ENVIRONMENT AGENCY NORTH WEST

FINE SEDIMENT DEPOSITION IN THE RIVER KEER

GEOMORPHOLOGICAL ASSESSMENT

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1.0 SYSTEM BACKGROUND

1.1 Introduction

The upper Keer had been previously identified by Central Area Ecology and Water Quality as experiencing fine sediment deposition problems. The purpose of this project is to identify the fine sediment sources, to comment on the activity of such sources, and to assess whether or not appropriate techniques should be applied to reduce sedimentation.

1.2 Physical Characteristics

The length of channel considered in this study extends from the headwaters of the Keer, (SD 583766), to the Keer Bridge on the Borwick-Gressingham road, (SD 540725), (shown in Fig. 1 below).

Table 1: Summary of the Physical Characteristics of the Keer

Mainstream Length	Approx. 13 km, (Focus length approx. 7km).
Average Slope (m/m)	0.019
Principle Tributaries	(All unnamed), from area of: Battle House, New Close Coppice, Docker Farm, Lancaster Bank and Petersgill Wood.
Channel description	Steep headwaters and middle reaches , moderately sinuous, lower gradient increased sinuosity in downstream reaches of focus length.
Bank Stability	Low, prone to erosion, especially in lower reaches (on Wick1 soils).
Bed Stability	Gravel/cobble component = moderate-stable, fine deposits = unstable
Bed Texture	Cobble-gravel in headwaters, trending to medium gravel in lower reaches. Fines (silt and sand) cloak bed gravels for much of lower reaches.
Geology	All of catchment solid geology = Carboniferous series. Includes, Yoredale rocks (limestones and shales, with some sandstone and coal measures) upstream of the Battle House tributary input, with Millstone Grit downstream. Grit overlain by recent alluvial drift downstream of Wash Dub Wood.
Soils	Brickfield 2 association upstream, and Wick 1 association downstream, (division conforms to basic split of solid geology outlined above). Former = glacial drift, slowly drained fine loam soil. Latter = alluvially derived coarse sandy-loamy soil, prone to erosion.

Landuse	Predominately grazing (sheep and cattle), some cultivation of silage grass, and a little woodland.	
Management History	Some evidence of resectioning on tributaries.	
Hydrology[1] at High Keer Weir (SD 522719)	Q95 Dry Weather Flow	0.06 m^3s^{-1}
	Mean Daily Flow	0.56 m^3s^{-1}
	Mean Annual Flood	17.5 m^3s^{-1}
	1:10 Year Return Flood	24.3 m^3s^{-1}
	1:100 Year Return Flood	33.3 m^3s^{-1}

[1] Calculated by Matthew Scott, Hydrological Systems Team, RFH, Warrington.

