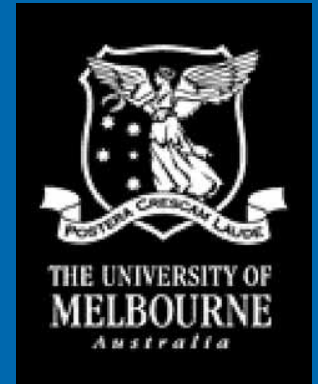


Australian
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***Protocols for the optimal
measurement and estimation of
nutrient loads
in the
Goulburn-Broken Catchment***

***Dr Teri Etchells
Prof David Fox
KS Tan***

Many potential estimation techniques exist ... which one is best?

*Scaled
average flow
x average
concentration*

$$Load = \int_{t_0}^{t_1} Q(t)C(t)dt$$

*Beale ratio
estimator*

*Simple ratio
estimator*

*Scaled
average load*

*Flow weighted
concentration
method*

*Linear
interpolation of
concentration
data*

*Flow-stratified
sampling*

Source: Adapted from Letcher, Jakeman, Merritt, McKee, Eyre and Baginska, 1999.
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Precision is reduced due to a relative lack of water quality data

$$\text{Load} = \sum_{i=1}^n (\text{Flow}_i \times \text{Concentration}_i)$$

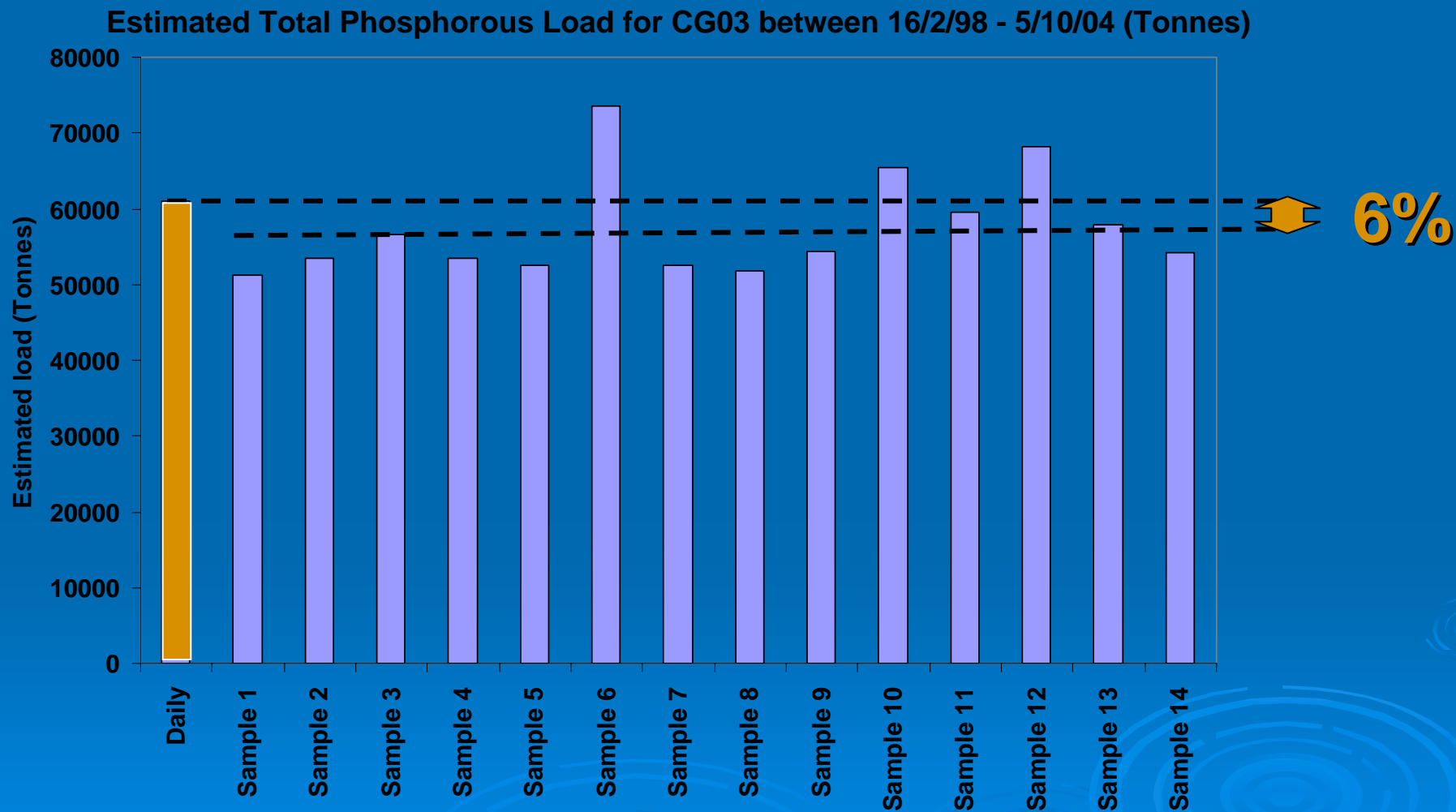


Daily Flows



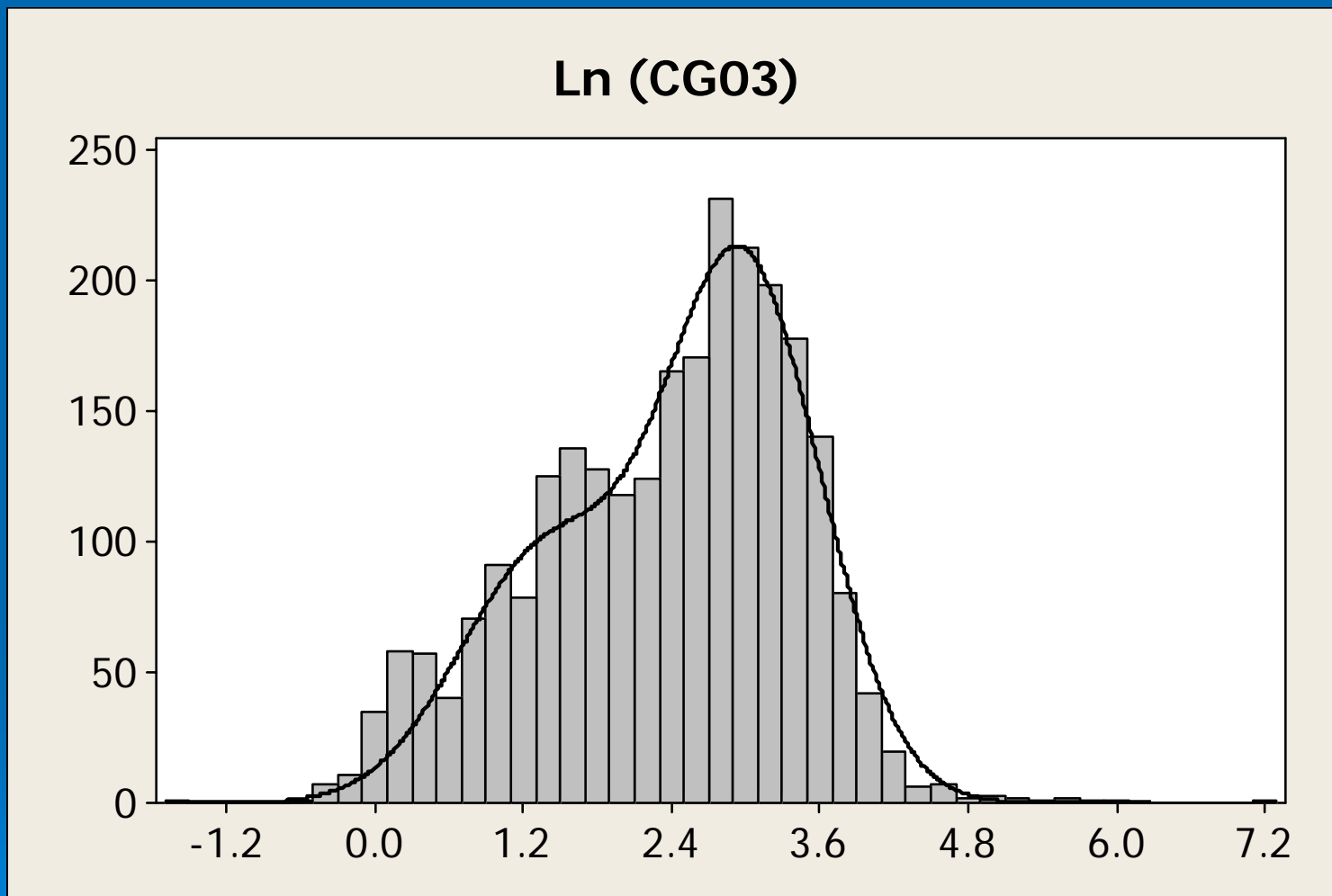
Fortnightly Sampling

