Assessing the Impact of Highway Derived Contaminated Sediments

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Presentation - Thursday 16th November 2006

Sponsors:

Highways Agency
Mike Whitehead

Environment Agency
Phil Chatfield

Contractors:

ECUS Ltd.
Chris Routh

University of Sheffield
Lorraine Maltby, Paul Gaskell
Ian Guymer (University of Warwick)

Outline

- Current assessment method
- Research Drivers
- HA/EA funded R&D projects
- Impact of contaminated sediments
- Quantifying loads – the physics
- Assessing impacts – the biology
- Proposed new assessment method

Current assessment method:

either Design Manual for Roads and Bridges, (DMRB)
Volume 11, Section 3, Part 10, Water Quality & Drainage.
HMSO, London, 1998.
Chapter 6 – Predicting Polluting Potential

or "Control of Pollution from Highway Drainage Discharges"
CIRIA Report 142
Luker, M. & Montague, K. (1994)

2 Stage assessment:

- dilution potential
- soluble pollutant concentrations

Current assessment method assumes:

Road accumulation for 5 days

rate dependent on Annual Average Daily Traffic (AADT)

Proportion assumed to wash off during a 24 hour summer storm
e.g for copper 40%

Design storm taken as 30% of a one year 24 hour storm

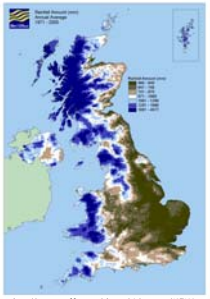
50% of the incident rain is assumed to reach the discharge point

Dilution potential:

"Assumes that 95% storm will occur while river is at 95% excedence flow"

Runoff volume = total road area x runoff coefficient (0.5) x rainfall depth

Dilution = 5% river flow (m^3/day)/ runoff volume (m^3)



http://www.metoffice.com/climate/uk/averages/1971200 0/rr/17.gif

Dissolved Pollutant Abatement Requirements

Traffic Flow AADT	Fishery ecosystem 1-4 Dilution 2	3	4	6	12	16
< 5000	-	-	-	-	-	-
5,000 to 15,000	D	-	-	-	-	-
15,000 to 30,000	D	D	-	-	-	-
>30,000	D	D	D	D	D	-

D = Assessment of copper and zinc dilution required

CIRIA Report 142 - Table 5.6a

Soluble pollutant concentrations, road accumulation for 5 days, rate dependent of AADT

Typical pollutant build-up rates (kg/ha/a)

Traffic Flow AADT	Pollutant: Total Solids	COD ($kg\ O_2$)	NH_4-N	Copper Total	Copper Soluble	Zinc Total	Zinc Soluble
< 5000	2500	250	4.0	0.4	0.2	0.4	0.2
5,000 to 15,000	5000	400	4.0	0.7	0.3	1.0	0.5
15,000 to 30,000	7000	550	4.0	1.0	0.4	2.0	1.0
>30,000	10,000	700	4.0	3.0	1.2	5.0	2.5

CIRIA Report 142 - Table 5.2

Increase in soluble pollutant concentration =
5 day build up / total flow (runoff + river flow)

Compare predicted concentration with Water Quality Objectives for class of fisheries ecosystem (DoE, 1993)

Impact if:
predicted concentration > standards concentration

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HIGHWAYS AGENCY

- executive agency of the Department of Transport, Local Government and the Regions

- responsibile for maintaining, operating and improving England's trunk roads and motorways, in accordance with legislation

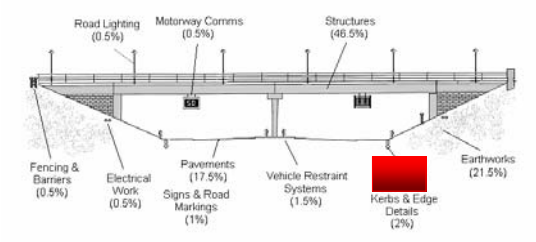
- as a Government Department - use it's resources effectively and efficiently

- ongoing programme of research into the ecological impact of highway run-off, to:

"develop advice on when run-off is likely to have a significant ecological effect, whether treatment measures are necessary and whether ecological indicators can be used to assess potential impacts"

HIGHWAYS AGENCY

- a statutory duty to ensure that run-off from its roads does not pollute receiving watercourses



Environment Agency

The Water Framework Directive 2000/60/EC (WFD)

