PRIORITISING INTERVENTIONS TO REDUCE DIFFUSE MICROBIAL (FIO) POLLUTION FROM AGRICULTURAL SOURCES TO COASTAL WATERS

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1. Significance of agricultural FIO sources[(a)]

PRIORITISATON OF MEASURES:

2. What are key contributing areas on farms?[(b)]
3. How effective are mitigation measures?[(b)]
4. Which parts of catchments should be targeted?[(c)]

Based on:
(a) Catchment studies undertaken by CREH and as part of EA's CSF initiative;
(b) Empirical studies and updated reviews funded by Defra project WQ0203; and
(c) Lab simulation/modelling work undertaken on behalf of EA and SEPA (via CREW)

CREH

Broad review of empirical data (‘ballpark’ figures)

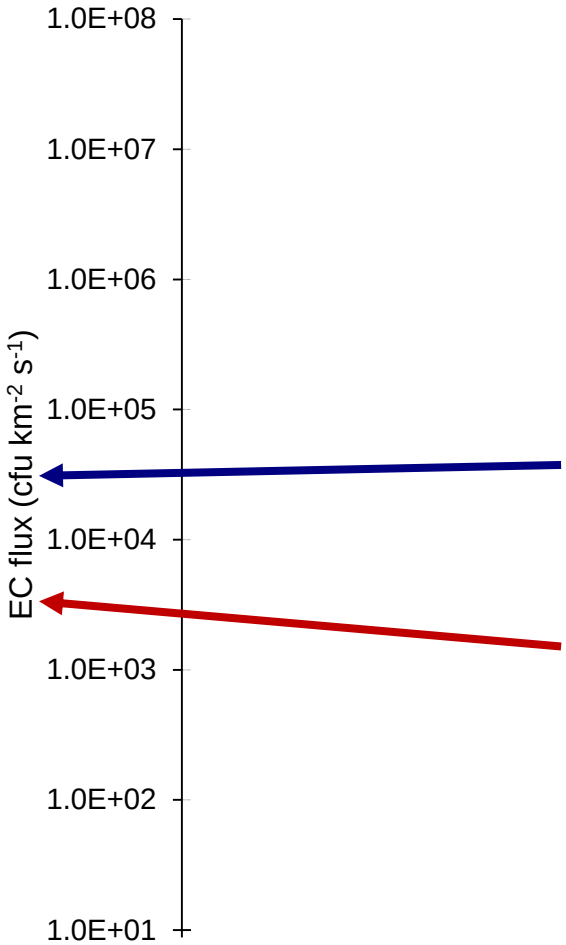
1. Significance

Agriculture (livestock farming) often accounts for ≥ 40% of FIO fluxes to coastal waters

Pollution loadings increase *c*.100-fold following rainfall

- Greater volumes of flow
- More extensive areas affected surface flow
- Increased connectivity between pollutant sources and watercourses

Label



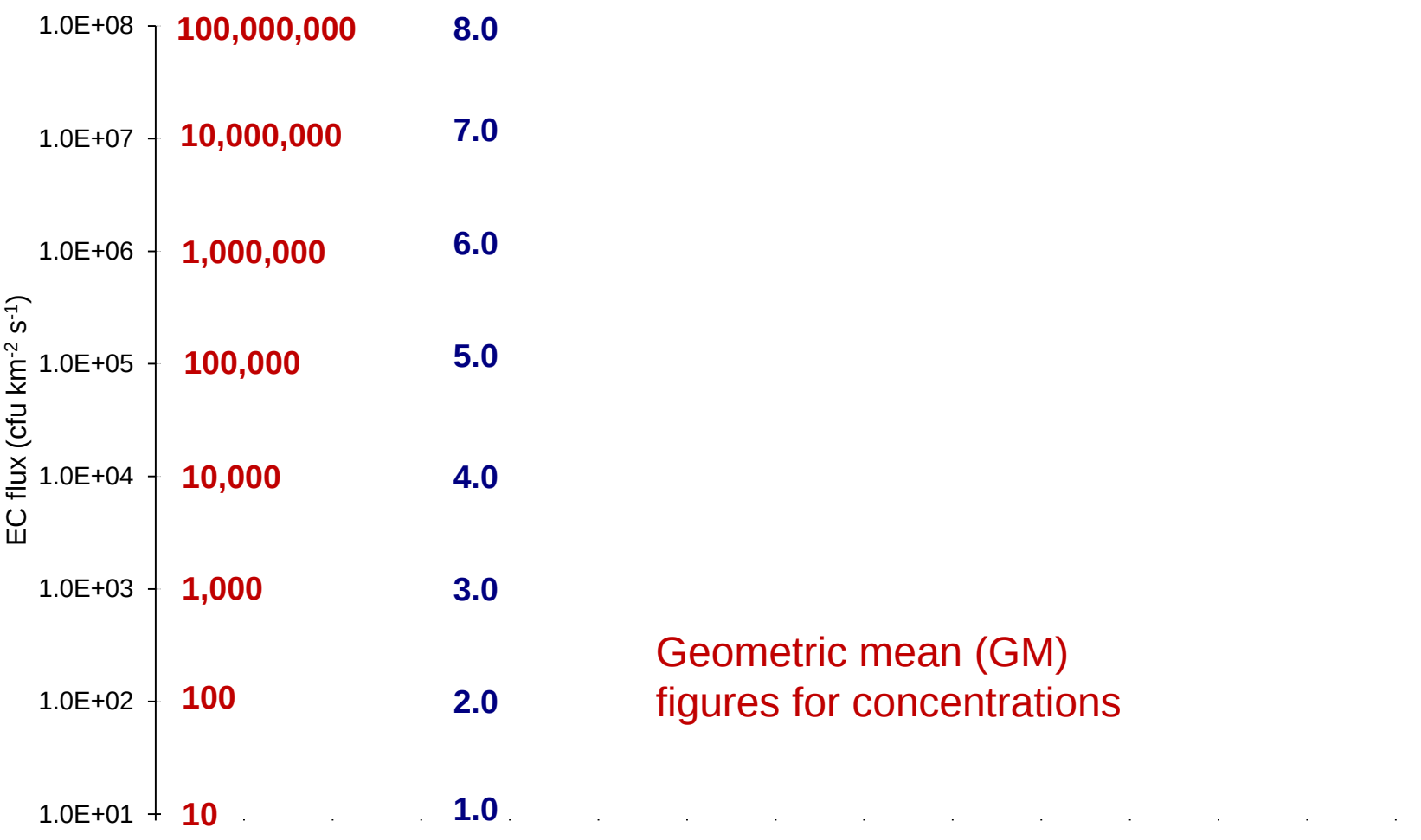
cfu = colony forming units

EC (*E. coli*, including presumptive EC)


Label
Actual
1.0E+08
100,000,000
1.0E+07
10,000,000
1.0E+06
1,000,000
1.0E+05
100,000
1.0E+04
10,000
1.0E+03
1,000
1.0E+02
100
1.0E+01
10
EC flux (cfu km-2 s-1)

Label	Actual	Log_{10}
1.0E+08	100,000,000	8.0
1.0E+07	10,000,000	7.0
1.0E+06	1,000,000	6.0
1.0E+05	100,000	5.0
1.0E+04	10,000	4.0
1.0E+03	1,000	3.0
1.0E+02	100	2.0
1.0E+01	10	1.0