Frequency of sampling can lead to significant bias in load estimates



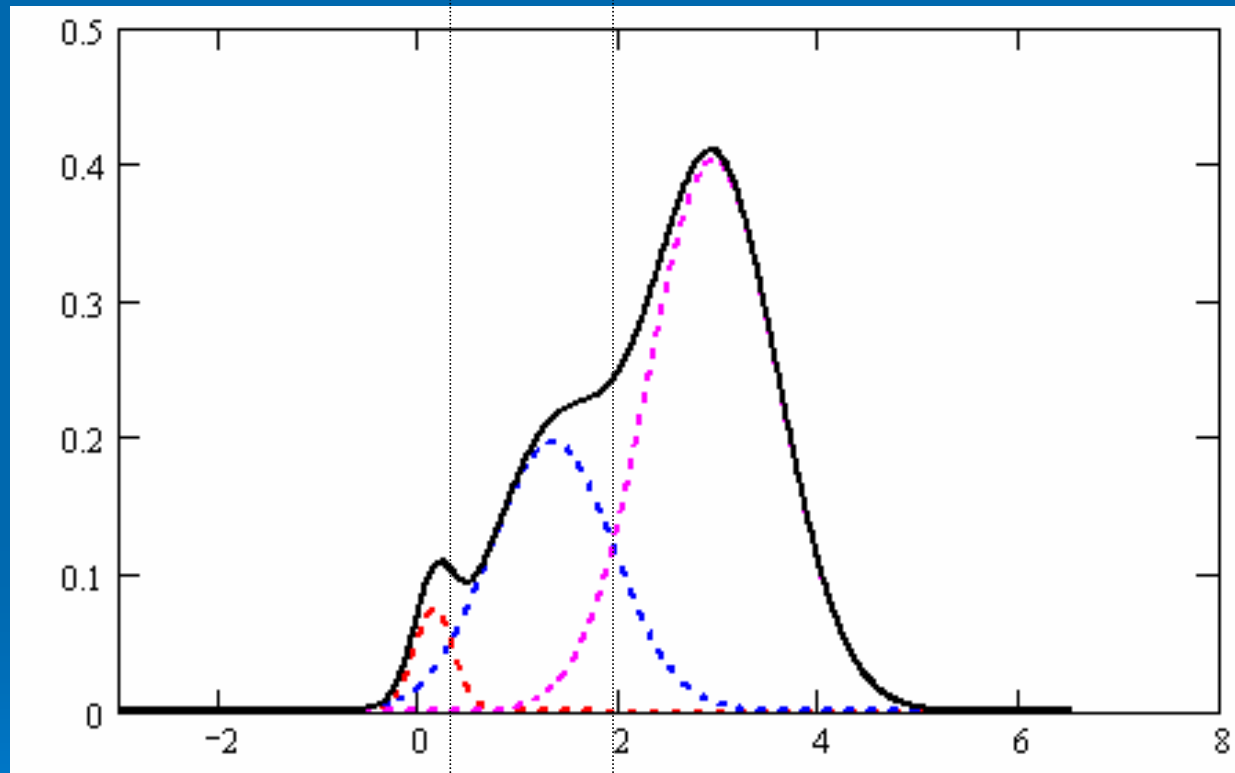
Source: Southern Rural Water

Example: Flow distribution for SRW site CG03 (I)



Flow distribution for SRW site CG03 comprises 3 main components

CG03 flows between 16/2/98 - 5/10/04



Dry / Baseflow

Irrigation
Flow

Storm or
