Sampling road runoff to estimate loads of copper and zinc

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Outline

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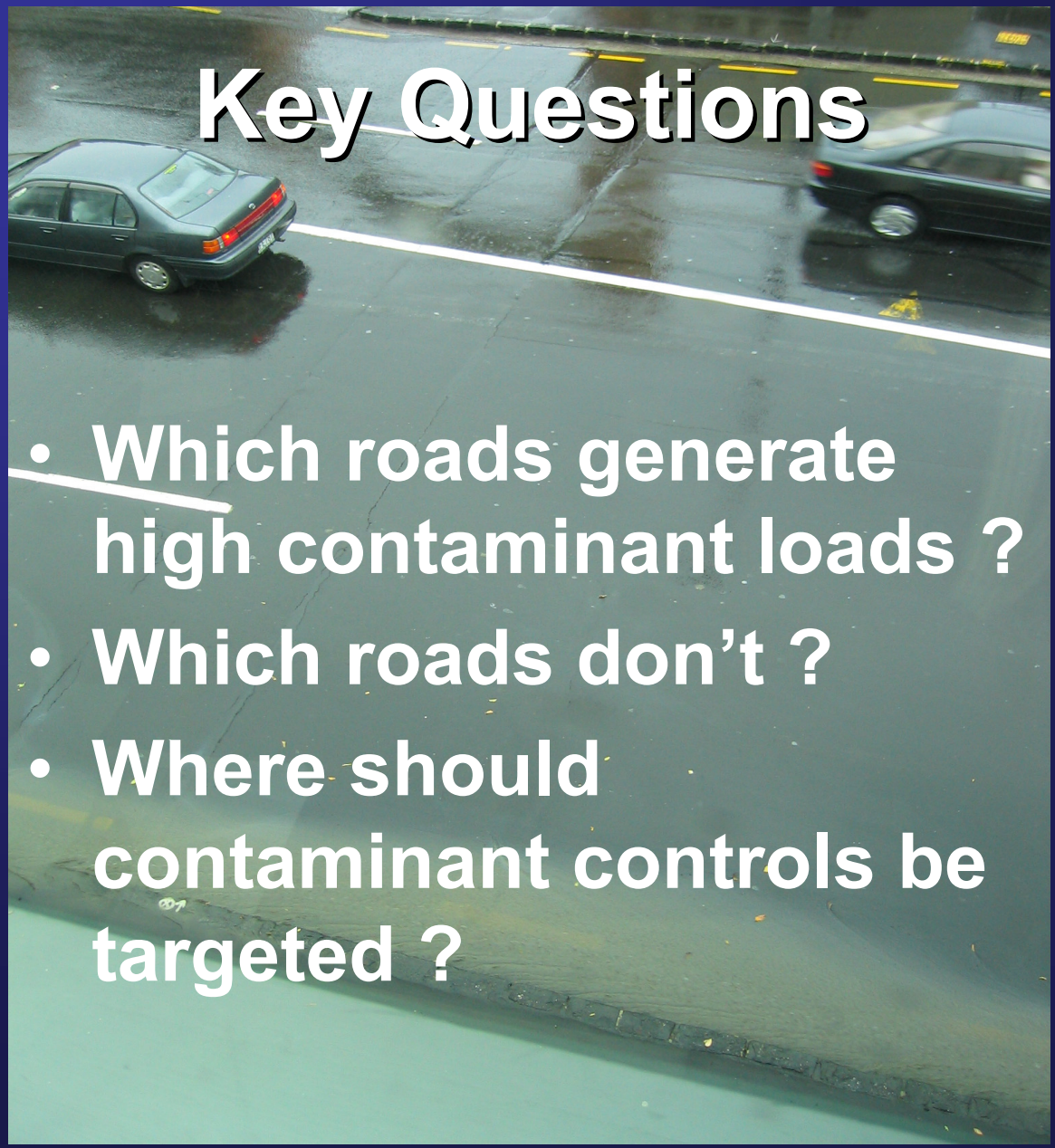


Key Questions

- Which roads generate high contaminant loads ?
- Which roads don't ?
- Where should contaminant controls be targeted ?

