Dealing with uncertain data (RELU workshop)

Centre for Sustainable Water Management, Lancaster Environment Centre, 21st March 2007

# Faecal Indicator Organisms

Dr. Dave Chadwick

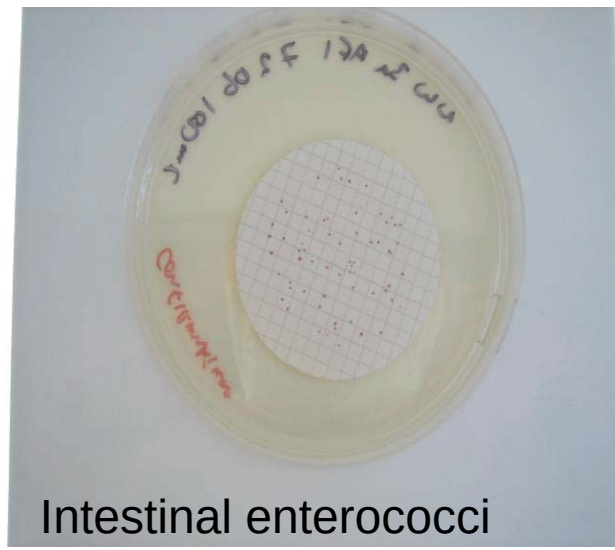
# Content

- What are FIOs?
- Why are we interested in them?
- Sources
- Survival
- Pathways
- Mitigation
- RELU project

# What are FIOs?

- Pathogens?
- Indicators
- Advantages

*Escherichia coli* (good guy)!



Intestinal enterococci

# Why are we interested in them?

- ‘Farm to Fork’



## The dark side of *E. coli*

Last month, the president of fast-food chain Taco Bell appealed to his customers in full-page ads in *The New York Times* and other US newspapers. “You can be confident our food is safe to eat,” his letter declared.

The ads were the fallout from a food-poisoning outbreak traced to the chain’s restaurants, which has affected at least 70 people across five states. The culprit was *Escherichia coli* O157:H7 — the same as in another outbreak this September and October linked to Californian spinach, which infected nearly 200 across the country and killed three.

The outbreaks have thrown the spotlight on a bacterium that is difficult to detect and virtually impossible to treat or eradicate. “We see it more and more and we don’t really know what to do about it,” says microbiologist John Fairbrother

At a meeting earlier this year on pathogenic *E. coli*, veterinary researcher David Smith of the University of Nebraska, Lincoln, and his colleagues reported that a vaccine containing proteins from O157 cut the number of cows shedding bacteria by 60–70%. Canadian company Bioniche Life Sciences, based in Belleville, Ontario, has submitted the vaccine for regulatory approval in Canada, and plans to do so in the United States.

Other groups are turning to viruses, called bacteriophages, that attack the O157 strain. A group led by microbiologist Todd Callaway of the US Department of Agriculture’s Food and Feed Safety Research Unit in College Station, Texas, has found that feeding sheep a mixture of bacteriophages cuts the number of pathogenic bacteria in their guts by over 1,000 times.

Cattle farmers may be forced to adopt vaccines or therapies because of pressure from food processors and the threat of lawsuits. But some microbiologists question whether these

**Green menace? *E. coli* O157 can spread if greens such as spinach are irrigated with tainted water.**

J. ERNST/REUTERS

# Why are we interested in them?

- ‘Farm to Field’

electronic Telegraph ▸www.telegraph.co.uk ▸ UK News Summary

BUY ISSUE 1544 Tuesday 17 August 1999

## Holiday girl dies as E-coli hits resort

By Sean O'Neill

External Links

The E. coli index - Birmingham University

What the heck is an E. coli? - Bugs in the News

E coli reference centre - Pennsylvania State University



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He and his wife, Julie, had taken Heather and her sister, Suzanne, 10, to Dawlish Warren because they believed it to be clean. He said: "There are three children from three different parts of the country who came here at the same time and caught this disease. The beach seems to be the common factor.

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Last Updated: Friday, 3 September, 2004, 13:20 GMT 14:20 UK

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**Health experts investigating an E.coli outbreak in north Cornwall believe its most probable cause was pollution from cattle grazing on fields near a stream.**

E.coli bacteria can cause serious infection

Warning signs were put up at Watergate Bay, near Newquay, after 12 people were reported to be suffering from an E.coli 0157 infection.

Soil samples are now being taken from the area around the bay.

The people who became infected included several children who had all paddled in the same stretch of a stream.

**Cattle manure**

Warning signs were put up at the bay after the outbreak.

Nick Hibbet, head of environment and health for Restormel Borough Council, said the incident appeared to be the result of an unusual chain of events.

He said: "What we're seeing with this particular case is that over a period of three days there was very heavy rainfall at the same time as the Boscastle incident.

"There were massive amounts of cattle manure finding their way into the stream.

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E.Coli 0157 is "relatively rare infectious gastroenteritis, which

# Why are we interested in them?

*Escherichia coli O157*, *Salmonella* spp,

*Campylobacter* spp & *Cryptosporidium parvum*.

- Gastro-intestinal illness estimated to cost the UK economy over £1 billion per annum.
- *Escherichia coli* O157 alone may cost the UK around £30M annually in healthcare
- Waterborne micro-organisms responsible for c 25% of hospital patients throughout the world.

# Legislation – EU Directives

- Shellfish Waters

- Bathing Waters

# Bathing Water targets

- UK compliance with the EU Bathing Waters Directive was 98% in 2003, compared with 77% in 1990, primarily due to capital investment in water treatment works.

