The Coal Authority

Resolving the impacts of mining

Metal Mine Failing Waterbodies Assessment - Overview Report

February 2020

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1.0 Introduction

The Coal Authority has been working with Natural Resources Wales (NRW) to develop and implement a methodology for the assessment of metal mine impacts to waterbodies across the country. The work is to support the next round of Water Framework Directive (WFD) planning (Cycle 3), providing a review of where and why waterbodies are not achieving Good status and deriving high level costs for a generalised set of mitigation actions required to achieve betterment or WFD status change for impacted waterbodies. Outputs from the work are standalone, but also directly inform other strands of WFD work that NRW is carrying out for other stressors.

As well as meeting the needs of WFD implementation (assessment, management and development of a programme of measures), the work is in line with the Environment (Wales) Act 2016, and in particular supports Sustainable Management of Natural Resources (SMNR). Outputs from this assessment will be used to develop a high level costed programme of works to help build resilience, improve water quality and as a result, improve biodiversity on a waterbody and river catchment scale and realise other benefits associated with mine legacy mitigation.

Future works will feed into the evidence base for: Natural Resources Policy (NRP) reviews; Area Statements; and future State of Natural Resources Reports (SoNaRR). Any works will need to be justified on their benefits, taking into account NRP and the Well-being of Future Generations (Wales) Act 2015.

This report lays out:

- The scope and methodology used for the Failing Waterbodies assessments;
- Outcomes of the assessment (including the estimated cost of mitigation works); and
- Next steps in developing a programme of works.

The costs laid out in the individual river system reports are high level budget estimates, with varying degrees of confidence for individual elements. Further refinement and a reduction in uncertainty would be expected when budgeting for individual work packages, but the reported budget estimates provide an order of magnitude indication of the cost of a programme of works needed to have significant positive impacts on the water environment (up to and including WFD status change).

Individual reports are provided for every impacted river system, which form Appendix C of this report. Each report provides detail as to the evaluation of each river system and the works required to address identified significant impacts, as determined by the standardised methodology. A combined summary of the outcomes is provided in this overview report.

The contents of the main report and appendices can be used to inform as appropriate:

- Ongoing development of Area Statements, Public Service Board or Partnership engagement;
- WFD consultation on Significant Water Management Issues; and
- Waterbody objectives in the draft River Basin Management Plan.

2.0 Scope

The scope of work completed to date has included the development and implementation of a methodology to complete the systematic, high level appraisal of Welsh surface and groundwater waterbodies that fail to achieve WFD Good status due to pollution from mine waters (metal and non-metalliferous). This includes a review and assessment of Wales' evidence base to identify at a waterbody scale where technical constraints and costs relative to benefits of mine water remediation, are likely to prevent the achievement of Good status. The scope included:

- Developing a method for strategically assessing remediation requirements and thereby the technical feasibility of meeting WFD Good status, in water bodies failing due to metal mine pollution using existing evidence.

- Delivering a strategic assessment of all water bodies identified as failing in Wales, along with technically feasible proposals for mitigation and where possible an estimate of the scale of associated costs.

The scope also included a requirement to engage stakeholders in the process, in line with principles of SMNR and the WFD. Stakeholder engagement has been invited through presentation at Wales Water Forum and through direct discussion with local NRW officers.

In order to deliver the scope, a methodology has been developed for assessing each waterbody not achieving Good status, in a holistic manner as part of a whole river system rather than in isolation. The Reasons for Not Achieving Good (RNAG) for each waterbody have been derived and documented by NRW and supplied to the Coal Authority for incorporation into the assessment. The methodology takes into account an evidence base, including specialist knowledge of metal mine legacies and metal mine treatment (remediation and water treatment) held by both NRW and the Coal Authority, plus local knowledge of specific mine sites and river systems held by NRW.

The evidence base includes:

- Previous NRW assessments as part of previous WFD cycles;

- The location, size and features of metal mines in each waterbody and river system;

- Summaries of quality, flow and loading data for each waterbody and mine site;

- Simple loading models to test loading removal hypotheses; and

- Standardised costs for metal mine treatment activities, based on Coal Authority experience of similar works.

The methodology uses the available evidence base to answer three main questions:

- Is the waterbody failing as a result of metal mine input?

- Would removal of metal mine input improve the status of waterbodies relating to metals?

- Is there any evidence that treatment is technically infeasible?

The answer to each question is given a confidence rating, which is compiled into an overall confidence rating in the assessment.

Costs for mitigation are generated based on:

- Coal Authority framework rates for environmental engineering and development of mine water treatment works;
- Quantitative capping and drainage provisions for exposed mine waste tips, with areas estimated from GIS aerial photos and historical maps;
- Construction and operating costs for passive schemes based on the Force Crag vertical flow pond (VFP) type facility for flows less than 10 l/s;
- Construction and operating costs for active treatment schemes based on a generic high density sludge (HDS) plant for flows of 10 l/s or greater;
- Capital costs and operational costs for passive and active treatment works scaled using a 6/10 rule rather than linear scaling; and
- Minimum costs for treatment based on Coal Authority experience.

All costs are discounted in line with Treasury 'Green Book' methodology over a 40 year time period. This includes base assumptions of a major input of capital for large scale maintenance at Year 20.

A standard cost model/methodology has been used and tested against more detailed studies for robustness of figures and to develop a scaling factor for active treatment. The one exception is for Parys Mountain on Ynys Mon, where the flow and quality is more extreme than any of the other discharges assessed. The Coal Authority's active plant costing method has been used directly for this one instance to get a more reliable cost estimate.

A full breakdown of the assessment methodology is provided in Appendix A, with the costing methodology provided in Appendix B.

It should be noted that the cost estimates generated are high level, hence rounded to the nearest £10,000 for CAPEX and OPEX and to the nearest £100,000 for TOTEX. They need to be considered relative to the assigned confidence level to account for risk, uncertainty and optimism bias. For many of the hundreds of mine sites, the evidence base is low and therefore status of sites and associated costs should be expected to change as more information becomes available. More detailed assessment and mitigation development can result in schemes being deemed unnecessary, as well as identifying additional mitigation requirements. Cost variations can therefore be both negative and positive, although increases are more likely if additional schemes are identified over and above the ones previously assessed.

