Development of Type-Specific Reference Conditions

Development of Hydromorphological Reference Conditions and Draft Classification Scheme For Transitional and Coastal Waters

Work Package 6b: Final Report

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Environment Agency
Rio House
Waterside Drive, Aztec West
Almondsbury, Bristol BS32 4UD
Tel: 0870 8506506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

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Author(s):

Freeman, S., Hull, S. (ABPmer)
Whitehouse R (HR Wallingford)

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Research Contractors:

ABP Marine Environmental Research Ltd (ABPmer)
Pathfinder House, Maritime Way, SO14 3AE
Tel: 023 8033 8100

HR Wallingford (HRW)
Howbery Park, Wallingford, Oxon., OX10 8 BA
Tel: 01491 835381

Institute of Estuarine and Coastal Studies (IECS)
University of Hull, Cottingham Road, Hull, HU6 7RX
Tel: 01482 465503

Centre for Environment, Fisheries and Aquaculture Science (CEFAS)
Pakefield Road, Lowestoft, Suffolk, NR33 0HT
Tel: 01502 562244

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Environment Agency's Project Manager:
Andrew Richman, Rivers House, Lower Bristol Road, Bath. BA2 9ES.

Collaborator(s):
CEFAS, DEFRA, EHS (NI), FRS (Marine Lab), SEPA, SNIFFER.

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The development of UK-wide classification methods and environmental standards that aim to meet the requirements of the Water Framework Directive (WFD) is being sponsored by UK Technical Advisory Group (UKTAG) for WFD on behalf its member and partners.

This technical document has been developed through a collaborative project, managed and facilitated by Environment Agency/SNIFFER and has involved the members and partners of UKTAG. It provides background information to support the ongoing development of the standards and classification methods.

Whilst this document is considered to represent the best available scientific information and expert opinion available at the stage of completion of the report, it does not necessarily represent the final or policy positions of UKTAG or any of its partner agencies.

A Richman Environment Agency Project Manger

Contents

1. Background

The purpose of this Working Paper is to demonstrate how the metric classification system outlined in Working Paper 6a *'Development of a draft hydromorphological classification scheme'* can be applied. More specifically, the paper is to demonstrate where appropriate that a revision of a particular metric has occurred and/or where it has been shown to be less effective than previously thought.

The paper was reviewed and discussed at the Project Board meeting on 20th October 2005 and suggested modifications to the metrics have been incorporated in this final paper.

2. Requirements of Work Package 6b

As previously stated in Working Paper 6a, the project brief requires the development of a draft hydromorphological classification scheme to quantitatively assess, for each hydromorphological quality element, high status and the level of deviation from high status allowable to achieve good and moderate status. Moreover, the brief outlines a number of tasks to be undertaken.

- Revision of classification scheme in light of review comments
- Testing of the classification scheme through case studies
- Presentation of preferred options(s) to Project Board
- Prepare proposal for UK wide testing and application of scheme (note that this aspect has still to be developed).

All metrics were tested for the Ribble Estuary. However, in some cases a more simplistic approach had to be adopted because of non-availability of sufficiently detailed data to apply particular metrics. Individual metrics were also tested for specifications for which data were available. Where possible, metrics were tested at a national level in order to explore their wider applicability.

Following discussions with Andrew MacKenny-Jeffs (Environment Agency), it was noted that an approach being adopted currently for river water bodies in England and Wales is to use simple means of determining whether or not the hydromorphological conditions meet high status, i.e. it is a 'yes' or 'no' approach, rather than prescribing thresholds for certain parameters for each class band reflecting the role of hydromorphological supporting elements according to Ecostat guidance on classification. The example given related to hydrological elements and the assessment would be based on an expert assessment of whether or not the Q95 value was totally or nearly totally at undisturbed conditions (e.g. impacts <10%), aided by a qualitative assessment of other factors that could influence river flows, such as urbanisation or flow regulation (these factors being used as filters to exclude water bodies from classification as 'high' status). Water Resource regulatory standards for supporting good ecological status in rivers and lakes have been established by UKTAG project WFD 48. It is unclear yet how these will play a part in classification.

It should be noted that a number of data issues have arisen during the case study phase of the project. These relate to delays in tracking down and receiving data, cost of buying data and copyright restrictions. Purchasing a historical map of the Ribble, for example, is expensive (1st edition 1847-1850 ~£850, and Epoch 2 1891-1895 £2304). The EA does not currently hold an OS licence for historical maps. Copyright restrictions were encountered when conducting metric 2 on sediment budget. The Ribble has extensive datasets (and includes invertebrates, bathymetry, macroalgae, saltmarsh survey etc) but unfortunately some of these were not made available in time to be captured in this report.

The Marine Task Team reviewed the proposed classification at its meeting in August 2005 and again in October 2005. They made a number of recommendations for the modification of the proposed classification as follows:

- The classification needs to give equal weighting to all metrics and apply the one out all out principle;

- Metric 2b should be incorporated into metric 3.

- Metrics for salinity and migratory fish be reinstated in the metric scheme despite being dropped following the August 2005 meeting;

- Longitudinal connectivity should be dropped as a metric but the methodology should be included in metric 1 as appropriate for analysing habitat change.

The metrics tested and the locations of the case study sites are presented in Table 2.1 below.

Table 2.1 Metrics tested and locations of case study sites with subsequent revisions to metrics following Project Board Meeting in October 2005

Final Metric	Interim Metric	Old Name /No.	Description	Assessment Threshold	Primary Location Tested	Site-Specific Location Tested
1	1	Headline criterion	% habitat loss	% habitat loss	Ribble	None
2	2a	1a	Changes in sediment budget & composition	Length of frontage influenced by reinforcement or beach management/total length of WB frontage	Ribble	None
3a	3	2	Changes in morphology: Bed disturbance	Relative bed disturbance in relation to WB sensitivity (take account of fishing gear type)	Ribble	N.E. coast (N & S Yorkshire/Lincolnshire, South East Coast (Isle of Wight East, Portsmouth Harbour, Langstone Harbour, Chichester Harbour, Sussex and East Sussex).
3b	2b	1b	Changes in sediment budget & composition	Qualitative assessment based on expert judgement of available evidence & locations/extent of dredging/ reclamation activities	Ribble	Humber and Studland Bay (Coastal Water Body)
4	4	3	Hydromorpholoical element: Hydrological conditions	Area influenced by structures/area of WB	Ribble	None
5	5	4	Changes in forces: Tides	Presence/absence of artificial barrages etc	Ribble	None
6	6	5	Changes in forces: River flow	Is river flow at downstream assessment point of the adjacent river WB at high status (10% less than QN95)?	Ribble	None
7a	7	6	Changes in forces: Stratification/ flushing	Sea loch	Scotland	None
7b	-	6	Salinity	% of area or length influenced	N/a	N/a

3. Classification Scheme

Therelative merits and limitations of the initial approaches for the classification scheme were debated with the Project Board. These discussions helped to shape the development of the classification. One of the concerns raised at the Project Board meeting in May 2005 was that the use of a historical habitat loss/change criterion alone would not take into consideration other important hydromorphological processes. It was therefore proposed to use a series of metrics that cover wider-reaching hydromorphological aspects. The final metrics were refined to relate back to the normative definitions used in the Annex V tables. Consequently, the normative definitions relating to 'Tidal Regime' and 'Morphological Conditions' have been adopted.

