Llifogydd Cymru Chwefror 2020:

Adolygiad Rheoli Ystadau Tir Cyfoeth Naturiol Cymru

Cyhoeddwyd 22 Hydref 2020

Cyhoeddwyd gan:
Cyfoeth Naturiol Cymru
Tŷ Cambria
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Caerdydd
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Cynnwys

Rhestr o ffigurau

Rhestr o Dablau

Ynglŷn â Cyfoeth Naturiol Cymru

Diben Cyfoeth Naturiol Cymru yw ceisio rheoli adnoddau naturiol yn gynaliadwy. Mae hyn yn golygu gofalu am yr aer, tir, dŵr, bywyd gwyllt, planhigion a phridd i wella llesiant Cymru a chynnig dyfodol gwell i bawb.

Crynodeb Gweithredol

Mae'r adroddiad hwn yn amlinellu canfyddiadau adolygiad a gynhaliwyd gan Cyfoeth Naturiol Cymru i oblygiadau llifogydd Chwefror 2020 ar gyfer sut rydym yn rheoli'r tir yn ein gofal (Ystad Cyfoeth Naturiol Cymru) wrth symud ymlaen. Yr elfen o Ystad Cyfoeth Naturiol Cymru sydd fwyaf perthnasol i'r adolygiad hwn yw Ystad Goetir Llywodraeth Cymru. Mae'r adroddiad hwn felly'n canolbwyntio'n bennaf ar oblygiadau ar gyfer rheoli'r coetiroedd sydd dan ein gofal.

Fel rhan o'r adolygiad, edrychom yn gyntaf ar rôl coedwigoedd a choetir wrth reoli dŵr, ac yna'r goblygiadau ar gyfer newidiadau ar raddfa fawr mewn mathau o ddefnydd tir ar Ystad Cyfoeth Naturiol Cymru yn deillio o ddigwyddiad Chwefror 2020:

- Er bod coedwigoedd yn dylanwadu ar ddŵr mewn ffordd gadarnhaol ar y cyfan, mae tystiolaeth yn awgrymu nad ydynt yn cael effaith addasu sylweddol yn ystod digwyddiadau llifogydd mawr, waeth beth fo'r arfer rheoli. Rydym yn dod i'r casgliad nad oes fawr o gyfiawnhad dros newidiadau mawr mewn defnydd tir ar Ystad Cyfoeth Naturiol Cymru i leihau'r risg o'r math o lifogydd a welwyd ym mis Chwefror 2020. Er enghraifft, ni fyddai newid tueddiadau cyfredol o ran maint gorchudd canopi ar Ystad Cyfoeth Naturiol Cymru yn cael fawr o effaith ar y risg o lifogydd mawr yn gyffredinol.

- Fodd bynnag, mewn rhai dalgylchoedd llai lle mai coedwigaeth yw'r prif ddefnydd tir, gall coetir gael effaith gadarnhaol yn ystod amodau llai eithafol. Gallai gwaith y gallwn ei wneud ar ein tir i ddal ac oedi rhyddhau dŵr gyfrannu'n gadarnhaol at reoli llifogydd i lawr yr afon, yn enwedig o'i gyfuno â chamau gweithredu eraill ar draws y dalgylch ac wrth ystyried goblygiadau newid yn yr hinsawdd yn y dyfodol.

Edrychom felly ar dair elfen allweddol rheoli tir ar Ystad Cyfoeth Naturiol Cymru a dod i gasgliadau fel a ganlyn:

- **Cynllunio adnoddau coedwigoedd a defnydd tir arall:** Oherwydd y tebygolrwydd cynyddol o lawiadau eithafol, mae angen i ni wneud mwy i feddwl am swm y dŵr yn ogystal ag ansawdd y dŵr. Mae llawer o systemau a data da eisoes ar gael, ond mae angen i ni wneud y rhain yn haws i'w cyrraedd er mwyn sicrhau y gellir eu defnyddio i helpu i gynllunio ar gyfer risg llifogydd a rheoli dŵr yn gynnar. Mae angen cyfeirio gwaith cynllunio o'r fath lle bydd yn cael yr effaith fwyaf, felly nodi darnau o dir sy'n gysylltiedig â risg uwch o lifogydd yw un o'r tasgau cyntaf y mae angen ei chwblhau.
- **Seilwaith a pheirianneg sifil:** Gallai datgysylltu draeniau coedwigoedd ac ochr ffordd ymhellach fod yn fuddiol. Mae angen i ni hefyd fuddsoddi mwy mewn archwilio, cynnal a chadw ac ailosod hen strwythurau er mwyn sicrhau eu bod yn

parhau i weithio fel y dyluniwyd. Mae materion adnoddau y bydd angen mynd i'r afael â nhw i gynyddu cyflymder y newid yn y maes hwn, a bydd angen blaenoriaethu'r meysydd â'r risg uchaf.

- **Gweithrediadau Coedwigaeth:** Mae'r arfer gweithredol cyfredol yn annhebygol o waethygu'r risg o lifogydd. Fodd bynnag, yn ystod y cyfnod gweithredol mewn safleoedd risg uchel - yn enwedig ar ôl cynaeafu a chyn ailstocio - mae cyfleoedd i wneud newidiadau a fydd yn lleihau'r risg o lifogydd. Enghraifft allweddol o hyn yw datgysylltu draeniau coedwigoedd o'r rhwydwaith draenio ehangach yn unol â Chynllun Rheoli Dŵr. Mae codi lefelau hyfforddiant ac ymwybyddiaeth ymhlith staff hefyd yn bwysig yma.

Rydym wedi cyfuno'r camau gweithredu posibl o'r casgliadau hyn i'r 10 argymhelliad allweddol canlynol ar gyfer newid ein dull cyfredol:

- Cynllunio adnoddau coedwigoedd a defnydd tir arall 1: Cryfhau'r defnydd o'r offer sy'n bodoli'n barod i nodi'r risg o lifogydd a chyfleoedd lliniaru fel y gallwn flaenoriaethu'r ardaloedd risg uchaf ar Ystad Cyfoeth Naturiol Cymru ac ymgorffori hyn yn y Cynlluniau Adnoddau Coedwigoedd ar gyfer yr ardaloedd hynny.
- Cynllunio adnoddau coedwigoedd a defnydd tir arall 2: Datblygu Cynlluniau Rheoli Dŵr ar y raddfa sydd fwyaf priodol ar gyfer rheoli dŵr a datblygu ymhellach ystyriaeth o swm dŵr yn ogystal ag ansawdd dŵr.
- Cynllunio adnoddau coedwigoedd a defnydd tir arall 3: Cynnwys arweiniad ar fapio draenio manwl a datgysylltu draenio artiffisial yn y canllawiau ar gynllunio coedwigoedd.
- Cynllunio adnoddau coedwigoedd a defnydd tir arall 4: Gwella'r broses o gynnwys cymunedau lleol ymhellach yn y gwaith o gynllunio adnoddau coedwigoedd a gweithrediadau coedwigoedd mewn ardaloedd risg uchel.
- Seilwaith a pheirianneg sifil 1: Defnyddio blaenoriaethu yn seiliedig ar reoli dŵr ac ystyriaethau allweddol eraill, megis iechyd a diogelwch, i gynllunio, darparu adnoddau a darparu rhaglen hirdymor (10-60 mlynedd) o waith uwchraddio a chynnal a chadw seilwaith coedwig. Dylai hyn gynnwys arolygon ar ddatgysylltu rhwydweithiau ffyrdd o ddraenio coedwigoedd.
- Seilwaith a pheirianneg sifil 2: Symud o ddull 'mewn pryd' o adeiladu seilwaith newydd ar gyfer cynaeafu i ddull 'adeiladu ymhell ymlaen llaw" (dwy flynedd) gan gynnwys, er enghraifft; comisiynu gofynion seilwaith ymlaen llaw ar gyfer cynaeafu llennyrch ac adnewyddu'r contract fframwaith peirianneg sifil.
- Seilwaith a pheirianneg sifil 3: Datblygu system rheoli asedau gan gynnwys cronfa ddata ar-lein, canllawiau ar safonau adrodd, ac adnoddau ar gyfer trefn arolygu barhaus.
- Seilwaith a pheirianneg sifil 4: Cynyddu'r broses o orfodi cyfyngiadau cludo, yn enwedig ar ffyrdd bregus ac ar adegau bregus.
- Gweithrediadau Coedwigoedd 1: Hyfforddiant, codi ymwybyddiaeth a datblygu gallu ar ddulliau cyfredol o reoli'r risg o lifogydd a dulliau a fydd yn cael eu diwygio, yn ystod y camau cynllunio a gweithredol ar gyfer yr holl staff perthnasol.
- Gweithrediadau Coedwigoedd 2: Gwella'r trosglwyddiad o gynaeafu i swyddogaethau sefydlu i leihau risgiau a chynyddu cyfleoedd rhwng cwympo ac ailblannu coed.

Byddai gweithredu'r argymhellion hyn ar draws Ystad gyfan Cyfoeth Naturiol Cymru yn gofyn am lawer o waith a buddsoddiad sylweddol o adnoddau, a'r awgrymiadau ar seilwaith a pheirianneg sifil fyddai'r rhai mwyaf costus i'w gweithredu. Yn nodweddiadol, rydym yn gwario tua £4M y flwyddyn ar ein seilwaith coedwigoedd ac roeddem eisoes wedi bwriadu cynyddu'r gwariant yn 2020/21 i £8.8M trwy fuddsoddi mewn asedau allweddol. Bydd faint mwy a wnawn, a pha mor gyflym yr ydym yn ei wneud, yn dibynnu ar y dewisiadau a wnawn ynghylch blaenoriaethu cymharol â buddion cyhoeddus pwysig eraill. Er hynny, bydd angen i Cyfoeth Naturiol Cymru flaenoriaethu ymyrraeth yn y blociau coedwigoedd lle mae'r risg o lifogydd ar ei huchaf a lle mae cyfraniad gan Ystad Cyfoeth Naturiol Cymru yn debygol o sicrhau'r canlyniadau mwyaf.

Er mwyn ein galluogi i sefydlogi ansawdd asedau a gweithredu uwchraddiadau angenrheidiol, rydym yn amcangyfrif y byddai angen i ni sicrhau cynnydd parhaol o £1.4M y flwyddyn yn ein hadnoddau ar gyfer archwilio a chynnal a chadw seilwaith coedwigoedd. Byddai gweithredu rhaglen o'r fath o uwchraddio seilwaith coedwigoedd yn gofyn am fuddsoddiad untro o £35.8M. Gan y gallai cynllun gymryd rhwng 10 mlynedd (y gyfradd gyflenwi gyflymaf posibl) a 60 mlynedd (cylchdro coedwig nodweddiadol) i'w gwblhau, yn dibynnu ar ddyraniadau adnoddau.

Hyd yn oed gyda blaenoriaethu a chynllunio o'r fath ar waith, bydd gwneud y newidiadau a argymhellir yn yr adolygiad hwn bron yn sicr yn gofyn am adnoddau ychwanegol y tu hwnt i'r hyn sydd ar gael trwy adleoli yn unig, h.y. byddai angen adnoddau ychwanegol ar draws Cyfoeth Naturiol Cymru yn gyffredinol. Fodd bynnag, o ystyried yr effaith negyddol y mae llifogydd yn ei chael ar gymdeithas a'r economi - yn enwedig y rhai yn ein cymunedau mwyaf agored i niwed - a gyda'r risg uwch o lifogydd oherwydd newid yn yr hinsawdd, credwn fod y newidiadau hyn yn werth eu gwneud.