It should also be noted that costs are based on current tried and tested technologies. Much research, development and innovation is being carried out on metal mine treatment, which could lead to significant improvements, including cost and carbon savings as part of design development (outline and detailed). The costs therefore provide a high level base cost to be challenged and refined as projects progress and uncertainty is managed and mitigated.

3.0 Outcomes

3.1 Overview

Fifteen individual reports, fourteen river system reports and one groundwater report, have been developed summarising the assessments and outcomes of this project. Each is provided as an appendix to this report (Appendix C) and should be read in conjunction with this overview report.

For each river system, mines from NRW's metal mine list were identified and provided with a Red/Amber/Green (RAG) status; Red mines being those known or highly likely to be impacting the water environment; Green mines being unlikely to be impacting; and Amber mines which might be impacting, but need additional data to inform either way. The distribution of Red sites is shown on Figure 1.

Overall, 129 Red, 140 Amber and 278 Green mine sites have been identified and characterised. This has been largely carried out using GIS, with the layers used summarised in Appendix D. The GIS screening has been used with other evidence, such as previous reports and NRW monitoring data to develop a desk top study for each river system. Each desktop study has been supplemented by individual site knowledge from NRW's central and area teams. The evidence base used for each river system assessment is summarised in the individual river system summary reports (Appendix C).

3.1.1 Discounted Costs to Mitigate River Systems

High-level mitigation costs for each river system derived from the methodology presented in Appendix A are summarised in Table 1. These costs have been discounted over a 40 year period in accordance with Treasury 'Green Book' rules.

As well as costs, the confidence of assessment, in line with the methodology summarised in Appendix B, has been included. Confidence statements (inter-comparative and based on professional judgement) have been used to amend mitigation cost figures as follows: those with high confidence may increase by up to 50%; with medium up to 100%; and where there is low confidence, up to 200%. The overall confidence level assigned for each waterbody and river system is based on the lowest confidence level for individual assessments of waterbody improvement requirements and technical feasibility screening as defined in Appendix A.