Box 1. Link between proposed metrics and WFD Annex V normative definitions

Metric
Relevant Normative Definition

No
Name
Transitional
Coastal

1
Historical hindcasting
Composition and abundance of benthic infauna and other aquatic flora
Composition and abundance of benthic infauna and other aquatic flora

2
Changes in sediment budget and composition
depth variation, substrate conditions, and both the structure and condition of the inter-tidal zones
depth variation, structure and substrate of the coastal bed, and both the structure and condition of the inter-tidal zones

3a
Bed disturbance
depth variation, quantity, structure and substrate of the bed
depth variation, structure and substrate of the coastal bed

3b
Changes in sediment budgets

4
Hydromorpholoical element:
Hydrological conditions
the freshwater flow regime

N/A

5 Changes in forces - tides   6 Changes in forces - river flow   7a Changes in forces - stratification/flushing *the freshwater flow regime* *the freshwater flow regime and the direction and speed of dominant currents* 7b Salinity

These modifications were incorporated into the revised classification and the revised metrics were tested through the case studies. The general concluding view was that the classification approach would best be taken forward using a combination of qualitative and quantitative assessments.

Box 2. Schematic representation of initial approach and subsequent modifications following Project Board Meeting October 2005

Final Metric
Metric
Description
Assessment Threshold

1
1
Historical hindcasting
Habitat loss High = <5%

2
2a
Changes in sediment budget and composition
Length of frontage influenced by reinforcement or beach management/total length of WB frontage = <15%

3a
3
Changes in morphology: Bed disturbance
Relative bed disturbance in relation to WB sensitivity (take account of commercial fishing, aggregate extraction, navigation dredging and maintenance dredging)
High = >70% and Good = 70-30%

3b
2b
Changes in sediment budget
Qualitative assessment based on expert judgement of available evidence & locations/extent of dredging/reclamation activities

4
4
Hydromorpholoical element: Hydrological conditions
Area influenced by structures/area of WB
High = 10% and Good >10%

5
5
Changes in forces: Tides
Presence/absence of artificial barrages etc

6
6
Changes in forces: River flow
Is river flow at downstream assessment point of the adjacent river WB at high status (10% less than QN95)

7a
7
Changes in forces: Stratification/flushing
Sea loch. Expert judgement.

7b
N/a
Salinity
% of area or length influenced* Expert judgement.

Note that no threshold has been established as further research is required

The approach would permit the incorporation of broader aspects of hydromorphological pressure and thus use as much information as possible on hydromorphological status.

Supplementary notes: Whilst the contractor consortium acknowledges the reasons for MTT's decisions, we suggest that some further review of the scope of the hydromorphological classification and the amalgamation of metrics to form the overall classification would be appropriate. The following discussion is included to capture these thoughts.

There is some uncertainty on the use of an annual measure of flow in a general freshwater flow metric based on a percentage of Q95 as it may not be appropriate for protecting migratory and resident fish from changes to the flow regime. For example, upstream migration of salmon is generally accepted to be triggered by increases in freshwater flow during the summer period and these requirements are not well represented by an annual flow metric. This suggests a seasonal flow metric might be required. This approach was also suggested by Andrew MacKenney-Jeffs of the Environment Agency. Similarly, it is unclear whether an annual flow metric adequately represents the relationship between salinity and habitat/species distributions in transitional waters. For example, such distributions may be significantly influenced by both extreme high and low flows.

We accept that a metric for lateral connectivity - proportion of shoreline reinforced - is already mirrored by metric 1 for habitat loss and metric 2 changes in sediment composition. Nevertheless, we think it is important to recognise the importance of lateral connectivity in influencing the ecological quality of water bodies, although we accept that such influences are not well documented in the scientific literature.

In the draft classification proposed by the contractor consortium, the metric for % habitat loss was proposed as a headline metric with the remaining metrics taking the role of ancillary criteria. The reasoning behind this was to provide competent authorities some flexibility in assigning a class in the face of what will inevitably be very uncertain (and thus contentious) estimates of habitat loss. While we recognise the need to comply with the requirements of the Water Framework Directive, and ensure that the classification is consistent with normative definitions, we are unaware of any constraints on how competent authorities might seek to combine the relevant elements within an overall classification. We are concerned that the current system will not provide sufficient flexibility to deal with the uncertainties surrounding historic habitat loss.

4. Development of Metrics

4.1 Hydromorphological Elements

Specifically considering 'Morphological Conditions', the normative definitions refer to *"depth variations, substrate conditions, and both the structure and condition of the intertidal zones"* for transitional waters (Annex V, Table 1.2.3) and, for coastal waters (Annex V, Table 1.2.4), *"depth variations, structure and substrate of the coastal bed, and both the structure and condition of the inter-tidal zones"*.

For the hydromorphological quality element relating to 'Morphological Conditions' to be at high status requires the above aspects to *"correspond totally or nearly totally to undisturbed conditions"*. Using this definition, we have assumed that a water body can only depart from high status through anthropogenic intervention, since any other change must be part of the natural dynamics of that particular system.

Specifically considering 'Hydrological Conditions', the normative definitions refer to *"the freshwater flow regime*" for transitional waters (Annex V, Table 1.2.3) and, for coastal waters (Annex V, Table 1.2.4), *"the freshwater flow regime and the direction and speed of dominant currents".*

For the hydromorphological quality element relating to 'Hydrological Conditions' to be at high status requires the above aspects to *"correspond totally or nearly totally to undisturbed conditions"*. Using this definition, we have assumed that a water body can only depart from high status through anthropogenic intervention, since any other change must be part of the natural dynamics of that particular system.