February 2020 Floods in Wales: Natural Resources Wales' Land Estate Management Review

Purpose and scope

This report forms part of Natural Resources Wales' Winter Floods Recovery & Review Programme and covers the area of Flood Review looking at the land managed by NRW. This estate includes National Nature Reserves (NNRs) which vary from upland and lowland bogs, heaths and coastal sand dune systems, to native woodlands and the Welsh Government Woodland Estate (WGWE). The WGWE is the largest part of this managed land and as a result, will be the main focus of the report.

The purpose of this report is to:

- Review how we manage the land in our care and identify where evidence shows current practices could be modified to reduce the risk of flooding.
- Identify types of land-use or particular operations on the NRW Estate that may be connected to water damage and flood risk reduction within communities, recommending changes in planning or management practices that could be made to reduce the risks.

Elements such as contingency planning, incident response, and the construction and management of built infrastructure to manage flood risk, are not included as they are being covered in other parts of our review of the February 2020 event. Wider natural flood solutions beyond the NRW Estate are also out of scope (but see comments on this and link to further information below).

In compiling this report, NRW considered the extensive research available on forests and water, amongst other subjects (Appendix 1)[1], and gathered detailed comments and insights on current and past practice from staff. This employee interaction was achieved through a mixture of direct conversations, written submissions and, in some cases, informal questionnaire surveys. Following the background and general information on forests and water management, the layout of this report follows the chronological order in which work is carried out: forest planning, infrastructure development, and implementation of operations. Using our experience and knowledge of forestry and other types of land management, we have drawn together the narrative and recommendations within this report, testing them on selected colleagues including Dr AJ Moffat, who has acted as an independent critical reviewer.

[1] This is instead of formal citations or a bibliography as this is a review report not a scientific research report.

Background to the February 2020 floods

During February 2020, Wales experienced four noteworthy rainfall events, on the back of a very wet winter period. Three of these storms fell under the naming convention introduced by the Met Office and its European counterparts:

- Storm Ciara – 8 – 9 February 2020
- Storm Dennis – 15 – 17 February 2020
- Unnamed Storm – 21 – 24 February 2020
- Storm Jorge – 28 February – 1 March 2020

This report focuses on Storms Ciara and Dennis, as these were the most significant events of the month, due to their relative impacts. Storm Ciara was the third named storm of the 2019/2020 season, with weather warnings issued by the Met Office for both strong winds and heavy rain. The main impacts of Storm Ciara were in North Wales, with flooding impacts inland and on the coast.

A week after Storm Ciara, Storm Dennis brought heavy and persistent rain across much of Wales, with the South Wales Valleys, Brecon Beacons and Usk Valley areas particularly affected. The Met Office issued a red warning for rain across parts of South Wales with some areas receiving more than 130mm of rain falling on saturated ground, leading to major and widespread flooding.

The flooding caused by these storms had substantial, and in many cases long-lived, impacts on individuals, communities and businesses. The exceptional rainfall and challenging conditions also stretched all organisations involved. However, the efforts of communities and the responder organisations throughout was huge and should be acknowledged. Met Office climate change predictions for 2080[2] suggest we should expect the climate in Wales to move to warmer, wetter winters and hotter, drier summers. These changes will exert a strong influence on forest water use and water yields. However, it is not just the overall climate change projection above that is at issue here, but also the likelihood of more frequent and more severe weather events such as Storms Ciara and Dennis throughout the year[3].

These events, although less predictable, will now need to form a larger part of both the short and long-term planning decisions NRW makes on its land. Met Office data shows that February 2020 was the wettest February on record and the 5th wettest month ever recorded. Significant rainfall totals were reached over the entire month, but crucially, significant rainfall amounts were recorded in short periods, with many catchments receiving around 70% of the average rainfall for February in single 24 hr periods during storms Ciara and Dennis. This intensity of rainfall falling on already saturated catchments, combined with the rapid response nature of the river catchments in parts of Wales, led to some of the most impactful flooding in a generation.

Although the effects of the February storms were felt across Wales, some communities were harder hit, particularly in the North West and South Wales Valleys. As the Valleys region is unique in the UK, possessing extensive blocks of forest on steep sided valleys near large urban populations, this report will use some of the incidents that occurred here in

[2] https://www.metoffice.gov.uk/research/approach/collaboration/ukcp/index
[3] https://www.metoffice.gov.uk/research/climate/understanding-climate/global-extreme-events_heavy-rainfall

February as examples. However, any actions or lessons learned resulting from this analysis should be transferrable more widely across the estate. The incidents considered were:

- **Pentre –** In the Rhondda Valley. During the February storms, a culvert on the boundary of NRW land overtopped and the flood water caused damage to a number of properties in the village. At Pentre, we assessed the implications of the flooding for our forestry operations in the days after the incident which informed our immediate recovery work and provided some evidence for this review. We include the report in Appendix 2 for this reason. We are working with Rhondda Cynon Taff Borough Council (RCTBC) and Dwr Cymru Welsh Water to work out the causes of the flooding at Pentre to help us all understand how to protect this community in the future.

- **Darranlas –** near Mountain Ash in the Cynon valley. NRW manages the land directly above several streets. Forest operations in this catchment were completed some years ago with no recent significant operations. During the storms, a grid that protects a culvert which enters the main drainage system became blocked, resulting in water running across our land directly into gardens and some homes. Following this, NRW and RCTBC have increased inspection and maintenance of the culverts and watercourses. We are also working with Flytipping Action Wales to raise awareness of the problems related to flytipping into the watercourses. A geotechnical report commissioned by our local team in 2012 recommended a set of actions to help alleviate flood risk, which were implemented.

- **Blaenllechau –** near Ferndale in the Rhondda valley. Our site in this area was clear felled a few years ago and has since been restocked. Water damage to nearby properties had been an issue experienced during the felling operations and more recently after restocking. It has not been possible to find a direct connection between this water damage and the forest operations and the issue so far remains unresolved. The properties affected are built into the bank on the edge of the woodland and we have been informed that they have flooded regularly for years. The causes of this appear complex - they may be related to old mine workings and historic diversion of hillside streams under-ground, which are associated with housing development. We have asked the Coal Authority to survey the site to help us understand more about the geology and old mine workings to enable us to identify whether there are any potential measures available to mitigate the risk of further flooding.

A wider, more detailed review of the February 2020 floods in Wales is also available as part of our overall incident review.

The role of forests and woodland in water management

Background

It is important to understand basic forest hydrology and the role that woodland might have in relation to flooding. This will help put into context the analysis of planning and operations covered in the rest of the report, as well as inform whether or not we should look at largescale changes to land-use types on our Estate.

Trees use or lose water through two main processes. Firstly, water is taken up by tree roots from the soil and lost through the pores or stomata on the surface of leaves. This is termed ‘transpiration’ and is a physiological process responding to soil and atmospheric factors. The second process is the interception of water by the surfaces of leaves, branches and trunks during rainfall, and its subsequent evaporation. Interception losses are enhanced by the high atmospheric turbulence created by forest canopies due to their height and rough aerodynamic profile. Taken together, these two processes are often referred to as ‘evapotranspiration’.

The main distinction is between conifers and broadleaves. Evergreen conifers tend to have a greater water use because high interception losses are maintained throughout the year, particularly during the winter period when conditions are usually wettest and windiest.

Studies in the UK have found that between 25 and 45% of annual rainfall is typically lost by interception from conifer stands, compared with 10–25% for broadleaves. These percentages remain remarkably constant over a wide range of total annual rainfall. Tree roots also significantly increase water infiltration in the soil. Preferential infiltration can increase the soil’s capacity to store water and contribute to reduced surface water run-off.

Forests and woodlands have long been associated with an ability to reduce flood flows compared to other land uses. There are four main ways that woodland can help:

- The greater water use of trees reduces the volume of flood water at the source
- The higher infiltration rates of woodland soils reduce rapid surface runoff and flood generation. For example, studies in Pont Bren in Mid-Wales found that due to the changes in soil structure in even relatively small new shelterbelt woodlands, the infiltration rates of water into the soil were up to 60 times higher compared to grazed pasture
- The greater hydraulic roughness exerted by trees, shrubs and large woody debris (LWD) along stream sides and within floodplains acts as a drag on flood waters, slowing down flood flows and enhancing flood storage
- The ability of trees to protect the soil from erosion, as well as interrupt the delivery of sediment via runoff to watercourses, helps to maintain the capacity of river channels to convey flood waters downstream and reduces the need for dredging.

Choice of forest management can have an impact on the water use of a stand of trees. Clear-felling is the most dramatic intervention, although the removal of the trees does not eliminate the use of water completely as the infiltration benefits provided by the root systems and woody debris remain after the trees have been removed. Much depends on whether an understorey of small trees, shrubs, or other vegetation is present; the degree to which it remains undamaged by felling operations; and how the remaining cut branches and tree tops (harvesting residues or ‘brash’) are managed. While the understorey makes a

relatively small contribution to the water use of most stands, this situation rapidly changes following the removal of the shade and shelter provided by the woodland canopy. The more developed the understorey and the less it is damaged by felling, then the smaller the change in water use.

The largest reduction in water use will occur for clear felled conifer stands with little or no understorey or ground vegetation. However, even if felling leaves a temporarily unvegetated site, and thus no transpiration loss, there will remain some rainfall interception by the brash residues, as well as a small amount of evaporation from areas of bare soil. Research has shown that a thick pile of brash can intercept as much as 15% of annual rainfall, which is similar to that lost from a broadleaved woodland canopy (Johnson, 1995). This loss will decline over several years with the breakdown of the brash, although the effect on water use will be counteracted by a rise in transpiration rates as the site re-vegetates. Research has generally found that the clearance of forest from less than 20% of a catchment results in little detectable change in water yield.

Improvements in forestry practice within the UK relating to water were driven by the creation of the Forests and Water Guidelines, first published in 1988, as well as the introduction of the European Water Framework Directive (WFD) in 2000. Both underpin the UK Forestry Standard (UKFS) which is the reference standard for sustainable forest management in the UK. It covers both woodland management and woodland creation and effectively equals Sustainable Management of Natural Resources (SMNR) for woodland. The UKFS has been endorsed by all country governments in the UK and applies to all types of forests and woodlands. It is the basis of forestry regulation[4], monitoring and reporting, and ensures that international directives and conventions are applied in the UK. It is also the basis of the UK Woodland Assurance Standard (UKWAS), a voluntary and independent audit standard[5].

At NRW we achieve this standard, which means timber from the WGWE can be sold as certified under both the Forest Stewardship Council® (FSC) and Programme for the Endorsement of Forest Certification (PEFC) schemes. This informs and reassures stakeholders about the sustainability of the forests from which wood and other forest products are produced. However, it should be noted that throughout the guidelines and standards, much of the emphasis is on the quality of water, and the protection that forests offer against diffuse pollution with sediment, pesticides, or high levels of nitrates, etc. There are many references to flooding within these documents, but evidence of the benefits of forestry in flood reduction is less clear cut than is the case with water quality. Therefore, the standards tend to be less clear on what to do about water quantity.

