Contaminant run-off from impervious surfaces such as carparks and roofs

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Outline

Introduction

Methods

Results

Contaminant build-up and wash-off
Surface comparison
Wind effects
Roof runoff

Introduction - Background

- Urban waterways often improve aesthetics of cities, but also act as stormwater drainage channels
- Pollutants accumulating on impervious surfaces are washed off and discharged into waterways
- Main contaminants: heavy metals (zinc, copper, lead), suspended solids

  → Levels in runoff well above guidelines relevant for aquatic ecosystems
- Main sources: - traffic (e.g. brake dust, tire wear)
  - metal roofs (e.g. galvanized iron, copper)
- Models useful to predict contaminant loads – but need input parameters for accurate pollutant build-up and wash-off
- Difficult to obtain this data from real runoff samples
  - Variability of natural rainfall events
  - Time consuming and costly

→ Development of method enabling controlled conditions

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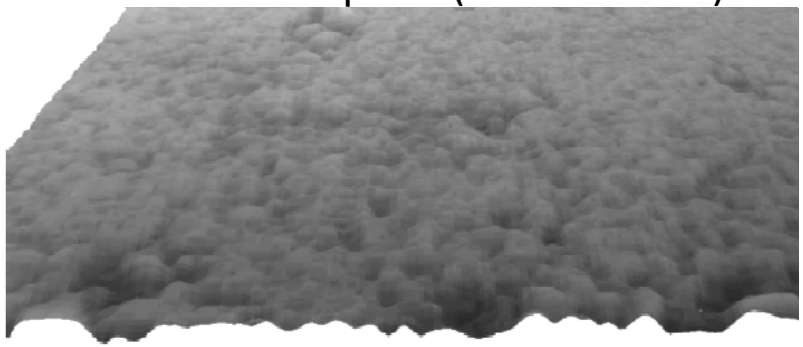
Methods - Boards

- thin boards (75 cm x 75 cm, height: 3 cm) filled with different materials commonly used for impervious surfaces:
  - concrete
  - smooth asphalt (3 mm max grain size)
  - coarse asphalt (14 mm max grain size)

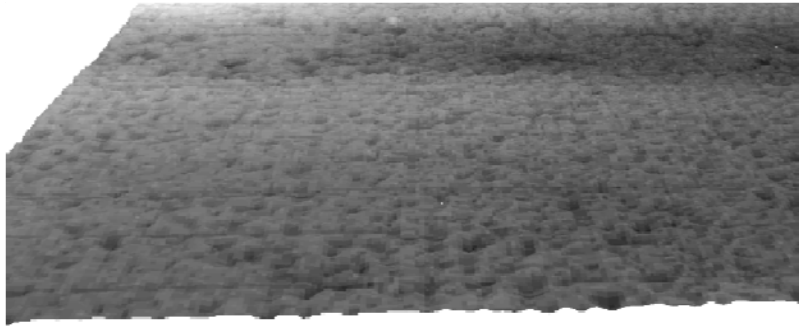
Methods - Boards

- Assessment of surface roughness using laser scanner

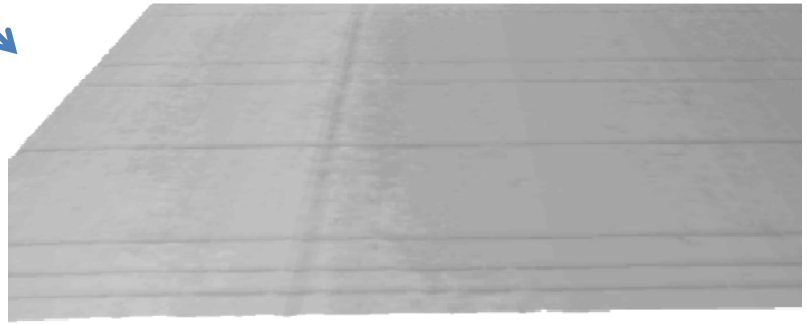
Coarse asphalt (max. 14 mm):



Smooth asphalt (max. 3 mm):

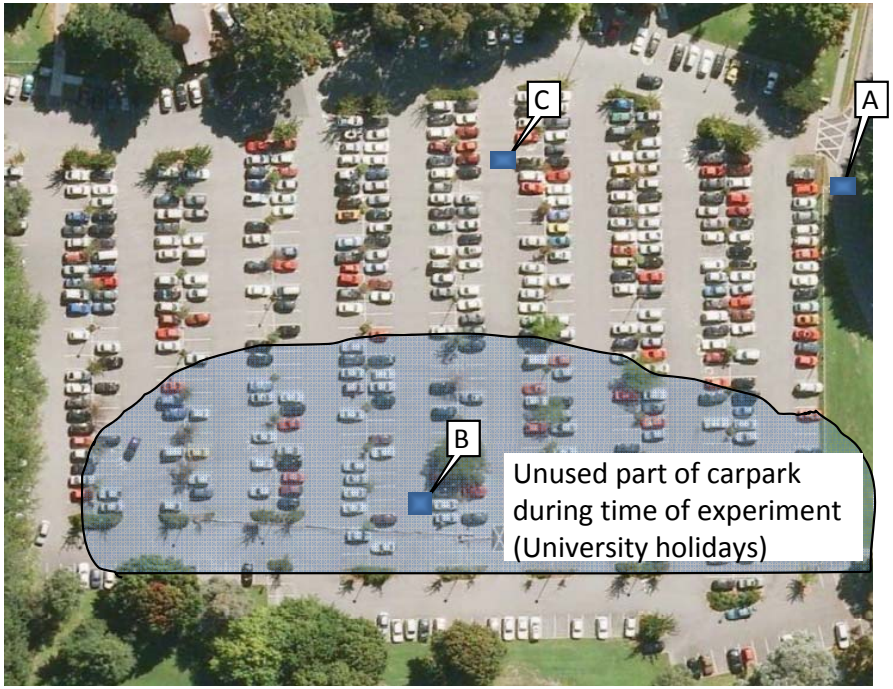


Concrete:



Methods – Board exposure

- Boards placed at different locations within the catchment for desired timeframe depending on research question, e.g.:
  - Comparison of different surfaces regarding contaminant wash-off
  - Contaminant build-up over time (determination of build-up functions)
  - Spatial variability of contaminant accumulation
  - Contaminant transport before rain event (e.g. wind-blown effects)



Methods – Rainfall Simulator

- Two Veerjet 80100 nozzles simulating natural rain
- Adjustable rain intensity
- Feed water adjusted to pH=6 (unbuffered) to simulate rain

- Runoff samples analyzed immediately for pH, color, conductivity, and turbidity
- Heavy metal concentrations and TSS analyzed in lab

