, Third, Fourth and Fifth Creeks that drain from the Hills Face Escarpment to the River Torrens through numerous suburbs to the East of Adelaide. The creek systems have had a history of flooding and despite flood protection works being undertaken on First to Fourth Creek during the 1980's, there is still significant potential for flooding and subsequent property damage.

Flood damages provide stakeholder groups with important information that can be used to prioritise flood mitigation or flood prevention works. They indicate the magnitude of damages caused by a design flood event of a given annual exceedance probability (AEP).

The magnitudes of flood damages are dependent upon a number of factors including property values, property size and the preparedness of the community to respond to the threat of flooding. These factors (and others) are included in the damages assessment calculations and are detailed in the following section.

The damages assessments have been based on the hydraulic modelling results undertaken by both TONKIN Consulting (First and Second Creek) and WBM (Third, Fourth and Fifth Creek). There was some overlap in the model domains between First and Second Creek and between Second and Third Creek and consequently there will be some duplication of damages in each of these three systems. Due to this duplication, the results have been presented individually for each of the 5 Creek systems and not combined together to generate an overall damages assessment.

2 FLOOD DAMAGES ASSESSMENT

Flood damage assessment is an important component of any floodplain management framework. This type of analysis enables the floodplain manager to gain an understanding of the magnitude of assets under threat from flooding. Assessment of damages was undertaken using the ANUFLOOD method. The methodology and results from these assessments is presented in the following sections.

2.1 Methodology

The basic procedure for calculating the monetary flood damages is provided below.

- Identify the areas inundated and the depth of inundation for a range of design flood events (1:20, 1:50, 1:100 and 1:500 year AEP design storm events in this study) modelled using the TUFLOW hydraulic model.
- Determine if flooding had occurred within a property's boundary. Cadastral data was used for this analysis and it was assumed that inundation of the property had occurred if the flood extended to at least the centre of the block. In addition to this, the property had to fall within a mapping limit provided by TONKIN Consulting. Properties intersecting the mapping limit were excluded from the analysis.
- The depth of flooding within each property for each AEP event was calculated using the ground survey information. As no floor levels were available, it was assumed that the floor levels for residential properties was 150mm above the surveyed ground level and floor levels for commercial and industrial premises were equal to the ground level.
- Stage-damage relationships were determined for the residential and commercial properties. These relationships accounted for factors such as the relative degree of flood preparedness of the community.
- Produce total flood damages for the range of flood events for residential and commercial/industrial properties.
- Sum damages for each AEP event and present the results in a probability-damage graph.
- Assume indirect damages are 30% of direct damages as recommended in the RAM (Rapid Appraisal Method) report (NRE, 2000).
- Determine the average annual damages (AAD).

Damages to public infrastructure have not been included in this analysis.

2.1.1 Stage-Damage Curves

ANUFLOOD residential stage-damage curves were used for this flood damage assessment. These curves were sourced from NRE (2000). The non-residential stage-damage curves, also ANUFLOOD curves, were sourced from a journal paper by Smith (1994) 'Flood Damage Estimation – A review of urban stage-damage curves and loss functions'. The curves have been indexed to 2005 units using appropriate CPI factors sourced from Bureau of Statistics (December 2005 Quarter – at the time of analysis, CPI figures for the March 2006 Quarter were unavailable).

ANUFLOOD has 15 non-residential stage-damage curves. For each building size (small, medium and large), there are 5 curves representing 5 value classes. The ANUFLOOD stage-damage data is presented in Table 2-1 to Table 2-4. Because no data was available on the type, size or condition of each of the buildings considered, the size and condition of each residential building was assumed to be medium and good respectively. Commercial and Industrial buildings were also assumed to be in good condition, and their respective size was assumed to be 90% of the cadastral property footprint.