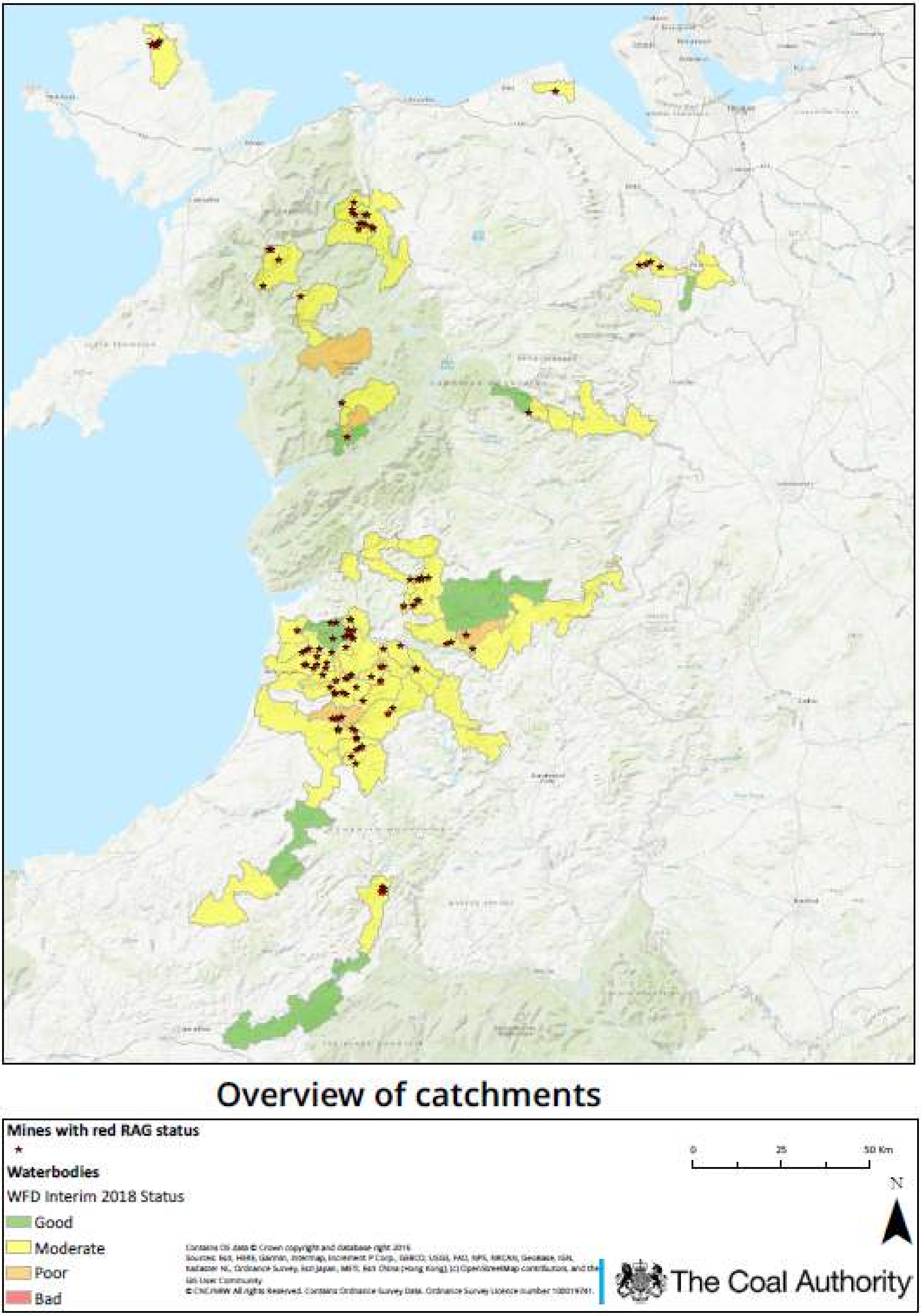


Figure 1: Overview of Catchments

Table 1: Summary of mitigation costs

River System	Number of waterbodies impacted (not including groundwater)	Total length of impacted waterbodies (km)	Potential mitigation cost estimate (£M)	Total Length of waterbodies improved (km)	Cost per km improved (£M)	Total length of waterbodies status change (km)	Cost per km of status change (£M)	Confidence
Rheidol	**7 (inc. 1 lake)**	**68.1**	**53.7**	**68.1**	**0.79**	**41.8**	**1.29**	**Medium**
Owing to the number of mines, their extent and uncertainty over many sources, it is infeasible to improve all waterbodies to Good status relative to metals without taking a long term iterative approach. Improvements can however, be made to individual waterbodies through identified measures, with some waterbodies or parts of waterbodies likely to attain Good status relative to mine related impacts within one or two RBMP cycles. This will be dependent on high levels of treatment for the main discharges and a focus on the most impacted waterbodies, together with gaining a better understanding of mine spoil and sediment impacts on the combined river systems.								
Teifi	**3**	**41.8**	**11.4**	**41.8**	**0.27**	**41.8**	**0.27**	**High**
Approximately 41.8km improved with resilience provided to a further 50.6km that failed previously because of metal mines, based largely on removal of two sources at Abbey Consols and Esgair Mwyn.								
Ystwyth	**4**	**53.6**	**34.4**	**53.6**	**0.64**	**31.9**	**1.08**	**Low to Medium**
It appears from the simple modelling that status change is not possible even with 100% removal of all known sources, as there is significant residual metal loading, primarily zinc. Treatment of the main known sources of pollution, comprising Pugh's, Gill's and Frongoch adits, the residual small seepages from the Frongoch mine, Level Fawr and erosion of mine waste around Wemyss, will significantly improve water quality and potentially ecology in the river system (although remaining non-metal mine stresses are noted). Better monitoring will also help determine where future effort can be focussed, once the impacts of early mitigations have been observed / confirmed.								
Clarach	**2**	**25.4**	**15.7**	**25.4**	**0.62**	**25.4**	**0.62**	**Low to High**
Estimations are based on simplistic modelling, not taking into account contaminated sediments or variations from mean quality. Therefore, once the main sources have been addressed, validation and further characterisation of residual pollution would be needed to identify any further mitigation required to achieve / maintain Good status.								
Dyfi	**4**	**53.8**	**17.0**	**53.8**	**0.32**	**38.1**	**0.45**	**Low to High**
Upper Twymyn waterbody will improve, but not necessarily achieve status change relating to Zn, based on remediation of multiple mine sites at Dylife and on the Afon Fachdre & Nant Caeconroi tributaries. High levels of uncertainty relate to sediment impacts and interactions with workings within the watercourse. Simple modelling of known inputs does not result in status change.								

River System	Number of waterbodies impacted (not including groundwater)	Total length of impacted waterbodies (km)	Potential mitigation cost estimate (£M)	Total Length of waterbodies improved (km)	Cost per km improved (£M)	Total length of waterbodies status change (km)	Cost per km of status change (£M)	Confidence
Mawddach	**4**	**32.5**	**7.5**	**32.5**	**0.23**	**25.6**	**0.29**	**Low**
Afon Gain upstream of many of the failing waterbodies is failing because of non-mine related natural mineralisation and contaminated land derived metals and masking mine related impact downstream. Improvements are proposed at Glasdir, even though waterbody not failing as a result of mines, in order to improve water quality and increase resilience, although decreased metal loadings will not effect status change.								
Leri	**3**	**32.1**	**14.2**	**32.1**	**0.44**	**18.4**	**0.77**	**Low**
Currently there is insufficient evidence to determine which mines are having the most significant inputs. Further work is needed on the mines in the upper waterbodies and sediments within the whole catchment, to focus and direct mitigation efforts and increase confidence in outcomes. There is potential to improve the status of up to 23.9km of watercourse, assuming Afon Cyneiniog should be reclassified (currently already Good and not included in status change column). This could change with provision of additional data, as there are many mines in the waterbody area.								
Tywi	**2**	**69.3**	**12.5**	**69.3**	**0.18**	**0**	**N/A**	**High**
Both assessed waterbodies currently classed Good, but mine impacts identified that should prevent this. NRW monitoring data for the Tywi not from d/s of Nant y Mwyn in the 2018 classification, but that may change in the next classification.								
Glaslyn & Dwyryd	**3 (inc. 1 lake)**	**39.5**	**5.7**	**39.5**	**0.14**	**14.9**	**0.38**	**Low**
Metal inputs from natural geology and other Environmental Permit Regulations (EPR) activities likely to prevent status change relating to metals within river system. More information is needed to provide focus for most effective betterment within the river system.								
Conwy	**3**	**84.3**	**30.7**	**84.3**	**0.36**	**73.1**	**0.42**	**High**
Full status change possible, provided pH effects in Llugwy are mitigated.								
Goch Dulas	**1**	**3.8**	**5.7**	**3.8**	**1.51**	**3.8**	**1.51**	**Medium**
Good mitigation potential, but high costs for a limited length of watercourse, so wider benefits need to be identified and incorporated into cost effectiveness assessment.								
Goch Amlwch	**1**	**3.5**	**26.5**	**3.5**	**7.68**	**3.5**	**7.68**	**Medium**
Good mitigation potential, but high costs for a limited length of watercourse, so wider benefits need to be identified and incorporated into cost effectiveness assessment.								
Severn	**9**	**113.6**	**3.6**	**113.6**	**0.03**	**37.1**	**0.10**	**Low**

River System	Number of waterbodies impacted (not including groundwater)	Total length of impacted waterbodies (km)	Potential mitigation cost estimate (£M)	Total Length of waterbodies improved (km)	Cost per km improved (£M)	Total length of waterbodies status change (km)	Cost per km of status change (£M)	Confidence
Quality improvement relating to metals possible for many waterbodies, although majority (by length) currently classed Good, with inactive historical failure parameters. Mitigation therefore promotes resilience over much of the river system, with relatively small lengths of status change.								
Wye	**6**	**55.3**	**6.6**	**55.3**	**0.12**	**47.2**	**0.14**	**Low**
Two waterbodies currently classed Good, but metals were not assessed in latest round. Monitoring data indicates at least one should fail for metals and has been included in status change column as a result.								
Clywedog, Trefnant Brook & Y Garth	**4**	**30.0**	**31.7**	**30.0**	**0.84**	**30.0**	**0.84**	**Low**
Zn data from previous monitoring and a note on RNAG sheet not to deactivate for Clywedog - Gwenfro to Black Brook (GB111067051690). Not assessed for metals in 2018, but considered likely to have failed if it was. Therefore included in status change column for this assessment.								

Notes: All waterbody lengths based on shape files from GIS and include main rivers only, without minor tributaries.
Costs are quoted excluding any allowance for assessment confidence statements.