Previous NZ Studies

- Field based
  - Kennedy & Gadd (2003) – road dust, Waitakere City
  - Timperley et al. (2005) – runoff, Richardson Rd
  - NIWA (2005-7) - FRST funded road runoff study, northern motorway and North Shore
- Modelling
  - Kennedy & Gadd (2003) – VFEM-W
  - Gardiner & Armstrong (2007) – Vehicle CLM
- Other studies from which loads can be estimated
  - ARC – SH 1, Otahuhu
  - Larcombe (2003) SH 1, Silverdale
  - Sherriff (1998) SH, Tawa

Vehicle Emission Factors (VEFs)

Load of a contaminant conveyed in road runoff (VEF_{runoff}) per vehicle per unit road length

$$VEF = \frac{\text{contaminant load}}{\text{vehicle numbers x road length}}$$

Units mg / veh / km

Focus here is copper and zinc

Influences on Cu and Zn VEFs

Traffic behaviour

- Cu from brake linings
- Zn from tyre wear
- Higher emissions where greater wear
- Intersections, congested roads, on/off ramps, hills, bends, roundabouts

Fleet composition

- wear rates for HCVs 7-31 x cars (Kennedy et al, 2002)

Composition of tyres and brake linings

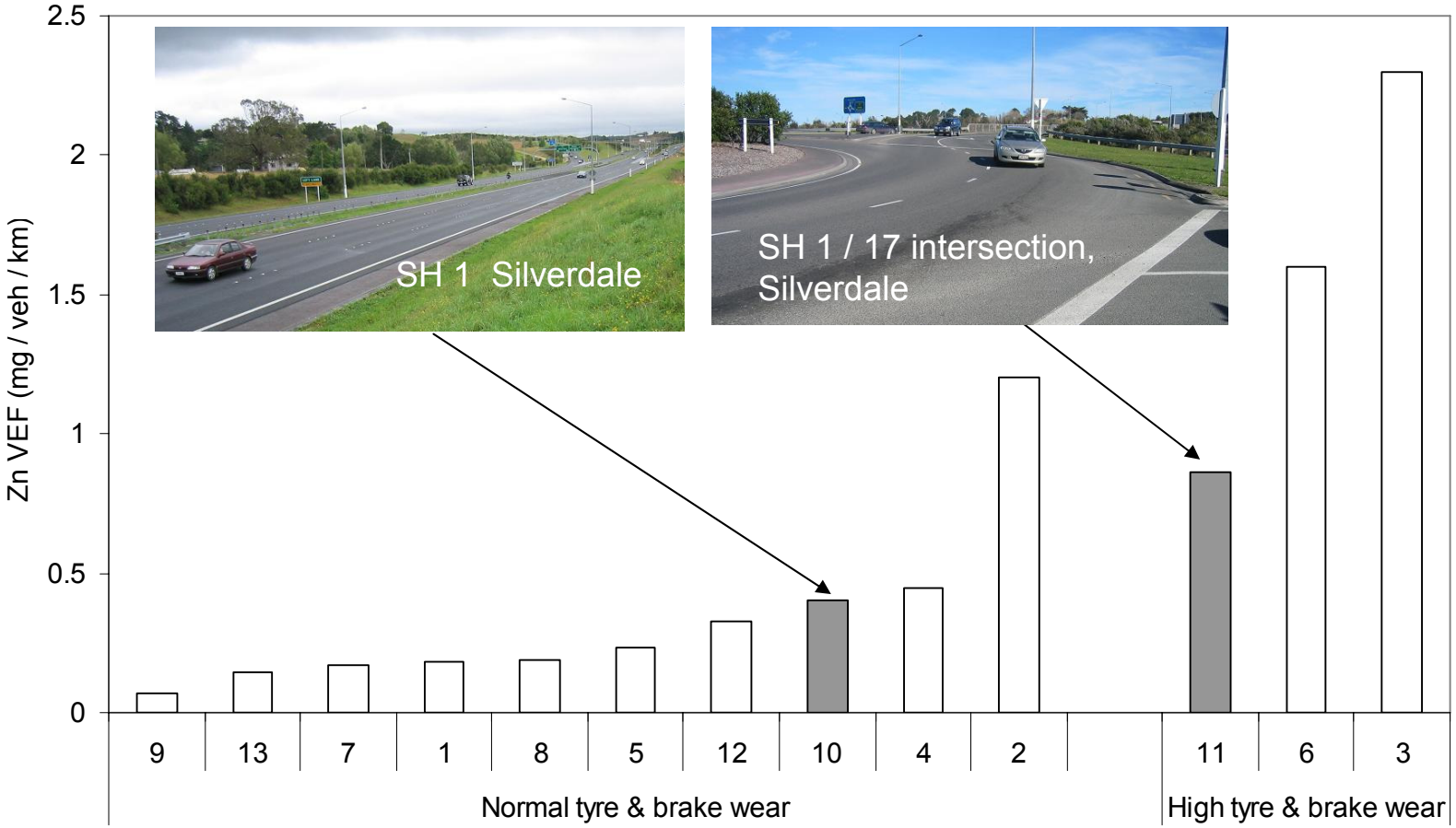
Road characteristics

- Exposure to wind dispersal

Temporal factors

- Rainfall event characteristics
- Antecedent conditions

Previous estimates of VEFs - Zn



Summary – previous studies

- VEFs generally higher where greater brake & tyre wear likely
- Uncertainty
  - lots of assumptions made in derivation of estimates based on reported Zn & Cu concentrations
  - results from NIWA sites based on limited sampling
  - possible influence of experimental factors

Need for more extensive runoff sampling programme to derive representative VEFs

Objectives of this study

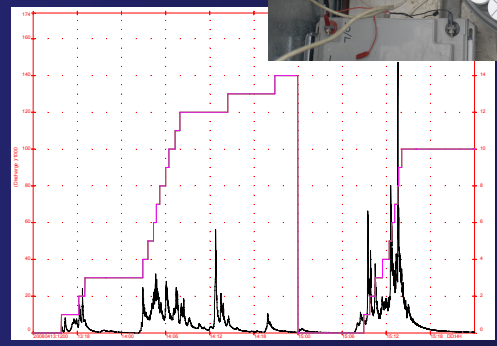
A programme of road runoff sampling to investigate:

1. VEFs for roads subject to different traffic behaviour
2. Effectiveness of contaminant removal at the selected sampling locations