Considers ecological and chemical status

Need to achieve or maintain rivers in a "good ecological status" by 2015

Crabtree *et al* (2005):
ensuring that the HA is able to comply with its legislative responsibilities and meet the new requirements of the Directive is problematic because;
- limited understanding of the complex chemistry of highway runoff
- insufficient knowledge to accurately predict the polluting effects of highway runoff on receiving waters

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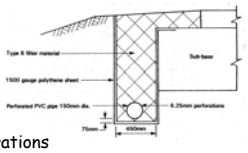
Completed research project:

Improve the understanding of contaminants in routine non-urban highway runoff (WRc)

- 1997 to 2003
- data collection study
- to examine the treatment efficiency of associated drainage systems and drainage devices

Moy, F., Crabtree, R. and Simms, T. (2003) Long Term Monitoring of Pollution from Highway Runoff. Environment Agency R&D Report No. P2-038.

Objectives to:



- create a database of flows, pollutant loads, rainfall and site details
- identify key determinands and concentrations
- establish relationships
  - pollutant concentrations, traffic flows,
  - rainfall totals, antecedent dry periods,
  - rainfall intensity & rainfall duration
- identify the treatment efficiency of drainage types and treatment devices
- to evaluate the chemical and biological impact

The Improved Determination of Pollutants in Highway Runoff WRc - current

- measuring pollutants in highway runoff at locations under a range of site conditions throughout England
- data collection from storm events at 24 locations
- aim to identify the key contaminants in routine runoff and the relationships between pollutant concentrations and site characteristics
- data will be used to develop a predictive methodology for:
  - highway runoff pollution concentrations
  - resulting pollutant loads

Approach and methodology:

http://www.metoffice.com/climate/uk/averages/19712000/rr/17.gif

Wet/dry 800mm rainfall boundary

Warm/Colder 3 degree temp boundary

- 4 climatic regions in UK
- range of traffic bands
- 4 sites determining storm temporal concentrations
- 20 sites quantifying Event Mean Concentration values
- regression type analysis of parameters
- development of WRc's Rapid Assessment Tool (RAT) originally for run-off from small urban areas
- outputs used in conjunction with assessment tools

The Effects of Soluble Pollutants on the Ecology of Receiving Waters – White Young Green & King's College London – current, now with WRc

laboratory tests of taxa to establish the sensitivity to pollutants in road runoff (duration, concentration matrix)

to set critical ecological impact thresholds for selected pollutant and taxa

predictive assessment model of the potential impacts of soluble pollutants on the ecology of receiving waters

field studies to verify results

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The Accumulation and Dispersal of Suspended Solids in Watercourses – current
ECUS and the University of Sheffield

determine the fate of suspended solids discharged from highways

partitioning, mobilisation, and bio-availability and bio-accumulation

metal and hydrocarbon contaminants

determine the ecological significance of contaminated sediments in watercourses

devise a procedure for the impact assessment of the ecological effects of sediments on receiving watercourses.

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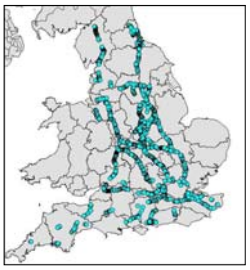
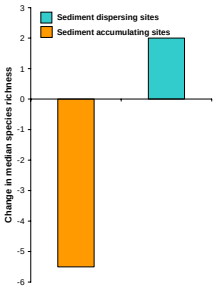
Stage 1 - Site selection

1863 Sites
(URS Thorburn Colquhoun)





- 44 sites visited, full surveys at 19
- greater change in community structure at sediment accumulating sites

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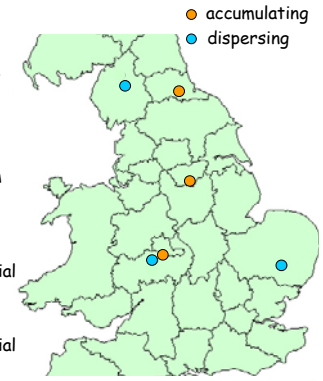
Stage 1 – Sites selected

- Good receiving water ecology
  - able to detect impact
- Small channel & low flow
  - safe working and minimum dilution
- No treatment devices
  - maximum polluting potential
- High AADT
  - maximum polluting potential



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Stage 2 - Objectives

- to determine the fate of suspended solids discharged from operational highways
- to identify the factors which determine accumulation and dispersion
- to understand and quantify the processes involved in the mobilisation and bioavailability contaminants in accumulated sediments
- to determine the ecological significance of contaminated sediments in watercourses

Engineering (physics) - long term and storm monitoring

- quantify the flow, sediment and contaminant load from 10 storms at 6 sites
- quantify the sediment deposition and associated contaminant concentrations

