The Rotorua P-Project

Summary for the Lake Rotorua Stake Holder Advisory Group

Attenuating nutrient and sediment loss from pastoral farmland during storm water runoff events

Prepared by John Paterson

Acknowlgements:
D Clarke, D Hamilton, J Abell, R Moore, M Scarsbrook, K Thompson, A Bruere, J Peryer-Fursdon, O Parsons.
18 DBs courtesy of Farmers:
J&C Paterson, N Saville-Wood, M Lealand, D Reeves, T&M Cairns, S Morrison, Waitetī Trust & M Scott, M Lane & Landcorp, P&G Schweizer, M&J Pudney

Water Quality Drivers

Water quality can be either nitrogen (N) limited or phosphorus (P) limited or limited by both.

Nutrient-loss from land use activities has two distinctly different transport processes:

- **N (leaching) and P (runoff)**
- **P-Project – focus on the P-loss sources and transport mechanism**
- **Runoff events during high intensity rainfall**

Ephemeral storm water flow

Pic courtesy of Mark and Sophie Dibley


Lots of water runs off during heavy rainfall
Pic courtesy of Daniel and Kim- Hauraki sub-catchment, Kaharoa


Sediment and nutrient highway
flow over usually dry paddocks

Why bother taming floodwater?

How much P delivered in storm water?

- Sampling of streams during floods (NIWA 2008)
- Sum of P-load of storm sampled permanent streams = 9.6T
- 25% of the catchment only has no permanent streams (not sampled)
- Storms deliver > 12 T P per year - in just a few events per year

How can we intercept this load of P in storm water?

- Key to influencing P in storm loads is not at the lake edge
- Manage near the source rather than near the destination
- On-farm ephemerals, where runoff is first apparent.

The challenge

- Best suited sites for detaining storm water are in the upper catchments
- Usually the best paddocks on the farm!
- Who would want to detain flood water on their best paddocks?

P-Project Objectives and Outputs

Objective

- **to identify and implement practical, durable and cost effective pastoral-based P mitigation in the Lake Rotorua catchment over five years**

Outputs

- **Desk-top analysis report on P-mitigation opportunities**
- **Funding criteria and mitigation approval process**
- **Stakeholder meetings with sub-catchment groups and one-to one landowner liaison**
- **Multiple landowner agreements and physical mitigation implementation with up to 5 structures completed in Year 1**
- **Annual progress reports, including estimates of P mitigation efficacy individually and collectively (as science permits)**

1st Task – What are the P-mitigation opportunities?

A train of P-loss Prevention and Mitigation tools
Cost / Benefit Summary

Table 2. Summary of efficacy and cost of P mitigation strategies

Strategy		Effectiveness (%)	Cost (NZD $/kg P conserved)
Optimum soil test P	management	5-20[1]	highly cost-effective[1]
Low solubility P fertilizer	management	0-20	0-30
Stream fencing	management	10-30	5-65
Greater effluent pond storage	management	10-30	30
Low rate effluent application to land	management	10-30	45
Tile drain amendments	amendment	50	25-100
Restricted grazing of cropland	amendment	30-50	150-250
Alum to pasture	amendment	5-30	150->500
Alum to grazed cropland	amendment	30	160-260
Grass buffer strips	edge of field	0-20	>250
Sorbents in and near streams	edge of field	20	350
Retention dams / water recycling[2]	edge of field	10-80	>500
Constructed wetlands[3]	edge of field	-426-77	>500
Natural seepage wetlands[3]	edge of field	<10%	>500

[1] depends on existing soil test P concentration, but no cost if already in excess of optimum.

[2] upper bound only applicable to retention dams combined with water recycling

[3] potential for wetlands to act as a source of P renders upper estimates for cost infinite.

From AgResearch
R. McDowell, 2010

Good Management Practices

- **GMPs – top of the list for both P-mitigation effectiveness and cost effectiveness**
- **An effective on-farm Environment Management System (EMS) can assure good uptake of GMPs**
- **Two NZ Ag Industrys have EMS type templates for managing the effective uptake of GMPs:**

❖ **DairyNZ – Sustainable Milk Plans (SMP)**

❖ **Beef + Lamb – Land and Environment Plans (LEP)**

Rotorua Soil Class		Soil Series Name	ASC	Topsoil bulk density (g/cm³)	Topsoil Clay content	Dairy Optimal Range Olsen P	Drystock Economic Range Olsen P*
Pumice						40 – 45 (35-40 Steeper) (DG 35-40)*	15 – 30 (DG 25 – 30)*
Typic Orthic Pumice Soils	Ot OtH	Oturoa sand Oturoa hill soils	87%	1.18 g/cm³	2 – 6%		
Typic Orthic Pumice Soils	Or	Oropi Oropi hill soils	51%	1.18 g/cm³	5 – 10%		
Typic Orthic Pumice Soils	Rt RtH	Rotoiti	51%	1.18 g/cm³	3 - 8%		
Immature Orthic Pumice Soils	Wh	Whakarewarewa	51%	0.91 g/cm³	10 – 15%		
Podzols						40 – 45 (35-40 Steeper) (DG 30-40)*	15 – 30 (DG 20 – 30)*
Humose Orthic Podzols	No	Ngongotaha loamy sand Ngongotaha hill soils	42%	1.18 g/cm³	5 – 10% 15 – 20%		
Typic Orthic Podzols	W	Waiteti loamy sand Waiteti hill soils	42%	1.18 g/cm³	5 - 10% 10 – 15%		
Humic Orthic Podzols	Mg	Mangowera sandy loam	42%	1.09 g/cm³	10 – 15%		
Typic Orthic Allophanic	Na NaH	Ngakuru sandy loam Ngakuru hill soils	83%	0.78 g/cm³	10 – 18%		
Organic						40 – 45 (DG 35 - 45)*	15 - 30 (DG 25 – 35)*
Mellow Humic Organic Soils	Ut	Utuhina peaty loam	62%	0.18 g/cm³	5 – 10%		
Recent						40 – 45 (35-40 steeper) (DG 30 – 40)*	15 – 30 (DG 20-30)*
Typic Tephric Recent Soils	R	Rotomahana R sandy loam R silt loam	32%	1.09 g/cm³	10 – 20% 20 -25%		
Mottled Tephric Recent Soils	Wa	Waiowhiro	32%	1.18 g/cm³	2 – 5%		
	OkS	Okareka	32%		20 – 30%		

Table from Edmeades et. al. 2006 NZ Journal of Agricultural Research, 2006 Vol. 49: 207-222

Table 1 Estimated relative pasture production at Olsen P (0–75 mm, µg P cm^{-3} dried and sieved soil) levels of 25 and 50 and critical level required to achieve 97% maximum production, for the major soil groups in New Zealand (numbers in brackets are the confidence intervals ($P < 0.05$)).