The Rapid Appraisal Method (RAM) for Floodplain Management suggests that the ANUFLOOD curves underestimate flood damages. To address this issue, the RAM report recommends increases of 60% be applied to both the residential and non-residential curves. Section 3.1 of the RAM report provides a detailed explanation for the increase, but in brief, the increase to the stage-damage curves is required as the original curves are based primarily on the Sydney 1986 flood event and they needed updating. Further studies into flood damages undertaken by Water Studies for flood events at Geelong (1995), Traralgon (1995), Inverall (1991) and Nungan (1990) indicated that the mean level of potential damages was 37% higher that the potential damages predicted by applying the ANUFLOOD methodology. A further comparison is made to these results from the Water Studies analysis and the applied damages using the RAM methodology. Based on this comparison, the report suggests that the detailed stage-damage curves in ANUFLOOD need updating. This can only be undertaken properly by surveying inundated properties after the actual flood events. Therefore, until these curves can be updated, it is suggested that the damages implied by the existing ANUFLOOD stage-damage curves should be increased by 60% (NRE 2000). The 60% increase has been applied to the damages in Table 2-1 to Table 2-4.

Damages to property that actually occur (actual damages) are normally less than those that could occur (potential damages) if residents took no action to reduce damages during a flood, eg, lift furniture. Ratios to convert Potential damages to Actual damages were used as per the recommendations from the RAM. That is, for a community who is generally unaware of their flooding risks and who have a warning time of between 2 and 12 hours, a factor (ratio) of 0.8 is used to reduce the potential damages to actual damages. This factor also applies to communities who regularly experience floods who have a warning time of less than 2 hours.

Table 2-1 ANUFLOOD Stage-Damage Curves - Residential

Flood Heights Above Floor Level (m)		ANUFLOOD Stage Damage Values ($2005)					
		Poor Condition		Fair Condition		Good Condition	
From	To	From	To	From	To	From	To
0	0.1	0	5120	0	10080	0	22720
0.1	0.6	5120	15200	10080	25280	22720	50720
0.6	1.5	15200	32960	25280	37920	50720	65760
1.5	2	32960	35520	37920	40480	65760	68320
2	10	35520	35520	40480	40480	68320	68320

Table 2-2 ANUFLOOD Stage-Damage Curves – Small Commercial/Industrial

Flood Heights Above Floor Level (m)		ANUFLOOD Stage Damage Values ($2005)					
		Poor Condition		Fair Condition		Good Condition	
From	To	From	To	From	To	From	To
0	0.25	0	7520	0	20000	0	60000
0.25	0.75	7520	18720	20000	49920	60000	149920
0.75	1.25	18720	28160	49920	75040	149920	224960
1.25	1.75	28160	31200	75040	83360	224960	249920
1.75	2	31200	33120	83360	88320	249920	264960
2	10	33120	33120	88320	88320	264960	264960

Table 2-3 ANUFLOOD Stage-Damage Curves – Medium Commercial/Industrial

Flood Heights Above Floor Level (m)		ANUFLOOD Stage Damage Values ($2005)					
		Poor Condition		Fair Condition		Good Condition	
From	To	From	To	From	To	From	To
0	0.25	0	23680	0	63360	0	189920
0.25	0.75	23680	57440	63360	153280	189920	459840
0.75	1.25	57440	87520	153280	233280	459840	699680
1.25	1.75	87520	96800	233280	258240	699680	774720
1.75	2	96800	103040	258240	274880	774720	824640
2	10	103040	103040	274880	274880	824640	824640

Table 2-4 ANUFLOOD Stage-Damage Curves – Large Commercial/Industrial

Flood Heights Above Floor Level (m)		ANUFLOOD Stage Damage Values ($2005/m^2)					
		Poor Condition		Fair Condition		Good Condition	
From	To	From	To	From	To	From	To
0	0.25	0	13	0	37	0	107
0.25	0.75	13	69	37	186	107	539
0.75	1.25	69	141	186	379	539	1133
1.25	1.75	141	232	379	621	1133	1858
1.75	2	232	279	621	741	1858	2221
2	10	279	279	741	741	2221	2221

2.1.2 Outside Buildings

Damages to equipment outside the building are not included in the standard stage-damage curves used. Such damages may include damage to fences, driveways, lower level laundries and outdoor equipment. To account for this $1000 was applied to each property that was inundated.

2.1.3 Indirect Damages

Indirect damages refer to the costs incurred to a community during a flood and include emergency response and disruptions to employment, commerce, tourism, transport and communication. The RAM report suggests that these costs are approximately 30% of direct damages.