The metrics used supported by a range of thresholds covering different either direct or indirect affects relating to morphological parameters (i.e. depth, structure and condition of the sub- and inter-tidal areas). The types of changes that could be important in affecting sub- and inter-tidal depth variations, substrate conditions and structure are:

Changes in astronomically-driven (i.e. tidal) and meteorologically-driven (i.e. river flow, waves, surges) forces impacting on a water body. At the water body scale, these are largely natural or quasi-natural changes (i.e. sea level rise, increased storminess), but forcing within parts of a water body may also be influenced by the presence of marine structures (e.g. barrages, tidal barriers, etc.) and flood and coastal defences (e.g. offshore breakwaters, fish-tail groynes) that alter wave and/or flow conditions and hence alter the currents and in turn the potential for erosion, transportation or deposition of sediments). This aspect is therefore considered further as a hydrological condition (Section 5.2).

- Changes in sediment supply. Reduced or increased sediment supply, or changes in type of sediment supplied to a water body, will ultimately result in morphological changes in the sub- or inter-tidal morphology, if they are changes of a significant magnitude. This can be caused by natural changes (e.g. reductions in contemporary supply as sources have become exhausted throughout the Holocene) or human-induced (e.g. sea walls fronting soft cliffs ceasing the supply of fresh input to the littoral system, beach replenishment undertaken with material derived from outside the water body, etc.).

- Changes in sediment transport. Changes in the direction and/or rate of sediment transport can lead to morphological changes (i.e. increased erosion/deposition). A typical influence on sediment transport rates is the construction of groynes or offshore breakwaters along a shoreline frontage.

- Changes in sediment output. Reduced or increased sediment output from a water body will ultimately result in morphological changes in the sub- or inter-tidal morphology, if they are changes of a significant magnitude. This can be caused by factors such as marine aggregate extraction or navigation dredging and disposal of material outside of the water body.

- Changes in sediment composition. This can be either a consequence of changes in sediment supply and/or forcing conditions (these aspects are considered elsewhere) or can be a human-induced activity (i.e. purposely replenishing a beach with a coarser fill material to reduce sediment mobility along a frontage).

- Changes in bed level/gradient. Again, this aspect can be either a consequence of other changes (i.e. reduced sediment supply, changes in erosion/deposition patterns, foreshore steepening due to squeeze against a static backstop defence structure) or can be a human-induced change (i.e. reprofiling of inter-tidal profiles or bed-levelling of substrate).

- Changes in area extent of sub- and inter-tidal zones. This can be caused by direct reclamation or landward re-alignment of flood defences or as a consequence of changes identified above and can result in net loss/gain of different morphological zones and, possibly, increased fragmentation within inter-tidal zones (i.e. longitudinally separating two areas of inter-tidal).

It should be noted that even under totally or nearly totally undisturbed conditions, there will be natural degrees of change in depth, sediment composition and structure, and in defining suitable criteria to enable classification of hydromorphological status it is necessary to attempt to establish metrics that will discern an anthropogenic effect above this natural variability.

On the basis that a particular water body can only depart from high status through anthropogenic intervention, some of the key anthropogenic pressures that potentially can influence morphological status include:

- Land claim;
- Construction of flood and coastal defences and other marine developments (e.g. piers, jetties, ports, marinas, etc.);
- Marine aggregate extraction;
- Navigation dredging; and
- Disposal at sea of spoil material.

Deviation from high status could be deemed to occur if the degree of anthropogenic intervention (as measured by some metric) exceeds a certain threshold. Setting this threshold, however, is 'judgement-based' and a variety of thresholds may apply. For example, it is feasible that some metrics require different thresholds for each of the status classes to reflect the relative significance of the pressures that different activities exert on hydromorphological status. Similarly, it could be that some types of water body are more sensitive to certain pressures than others and they too require different thresholds. For river flow high status is viewed any minor change in the supporting element, which could count as deterioration from high, according to normative definition. However with respect to supporting good status, WFD48 standards project does set flow type-specific standards.

The following section proposes a range of ancillary metrics, each applicable to some or all of the different water body types, and each associated with a particular threshold value. The section describes the assumptions and practicalities used to calculate the metrics, which included reference to problems in data availability. The following appendices provide detailed case study for the metrics describe.

4.2 Metric 1: Historical Hindcasting of Habitat Loss

The evaluation of habitat loss is described in Appendix 1. Hindcasting was used to assess historic reclamation against the original habitat area in order to classify % habitat loss. However, it was difficult to quantify the precise magnitude of habitat loss, due to uncertainties about historical change. In another study Healy et al (2002) used historical maps on land reclamation in the intertidal wetlands of the Shannon Estuary, Western Ireland, to determine the spatial extent of impact of such human intervention. The methodology was based on the availability of cartographic and documentary data on land reclamation in this area. Identification of reclaimed land was based on Ordnance Survey maps, where maps represented landscape features relating to reclamation, such as embankments, artificial arterial drainage channels and sluices. Using such indicators for the purpose of demarcation, the extent of the lands reclaimed was mapped. Documentary information on reclamation schemes from National Archives (that included letters, memoranda, draft bills and Government Acts, legal documents and statements of account) were used to support and supplement cartographic data.

The historical hindcasting is limited by the availability of good information, which may exist for around half of the transitional waters and some coastal areas in the UK. For other water bodies, new information would need to be developed through review, digitising of historical maps and charts. The Ribble case has been presented in Appendix 1 to show the approach and what uncertainties exist in one site. This showed that about 10% to 12% of the estuary area had been lost directly to reclamation since the 19th century. The metric should be expressed in relation to water body area and also in relation to change in intertidal area. The evaluation of the metric can be made for the other estuaries for which data already exists.

Indication of habitat change can be quantified by the relative fragmentation of a habitat within a transitional water body was examined using an assessment of land use changes from a historical perspective (see Appendix 5).

