Geo Factsheet

Number 42

River Management

This Factsheet reviews traditional hard and new engineering solutions to river management problems. In the face of worldwide accusations that they have only increased flood risk and at the same time destroyed the ecology of riverine areas, hydrologists and water engineers have had to rethink the way they manage rivers. The 1993 Mississippi and the 1994 Rhine floods, along two of the most managed rivers in the world, emphasised this point. Looming over the debate is the spectre of global warming, and the possible impact of rising sea levels, and more unpredictable weather, such as the extremely violent El Nino cycle in 1998. Finally then, the Factsheet reviews the new thinking on river management which is beginning to emerge in the USA and Western Europe.

Why manage rivers?

The primary reasons for river management are to try to prevent flooding, to manage conflicting demands of water users, and to permit activities such as river navigation or direct abstraction of the water for drinking.

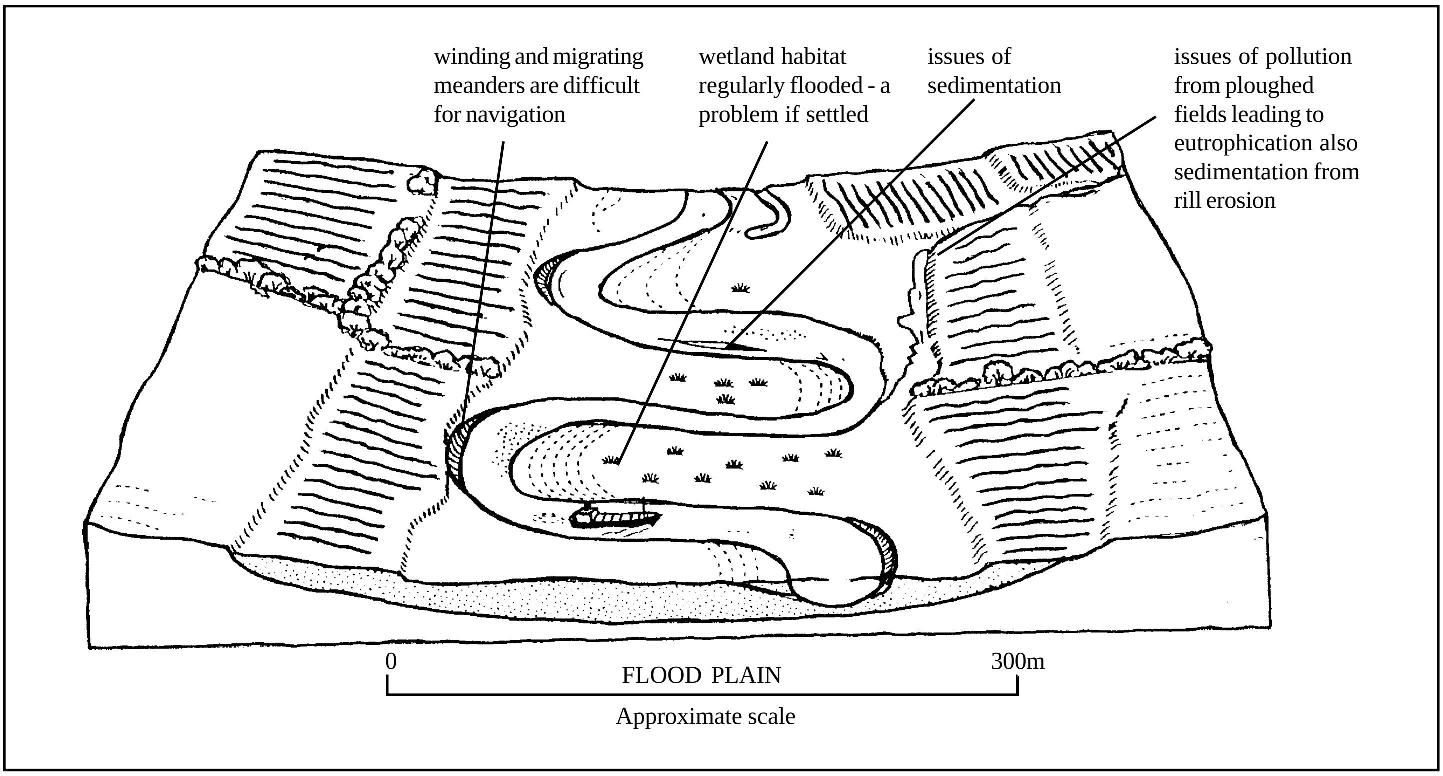
Fig 1 shows a flood plain of a large river such as the Mississippi or the Rhine with many potential management issues. Whilst physical processes such as meandering and sedimentation may lead to changes in the river channel, it is human factors which lead to the management problems. The Mississippi's problems, for example, have their roots in the **Swamp Land Acts**, passed by the US Congress in the mid nineteenth century. Over a quarter of a million square kilometres of swamp land, which once drained could become very rich farmland, was given to the state governments to sell to private investors, thereby generating the development of riverside settlements on the flood plain. Deprived of the natural water storage capacity of its former wetlands, the river Mississippi burst its banks in spring, in its lower course, with huge floods in 1862, 1866 and 1867. Thus began the cycle of **levee building, river channelling, straightening** and **damming** in an effort to protect the ever increasing settlements from flooding.