Methods - Estimating VEFs

Flow measurement

Samples collected and analysed for total Cu & Zn



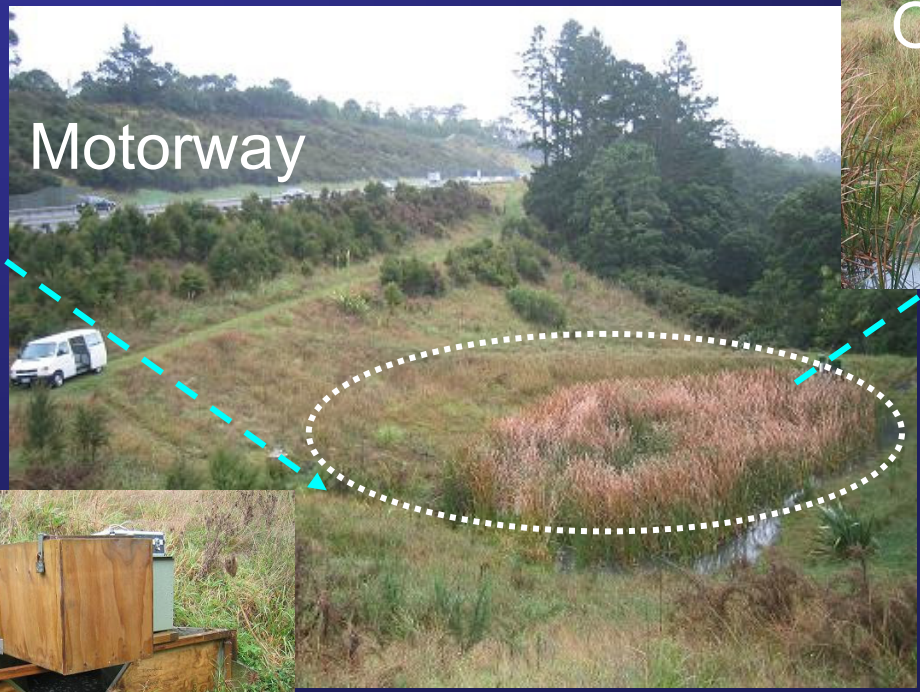
Cu & Zn Loads

Vehicle numbers

Road catchment length

Cu & Zn VEFs

Methods – Performance of Treatment



sample untreated runoff

sample treated runoff

Performance assessed as percentage removal of contaminants: TSS, Cu, Zn

Site Selection

Based on:

- Traffic behaviour – congestion (AADT/capacity)
- Characteristics of road catchment
- Type of treatment present

Sites where ‘normal’ VEFs anticipated

Rural motorway
Congestion = 0.4


SH 1, Redvale (northern motorway)