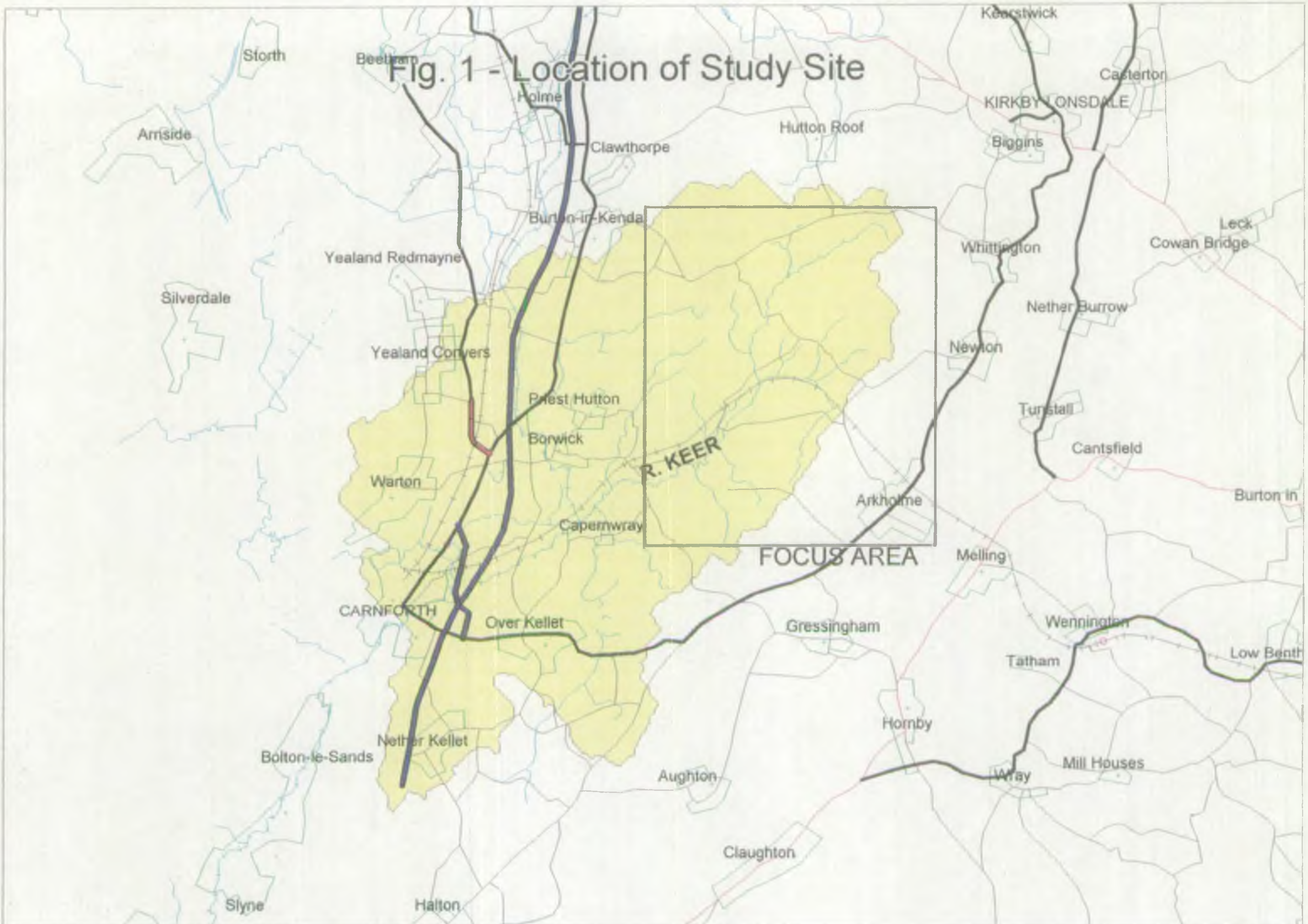


Fig. 1 - Location of Study Site
Storth
Arnside
Holme
Clawthorpe
Hutton Roof
Kearstwick
Casterton
KIRKBY LONSDALE
Biggins
Burton-in-Kendal
Yealand Redmayne
Silverdale
Whittington
Cowan Bridge
Leck
Nether Burrow
Yealand Conyers
Newton
Priest Hutton
Borwick
Tunstall
Cantsfield
R. KEER
Warton
Arkholme
Burton in
Capernwray
FOCUS AREA
Melling
CARNFORTH
Over Kellet
Gressingham
Wennington
Tatham
Low Benth
Hornby
Nether Kellet
Bolton-le-Sands
Aughton
Wray
Mill Houses
Claughton
Slyne
Halton

1.2 Summary of Natural Sediment Transfer Processes in the Keer

Morphologically the Keer is a typical example of an 'upland' gravel bed river. Its headwaters and upper reaches (source to approx. 4 km. downstream) exhibit comparatively low sinuosity and high gradient, giving high velocities, erosive power and sediment transport capabilities. Consequently bank erosion is common, but the bed surface comprises coarse gravel and cobbles and finer material is transmitted downstream. In the case of the Keer two factors serve to polarise these characteristics, the drift geology and soil associations of the catchment largely comprise of recent Alluvial drift and Wick 1 brown earths, such materials are well-drained sands and gravels and sandy-loams, which give rise to relatively erodible river banks. Secondly catchment rainfall is high, and the river regime is flashy, fast rise times and high discharges serve to further increase erosive impact and sediment transport efficiency.