Processes such as channellisation can exacerbate the management problems. The case study of the **Rhine Rift Valley** shows how the 'rectification' projects started nearly 200 years ago by Johann Tulla, who claimed that 'no river needs more than one bed', channelled the meandering and multi-channelled Rhine into a single blue channel, thus cutting it off from its flood plain. Although the benefits of the scheme included improved navigation, the costs included downstream problems of flood surges (from the quickening flow) and clear water erosion leading to scouring (silt starvation of the channellised river). This has led present day engineers to begin plans to 'undo' the 19th century "improvements".

Hard Engineering Solutions

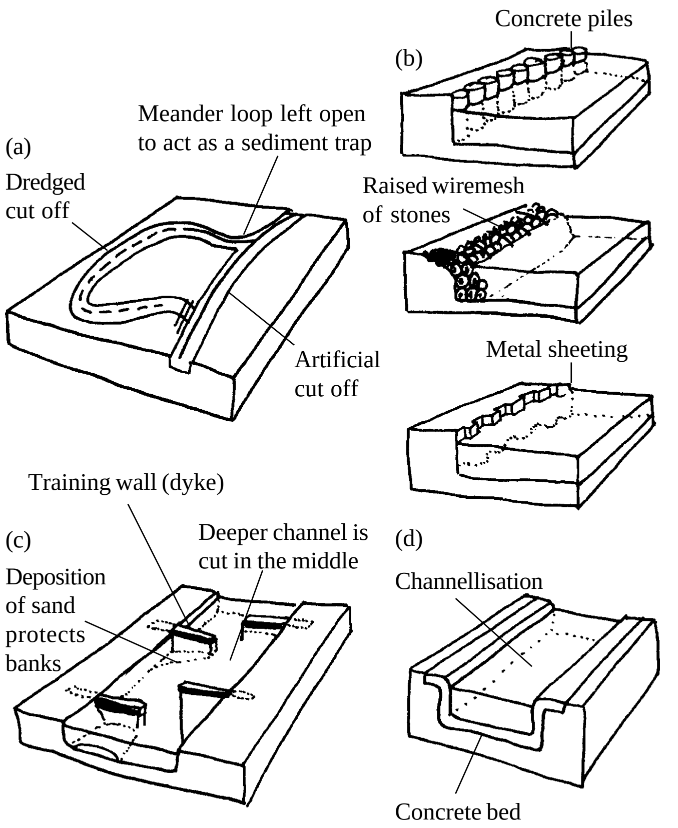
The characteristics of the river channel, namely width, depth and sinuosity (degree of bending) are adjusted to the natural flow regime at bank full discharge. People attempt to manage the river channel by changing some of the variables in order to alter channel characteristics such as speed of discharge or sedimentation. This deliberate modification is known as **channellisation**.

Fig 1. River Management - the potential problems



The most important hard engineering solutions are shown in Fig 2.

Fig 2. Hard Engineering Solutions



Method	Purpose	Impact
Realignment and straightening (a)	To increase the gradient of the long profile - increased velocity.	Reduces risk of flooding upstream. Helps river navigation by reducing journey times. May lead to increased erosion and bank collapse. Loss of pool and riffle sequence.
Bank protection (b)	To control meander migration and prevent bank erosion and land loss.	Loss of banks side habitats. Separation of river from flood plain, loss of natural bank profiles.
Wing dykes (c)	Deflection of current sediment deposited in lee (cf groyne).	Bank protection. Increase of central channel velocity. Creation of deeper central channel for navigation.
Channellisation by concrete lining **resectioning** (d)	To reduce friction and increase river speed thus reducing upstream flooding.	Destruction of bed and bank habitats. Possible increase of downstream flooding.