SH 16, Kumeu

Rural highway
Congestion = 0.47

Sites where ‘high’ VEFs anticipated

Urban motorway

Congestion = 0.66

SH 1(N), near Esmonde Rd, north of Auckland Harbour Bridge

Arterial road, urban fringe

Congestion = 1.39

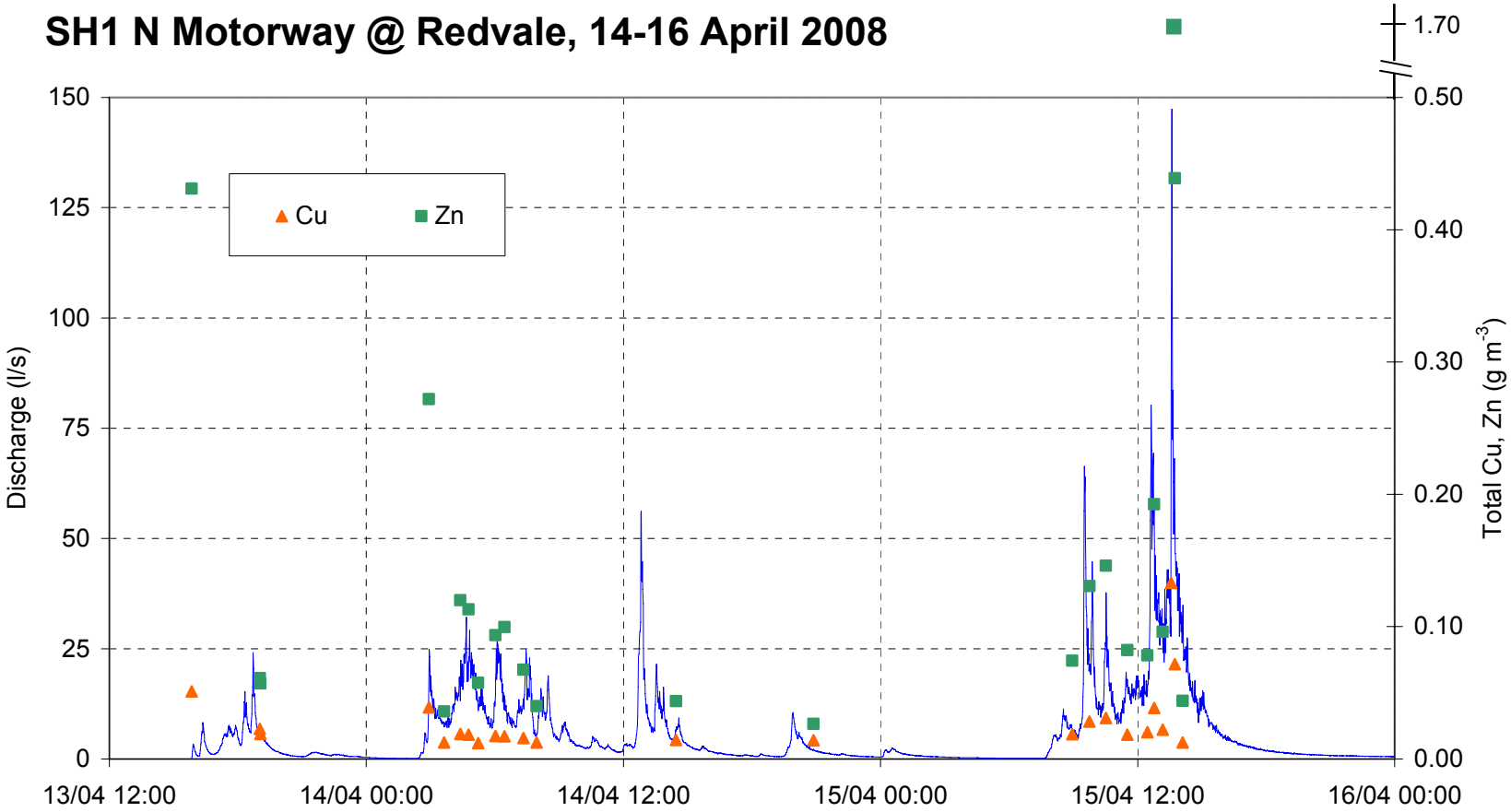
SH 18, Westgate, West Auckland

Results – Storm Event Characteristics

More congested

Site name and location	Period of runoff (flow) monitoring	Number of events sampled	Range of rainfall depths	Range of antecedent dry periods
SH 18 @ Westgate	April 2008 - October 2008	6	14 – 36 mm	2 to 15 days
SH 1 (Northern motorway) @ Northcote	September 2008 - (in progress)	3	20 – 42 mm	2 to 20 dry days