Further downstream, (including the remainder of the study reach), channel gradient is reduced, average channel width increases slightly with increasing flows, and the sinuosity of the river increases. This affects a natural reduction in velocity, erosive power and sediment carrying capacity. Under natural conditions erosion will still occur, particularly under high flow conditions, but it is generally localised to the outside banks of meanders. Deposition will also occur locally, and with bedforms such as point, side and occasionally medial bars forming frequent features of the bed environment. However erosion occurs predominately under high flows, and thus sediment supply and sediment transport capacities retain a state of fluctuating equilibrium. Therefore, although some fine sediment may exist, particularly in depository features such as bars, the bed surface generally comprises of fine and medium gravels.

Most fine sediment is transmitted fairly rapidly to downstream estuarine environments, where it naturally accumulates, in an eco-system adapted to a high fine sediment yield.

1.3 The Fine Sediment Problem

Although the presence of minor deposits of fine sediment may not be a problem, larger areas of deposition lead to a decline in ecological and fisheries value in a coarse gravel-bed river such as the Keer. Biological surveys conducted in the area of the study site over the past three years, suggest a change in substraight composition, favouring an increase in fine material. However assessment is subjective and a change of monitoring personnel during this period means that such observations alone, do not provide significant evidence of increasing fine sediment deposition. Increases in the rate of fine sediment deposition can however be implied by the observed affects on fisheries over recent years. A general decline in the number of trout and salmon redds during the late 80's and early 90's seems evident, the most dramatic affects have however been noted in terms of rod catches. From 1974 - 1988 the Keer provided a sizeable salmonoid yield, mean catch 205.17 fish p.a., in the period 1989 - 1994 this sunk to a figure of 47.08, (a 77% reduction).

2.0 EVALUATION OF SEDIMENT SINKS AND SOURCES

2.1 Features Examined

An evaluation of the varying intensity of *accelerated* sediment sources, and areas of *artificially increased* deposition is undertaken in table 1, below. Figures 2 and 3 show the position of the different reaches and graphically summarise the variations in accelerated erosion and increased deposition.

Erosion and deposition occur naturally in gravel-bed rivers, as discussed above, hence for the purpose of this evaluation 'accelerated inputs' are: erosion that shows obvious signs of artificial initiation or intensification, eg. hoof prints, associated dung, or erosion which is occurring at unnatural locations in the channel, (such as the inside of meander bends), [see photos 1 & 2 in Appendix], or point source inputs such as fines from milled timber or runoff from channel resectioning, [see photo 3 in Appendix]. 'Artificially increased sediment deposition' is the sustained presence of particles of sand grain size or less across the majority of the channel.

Reaches were determined in the field, by walking the length of the focus area, and noting changes in erosion and deposition activity, they are intended solely to give an overview of processes in the study area, reach boundaries are zones of transition rather than abrupt change, and variation exists within each of the reaches.

Severe erosion equates to the input of approx. $30m^3km^{-1}yr^{-1}$ (approx. 80 tonnes, [assumed specific gravity = 2.65]), whereas semi-severe equates to about $20m^{-3}km^{-1}yr^{-1}$ (approx. 50 tonnes), and minor implies natural levels plus up to 5-10%. Severe deposition equates to the cloaking of the majority of the bed in fine sediment.