  Current standard is 95%'tile *E. coli* of 2,000cfu per 100ml);

- Revisions to the Directive, with stricter water quality standards, will result in reduced compliance*:

  > 15.5% will not achieve 'Good' status (95%'tile FC Standard of 500cfu per 100ml);

**Based on Environment Agency analysis of 2001-2004 bathing water season (15th May to 30th September) data.*

# Revised Bathing Water targets

- A 4-tier classification system
  - poor, sufficient, good and excellent.
- All bathing waters - at least ‘sufficient’ by end of 2015 season.
- If not, requirement to identify sources and implement actions

**Quality standards in the revised Bathing Water Directive**

| Parameter (cfu/100ml) | Excellent quality | Good quality | Sufficient quality |
|---|---|---|---|
| Intestinal Enterococci | 100[1] | 200[1] | 200[2] |
| *E. coli* | 250[1] | 500[1] | 500[2] |

[1]Based on a 95 percentile evaluation
[2]Based on a 90 percentile evaluation

# Source of FIOs - livestock

## Steadings


# Source of FIOs - livestock

Slurry, solid manure, dirty water spreading

# Source of FIOs - livestock

Grazing


tracks

# Example, intensive dairy farm

- 150 lactating animals, 120 followers

- Generate *ca*. 5000 t of excreta per year

    - *ca*. 3000 t during housing (180 d)
      collected as slurry and stored before spreading
      - spread in spring, summer (and autumn)

    - *ca*.  2000 t at grazing (185 d)

1 t of fresh slurry might contain anywhere between $1 \times 10^{10}$ and $1 \times 10^{14}$ viable *E coli* cells.

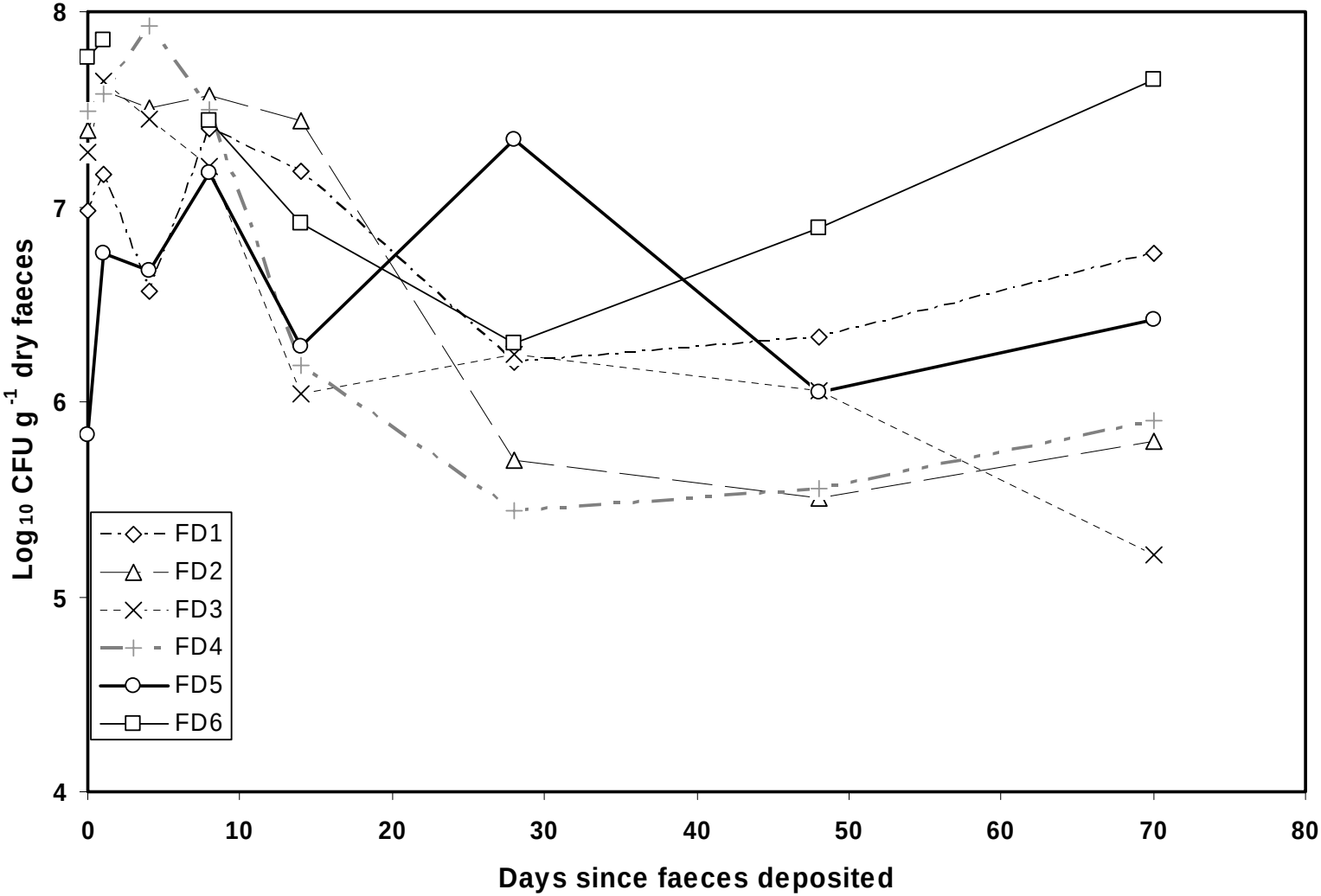
# Don’t forget the human source !