Although there is evidence of forests having a positive impact on reducing flood flows/peaks at a local level (<100 km2) and for smaller flood events, forest hydrology studies in the UK and worldwide generally provide little support for a significant effect on extreme flood flows at a wider landscape level. However, it is difficult to draw a definitive conclusion from such work due to the limited data records available on extreme flood events thanks to their rarity. Similarly, little information is available in relation to the varying local effects of different forestry practices on flood run-off and the problems with upscaling local field based measurements. Another challenge is the difficulty of isolating a forestry effect from the other land uses and activities present within larger catchments.

[4] e.g. felling licences, Environmental Impact Assessment (EIA) Regulations for forestry projects
[5] The whole of the Welsh Government Woodland Estate (WGWE) is certified.

Nevertheless, based on recent research - much of which has taken place in the UK including Wales[6] - there appears to be scope for using woodland to help reduce flood risk in some circumstances. The greater water use of conifers and the woodland soil sponge effect appear to be most effective at a local catchment scale and for small and moderate flood events. On the other hand, modelling studies predict that floodplain and riparian woodland have the greatest potential for attenuating large floods within downstream towns and cities. Although more studies are required to test model predictions, there is probably enough evidence to promote floodplain and riparian woodland planting to reduce flood risk in appropriate locations, especially when other benefits are factored into the equation.

Much of the information above is included in three documents on forestry and water which can be read in full by following the links below:

- Woodland for Water: Woodland measures for meeting Water Framework Directive objectives: https://www.forestresearch.gov.uk/research/woodland-for-water-woodland-measures-for-meeting-water-framework-directive-objectives/
- Water Use by Trees: https://www.forestresearch.gov.uk/research/archive-water-use-by-trees-2/
- The role of productive woodlands in water management: https://www.confor.org.uk/media/79557/1208-confor-productive-woodlands-plus-water-12pp-aw-sml.pdf

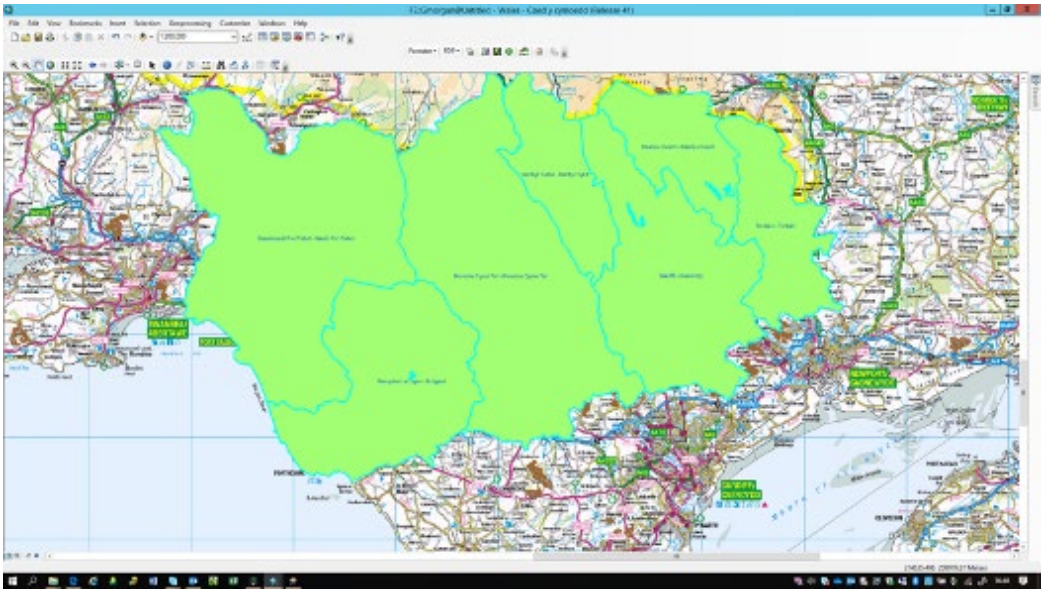
The scope for large scale changes to the NRW estate to reduce flood risk

The information above demonstrates that, while woodlands are usually benign or helpful when reducing flood risk, they are not the universal solution, particularly for the kind of extreme event we saw in February 2020, which is now more likely to happen again due to climate change. To make a difference to events such as main river flooding or across a region (e.g.: South Wales Valleys), the scope for changes on the NRW Estate would need to be significant on a landscape scale. Below, using the South Wales Valleys as an example, we show how despite its size, the scope of changes possible on the NRW Estate does not provide this kind of scale.

Of the 175,565ha that the 8 unitary authorities in the South Wales Valleys cover, 29,552ha or 17% is managed by NRW, 29,122ha is WGWE and 430ha is National Nature Reserves (NNR) managed directly by NRW (Fig. 1). Of the 29,122ha land managed by WGWE, 22,556ha or 77% is woodland. The rest has other forms of “natural” land-use, such as open habitat including wet bog, or is under renewable energy facilities. Converting this 6,566ha of open land to tree cover would not be desirable for many reasons. It would almost certainly transgress requirements under UKWAS and making up just 3.7% of the area of the Valleys, is unlikely to make much impact on preventing the risk of flooding from events such as that in February 2020.

[6] https://www.cymerau.org/blog/pumlumon-project-slowing-the-flow-with-the-local-community

Fig. 1: Area of the Natural Resources Wales (NRW) land Estate in the South Wales Valleys.



Total area of unitary authorities: 175,565ha.

Welsh Government Woodland Estate: 29,122ha

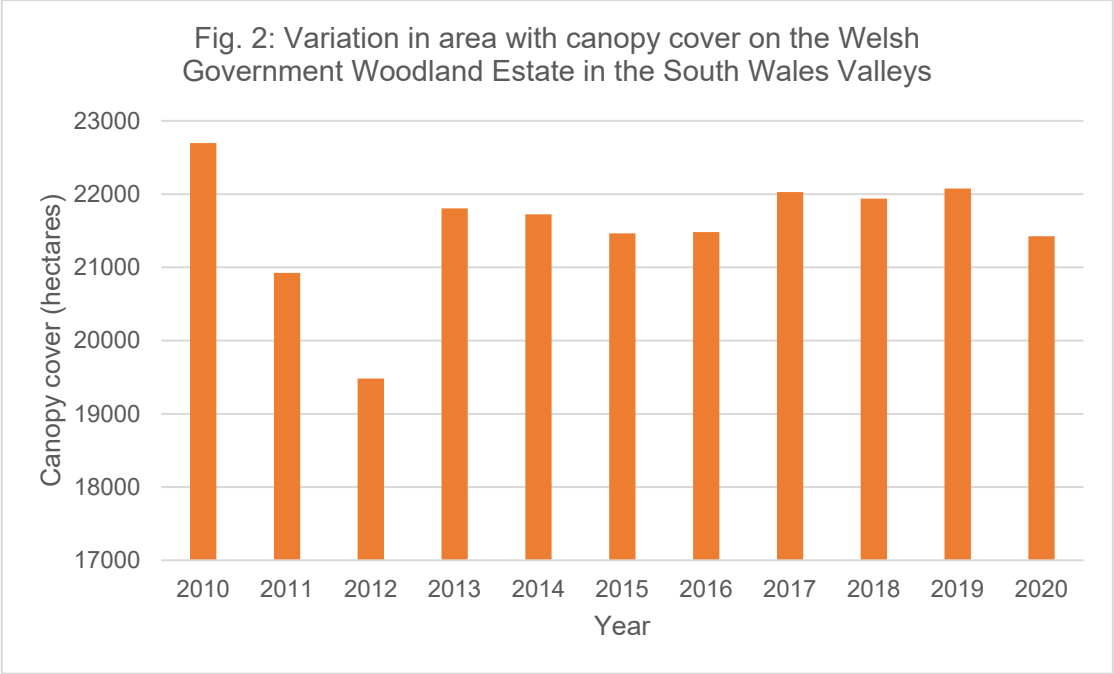
National Nature Reserves managed directly

Of the 22,556ha WGWE land that is woodland, 1,132ha or 5% is currently felled following routine harvesting or removal of larch infected with *Phytophthora ramorum* and awaiting "restocking"[7]. Converting to 100% canopy cover at all times would have significant negative impacts on nature conservation, timber supply, jobs and tree safety, while having little impact on flood risk; it would represent just 0.6% of the land area of the Valleys.

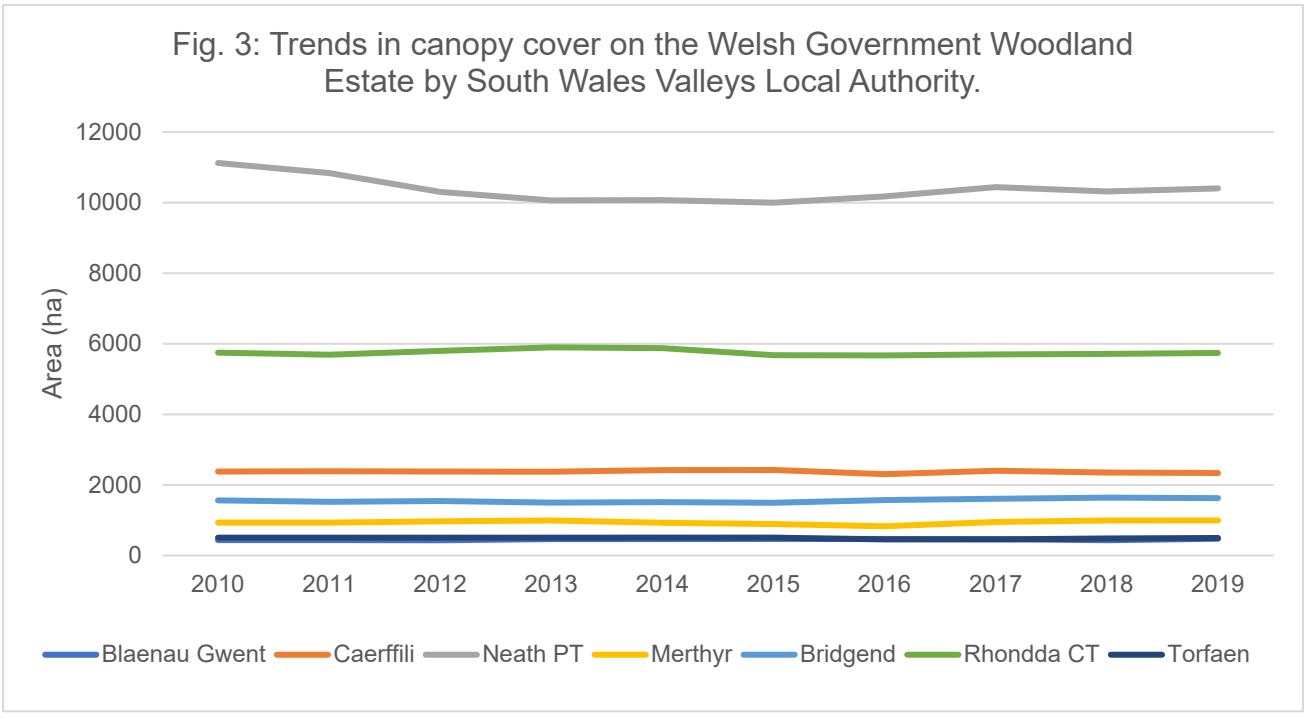
Taking into account area felled and not yet restocked, as well as areas managed as open habitat or under renewable energy facilities, canopy cover of the WGWE has varied from 22,697ha (77%) in 2012 to 21,424ha (72%) today. In the area of the Valleys specifically, this has reduced from 12.9% to 12.2% (Fig. 2).