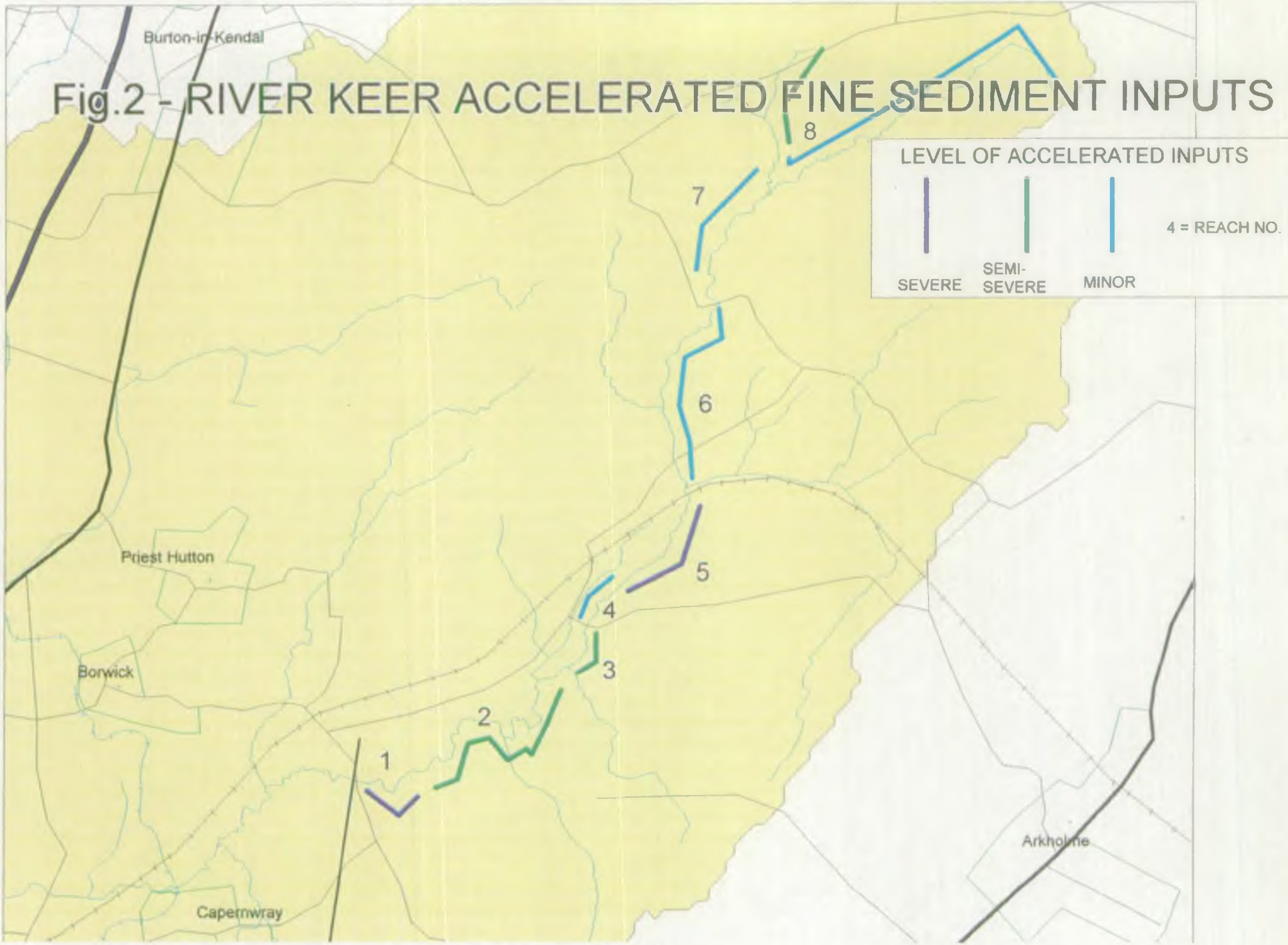
Local gradient is presented in table 1 to give an idea of changing hydraulic properties through the study area, insufficient flow data is available to give indications of changing velocities or stream power, however a similar pattern would be expected.

Table 1: Summary of Accelerated Inputs and Increased Deposition in the Focus Area

Reach No.	Accel-erated Inputs	Fine Sedi-ment Depo-sition	Est. Sinu-osity	Local Grad-ient (m/m)	Bankside Landuse	Additional Comments
1	Severe	Severe	1.6	0.004	Heavy grazing	Fencing at left bank only. Lack of pools or deep glides. Dilapidated weir, [photo 4, appendix].