EC flux (cfu km^{-2} s^{-1})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EC flux (cfu km-2 s-1)
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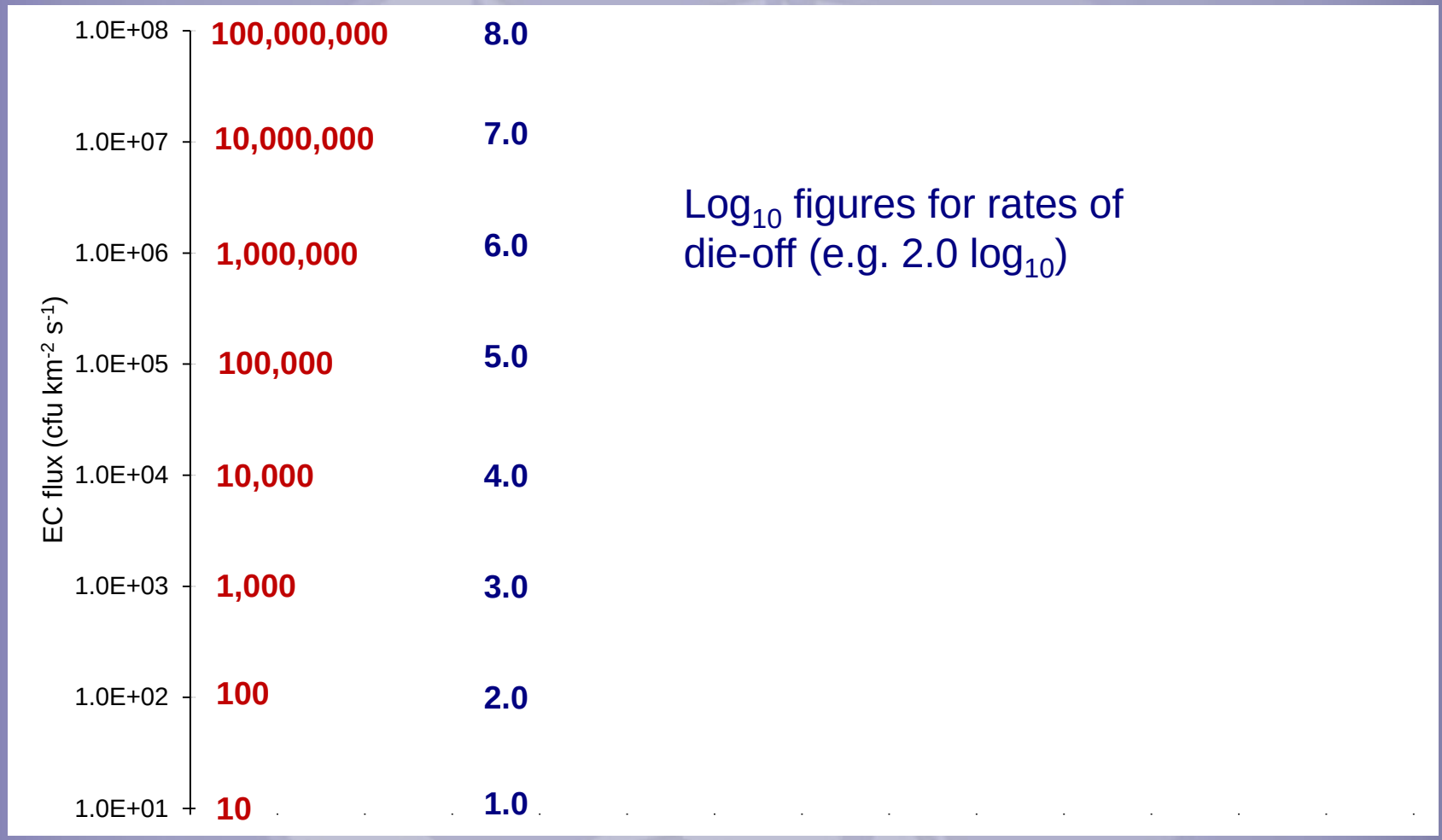
Geometric mean (GM) figures for concentrations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10,000
4.0
1.0E+03
1,000
3.0
1.0E+02
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10
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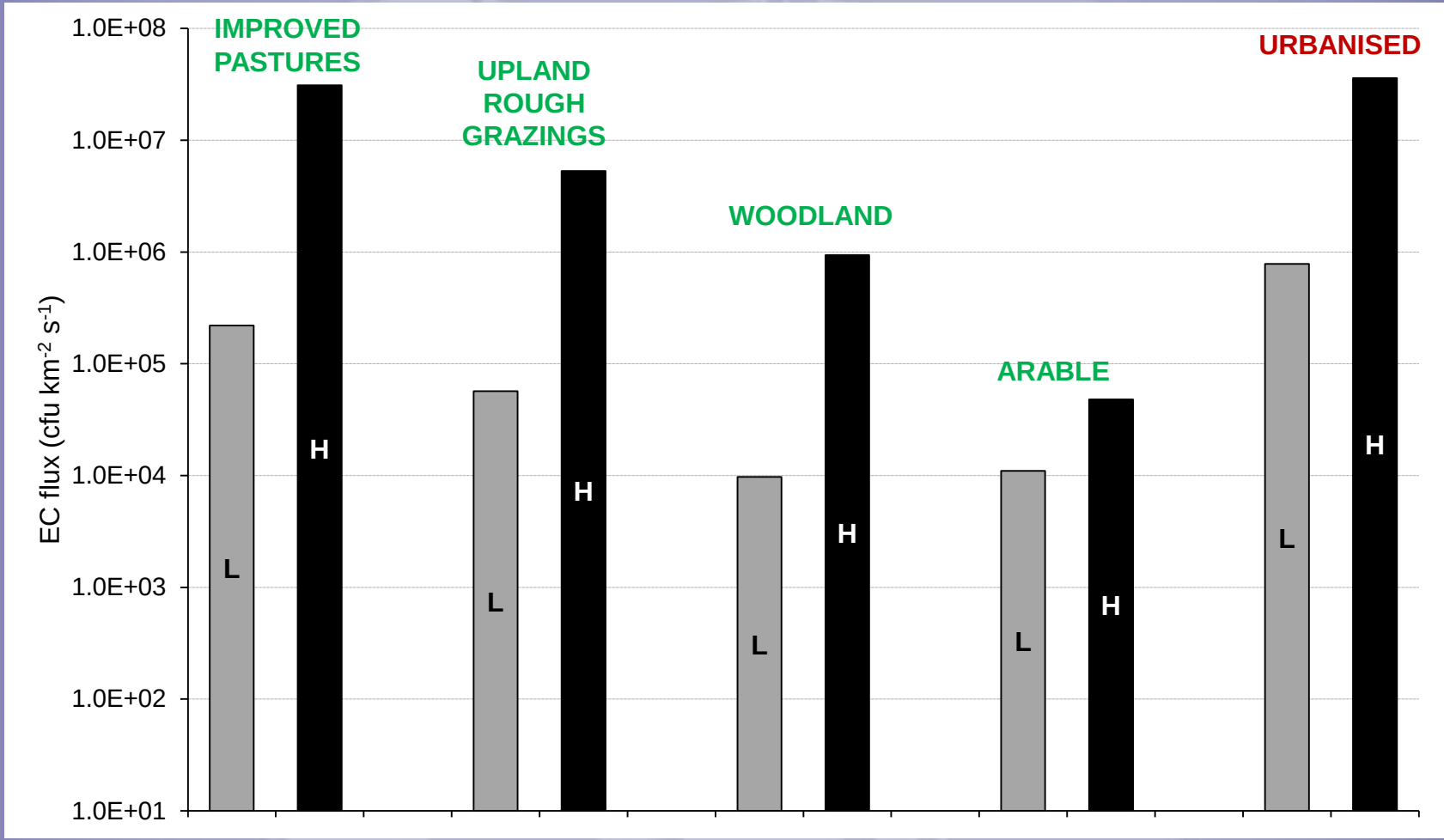
EC flux (cfu km-2 s-1)
Log10 figures for rates of die-off (e.g. 2.0 log10)