Soil group	Relative pasture production		Critical level
	Olsen P 25	Olsen P 50	
Pumice	89 (88–91)	97 (95–98)	50 (43–61)
Volcanic	92 (88–94)	99 (98–100)	32 (27–38)
Peat[1]	95	99	40 (35–45)
Sedimentary	95 (93–97)	100	30 (26–32)
Recent soils	97 (96–98)	99 (98–100)	25 (20–30)
Podzols	96 (94–99)	100	25 (22–30)
Sands	100	100	12 (10–15)

Consensus on OlsenP ranges

Simplified Table

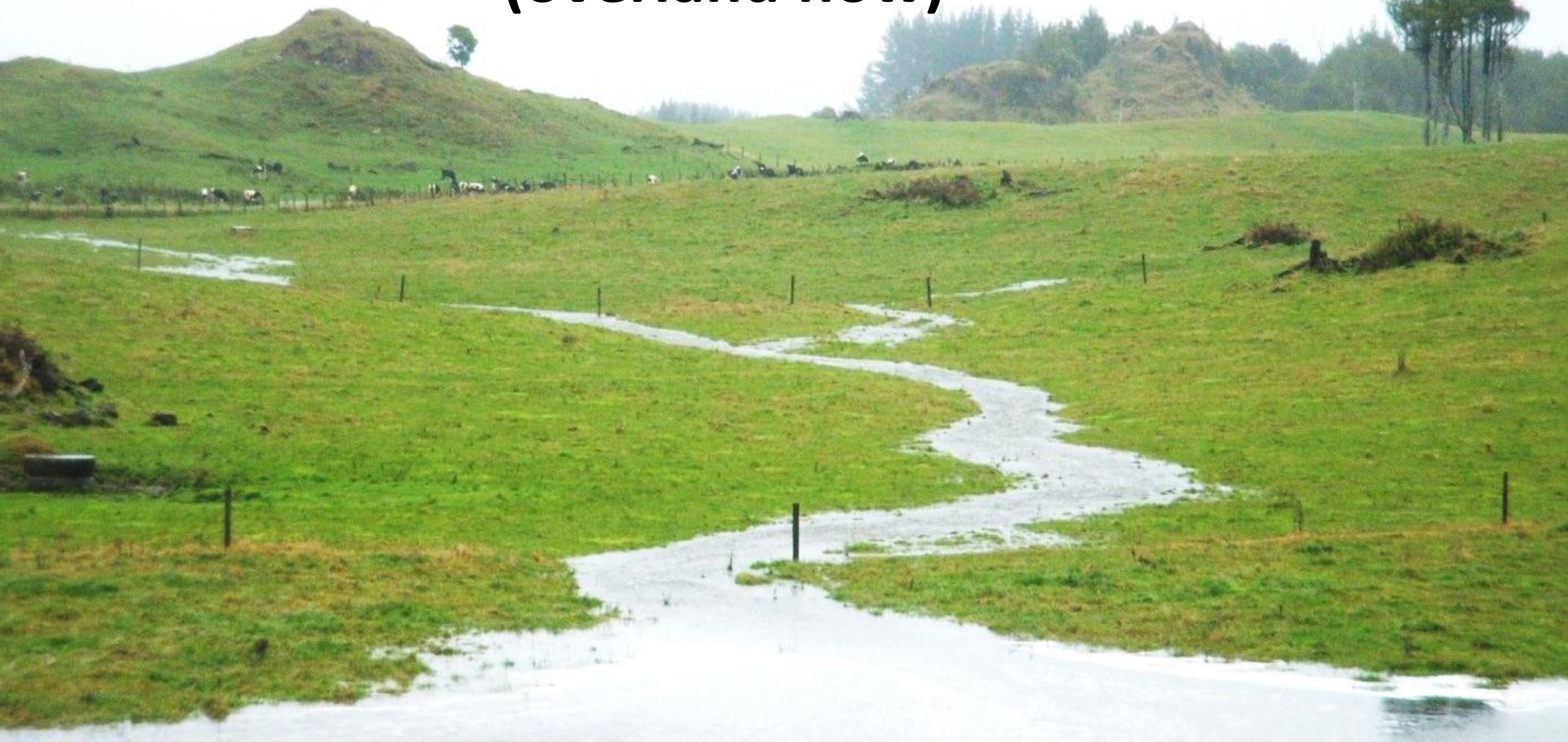
Soil Class:	Dairy Optimal Range (Olsen P)	Drystock Optimal Range (Olsen P)
Pumice, Podzols, Recent	40 – 45 steeper land 35- 40 (DG 30 – 45)*	15 – 30 (DG 20 – 35)*

Optimal OlsenP survey participants July 2010:

- agKowledge – V. Fulton, D. Edmeads
- Perron Ag Consultants – Lee Matheson
- AgFirst – Mark MacIntosh,
- Headway – Simon Park
- BOPRC - D Guinto, A. McCormack, S Stokes

* (DG) refers to results reviewed by Dani Guinto (DG), Soil Scientist BOPRC

Ephemeral streams
(overland flow)



The predominant pathway for P and sediment export from pastoral farmland to freshwaters

DBs on usually dry paddocks

Kaharoa 2012

Detention Dams - built in Rotorua since 1970's

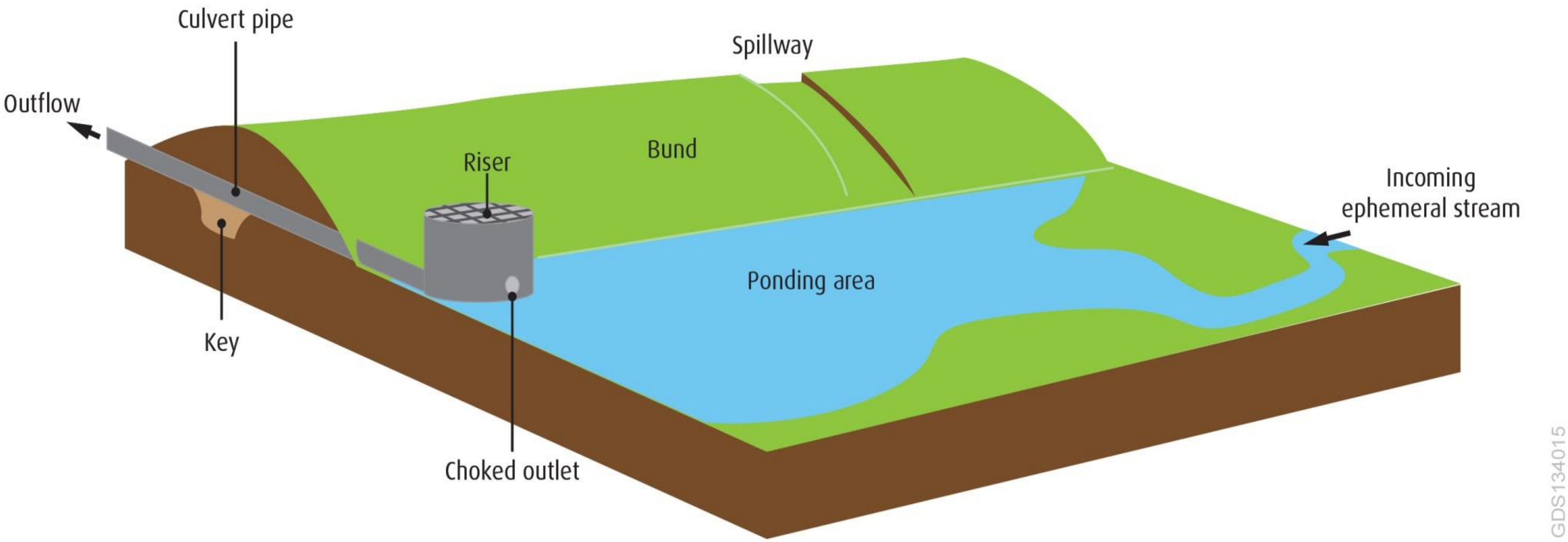
Detainment Bunds - very similar plus P-loss focus