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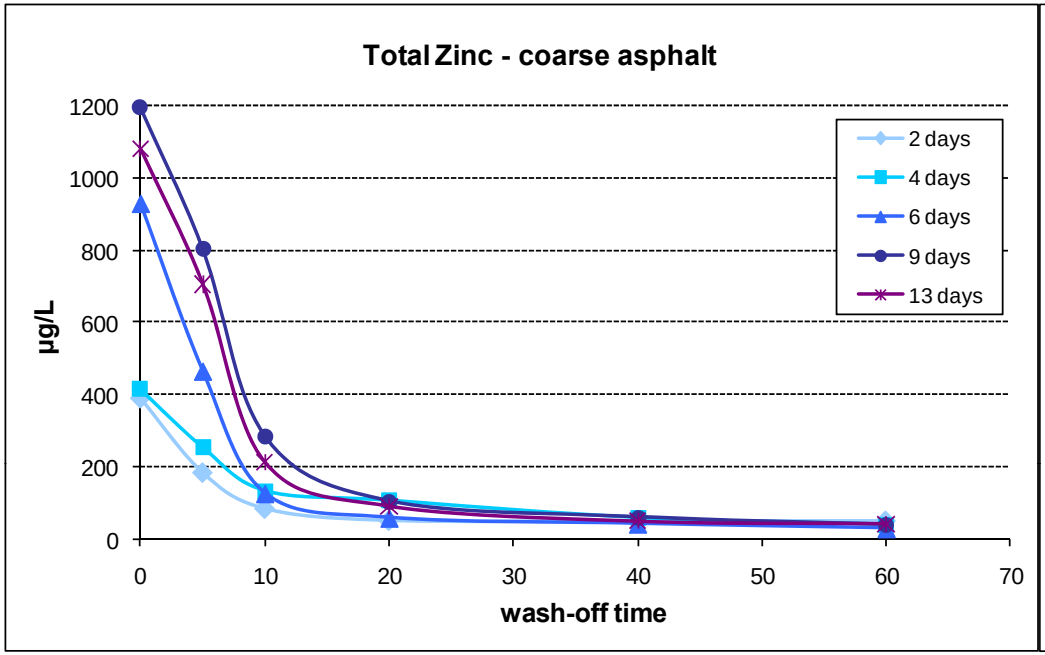
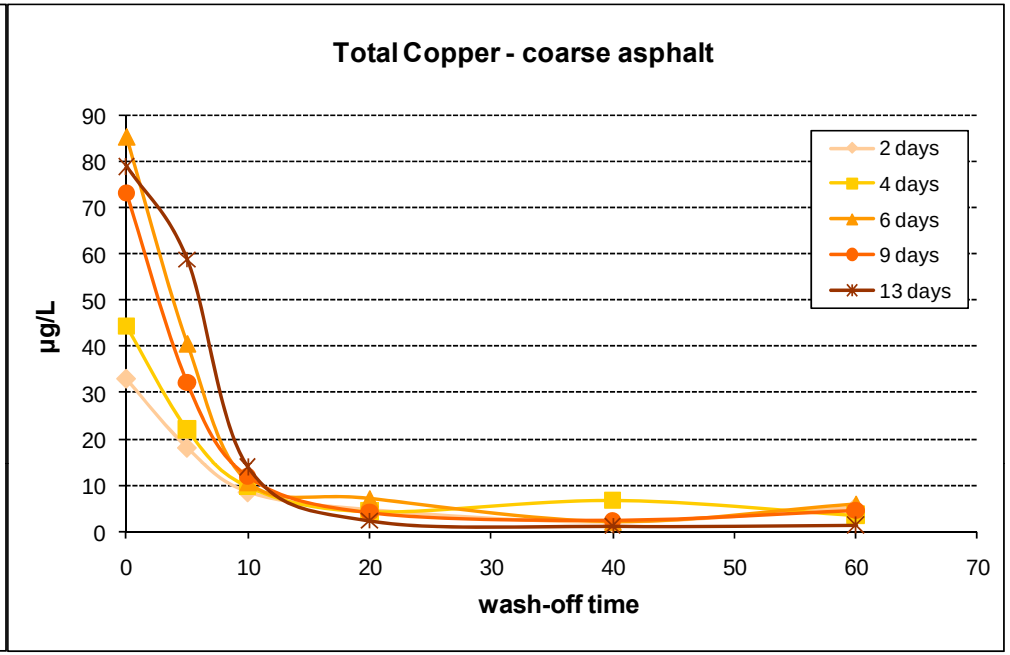
Results – Heavy metal concentrations





- Most contaminants washed off after 10-15 minutes (First-flush)
- High heavy-metal concentrations in first flush

→Exceedance of relevant guidelines in Australia and New Zealand (90% ANZECC guidelines) up to:

