Appendix A: Tasmanian Hydrologic Regions

A.1 Introduction

Achievable treatment objectives for stormwater quality have been defined in Tasmania. These objectives are expressed as reductions in the mean annual pollutant loads that are discharged from typical urban areas with no stormwater treatments installed (eg. 80% reduction in TSS and 45% reduction in TP and TN). A range of stormwater treatment measures are capable of treating urban stormwater to meet treatment objectives. The design of stormwater treatment measures often requires a continuous simulation approach to properly consider the influence of antecedent conditions of the treatment measure during the occurrence of a storm event and the wide range of storm characteristics and hydraulic conditions that the individual treatment measures are to operate in. Computer models such as MUSIC have been developed to enable continuous simulations of complex stormwater management treatment trains to aid in the development of stormwater management strategies and the design (sizing) of stormwater treatment measures.

This report is adapted for Tasmania from Melbourne Water's "WSUD Engineering Procedures: Stormwater" and builds upon earlier work (described in "Hydrologic Regions for Sizing of Stormwater Treatment in Victoria", October 2003) and its purpose is to develop a simple design procedure that can be used in small development projects (eg. single or a small clustered allotment development type) and can serve as a preliminary design procedure. In addition it could be used as a simple design checking tool.

This methodology stems from the theory that sizing stormwater treatment systems could be based around defining simple empirical design equations that would be applicable in their respective designated Hydrologic Region within Tasmania. This report presents results of developing the empirical relationships and the number of regions

A.2 Methodology

After initial consideration of possible design approaches, the following approach was used to develop the different regions and adjustment factors for sizing stormwater treatment measures throughout Tasmania–

1. Select a rating to represent the effectiveness of different design configurations of various stormwater treatment measures. Reduction in total nitrogen is a logical choice as it is commonly the limiting parameter in meeting best practice stormwater quality objectives.

2. Select a reference site for which detailed investigation and design simulations are undertaken to determine the relation between design configurations (eg. area, extended detention depth, permanent pool volume etc.) of a range of stormwater treatment measures and the

corresponding stormwater quality improvement performance. Hobart was selected as a reference site.

3. Define Hydrologic Regions within Tasmania where practitioners wanting to design a stormwater treatment measure at any location in Tasmania could refer to the design requirements developed for the reference site and apply an Adjustment Factor to that size to determine the appropriate dimensions of the treatment measure for their particular site.

For example, it is determined that in order to meet best practice objectives, a wetland at the reference site must be at least 2% of the contributing impervious area of its catchment. A practitioner designing a wetland of similar configuration in Kingston can simply use an empirical equation to calculate the Adjustment Factor that is then applied to the size of a wetland sized for the reference site.

A.3 Determining hydrologic regions

The Hydrologic Regions for WSUD in Tasmania were determined by selecting a set of pluviographic stations with sufficiently long record to enable continuous simulations of the performance of a number of stormwater treatment measures to be undertaken. A total of forty eight stations were selected for analysis. Figure A.1 show the respective spatial locations of the selected stations.

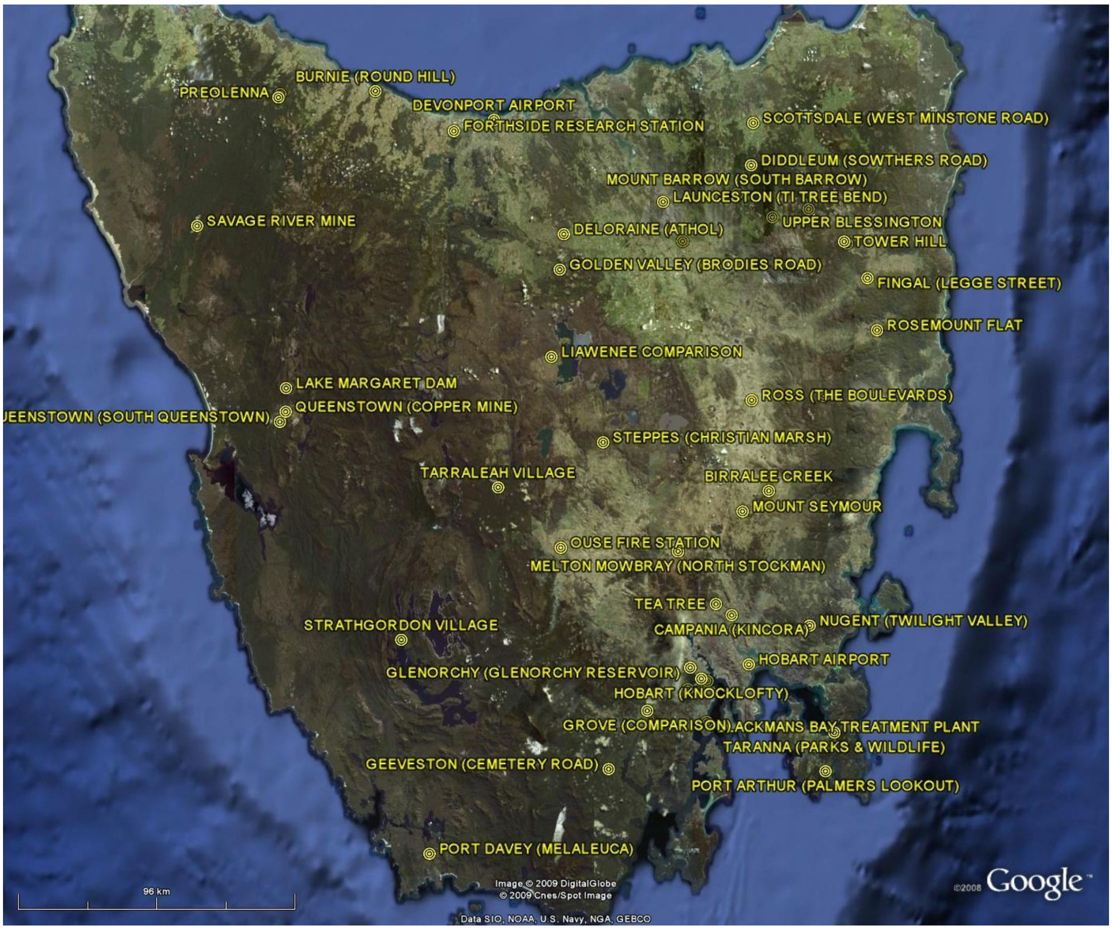

Figure A.1. BOM pluviographic rainfall stations

The mean annual rainfall for the sites selected during the modelled periods ranged from 342 mm to 3173 mm.