2.1.4 Public Infrastructure Damages

The RAM Report provides some guidance for appropriate values that can be used to determine the damages that can be applied to public infrastructure. The values provided are for damages to roads and bridges only, because damages to other infrastructure (telecommunications, electricity, water, sewerage and other underground services) are insignificant when compared to damages associated with roads and bridges. The values provided for road and bridge damage are based on actual flood damages that occurred in North-East Victoria during the Spring 1993 floods. However, these damages are ideally suited to rural roads and the damage that is actually incurred is dependant upon the direction and magnitude of flow and velocity. The RAM report suggests that for a major sealed road, the damages incurred would be $48,000 per inundated kilometre or $15,000 per inundated kilometre if it were a minor sealed road. For this damages assessment, the roads would not be subject to the same magnitudes of low and velocity and the flows are more likely to be running along the road, not perpendicular to it. The damages attributed to roads in the study area would be significantly less than these values and would be insignificant when compared to the total damages for each creek. Therefore, damages to public infrastructure were not included in this analysis.

2.1.5 Total Damages Calculations

Total damages were determined using the ANUFLOOD methodology. This methodology determined the peak depth of above floor flooding at the centre of the each lot for the 1:20, 1:50, 1:100 and 1:500 AEP events and the associated cost was extracted from the stage-damage relationships. Total damages for each flood event were determined by summing the predicted damages for each individual dwelling. The total damages were then used to calculate the average annual damage (AAD) as described below.

2.1.6 Average Annual Damages

The AAD is the average damage in dollars per year that would occur in a designated area from flooding over a long period of time. In many years there may be no flood damage, in some years there will be minor damage (caused by small, relatively frequent floods) and, in a few years, there will be major flood damage (caused by large, rare flood events). Estimation of the AAD provides a basis for comparing the effectiveness of different floodplain management measures (i.e. the reduction in the AAD).

The damages associated with a range of flood events (1:20, 1:50, 1:100 and 1:500 AEP) were determined and plotted on a flood damage curve (total damages as a function of the flood exceedance probability). The AAD is the area under the damages-probability curve and is calculated by integrating the curve.

Ideally the probable maximum flood (PMF) damages are included in the AAD analysis. WBM did not run PMF events on the models, so TONKIN Consulting provided an estimate of the PMF damages. The PMF damages were calculated by factoring the 1:500 AEP damages by a number that was representative of the increased property inundation from the 1:500 AEP event to the PMF event. The PMF damages are shown in Table 2-5. As advised by TONKIN Consulting, it was assumed that no damages would occur in the 1:10 AEP event or lower.

Table 2-5 PMF Damages supplied by TONKIN Consulting

Creek System	Supplied PMF Damages
1st Creek	$194,924,000
2nd Creek	$426,436,000
3rd Creek	$383,367,000
4th Creek	$84,732,000
5th Creek	$35,636,000

2.2 Flooded Properties

As no floor level data was available, it was assumed that floor levels for residential properties were 150 mm above the ground surface, and that commercial and industrial properties had floor levels equal to ground level. The depth of above ground level flooding was calculated by subtracting the assigned floor level at each property from the flood height at that property for each design event.

The number of properties (residential and commercial) within the flood extent and the number with above floor flooding are shown in Table 2-6 (1:20 AEP), Table 2-7 (1:50 AEP), Table 2-8 (1:100 AEP) and Table 2-9 (1:500 AEP).

Table 2-6 Number of Flooded Properties – 1:20 AEP Event

Creek System	Number of Properties	
	Within Flood Extent	Flood Above Floor Level*
First Creek	192	67
Second Creek	491	7
Third Creek	230	87
Fourth Creek	61	35
Fifth Creek	9	5

*Residential property floor levels assumed to be 150 mm above ground level, and commercial property floor levels assumed to be at ground level.

Table 2-7 Number of Flooded Properties – 1:50 AEP Event

Creek System	Number of Properties	
	Within Flood Extent	Flood Above Floor Level*
First Creek	629	185
Second Creek	631	36
Third Creek	291	114
Fourth Creek	75	38
Fifth Creek	12	6

*Residential property floor levels assumed to be 150 mm above ground level, and commercial property floor levels assumed to be at ground level.

Table 2-8 Number of Flooded Properties – 1:100 AEP Event

Creek System	Number of Properties	
	Within Flood Extent	Flood Above Floor Level*
First Creek	801	237
Second Creek	800	52
Third Creek	341	138
Fourth Creek	97	42
Fifth Creek	32	6

*Residential property floor levels assumed to be 150 mm above ground level, and commercial property floor levels assumed to be at ground level.