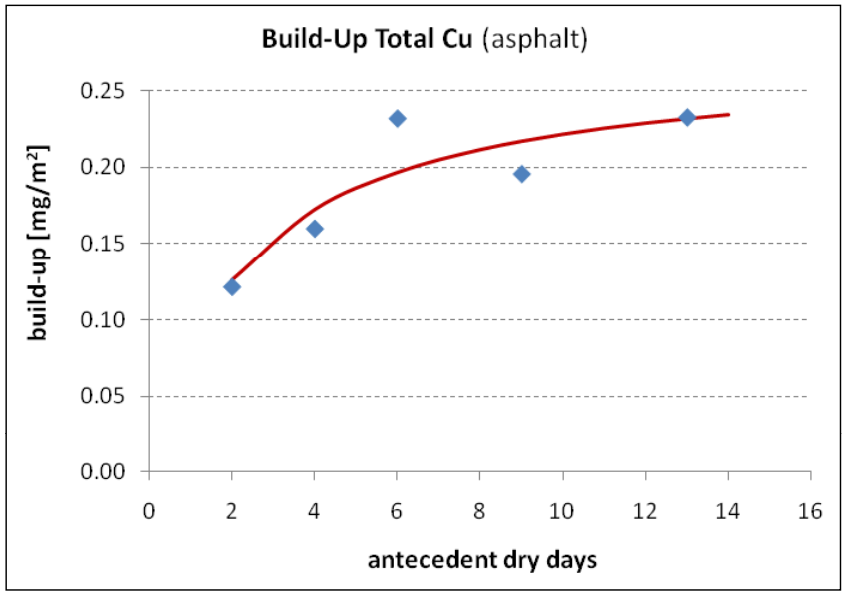
Zinc: 80-fold

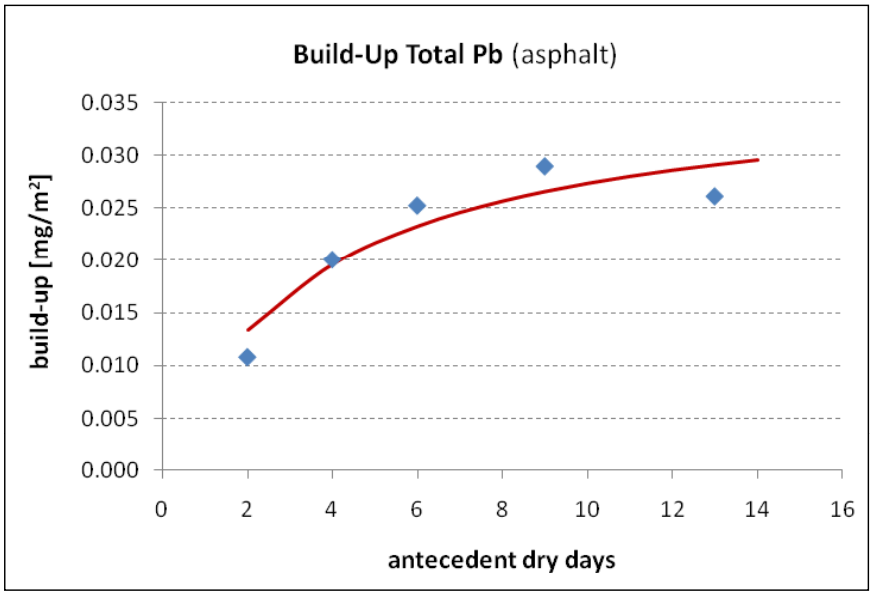
Copper: 45-fold

Lead: 2-fold

ANZECC guideline values (90%)	
Zn	15 µg L^{-1}
Cu	1.8 µg L^{-1}
Pb	5.6 µg L^{-1}

Results – Contaminant build-up





- Total Yields (mg m^{-2}) determined from wash-off curves
- Build-up approaches maximum between 6 and 13 days
- Saturation function (as in SWMM) used to determine build-up coefficients:

$$B = \frac{B_{max} \cdot t}{A + t}$$

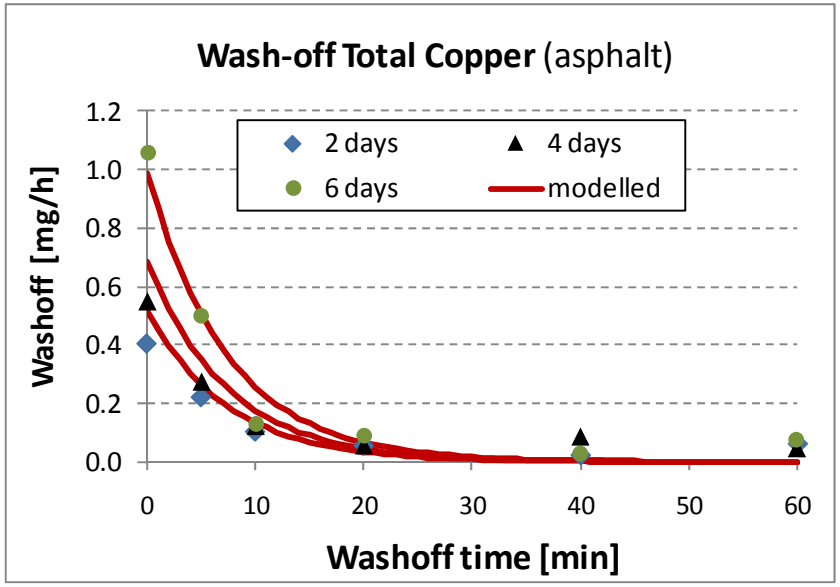
B – Build-up [mg m^{-2}]
B_{max} – maximum build-up constant [mg m^{-2}]
A – half saturation constant [d]
t – number of antecedent dry days

Results – Wash-off

- Wash-off functions determined from runoff concentration profiles
- first order decay relationship employed to represent wash-off characteristics:

$$W = C_1 \cdot q \cdot B$$

W – Wash-off load [mg h^{-1}]
C_1 – Wash-off coefficient
q – runoff rate [mm h^{-1}]
B – remaining amount of pollutant [mg]



Contaminant	Concrete				Asphalt		
	Build-up		Wash-off		Build-up		Wash-off
	B_{max} mg/m²	A [d]	C_1		B_{max} mg/m²	A [d]	C_1
TSS	353	5.4	0.24		165	3.9	0.27
Total zinc	1.0	5.4	0.32		5.2	4.8	0.32
Total copper	0.25	3.2	0.20		0.27	2.4	0.34
Total lead	0.04	1.7	0.29		0.04	3.6	0.33

- Coefficients can be used for modeling purposes, e.g. in SWMM

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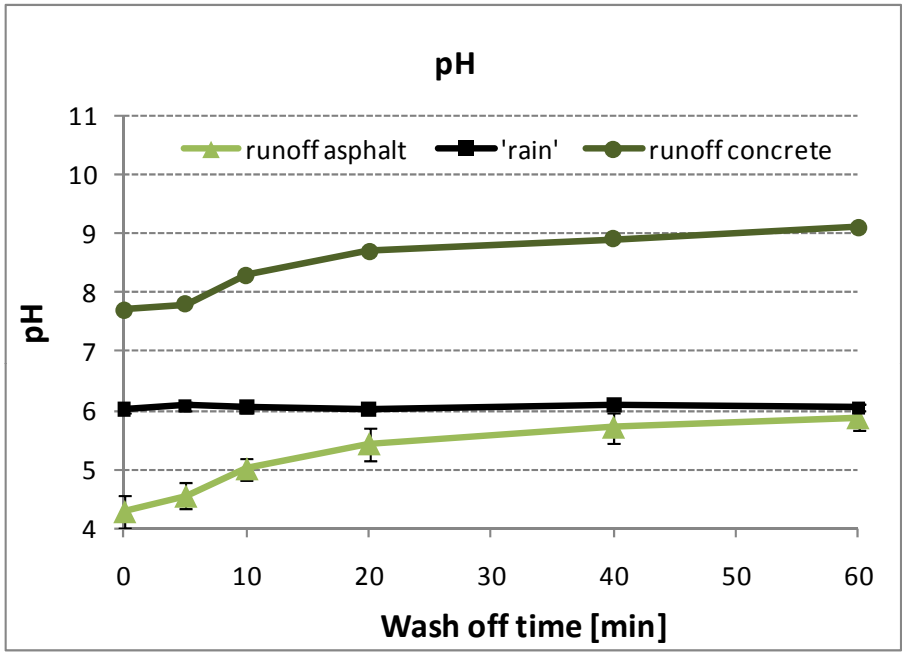
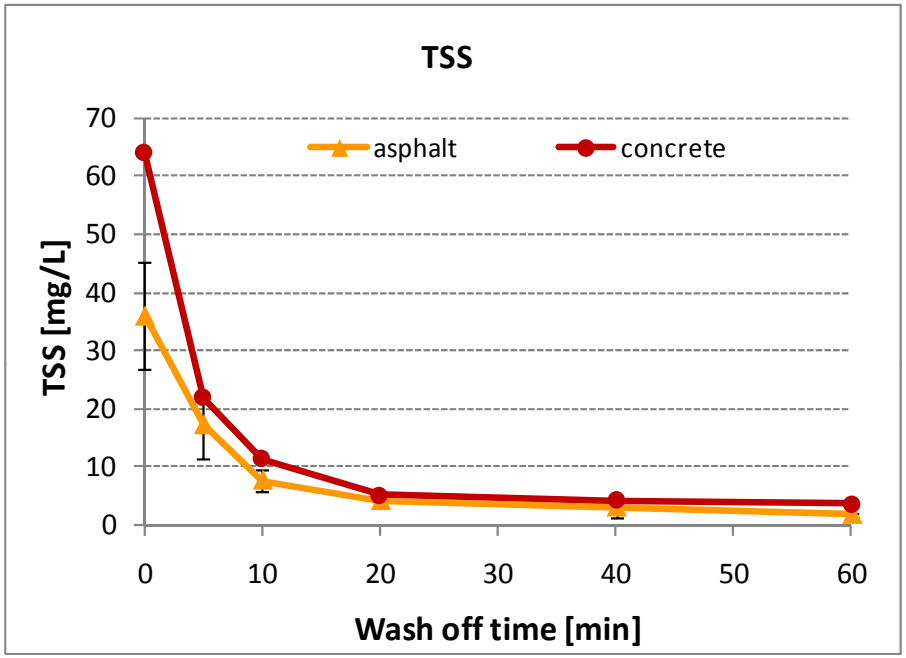
Results – asphalt vs. concrete