Total Nitrogen was selected as the measure for representing the effectiveness of various sized treatment devices. Previous attempts to define the most suitable Hydrologic Region and corresponding predictive equations, the influence of the following factors have been considered in Tasmania and Melbourne:

- mean annual rainfall;
- the ratio of mean summer raindays to mean winter raindays (as a measure of rainday seasonality);

- the ratio of mean summer rainfall to mean winter rainfall (as a measure of rainfall seasonality); and
- site elevation.

The Model for Urban Stormwater Improvement Conceptualisation (MUSIC) developed by eWater was used to simulate the performance of wetlands, bioretention systems, vegetated swales and ponds to size these systems to meet best practice objectives. These sizes were then expressed as the ratio of the size of the treatment area for the reference site. This is thus the Adjustment Factor described in Step 3 in the methodology (see Section 2).

Following extensive testing and analysis of the significance of the above possible influencing factors, it was determined that mean annual rainfall was the most significant influencing factor. For this reason, mean annual rainfall (MAR) has been selected to represent Tasmania with eight Hydrologic Regions.

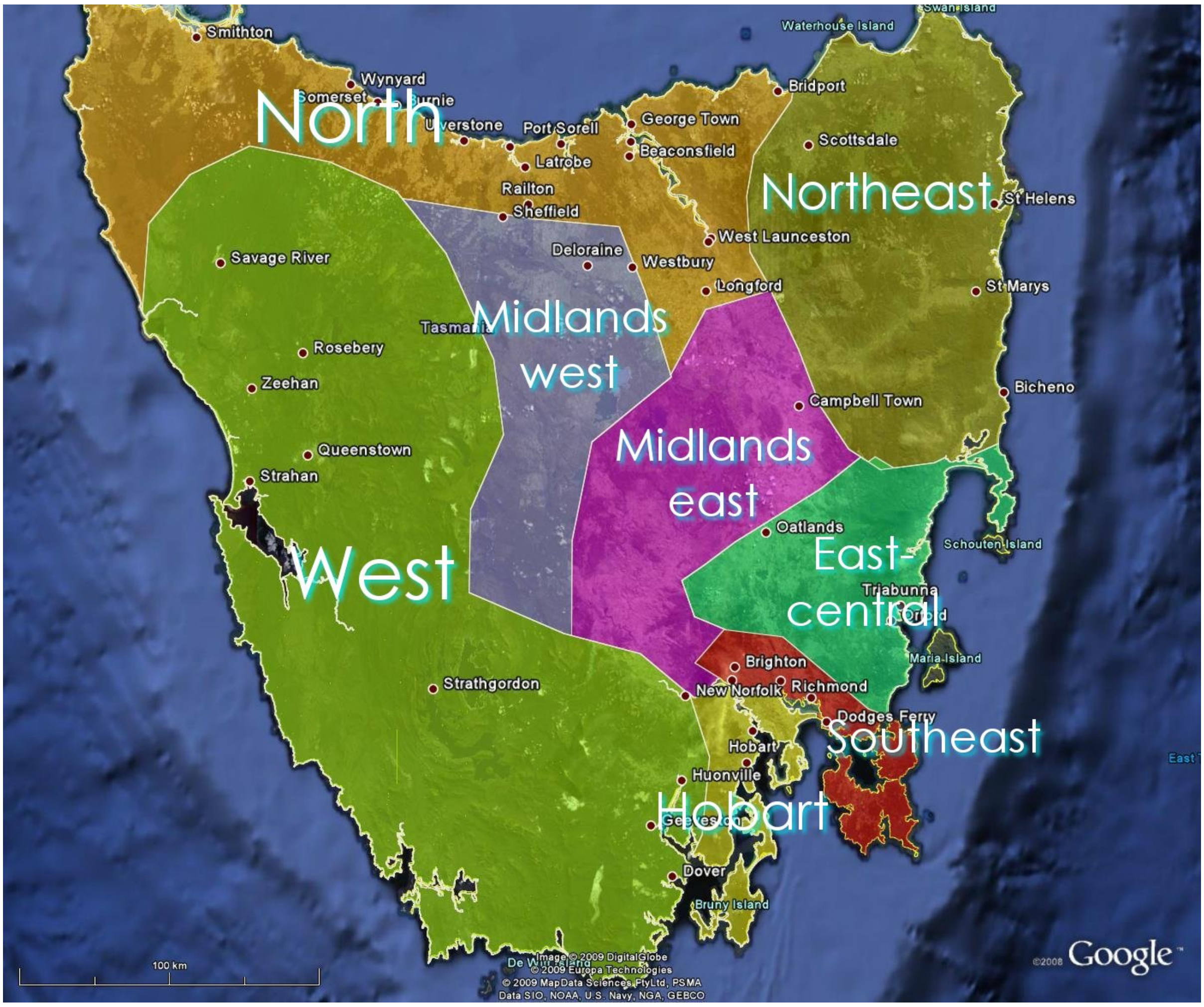

Figure A.2. Tasmanian Stormwater Hydrologic Regions

A.4.1 Hydrological Region Adjustment factors for Tasmania

Adjustment Factors for Tasmania

Region: North

Figure A.3 shows a plot of the *Adjustment Factor*s for bioretention, swales, ponds and wetlands derived against mean annual rainfall for the 'North' Hydrologic Region.. A trend of increasing *Adjustment Factor* with mean annual rainfall is evident for each of the system types.