[7] For further information on restocking see Appendix 3.

Fig. 2: Variation in the area with canopy cover on the Welsh Government Woodland Estate in the South Wales Valleys



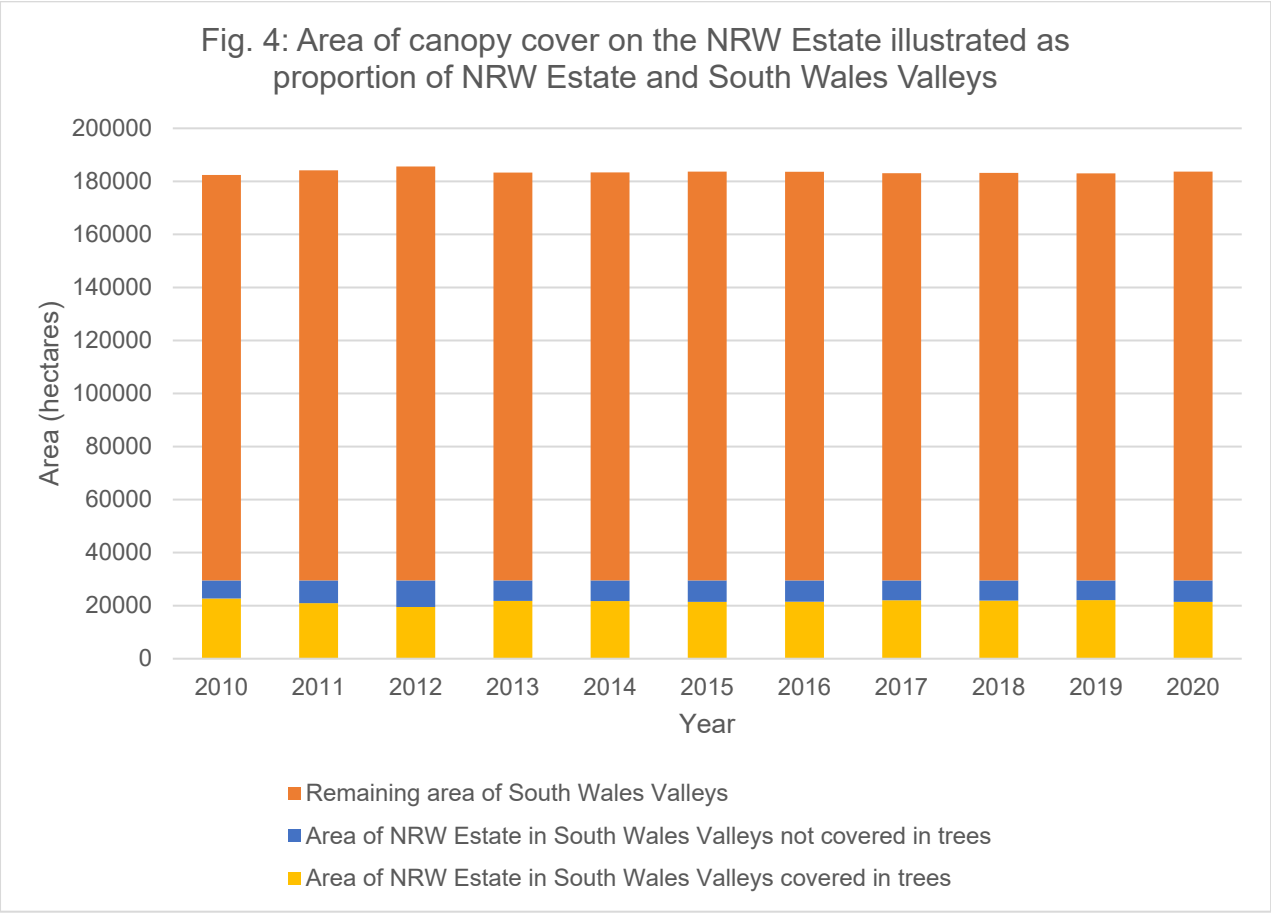
Future plans show a similar trend and scale of changes. Over the next 10 year period, we plan to fell 4,257ha, restock or allow self-seeding with trees 3,146ha (74%) and convert the remaining 1,111ha to permanent open habitat or other non-treed land-uses. Under current plans, this means that in 2031, the canopy cover will be 69.7%. This holds true when broken down at South Wales local authority level (Fig. 3) where we see a similar pattern of trends between local authorities.



Conclusions

While the NRW Estate may seem large, it is not large enough on a landscape scale to have any significant impact on the risk of flooding during events such as those in February 2020. Figure 4 puts the scale in context.

Fig. 4: Area of canopy cover on the NRW Estate illustrated as proportion of NRW Estate and South Wales Valleys



These conclusions hold true across Wales, where the NRW Estate is 7% of the total area of Wales. WGWE and NNR share similar patterns and trends in canopy cover. We therefore conclude that there is little evidence that large scale changes to the NRW landed Estate, such as reversion to near 100% canopy cover, would reduce the risk of flooding from weather events such as the February 2020 storms.

However, there may be a stronger case for looking at the role of the NRW Estate in enabling changes in land-use on a wider scale, beyond the boundaries of the Estate. This is out of scope for this review, but we are looking at this via other mechanisms. Across NRW, we have recently assessed the latest evidence on the role of land-use in managing flood risk, or natural flood solutions.

As a result of this we are:

- Embedding natural flood management measures within flood risk management operations
- Funding small scale natural flood risk management projects
- Supporting the delivery of flood risk and environmental benefits through wider programmes and projects.

In keeping with this, there is evidence that changes to how we design, manage and run land management operations on the WGWE could have a positive impact on a more local scale in some high risk areas. This appears especially relevant to less extreme rainfall events, and in some local catchments in the South Wales Valleys where the WGWE is a high % of the total catchment of smaller rivers, streams; and areas prone to flooding upstream from main rivers.

Between local authorities there can be significant variation in the relative proportion of the land area that is influenced by the WGWE. For example, in the Valleys, the total % cover by the WGWE ranges from 29% in Neath Port Talbot and 21% in Rhondda Cynon Taff to 5% in Blaenau Gwent (Table. 1). The treatment of the WGWE does not vary between local authorities by enough to have a differential impact on flood risk at the local authority scale. For example, the percentage of the WGWE that has been recently felled ranges from 0.7% (Merthyr Tydfil) to 7.6% (Torfaen), both well below the thresholds at which extent of felling could have an impact on water management at this scale. Nevertheless, much of the political and community response to flooding is mediated at the local authority level, so there are implications for how we need to work more closely with some local authorities than others when deciding how to manage the NRW Estate.

Table 1: Welsh Government Woodland Estate (WGWE) areas on South Wales Valleys Local Authorities.

		Welsh Government Woodland Estate (WGWE)					
		Total		**With canopy cover**		**Felled**	
Local Authority (LA)	**Area of LA (ha)**	**Area (ha)**	**% of LA**	**Area (ha)**	**% of WGWE**	**Area (ha)**	**% of WGWE**
Blaenau Gwent	10875	530	4.9	498	94	12	2.3
Caerffili – Caerphilly	27738	2754	9.9	2359	86	170	6.2
Castell Nedd- Port Talbot	45186	13277	29.4	10316	78	535	4.0
Merthyr Tudful / Merthyr Tydfil	11195	1039	9.3	993	96	6.9	0.7
Pen-y-bont ar Ogwr - Bridgend	25532	2064	8.1	1878	91	54	2.6
Rhondda Cynon Taf	42414	8828	20.8	6139	70	346	3.9
Torfaen	12622	724	5.7	587	81	55	7.6

We examine the implications for these elements of land management on the NRW Estate below.

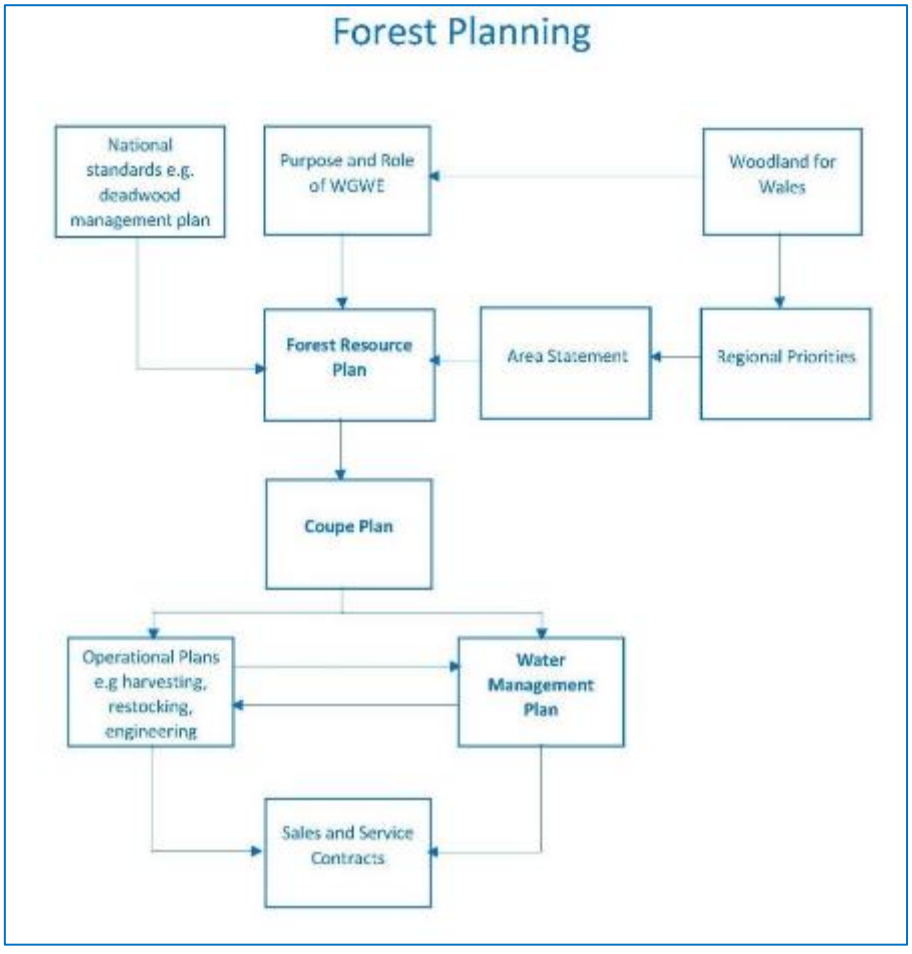
Forest and other land-use resource planning

Background

Under UKWAS, the guidance for management planning is that it should be “proportionate to the scale and intensity of woodland management, and to the potential economic, environmental and social impacts of management activities including where those effects are outside the boundaries of the woodland.” It also adds that the “owner/manager shall mitigate the risks to public health and safety and other negative impacts of woodland operations on local people”.