- Septic tanks

# Survival

- Factors
- Abiotic
  - Dessication
  - UV
  - Temperature
  - Nutrients?
  - Biotic - Predation

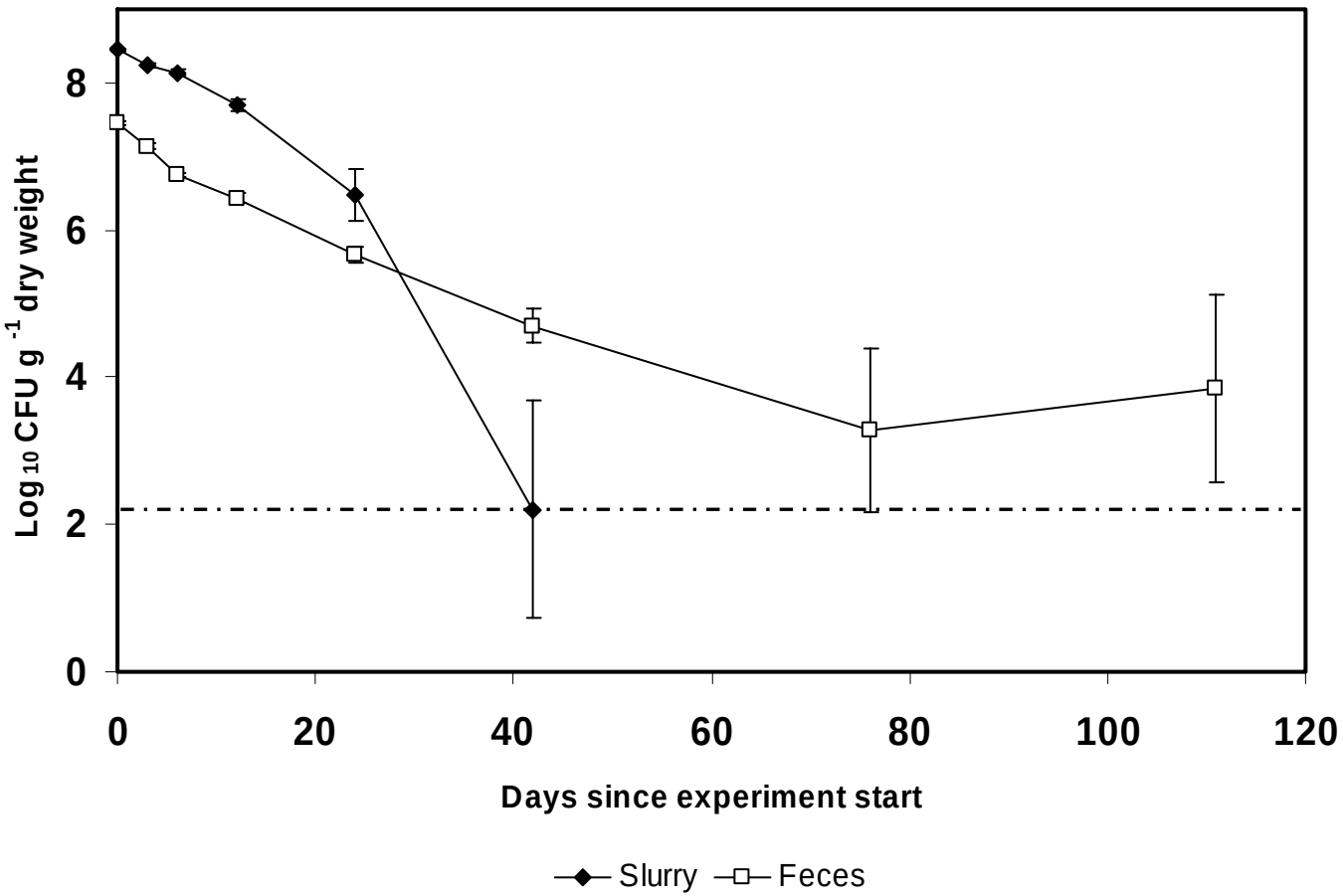
# Survival – in faeces




6 reps of faecal deposits: decline of *E. coli* in faeces deposited in the field

(Start month = July, exposed to rainfall)