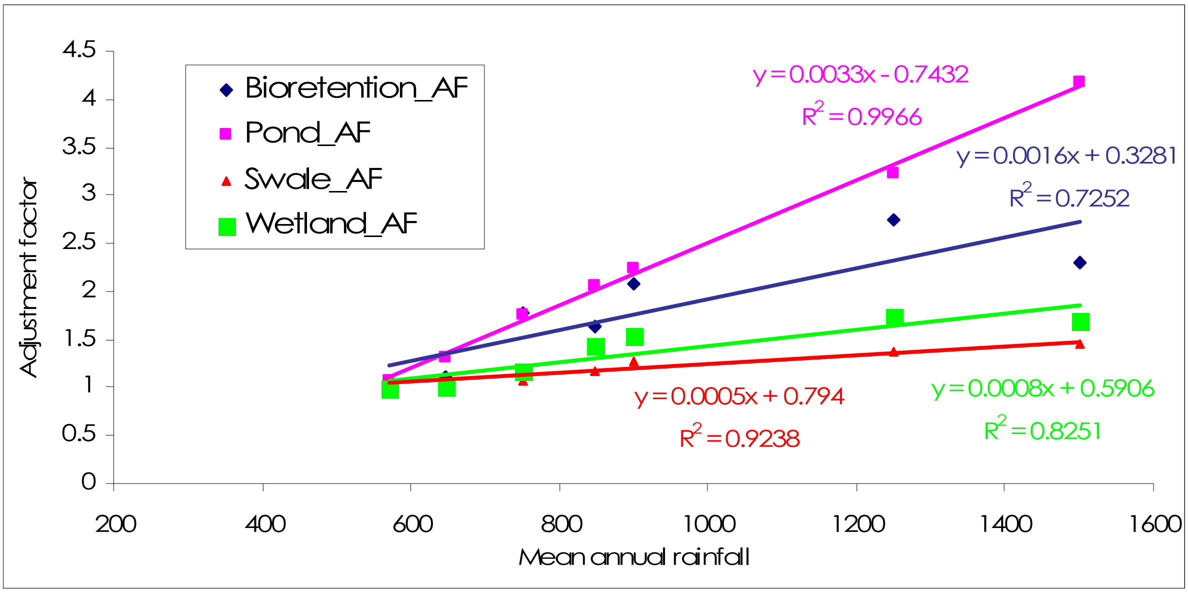

Figure A-1. Plot of *Adjustment Factor* Vs Mean Annual Rainfall (MAR) for the North region

Equations to compute *Adjustment Factors* for each treatment system were obtained by plotting a linear trend (ie 'line of best fit') through for the points on the chart above for each treatment system. The North *Adjustment Factor* equations are shown in the table below.

	North
Bioretention	0.0016(MAR)+0.3281
Pond	0.0033(MAR)-0.7432
Swale	0.0005(MAR)+0.794
Wetland	0.0006(MAR)+0.5906

Region: Northeast

Figure A.4 shows a plot of the *Adjustment Factor*s for bioretention, swales, ponds and wetlands derived against mean annual rainfall for the 'Northeast' Hydrologic Region. A trend of increasing *Adjustment Factor* with mean annual rainfall is evident for each of the system types.

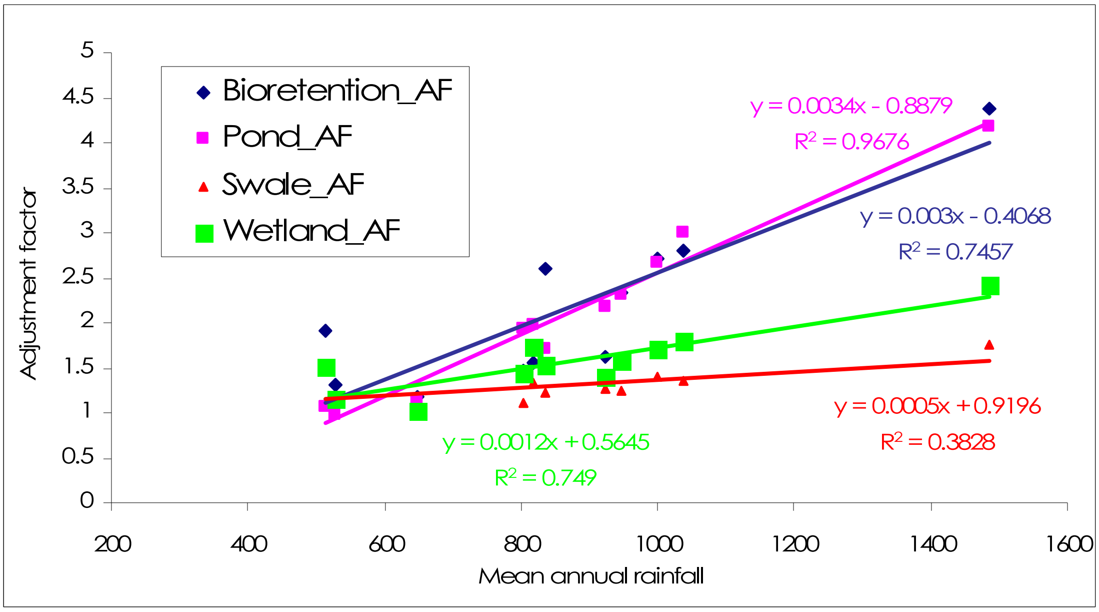

Figure A-2. Plot of *Adjustment Factor* Vs Mean Annual Rainfall (MAR) for the Northeast region

Equations to compute *Adjustment Factors* for each treatment system were obtained by plotting a linear trend (ie 'line of best fit') through for the points on the chart above for each treatment system.

Whilst the coefficient of determination for the swale relationship is lower than others, the lesser slope (m) on the linear curve indicates lower variation in adjustment factor between sites modelled and hence impact of the weaker correlation is not significant.

The Northeast *Adjustment Factor* equations are shown in the table below.

	Northeast
Bioretention	0.0034(MAR)-0.8879
Pond	0.003(MAR)-0.4068
Swale	0.0005(MAR)+0.9196
Wetland	0.0012(MAR)+0.5645

Region: West

Figure A.5 shows a plot of the *Adjustment Factor*s for bioretention, swales, ponds and wetlands derived against mean annual rainfall for the 'West' Hydrologic Region. A trend of increasing *Adjustment Factor* with mean annual rainfall is evident for each of the system types.