There are various levels at which we gather information and plan and assess the risk factors to be dealt with. We start at a strategic level through the Woodlands for Wales Strategy, UKFS, Area Statements, or River Basin Management Plans; and then move down to a more local level through Forest Resource Plans (FRPs), Coupe Plans, Water Management Plans (WMPs), and work plans, etc. (Fig. 5). Delivering all the multi-purpose objectives we could within every forest or woodland block is rarely realistic, and decisions on priorities need to be made throughout the planning steps described below. This can mean that despite these multiple objectives, the planning outcomes may be dominated by a single important factor - if current climate trends continue, this factor is likely to be water management in an increasing number of cases.

Fig 5 Forest Planning



Catchment scale planning

Forestry can have an effect within a catchment - usually where it forms a relatively large percentage of the land use in that catchment. In some cases, it can also have an effect through direct connections to things such as drinking water supplies or sensitive species. This has mostly manifested itself through the designation of nitrate sensitive areas and the planning for appropriate maximum levels of clear-felling within these areas.

There are two current examples described below where we are involved in working at this catchment level, although, as noted above, water quality is the predominant focus.

Talybont Reservoir Catchment Partnership (TRCP):

Since 2014 Dwr Cymru Welsh Water and NRW have been working in partnership to make changes to the management of the commercial forest which makes up 30% of the Talybont Reservoir catchment. Approximately 15% of the forest has had to be cleared over the last few years due to *Phytophthora ramorum* and this has provided the opportunity for a fundamental review of forest design and management to improve water quality as well as other ecosystem services the forest provides.

A study considered the delivery of different ecosystem services against three different scenarios: (i) *status quo* (c.80% conifer, low species diversity); (ii) mixed broadleaves (c.70%) under minimum intervention; and (iii) 50-50% diverse species broadleaf/conifer mix with changes to management practice e.g. initial spacing, weeding, pruning, thinning regimes, harvesting methods and long-term silvicultural systems, as assessed coupe by coupe. The third option (50-50% diverse species broadleaf/conifer mix) produced the highest score and is now being adopted, with management changes underway.

NRW and Dwr Cymru Welsh Water aim to replicate this forestry management approach in other reservoir catchments in the Brecon Beacons, where the land is leasehold with Welsh Water.

Dyfi catchment: The Dyfi has an outstanding natural environment and is one of the most scenic areas in Wales. The geography of the area ranges from the mountains of Aran Fawddwy in south Snowdonia, to beaches at Borth and Aberdovey. The area comprises of a wide range of habitat types, from blanket bogs in the mountains, through woodland and farmland, down to the coastal salt marshes, mud-flats and sand dunes. Since 2015, we have been working with a range of stakeholders to produce an opportunities document for sustainable management of the Dyfi's natural resources.

Key projects have included:

- Mapping barriers to fish migration in the Dyfi
- Dyfi habitat network – restoration of 78-hectare plantation on ancient woodland sites on the WGWE to form part of a Dyfi 'resilience' network
- Pennal 2050 natural flood risk project to model the Pennal catchment and make recommendations on changing the drainage network in the NRW managed estate

The last item is the most relevant to this report. With the bridge in the village being a pinch point, there have been several issues with flooding, and the nearby forest forms 60% of the local catchment. There are many years of flow monitoring data already available, therefore,

as the project progresses with modifications in the forest, any changes to the catchment hydrology can be observed. The initial proposals are to disperse water by creating additional culverts and drainage, changing some of the water "connections" within the forest block, and incorporating natural flood management in the streams using blocking techniques such as "leaky dams".

As well as the Pennal 2050 project, there are other smaller projects underway elsewhere on the WGWE looking at natural flood management techniques such as in Myherin[8]. The Strategic Flood Management team is also involved and is currently working on a draft position statement[9]. There needs to be careful thought given to these measures as many factors need to be considered in their design (Appendix 4) including issues such as the effect on fish movement and habitat. Implementing such a measure is discussed further in the section on Forest Operations.

Forest Resource Plans

Forest Resource Plans (FRPs) set out the framework for management within a forest area. They detail what work will be carried out and when. These programmes of work are developed to meet the forest objectives, which are created based on policy guidance and Area Statements. They are refined through coupe plans and detailed site plans for operational delivery.

FRPs will replace Forest Design Plans (FDPs), although they serve the same basic function. The new FRPs better reflect the wider landscape and ecosystems approach. There are currently only a few approved FRPs, although many more are in progress, and FDPs will remain in place as working plans until they are replaced by them.

FRPs take into account the individual features and opportunities of a particular forest area, ensuring plans are developed with these in mind. This includes considering factors such as water catchments, adjoining woodlands, farmland and urban and rural communities, as well as the wider environmental, historical and visual context. FRPs incorporate the Welsh Government's requirements, and those set out in UKFS and Guidelines.

These plans will incorporate all issues related to the wider landscape and ecosystem goods and services within their objectives, but parts of the design at coupe level may still be strongly influenced by local issues. However, more extreme elements, such as 1:100-year flood risk are unlikely to be taken into account given that we do not currently use flood data sets in plan scoping.

Generally speaking, design features such as broadleaf woodland, long term retention, and open space can help to improve the structure of forests and deliver a number of benefits. But, if we focus on a single overriding issue such as flooding, this may lead us to design differently.

To ensure plans are better able to deliver protection from extreme events, they need to be carefully considered at the start of the process. Simply incorporating more permanent

[8] https://naturalresources.wales/about-us/news-and-events/news/innovative-river-project-to-help-wildlife-and-communities/?lang=en
[9] Draft Position Statement on Natural Flood Mgt

structures like broadleaved and transitional woodlands does not remove all the risks. The creation of areas of forest that function primarily to protect communities or habitats may be a positive step, but this needs to be planned with consideration for the appropriate infrastructure and future implications on resources. Without this, these areas have the potential to create their own problems such as tall high forest crops that risk erosion and are vulnerable to wind blow, or shrub covered areas that are prone to fire and inaccessible when action is required.

Most areas that are managed by methods other than clear felling and replanting will require more infrastructure. However, any specification of a particular type of forestry feature, such as continuous cover forestry (CCF), must have a realistic plan in place for future management and maintenance of these areas.

Another key factor in ensuring that plans effectively cover the important issues is the involvement of local staff. The FRP process is led by specialist resource planners, some of whom may be contract staff or those who do not have wide experience of managing the forest area. They require input from a wide range of local staff to not only ensure that the correct objectives are set, but that the design meets these objectives and is operationally deliverable. Although this engagement is an embedded part of the process, the level to which this actually occurs varies and is one of many competing pressures facing teams working in land management, forest operations, and integrated engineering. While Environment Teams are asked to provide information to help develop plans, this is often focused around biodiversity and social requirements, with limited information provided regarding flood risk.

There is also a requirement to involve stakeholders, particularly local stakeholders, in the development of FRPs. This provides an opportunity to further improve community engagement in forest planning, which is particularly important in communities vulnerable to flooding. Within these communities we could use forest resource planning to help develop greater confidence in the NRW Estate and its contribution to reducing flood risk.

As FRPs are long term plans, they need to be viewed in this context. Changes in structure and species may not be fully realised for decades so the design maps need to represent a snapshot of the end product in 25 years or more. Clear-felling will create some short-term disruption and risk, but plans should aim to minimise this through the design and timing of felling coupes. This is more difficult in areas affected by the larch disease *Phytophthora ramorum,* especially where larch is a major component of some forests. Different zones were created where the disease was either broadly accepted as being present, with extended time to deal with it, or where swift action was needed to contain and eradicate it.

This has helped to avoid the need to fell all the infected trees within a short period. However, as larch dies, it becomes more hazardous to clear safely, particularly on steep ground where there is more need for manual felling with chainsaws. As a result, for at least the next five years, a high level of felling will continue in the areas driven by the disease.

This has meant changes have had to be made to the original, carefully phased felling plans, and has resulted in some of this work being brought forward. As the larch plantings were traditionally located on steeper, freely draining ground on the lower valley sides, a larger proportion of these clearance areas are close to communities. The benefit of this accelerated felling programme is that it allows for quicker conversion to different management or land use type.

A recent new style FRP is available for the forest which covers the areas at Blaenllechau and Darranlas - extracts of which are shown in Figures 6 & 7. The intention is to have buffers of broadleaved or transitional woodland, as well as open space on the lower slopes nearer to the communities. The dark blue and purple areas also indicate the extent of felling that has recently taken place or will be completed by 2026 in these same locations.

Fig 6 Extract from Llanwynno Forest Resource Plan Forest Management Systems Map

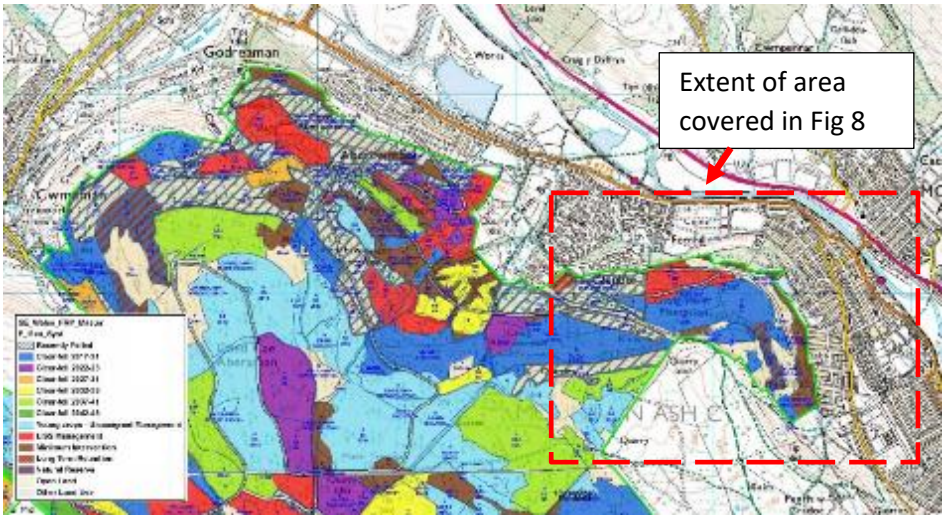
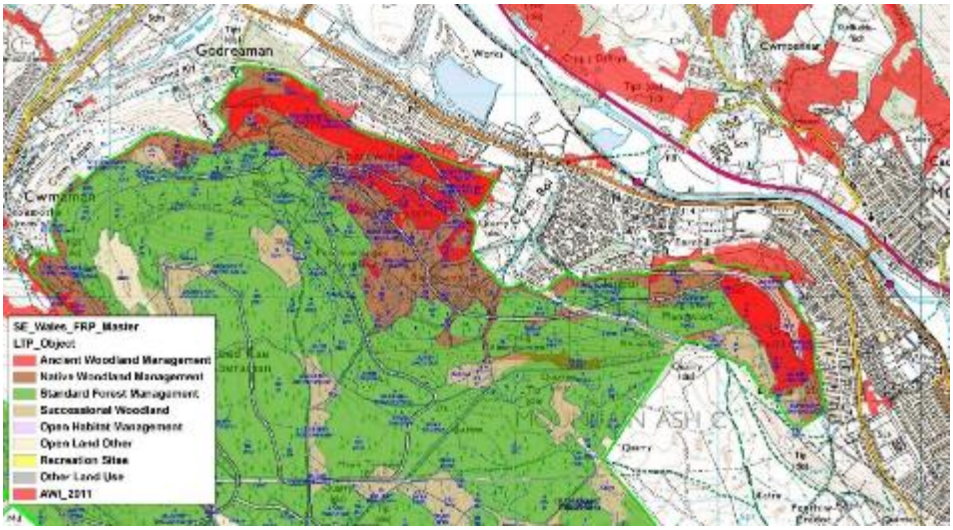


Fig 7 Extract from Llanwynno Forest Resource Plan Long Term Primary Objectives Map



Now is a good time to refine our approach to Forest Resource Planning as the bulk of the work to convert old style FDPs to new style FRPs will be happening over the next two years. There are 98 different FRPs / FDPs covering the WGWE area across 72 design units and 398 forest blocks.