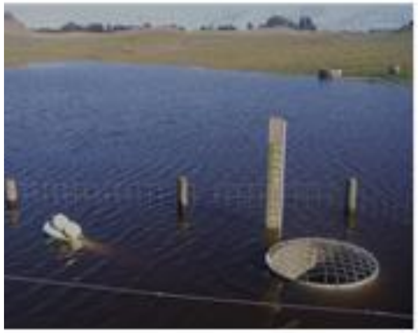
Detainment Bunds – Key Features

- An earth bund which ponds ephemeral stream water
- Aims to **control residence time** of storm water, specifically for P mitigation
- Storage capacity >120:1 (100 m^3 storage per hectare of catchment)
- Permitted activity (if under < 1.5m high and 10,000 m^3 storage, or under 2.5 m high and 5,000 m^3 storage) Rule 46.
- Ponding time – up to 3 days

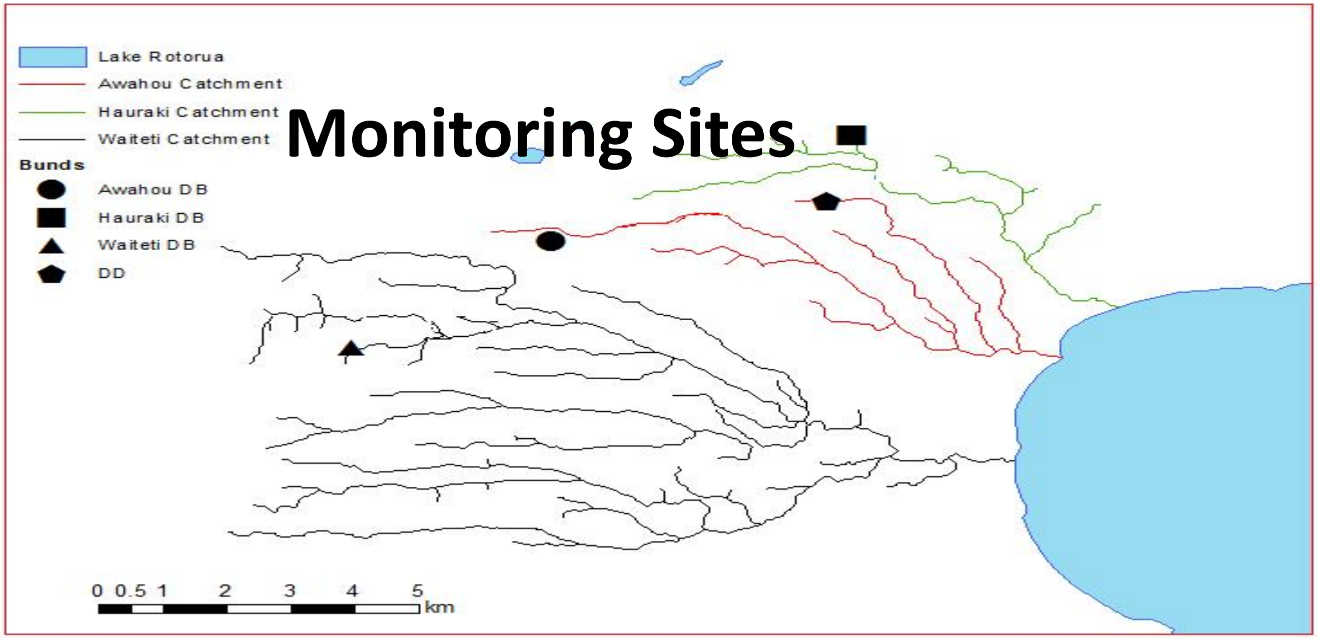
Bay of Plenty
REGIONAL COUNCIL

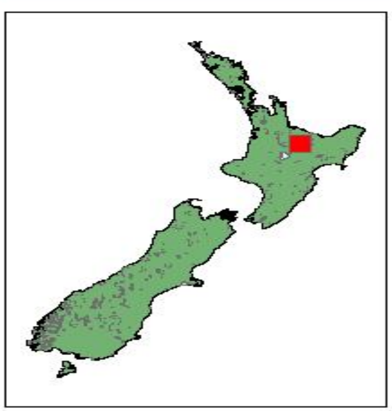
Detainment Bunds are a similar design with specific focus on retaining water for P-mitigation

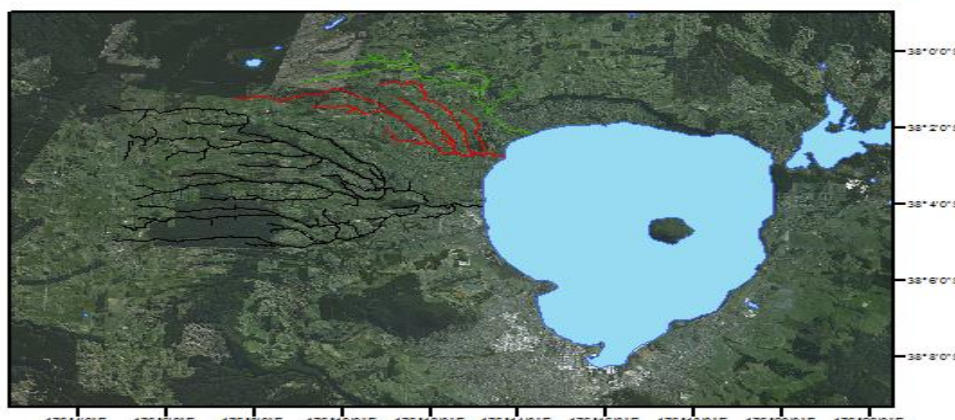




P-Project Trials: *The Performance of DBs*







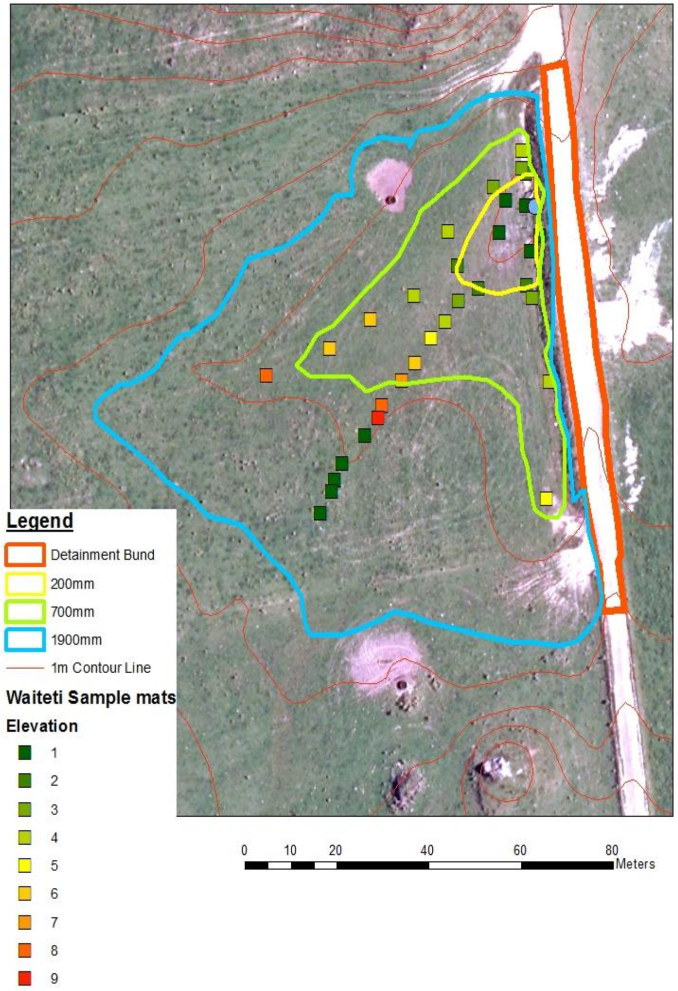
Methods

- ‘**Storm chasing**’ - collection of water samples during and after storm events from inflow ephemeral streams & outflows from the DBs

- **Sediment mats** - to catch sediment deposited in the DB ponding area

- **Forensic** - Soil samples taken from a historic detainment dam.