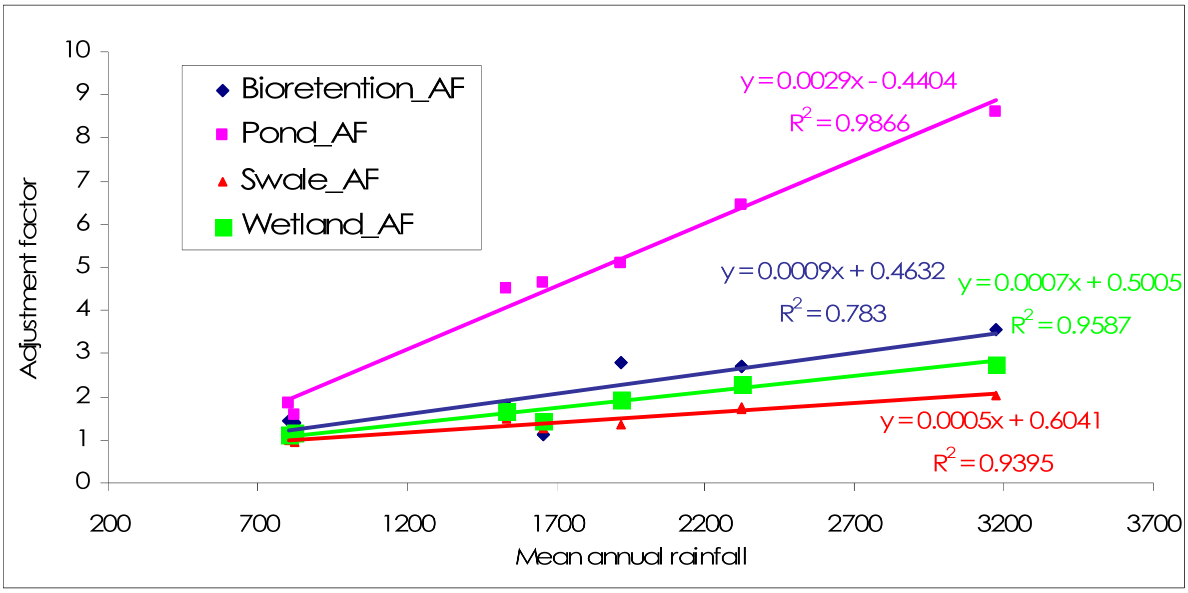

Figure A-3. Plot of *Adjustment Factor* Vs Mean Annual Rainfall (MAR) for the West region

Equations to compute *Adjustment Factors* for each treatment system were obtained by plotting a linear trend (ie 'line of best fit') through for the points on the chart above for each treatment system.

The West *Adjustment Factor* equations are shown in the table below.

	West
Bioretention	0.0009(MAR)+0.4632
Pond	0.0029(MAR)-0.4404
Swale	0.0005(MAR)+0.6041
Wetland	0.0007(MAR)+0.5005

Region: East-central

Figure A.6 shows a plot of the *Adjustment Factor*s for bioretention, swales, ponds and wetlands derived against mean annual rainfall for the 'East-central' Hydrologic Region.. A trend of increasing *Adjustment Factor* with mean annual rainfall is evident for each of the system types.

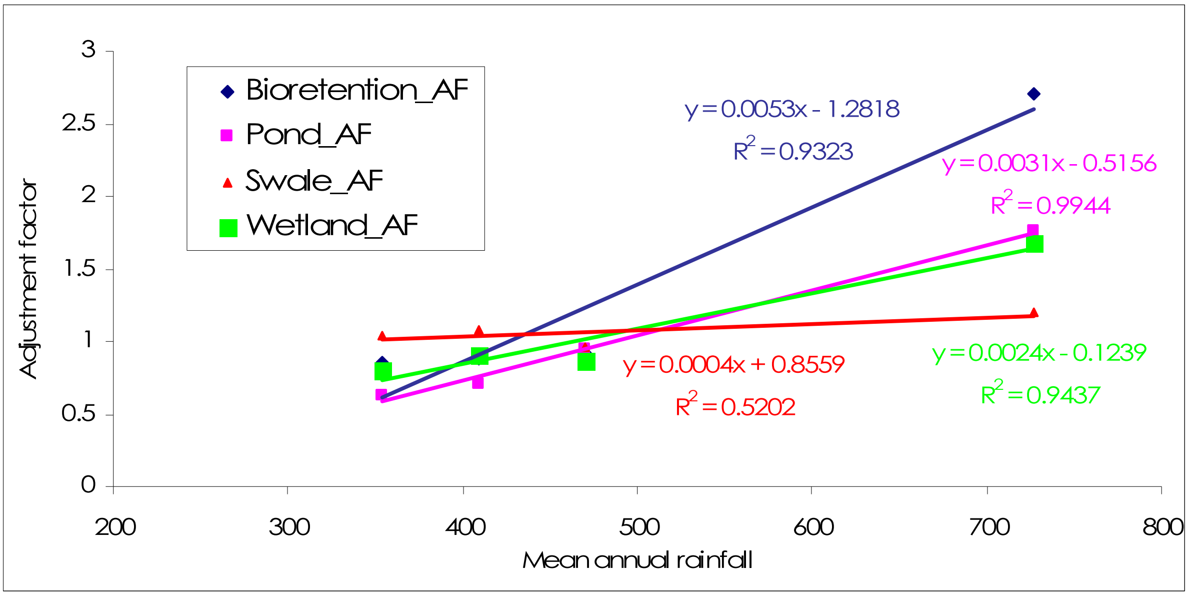

Figure A-4. Plot of *Adjustment Factor* Vs Mean Annual Rainfall (MAR) for the East-central region

Equations to compute *Adjustment Factors* for each treatment system were obtained by plotting a linear trend (ie 'line of best fit') through for the points on the chart above for each treatment system.

Whilst the coefficient of determination for the swale relationship is lower than others, the lesser slope (m) on the linear curve indicates lower variation in adjustment factor between sites modelled and hence impact of the weaker correlation is not significant.

The East-central *Adjustment Factor* equations are shown in the table below.

	East-central
Bioretention	0.0053(MAR)-1.2818
Pond	0.0031(MAR)-0.5156
Swale	0.0004(MAR)+0.8559
Wetland	0.0024(MAR)-0.1239

Region: Southeast

Figure A.7 shows a plot of the *Adjustment Factor*s for bioretention, swales, ponds and wetlands derived against mean annual rainfall for the 'Southeast' Hydrologic Region. A trend of increasing *Adjustment Factor* with mean annual rainfall is evident for each of the system types.