Many hard engineering solutions have been deployed on the Rhine and the Mississippi (see Case Studies). An extreme form of channellisation not shown in Fig 2 is **culverting**, where the river is contained underground in a pipe.

Hard engineering solutions of this kind can have negative impacts: culverts can be frequently blocked by flood debris, which may lead to flooding upstream.

Resectioning increases stream flow and the higher velocities in smooth concrete channels (less friction) result in greater erosion rates **downstream** and more risk of flood surges, especially where the river flows in a high energy environment. The high flood flows experienced by the **River Witham** in Lincoln in the 1970s were linked by researchers to the extensive channellisation of high value 'agricultural' areas and the dredging of the Shire Dyke reach some 20 kms upstream. **Dredging** involves the removal of sediment from a river's bed to enlarge its capacity (i.e. cross-sectional area). Whilst dredging reduces flood risk on site, it may transfer problems downstream.

Realignment or straightening of the river channel may lead to dramatic changes, especially in high energy rivers or those flowing across easily erodable areas such as sand or gravels. The formation of a new, straight channel increases the downstream gradient. This creates a period of disequilibrium in the system as the energy of the river increases on site enabling it to transport more sediment. This leads to on site erosion of the channel bed. Bank protection methods and concreting of the bed and banks are needed to prevent the river remeandering. **Downstream** of the realigned reach, aggradation can take place leading to the formation of large point bars on the inside of meander bends. Yet again the problem is merely transferred downstream.

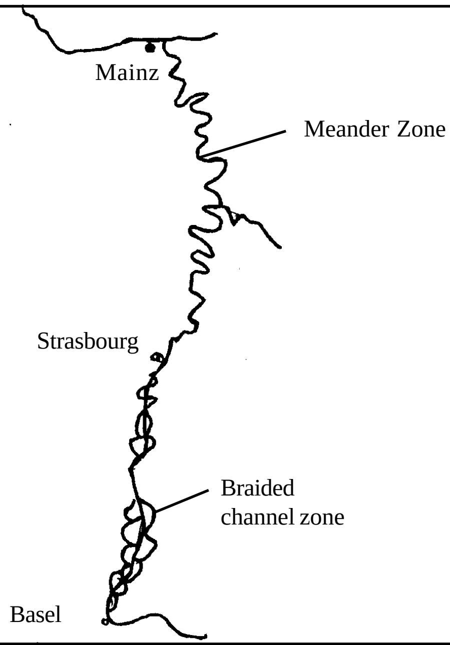
Channels produced by hard engineering have a very negative impact on the **environment** and **ecology** of a river. Engineered channels, especially those which are very heavily managed (concrete), lack both flow variability and an ability to provide ecological sites in their beds and banks. Any modern schemes are required to carry out **Environmental Impact Assessment** (EIAs) and **cost-benefit analysis** before the implementation of management plans. In scheme (a) in Fig 2, although the channel is realigned a meander has been retained as an ecological habitat

The Environment Agency (EA)
The EA produce regional and local catchment management plans and are responsible for:

- control of **point source** pollution, for example effluent from a factory site, by the implementation of **effluent discharge standards.**
- **Land use regulation** (including the definition of **flood protection zones**, and protection zones for **groundwater** such as buffer strips to minimise diffuse source pollution.
- **Water allocation** to meet seasonally - variable instream and bank side flow needs.
- **Channel** and **flood plain** management to sustain morphological and ecological diversity.
- Controls on **human uses** of rivers for fishing and recreation.
- Controls on **biota** to prevent over population of certain species, for example those introduced accidentally, or by biological invasion.

Case Study - River Management on the River Rhine 'Full Circle'

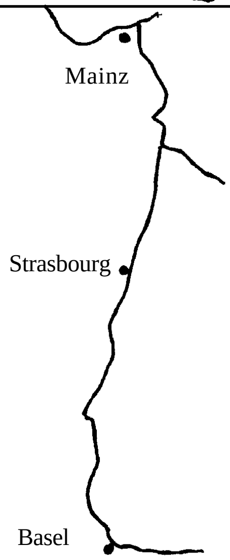
Pre Management



Rectification Schemes (i.e. "make it right") began in 1807 with the work of Tulla. These aimed to concentrate the river into one channel in the braided stretch to improve navigation, control flooding and lower the level river bed.