Costs per km improved have been included as well as those for status change. Using status change only as a metric does not take into account benefits arising from significant betterment, including increased resilience of river systems. There is also a recognition that climate change impacts may result in future derogation in status for rivers where impacts are not currently sufficient to prevent classification as Good. It should be noted however, that the quoted improved lengths include the entire length of the impacted waterbody regardless of the mine impact entry point (therefore confirmed as mildly overstated). On the other hand, quoted lengths only include major watercourses that are digitised into the GIS system used for assessment and exclude minor tributaries that are commonly the entry point for mine pollution (likely therefore mildly understated to an uncertain degree).

For the Mawddach, there is a significant input from Glasdir mine, part direct discharge but largely diffuse owing to the adit being plugged. This impacts the (unclassified) tributary on which it sits, but does not affect the WFD status at the remote downstream monitoring point. By including improved waterbodies, as well as those amenable to status change, all significant identified discharges are included in the assessment, which is considered as being more in line with current Welsh legislation and policy. It is noted that the WFD was developed, not to force compliance with highly location specific quality objectives, but to more widely provide a high quality water environment that protects human and animal health and provides valuable environmental benefits at a regional to national level.

An alternative metric for the mitigation works could be an estimate of mass of metals removed from the water environment (both as a percentage of current emissions, or as a total loading per annum), which would be more in-line with some other priority pollutant control approaches. Data to allow this type of measurement are generally available and will continue to be gathered in the future, so such an approach could be tested and compared at a later date.

3.1.2 Risks and Uncertainties

Identified uncertainties which have led to lower confidence statements within the reported assessments include:

- Those resulting from poor data availability and appropriateness;
- The absence of agreed high level objectives and what constitutes feasible and cost effective intervention;
- The absence of an established delivery vehicle for metal mine legacy management; and
- The absence of accepted monetised benefits for mine site mitigation / water quality and sediment betterment (as opposed to status change).

Many of these uncertainties can be resolved by more detailed site assessment. Cost variation as a result of more detailed assessment and increased knowledge has been accounted for through a percentage variability in base cost based on confidence level statements.

The RAG status of individual mine sites also needs to be further tested / ground truthed, especially for the assumed absence of discharges from levels. The actual absence of such discharges can only be determined through site visits, with monitoring then required to establish the significance of any newly discovered discharges.

The generic mitigation approaches utilised (for purposes of consistency and comparability) in this assessment methodology, are subject to significant site specific influences and modifiers that will almost certainly alter the scope and cost of individual remediation schemes as they are developed. This will in turn impact on river system and nationwide programmes and budgets (both positively and negatively to a currently unquantified degree). Such impacts can be better estimated once actual implementation costs begin to be paid out.

Cost certainty at all levels can be better defined through comparison of actual realised costs against the cost matrix used for water body assessments. This should be included as a periodic review of any forward programme, taking into account particularly advances in treatment technology.

3.2 Identified Issues

3.2.1 Sampling Network Discrepancies

For some waterbodies, established classification monitoring locations are actually upstream of identified mine discharges, or on tributaries unaffected by mining (*eg* the Tywi) and effectively result in unrepresentative classification.

3.2.2 Coastal Waters

Coastal waters have not been taken into account in the assessments. Removal of large inputs of metals to coastal waters, such as from Parys Mountain, could have significantly larger benefits that are not currently accounted for, even if only on a local basis rather than for coastal waterbody WFD status.

3.2.3 Sediment

Contaminated sediment within mine impacted river systems is not easy to assess or mitigate. Typically mitigation is related to stopping ongoing erosion of exposed mineral waste. Sediment impacts are not well understood or monitored in any detail, making appropriate mitigation responses difficult to define.

Sediments are known to collect in river systems and form potential secondary contaminant sources (*eg* in reservoirs along the Rheidol). Such sediments can be harmful to bottom dwelling invertebrates resulting in contamination moving up the food chain. Disturbance of contaminated sediments is also not without risk and therefore careful assessment is required prior to the implementation of any river sediment management programme.

Any removal of sediment from check weirs or behind dams, generates (potentially hazardous) wastes that can be difficult and costly to manage. Routine sustainable solutions and an agile, flexible regulatory regime are not currently available / in place, potentially impacting compliance with SMNR principles.

3.2.4 Groundwater

Local groundwater bodies will gain status improvement through identified discharge and mine site mitigation, however, groundwater systems are complex and (in the absence of targeted groundwater remediation) groundwater local to the mines is unlikely to improve in terms of chemical quality. The focus is therefore to prevent deterioration (keep clean water clean) and to incorporate groundwater mitigation into individual schemes where appropriate, so as to ensure mine impacted groundwater is not adversely affecting surface water quality and ecology through polluted base flow. More widespread groundwater mitigation is likely technically infeasible and/or excessively costly.

3.2.5 Slate mining and natural mineralogy

Metal rich mineralisation occurs widely in a range of strata across Wales and not just those worked as metal mines (which exacerbates the exposure and release of metal contamination into the environment). Where natural weathering and erosion results in the exposure of mineralised rocks at the surface and in particular, in upland areas where active erosion and weathering deep into the rock can occur in river valleys etc, surface waters can exhibit significantly elevated levels of metal pollution, even in the absence of any historical mining. Additionally, other types of mining, such as slate mines, and surface extraction (quarries) can also expose metal rich minerals resulting in polluting runoff. This is prevalent in the Dwyryd river system.

This phenomenon can be exacerbated by low pH stresses (not mine related) that are also commonplace across many parts of upland Wales, as demonstrated in the Mawddach.

3.3 Sustainable Management of Natural Resources & Well-being of Future Generations

The Environment (Wales) Act and the Well-being of Future Generations (Wales) Act together, create modern legislation for managing Wales' natural resources to improve the social, economic, environmental and cultural well-being of Wales. As summarised in Table 1, mine water mitigation can deliver significant benefits in the form of improved water quality and freshwater ecosystems on a local and large scale, which is considered well aligned with the spirit of the current legislative framework. There are recognised further benefits associated with the proposed programme that are also in line with Wales' legislation, some of these are described below.

3.3.1 Climate Change

As previously discussed, the river system provisions reported here are based on the current situation / status of waterbodies, but include proposals for addressing identified significant impacts even if no status change will result. Such an approach adds resilience to the impacted river systems and reduces the likelihood of deterioration due to climate change effects. Qualitative assessment of likely climate change suggests that the trend is towards heavier storms, more flushing of mine systems and greater erosion of mine waste, thereby increasing impacts compared to the present day.