Event Flow

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These distributions are described using a 3 component lognormal distribution

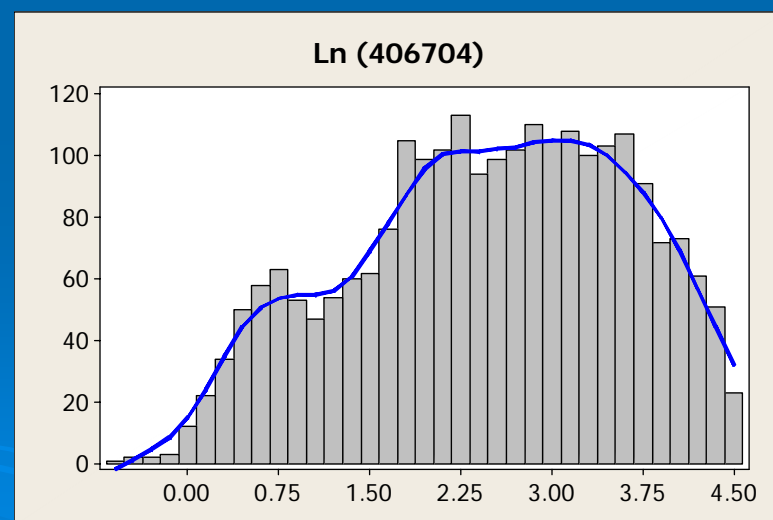
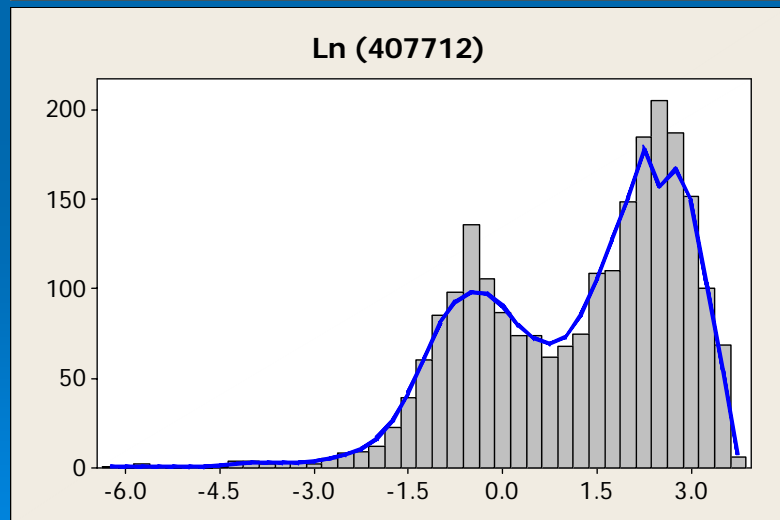
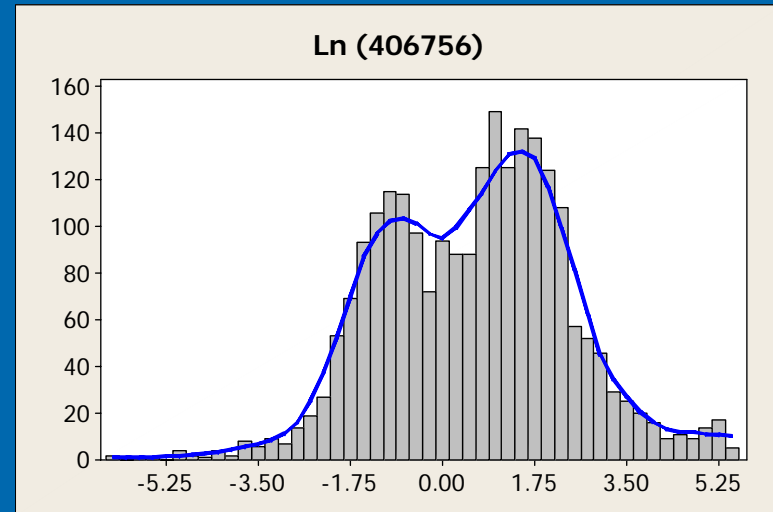
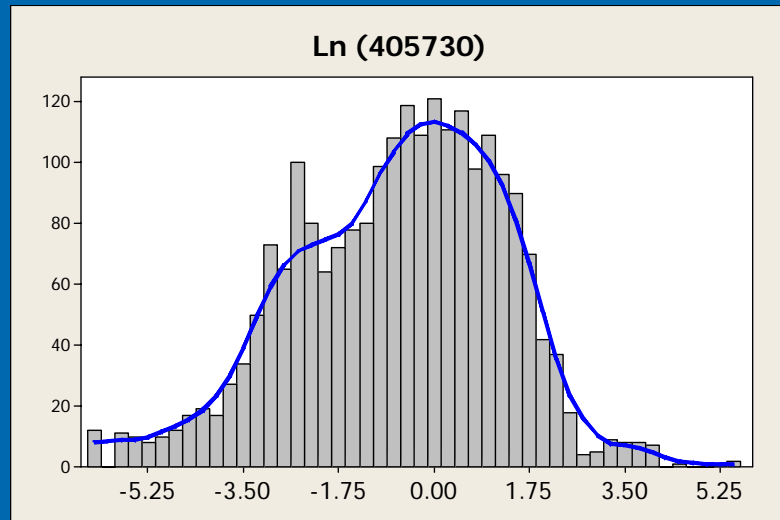
Distribution of Log Flows:

$$F = \lambda_1 \cdot N(\mu_1, \sigma_1) + \lambda_2 \cdot N(\mu_2, \sigma_2) + (1 - \lambda_1 - \lambda_2) N(\mu_3, \sigma_3)$$

Parameters estimated using Maximum Likelihood Estimator: Log Likelihood Function

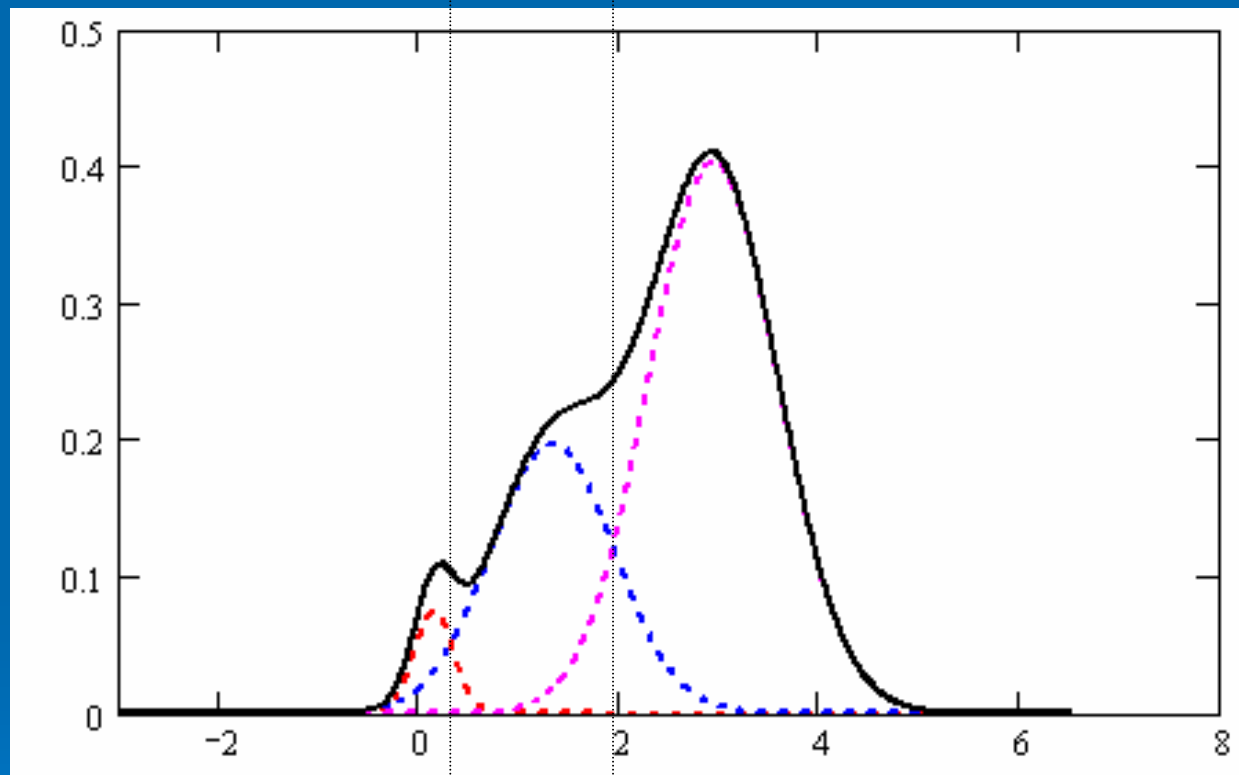
Two component distribution could also be appropriate

Flow Distributions for GMW



Concentration characteristics for SRW CG03

CG03 flows between 16/2/98 - 5/10/04



Mean TP Concentration =	1.11	0.79	1.26	<u>Overall</u>
SD =	2.59	1.25	1.82	1.74

Sampling effort is not aligned with load contribution

CG03 concentrations between 16/2/98 - 5/10/04

	<u>Base</u>	<u>Irrigation</u>	<u>Storm</u>	<u>Overall</u>
Mean	1.11	0.79	1.26	1.12
SD	2.59	1.25	1.82	1.74
# Samples	127	678	1620	2424
Sampling effort	5%	28%	67%	
%Load	0%	3%	96%	

Other segmentations of flow for SRW site CG03 could potentially inform estimates (III)

	<u>Average Contribution to Annual Load (%)</u>	<u>Standard Deviation of Contribution (%)</u>
Summer	37%	11%
Autumn	28%	11%
Winter	6%	4%
Spring	29%	18%

Also ... potential for divisions according to rising and falling limbs

Where to from here: Improving estimates using bias correction

Example: CG03

	True Load (Tonnes)	Naïve estimate (Tonnes)	Bias corrected estimate (Tonnes)
Annual Load	9 826	8 940	9 859
Error		- 9.0%	+ 0.3%

Source: Fox, 2004

Where to from here: Improving sampling using optimal allocation

Optimal allocation can be flow based or load based:

- Allocation will skew sampling to flows with highest loads

Objective is to remove bias in estimates

Optimal allocation will inform probabilistic sampling

Summary

Estimates of nutrient loads need to be accurate to inform management decisions

Significant uncertainties exist in load estimates

- **Wide choice of load estimation procedures**
- **Potential for bias in estimates**

Segmentation of flows can help improve load estimates by informing:

- **Bias correction factors**
- **Optimal allocation of sampling effort**