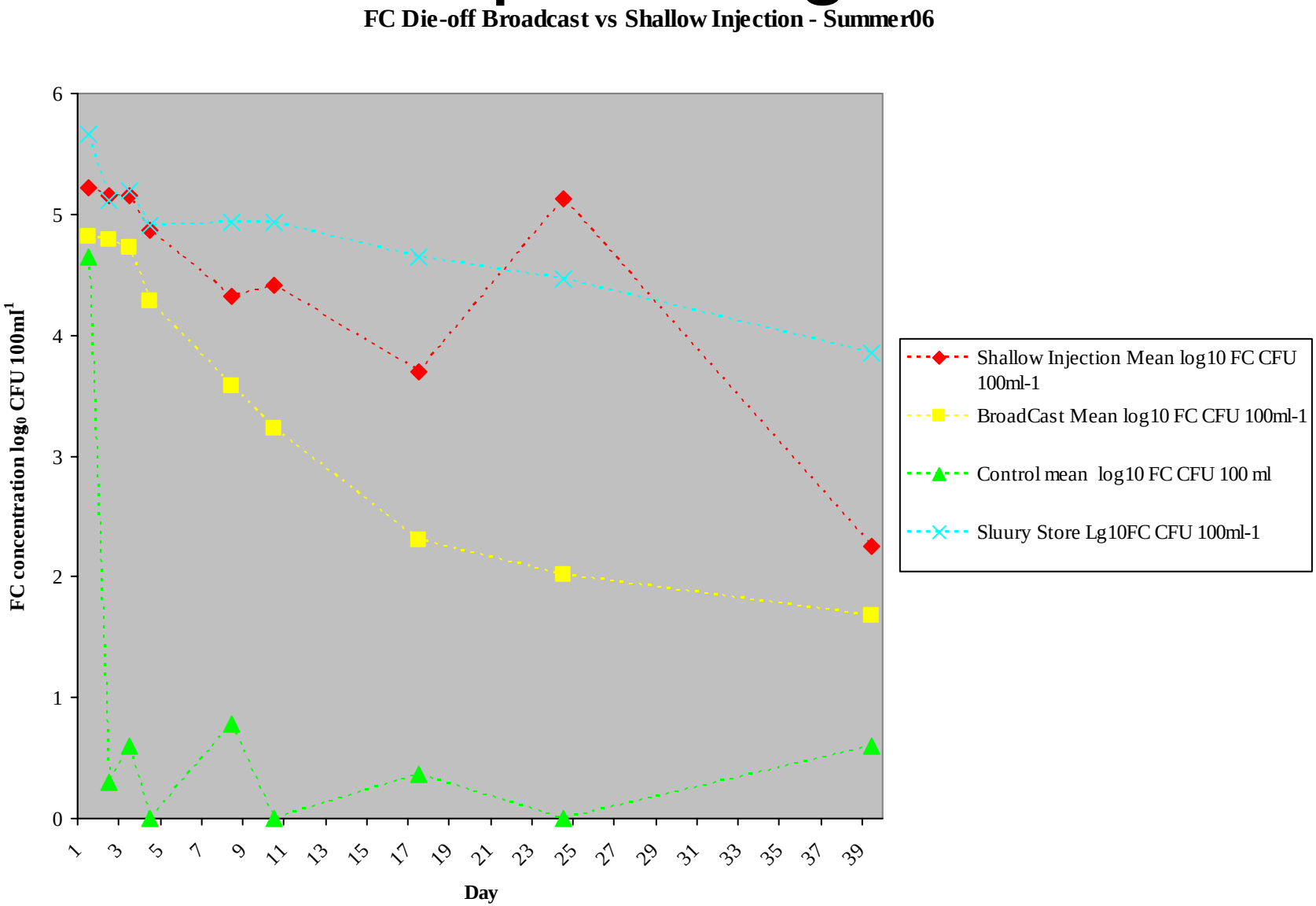
# Survival – comparison in slurry and faeces