SH 16 @ Coopers Creek	October 2008 - (in progress)	4	9 – 42 mm	2 to 7 dry days
SH 1 (Northern motorway) @ Redvale	November 2007 - October 2008	8	22 – 75 mm	12 hrs - 10 days

Sampling Results - Example



Results – VEFs

Site name and location	VEF – total copper (mg/veh/km)		VEF – total zinc (mg/veh/km)	
	all events combined	range, individual events	all events combined	range, individual events
SH 18 @ Westgate	0.09	0.02 – 0.4	0.5	0.1 – 2.0
SH 1 (Northern motorway) @ Redvale	0.08	0.03 – 1.1	0.4	0.1 – 8.4

Uncertainty in VEF Estimates

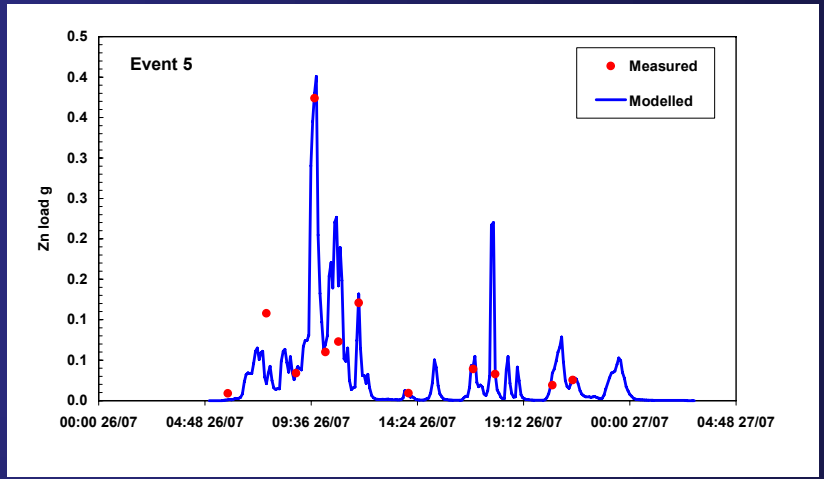
- Inter-event variations influenced by
  - event rainfall intensity & duration
  - Length of antecedent dry period