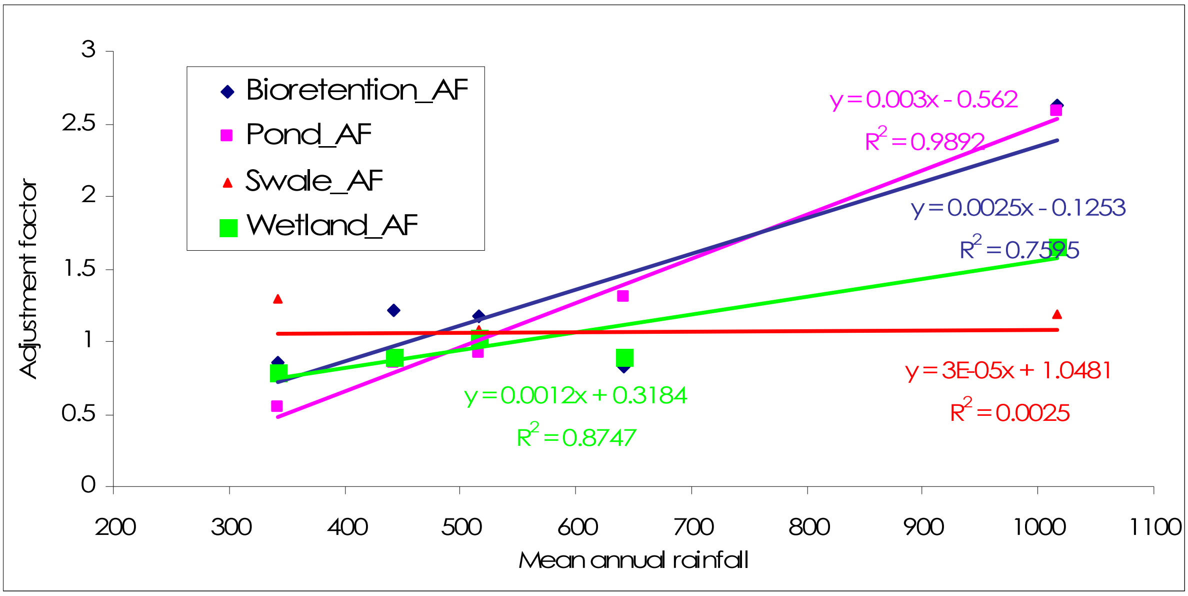

Figure A-5. Plot of *Adjustment Factor* Vs Mean Annual Rainfall (MAR) for the Southeast region

Equations to compute *Adjustment Factors* for each treatment system were obtained by plotting a linear trend (ie 'line of best fit') through for the points on the chart above for each treatment system.

Whilst the coefficient of determination for the swale relationship is lower than others, the lesser slope (m) on the linear curve indicates lower variation in adjustment factor between sites modelled and hence impact of the weaker correlation is not significant.

The Southeast *Adjustment Factor* equations are shown in the table below.

	Southeast
Bioretention	0.0025(MAR)-0.1253
Pond	0.003(MAR)-0.562
Swale	0.00003(MAR)+1.0481
Wetland	0.0012(MAR)+0.3184

Region: Midlands-east

Figure A.8 shows a plot of the *Adjustment Factor*s for bioretention, swales, ponds and wetlands derived against mean annual rainfall for the 'Midlands-east' Hydrologic Region.

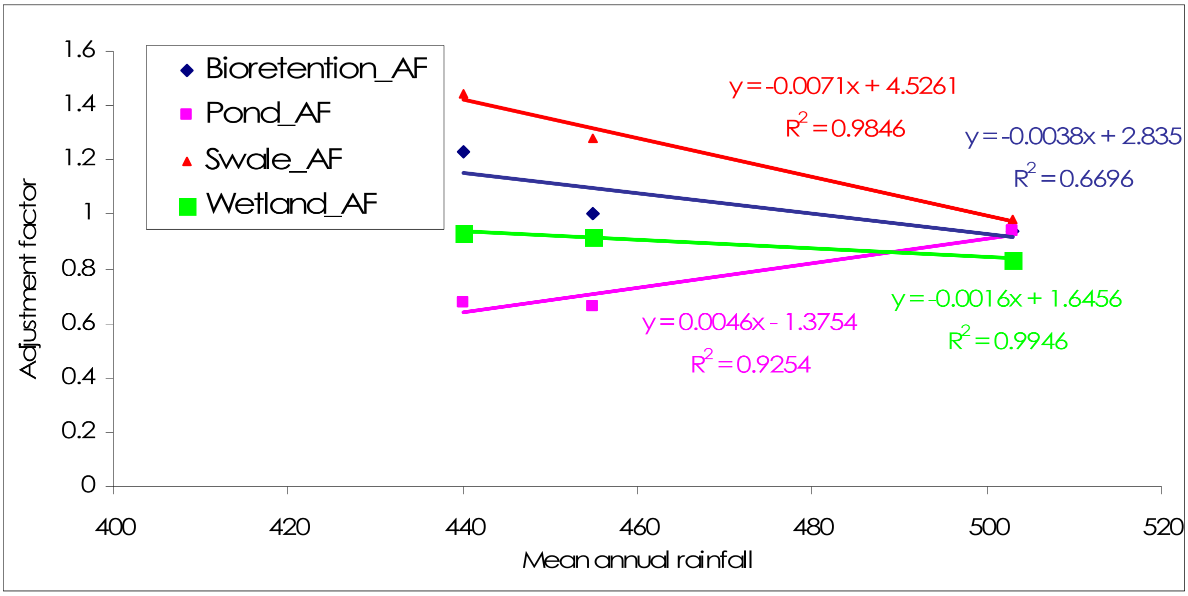

Figure A-6. Plot of *Adjustment Factor* Vs Mean Annual Rainfall (MAR) for the Midlands-east region

Equations to compute *Adjustment Factors* for each treatment system were obtained by plotting a linear trend (ie 'line of best fit') through for the points on the chart above for each treatment system. A trend of decreasing *Adjustment Factor* with mean annual rainfall is evident for swales, bioretention and wetlands while adjustment factor increases with MAR for ponds. This may be due to higher intensity rainfall in areas with lower total annual rainfall.

The Midlands-east *Adjustment Factor* equations are shown in the table below.

	Midlands-east
Bioretention	-0.0038(MAR)+2.835
Pond	0.0046(MAR)-1.3754
Swale	-0.0071(MAR)+4.5261
Wetland	-0.0016(MAR)+1.6456

Region: Midlands-west

Figure A.9 shows a plot of the *Adjustment Factor*s for bioretention, swales, ponds and wetlands derived against mean annual rainfall for the 'Midlands-west' Hydrologic Region.