Lab survival (*E. coli*) fresh slurry vs cow faeces at 15$^{o}$C

Dashed line = limit of detection

# *E coli* survival – after slurry spreading



# IE Survival – after slurry spreading

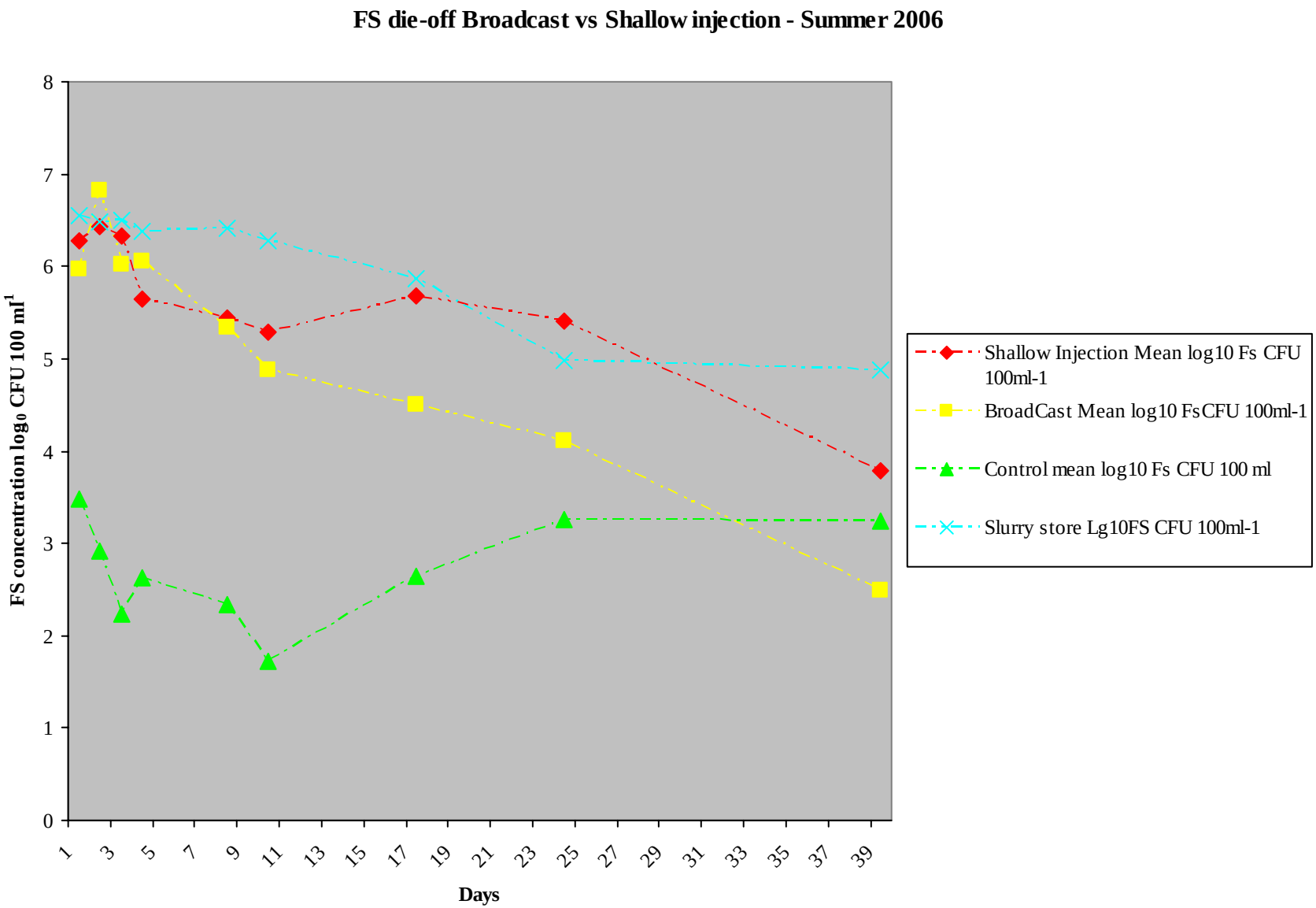


**Table 1 FC Die-Off, Summer 2006**

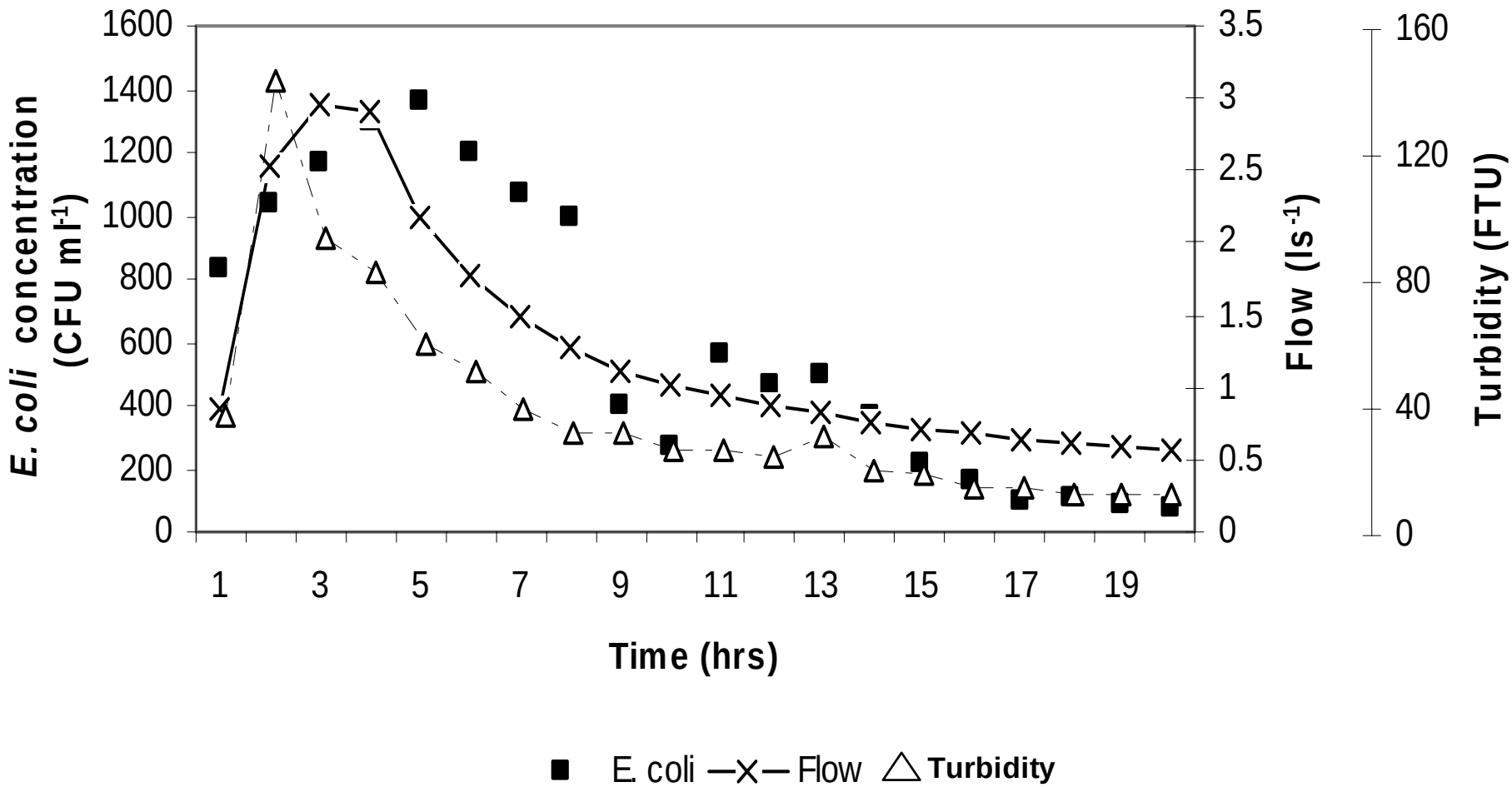
| Treatment | Equation | $R^2$ | Prediction days |
|---|---|---|---|
| Shallow injection | y = -0.0619x + 5.208 | 0.6469 | 84 |
| Broadcast | $y = 4.7199e^{-0.0307x}$ | 0.9216 | 50 (?) |
| Slurry | y = -0.0375x + 5.3058 | 0.8814 | 141 |