Table 2-9 Number of Flooded Properties – 1:500 AEP Event

Creek System	Number of Properties	
	Within Flood Extent	Flood Above Floor Level*
First Creek	1160	424
Second Creek	1456	203
Third Creek	579	217
Fourth Creek	464	122
Fifth Creek	96	14

*Residential property floor levels assumed to be 150 mm above ground level, and commercial property floor levels assumed to be at ground level.

2.3 Flood Damages

The following sections detail the flood damages for each of the five modelled creeks.

2.3.1 First Creek

The total existing conditions damages using the ANUFLOOD methodology for each design flood event are presented Table 2-10 and illustrated in Figure 2-1. The existing conditions annual average damages (AAD) are $548,000 based on the ANUFLOOD methodology.

Table 2-10 ANUFLOOD Damages Summary (First Creek)

Event		Existing Case			
(Years ARI)	AEP	House Damages	Indirect Damages	Total Damages	Incremental Average Annual Damages
PMF*				$194,924,000	
500	0.2%	$12,398,000	$3,719,000	$16,117,000	$200,000
100	1%	$6,162,000	$1,849,000	$8,011,000	$97,000
50	2%	$4,967,000	$1,490,000	$6,457,000	$72,000
20	5%	$1,580,000	$474,000	$2,054,000	$128,000
10	50%			$0	$51,000
Average Annual Damage					**$548,000**

* PMF (probable maximum flood) damages were advised by TONKIN Consulting and have been determined by factoring the 1:500 AEP damages in line with the increased property inundation caused by the PMF flood when compared to the 1:500 AEP flood.

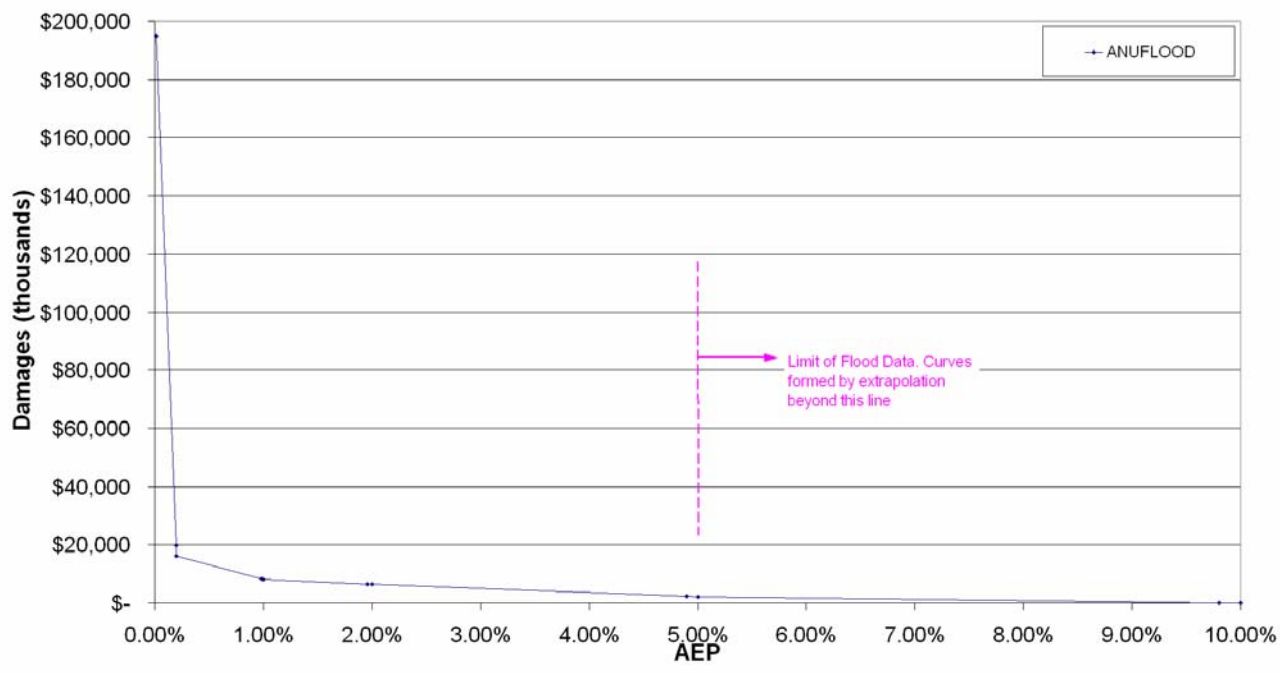

Figure 2-1 Existing Condition Probability Damages Curve (First Creek)

2.3.2 Second Creek

The total existing conditions damages using the ANUFLOOD methodology for each design flood event are presented Table 2-11 and illustrated in Figure 2-2. The existing conditions annual average damages are $631,000 based on the ANUFLOOD methodology.