Summer bathing season GM EC fluxes under low and high flow conditions from rural catchments (< 2.5% built-up land) dominated by (≥ 66.7%) a single land use, with comparative data for urbanised catchments (≥10.0% built-up land)

2. Key source areas

(a) Farm steadings

Faecally contaminated ‘dirty’ waters from:

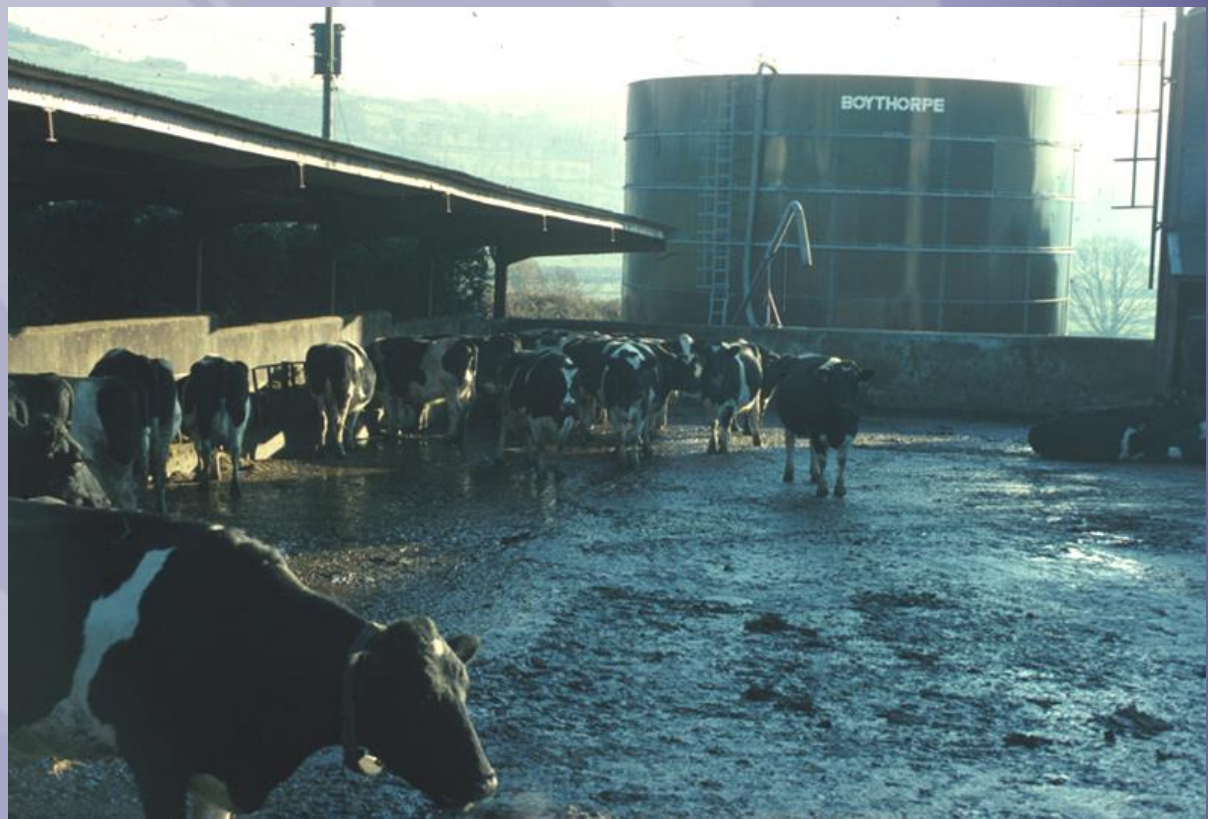
- Yard runoff (natural)
- Washings from buildings and yards

Obvious, and should be readily containable for:

Storage (as slurry) for subsequent ‘safe’ disposal to land

OR

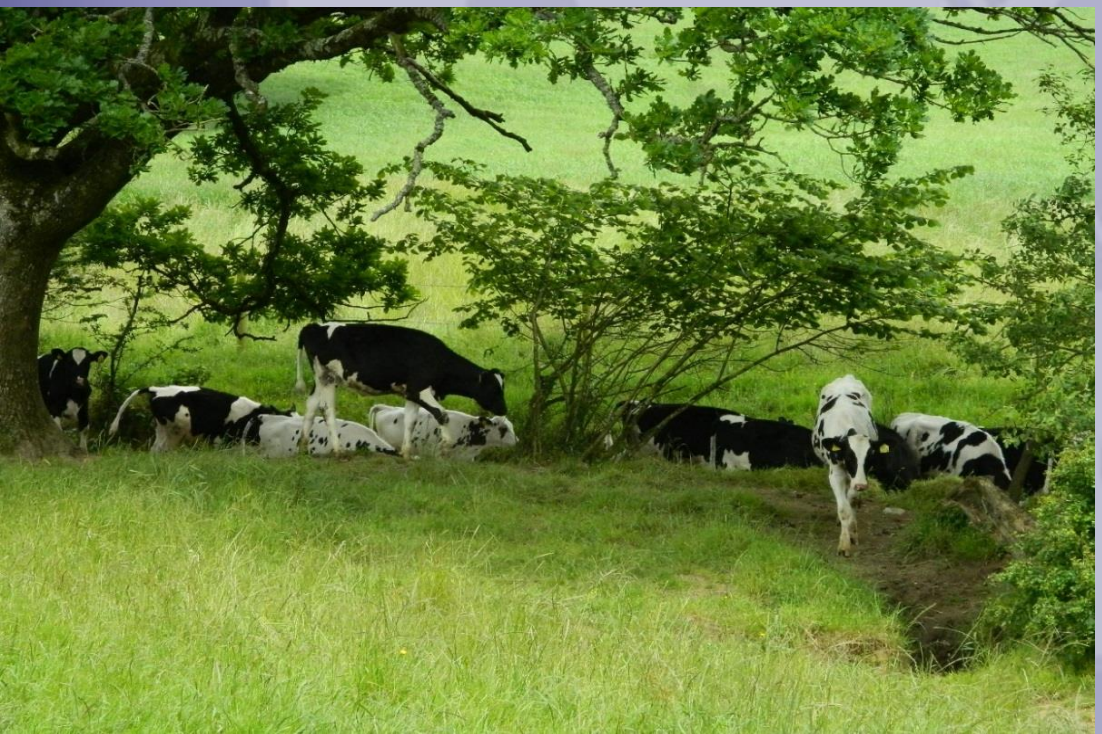
On-farm treatment



(b) Intensively grazed (particularly streamside) pastures

Key transmission routes:

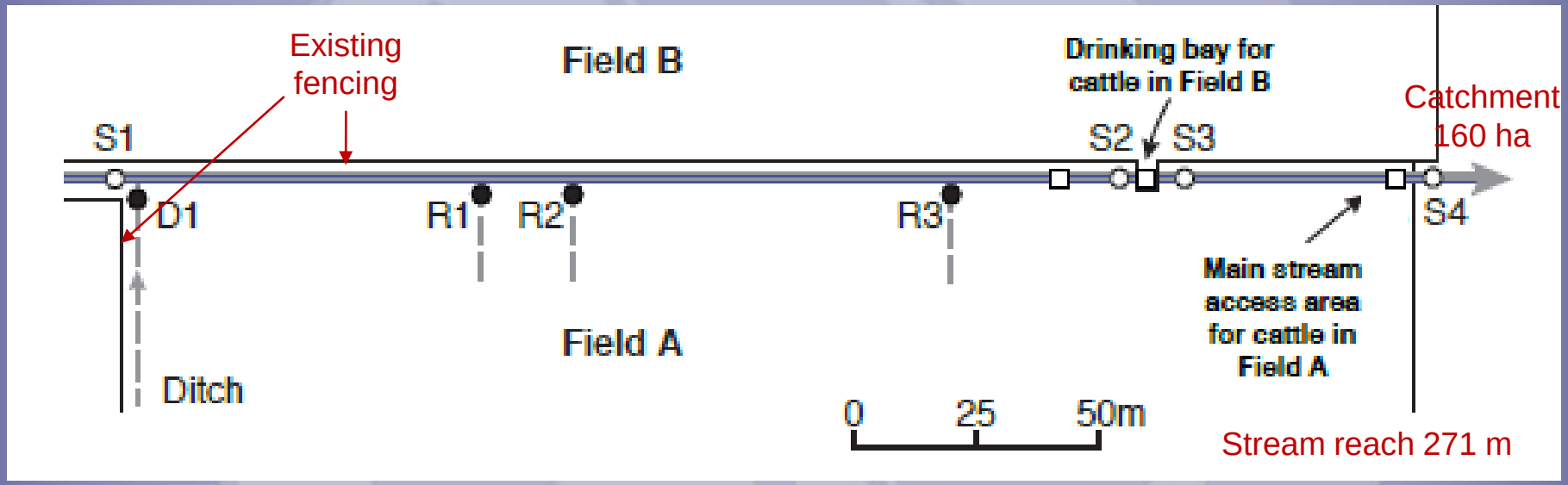
- Defecation to watercourses
- Surface runoff from pastures
- Track runoff
- Drain flow

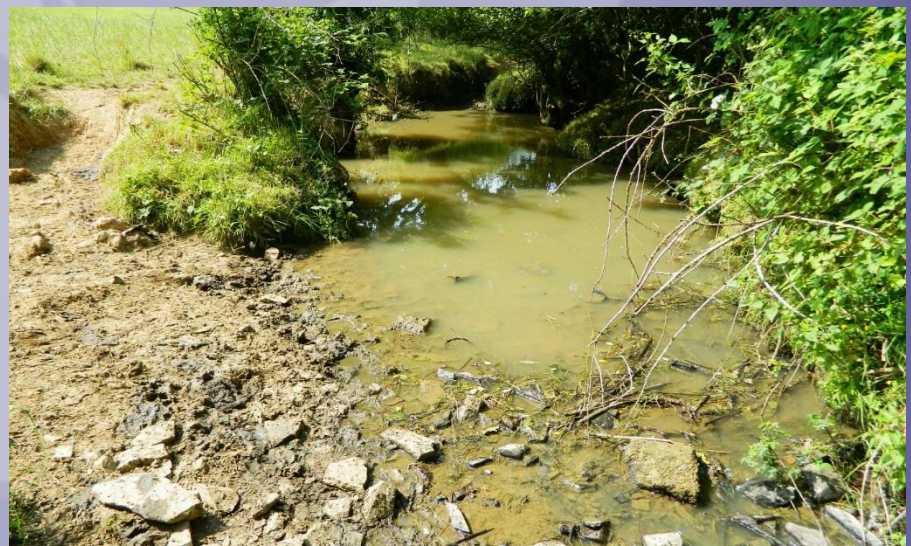


…. exacerbated along tracks and in congregation areas as result of poaching by livestock

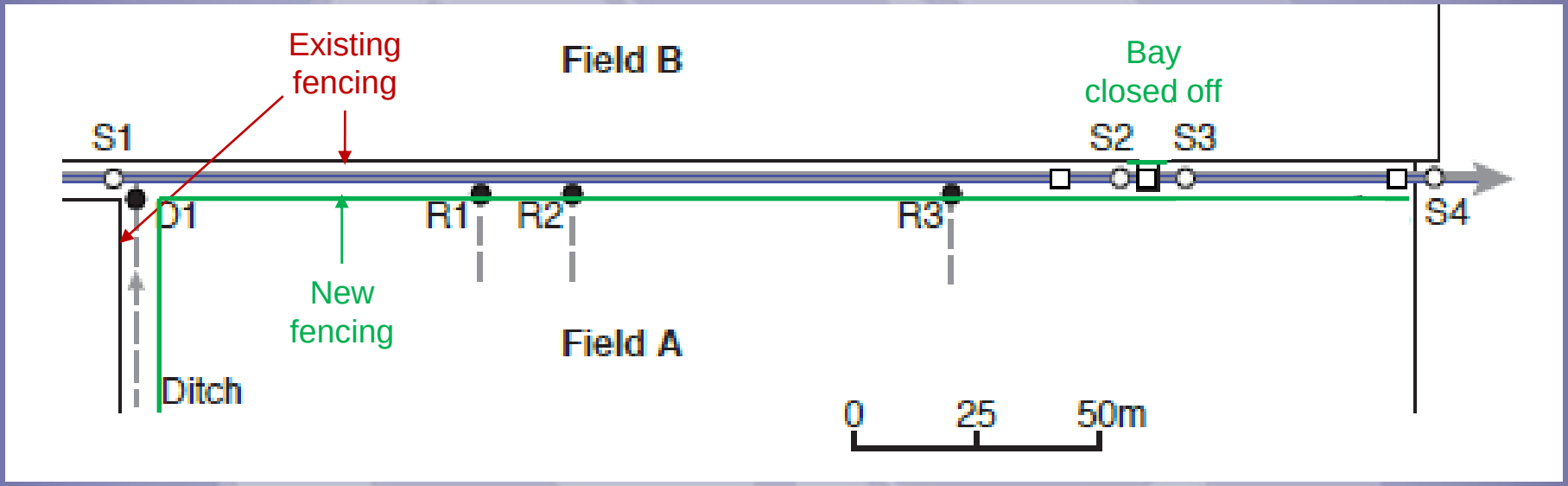
Case study (1): Field-scale SBF investigation, Tamar DTC

(a) Before intervention (Unfenced stream) [Summer 2013]





(b) After intervention (SBF + drinking troughs) [Summer 2015]



Main aims – to investigate (before/after intervention):

- Spatial distribution of cattle
- Changes in FIO concentrations/fluxes/input loadings down stream reach
- FIO concentrations in runoff from pastures

Key findings in terms of FIO sources*:

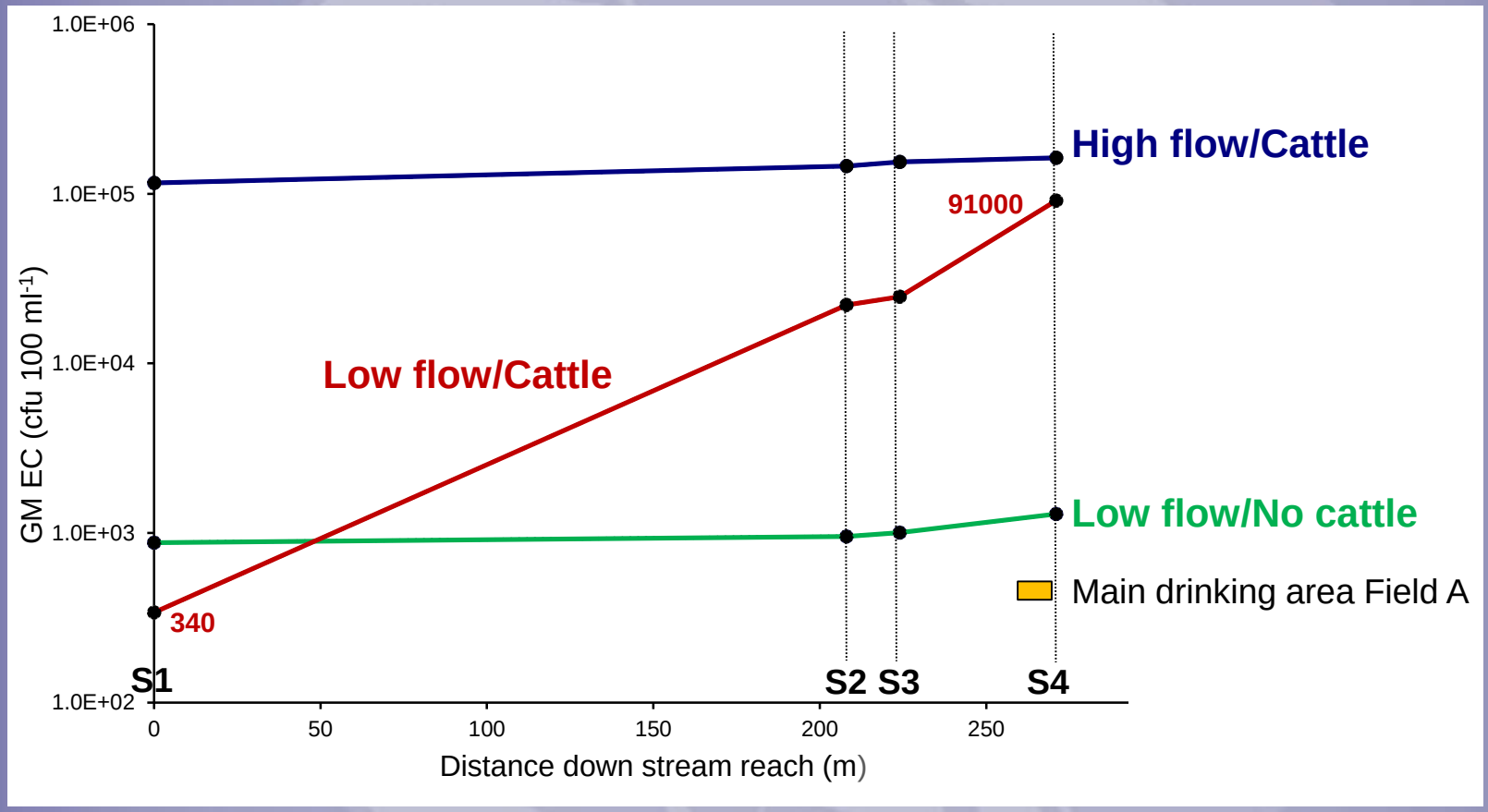
1. Where an unfenced stream is only water source, cattle spend a disproportionately large amount of time in the watercourse (3.1%) and riparian zone (9.4%) – other studies suggest that typically 5.7% of defecation is in watercourse.

2. Principal FIO transmission routes:

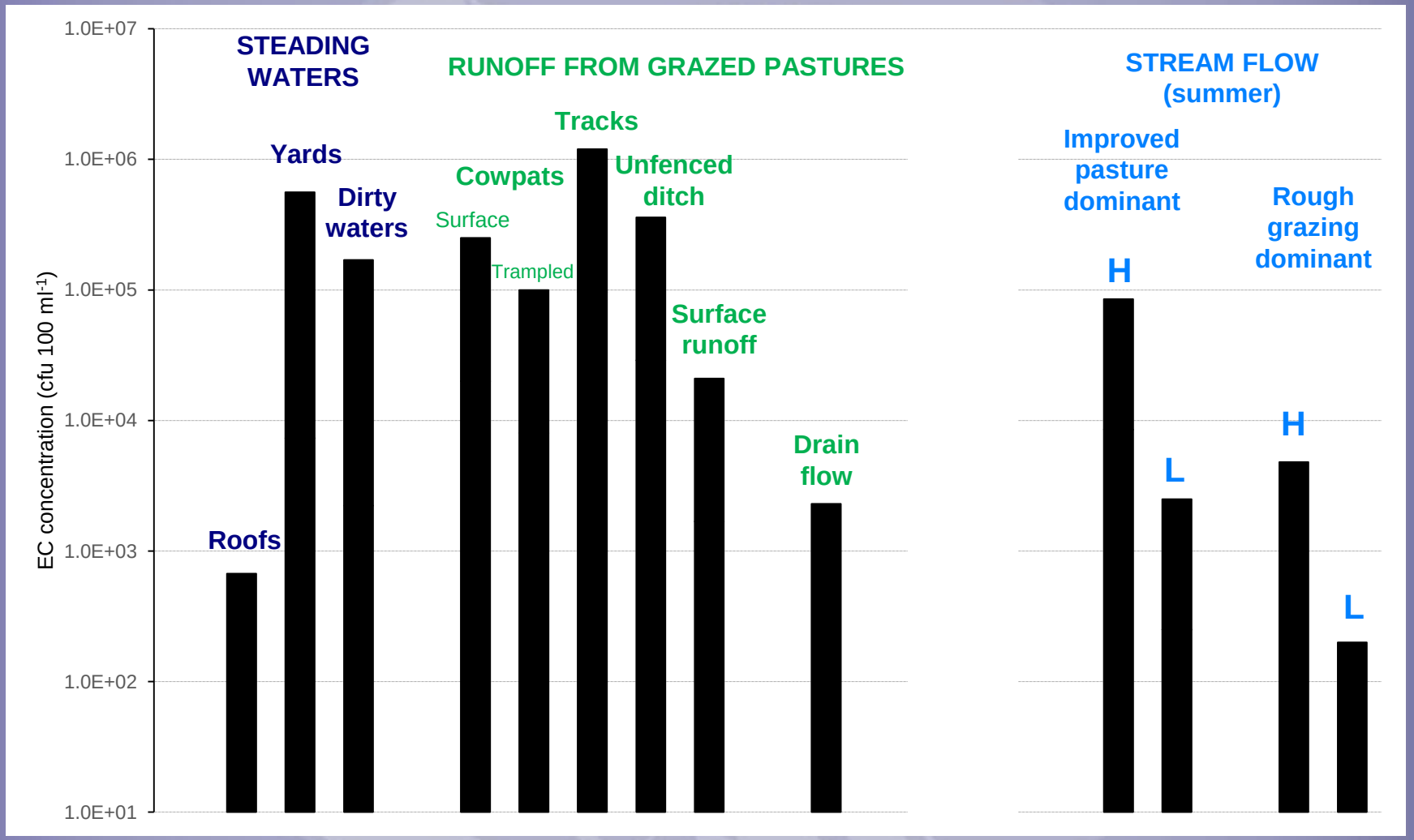
   - Defecation to the stream

   - Release/mobilisation of FIOs from cowpats at times of high flow as a result of:
     - Rising water levels in the riparian zone
     - Headward extension of ditch flow
     - Surface runoff from adjacent pastures

e.g. Changes in GM EC concentrations down stream reach prior to intervention



Literature survey data:



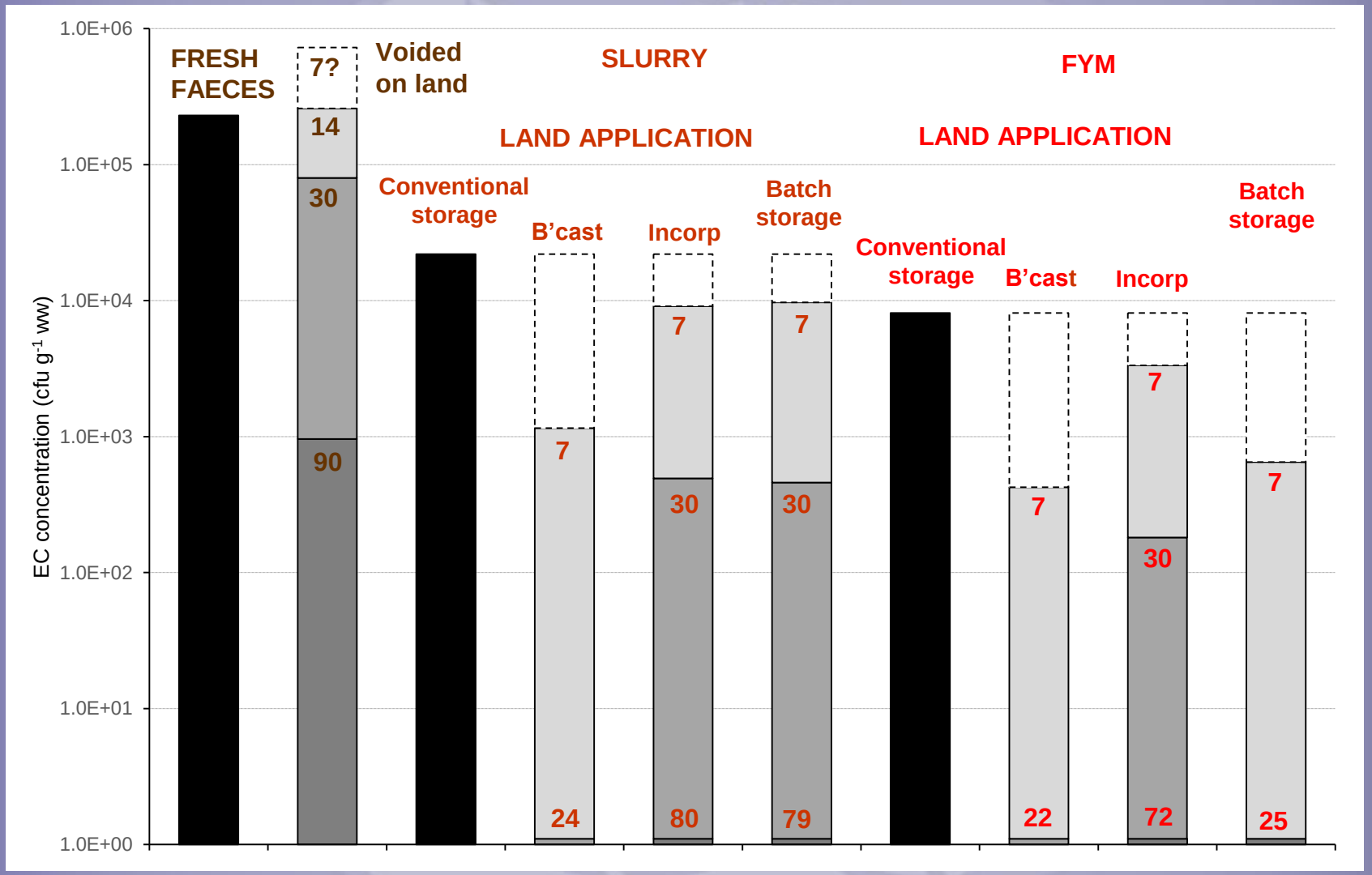
GM EC concentrations in stream flow from catchments

3. Effectiveness of mitigation measures

Underlying principles:

- Fresh faeces are most potent FIO source (FIOs generally die-off rapidly outside the animal gut)
- Keys to effective mitigation of FIO loadings delivered to watercourses:
  - Exposing faeces and faecally-contaminated materials to conditions that promote die-off
  - Reducing the speed of transmission of FIOs to watercourses, thereby increasing the time available for die-off

Literature survey data (Defra Project WQ0203):



EC concentration in cattle faeces at different stages of decay: FYM

Effectiveness of measures

Dirty water treatment

e.g. FWS Constructed farm wetland (CFW)

Measure	EC attenuation (Mean, log_{10})
FWS CFW	1.88
Other DW treatment systems	1.34-2.92

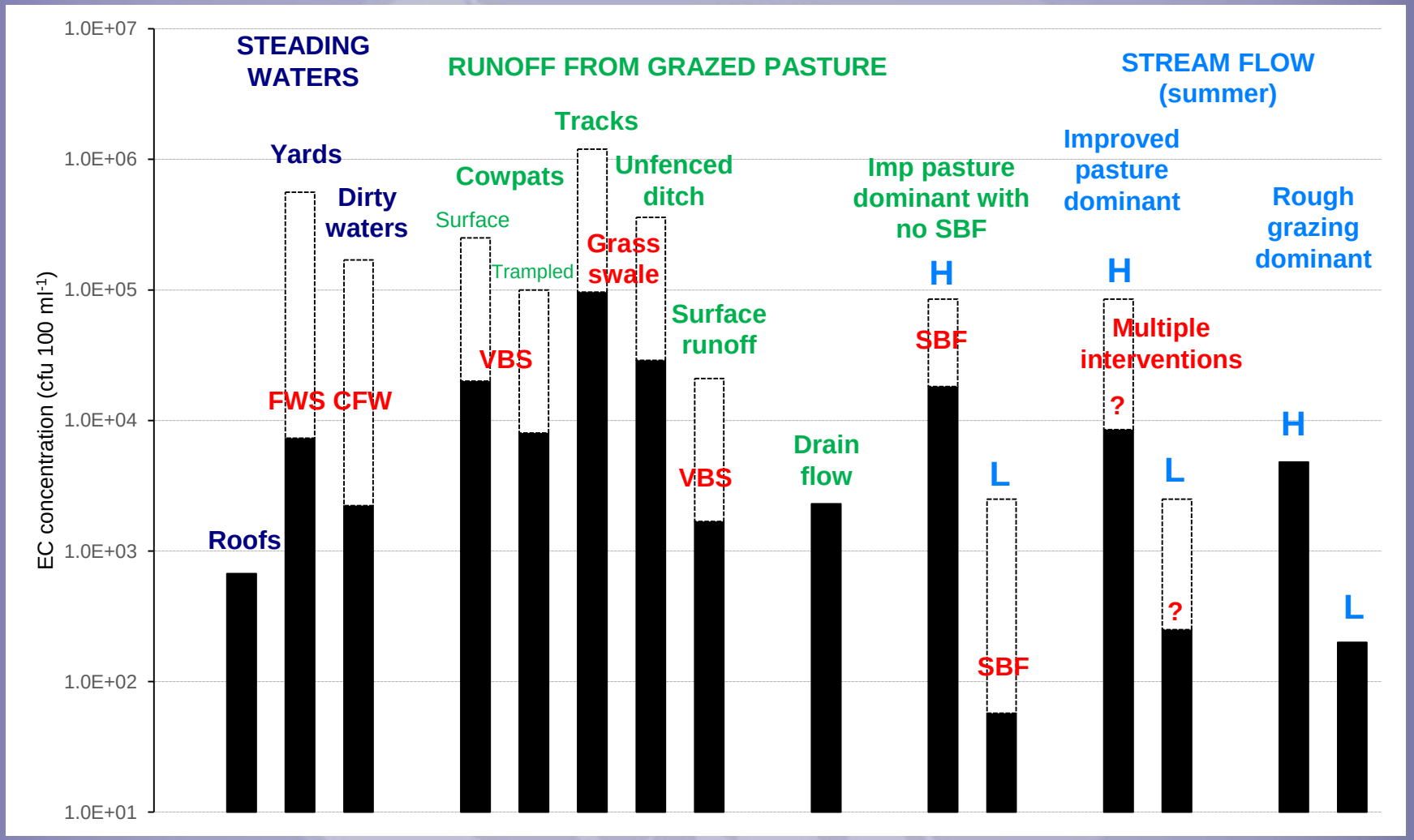
Pastures

e.g. Streambank fencing (SBF)

Measure	EC attenuation (Mean, log_{10})
SBF: Low flow*	1.64
SBF: High flow*	0.76
SBF + drinking bays: Low flow*	1.60
Veg buffer strips (VBS)/Swales	1.10

* Includes Tamar DTC data

Literature survey data (Defra Project WQ0203):