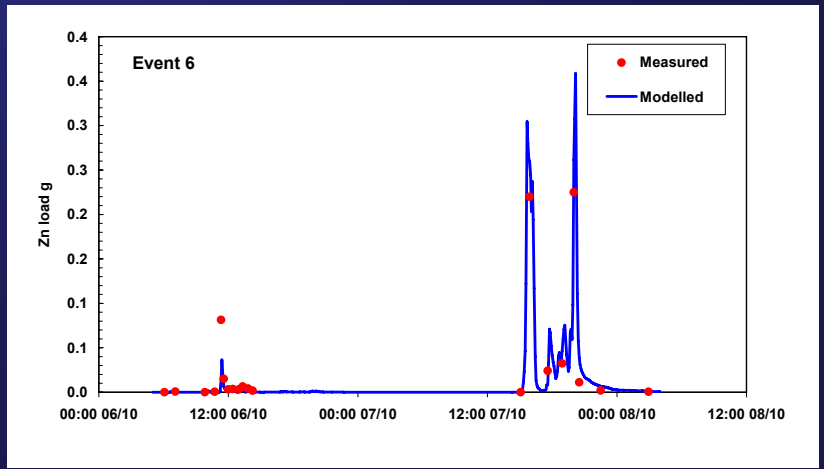
As a result, VEF estimates can be strongly influenced by characteristics of sampling events

- Samples collected post-catchpit
  - Likely to understimate true loads by 10-15 %
  - Need to adjust estimates accordingly

VEFs from Load Modelling

- Contaminant accumulation / wash-off model – STORMQUAL (Timperley et al. 2005)
- Model calibrated against sampling results
- Loads estimated for entire period of runoff measurement (≥ 6 months compared to 6 - 8 events)





Results – Modelled VEFs

Compared to estimates based on storm event loads:

- **Modelled VEFs are lower**
- **Greater difference between high / low congestion sites**

Site name and location	VEF – total copper (mg/veh/km)		VEF – total zinc (mg/veh/km)	
	all events combined	modelled	all events combined	modelled
SH 18 @ Westgate	0.09	0.07	0.5	0.45
SH 1 (Northern motorway) @ Redvale	0.08	0.04	0.4	0.28

Results – Pond Performance

- 70% TSS removal (range 27% to 91%)
- Total metals
  - 67% zinc removal (range 27% to 82%)
  - 40% copper removal (range 18% to 59%)
- Dissolved metals
  - Greater proportion of Cu in dissolved form than Zn
  - -5 % d Zn removal
  - -20% d Cu removal
- Similar to previous results at unvegetated pond

Summary

- Previous studies suggest Cu and Zn VEFs vary with traffic characteristics
- This study aims to investigate VEF variations AND the performance of road runoff treatment
- Sampling complete at most and least congested sites
- Cu and Zn VEFs higher at the more congested sites, BUT
- VEFs influenced by characteristics of sampling events
- Modelled VEFs likely to be better estimates of long-term VEFs
- Vegetated pond achieved 70% reduction in TSS, 67% Total Zn and 40 % Total Cu loads
- Dissolved metal load not reduced
- Poor performance for Cu reflects higher proportion of this metal in dissolved form

Next Steps

- Complete sampling at 2 intermediate sites
- Modelling to estimate loads & VEFS
- Estimate treatment efficiency
- Report & dissemination of research findings

Acknowledgments

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Key to slide 11

Previous Studies

1. Median VEFs, Waitakere City road dust sampling (Kennedy & Gadd, 2003)
2. VFEM-W model, normal driving conditions (Kennedy & Gadd, 2003)
3. VFEM-W model, congested driving conditions (Kennedy & Gadd, 2003)
4. Richardson Rd runoff sampling (Timperley et al., 2005)
5. VCLM model, Richardson Rd, free traffic flow (Gardiner & Armstrong, 2007)
6. VCLM model, Richardson Rd, congested traffic flow (Gardiner & Armstrong, 2007)
7. SH 1 Southern motorway, Otahuhu (estimated from data held by ARC, unpublished in Kennedy, 2003)
8. SH 1 Northern motorway, Silverdale (estimated from data in Larcombe, 2003)
9. SH 1 motorway, Tawa (estimated from data in Sherriff, 1998)

NIWA runoff sampling sites

10. SH 1 Northern motorway, Silverdale
11. SH 1 / SH 17 intersection, Silverdale
12. SH17, Dairy Flat
13. East Coast Rd, North Shore