- After his scheme in 1807
  - 2000 islands of silt had been removed
  - the river was over 100 kms shorter
  - the flow was 30% faster in the braided stretch
- In the late nineteenth century diversion structures were used to train the river to cut through its meanders
- Banks were stabilised to ensure the river kept to its realigned course.
- Although some protection was developed against flooding, navigation was still a problem because of sedimentation (point bars & eyots) especially below the realigned and channellised stretches.

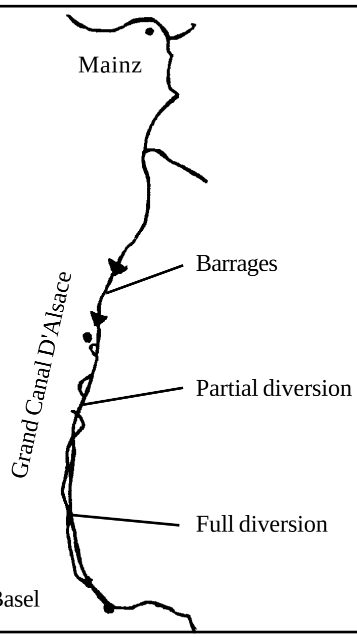
1900



Further management included wing dykes to maintain channel depth. The narrow channel led to the river scouring out its bed, lowering it by 4 metres, but this caused downstream pile ups of sediment.

- Levees were built to strengthen flood banks.
- In 1959 the navigation canal ‘Grand Canal d’Alsace' was built. This separated the channel from its flood plain and led to all sorts of management problems including a falling water table and a loss of wetland habitat.
- Barrages were built downstream to regulate the flow to avoid the problems of flood surges so there was a huge loss of natural storage (60% flood plain loss in the braided section).
- Flood risks actually became worse below Strasbourg in spite of engineering schemes.

1990



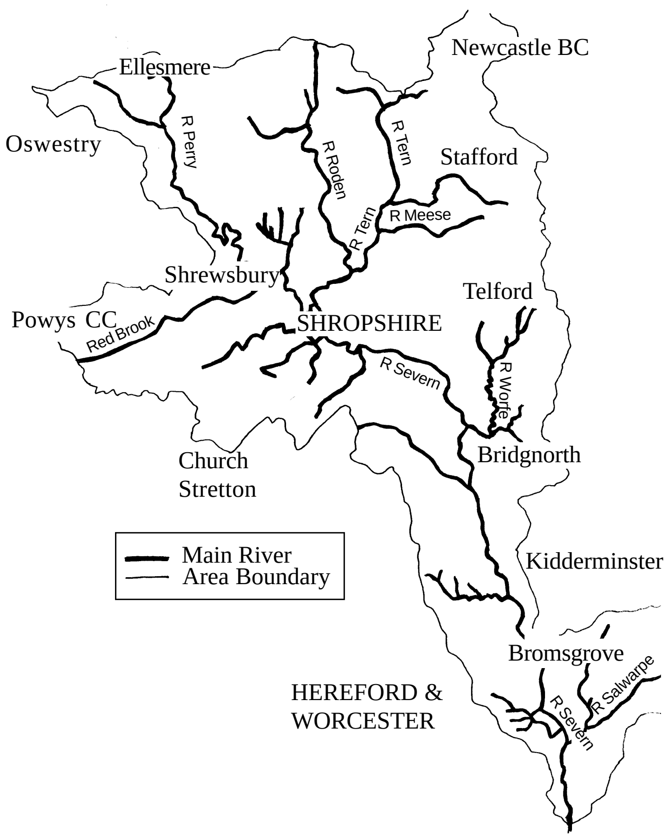
- New thinking in 1990
  - New flood plain retention basins
  - Removal of some levees
  - Reintroduction of relief channels and meanders

Exam Hint *- Candidates are often asked to describe and explain the river management processes in a large drainage basin - for instance the Rhine, Colorado, Mississippi, Thames or Severn - definitely* ***not*** *the River Roding.*

Case Study - Middle Severn

The middle Severn lies mainly within the counties of Shropshire, Hereford and Worcester and is an area valued for its rich natural beauty and unspoilt countryside. Over the years human and development pressures have impacted on the area, including flood alleviation and hard engineering schemes in the 1970s. Problems include degradation of some river corridors such as the Rivers Perry and Tern, and over-abstraction leading to low flows in the River Worfe.