- High pH in runoff from concrete

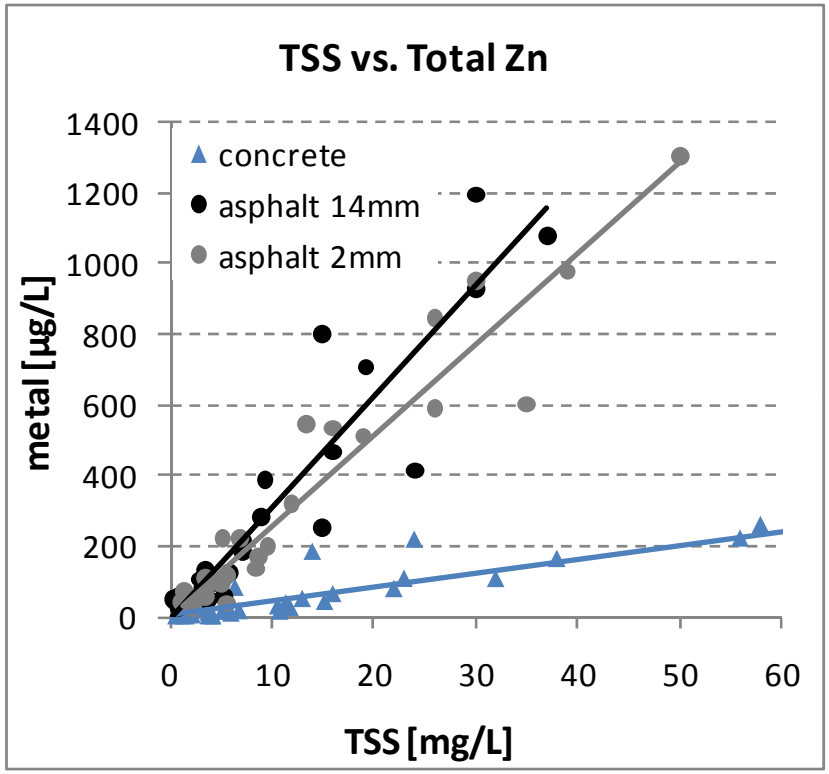
  → hydroxides produced during cement binding

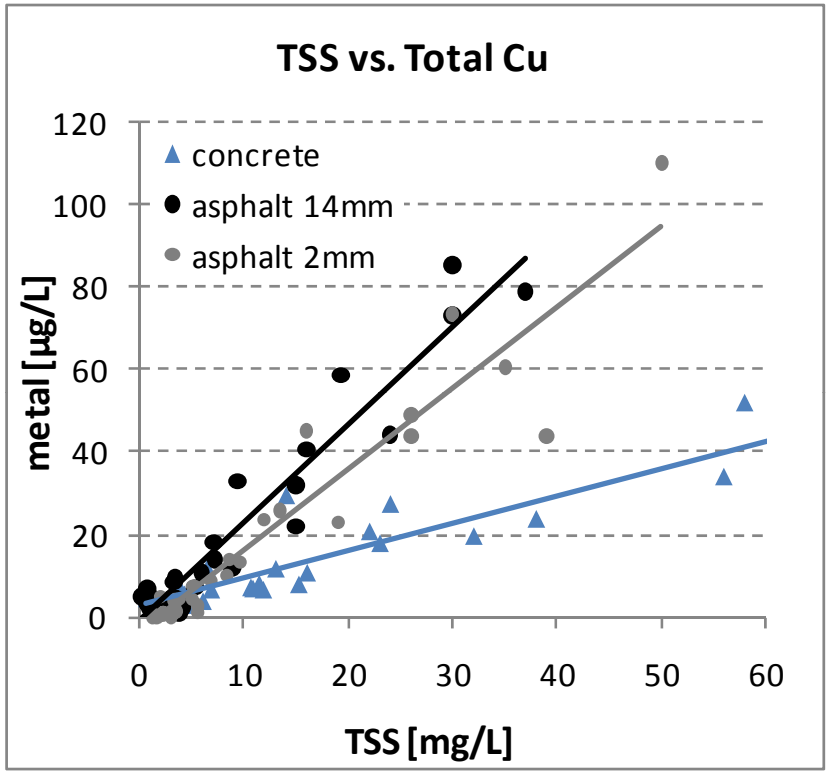
  (still present after 9 months and several wash-offs)

- Lower TSS concentrations and turbidity for asphalt runoff

  → some particles held back in pores

Results – asphalt vs. concrete





- Different runoff-characteristics for concrete and asphalt
- Only little difference between two asphalt types (coarse / smooth)
- Particulate contaminants held back in asphalt pores released in dissolved form