Table 2-11 ANUFLOOD Damages Summary (Second Creek)

Event		Existing Case			
(Years ARI)	AEP	House Damages	Indirect Damages	Total Damages	Incremental Average Annual Damages
PMF*				$426,436,000	
500	0.2%	$10,357,000	$3,107,000	$13,465,000	$418,000
100	1%	$3,138,000	$941,000	$4,079,000	$70,000
50	2%	$2,119,000	$636,000	$2,755,000	$34,000
20	5%	$1,300,000	$390,000	$1,690,000	$67,000
10	50%			$0	$42,000
Average Annual Damage					**$631,000**

* PMF (probable maximum flood) damages were advised by TONKIN Consulting and have been determined by factoring the 1:500 AEP damages in line with the increased property inundation caused by the PMF flood when compared to the 1:500 AEP flood.

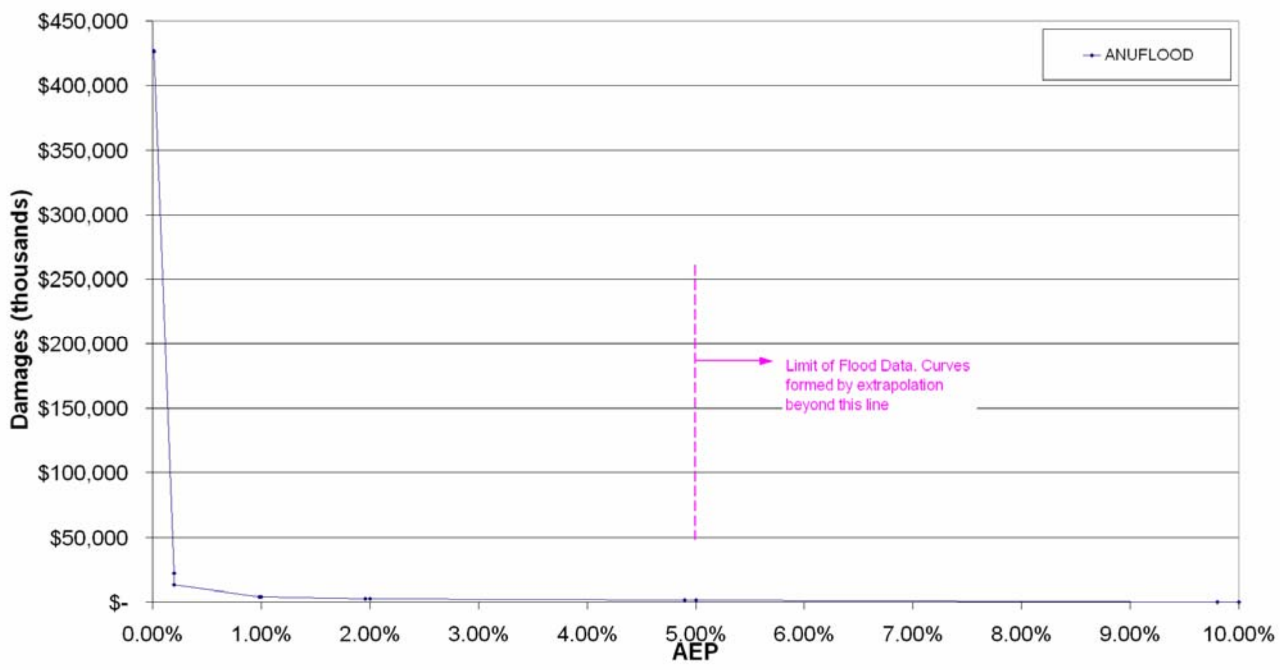

Figure 2-2 Existing Condition Probability Damages Curve (Second Creek)

2.3.3 Third Creek

The total existing conditions damages using the ANUFLOOD methodology for each design flood event are presented Table 2-12 and illustrated in Figure 2-3. The existing conditions annual average damages are $701,000 based on the ANUFLOOD methodology.