On the NRW Estate as a whole, 20,806ha, or 13%, are already covered by up to date FRPs. In the South Wales Valleys, this is 8,187ha, or 25%, with FRPs at Neath Valley, Margam and Llanwynno. We plan for all areas of the WGWE to have new style FRPs by the end of 2025. This means that over the next three years, 87% of the WGWE will have new style FRPs developed, 75% in the South Wales Valleys.

This offers a significant opportunity to make the changes referenced in this review to those forest plans where flood risk management is a high priority.

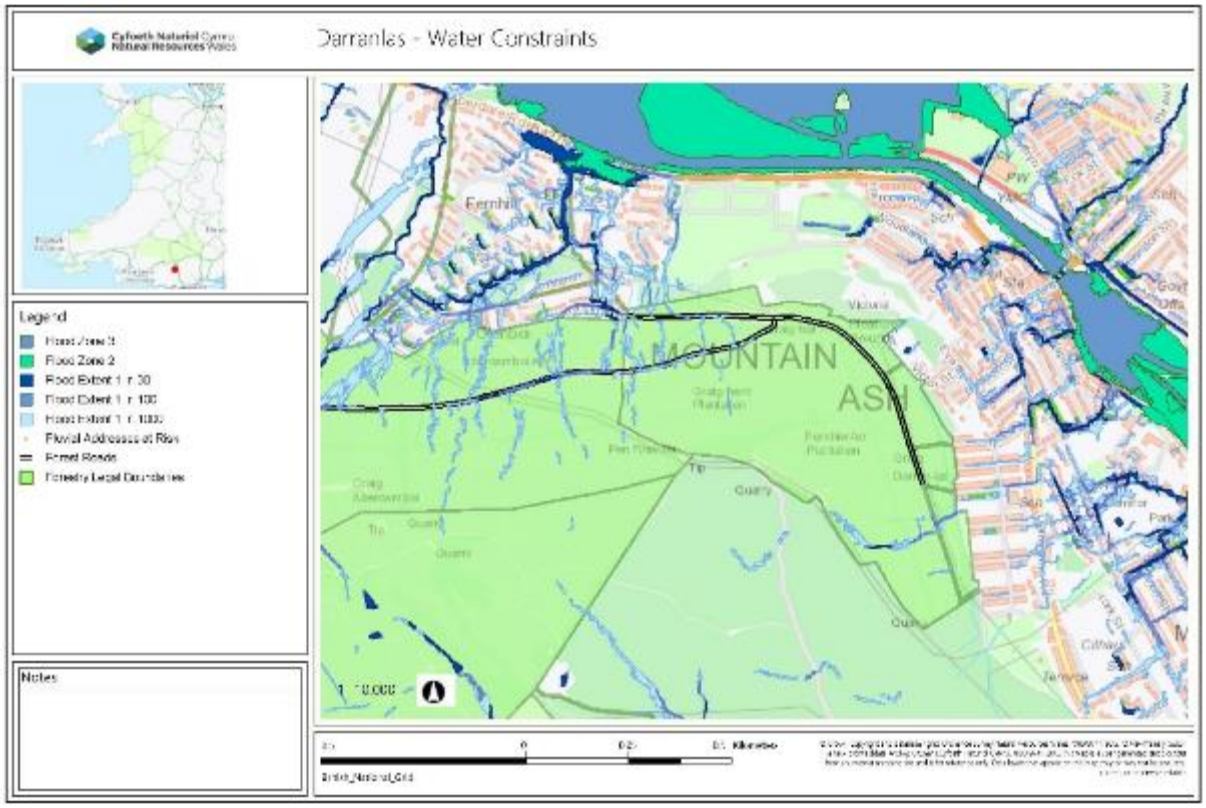
Coupe planning

A coupe is the operational working unit in the forest, setting out the shape and extent of these areas as illustrated in Fig 8. Coupe planning is carried out for individual areas that require the harvesting operations identified in the five-year felling phases of the FRP/FDP, or from the Thinning Plans. If the operation involves clear-felling, then there will also be an element of coupe planning to deal with the establishment of a new crop.

This function sits within local teams and may be shared amongst individuals with wider roles. This can mean that the coupe planner is also the harvesting contract manager as well as the officer responsible for the subsequent establishment. Staff ability and experience in these roles is variable and the skillsets required are wide ranging. Therefore, we need to put energy into achieving consistent standards.

As with the FRP level planning, local communication and liaison with all those involved in either managing the land or carrying out the subsequent operations, is key. The process is well established and generally works well, but as with FRPs, we could make better use of the spatial information available in terms of flood risk (see Fig. 8). The system itself does allow for the risk level of the coupe plan to be set at high, medium or low. Guidance indicates that water/flood issues are reasons for setting a high-risk status and this should prompt a more detailed consideration of operational factors such as working methods that might have an influence.

Fig 8 Example of Spatial data on flooding



FRPs give broader restocking objectives rather than detailed prescriptions for species. These decisions are made at the coupe planning stage. This enables the coupe planner to make better site-based decisions to reflect landform, such as deciding on riparian zones. It also provides them with more flexibility to respond to any specific coupe conditions.

The UKFS Forests and Water Guidelines require all watercourses to have a buffer area established with minimum widths set out. Maximising the development of an understorey and ground vegetation in these buffer zones will increase the length of time it takes for water to travel due to the roughness of the vegetated land and the increased infiltration into the soils slowing the over-land flow. Most, if not all coupes of productive conifer crops when felled and restocked, include a variety of these riparian/roadside buffer zones, or broadleaved components, which can account for up to 40% of the original area.

Water management plans

Water Management Plans (WMPs), for operations relating to coupes, have been established in forest operations for some years. The format of WMPs allows for an individual plan to be created for different operations related to the same area such as harvesting, engineering, and restocking work.

All WMPs involve an environmental risk assessment which includes a map of the area detailing all water pathways, risks and mitigation, as well as water monitoring points. They also include details of any mitigation put in place ahead of operations starting. The documents are kept 'live' and are updated with information, lessons learnt and a record of any infrastructure that requires ongoing management. The plan will include an assessment of the operation including how any existing issues in and around the coupe could be removed or mitigated, as well as what issues might be caused as a result.

Although plans are drawn up for individual operations, they tend to be done in isolation and do not always build on the single document format that has been provided. As with the other parts of the planning process, the focus is mostly on the risk of diffuse pollution, despite the fact the measures put in place can also have an influence on flow.

The first stage of the WMP is a largely desktop-based assessment made during or immediately after the formation of the source coupe plan. At this stage, there could be an opportunity to better consider the coupe's WMP to contribute to the longer term aims of the FRP for water catchment management. This would require the FRP to identify these aims and opportunities. The subsequent key stages of the coupe WMP are currently drawn up as part of a detailed contract plan focussed on individual operations. They therefore concentrate on the issues relevant to the planned works. It could be more effective to consider water management at a wider level, beyond the immediate area, either to follow the water connections through, or to check the access routes to see if other problems exist that can be included in the planned operations.

Disconnecting drains is an option noted for managing water in coupes. In practice, this may need to be done at multiple locations, at significant distances up or downstream from the coupe, in order to reduce flow. It would also require this wider view of the local forest to be taken. As well as disconnecting drains, the use of techniques such as woody debris dams may be appropriate (Appendix 3).

Wetting the forest brings the need for careful planning to ensure that future access, productivity and stand stability are not adversely affected, and unintended consequences,

such as uncontrolled surface flows of water, are avoided. If a more strategic, wider WMP view is taken as part of the coupe plan, the potential costs and benefits of disconnecting drains could include a review to identify other synergistic opportunities, such as the creation of inline ponds or reservoirs, as well as ponds located to pick up water from the point of disconnection. These interventions could then be complemented with suitable alternative planting.

The Eddleston Water project in Scotland provides an example of combining natural intervention options for catchment management, including ponds (Tweed Forum, 2016). Undertaking such interventions at a scale sufficient enough to impact the catchment could encounter significant design challenges due to the current structure of the forest, therefore using a combined approach may be more practical. The work in Brechfa and Clocaenog, mentioned elsewhere in this report, shows ways in which this approach could be implemented.

Previous work by the Forest & Water Specialist Advisor in NRW saw the development of an action plan for work on the WGWE to improve compliance with the WFD. It included the following recommendations:

- Review the forest riparian management and drainage systems in priority water bodies to ensure they meet best practice for water management by 2021. Twenty-two priority water bodies in WFD Cycle 113 were identified where NRW actions could lead to a significant improvement in their status. Much of the work subsequently identified below has been undertaken in the prioritised water bodies.
- Review and update FDPs and FRPs to identify and facilitate restructuring opportunities on the WGWE, including greater use of Low Impact Silvicultural Systems (LISS), better riparian management and open habitat restoration.
- Survey rivers to identify ways to improve forest riparian management. We have developed a standard methodology for “river walks” and all local staff in forest planning teams have received training and instruction. Surveys record a wide range of information including riparian habitat quality, the presence of invasive non-native species (INNS), fish blockages, forest and roadside drain connections.
- Survey culverts and drains on the WGWE, sometimes in partnership with others. For example, in 2017, we started the “Culvert Assessment and Prioritisation Pilot – Gorlech, Cothi and Melinddwr, Brechfa Forest” working collaboratively across NRW (planning, fisheries and operations delivery teams) and with Afonydd Cymru Rivers Trust. The pilot will identify a priority work programme of culvert replacement and amendments to waterbodies within Brechfa Forest with the aim of reducing barriers to migratory fish. The project will run into 2020.
- Roll out Water Management Plans (WMPs) as a requirement for all operations on the WGWE including harvesting, civil engineering, restocking operations and recreational activity like rallying and mountain bike trails, in order to minimise the risk of sediment delivery to watercourses. To date, over 250 WMPs have been completed. Staff and contractors have been given training on producing WMPs at water awareness events.

This plan was focused on water quality but much of it is relevant, or could be made relevant, to water volume. Implementing the current plan and amending it to include water volume would require additional resources.

Peat restoration

Deep peat is classified as a peat layer over 50cms in the UK Forestry Standard (UKFS). The total afforested deep peat area in Wales over 40cms in 2012 was estimated as 18,092 ha. Of this, 11,232 ha is under coniferous tree cover – 11,038ha of which is on the WGWE, with 5,956ha of this meeting the UKFS classification of over 50cms.

Peatland in pristine or good condition provides a range of critical ecosystem functions, contributing to biodiversity, carbon storage and sequestration, regulation of stream base flows, water runoff and downstream flood peaks. It also contributes to nutrient regulation and retention. However, afforested deep peat may generate sub-optimal benefits, and there is a case for considering restoration to open habitat instead, where there is a clear ecosystem service benefit, and where the viability of successful restoration has been assessed.