Metric 1	Habitat Loss <5 % = High
This can also include expert judgement based on land change analysis using historical maps to show spatially where change has occurred from natural to urban, urban to natural or natural to another natural habitat type.	
Natural to natural:	Mudflat to channel Mudflat to saltmarsh Saltmarsh to mudflat
Urban to natural:	Urban to saltmarsh
Natural to urban:	Channel to urban Mudflat to urban Saltmarsh to urban
No change:	-

4.3 Metric 2: Changes in Sediment Composition

Sediment budgets within water bodies, involving the input, transport and output of sediment, can principally be anthropogenically influenced by shoreline reinforcement and control measures, beach management activities, and dredging (navigation and/or aggregate). Some of these activities, e.g. beach replenishment or sediment recycling, can also change the sediment composition of parts of the water body. Particular examples include:

- Constructing coastal defences (e.g. sea walls, revetments, brushwood fencing) in front of recessional sea cliffs or dunes - reduced sediment input;
- Drainage and slope reinforcement works on soft sea cliffs to reduce instability - reduced sediment input;
- Reducing the amount of inter-tidal beach/shore platform lowering through stabilisation of inter-tidal foreshores: this generally is achieved through the construction of groynes, detached breakwaters, polders, vegetation planting, etc. that are designed to reduce the sediment transport potential along the frontage and in doing so stabilise the beach - altered sediment transport;
- Undertaking beach replenishment and sediment recycling/bypassing operations - increased sediment input (if fill imported from outside of water body) and altered sediment transport;
- Constructing piers, jetties, harbour arms, training walls, etc. that intercept sediment transport - altered sediment transport;
- Beach replenishment with fill of a different grain size to the indigenous beach material - altered sediment composition;
- Beach re-profiling (e.g. gravel barriers), which results in poor sorting of material on the beach face and in turn affects its permeability and performance under a range of natural forcing events - altered sediment composition; and
- Navigation dredging or marine aggregate extraction - increased sediment output.
- Degree of interruption to sediment input and sediment transport, leading to alterations to the sediment budget;
- Degree of interruption to natural sediment composition and structure, leading to alterations in the natural sizing and sorting (and hence behaviour) of the inter-tidal1; and,

[1] Sediment composition can also be affected by anthropogenic changes in the forcing conditions (e.g. reduced or increased wave exposure due to the construction of marine structures), but this is covered in Section 5.2.

- Inhibition of natural transgression across low-lying hinterland, leading to coastal squeeze.

Metric 2 =	$\frac{\text{Length of frontage influenced by reinforcement or beach management}}{\text{Total length of water body frontage}}$	
NB:	'influence' is usually represented by the actual length reinforced or managed, but in the case of groynes the zone of influence can be considered to extend downdrift by 5 times the last groyne length, and in the case of isolated piers, harbour arms the zone extends either side by a distance of 5 (for open structures) or 10 (for solid structures) times the length of the structure.	
Thresholds	High	<15 % of shoreline influenced
	Good	>15 % of shoreline influenced
Water Body Applicability	TW1, TW2, TW3, TW4, TW5, TW6, CW1, CW2, CW3, CW4, CW5, CW6, CW7, CW8, CW9, CW10, CW11, CW12	

The metric was evaluated for the Ribble in Appendix 1 and some key points were brought out in this assessment, for example, that relevant datasets are held in the NFCDD database but that it needs to be filtered before evaluating the metric. The metric calculated was able to show that 60% of the water body frontage was defended but did not provide directly any information about other coastal management or estuary management practices. Thus the metric remains evaluated based on the length of shoreline reinforcement that is identified and other factors need to be brought in through consultation of other data sources.

The metric has not included the effect of training walls where they are present in the water body; as in the Ribble. The direct area of disturbance from the physical size of the training walls is not representative of the change in sediment budget as the walls have the effect of changing the flow and sedimentation composition over the area of the transitional water body. A rough estimate of 5 to 10 times the area enclosed between the walls might provide a reasonable estimate of the spatial extent of the effect.

4.4 Metric 3a Bed Disturbance and 3b Sediment Budget: Changes in Morphology

Metric 3a: Bed disturbance

There were a number of anthropogenic pressures that give rise to significant direct bed disturbance in transitional and coastal waters:

- Fishing (principally otter and beam trawls, dredge and suction dredge)
- Aggregate extraction
- Navigation dredging
- Dredge material disposal

Bed disturbance may also be caused by other pressures, for example, swinging moorings, propeller wash, vessel grounding etc. but these are considered less significant at a water body scale.

Other pressures can also contribute to indirect change in bed disturbance, for example, where pressures alter local flows or wave exposure, but such pressures are accounted for elsewhere in the classification.

Other considerations relate to the requirement of high-resolution data, which may not be available for the majority of water bodies. As a consequence the metric would be problematic in implementing. Temporal change would also need to be captured in future refinements of the metric.

A bed disturbance metric was based on the most significant direct pressures namely, fishing, aggregate extraction, navigation dredging and disposal. The metric took these pressures into account through use of the following elements:

- Intensity of disturbance, which was a combination of fishing, aggregate extraction, navigation an disposal (scale low (1) to high (3));
- Spatial extent of disturbance (average area of water body disturbed per year);
- Average sensitivity of water body to bed disturbance.

Intensity and spatial extent

For bed disturbance all pressure activities (fishing, aggregate extraction, navigation an disposal) assessed in the case studies were at a resolution of 1km^2 (see Appendix 3). This provided an overall picture for individual water bodies that could account for cumulative pressures.

Intensity of disturbance for individual pressures will vary depending on the nature of the pressure. For example, aggregate extraction and navigation dredging will result in 100% removal of benthic infauna in the area of direct removal, whereas otter trawling and dredge material disposal may result in relatively little impact. The intensity of disturbance from dredge material disposal will be assessed based on the amount of material disposed at the disposal site in relation to the area of the disposal site. This metric was used as part of the Article 5 risk assessment for TraC waters in England and Wales and can be relatively easily established at UK level.

The intensity and spatial extent of pressure can be converted into a single pressure metric for individual water bodies as follows (equation 1):

$$(1) \qquad \frac{\_\ (\text{Relative intensity x area of water body})^{\text{Low to High}}}{\text{Maximum Intensity x Area of Water Body}}$$

It should be noted that since proposing the scales None, Low, Medium and High, only a distinction between High (>70%) and Good (70-30%) status is now required. Thus, values for Low and Medium could be considered to equate to Good status.

Water body sensitivity

The consequences of bed disturbance within a water body will depend to a large extent on the amount of natural bed disturbance within the water body. The assessment of the extent to which bed disturbance is likely to affect biological quality elements therefore needs to take this into account.

Water body sensitivity based on current expert knowledge of sediment transport processes within a water body. It was proposed that an average sensitivity map for water bodies could be developed, sensitivity being related to the characteristics of habitats (and associated biological elements) within the water body, for example naturally disturbed in shallow water, wave affected environments (less sensitive to anthropogenic bed disturbance) and quiescent non-wave/current affected deeper water environments (more sensitive to anthropogenic bed disturbance).

The sensitivity of the receiving environment can be estimated by expert judgement of sediment transport processes within a water body to generate an average sensitivity map for water bodies. Over time it may be possible to develop a more sophisticated approach where sensitivity is assessed at the same scale as the pressures and/or incorporates information on the sensitivity of particular biological quality elements.