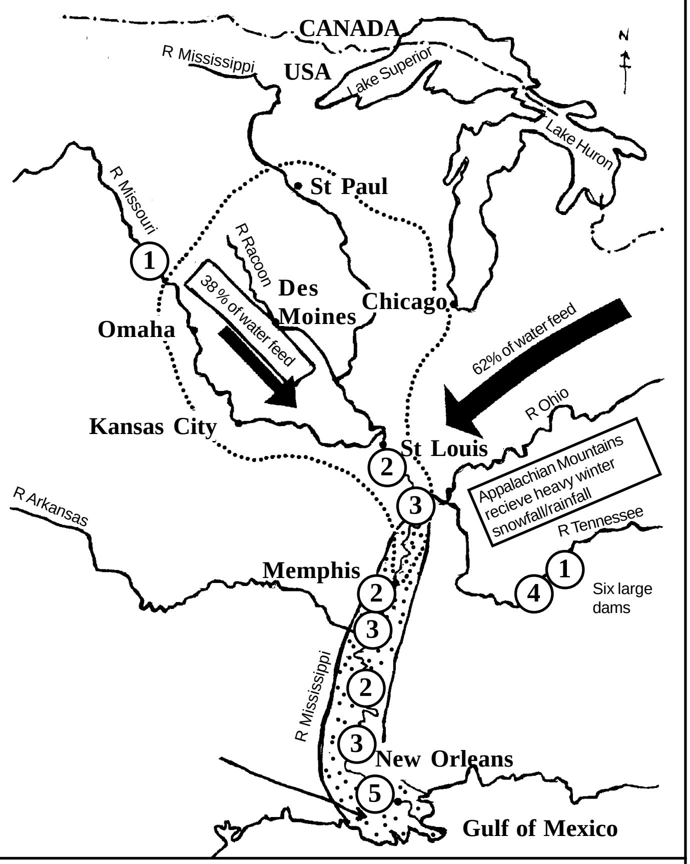
Management issues in the Mid Severn Catchment



The November 1997 Action Plan identified 22 issues and suggested the following improvements:

- *controlling agricultural pollution from nitrates by further regulation (widespread)*
- *negotiation of improvements to rural sewage disposal eg. in Waters Upton*
- *creation of new wetlands and river corridor projects eg. in River Perry and Tern, with the addition of buffer strips*
- *attempting to control escalating abstraction demands for irrigation eg. River Worfe*
- *protection of all SSSIs eg. Aqualate Mere or Marton Pool (high quality wetland areas)*
- *protection of high quality coarse and game fishing area eg. Cound Brook*
- *input into Ironbridge World Heritage Site by providing more bank side stabilisation*
- *development of flood alleviation schemes for the built up areas of Bewdley and Diglis area of Worcester but also controlling further development of the flood plain*
- *managing recreational development especially in the Telford area (growing demand)*
- *developing options for controlling flows from Upper Severn area to manage low flows in summer and flood risks in autumn and winter.*

Case Study - The River Mississippi - one of the most engineered rivers in the world



KEY

- Usual area affected by Spring flooding
- Area affected by Summer flooding in 1993
- International boundary
- Major towns
- Discharge of river system below St. Louis
- Lakes/sea

Existing flood controls

1. Dams and reservoirs
   105 dams on the Missouri
2. Strengthened levees
   Some up to 15m high. 3000km of levees
3. Straightened course
   1750km of artificial channels
4. Afforestation of valley sides and watersheds
   eg. in River Tennessee
5. Diversionary spillage
   Bonne Carre floodway diverts floodwater to sea