We have a programme put in place to manage restoration on these sites over the next 15 years. As of May 2020, a total of 698ha have been restored, restoration work is in progress on 197ha, and a further 1,162ha of restoration is planned. Under the peatland programme, we are currently assessing the remainder of the afforested deep peat to establish the most appropriate programme of restoration.

We also developed a Field Assessment Tool (FAT) for practitioners to prioritise sites based on the delivery of multiple environmental benefits. Any potential restocking on deep peat requires application of the FAT and can only be considered when certain criteria are met. If restocking on deep peat sites is the best option, there are guidelines that must be followed to minimise any negative impacts. These include careful selection of tree species, planting specifications for riparian areas, retaining areas of semi-natural open habitat, restrictions on changes to drainage infrastructure and no mechanised ground preparation.

The previous programme of peat restoration was based on an analysis of the whole Estate that created a “top ten” sites for restoration. There is scope for further peat restoration on the estate. However, decisions are not straightforward due to uncertainties about the scale and nature of their impact on flood risk, and the potential negative effects on carbon emissions in some circumstances. Further restoration may not be through large areas, such as the previously targeted “top ten”, but through looking at the coupe scale changes that could be made as a result of the field assessment process and proactive management of existing open space and riparian zones. This revised approach, and the resulting outline programme, is set out in our new peatland programme which is under development at the time of writing.

Drain blocking for bog restoration can also contribute to flooding in some circumstances. The work in some of our NNRs has created tension with neighbours due to the backing up of shared drains, and has constrained the ability of NNR managers to go ahead with re-wetting objectives. This is a less likely scenario in our management of forest blocks, as the bog areas tend to be upland areas adjacent to unimproved habitats.

We should also note that, as with the caveats on water use by woodlands, once the ground is saturated, it is saturated. Peat bogs usually help to reduce flood risk but there is little evidence that extending or improving them could have made much difference to the February 2020 floods.

Woodland creation

The Welsh Government has ambitious targets in place for woodland creation through both the Glastir scheme and initiatives such as the “National Forest”. NRW is acquiring 350ha of land for “compensatory planting” - woodland creation to replace woodland that was permanently removed during the development of renewable energy facilities on the WGWE - and may look to increase this area in the future.

The benefits that new woodlands can bring for water management are well documented, and where these can be designed ‘from scratch’, efforts should be made to ensure these benefits are maximised. Detailed guidance is available on planning the best layout and using the most appropriate techniques for both the establishment phase and for future management. As with planning for our existing woodland, we need to ensure that water issues are regarded as a key element of this process.

Tips and landslips

There are hundreds of coal spoil and similar man-made sites within our forest boundaries, as well as other natural areas of steep and potentially unstable ground that have the potential to suffer landslip. The coal tips are concentrated in the forests of South Wales and through our contract with the Coal Authority, we have a good inspection and monitoring regime in place and are aware of and dealing with any problems. Local staff indicate that landslip issues tend not to be linked directly to operations, but rather to the inherent instability of the land features and the effect of the environment on them. However, as part of the FRP and coupe planning process, we should still consider how trees will develop over time in these areas, whether certain conditions or operations could change the stability, and if a different tree species or forest type would be better suited.

In 2009, the British Geological Survey (BGS) was commissioned to assess hazards posed by land sliding to third party assets surrounding the then Forestry Commission Wales (FCW) managed land. There were 128 sites identified, with individual reports then completed for each, and these are shown highlighted in red in Fig 9. The risks were identified using various parameters and the results are available as spatial data in our GIS systems as shown in Fig 10. There is also guidance available on how to use the data, including a matrix for implementing control measures on forestry activities to help prevent landslip.

There is some evidence that not all staff are aware of this data or that they are not using it in their decision-making and some operations are still being proposed in high-risk landslide hazard areas. However, whilst guidance may suggest avoiding clear-fell and implementing different silvicultural systems, this may not be possible to implement due to disease, or the age and structure of the existing crop.

The data sets and reports are not available by default in the main forest planning and management GIS, Forester, and require some effort to locate and install. It would be better if they were part of the standard set of layers used to generate a list of constraints, and if the detailed reports themselves were not directly linked to the spatial data. This may require additional development to the planned Forester Replacement system and will need to be funded. Also, better awareness of the availability of the data, and the procedures to be followed to access it, are necessary for all staff involved in planning operations.

Although staff felt there were few direct problems with the areas of “made-up” ground currently managed as woodland, we need to consider that, with a changing climate and more frequent extreme events, this may not always remain the case. Woodlands provide ground cover and root systems that can help to stabilise the slopes, but the structure and management of that woodland need to be right to provide these benefits and not add to the risks.

Maintaining a vigorous understory vegetation, and lower intervention can help to reduce landslide potential. There are therefore benefits of using relatively slow growing trees or shrubs that have low wind-throw risk on vulnerable slopes. Pure stands of fast growing, tall conifers are considerably more vulnerable to uprooting in storms and are therefore less appropriate for soil protection. In addition, clear-fell-replant regimes add to the vulnerability of slopes as they leave the site with a lower cover or root reinforcement for several years between rotations. The design of civil engineering can also influence land slip; roads and drains need to be well built and maintained with adequate culverts to avoid washouts that can lead to debris flows.

There is a lack of easily accessible information on the extent of the spoil tips or other made up ground on which we have woodland. Although the BGS data should have identified the main risk zones, the FRP and Coupe planning of these areas would benefit from more detailed information. The Coal Authority has however started to build a GIS layer outlining all the Colliery Tips in South Wales and it would most likely be possible to transpose the area from this. This is currently a project being undertaken for Welsh Government and is in its infancy

Fig 9 British Geological Survey Data on Landslip

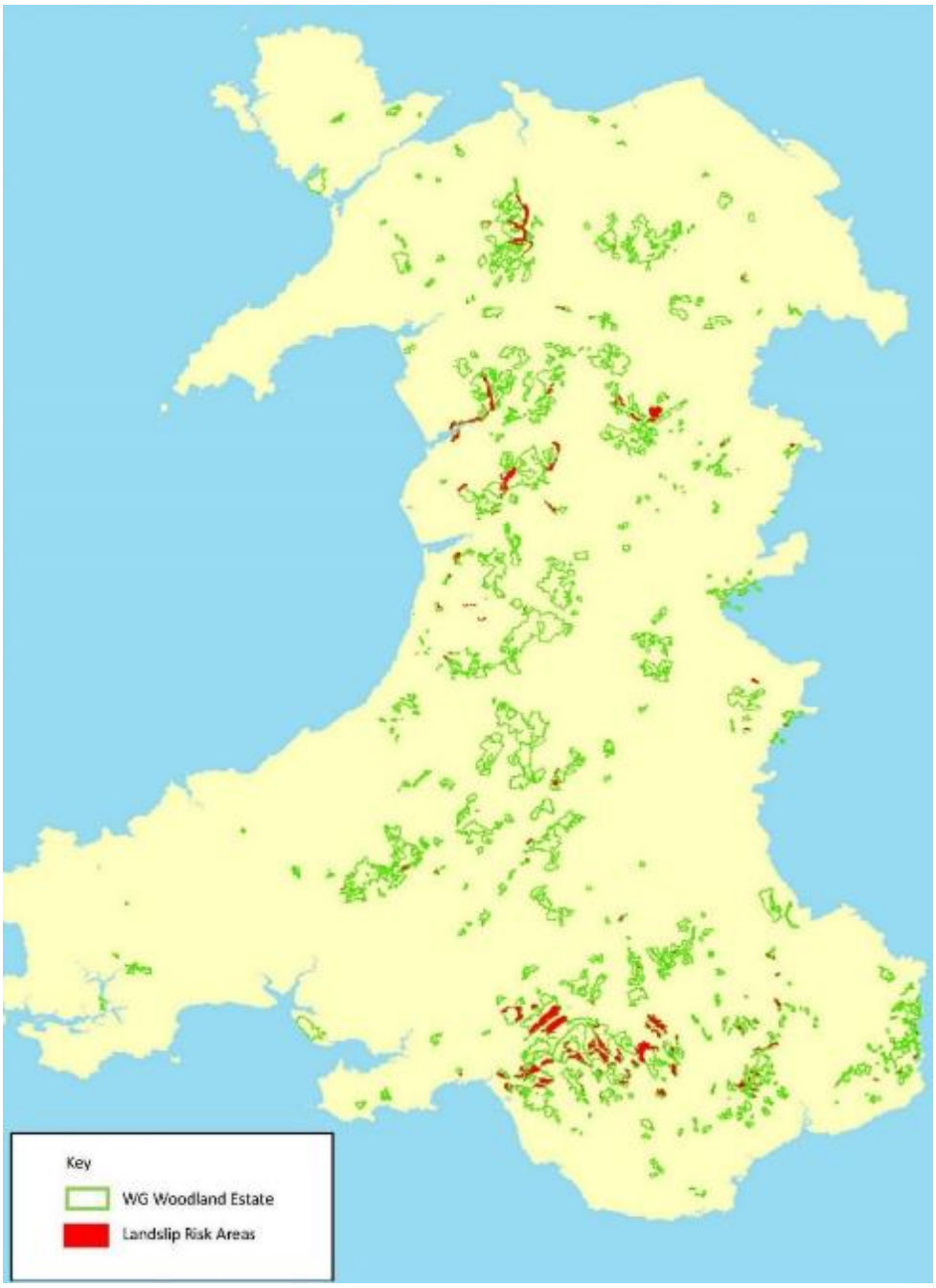
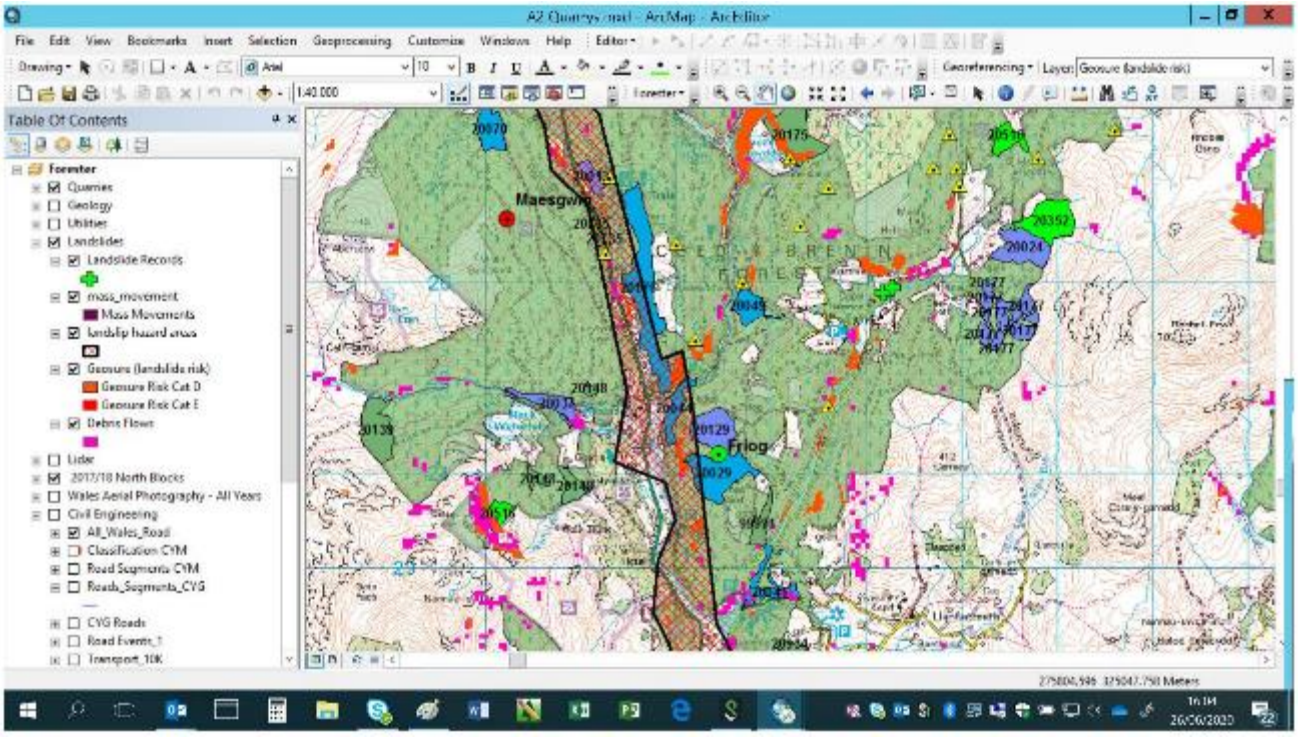