Sediment sampling



Results

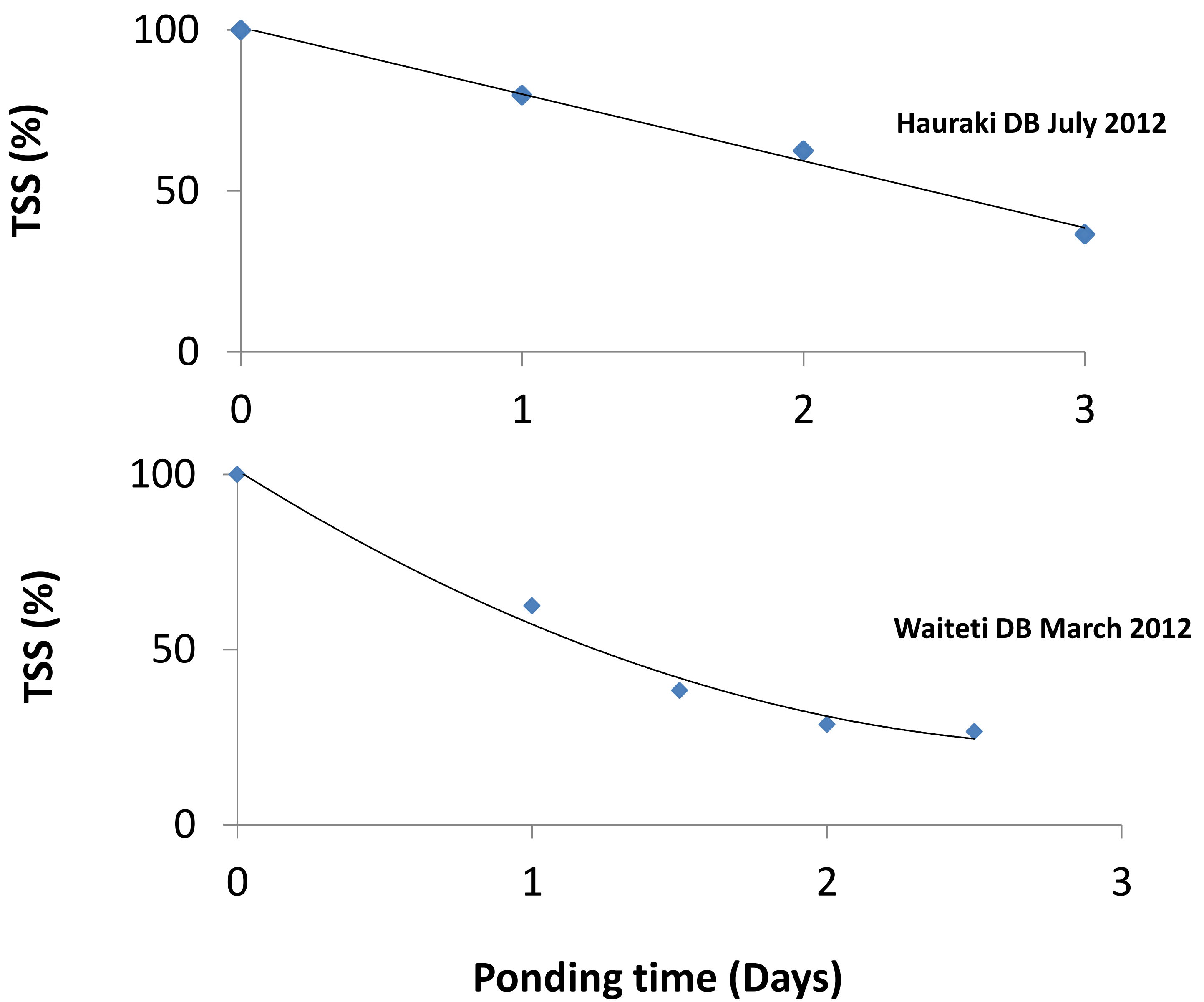
- What ran off depended on what was happening in the contributing catchment. Different for each event.

Total suspended sediment in outflow from DB

Day 1 **Day 2** **Day 3**

Hauraki DB, March, 2012

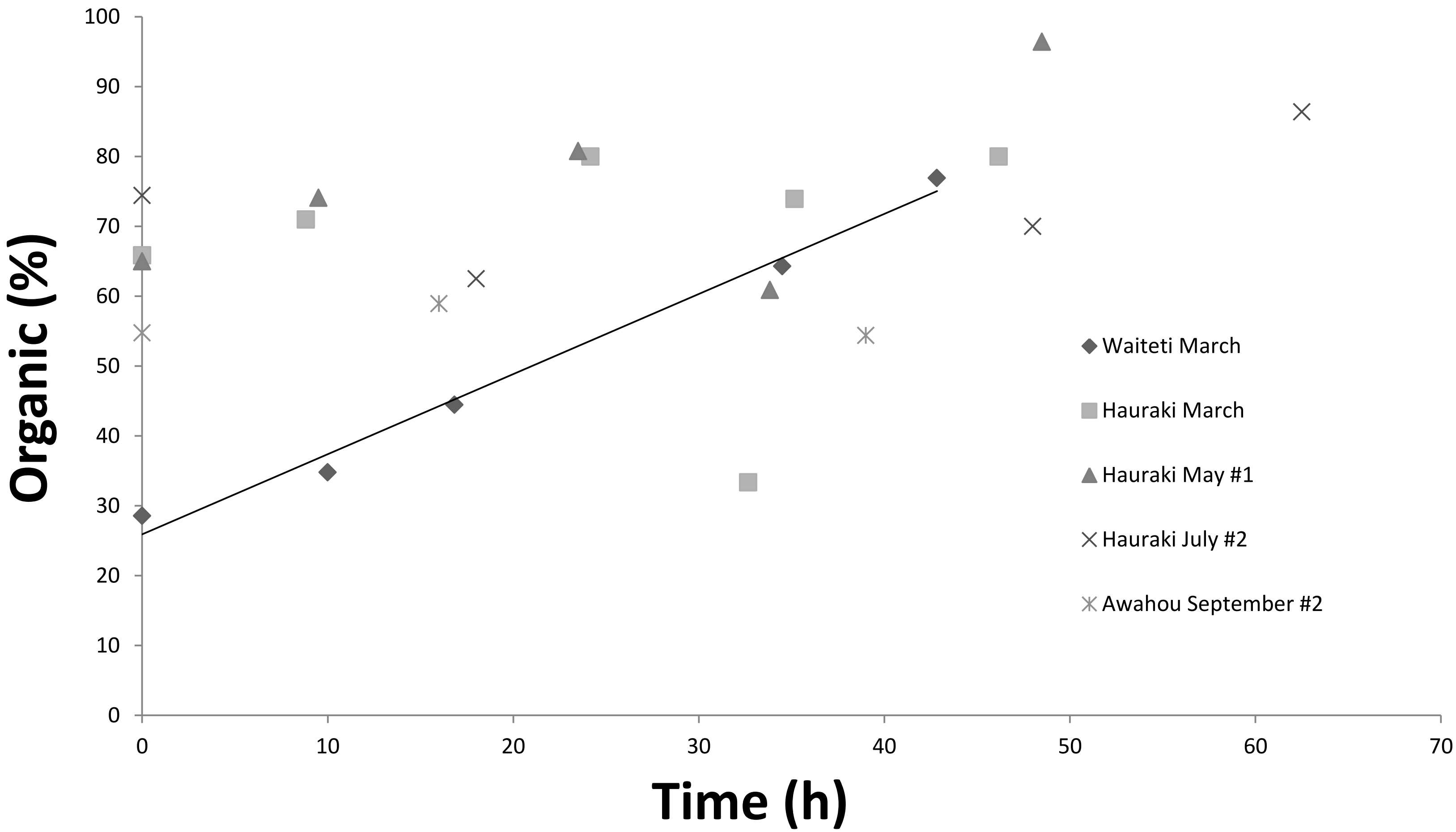
Total Suspended Sediment (TSS)