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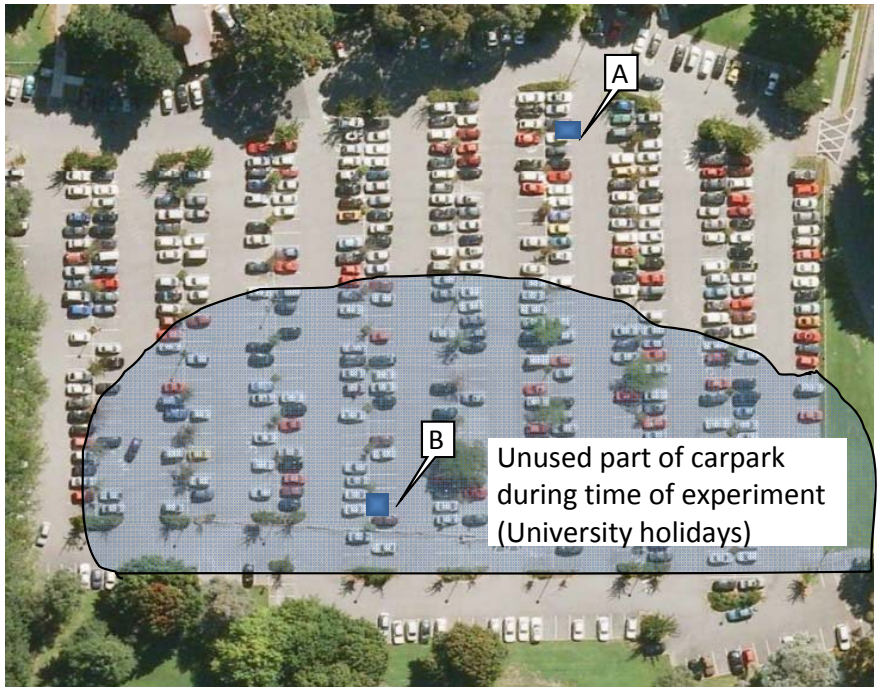
Wind-blown contaminants

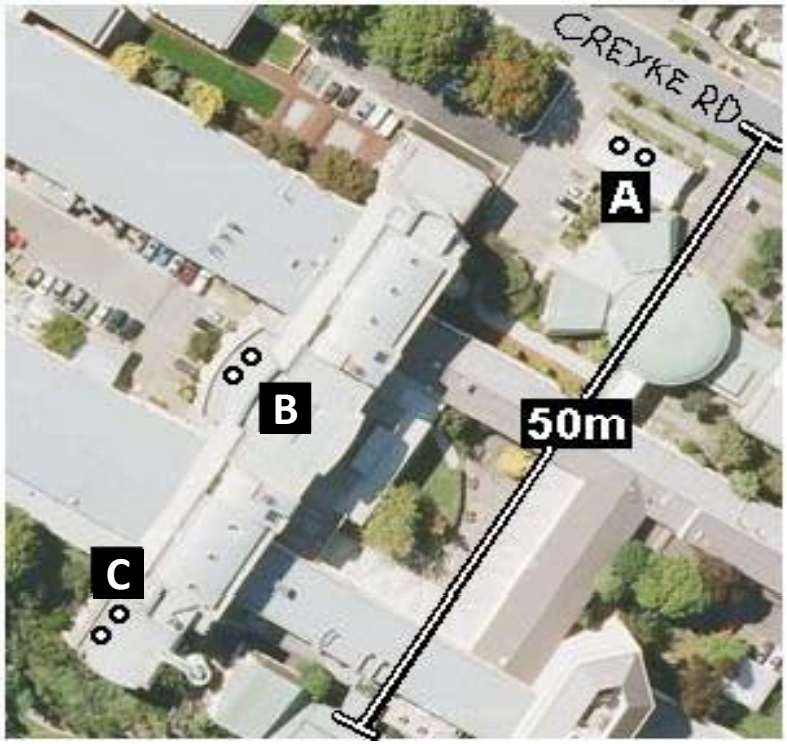


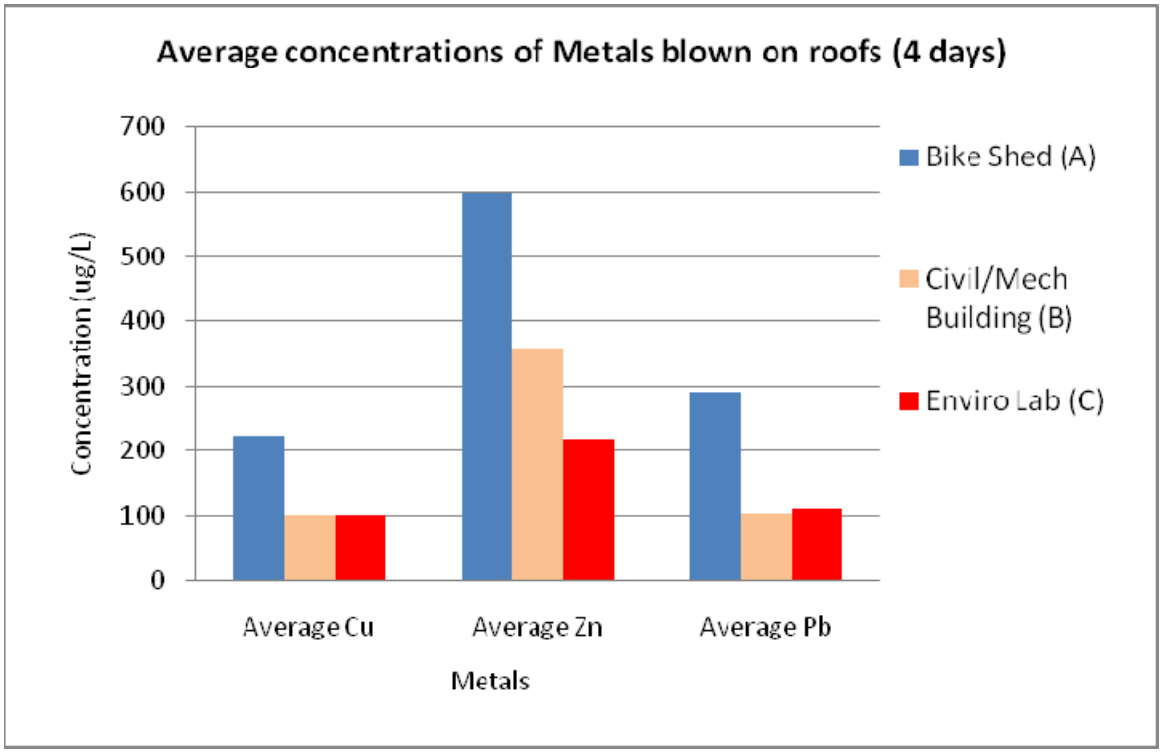
Yields / day [mg/m²/d]	Smooth Asphalt		
	Used	Unused	%
TSS	38.9	19.9	51
Total zinc	0.60	0.30	50
Total copper	0.026	0.016	62
Total lead	0.005	0.003	60