GM EC concentrations in catchment waters and impact of interventions

4. Targeting implementation of measures

Case study (2): Modelling die-off along watercourses

Key factors promoting die-off:

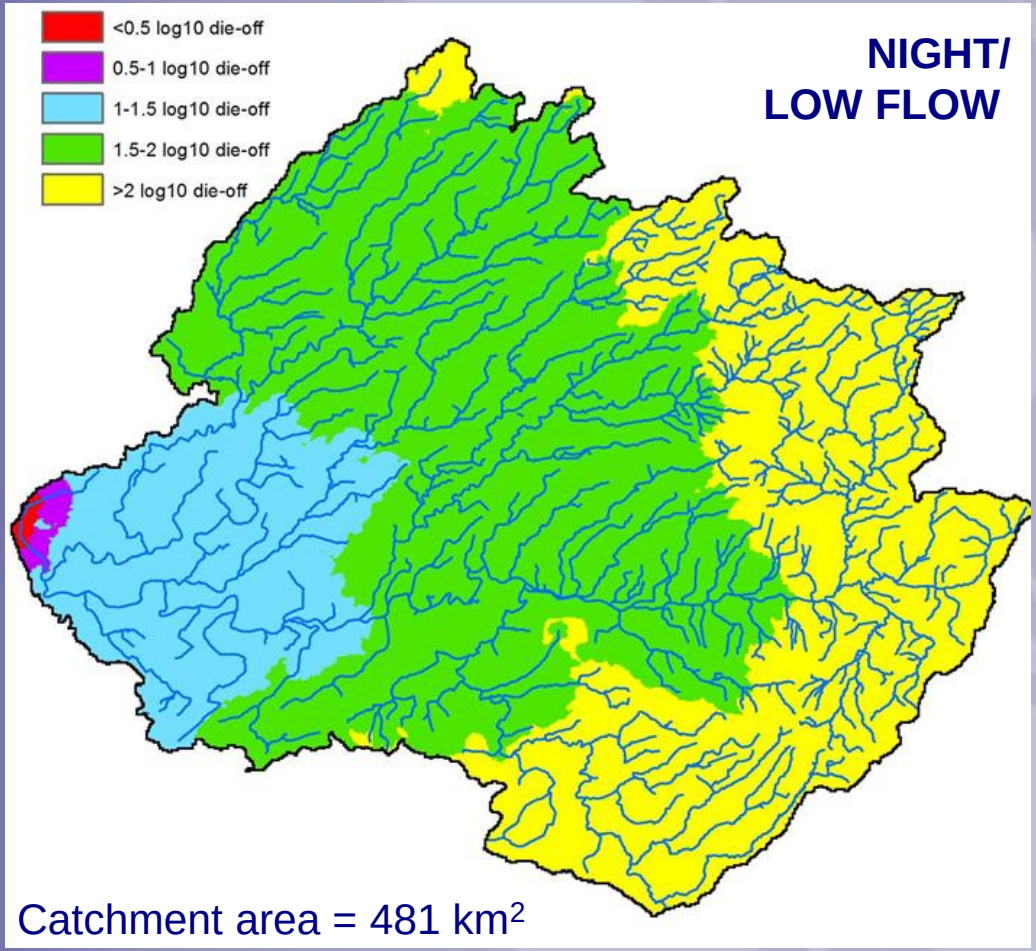
- Sunlight (UV)
- Clear water (not turbid)
- Low velocity of flow

Likely range of rates of die-off:

Conditions	Time for 1.0 log_{10} die-off
Very sunny/very clear water*	3 h
Very sunny/very turbid water*	20 h
Dark/Night time	50 h