Particulate P (PP) in ponded water

- Variable trends in PP observed between sites/ events
  - up to 36% reduction over a 20 h ponding.
- PP settlement depends on the suspended sediment characteristics (size of particles, amount of suspended sediment, organic content).
- With high levels of suspended sediment (very dirty) – more dissolved P can attach onto particulates
- P can also desorb again on route downstream

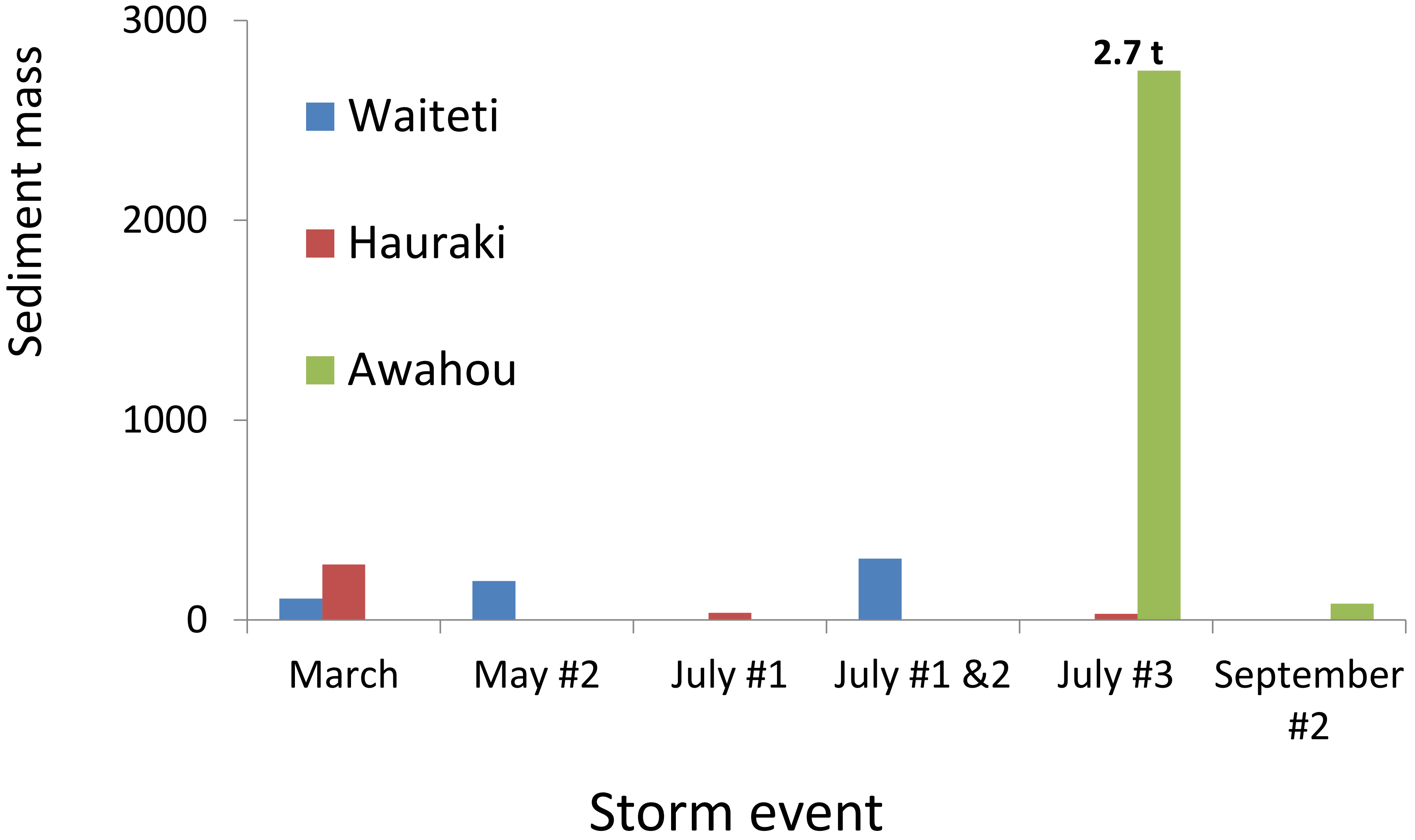
Organic material can stay suspended