- Contaminants distributed by wind over carpark area (at least 50m)
- possible influence from further sources (e.g. nearby road)

Wind-blown contaminants

- Neutral surface (corrugated plastics) used to accumulate contaminants at different heights and distances from road (Creyke road)





→ Particulate metals transported on top of roofs, 50m from road

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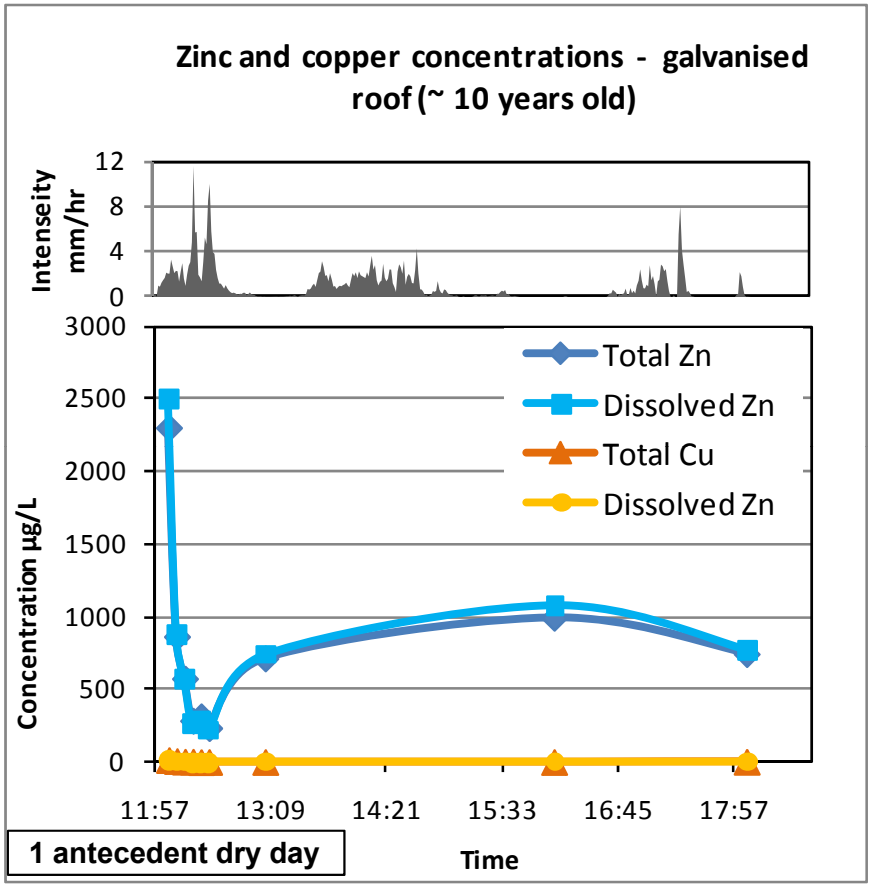
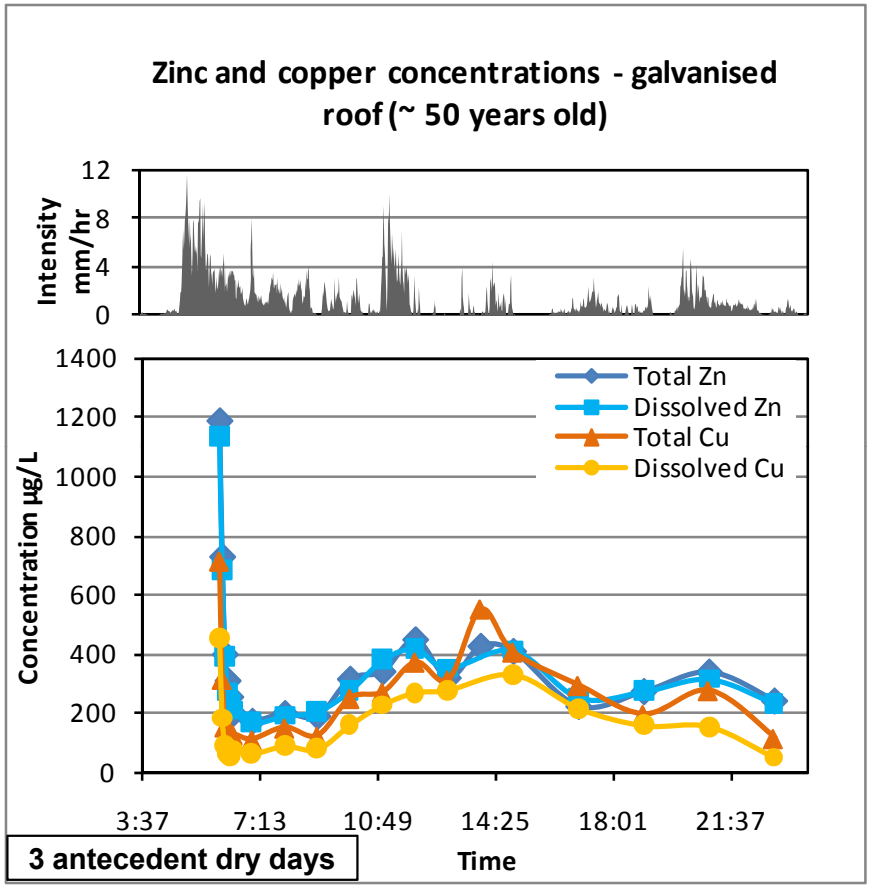




- First flush effect
- High zinc concentrations over long time range (several hours)

- Copper concentrations almost as high as zinc concentrations due to copper guttering