Ecology (biology) – combination of field surveys and both lab and field experiments

- quarterly surveys
- bioassay deployments

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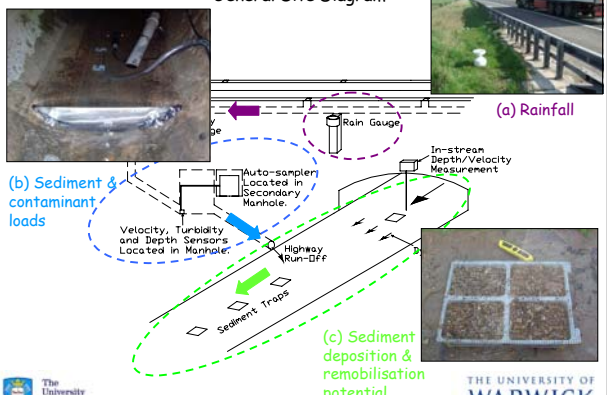
General Site Diagram



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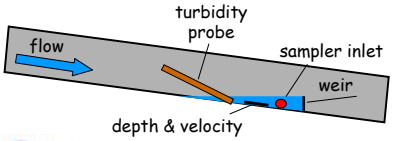
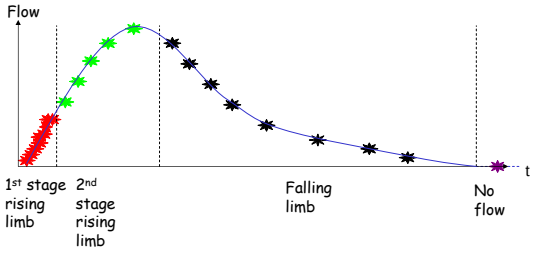
Sediment & contaminant loads in drainage pipes

- turbidity, depth & velocity monitored every 1 min
- autosampler triggered by increase in depth and turbidity upstream of weir plate
- autosampler employed non-uniform time programme



Storm hydrograph - estimate for sample separation



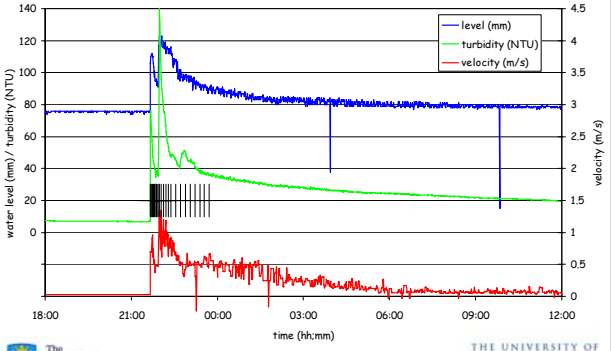
- 9 @ 2 mins, 5 @ 5 mins, 8 @ 10 mins, 1 @ 1440 mins
- analysed for suspended solids concentrations, metals & PAH's

The challenges of fieldwork !

HA11 – Penrith/Carlisle

River Petteril flooding

storm event in-pipe data



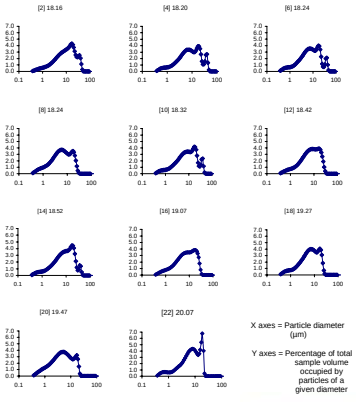
Frequency distributions of particle sizes

11 individual samples of storm runoff

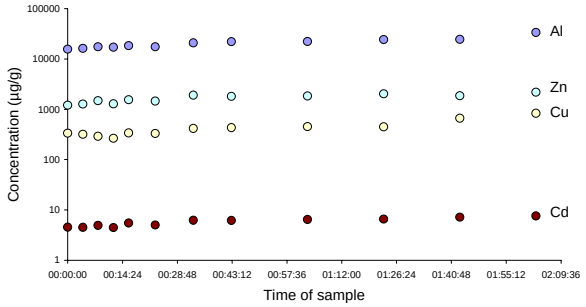
time indicated (GMT)

11 February 2006

Site HA11

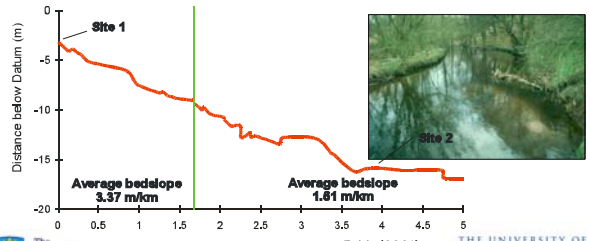


Sediment associated metal concentrations during storm event



How much highway derived sediment will deposit and how long will it remain in the reach?
Sediment accumulation or dispersal?