<u>Particulate **N**</u>

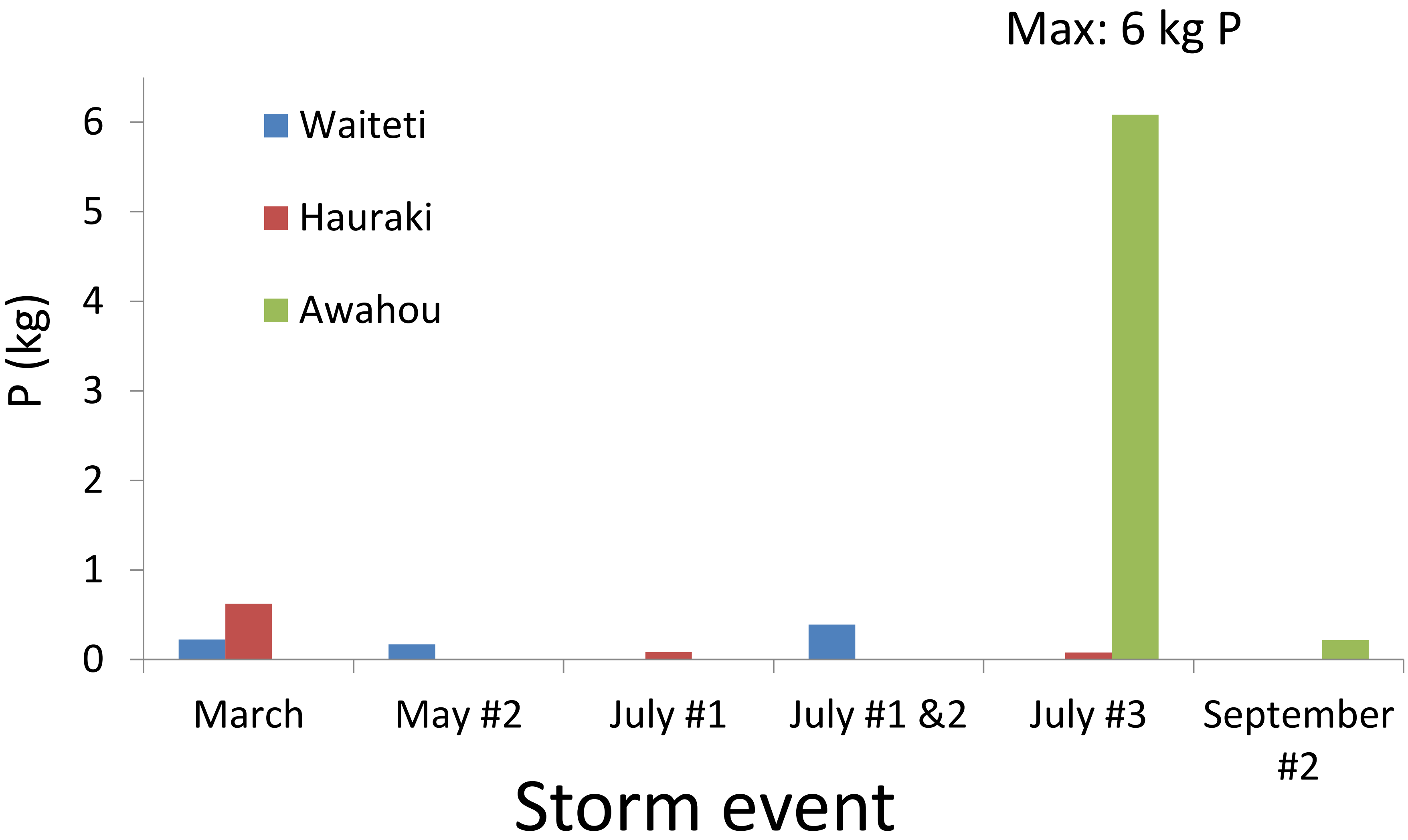
- In some cases, reductions in Particulate Nitrogen concentrations of outflow water were observed
- E.g. a 42% reduction in PN concentration over 20 hours
- Attributed to a recently grazed winter forage crop

Sediment deposited

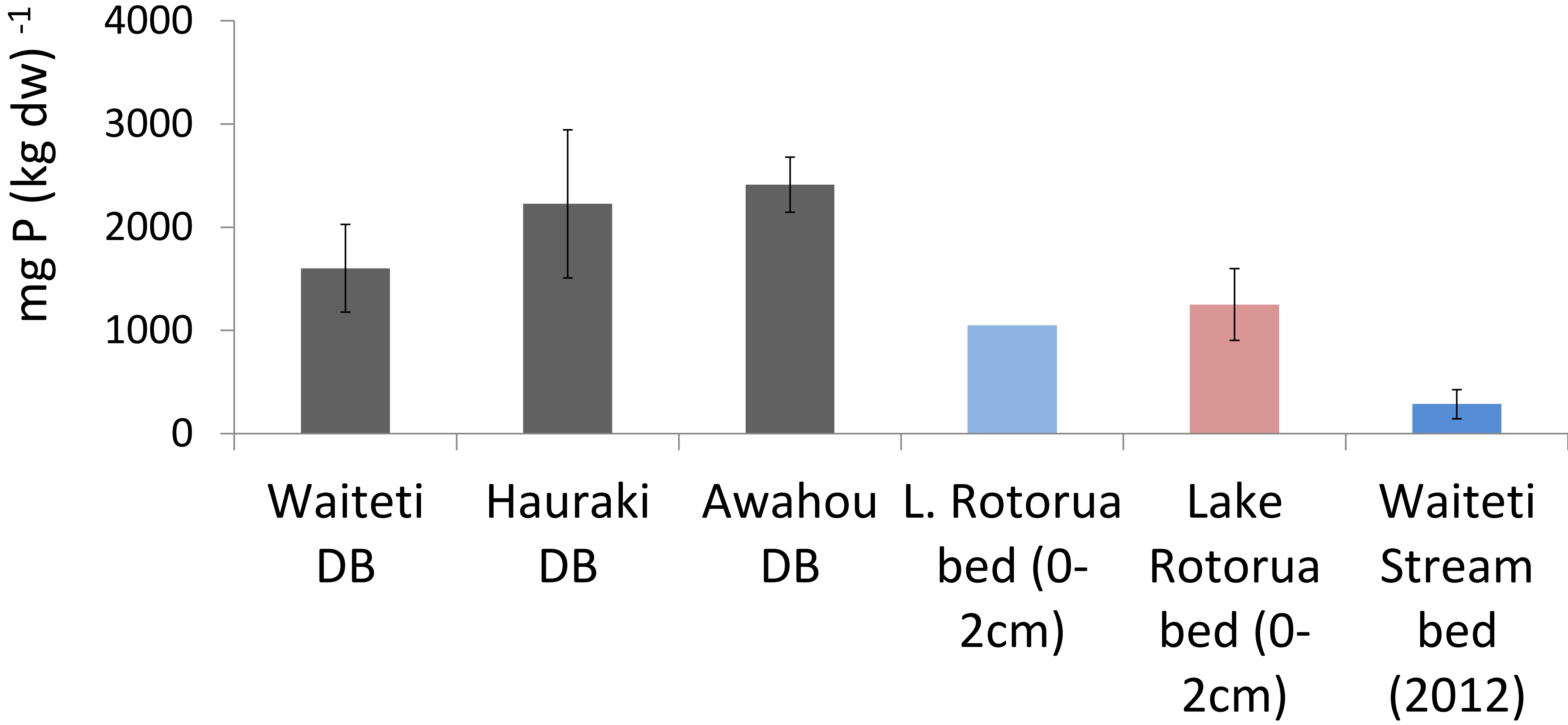


2.7 t sediment deposited extreme case

P retained


Max: 6 kg P
Waiteti
Hauraki
Awahou
P (kg)
0
1
2
3
4
5
6
March
May #2
July #1
July #1 &2
July #3
September #2
Storm event