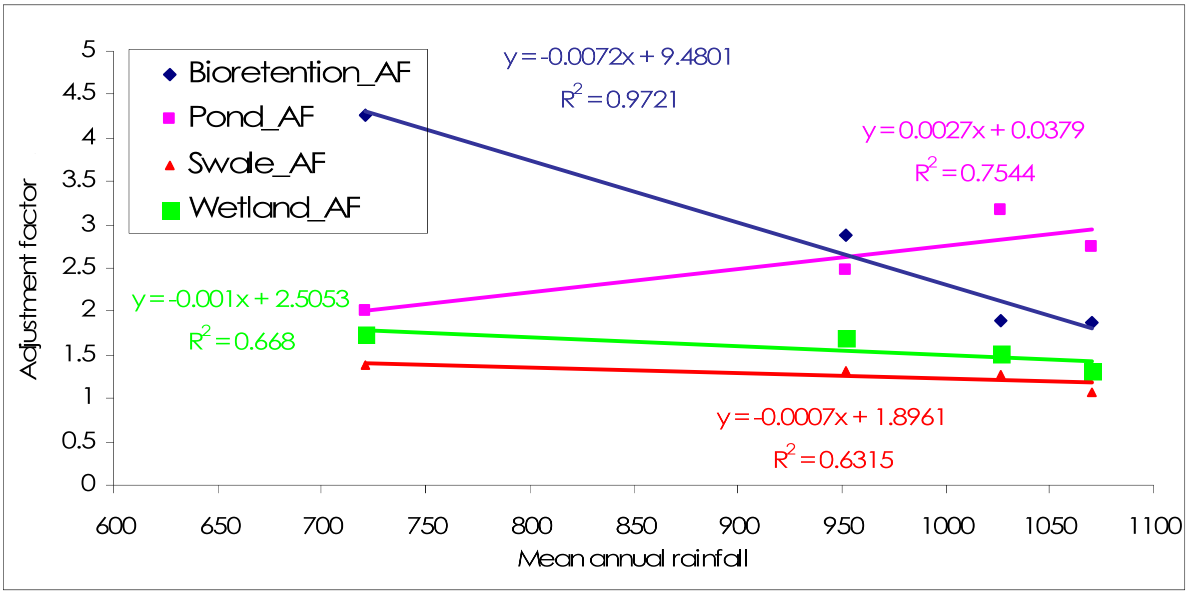

Figure A-7. Plot of *Adjustment Factor* Vs Mean Annual Rainfall (MAR) for the Midlands-west region

Equations to compute *Adjustment Factors* for each treatment system were obtained by plotting a linear trend (ie 'line of best fit') through for the points on the chart above for each treatment system.

A trend of decreasing *Adjustment Factor* with mean annual rainfall is evident for swales, bioretention and wetlands while adjustment factor increases with MAR for ponds. This may be due to higher intensity rainfall in areas with lower total annual rainfall.

The Midlands-west *Adjustment Factor* equations are shown in the table below.

	Midlands-west
Bioretention	-0.0072(MAR)+9.4801
Pond	0.0027(MAR)+0.0379
Swale	-0.0007(MAR)+1.8961
Wetland	-0.001(MAR)+2.5053

Region: Hobart

Figure A.10 shows a plot of the *Adjustment Factor*s for bioretention, swales, ponds and wetlands derived against mean annual rainfall for the 'Hobart' Hydrologic Region. A trend of increasing *Adjustment Factor* with mean annual rainfall is evident for each of the system types.

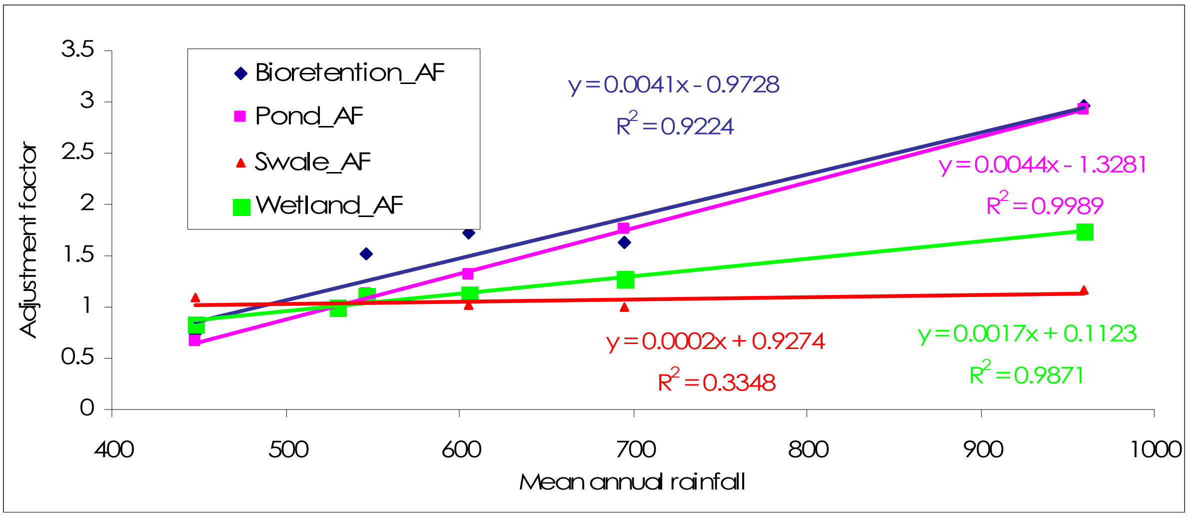

Figure A-8. Plot of *Adjustment Factor* Vs Mean Annual Rainfall (MAR) for the Hobart region

Equations to compute *Adjustment Factors* for each treatment system were obtained by plotting a linear trend (ie 'line of best fit') through for the points on the chart above for each treatment system.

Whilst the coefficient of determination for the swale relationship is lower than others, the lesser slope (m) on the linear curve indicates lower variation in adjustment factor between sites modelled and hence impact of the weaker correlation is not significant.

The Hobart *Adjustment Factor* equations are shown in the table below.

	Hobart
Bioretention	0.0041(MAR)-0.9728
Pond	0.0044(MAR)-1.3281
Swale	0.0002(MAR)+0.9274
Wetland	0.0017(MAR)+0.1123

Adjustment factor verification

In order to verify the predictive ability of the adjustment factor relationships presented above, observed adjustment factors (from the MUSIC modelling exercise) are plotted against adjustment factors calculated using the equations above for each climate station used.