Case Study

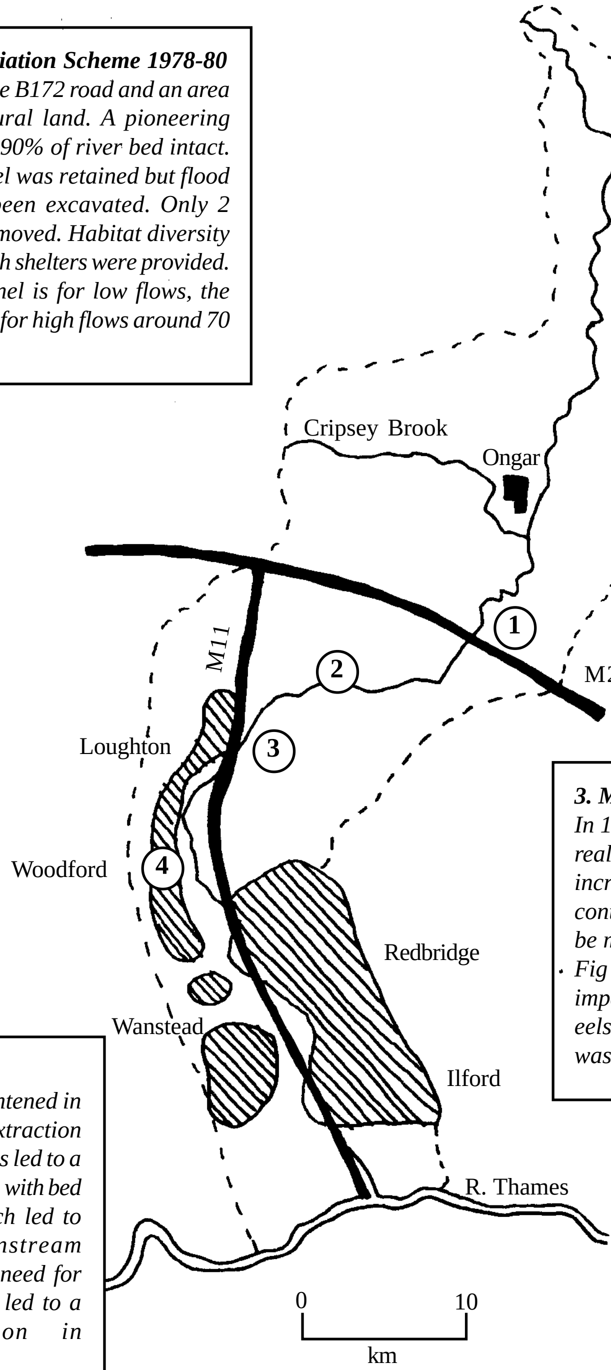
The River Roding - evolving management strategies

. The River Roding is located in South Essex. It is 80kms long and has a catchment area of approximately 350 square kilometres. It flows over glacial deposits in its upper reaches, which provide high quality soil for intensive arable farming. Flood control was necessary because of the large areas of urban development on the alluvial flood plains in the lower reaches.

*Early management of the river involved the use of traditional engineering methods; **straightening, dredging, training walls** and **bank protection** with **exposed gabions** (rocks in netting) **sheet piling** and **lining** the channel with concrete blocks. More recent schemes such as the Abridge Flood Alleviation Scheme at site 2, which was carried out between 1978 and 1980 have attempted to use more environmental forms of channel management for example at site 1 (Passingford). At site 3 downstream from the Abridge scheme, an attempt was made to upgrade the river reach to introduce a more environmentally sensitive scheme when the M11 was built and changes in alignment were required.*

Management of the River Roding

2. Abridge Flood Alleviation Scheme 1978-80
To protect the village, the B172 road and an area of high value agricultural land. A pioneering scheme which retained 90% of river bed intact. The meandering channel was retained but flood overspill areas have been excavated. Only 2 meanders have been removed. Habitat diversity remains high because fish shelters were provided. The old meander channel is for low flows, the newly excavated area is for high flows around 70 days per year.



1. Shank's Mill/Passingford Bridge
Shank's Mill was first established to provide power for the mill in the 18th century. This led to a 60% increase in gradient. The straight narrow channel remains even after 200 years. In 1982 the building of the M25 required a whole channel realignment for four kilometres downstream from Passingford Bridge. The realigned channel was designed to maintain habitat diversity with riffles and pools, and carefully landscaped bank protection walls made of elm stays and covered by alders. In 1992 the scheme was appraised. The new cut was stable, the channel full of fish, but no clear riffle and pool sequence had formed, and the banks were not fully colonised with vegetation. Overall, the channel looked attractive, and the habitats healthy.

3. M11
In 1973 this reach was straightened and resectioned and realigned for the M11 motorway to be built. The gradient increased by 40%. Concrete blocks lined the channel to control erosion. In 1979-80 the scheme was upgraded to be more environmentally sensitive using wing dykes (see Fig 2) to create riffles and pools. This had a dramatic impact on the diversity of fish, with chub, dace, pike, large eels and roach returning to the stretch of river. A new weir was designed to provide habitats for fish.