However, at this stage, it was not possible to develop sensitivity at more than a generic level for each water body due to the lack of detailed information on sediment transport and coastal process regimes within the water bodies considered. For the purposes of this paper, therefore, sensitivity in all cases has been assumed to be 'moderate'.

Overall bed disturbance assessment

The overall assessment would combine the relative intensity metric with the sensitivity metric to produce an overall classification:

		Sensitivity		
		H	M	L
Intensity	H	Mod	Mod	Mod
	M	Mod	Mod	Good
	L	Mod	Good	High

Metric 3 =	Relative bed disturbance based on commercial fishing, aggregate extraction, navigation dredging and maintenance dredging, but at this stage not taking account of sensitivity	
Thresholds	High	>70%
	Good	70-30%

Working example of Metric 3

There are three components to this metric.

1) Calculation of the intensity of disturbance for different anthropogenic activities using the following scale.

None = 0
Low = 1
Med = 2
High = 3

The anthropogenic activities fall into four types as follows.

- Commercial fishing intensity. This is ranked based on standardised Sea Fisheries Committee (SFC) fishing effort data for beam and otter trawl activities only (see Working Paper 6a: Appendix 2).

  Low = 1 (0.001 to 0.149)
  Med = 2 (0.159 to 0.299)
  High = 3 (>0.300)

- Aggregate extraction and maintenance dredging. In this case only one scale could be determined because impact will result in 100% removal of benthic infauna in the area and currently no intensity data is available.

  High = 3

- Dredge material disposal. This is ranked using disposal volumes divided by disposal area relative to water body size. The following scores were obtained.

  Low = 1 (<10cm)
  Med = 2 (10-30cm)
  High = 3 (>0.3m3 per m^2)

2) Calculation of the spatial extent of the disturbance based on the results of component 1 above by summing the rank scores in each cell and then expressing these as a proportion of the total possible intensity for the water body. This is expressed in cell units of $1nm^2$ for each water body. Figure 1 shows an example of the spatial extent of the bed disturbance based on component 1.

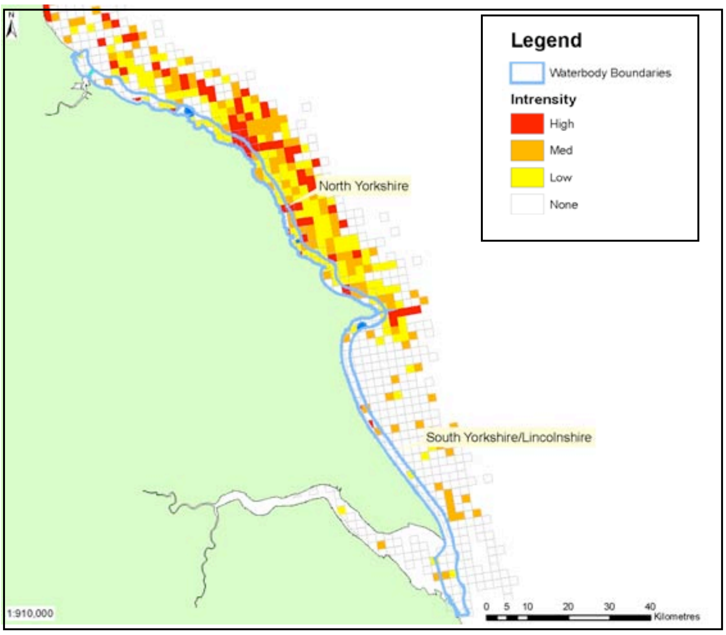
The intensity and spatial extent of pressure can be converted into a single pressure metric for individual water bodies using equation (1) above.

For example, the total number of cells categorised as either low, medium or high (based on their relative intensity to water body area) in East Isle of Wight water body is:

Low = 0
Med = 2
High = 57

Therefore the sum of these cells equal 59. By dividing this value with the cells categorised as having the maximum intensity to water body area, the metric value equals 0.62 or 62%. This is considered as Medium bed disturbance. However, it should be noted that since proposing these scales, only a distinction between High (>70%) and Good (70-30%) status is now required. Thus, values for Low and Medium could be considered to equate to Good status.

Figure 1. An example of the spatial extent of the bed disturbance based on component 1



3) Water body sensitivity is based on expert knowledge of sediment transport processes within a water body.

In the example above, expert knowledge was used to determine the relative sensitive of the water body as Medium. Consequently, the final overall classification for this water body is Good.

Metric 3b: Sediment budget

This was based on the degree of impact on sediment outputs/inputs (due to dredging/reclamation, for example), leading to alterations to the sediment budget. The scientific literature and consultant reports were used in the assessment (Appendix 2). Expert judgement was used to determine whether High or Good status was achieved for the water body being examined.

Metric 3b =	Qualitative assessment based on expert assessment of the available evidence and locations/extent of various anthropogenic and natural activities	
Thresholds	High	No identifiable long-term impacts on sediment budget
	Good	Slight identifiable long-term impacts on sediment budget

Working example of Metric 3b

The best example is in Appendix 2. In general estimating the sediment budget of a water body is complex and often little detailed information is available. The metric is open to expert judgement based on supporting scientific literature and reports specific to the water body of interest. The Humber Estuary, for example, the sediment budget appears to be finely balanced. Using information on the historical analysis of bathymetric change, the inputs are currently sufficient to allow the system to adjust to sea level rise. Moreover, the evidence suggests that the system appears to be importing sediment, which is consistent with geological evidence that suggests that much of the succession of Holocene sediment in the estuary is of marine origin. In addition, the evidence appears to show that the system is a complex balance between the coarser sediment exported in the ebb dominant tide channel and the finer sediment imported and deposited on the intertidal mudflats. Based on such a report expert judgement is used to decide the metric outcome. In this example the status is Good.

4.5 Metric 4: Changes in Forces – Waves

Whilst both transitional and coastal water bodies can be subject to wave activity, most human intervention that influences wave processes occur directly in coastal water bodies, particularly CW1-6, and therefore this metric focuses on these.

Offshore structures, such as detached breakwaters, surfing reefs, wind and wave turbines, and offshore platforms, all have the potential to affect the wave regime over part of a water body area. Since wave processes, in combination with other meteorological and tidal effects, can be important in mobilising and transporting sediment, they also have the potential to cause sedimentological or morphological change.