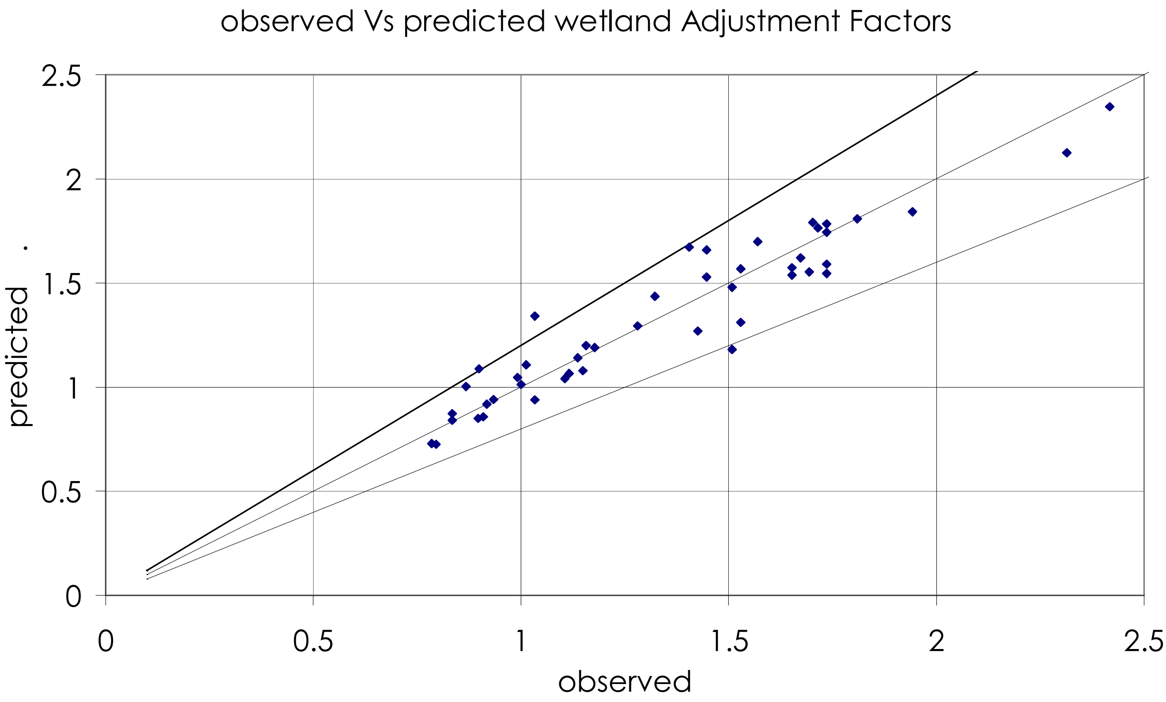

Figure A-9. Observed Vs predicted adjustment factors for wetland systems

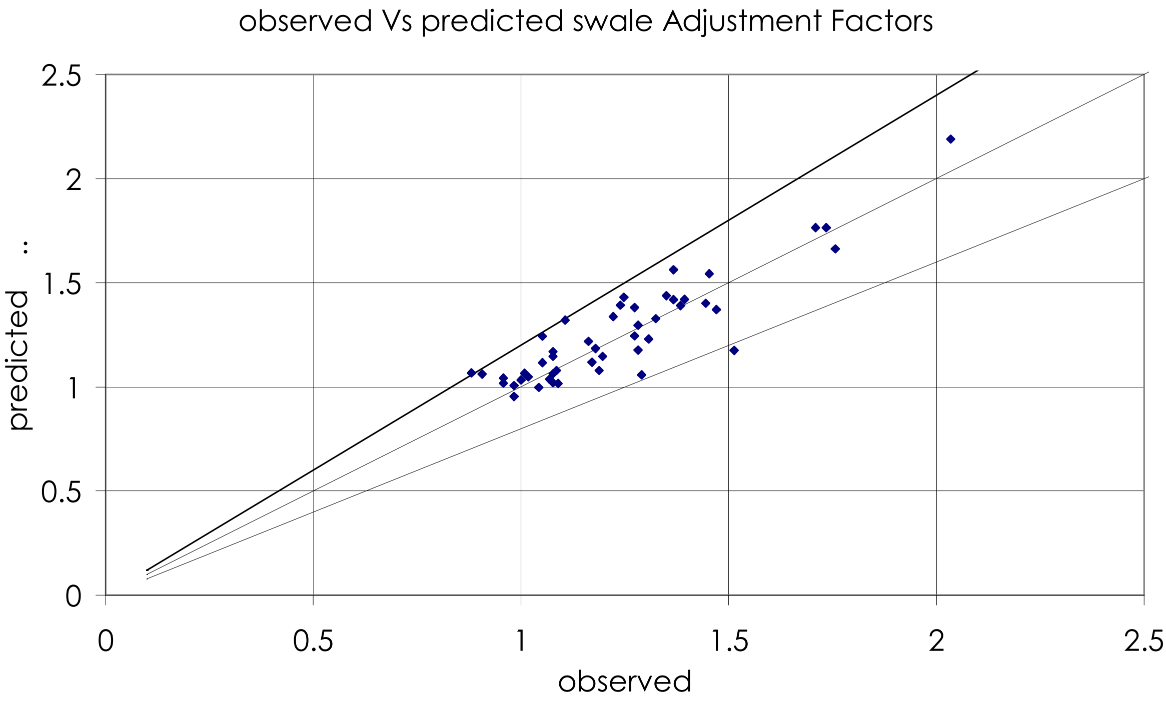

Figure A-10. Observed Vs predicted adjustment factors for grassed swales

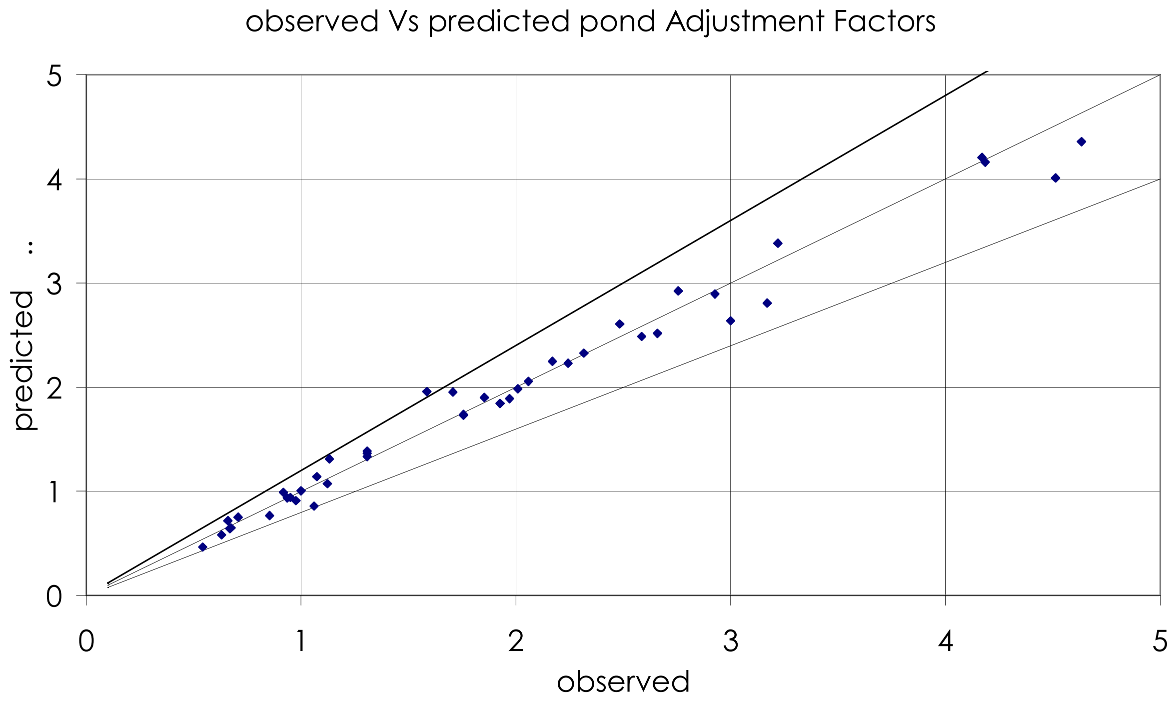

Figure A-11. Observed Vs predicted adjustment factors for ponds

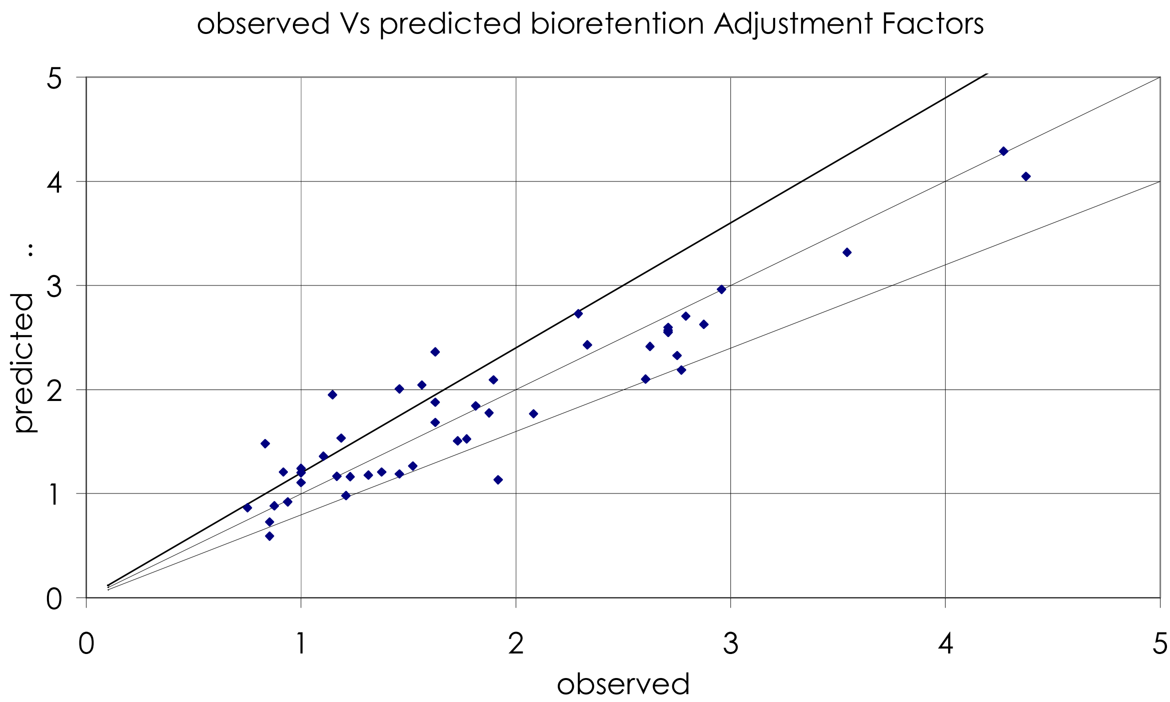

Figure A-12. Observed Vs predicted adjustment factors for bioretention systems

A.5 Adjustment factors for reference rainfall stations

The regional equations and constants for computing *Adjustments Factors* are the result of pooling modelling results for relevant reference pluviographic stations within each hydrologic region. To ensure a systematic application of the procedure, it is recommended that computation of *Adjustment Factors* should exclusively use the regional equations or constants provided instead of individually derived Adjustment Factor values, irrespective of the proximity of the site in question to a reference pluviographic station. This would avoid situations where practitioners get to choose between the adjustment factor computed from the regional approach and that derived for the reference pluviographic station of close proximity to the site in question.

If the option for practitioners to use *Adjustment Factors* derived for individual reference pluviographic stations is to be provided, a consistent approach to define the areal extent of applicability of *Adjustment Factors* derived for individual pluviographic station will need to be developed. This areal extent of applicability for individual reference pluviographic station may vary depending on its proximity to other pluviographic stations and will more than likely be determined in an ad-hoc manner. Furthermore, this option could also introduce debate amongst practitioners about the selection of reference pluviographic stations for the present analysis ahead of others which may be of "more relevant" to their particular sites.