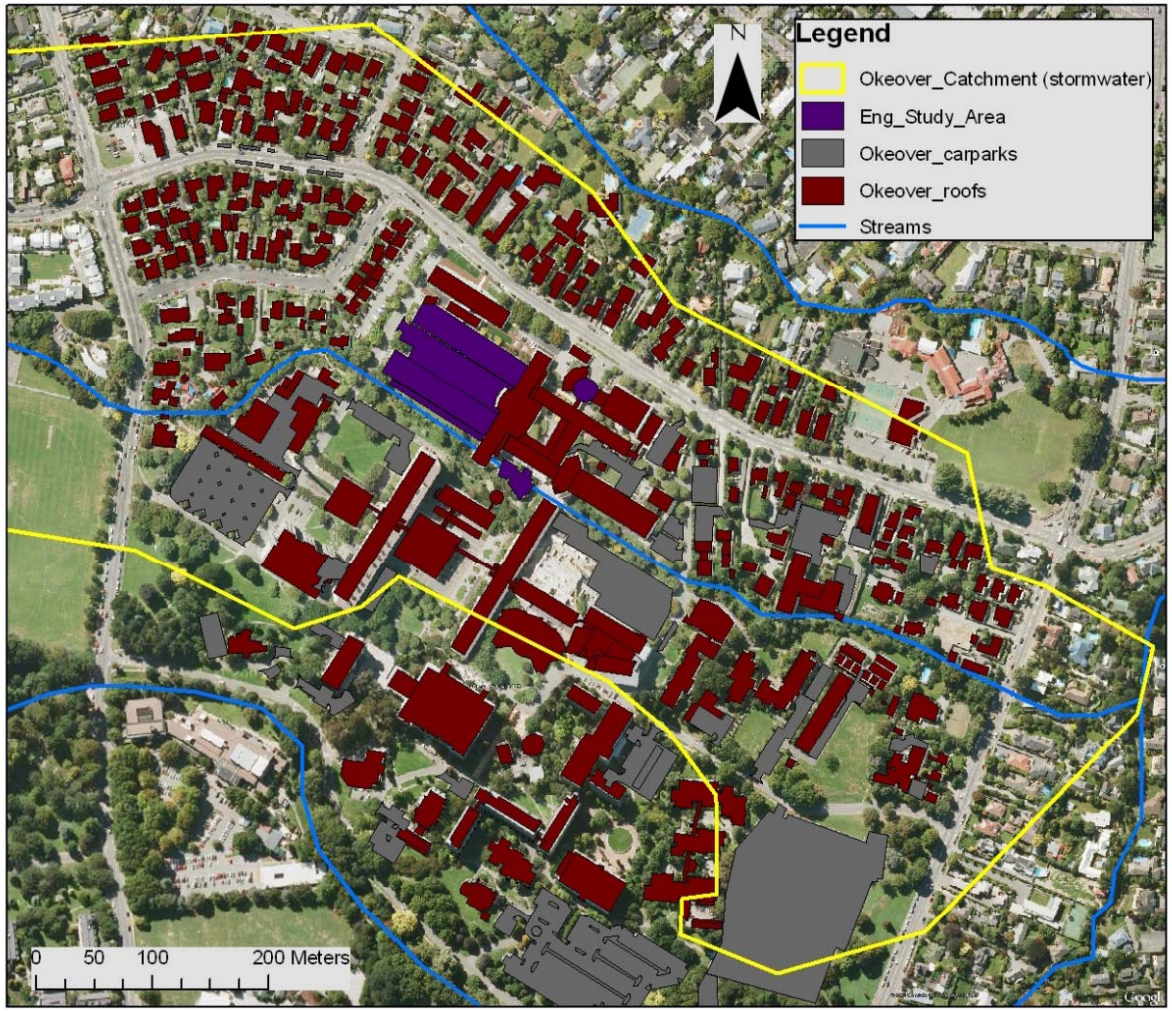
Outlook

- Development of GIS-based model to predict contaminant concentrations entering the Okeover Stream during individual storm events

  → which are critical areas (higher concentrations) regarding storm runoff

  → locations for possible treatment systems

  →incorporate treatment efficiencies



Conclusions

- Method very useful for investigation of stormwater related contaminant transport processes in urban catchments
  - Controlled conditions (e.g. rain intensity, # antecedent dry days, rain pH)
  - Boards can be placed at various locations of interest in urban catchments
  - Different surface types
- High first flush concentrations in runoff from carpark-exposed boards for Zn and Cu, quick decline within 10-15 min
- Build-up of contaminants approaches maximum after 6-13 days at carpark
- Determination of build-up and wash-off coefficients for modeling purposes
- Contaminants transported by wind over carpark area and on roof tops
- Roof runoff can have high concentrations (exceeding ANZECC guidelines >10 fold) over several hours

Acknowledgements

Heavy metal analysis (ICP-MS) – *Sally Gaw & Rob Stainthorpe*

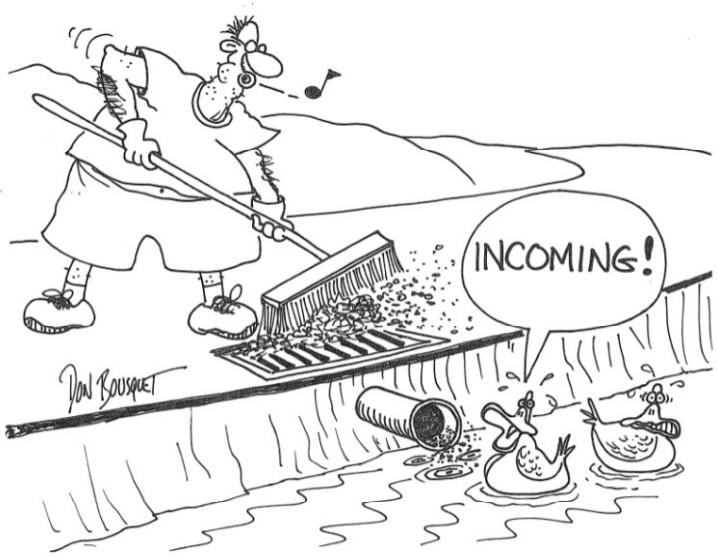
Digestion of samples – *Joseph Good*

Sampling and analysis – *Ingrid Cooper & William Jacobson*

Asphalt supply – *Fulton Hogan*

Making of concrete boards – *Tim Perigo*

Questions ?