2	Semi-Severe	Severe	1.6	0.004	Grazing and crop growth, (silage and oil seed rape)	Some mature bankside vegetation, old erosion scars vegetating in places. Lack of pools. Petersgill Wood and Lancaster Bank tribs. (resectioned, severe deposition in trib. channels.). V. large garden pond set back from channel, very low velocity and major deposition in vicinity
3	Semi-Severe	Natural to Minor	1.3	0.006	As Reach 2	Intermittent deposition, majority of gravels clear of fines
4	Minor	Natural to Minor	1.2	0.012	Grazing and Mowing grass	Well vegetated banks, some revetment (tyres and blockstone)
5	Severe	Natural to Minor	1.2	0.025	Heavy Grazing	Fencing at only one bank. Area of high natural erosion
6	Minor	Natural to Minor	1.15	0.03	Grazing and Mowing grass	Fenced both banks, good bankside vegetation
7	Minor	Natural to Minor	1.15	0.04	Rough grazing	Large bed material (median size cobbles) Well developed bedforms, (riffles, pools and transverse-clast-dams)
8	Minor/Semi-Severe	Natural to Minor	1.2	0.03	Rough grazing, forestry	Similar bed environment to R.7 Point source inputs of fines from agricultural resectioning (currently inactive), and timber processing, (sporadically active)