Metric 4 =	$\frac{\text{Area influenced by structures}}{\text{Area of water body}}$	
NB:	Area influenced by structures may be taken as 10 times the area occupied by structures in the absence of more detailed information.	
Thresholds	High	10% of sea bed influenced
	Good	>10% of sea bed influenced
Water Body Applicability	CW1, CW2, CW3, CW4, CW5, CW6	

This metric was evaluated for the Ribble in Appendix 1. It was clear that within the water body there was one coastal structure that could be included in the assessment, at Southport, and the 10 times area multiplier looked plausible on the accompanying figure. It was also recognised that the extensive training walls in the estuary would have had an influence on wave propagation but now that they were surrounded by extensive shallow seabed areas and intertidal areas they were not included. The data required for this evaluation was not contained in one dataset but had to be created from other sources.

4.6 Metric 5: Changes in Forces – Tides

Whilst both transitional and coastal water bodies can be subject to tidal activity, most human intervention that influences tidal processes occurs directly in transitional water bodies and therefore this metric focuses on these.

Artificial barrages or full- or part-tide barriers such as weirs or sluices across water bodies can all have the potential to affect the tidal regime over part of a water body area. Since tidal processes, in combination with meteorologically-driven processes such as surges and fluvial flows, can be important in mobilising and transporting sediment, they also have the potential to cause sedimentological or morphological change.

Metric 5 =	Presence or absence
Water Body Applicability	TW1, TW2, TW3, TW4, TW5, TW6

In the case of the Ribble (Appendix 1) it was the absence of a barrier that meant this metric was evaluated as 0. In terms of tidal flow patterns in the estuary the presence of the extensive training walls will have an effect on the detailed flood and ebb flow speeds and patterns and may have some influence on propagation of the tidal wave. The influence will be very much less than that caused by a barrier.

The data for barriers is not presented in the NFCDD database and would have to be imported from other sources to allow a formal evaluation of this metric for other sites.

4.7 Metric 6: Changes in Forces - River Flow

This metric is compatible to the approaches being developed for River Water Bodies in terms of the high status hydrological test at Q95, which relates to;

- the baseline of the 'natural' flow;
- applies to impacts which cause the flow to change either above or below this 'natural' flow.

In the present evaluation (see Appendix 1) the situation for the Ribble was conducted by analysing the available data for Q95, Q5 and daily mean flow. It was not possible directly to evaluate the Metric 5.

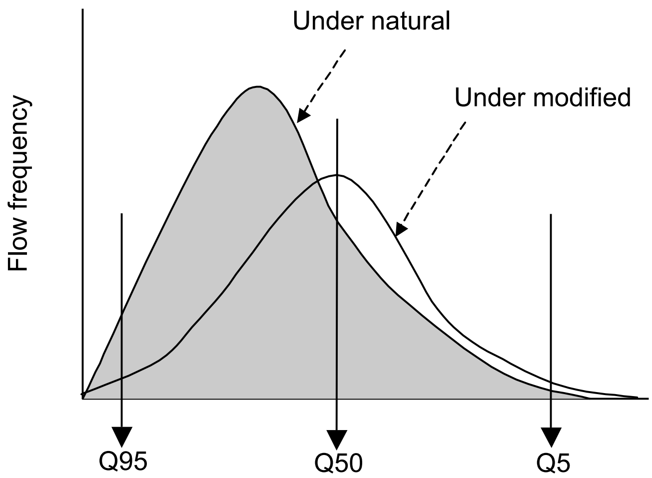
Metric 6 =	Does river flow at the downstream assessment point of the adjacent river water body pass tests for high status hydrological regime? Yes or No.	
NB:	If qualitative 'catchment urbanisation' or 'flow regulation' filters not passed, then the answer cannot be Yes.	
Thresholds	High	Passes filters and impacts <10% of Q95
	Good	N/A
Water Body Applicability	TW1, TW2, TW3, TW4, TW5, TW6	

An assessment can be adopted from the adjacent river body classification, rather than needing to be undertaken for each transitional water but this has not been undertaken at the present time.

Conceptually, it might be possible to relate freshwater flow rates based on the distribution curves of Q, where Q5, for example, represents the more extreme end of flows for a particular estuary and thus possibly having the greatest impact on the ecological elements. However it was considered that Q95 would not in fact reflect ecological requirements of fish migrating from transitional waters into rivers and that further research would be required. Similarly, the Q95 may not be adequately reflect flow impacts on benthic communities which were likely to be influenced by periods of extreme high and low flow.

The approach is based on the assumption that we have knowledge of what the effects are under Natural Conditions. Consequently, modifications to these conditions resulting from some hydromorpholoical impact could be detected and linked to the downstream impacts.

Conceptual relationship between natural and modified freshwater flow rates at the top-end of a transitional water body.



In the evaluation for the Ribble it was shown that for the change in Q95 to be greater than 10% would require one or more of the 5 gauged inflow points to the estuary to have significantly reduced freshwater flow.

4.8 Metric 7a Stratification/Flushing and 7b Salinity

Metric 7a: Stratification/flushing

This metric was evaluated for sea lochs in Scotland and for some transitional water bodies in England and Wales.

The presence or absence of stratification in a particular sea loch is determined by the interaction of a number of factors including tide, wind, sill depth(s), number and geometry of basins within the loch and freshwater flow. Tides and wind provide turbulent kinetic energy to mix the less dense surface water downwards. The balance between the tidal and freshwater inflows to the loch controls the mean salinity in the loch and the downward penetration of freshwater (mixing depth) is limited by the supply of kinetic energy relative to the inflow of freshwater. The sill depth relative to the mixed depth or the maximum depth of the basin affects the flushing of the surface and bottom layers of the basin. The mean flushing time of a loch can be defined as the loch volume divided by the tidal flow rate. However the presence of stratification and /or deep basins will tend to increase the retention times in the basin deep water. The aspect ratio (length/width) of the loch also impacts on the rate of exchange with low aspect ratio lochs exchanging more rapidly due to the increased importance of exchange due to the direct penetration of external eddies into the loch.

Some of factors controlling flushing and stratification are less subject to anthropogenic change than others. For example the tidal range at the mouth of the loch would only be changed by significant bathymetric changes seaward of the loch entrance. Based on the possible classifications of sea lochs proposed by Edwards and Sharples (1986) the most relevant factors for determining the potential impact of hydromorphological change on stratification/flushing would appear to be:

- Ratio of runoff to tidal flow
- Ratio of mixing depth to maximum depth
- Ratio of mixing depth to sill depth

- Aspect ratio

The first of these metrics was chosen for evaluation as the key hydromorphological parameter and the next section presents an example of how the metric has been derived previously and evaluated.