**Table 2 EI Die-Off, Summer 2006**

| Treatment | Equation | $R^2$ | Prediction days |
|---|---|---|---|
| Shallow injection | y = -0.0563x + 6.264 | 0.793 | 111 |
| Broadcast | y = -0.1003x + 6.3353 | 0.9388 | 63 |
| Slurry | y = -0.0498x + 6.6335 | 0.9107 | 133 |

# Survival – after grazing

Storm event, 38 days after cattle removed. Mole drain pathway



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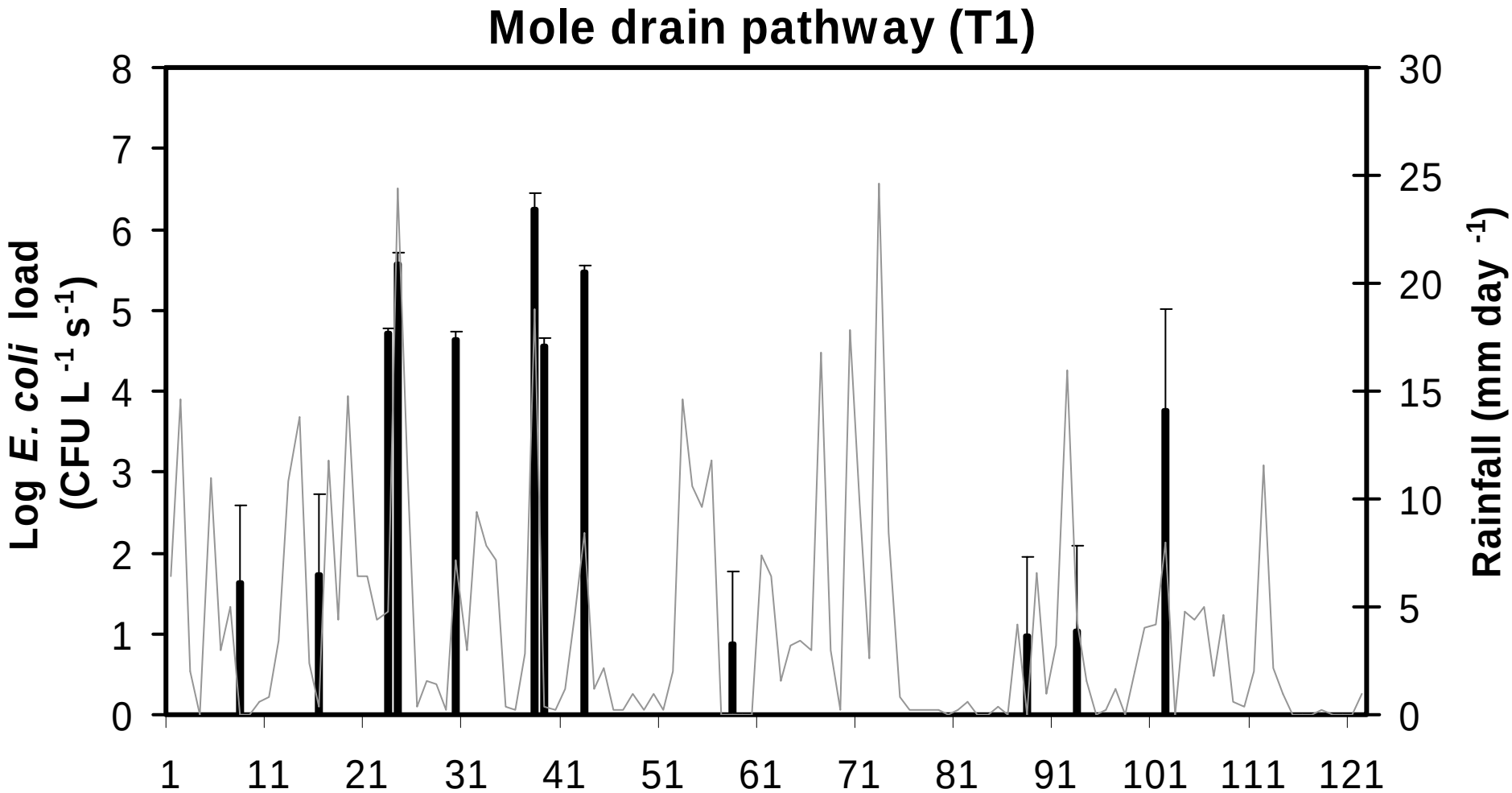
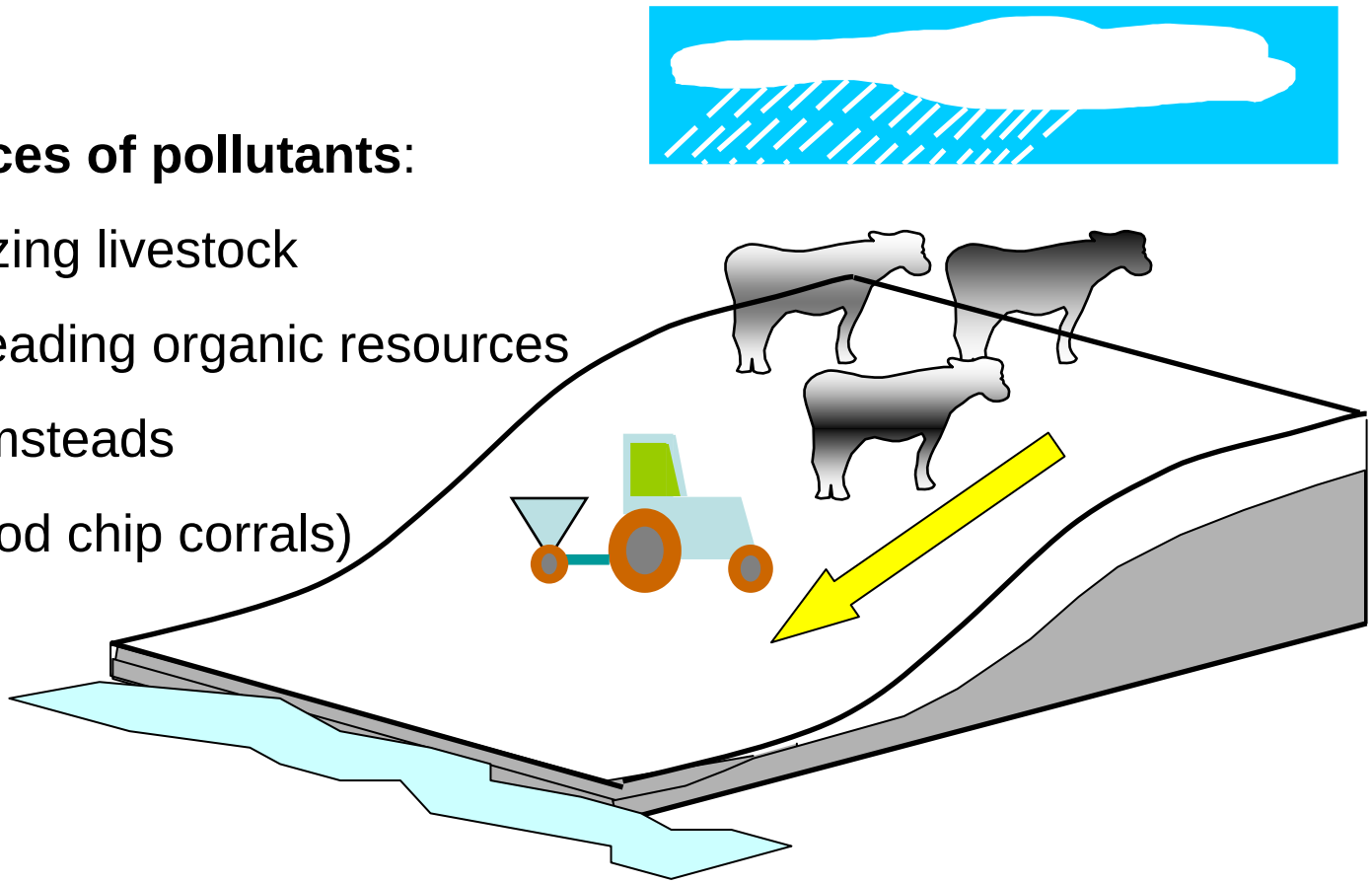