3.3.2 Contaminated land

Contaminated land (occupied or abandoned, typically industrial land) is also a recognised pollution threat to both groundwater and surface water bodies. The current legislative regime for contaminated land is heavily focussed on potential impacts to human and animal health, although there are a (relatively small) number of identified sites that also impact the water environment.

Notable examples are transport, storage and processing of minerals at depots/hubs or smelting works. These sites should be accommodated under Part 2A Contaminated Land Regulations by local authorities, but may add to WFD impacts such as Brymbo and Swansea. Existing Contaminated Land Strategies developed by local authorities, will need to be integrated with proposals for work at individual mine sites. Local authorities are therefore recognised as being important stakeholders in the development of effective mitigation schemes (site and river system level).

3.3.3 Economic development

Most of the sites are in relatively remote and heavily environmentally designated locations and therefore potential for commercial and economic development is limited. Their industrial heritage is however, of great value and can be enhanced to aid appreciation and enjoyment locally, including through the encouragement of tourism, education and the support of industrial heritage enterprises.

Many of the sites present technical challenges for mitigation and water treatment. These challenges provide opportunities for the development of transferable technology to (and from) the global industries of waste and industrial water treatment, metals production, active mining etc. Such technological development is currently exemplified by electrochemistry treatment trials being carried out by NRW at Cwm Rheidol and Frongoch (with other pilot and experimental projects previously completed and planned for the future). The trialling and commissioning of such technology can often support Welsh companies and contribute positively to economic activity within Wales.

3.3.4 Rich diverse community & culture

Funds used for mitigating mine sites can potentially attract, or even be used as, match funding increasing the likelihood of community and cultural heritage projects being realised or integrated into mine site remediation works. Generally, environmental improvement projects are viewed as positive opportunities for communities to become stronger, healthier and more resilient. For example, where power generation opportunities exist, such as at Cwmystwyth, these could be realised through social enterprise schemes, rather than owned and operated by NRW or private landowners. New visitor centres at or near to mine sites would encourage more people (local or tourists) into the area, especially if linked to new and existing cycle and walking routes and enhanced signage to explain the cultural heritage of the mines for past, current and future generations.

3.3.5 Surface water management to reduce flood risk

Mitigation of many of the sites includes capping (or at least covering) of exposed spoil and managed surface water drainage in areas of exposed metal rich spoil deposits and mine processing areas. This provides opportunities for changing runoff characteristics of the site and possibly whole small catchments, which can typically offer minimal run-off attenuation and high levels of active erosion. With appropriate planting and incorporation of Sustainable Drainage Systems (SuDS) features into mitigation designs, runoff and sediment generation can be managed to reduce flood risk in the catchment (and have positive impacts on receiving waterbodies more generally).

Although not universally appropriate on capped areas or within sensitive heritage and habitat landscapes, mixed tree planting opportunities should be actively pursued up gradient in the interests of runoff management, water retention enhancement and carbon sink maximisation, as well as providing greater biodiversity and visual amenity.

4.0 Next Steps

4.1 Prioritisation

The work to date forms a basis for the development and prioritisation of future works. This should include a combination of (as a series of parallel works programmes):

- Design, development and construction of mitigation schemes for those sites with a high confidence level statement of positive outcomes and amenable to established engineering and treatment techniques;
- Undertaking feasibility studies for sites with medium to high confidence of positive outcomes, but where preferred / feasible options have not yet been defined;
- Targeted investigation of sites and waterbodies where a lack of information and evidence results in high levels of uncertainty and prevents the immediate identification of a feasible mitigation approach.

Prioritised works from each category would then be incorporated into a costed forward programme of works, subject to refinement and reprioritisation on a regular basis, especially when new information is obtained.

4.1.1 Costed Forward Programme and funding to implement

The development of a costed forward programme allows the better definition of outcomes expected over a timeline, based on a specified funding profile. Initially it is suggested that a budget of c. £6M per year should be assumed in the first instance, split between capital and revenue (the first bullet in Section 4.1 above is a capital programme, while the other two bullets largely feature revenue expenditure). Delivery would be limited by the funding and staff resource available, but such an initial budget is in line with other programmes of a similar nature and scale (*eg* the Water and Abandoned Metal Mine (WAMM) Programme for England).

The confirmation of a funded forward programme would represent a significant improvement over the historical year to year / project by project funding basis, providing more certainty and effectiveness, as well as earlier and wider realisation of benefits. A publicly funded costed forward programme, should be transparent and open to challenge, subject to regular review and continuous improvement.

The implementation of such a programme in Wales would represent a commitment to ongoing funding as once in place, mitigations need ongoing adequate operation, maintenance and monitoring over extended timeframes (at least 40 years has been used to estimate total OPEX – failure to secure long term OPEX funding has been shown to quickly result in scheme deterioration and ultimately failure). It is noted that OPEX expenditure is separate from the other revenue spending required by the proposed programme of work. OPEX spend profile will start low and increase over time as more mitigation schemes are put in place.

An indicative operational spend has been estimated for the first 10 years, based on the cost model for this assessment plus the following assumptions:

- 1ha of capping and drainage works operational in Year 3 and a further 1ha each following year;

- Abbey Consols operational in Year 2;
- Cwm Rheidol operational in Year 4;
- Passive treatment facilities of 5 l/s on line in Years 6 and 10;
- An additional active treatment facility on line in Year 8.
- Nominal £5k/a for maintenance at Frongoch
- Nominal £15k/a for sediment removal from Esgair Mwyn sediment management system from Year 1
- Maintenance work has been based on having partial resource used elsewhere for other NRW works in initial years until sufficient schemes are on line to justify full time resource.

A summary of indicative costs on this basis is provided in Table 2.

Table 2: Summary of indicative operational costs

	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9	Year 10
Annual OPEX* (£M)	0.005	0.02	0.03	0.03	0.17	0.17	0.18	0.18	0.30	0.29	0.30

* Discounted based on Treasury 'Green Book'

In addition to OPEX, the proposed programme includes a significant amount of revenue spending, including the maintenance of a delivery team (without which no capital expenditure (CAPEX) can be secured). NRW has engaged the Coal Authority and others to assist with existing metal mine projects and a number of potential capital spending opportunities have been identified for the early years of a forward programme. On that basis, the proposed initial budget of £6M might be split approximately 5:1 capital:revenue, dependent on how much scheme development work can be capitalised (this is currently being developed by NRW).