4. Buckhurst Hill
The channel was straightened in 1975 to allow gravel extraction from the flood plain. This led to a gradient increase of 25% with bed erosion upstream, which led to bank collapse. Downstream sedimentation led to a need for regular dredging. This led to a significant reduction in biodiversity.

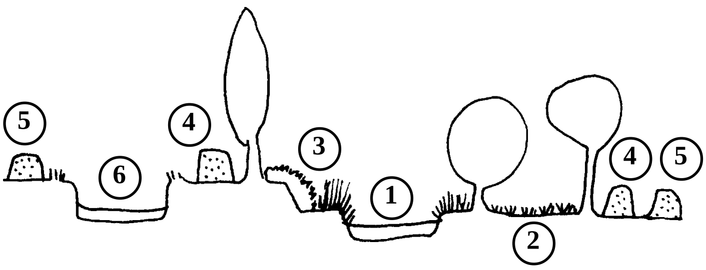
New Thinking on River Management

The new policy for flood plains (developed by the Environmental Agency in 1995) seeks to **control** development in areas which have an unacceptable risk of flooding, or where it would create or exacerbate flooding elsewhere. In Great Britain £250 million is spent annually constructing and maintaining flood defences and providing effective flood warning for areas at risk - largely as a result of historical development on the flood plain.

- Environmental options for **river channel** schemes include (Fig 3):

1. Restored natural river channel
2. Restored riparian zone with planted trees
3. Flood bank planted to created new wetland habitat
4. Flood embankments set back from the river's edge
5. Additional emergency flood plain embankment - may act as buffer
6. New wetland habitat of flood plain lake, water level controlled by sluice (eg. washlands scheme in Northampton)

Fig 3. Components of a rehabilitated river margin



7. The provision of **relief channels** which are constructed to divert high level flow away from the main channel, thus leaving the natural channel intact. A good example of this can be seen in the Maidenhead, Windsor and Eton flood alleviation scheme.
8. **Partial dredging**. A limited central section of the river is dredged to increase the cross sectional area, or limited weed clearance takes place. The dredging is concentrated at the shallow riffle sections, therefore allowing aquatic habitats to be maintained.
9. **Distant flood banks**. Where space is not limited the banks can be set some distance back from he river, often at the edge of the meander belt.
10. **Two-stage channels** can be created by excavating the upper section of the flood plain adjacent to the river. The natural channel is preserved in low flow periods, but during high flows the water is contained within the newly excavated **bends** (see **River Roding** case study). Whilst there are obvious advantages of these environmental methods, most are unsuitable for upland rivers and do need very careful designs.

Priority is also being given to the rehabilitation of river margins, **Buffer zones** can be used to mitigate the effects of diffuse pollutants such as the widespread use of nitrates from intensive arable farming and help to maintain valuable habitats and wildlife corridors through the landscape.

Restoration is commonly attemted in Germany (see River Rhine case study). River corridor restoration involves;

1. The establishment of the **model image** of the river, for which an analysis based on historical maps may be necessary to see where the old meanders went.
2. A feasibility study involving a full scale survey of the catchment, the riverside environment and the river channel, looking at landscape ecology, current river morphology and water resources management.
3. A pilot project based upon, for example, a single meander,
4. Final design and acquisition of permits from the landowners.

   River corridor restoration aims to restore low flows, reduce erosion of channel banks, control bed erosion and improve the flood plain and channel habitats. Restoration is usually accompanied by planned recolonisation of flora and fauna, for example fish restocking. At **Melksham** on the **River Avon** bends were put back into the river in late 1997, accompanied by three flat shelves of coir matting and aquatic plants such as irises and sedges to generate riffle and pool formation. Along the **River Skerne** at **Darlington** meanders have been put back into a polluted urban stretch of the river .

Conclusion

The new methods being used in Britain are paralleled by those in Europe, especially in the Netherlands, Germany and in USA, where the US Army Corps of Engineers has actually put back the meanders in a 69kms stretch of the River Kissimmee, which it only straightened 30 years ago. Despite all these examples of new thinking (some would say enlightenment) it will never be possible to return all the world's great rivers to an entirely natural state. It is not politically feasible to eject residents, industrialists, farmers etc. from their land and it would not be possible to compensate them were this to happen. Just as in coastal management, public lands and low value areas can be targeted for natural strategies and developed as new flood plains and wetland habitats (similar to natural retreat areas on coasts) leaving hard engineering schemes to be used only for highly settled, high value areas.

Acknowledgements;
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