Table 2-12 ANUFLOOD Damages Summary (Third Creek)

Event		Existing Case			
(Years ARI)	AEP	House Damages	Indirect Damages	Total Damages	Incremental Average Annual Damages
PMF*				$383,367,000	
500	0.2%	$7,498,000	$2,249,000	$9,747,000	$374,000
100	1%	$4,697,000	$1,409,000	$6,106,000	$63,000
50	2%	$3,806,000	$1,142,000	$4,948,000	$55,000
20	5%	$2,593,000	$778,000	$3,371,000	$125,000
10	50%			$0	$84,000
Average Annual Damage					**$701,000**

* PMF (probable maximum flood) damages were advised by TONKIN Consulting and have been determined by factoring the 1:500 AEP damages in line with the increased property inundation caused by the PMF flood when compared to the 1:500 AEP flood.

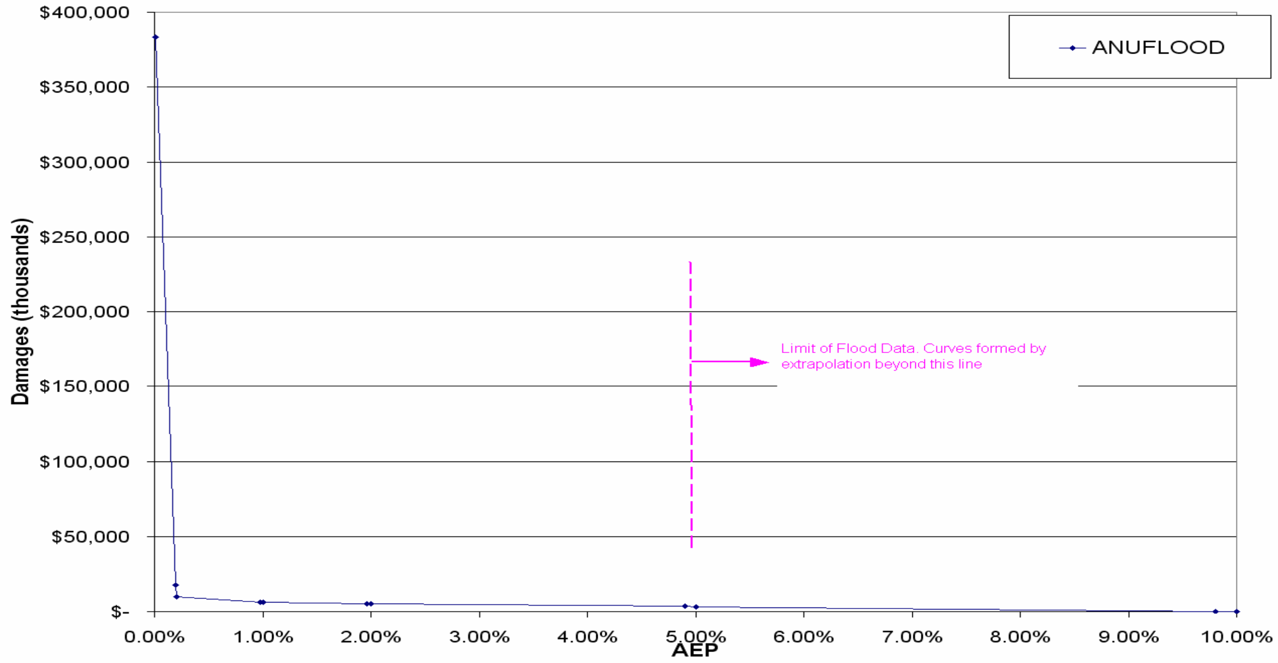

Figure 2-3 Existing Condition Probability Damages Curve (Third Creek)

2.3.4 Fourth Creek

The total existing conditions damages using the ANUFLOOD methodology for each design flood event are presented Table 2-13 and illustrated in Figure 2-4. The existing conditions annual average damages are $202,000 based on the ANUFLOOD methodology.