Effect of bed slope, velocity and boundary shear



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To deposit or not to deposit?
What is the "reach"?

Temporal variations in discharge
Spatial variations in velocity

solute tracing can provide an estimate of the velocity variation within the channel reach

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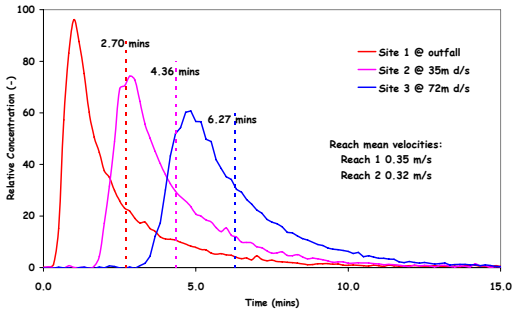
dispersing site - reach mean velocity sufficient to minimise sediment deposition



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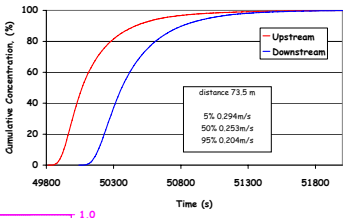
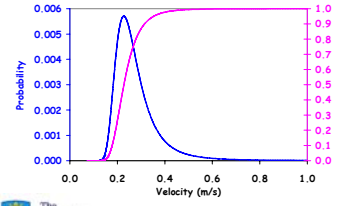
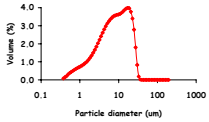
"Suggest method to define deposition potential over reach"

estimate velocity variation within reach





Particle size distribution



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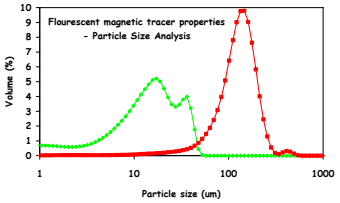
Sediment tracing study

Water pumped from river through outfall pipe

Coarse (red) and fine (green) particles injected into flow in outfall pipe



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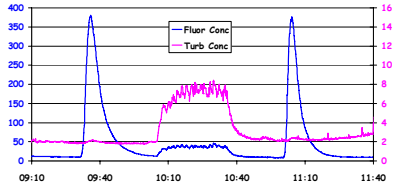

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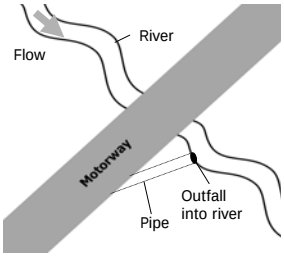
Assessing impacts – the biology

General field site layout



Characterisation:

Surveys will look for changes in the invertebrate and fish communities downstream of outfalls

+

Surveys that measure levels of contamination upstream and downstream of outfalls (in animals and in sediment)

= Observation of degradation within specific field sites

Placing caged "bioassay" organisms into the river above and below the outfall

= Measurement of standard biological response

Measuring toxicity of specific sediment contaminants in laboratory exposures (and variation under the range of conditions found in the UK)

= Investigation of mechanisms responsible

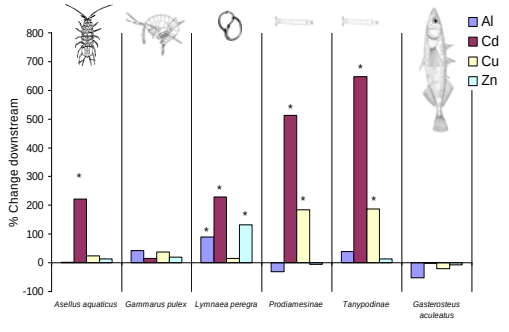
Survey examples

HA12: Invertebrate diversity (via Surber sampler)

Example of impact upon community below outfall

UPSTREAM BUGS		DOWNSTREAM BUGS
Pyralidae	*Agabus didymus*	
Tipulidae	*Plectrocnemia conspersa*	
Tipula	*Pisidium* sp.	
Pediciidae	Oligochaeta	Oligochaeta
Psychodidae	Hydracarina	Hydracarina
Ptychoptera	*Gammarus pulex*	*Gammarus pulex*
Dixa maculata	Tanypodinae	Tanypodinae
Tanytarsini	Prodiamesinae	Prodiamesinae
Empididae	Orthocladiinae	Orthocladiinae
Nemurella picteti	*Velia saulii*	*Leuctra sp.*
		Chironomini