The example in Appendix 4 has shown that there are a large number of input parameters to feed into the calculation of the dimensionless Metric 7 but that it can be evaluated in a consistent fashion.

Metric 7 =	runoff inflow	
NB:	Runoff and inflow in this example has been calculated in million cubic metres per year and the ratio presented in parts per thousand	
Thresholds	High Good	Not known at present Not known at present
Water Body Applicability		CW11, CW12, TW5, TW6

A similar metric was evaluated for the Ribble (Appendix 1) to show how this could be evaluated for other transitional waters. It was demonstrated that using two different datasets the Ribble was well mixed. However, there were uncertainties in the input data and it will be necessary to adopt a consistent dataset and method for evaluating this parameter between different transitional waters at different times.

A further evaluation was made using the Futurecoast dataset (Appendix 4) for transitional water bodies (estuaries). About 42 % of the 84 estuaries evaluated were probably well mixed but the limits between stratified and well mixed conditions are not precise and the mixing of the estuary will vary with tidal range and with the seasonal pattern of river inflow. Further comparison with field data will be required to work out when stratified estuaries give way to well mixed estuaries.

Metric 7b: Salinity

The salinity regimes of estuaries are known to be complex and highly variable both seasonally and temporally and as a consequence difficult to apply to a single ancillary criterion. Estuaries show a dynamic mixture of transitional conditions that are driven by changes in tidal amplitude and the volume of freshwater flows, although depth changes also play an important part (see[2]). On a broadscale, estuaries have been classified based on their salinity regimes as mixed, partially mixed or stratified. The significance of salinity changes on ecological elements is predominantly related to the challenges salinity has on the physiological processes of aquatic organisms. This is reflected in the distribution patterns of these organisms (e.g. oligohaline, euryhaline, stenohaline organisms) within an estuary.

Using the 3-band ‘sensitivity’ system developed by the freshwater hydromorphology project it is proposed that transitional waters with a flow ratio of $F<0.1$ and characterised as fully mixed have a low sensitivity to changes in freshwater input and hence could be screened out. Based on the above metric 7a this could equate to about 40 % of estuaries but will require a more in depth evaluation to judge the generality of the metric. It should be noted that further work is required to determine threshold values. Those transitional water bodies with $F>0.1$ would be required to undergo further assessment. It is proposed that this could be developed using standard measures of freshwater flows into an estuary, for example, Q95 distribution curves, although this approach needs further development.

It should be noted that there is insufficient data to support the development of a threshold value for salinity and further research is required. Moreover, the project board had

[2] McLusky, 1981 The Estuarine Ecosystem. Blackie & Son Ltd.

originally removed this metric from the classification because thee was a lack of insufficient data and understanding was currently available to determine a threshold.

Metric 7b= (Length of water body affected by natural Q5) - (current Q5) / Total length of water body

Thresholds	High	%* of length influenced
	Good	%* of length influenced

* Threshold not determined

5. Amalgamating Metrics Within a Draft Classification Scheme

The initial concepts outlined in Section 3 of this Working Paper were founded on the idea that there may be one headline criterion applicable to both transitional and coastal waters (discussed in Section 4). However, this approach has not been taken forward for testing. Instead it was considered by the Project Board to conform to the normative definitions of the directive and that 'one out all out' should be used for determining the difference between High and Good Status.

In many transitional waters, perhaps the principal hydromorphological pressure that has occurred historically has been inter-tidal habitat loss due to land claim. This has not only resulted in a direct loss of inter-tidal, but also has altered the morphology and hydrodynamics of the whole water body (or large parts of it). Whilst the issue of inter-tidal land claim and habitat loss has relevance to some coastal water bodies, a more relevant issue to a wider range of coastal areas is the effect of shoreline reinforcement and beach management activities on the non-cohesive sediment budget. For example, in many coastal water bodies the construction of sea walls and revetments or the installation of measures to reduce sea cliff instability has directly, and significantly, reduced the input of fresh material to the coastal sediment budget. Furthermore, many foreshore stabilisation measures such as groynes and beach replenishment have significantly affected the transportation of sand and gravel along the shore, resulting in morphological changes along reinforced/managed frontages and often along downdrift frontages also. Due to these factors, it may be necessary to consider different criteria for transitional and coastal waters.

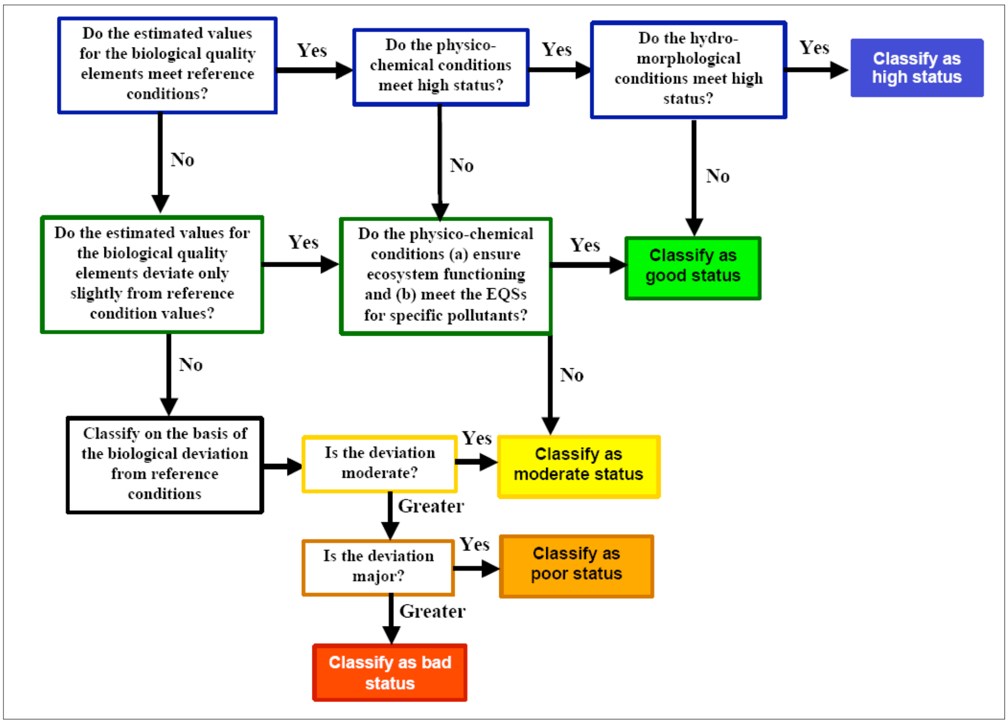
In developing the thresholds to be used to delineate high, good and moderate status for each of the metrics, it is not possible to prescribe absolute values with a high degree of scientific robustness due to the wide range and large number of site-specific issues and factors that always need to be considered. This is why expert assessment is such a fundamental component of all regulatory bodies' own approaches to specific consenting/assessment issues. It is, however, possible to provide an indication of the typical ranges that, under most circumstances, may be considered to represent 'minor' and 'slight' anthropogenic disturbances - especially if overlap exists between the high to good and good to moderate status bands enabling flexibility to accommodate a degree of expert assessment.