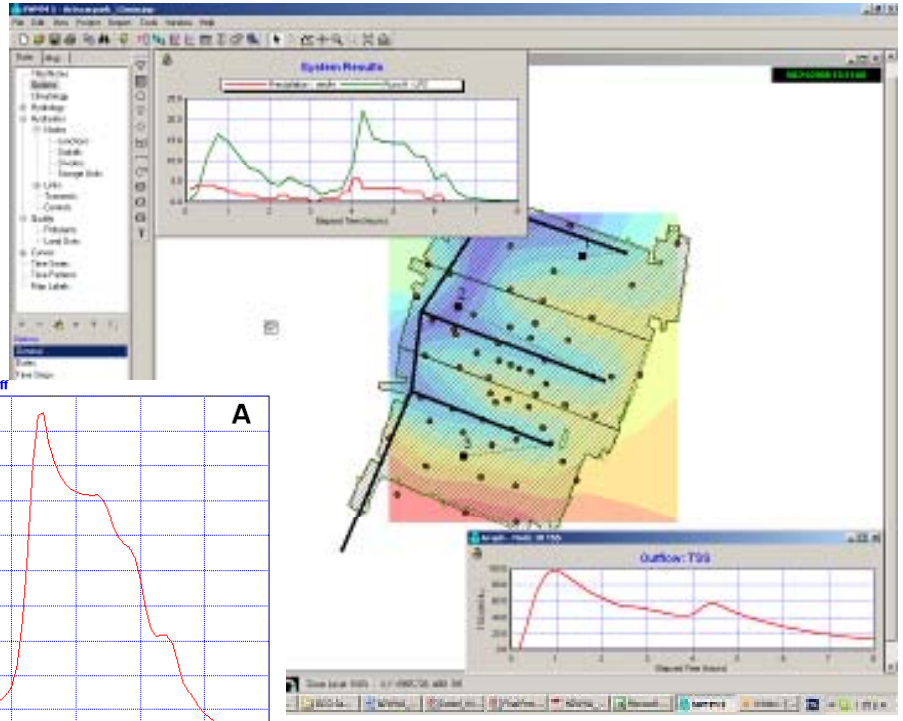


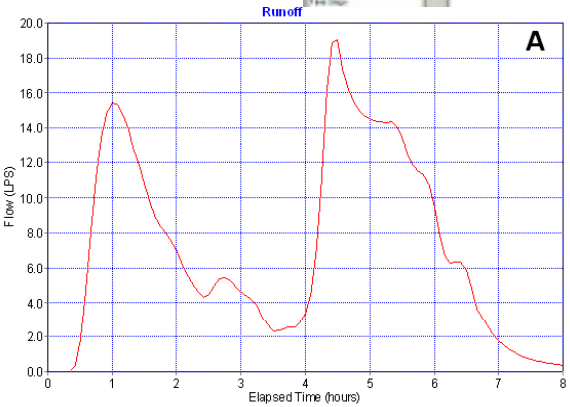
SWMM

- SWMM – Stormwater Management Model developed by US EPA

Case Study:

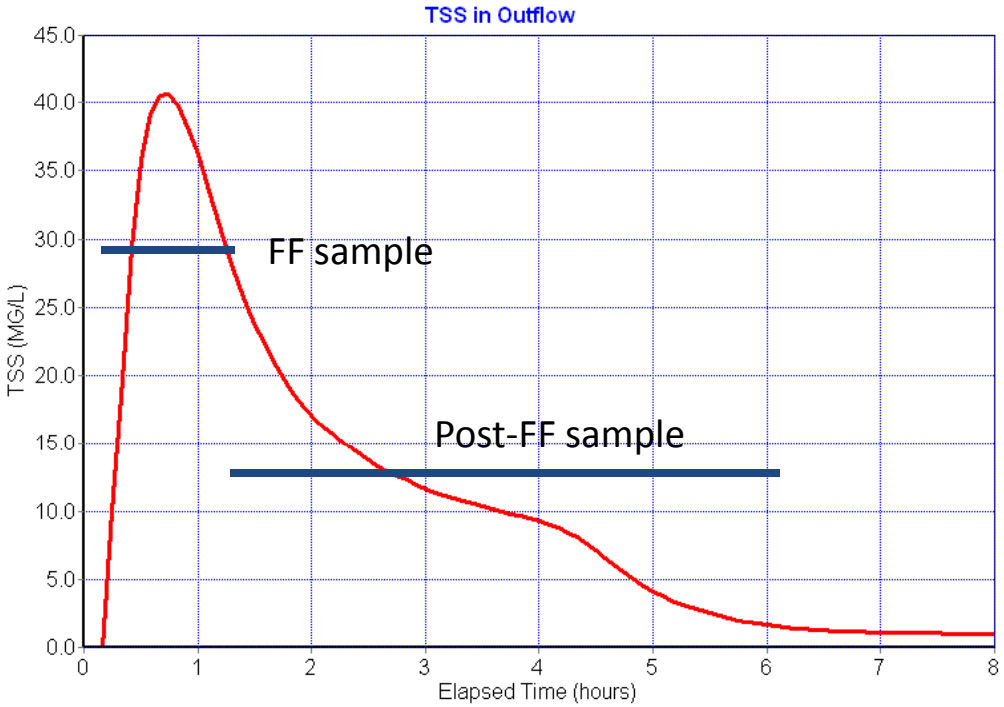
- Modeling of contaminant concentrations in discharge pipe of carpark
- Previous 6-hour storm event modeled, for which results of 2 composite samples of carpark runoff were available:
  - First flush (first hour)
  - Post first flush (hour 1-6)
- Build-up and wash-off coefficients as determined by board study
- Modeled curved compared to results of run-off samples



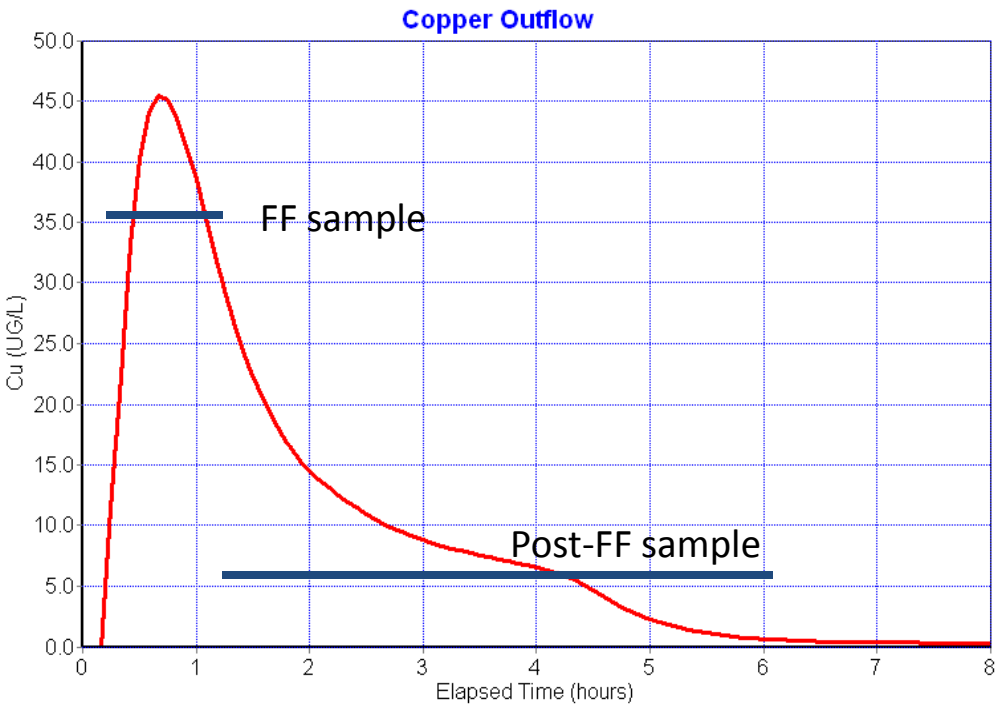


SWMM - Results

Total Suspended Solids (TSS)



Copper



- Good agreement of sample concentrations with modeled curves