# Pathways to water

**Sources of pollutants**:

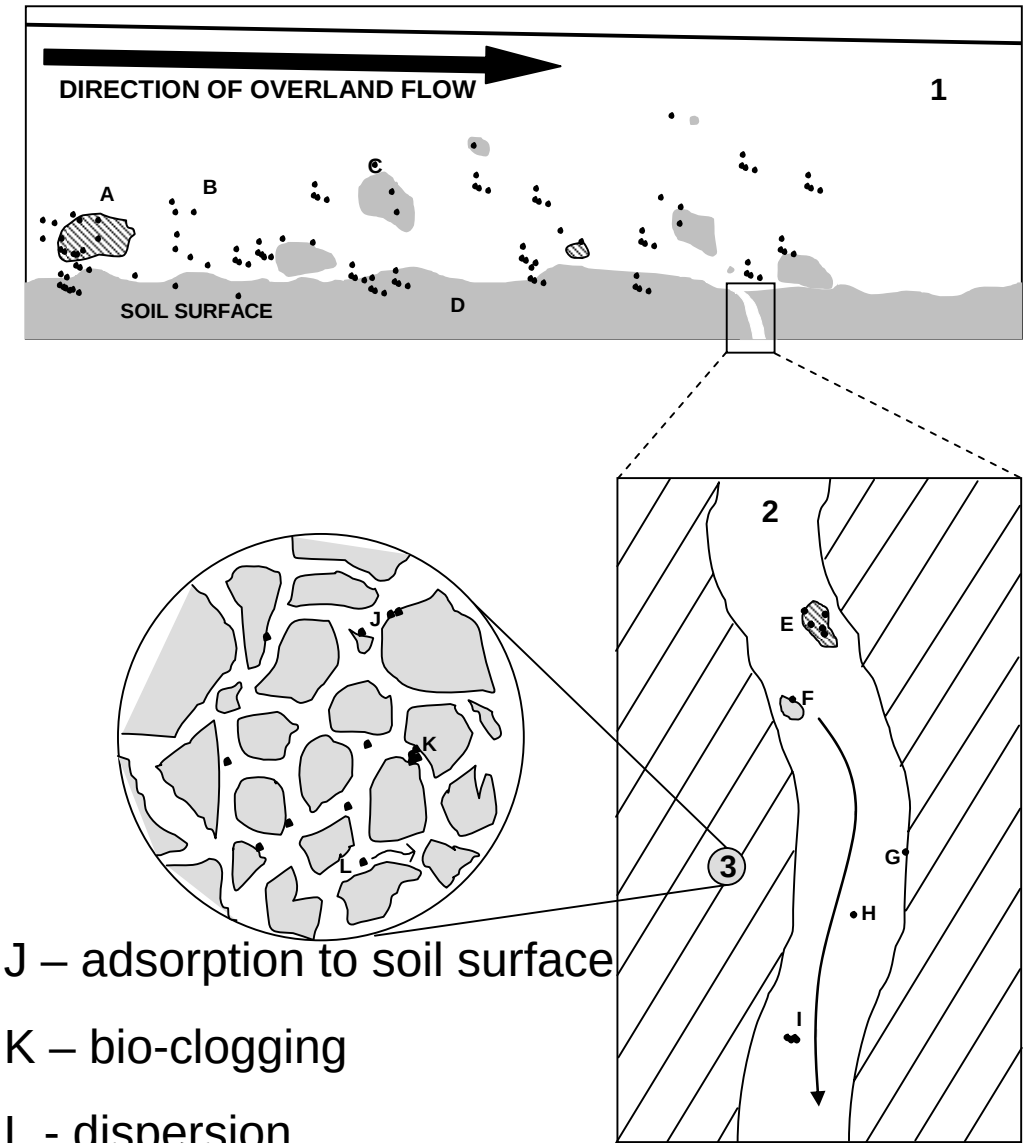
- Grazing livestock
- Spreading organic resources
- Farmsteads
- (Wood chip corrals)