Tissue metal contamination in native organisms



Characterisation cont.:

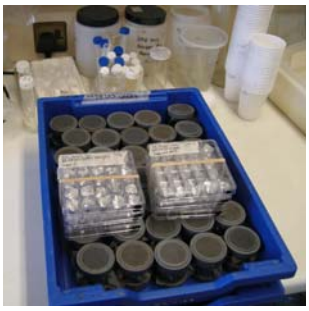
Surveys will look for changes in the invertebrate and fish communities downstream of outfalls + Surveys that measure levels of contamination upstream and downstream of outfalls (in animals and in sediment) = Observation of degradation within specific field sites

Placing caged "bioassay" organisms into the river above and below the outfall = Measurement of standard biological response

Measuring toxicity of specific sediment contaminants in laboratory exposures (and variation under the range of conditions found in the UK) = Investigation of mechanisms responsible

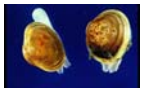
How?

- Caged invertebrates are placed within the river upstream and downstream of the outfall
- Toxic effects are measured by comparing feeding rates between upstream and downstream organisms
- Amounts of metals and PAHs accumulated by the organisms are also measured



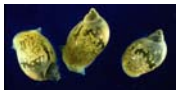
Bioassay cages

Organisms deployed:



Sphaerium (pea mussel)

OR



Lymnaea (snail)

PLUS:

Sericostoma (caddis)

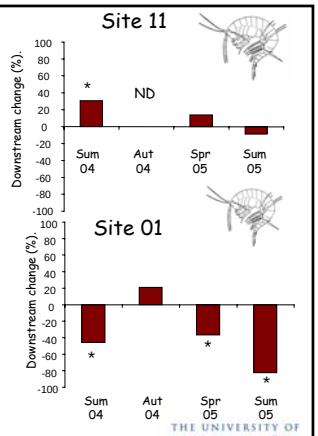
Erpobdella (leech)

Gammarus (shrimp)

Chironomus (midge larvae)

Bioassays Deployed

Species	*Sericostoma personatum*	*Gammarus pulex*	*Lymnaea peregra*	*Erpobdella octoculata*	*Chironomus riparius*	*Sphaerium corneum*
Order	Trichoptera	Amphipoda	Gastropoda	Hirudinea	Diptera	Bivalvia
Functional feeding group	Shredder	Shredder	Grazer	Predator	Collector	Filter feeder
Test food	Alder leaf discs	Alder leaf discs	Spinach puree mats	2nd instar chironomids	Brine shrimp nauplii	Algal suspension
Feeding measured	*In situ*	*In situ*	Post-exposure	Post-exposure	Post-exposure	Post-exposure



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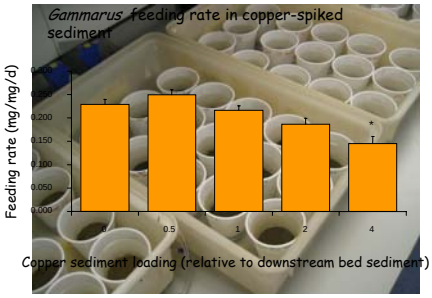
Placing caged "bioassay" organisms into the river above and below the outfall = Measurement of standard biological response

Measuring toxicity of specific sediment contaminants in laboratory exposures (and variation under the range of conditions found in the UK) = Investigation of mechanisms responsible

Sediment toxicity tests e.g.



Main conclusions from results to-date:

- Ecological impacts only observed where fine sediment (<63 μm) accumulates
- Sediment-associated PAHs are likely to be important toxins
- Soluble pollutants = acute toxicity
- Sediment-associated pollutants = acute and chronic toxicity

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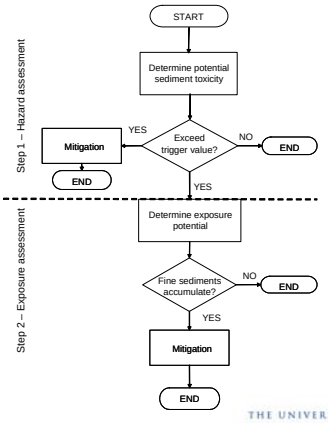
Project Objectives Stage 3

- To devise an assessment and prediction procedure for the impact assessment of the ecological effects of sediments arising from highway runoff on receiving watercourses.



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Thank you & any questions?

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