Fig.2 - RIVER KEER ACCELERATED FINE SEDIMENT INPUTS



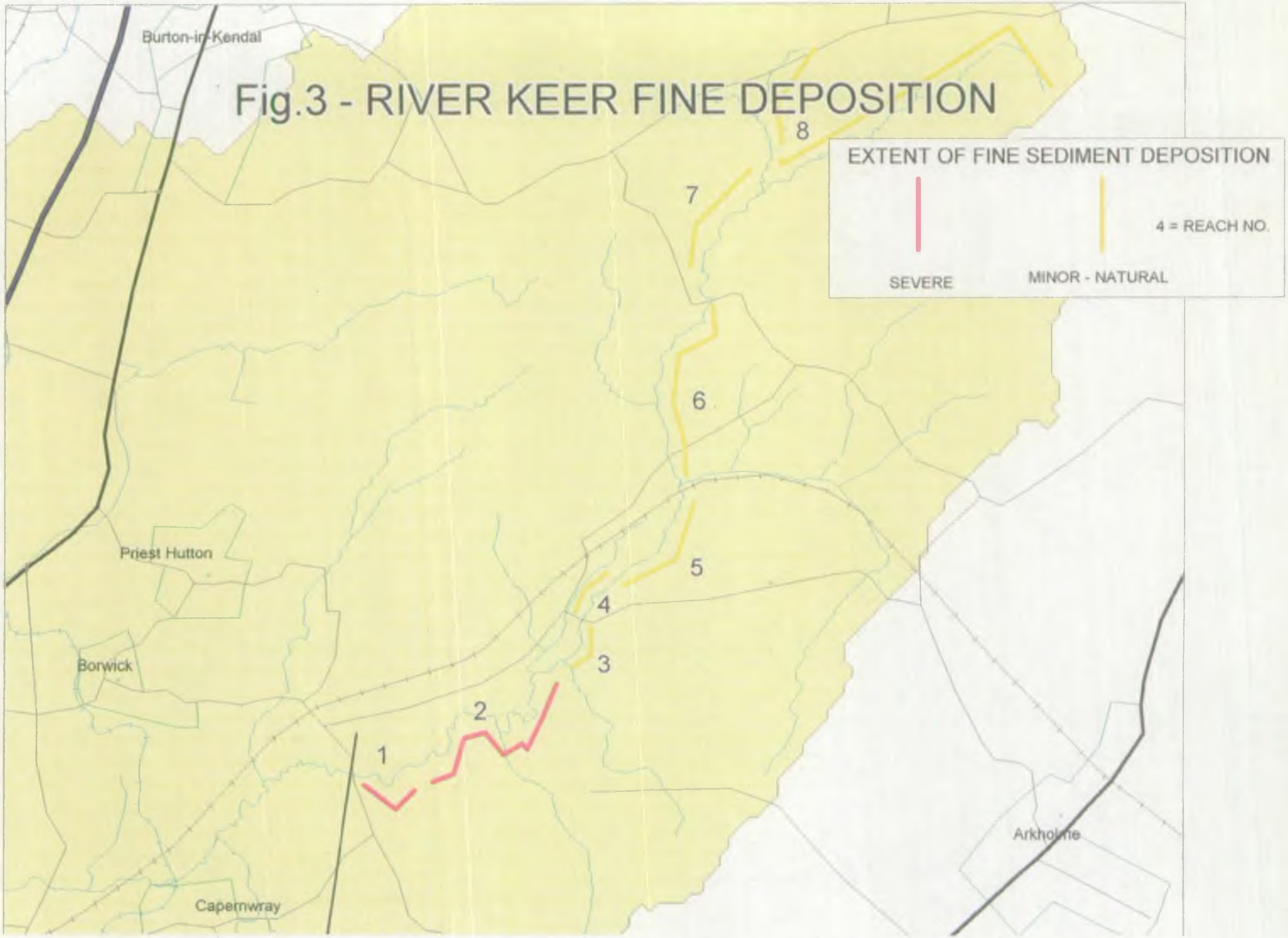


Fig.3 - RIVER KEER FINE DEPOSITION
EXTENT OF FINE SEDIMENT DEPOSITION
SEVERE
MINOR - NATURAL
4 = REACH NO.
Burton-in-Kendal
Priest Hutton
Borwick
Capernwray
Arkholme
1
2
3
4
5
6
7
8

2.2 Summary of Problems

Deposition

Fine sediment (silts and sands) cloak the majority of the bed in the downstream section of the focus area (reaches 1 and 2), this depository environment extends to SD 553732, approx. 250m downstream of the Arkholme-Borwick Road Bridge. This point corresponds to a marked downstream increase in sinuosity and a moderate decrease in bed slope, and therefore a consequent drop in stream power and sediment entrainment/carrying capacity. Above this point bed gravels are relatively free of fine deposits, [see photo 5, appendix]. One particular point of note is the area of the main channel in the vicinity of the large garden pond in the grounds of a recently built house near (not marked on the current O.S. 1:25000), close to the right bank in reach 2, identified in table 1 above. Velocities at this point appear to be abnormally low, and in-channel deposition is at its most extreme, with riparian vegetation fast colonising the in-channel deposits of fine sediment. A preliminary examination of licensed abstractions in the catchment does not appear to include this source, this may merit further investigation.

Accelerated inputs

There have been a few localised increases in supply, caused by such effects as the resectioning of the 'Battle House tributary' in Nov. 1994. Such events cause major increases in short term supply (in this case the entrainment of 10% of excavated material for instance, during the works and subsequent to them, when spoil was stock-piled at the bankside, would translate to approx. 80 tonnes of fine sediment). However, such sources of supply are unlikely to remain active for more than a year. Indeed the Battle House tributary site is now well revegetated and the source is totally 'switched off'. Although such events are significant as much of the fines yielded may still be resident in the lower part of the study area.

Dissipated sources of accelerated sediment supply are however of greater significance. In this case these are principally supplied by bank poaching from stock pressure. Inputs are at their highest in reaches 1 and 5, but are also substantial in reaches 2 and 3. The affects of such inputs are continuous, but are focused in the summer months when soil moisture stores are low and thus banks are at their most friable, and stock water demand is highest, with sources away from the channel likely to beat their driest. This is particularly bad in terms of fine deposition, as flows are at there lowest, and largely incapable of transporting fine sediments, which consequently remain in-situ, becoming vegetated in places, which in turn increases their resistance to entrainment.