Table 2-13 ANUFLOOD Damages Summary (Fourth Creek)

Event		Existing Case			
(Years ARI)	AEP	House Damages	Indirect Damages	Total Damages	Incremental Average Annual Damages
PMF*				$84,732,000	
500	0.2%	$2,545,000	$764,000	$3,309,000	$84,000
100	1%	$1,357,000	$407,000	$1,764,000	$20,000
50	2%	$1,224,000	$367,000	$1,591,000	$17,000
20	5%	$1,096,000	$329,000	$1,425,000	$45,000
10	50%			$0	$36,000
Average Annual Damage					**$202,000**

* PMF (probable maximum flood) damages were advised by TONKIN Consulting and have been determined by factoring the 1:500 AEP damages in line with the increased property inundation caused by the PMF flood when compared to the 1:500 AEP flood.

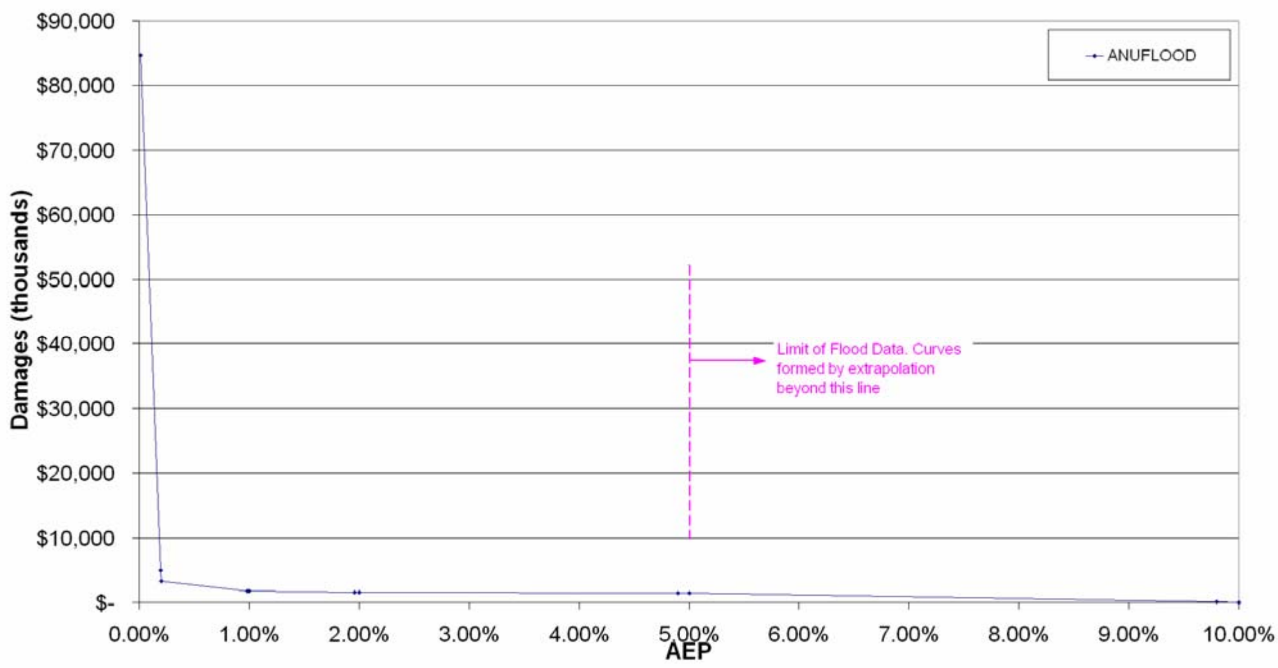

Figure 2-4 Existing Condition Probability Damages Curve (Fourth Creek)

2.3.5 Fifth Creek

The total existing conditions damages using the ANUFLOOD methodology for each design flood event are presented Table 2-14 and illustrated in Figure 2-5. The existing conditions annual average damages are $50,000 based on the ANUFLOOD methodology.

Table 2-14 ANUFLOOD Damages Summary (Fifth Creek)

Event		Existing Case			
(Years ARI)	**AEP**	**House Damages**	**Indirect Damages**	**Total Damages**	**Incremental Average Annual Damages**
PMF*				$35,636,000	
500	0.2%	$363,000	$109,000	$472,000	$34,000
100	1%	$186,000	$56,000	$242,000	$3,000
50	2%	$167,000	$50,000	$217,000	$2,000
20	5%	$141,000	$42,000	$183,000	$6,000
10	50%			$0	$5,000
Average Annual Damage					**$50,000**

* PMF (probable maximum flood) damages were advised by TONKIN Consulting and have been determined by factoring the 1:500 AEP damages in line with the increased property inundation caused by the PMF flood when compared to the 1:500 AEP flood.