It is noted that a programme of this nature is ultimately dependent on consistent government sponsorship and organisational support at a director / board level.

4.1.2 Improvements to current WFD monitoring and reporting

The failing waterbodies project has been successfully delivered on the basis of the existing nationwide monitoring, catchment management and WFD implementation regime. This is considered an indication of the overall robust nature of these activities.

The methodology and assessments reported here have nevertheless, identified requirements for improved future monitoring, assessment and reporting on metal mine impacts with respect to WFD objectives. This includes a number of data gaps and uncertainties associated with the current WFD monitoring regime, which can now be prioritised and appraised for improvement.

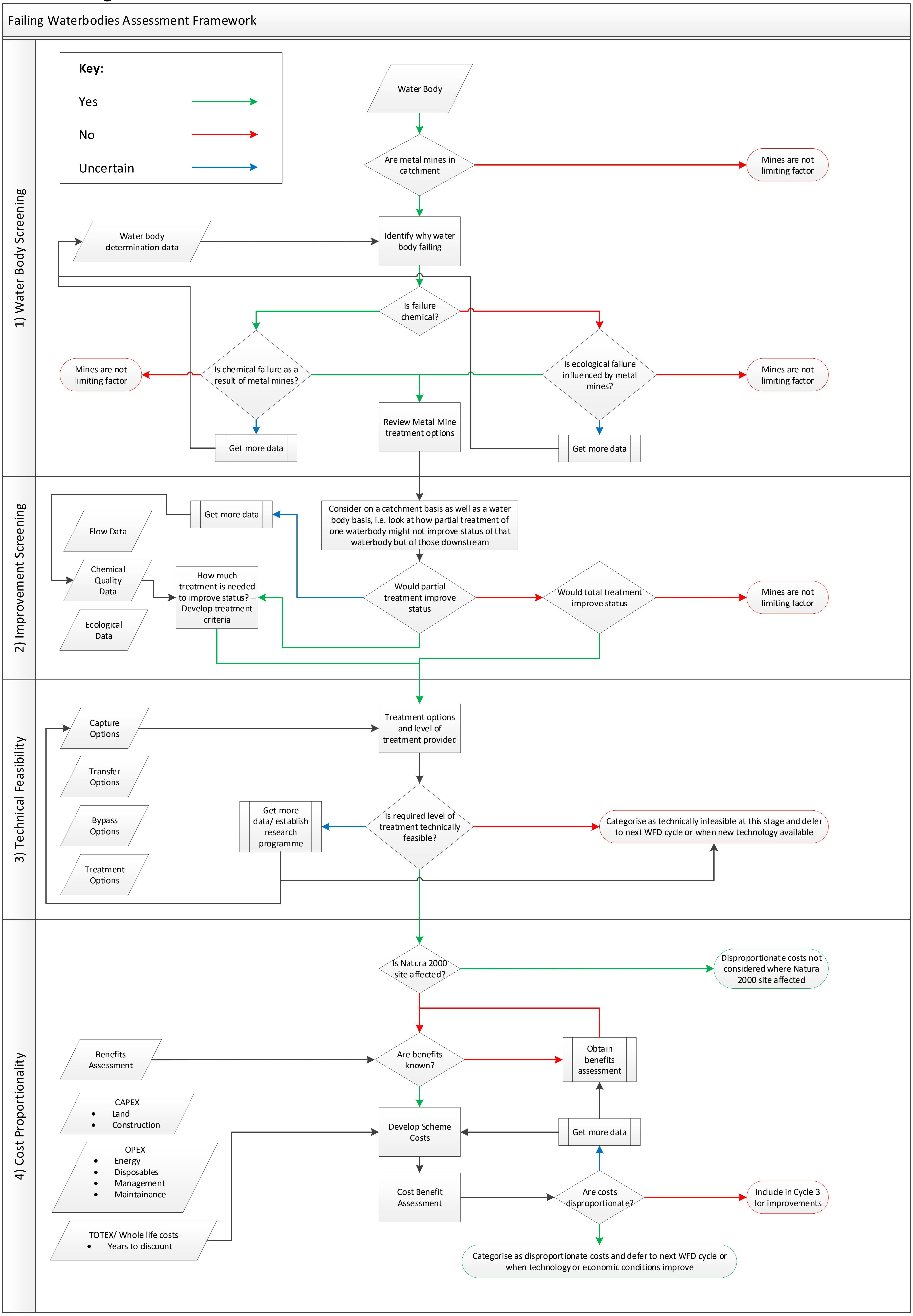
The costs summarised include nominal amounts for additional works to characterise the catchments. These are for studies over twelve months, the results of which might affect the regular monitoring by changing current monitoring and/or compliance locations. Some additional funding is likely to be necessary, drawing on the programme revenue expenditure. The extent of such funding demand is subject to regular reprioritisation and review as part of the routine programme management.

5.0 References

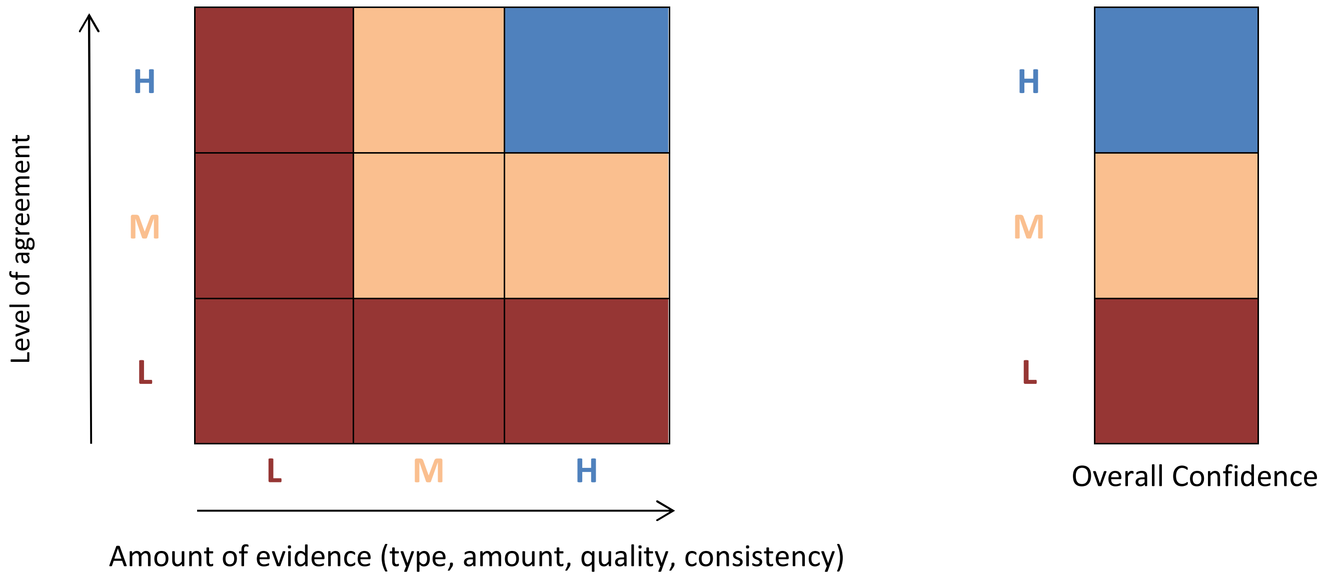
Included in individual river system reports – see Appendix C