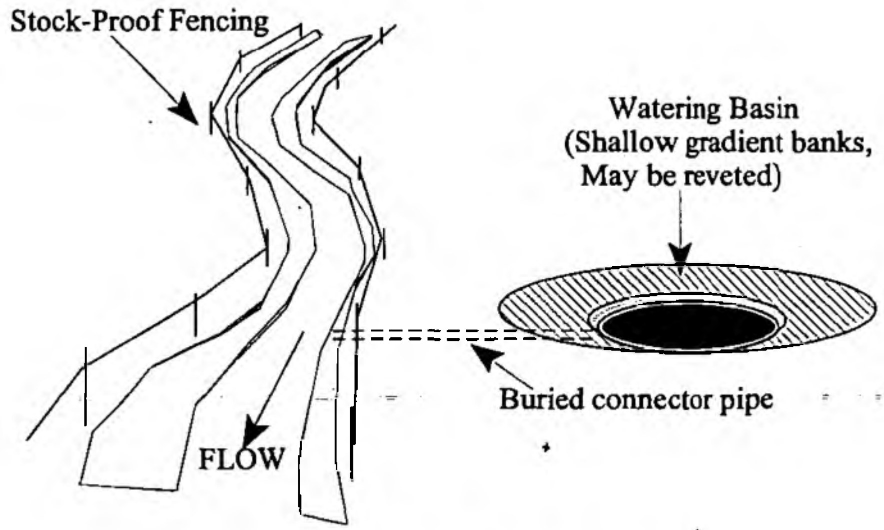
Predicted Developments

Given the continuation of the current flow regime, without the advent of an extreme flow event, and the continuation of current stocking patterns and widespread stock access to the channel then it is extremely unlikely that the Keer will naturally clear the deposits of fine sediment observed in reaches 1 and 2.

3.0 MANAGEMENT SUGGESTIONS

1. To produce any marked reduction in fine deposition at the bed, accelerated sediment sources must be switched off. Therefore fences should be erected where stock currently have access to the channel from one or both banks throughout the middle and lower reaches of the study areas, up to the downstream extent of Wash Dub Wood, (SD 560744). Controlled offline and/or online drinking provision should be made for stock, [see figs. 4 and 5 below, and N.B. points A & B below]. Additionally, landowners should be approached, and a close watching brief should be kept, in an effort to try and deter any future specific localised inputs of fine sediment, be it from resectioning/land drainage, forestry or any other form of rural industry.

Figure 4: Example of an Off-line Watering Structure.



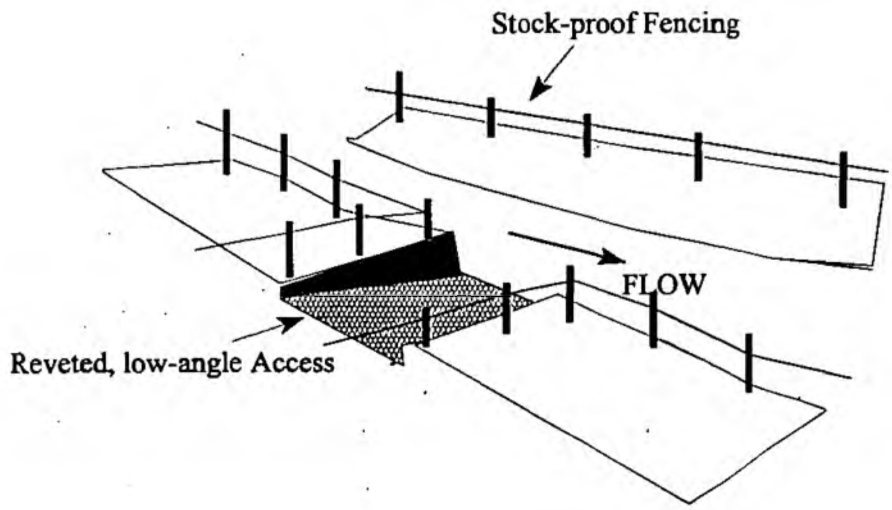


Figure 5: Example of an On-line Watering Structure.