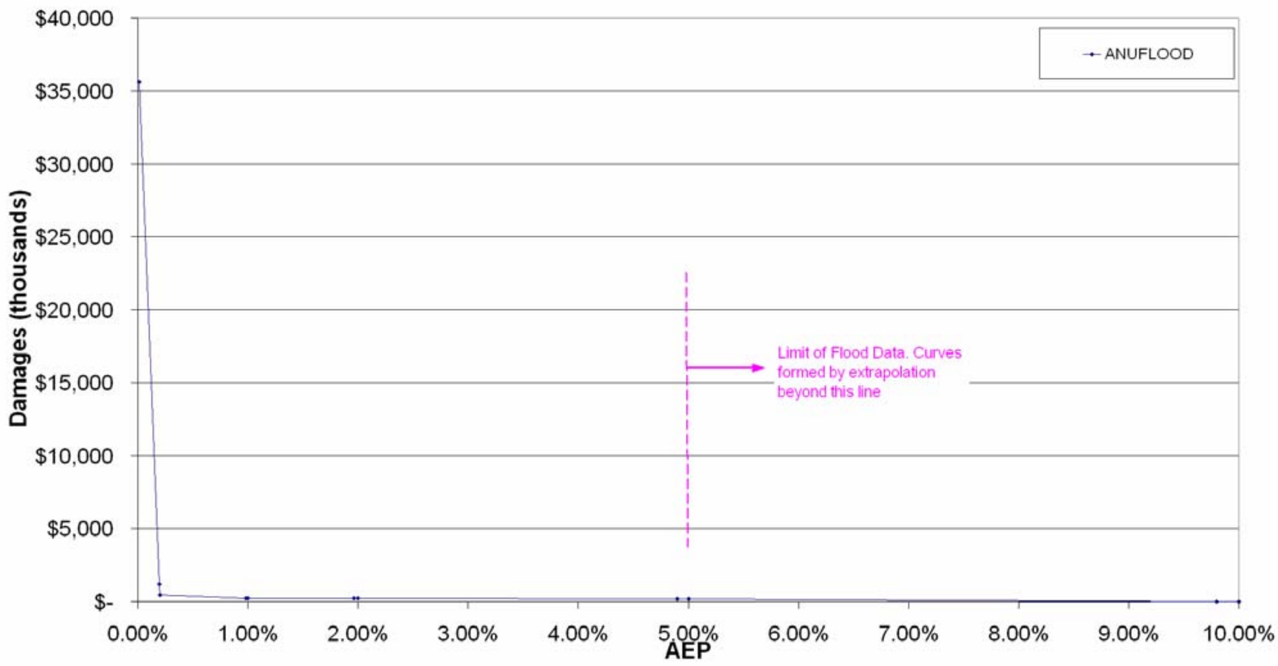

Figure 2-5 Existing Condition Probability Damages Curve (Fifth Creek)

3 SUMMARY

The AAD average annual damages have been calculated for the 1st to 5th Creek system using the ANUFLOOD methodology. The assessment was based on TUFLOW flood modelling resulting for the 1:20, 1:50, 1:100 and 1:500 AEP events. The PMF (probable maximum flood) damages were also included in the analysis, but these were based on an extrapolation of the 1:500 AEP results. The AAD are summarised below in Table 3-1.

Key assumptions in the analysis were that residential property floor levels were 150 mm above the ground level, commercial property floor levels were at ground level, and there was zero damages in the 1:10 AEP event.

Table 3-1 Damages Summary – All Creeks

Creek System	Annual Average Damages (AAD)
	ANUFLOOD
First Creek	$548,000
Second Creek	$631,000
Third Creek	$701,000
Fourth Creek	$202,000
Fifth Creek	$50,000

4 REFERENCES

NRE (2000), **Rapid Appraisal Method (RAM) for Floodplain Management**, Department of Natural Resources and Environment, State of Victoria, May 2000.