**Pathways:**

- Preferential flow
- Overland flow
- Leaching
- Livestock in streams
- Aerosols

# Pathways to water




A – faecal material

B – free suspension

C – soil particle

D – retention on soil surface

E – faecal material

F – soil particle

G – adsorption to soil surface

H – free suspension

I – microbial flocs

J – adsorption to soil surface

K – bio-clogging

L - dispersion

# Mitigation

## Source

- Batch store slurry
- Compost solid manure
- Siting field heaps
- Export manure
- Reduce stock numbers

## Mobilisation

- Limit application rate
- Don’t apply at high risk times
- Don’t apply to high risk areas
- Don’t leave manure of surface
- Adequate storage capacity

## Delivery

- Prevent direct access to streams
- Grass buffer strips (tilled land)
- Riparian buffers
- Wetland systems

(Defra User Manual, Cuttle et al., 2006)

RURAL ECONOMY AND LAND USE

# Sustainable and holistic food chains for recycling livestock waste to land

Dr. Dave Chadwick, Dr. Chris Hodgson (IGER)
Prof. Louise Heathwaite, Dr. David Oliver (Lancaster University)
Prof. Michael Winter, Dr. Theresa Selfa (University of Exeter)

IGER

UNIVERSITY OF EXETER

LANCASTER UNIVERSITY

# Background

*‘If tourism is the South West’s jam and clotted cream, farming is the scone upon which that luscious concoction perches’*

(http://www.nfuonline.com)

ISSUE 1544 Tuesday 17 August 1999

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BBC
BBC Cornwall
Surfing news, webcams and more from the BBC website for Cornwall

SEE ALSO:
Stream tested over E.coli scare
02 Sep 04 | Cornwall
Inquiry into E. coli infections
16 Jul 04 | Health
E. coli
08 Feb 03 | Medical notes

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Winners and losers in roads plan
China clay job cuts close docks

# Background

- Sources
- Mobilisation
- Pathways
- Survival
- Delivery
- Downstream impacts

# Aims

To determine the potential impact of introducing changes in management to control FIO transfers from:

- grazing livestock
- manures (slurry, dirty water, solid manure)
- other waste streams (e.g. biosolids)

And determine the impact on:

- Farm economics
- Practicalities at the farm level

And ‘knock-on’ effects on:

- local communities
- Industries

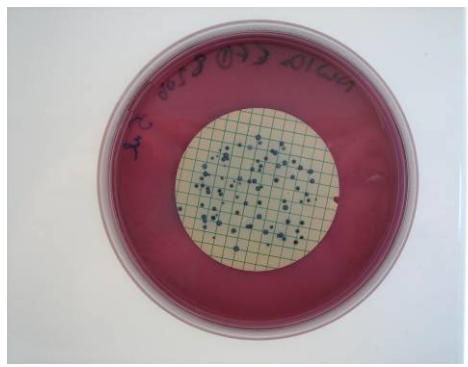
**Using a multi-scale approach from farm to regional level**

# Approaches - Farm and Regional Scale

- Determine current perceptions

- Undertake risk assessments of FIO transfers to the food chain

- Undertake targeted monitoring on farms (up to 10)

- Encourage changes in management practices to reduce risk of FIO transfers

- Assess impacts of changes in practices at the farm level on costs

- Assess costs, practicalities and applicability of FIO control measures on farms and impacts on **local communities and industries**

# Approaches - Farm and Experimental Scale

- Review pathogen/FIO controls measures

- Conduct additional experiments to determine:
  - controls on FIO survival on farmsteads
  - factors controlling FIO survival in soil following dung deposition/waste applications
  - mechanisms of FIO transport

Results from these studies will be used for:
- on-farm risk assessments
- measuring the impact, costs and applicability of on-farm management practices

# Farm / Field

# Catchment / Regional

**Farmer interviews**
Perceptions
Management
Hydrology/topography
Economics

**Farmer / stakeholder**
Questionnaire
Discussion groups
Citizen jury

**Risk assessment**
Farm-based tool
- Physical RFs
- Social RFs

**Monitoring**
Current
***Induce change***

**Risk assessment**
catchment

**Experimental**
Controls of survival
Transport mechanisms

**Regional impact**
Current
future

# Uncertainty