P concentration of Sediment



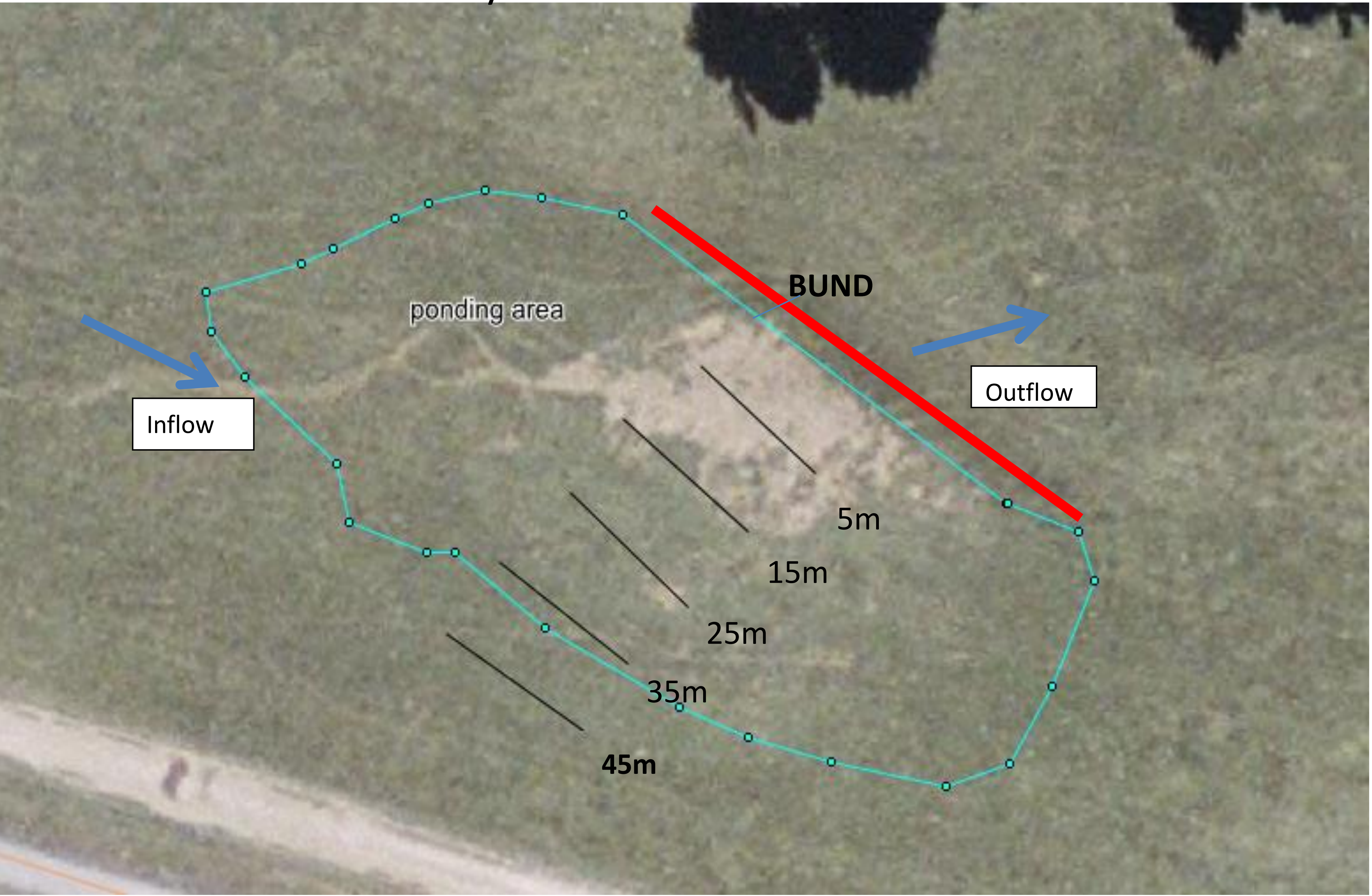
- P retained in the DBs higher than the lake bed
- Sediment captured would have desorbed P (Jamie Peryer-Fursdon)
- PP has potential to become bio-available (via desorption process)

DB Performance Data

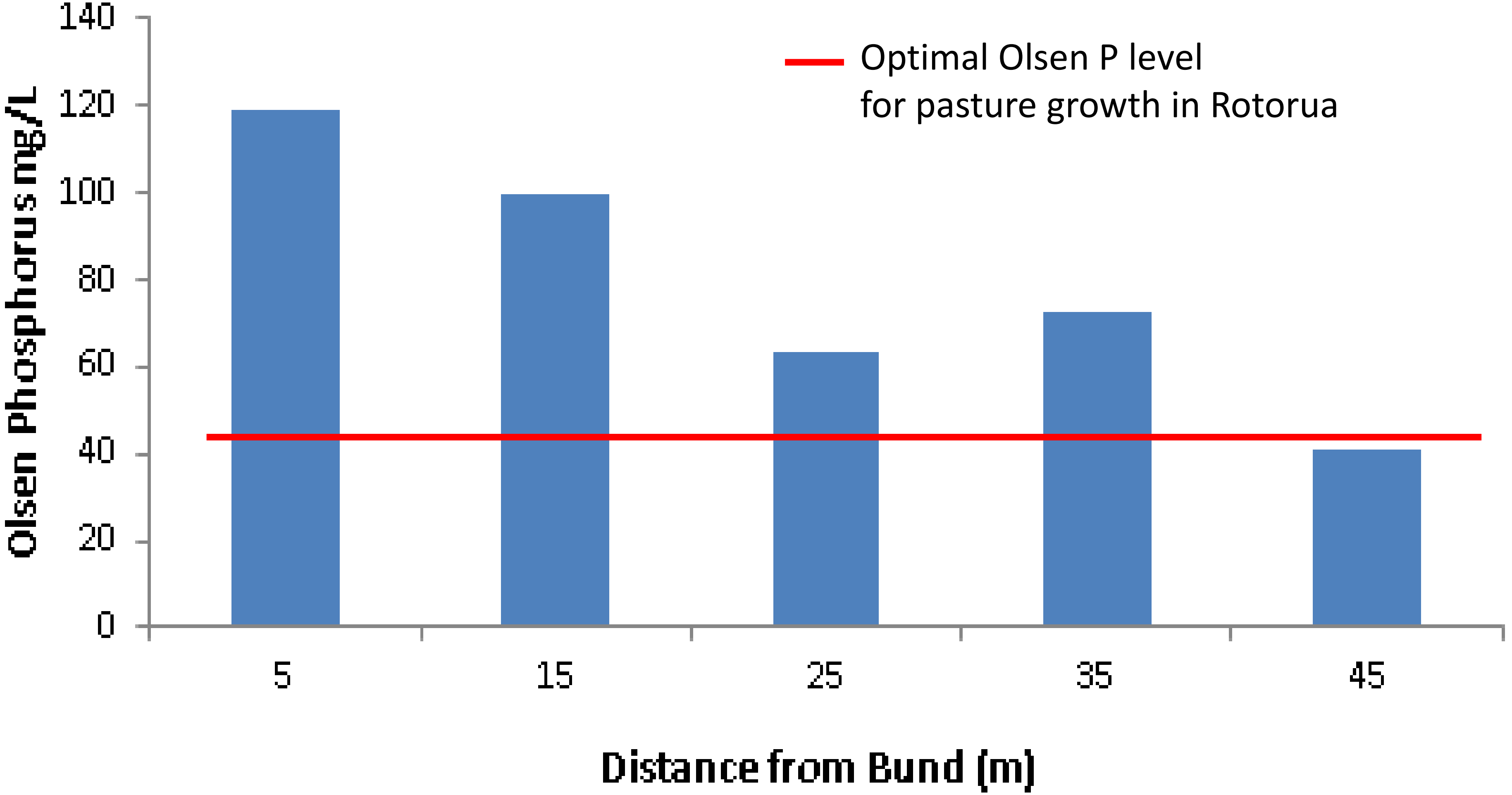
Month	DB Site (Sub catchment)	Sediment mass (kg)	Phosphorus deposited (kg)
March	Waitetī DB	107.0	0.22
March	Hauraki DB	278.0	0.62
May #2	Waitetī DB	195.4	0.17
July #1	Hauraki DB	35.3	0.08
July 1+2	Waitetī DB	306.7	0.39
July #3	Hauraki DB	30.3	0.08
July #3	Awahou DB →	2749.0	6.08
Sept. #2	Awahou DB	82.1	0.22
	Average	**473.0**	**0.98**
	Median	**151.2**	**0.22**
	Geometric Mean	**160.0**	**0.31**
		Sediment	**P**
	Estimated total deposited per year per DB Based on geometric mean and 5 events per year	**800.1**	**1.53**
	Total tons sediment for 16 DBs / yr	**12.8 Ton**	
	Total Kg P for 16 DBs / yr		**24.54**