Appendix A – Methodology

A1 – Flow diagram



A2 – Confidence levels for failing waterbodies assessment



Waterbody Screening

Level of agreement

- **H** Main reason for waterbody failure is mine related
- **M** Waterbody failure likely to be mine related, but there is potential for other inputs that could be significant.
- **L** Much uncertainty in evidence base that waterbody failure is mining related. Mine input could be relatively small.

Amount of evidence

- **H** Known mines and mine discharges in catchment with chemical failure from mined substances
- **M** Known mines and mine discharges in catchment with biological failure potentially influenced by chemical stressors relating to local mines.
- **L** Catchment contains known mines but link between these and waterbody failures is unclear, possibly owing to lack of knowledge of discharges or diffuse sources

Improvement Screening

Level of agreement

- **H** Source treatment should have a measurable improvement in catchment
- **M** Source treatment might have a measurable improvement in catchment but uncertainty as to other influences such as residual sediment
- **L** Although source treatment might have a measurable improvement in catchment there are other multiple sources such as residual sediment or unknown discharges and pinpointing the areas to focus on is not certain

Amount of evidence

- **H** Good loading data from catchment including sediment loading data
- **M** Good loading data from catchment but poor understanding of sediment loading and influence
- **L** Moderate to poor loading data within catchment - more data needed

Technical Feasibility

Level of agreement

- **H** Catchment and treatment to required standard with little residual input is tried and tested
- **M** Catchment and treatment to required standard with little residual input is using novel techniques with some uncertainty
- **L** Catchment and treatment to required standard is not currently achievable based on existing technology or evidence base

Amount of evidence

- **H** Tried and tested technology in these types of situation
- **M** No full scale plant only pilot plants or desk based using tried and tested technology used in other scenarios
- **L** Theoretical technology with no real world applications

Appendix B – Cost Breakdown

Table B1 – Unit cost and basis

Assumptions		Cost / £	Unit	Basis
1)	All sites need feasibility, specialist studies and planning. Standard cost for each.	135,000	Nr	Scoping £20k, Feasibility £45k, Topographical survey £10k, Ecology £10k, Heritage & Landscape £10k, Planning £20k, CBA £10k, Land negotiations £10k based on CA experience on similar projects.
	For low information treatment sites additional cost needed for characterisation	200,000	Nr	Nominal amount for sampling, monitoring and reporting for high level site characterisation.
	For medium information treatment sites additional cost needed for characterisation	100,000	Nr	Nominal amount for sampling, monitoring and reporting for high level site characterisation.
2)	Stakeholder Engagement	30,000	Nr	Based on previous CA experience on similar projects, however could vary greatly depending on number of stakeholders and their requirements.
3)	Investigations on a site basis as large and small sites often need similar investigation costs	80,000	Nr	£80k per site on average based on previous CA experience. However, could vary greatly depending on complexity of site conditions and mitigation proposed.
4)	Land Purchase - Capping: Area plus 10%	55,600	/ha	Based on agricultural rates from the Rural Land Survey undertaken by the RICS and Royal Agricultural University for 2018 for Powys and Ceredigion of £5-10k/acre, taking a mid-point of £7.5k, x3 as uplift value due to special purchase conditions. This figure is extremely variable for each specific site and cannot be known until negotiations take place. For the purposes of this spreadsheet only capital land values have been used - very often a site will be acquired as a long term lease.
5)	Land Purchase - Passive Treatment: based on flow	6,783	/l/s	Based on area of treatment from Nent Haggs scheme related to flow 0.122ha/l/s

Assumptions		Cost / £	Unit	Basis
6)	Land Purchase - Active Treatment: based on flow	232	/l/s	Based on area of treatment for Dawdon treatment plant (6,250m^2 for 150 l/s), pro-rated for flow but with minimum footprint of 400m^2 (20mx20m), *eg* two iso containers plus additional for compound area
7)	For capping works assume synthetic liner across entire area with unit rate	29.46	/m^2	Based on 2019 framework rates, preparation of surface £0.26/m^2, sand blinding £0.04/m^2, HDPE £6/m^2, drainage geotextile £8.58/m^2, Subsoil £4.95/m^3, erosion protection mat £9.07/m^2, topsoil £0.15/m^2, seeding £0.41/m^2
8)	For capping works assume drainage around entire area based on 4 x square root of area with unit rate	18	/m	Based on 2019 framework rates - Twin MDPE 150mm diameter in trenches not greater than 1.5m depth (£16.75/m) plus trench reinstatement (£0.94/m), assuming >50m required and in field reinstatement.
9)	Assume earthworks of average 1m across entire site area	10	/m^3	Based on 2019 framework rates, assume >50 to 1000m3 volume, Excavation £3.87/m^3, laying £6.03/m^3
10)	Include fixed ancillaries, management and design costs cost of 50% capping and drainage costs	50%	%	50% based on recent WAMM projects of similar nature with remote access.
11)	Assume OPEX for capping works landscape maintenance nominal cost of £2.5k/a	2,500	/a	Nominal amount for landscaping and drainage works, with potential for costs savings where multiple sites included in operational portfolio.
12)	For discharge works standard cost for capture and transfer	97,700	Nr	Based on 2019 framework rates for wetwell, pump (c. £80,000) and with nominal 100m of transfer pipework (1000@£17.69).
13)	CAPEX based on flow - <10l/s passive scheme, >10l/s active scheme - standard rate based on flow pro-rata based on Dawdon (active), Nent Haggs (Passive)	339,200	/l/s	Based on Nent Haggs for passive scheme costs with 6/10 rule rather than linear scaling.
		234,400	/l/s	Based Dawdon for active scheme costs with 6/10 rule rather than linear scaling