It is recommended that only regional relationships for Adjustment factors be used in WSUD Engineering Procedures for Stormwater Management in Tasmania.

13.6.1 A.6 Recommended Adjustment Factors

The plots comparing the predicted *Adjustment Factors* to those determined from MUSIC modelling indicate that the regional equations and constants derived for the eight hydrologic regions mostly fall within a $\pm$20% band. It is thus reasonable to adopt Adjustment Factor that is 1.1 times (ie. +10%) that predicted by these equations and constants to ensure that predicted size of stormwater treatment measures using this method will not be an under-estimation of what is required. This preserves the opportunity (and incentive) for practitioners to adopt a more rigorous approach (e.g. MUSIC modelling using local rainfall data) to further refine and reduce the size of treatment measures being considered if they so desire. The recommended equations and constants (including + 10% adjustment) for computing the appropriate *Adjustment Factors* for Tasmania are summarised in Table A.1.

Table A.1. Tasmania Adjustment Factors

	Bioretention	Pond	Swale	Wetland
East-central	0.0053(MAR)-1.2818	0.0031(MAR)-0.5156	0.0004(MAR)+0.8559	0.0024(MAR)-0.1239
Hobart	0.0041(MAR)-0.9728	0.0044(MAR)-1.3281	0.0002(MAR)+0.9274	0.0017(MAR)+0.1123
Midlands-east	-0.0038(MAR)+2.835	0.0046(MAR)-1.3754	-0.0071(MAR)+4.5261	-0.0016(MAR)+1.6456
Midlands-west	-0.0072(MAR)+9.4801	0.0027(MAR)+0.0379	-0.0007(MAR)+1.8961	-0.001(MAR)+2.5053
North	0.0016(MAR)+0.3281	0.0033(MAR)-0.7432	0.0005(MAR)+0.794	0.0006(MAR)+0.5906
Northeast	0.0034(MAR)-0.8879	0.003(MAR)-0.4068	0.0005(MAR)+0.9196	0.0012(MAR)+0.5645
Southeast	0.0025(MAR)-0.1253	0.003(MAR)-0.562	0.00003(MAR)+1.0481	0.0012(MAR)+0.3184
West	0.0009(MAR)+0.4632	0.0029(MAR)-0.4404	0.0005(MAR)+0.6041	0.0007(MAR)+0.5005