FORENSIC soil samples

In a 12 year old Detainment Dam



Olsen P concentrations across a historic ponding area



- Indicates that DB basins are P sinks in the long term

Storm event capability

Storm	Storm event volume (m^3)			DB Exceedance Factor Volume of storm event : Capacity of DB		
	Waitetī	*Hauraki*	*Awahou*	*Waitetī*	*Hauraki*	*Awahou*
March	21442	16780	7178	4.7	3.1	2.2
May	27484	25833	9201	6.0	3.9	2.8
July #1	39810	31156	13328	8.7	5.7	4.0
July #2	63911	50017	21396	13.9	9.1	6.5
July #3	46302	36236	15501	10.1	6.6	4.7
Sept # 1	14812	11592	4959	3.2	2.1	1.5
Sept #2	11221	47585	3757	2.4	1.6	1.1
DB Capacity (to spillway; m^3)	4589.0	5469.0	3298.0	**DB Capacity (m^3): Catchment area (ha)** 67 : 1	101 : 1	157 :1

- Large volumes of water going through the DB’s.
- Better ratio DBs hold a better proportion of water.

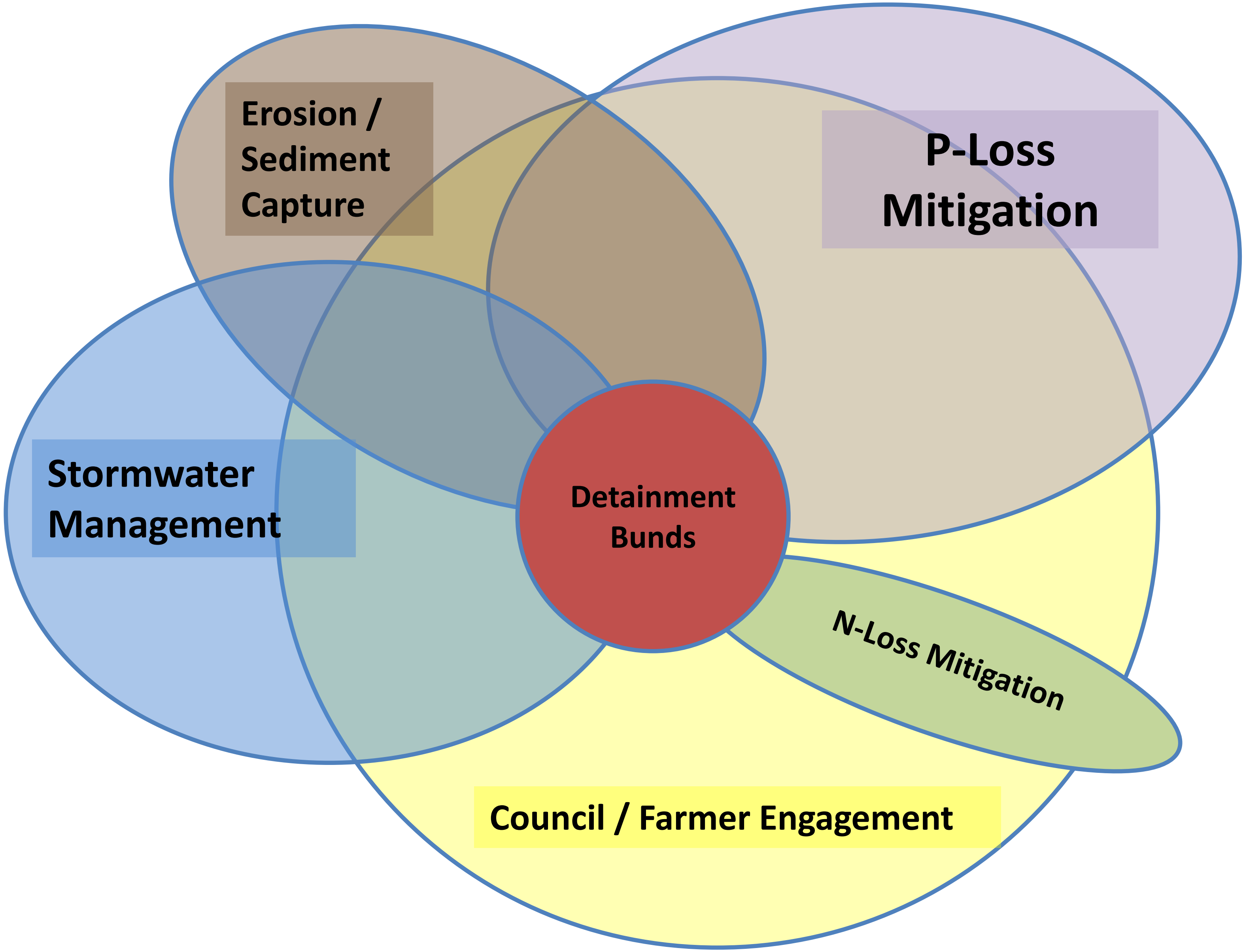
Integrating DBs into farm systems

- **We are building DBs on some of the best paddocks on the farm**
- **Aim to maintain the productive potential of the ponding area**

Optimal ponding time is a compromise between:

- maximising water treatment with long residency time
- maintaining pasture quality

The farmers are happy with up to 3 days inundation


Erosion / Sediment Capture
P-Loss Mitigation
Stormwater Management
Detainment Bunds
N-Loss Mitigation
Council / Farmer Engagement

Rotorua P-Project Summary

- DBs can be effectively used to reduce P loads to Lake Rotorua
- Numerous co-benefits
- 18 DBs Built in Rotorua Lakes catchments so far
- Whole sub-catchment treatments initiated:
  - Waimihia sub-catchment - 900ha / 39 proposed DBs
  - Rerewhakaaitu sub-catchment – 1600 ha GIS scoping completed
- DB user guidelines handbook drafted
- DBs are not a silver bullet – just one tool in the mitigation toolbox
- More quantitative research is needed on DB performance in different situations and soil types

Thanks again to the researchers and particularly the farmers for rising to the challenge of integrating DBs into their farming systems

Funding of the Rotorua P-Project:

- Bay of Plenty Regional Council
- DairyNZ
- University of Waikato
- New Zealand Transport Agency

Bay of Plenty REGIONAL COUNCIL

THE UNIVERSITY OF WAIKATO *Te Whare Wānanga o Waikato*

DairyNZ Profitability. Sustainability. Competitiveness.