Assumptions		Cost / £	Unit	Basis
14)	OPEX based on passive or active scheme standard rate based on flow - pro-rata based on Dawdon (active), Nent Haggs (Passive)	4,500	/l/s	Based on Nent Haggs for passive scheme costs
		132478 x flow$^{-0.921}$	Relationship	Dawdon for active scheme costs, with OPEX active plant relationship developed from Frongoch Adit, Cwm Rheidol Adit 6, Nant Minera, Pwll Deep Adit and Nantymwyn Deep Boat level. Dyffryn Adda Adit also considered but major outlier and so treated as a special case. Sludge disposal estimated as £150/t to allow for disposal as hazardous waste, however takes lower end of £150 to £200/t to allow for development of alternative uses or some being non-hazardous and based on CA experience from Wheal Jane.
15)	Permanent power and water supply for treatment sites	160,000	Nr	Based on CA experience of power and water connection for similar sites.
16)	Site access and buildings for treatment sites plus EPC	410,000	Nr	Based on CA experience for similar sites.
17)	Detailed design – Active	6%	%	Based on CA experience for similar sites.
18)	Prelims – Active	15%	%	Based on CA experience for similar sites.

Notes: * existing CA operational sites considered reasonable as cost basis in this instance

TOTEX costs based on 40 year life of site with Green Book discounting rates of 3.5% used for first 30 years and 3% for Years 31 to 40.

Large capital injection of 50% capital costs introduced at Year 20 to allow for major refurbishment of treatment plant for point source, with Green Book discount rate included.

The build for each scheme has been attributed to 1 year, however the actual build might be phased over 2 or more years.

Appendix C – Waterbody Reports

Waterbody reports are provided as separate documents supplementary to this report with the following references:

- OP16-154/F13/0/C1 – Leri river system report
- OP16-154/F13/0/C2 – Mawddach river system report
- OP16-154/F13/0/C3 – Rheidol river system report
- OP16-154/F13/0/C4 – Ynys Mon river system report
- OP16-154/F13/0/C5 – Dyfi river system report
- OP16-154/F13/0/C6 – Wye river system report
- OP16-154/F13/0/C7 – Severn river system report
- OP16-154/F13/0/C8 – Clarach river system report
- OP16-154/F13/0/C9 – Ystwyth river system report
- OP16-154/F13/0/C10 – Tywi river system report
- OP16-154/F13/0/C11 – Teifi river system report
- OP16-154/F13/0/C12 – Conwy river system report
- OP16-154/F13/0/C13 – Glaslyn & Dwyryd river system report
- OP16-154/F13/0/C14 – Clywedog, Trefnant Brook & Y Garth river system report
- OP16-154/F13/0/C15 – Groundwater report

Appendix D – GIS layers

A variety of GIS layers have been interrogated and developed as part of this project. These are:

Data downloaded (name on website)	Coverage	Data owner	License	Theme
AONB	Wales	Natural Resources Wales	OGL	Natural Designation
Conservation Areas	Wales	Cadw	OGL	Historic Designation
Historic Battlefields	Wales	Cadw	OGL	Historic Designation
Inventory of closed mining waste facilities	England and Wales	Environment Agency	OGL	Water
Listed Buildings	Wales	Cadw	OGL	Historic Designation
National Nature Reserves	Wales	Natural Resources Wales	OGL	Natural Designation
National Parks	Wales	Natural Resources Wales	OGL	Natural Designation
Open Access: Countryside & Rights of Way Act (CROW) Dedicated Land (Wales)	Wales	Natural Resources Wales	OGL	Natural Designation
OS Open Rivers lines	Nationwide	Ordnance Survey	OGL	Water
Parks and Gardens	Wales	Cadw	OGL	Historic Designation
Ramsar	Wales	Natural Resources Wales	OGL	Natural Designation
Scheduled Monument	Wales	Cadw	OGL	Historic Designation
Sites of Special Scientific Interest (Wales)	Wales	Natural Resources Wales	OGL	Natural Designation

Data downloaded (name on website)	Coverage	Data owner	License	Theme
Special Areas of Conservation (Wales)	Wales	Natural Resources Wales	OGL	Natural Designation
Special Protection Areas (Wales)	Wales	Natural Resources Wales	OGL	Natural Designation
WFD River Waterbodies Cycle 2 Draft	England and Wales	Environment Agency	OGL	Water
World Heritage Sites	Wales	Cadw	OGL	Historic Designation
Welsh Metal Mines	Wales	Natural Resources Wales		
Great Britain, Ordnance Survey (1:1million-1:10,560), 1900s	GB	National Library of Scotland		

Webfeeds have also been used in the GIS. These are:

Data	Website
WFD_Cycle_2_Interim_2018_Waterbody_Feature_Layer-WFD Lakes Waterbodies Cycle 2 Interim 2018	https://waterwatchwales.naturalresourceswales.gov.uk/en/
WFD_Cycle_2_Interim_2018_Waterbody_Feature_Layer-WFD Canals Waterbodies Cycle 2 Interim 2018	https://waterwatchwales.naturalresourceswales.gov.uk/en/
WFD_Cycle_2_Interim_2018_Waterbody_Feature_Layer-WFD River Waterbodies Cycle 2 Interim 2018	https://waterwatchwales.naturalresourceswales.gov.uk/en/
WFD_Cycle_2_Interim_2018_Waterbody_Feature_Layer-WFD Transitional Waterbodies Cycle 2 Interim 2018	https://waterwatchwales.naturalresourceswales.gov.uk/en/
WFD_Cycle_2_Interim_2018_Waterbody_Feature_Layer-WFD Coastal Waterbodies Cycle 2 Interim 2018	https://waterwatchwales.naturalresourceswales.gov.uk/en/
Base mapping	https://www.arcgis.com/home/item.html?id=10df2279f9684e4a9f6a7f08febac2a9

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