One conclusion is clear from the work that has been undertaken to date: there is no easily identifiable, universally applicable method for developing a draft hydromorphological classification scheme. It appears that many of the hydromorphological processes associated with the metrics tested is poorly understood and that in many cases information specific to testing the thresholds proposed is equally poor.

5.1 Inclusion of Good to Moderate Assessments

The proposed assessment can be used to determine whether the particular hydromorphological parameters being considered as based on the metrics are affected to such an extent by anthropogenic pressures that high status cannot be achieved. The principle being applied is the 'one out all out' (see Figure 2).

Figure 2. The role of hydromorphological classification within the overall classification process



6. Summary Overview of Classification for the Ribble

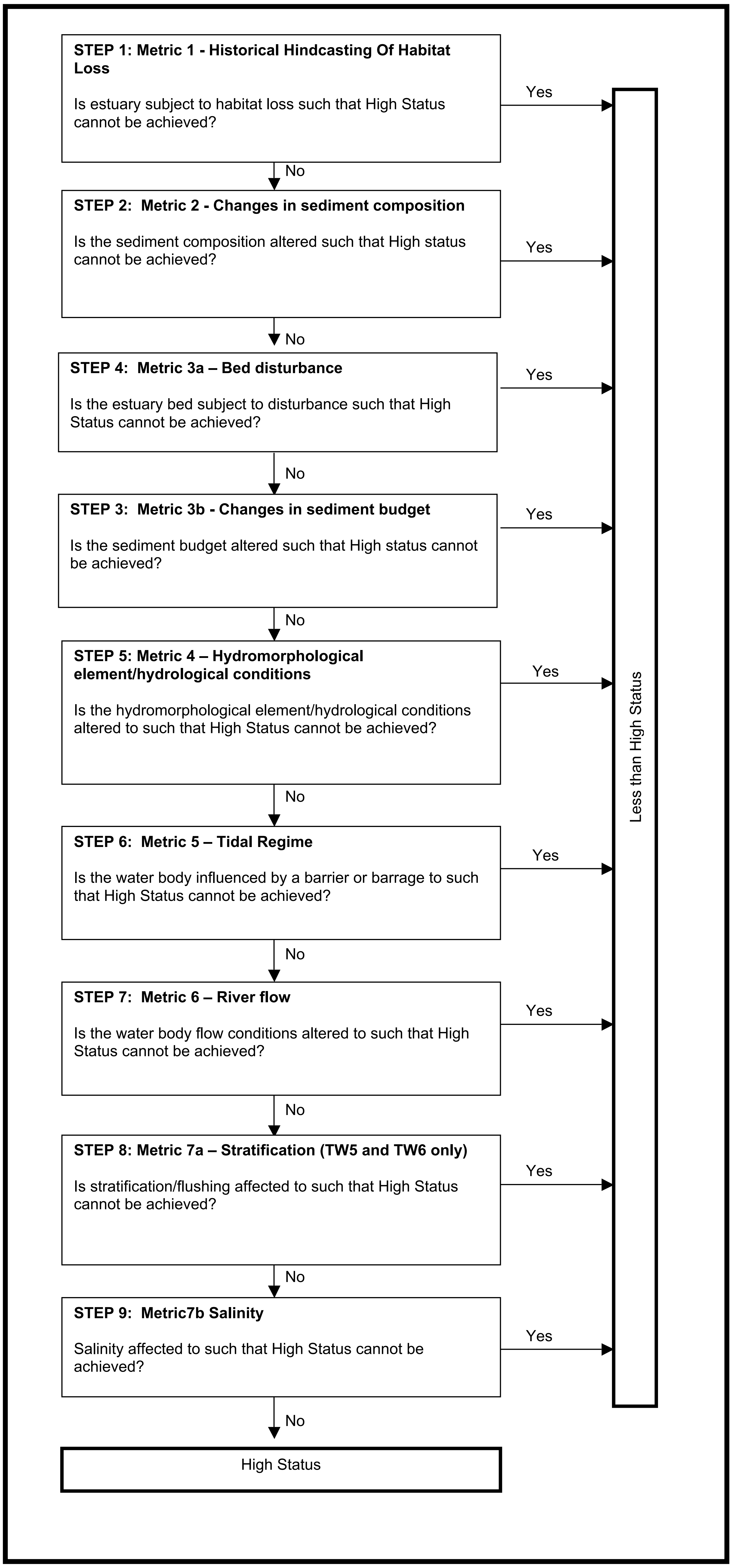
Based on the classification scheme outlined in figure 3 below, the following summary has been proposed for the Ribble, which is classified as Good Status.

Note: The threshold values in this table have been placed by expert judgement but remain to be verified. They should not be taken as general statements at this stage of development.

Metric	Question Proposed	Classification Response	Threshold See Note Above in Text
1	Is estuary subject to habitat loss to the extent that High Status cannot be achieved?	Yes	5 %
2	Is the sediment composition altered to the extent that High status cannot be achieved?	No	15 % sediment interruption
3a	Is the estuary bed subject to disturbance to such an extent that High Status cannot be achieved?	No	70%
3b	Is the sediment budget altered to the extent that High status cannot be achieved?	No	Qualitative
4	Is the hydromorphological element/hydrological conditions	No	10 % of area influenced

Metric	Question Proposed	Classification Response	Threshold See Note Above in Text
	altered to such an extent that High Status cannot be achieved?		
5	Is the water body influenced by a barrier or barrage to such an extent that High Status cannot be achieved?	No	Presence/absence
6	Is the water body flow conditions altered to such an extent that High Status cannot be achieved?	No	Change 10 % or less of Q95
7a	Is stratification/flushing affected to such an extent that High Status cannot be achieved?	No	10% of F value
7b	Salinity affected to such an extent that High Status cannot be achieved?	No	Not determined

Figure 3. Classification scheme for transitional and coastal waters



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