N.B. A. Off-line watering structures are preferable to on-line watering structures, as they remove all stock pressure from the banks, whereas on-line structures merely concentrate it onto revetted sections, and stock may still gain limited access to the banks from the channel side of the fencing.
B. Stock-proofing requirements differ between sheep and cattle, whereas cattle egress can be halted by a single strand of barbed wire, sheep fencing must be much more comprehensive.

2. Once the sources of accelerated supply have been capped, the issue of the restoration of the existing bed can be addressed. In terms of the question, *will the bed recover naturally?* The answer is a definite yes, however the rate of recover is largely dependant on the success of stock control, the speed of bank stabilisation and revegetation, and most significantly the hydrological regime. Average daily flows are not enough to begin to cleanse the bed of fine sediment, as a rule of thumb, a velocity of the order of 0.2 - 0.5 $m^{-1}s^{-1}$ is required to initiate the transport of non-cohesive fine sediment. However, in the Keer large the estimated mean annual flood will deliver velocities approx. 3+ fold in excess of this range, therefore it is likely that an average year would deliver several floods capable of entraining deposited fines. But it may take several years to affect widespread improvements, and in places where low gradient, low velocity environments predominate, it may take the advent of a more sizable flood event.

3. Improvements can be assisted by removing in-channel vegetation which is rooted in fine sediment deposits, [see photo 6, appendix]. Additionally the removal of the dilapidated weir in Reach 1 would locally increase the rate of fine sediment transport. Improvements can also be made by locally reducing channel width, and thus increasing velocities, with flow deflectors, such as locally derived boulders. (Indeed an incidence of opposite bank collapse at one location, leaving a narrow channel which has a restored gravel bed, gives an existing example of the applicability of the method). Longitudinally this technique should be employed sporadically at points of greatest deposition, creating intermittent reaches of higher velocity flow to encourage a wider improvement of the bed.

4. **It is however important to consider the downstream affects of any efforts to increase fine sediment transport**. At present the lower area of the study section is acting as a huge fine sediment trap, if that trap is emptied, particularly over an accelerated timescale by modifying channel geometry, then the fines may simply redeposit further downstream.

5. **Further Work** - It would be valuable to examine the area downstream of the study section to see if similar problems of accelerated erosion and sedimentation are occurring.

APPENDIX

Photos 1 & 2: Examples of Stock Accelerated Bank Erosion.

Photo 3: Channel Resectioning in the Headwaters, (No Longer an Active Input).

Photo 4: The Dilapidated Weir

Photo 5: The Bed in Reach 3, Uncloaked by Fine Sediment

Photo 6: In-channel Vegetation Resulting from Accelerated Erosion and Bank Collapse

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ENVIRONMENT AGENCY

memo

To	Mark Atherton	From	Ed Mycock
cc		Extn	4054
		Our ref	
		Your ref	
		Date:	6 November 1997

River Keer 5b Bid

I am sending you a copy of Jim Walker's Geomorph report, which includes (Section 3.0, p10) management suggestions.

From this report the length of river which needs fencing is 7 kilometres, I would regard this as a minimum estimate, 8 might be better for a "wish list" figure.

Again from a wish list point of view, the best option would be outright purchase of the marginal strips before fencing, second choice is the ability to pay compensation or rent on it. I assume that standard ball park figures are available for this.

I am concerned that there may be a conflict of interest on the lower reaches. My project concerns the length from Capernwray viaduct to the A6 Bridge, and is specifically targeted at remedying the damage caused an insensitive Land Drainage scheme in 1959. MFP funding sponsored a consultant's report on available options. There is now a locally based group comprising Parish Councils, Angling Club, RSPB, LWT, Lancaster City Council, Lancashire County Council and EA. A bid is in preparation for Landfill Tax funding, and some aspects can be funded from Countryside Stewardship.

Do you think the best option is to regard the 5b bid as a second go at this length, if the landfill etc is unsuccessful? I certainly want to avoid the situation whereby one project might queer the pitch for the other, and we need to resolve this.

Ed.

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