* Range of values recorded for EC

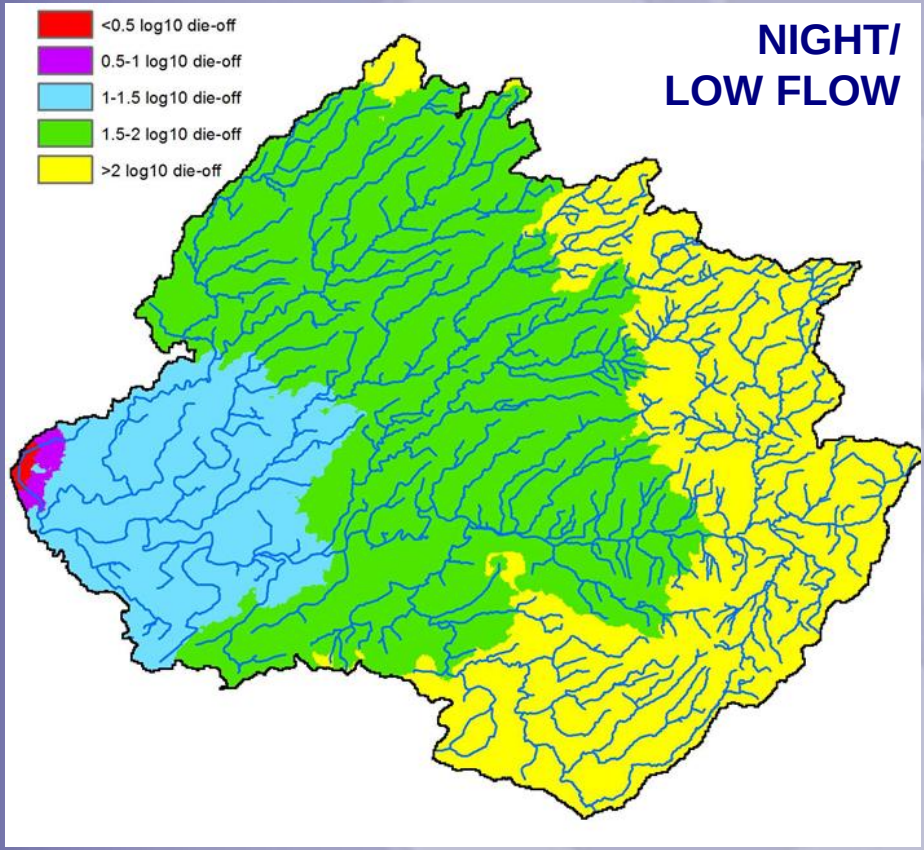
e.g. Outlet of R. Irvine, W. Scotland

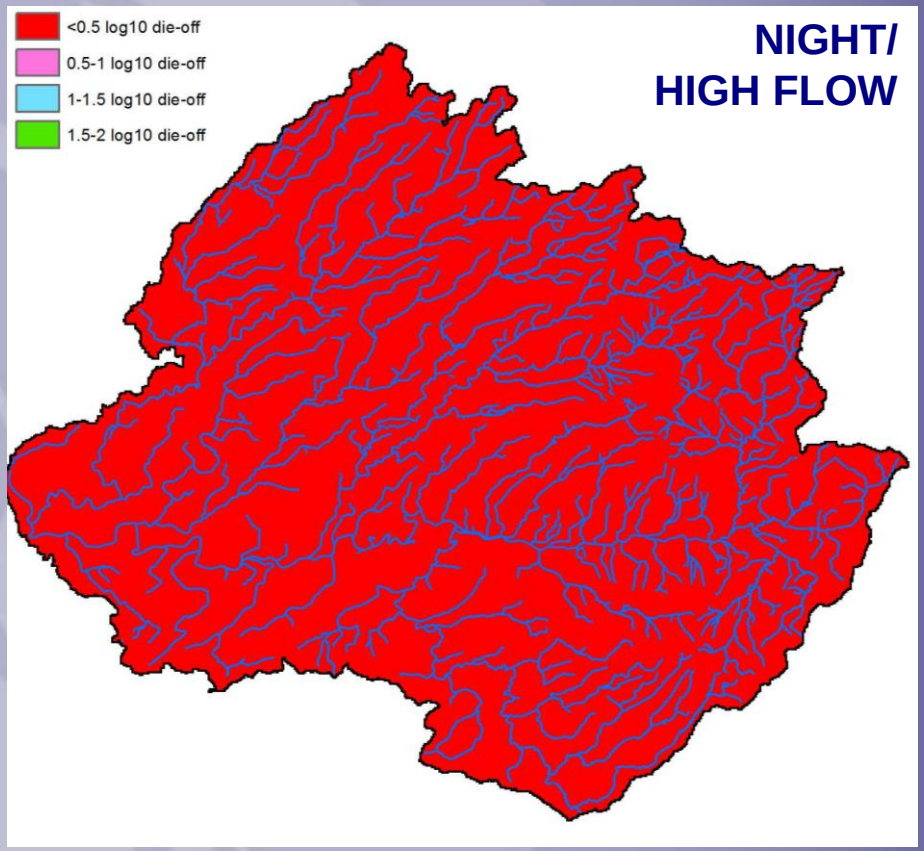


Catchment area = 481 km^2

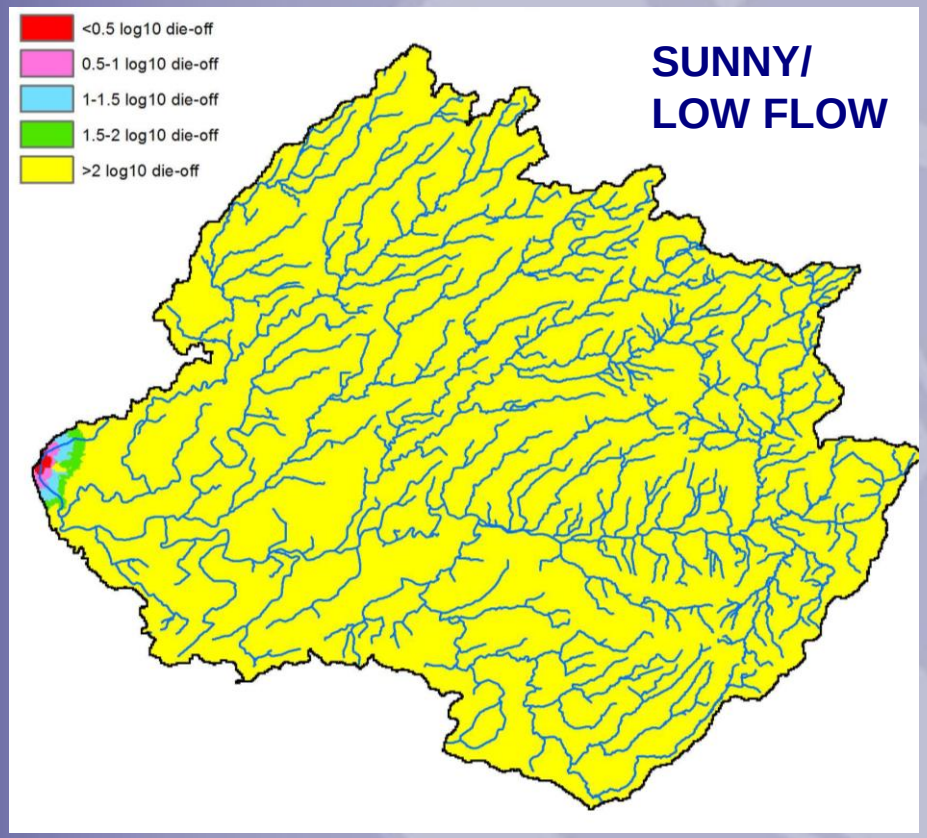
Zone of influence affecting water quality at Irvine catchment outlet: NIGHT/LOW FLOW

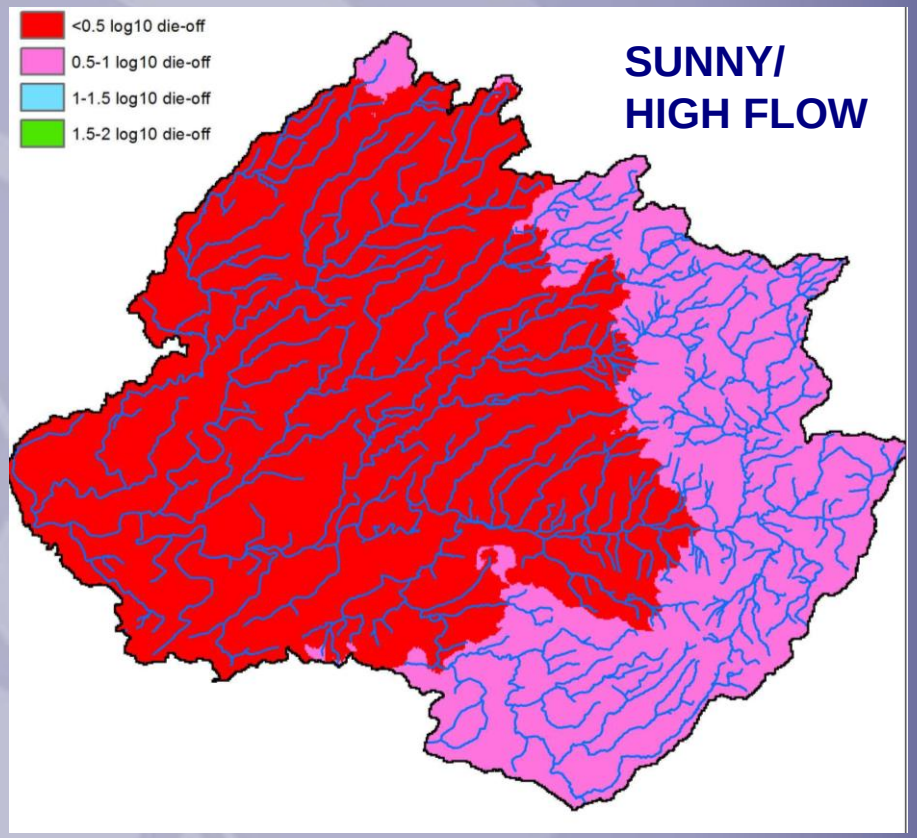
* Indicative data only – to illustrate application





Zone of influence affecting water quality at Irvine catchment outlet**: NIGHT TIME**





Zone of influence affecting water quality at Irvine catchment outlet**: SUNNY**

5. Conclusions: Prioritisation of measures

Key measures on individual livestock units:

1. **Prevent direct defecation to watercourses** by SBF and elimination of frequently used fords.
2. **Totally contain dirty waters from steadings used by livestock** either for storage for subsequent relatively ‘safe’ disposal to land, or treatment prior to release to watercourses, e.g. via FWS CFWs.
3. **Minimise surface runoff from pastures close to streams and/or heavily frequented by livestock**, e.g. reducing poaching in cattle congregation areas (troughs, etc.) by avoiding areas prone to runoff, moving them regularly or placing them on a bed of woodchips.
4. **Implement measures to attenuate FIO fluxes in surface runoff from heavily used pastures** – e.g. creation of grass swales along ditches and to treat runoff from farm tracks, and construction of riparian VBSs.

Account must also be taken of:

5. **Variations in stocking levels** (hence potential FIO source strengths per unit area), which will generally be greater in lowland regions.
6. **Ease with which measures can be implemented** – e.g. localised pollution 'hotspots' (steadings/streamside pastures) on more intensive lowland units are generally easier to confine and control than the more diffuse inputs typical of extensive areas of upland rough grazing.
7. **FIO attenuation along watercourses** – other things being equal, then priority should be given to pollutant sources closer to the coast.

Full implementation of key measures in areas of more intensive livestock farming is likely to reduce EC loadings delivered to coastal waters by *c*. 1 $\log_{10}$ under high-flow conditions.

CREH