Fig 10 – Example of British Geological Survey Landslip Hazard Layers



Conclusions and recommendations

In a changing climate, it is becoming clear that the flood risk aspect of water management, as well as the more familiar issue of water quality, must be factored into decision-making. NRW and forestry in general have done a lot on water quality over the past few decades but we must now make a similar effort on water quantity. With 157,000ha of managed land, we of course cannot address everything at once. Instead, we need to identify the higher risk areas and the most beneficial actions so that we can best use the resources we have available.

There is no simple universal solution as every land use type and management regime has its strengths and weaknesses. Fast growing conifer forest land is very effective at capturing both water and carbon while managing by clear-felling does not intrinsically create problems. A move to low impact or continuous cover systems would not be possible for many existing areas of mature or semi-mature crops until after felling.

Even after felling, it may not be desirable or economically viable to move to this approach due to the increase in infrastructure and management interventions required, which are even more difficult to implement on steep and uneven ground.

Mixed woodland, broadleaved woodland and other more open habitats have different sets of characteristics and benefits to conifer plantations, but they still need to be managed in a proactive way to maintain the species and woodland structure and realise these benefits. High forest continuous cover can be more prone to windthrow, which may increase the risk of erosion.

Open woodland, allowing for natural succession, may be better in locations vulnerable to windthrow. These could be managed by stem injection or ring barking to manipulate the canopy if it gets too dense. However, our experience as an organisation is not built upon low impact management of mixed or broadleaved woodland and the economics are more challenging. Therefore, targeting where the risks are highest and the benefits the greatest should drive any change to alternative systems, rather than a presumption in favour of one type of system.

There is a strong structure in place for planning from a strategic level right down through to operations, and the broad spread of NRW as an organisation has added to the information and expertise available to help with this. However, some of this knowledge and data has not yet found its way into everyday use therefore training and awareness need to be addressed here. Some of the good processes we have put in place are also used inconsistently or ineffectively, and action plans drawn up have yet to be fully implemented.

We already involve local communities and other external stakeholders in Forest Resource Planning. In high risk areas we need to use this engagement more actively to increase confidence in the role of the NRW Estate in helping reduce flood risk. At the same time, we need to raise awareness of its limitations in preventing events as extreme as the February 2020 floods. We also need to communicate better with communities during forest operations, discussed further below but referenced in the relevant recommendation arising from this section.

The following are specific actions to be considered for delivering change:[10]

- Better use of existing tools to identify risks, using the right data layers at all stages including flood risk/BGS landslip, FRP, Coupe Plan and Work Plans. This data needs to be made accessible by default in Forester and training needs to be provided for all planning and operations staff on how to use this data.
- Carry out an assessment of all our land to identify which areas are associated with communities and classify the relative level of risk that exists.
- In areas where potential risk is identified, review the associated Management Plans for these areas and where practical and proportionate propose changes that are likely to reduce risk significantly. Specific consideration should be given to areas designated as PAWS and Broadleaf areas, ensuring that there is a plan in place that allows for active future management, especially on steep slopes.
- All local staff involved in land management need to be engaged fully in the scoping and drawing up of FRP and Coupe Plans. A working group is needed to decide how to achieve this integration initially, including the People and Places Team who organise FRP work, along with Forest Ops/Land Management Team Leaders and Land and Assets Managers as appropriate. This needs to include consideration of how we involve local communities in high flood risk areas.
- Consistent use of Water Management Plans is required with all using the agreed template. Further training of staff is needed and would benefit from a bespoke training package. Alongside this, we also need a fundamental look at who delivers

[10] We have used these detailed, specific actions to inform the 10 key recommendations, it is this 10 that we will track for delivery, if agreed.

the Forest and Water Action plan and how. Further development of the WMP document itself is also important.

- Work on reassessing the Peat Restoration programme needs to be completed. Alongside this, some minor additional areas may be identified with potential for further disconnecting drainage and utilising natural flood management. Having allocated riparian corridors and open space through FRP and Coupe Plans, local teams should look for opportunities to proactively block existing drainage in these areas, creating useful habitat such as bog and wet woodland rather than just unmanaged space.
- Assess the potential to carry out detailed drainage mapping work as per Clocaenog windfarm and feed into FRP/Coupe/Operational planning. This should cover whole forests or management areas where possible.
- Build the principle of disconnecting artificial drainage, where appropriate, into guidance at all levels of planning. Identifying opportunities for natural flood management measures in the scale and types of catchment where they would be effective should also be included.

These can be consolidated into the following key recommendations for changing our current approach to forest and other land-use resource planning (FRP):

- FRP1: Strengthen use of existing tools to identify flood risk and mitigation opportunities so we can prioritise the highest risk areas on the NRW Estate and build this into the Forest Resource Plans for those areas.
- FRP2: Develop Water Management Plans at a scale most appropriate for water management and further develop consideration of water quantity as well as quality.
- FRP3: Build guidelines on detailed drainage mapping and disconnection of artificial drainage into guidance on forest planning.
- FRP4: Further improve engagement of local communities in Forest Resource Planning and forest operations in high risk areas.

Infrastructure and Engineering

Background

The majority of forests in the WGWE were planted over a 40-year period, with the peak being during the 1950s and 1960s. Infrastructure was designed to concentrate and move water out of the forest as quickly as possible, whereas today the focus would be on managing the water within the forest as much as possible to reduce flow and diffuse pollution.

Roads and their drainage have a significant influence on water concentration and many of the roads, tracks and structures that exist on the estate also date back to the 1950s and 1960s. The Forestry Commission in GB was the international pioneer of plantation forestry

at the time, as well as a leader in the construction of unmetalled roads and facilities to service these new plantations. All work during this era of construction was a centrally managed GB function. The team of engineers, supervisors and operators working within this field were responsible for the maintenance and repair of the growing network through a rolling programme of planned work.

The cost of building new roads has always been high, at tens of thousands of GBP per km. Maintenance, which is also expensive, was traditionally charged as a cost per unit of sale against any harvesting work. Recent road budgets in NRW have been around £3 million per year, which equates to approximately £3.50 - £4.00 per cubic metre. As budgets have often been cut, there has been pressure on the maintenance of our road network for many years, including before NRW was formed. Over time, this has manifested itself into the downgrading or abandoning of parts of the network, a reduction in planned maintenance programmes, and a move towards only undertaking reactionary repairs and works to facilitate current harvesting. We give further information on the costs of moving to a more active approach in the Concluding Remarks section below.

With the majority of our roads having been designed and built many years ago, many do not comply with current construction standards, nor have they been built with climate change in mind. In addition, the gross weight of modern timber haulage vehicles at 44 tonnes, and the speed at which modern harvesting methods can bring timber to roadside, has created pressures on the network that wouldn't have been envisaged when they were built. In 1964, the maximum gross weight of an articulated lorry was raised from 24 to 32 tons, increasing to 38 tons in 1980 44 tons in 1992.

Without regular maintenance, even minor changes to the road surface caused by traffic can disrupt the drainage of surface water and cause it to flow down the road instead. This is most often seen during periods of intense rainfall, causing erosion of the roads and occasionally, flood issues to land or properties outside the forest boundaries. Some clauses in contracts are used to restrict the number of loads and help protect the roads, but this is not always effective on its own.

To protect a road surface from significant damage, action needs to be taken early, possibly before any real deterioration is apparent, which can be hard to implement. After a period of frost, for instance, roads need to fully thaw and resettle before they are fit for heavy traffic, but we do not have a good system for implementing such a restriction in place. The capability of modern haulage equipment also allows it to cope with adverse conditions. Systems that allow tyre pressures to be automatically raised and lowered changing ground pressure, although generally beneficial can also allow travel when conditions are unfit. This is the context in which the following sections should be considered.

Organisation and resource issues

In 2019/20 we implemented a significant change to our Organisational Design (OD). We created six regionalised terrestrial and one marine integrated delivery function, all with a set of central functions covering particular business areas on a national scale, i.e. a hybrid functional and regional place based model. The restructure was implemented successfully with most roles now filled and the benefits being seen in many aspects of our work. Continued energy is needed to develop new ways of working that these structures are designed to achieve.

Since the OD, civil engineering, which covers the creation and maintenance of infrastructure on the NRW Estate, is now part of the wider integrated engineering function for each of the six Place teams. This provides strengths in terms of making the complex, prioritisation decisions at sub-national level that come our way as an integrated, place based environmental body. But, this is traded-off against a potential weakness in the consistency of standards and management oversight at the national level. This was addressed in OD through the formation of a central "Land Stewardship" function that includes forest standards and forest planning functions to support integrated engineering teams (among others) in each Place.

This OD needs to be used to evolve ways of working with particular reference to moving beyond a "Just in Time" delivery model for forest infrastructure focussed on delivering "in coupe" facilities to allow for timber harvesting. This model arose due to resource constraints and the need to deliver the timber harvest to market to generate income and to fulfil commitments on timber supply. While reasonable at the time, this approach has resulted in a gradual reduction in our maintenance capacity and capability, as well as subsequent deterioration in the condition of our infrastructure. The risks of this have become apparent when set against climate change and, while we were working on it already with improvements beginning to come through in some places, this work was drawn into sharp relief by the February 2020 storms.

Another factor associated with the "just in time for harvesting" approach is a relatively inflexible system for procurement of the contractor resource for the works. The current contract framework appears unable to provide enough capacity in certain areas to deliver the programmed work. It also lacks the flexibility to take on maintenance work as opposed to building new infrastructure. We are on track to resolve this issue with a new framework planned for mid-2021.

Sustainable Drainage (SuDS) Statutory Guidance[11] implemented in Wales in 2019 is also causing some additional work and delays on projects. It requires surface water drainage systems to be approved by the SuDS Approving Body (SAB) before construction work with drainage implications can begin. At present, although forestry works are exclusively permeable structures, there is no automatic exemption, and a lack of clarity and consistency on what is required from the individual local authorities is causing issues. In some cases, engineering teams are having to design and implement SuDS schemes as well as arrange the provision of additional site investigation data. On the positive side, SuDS could prove useful in confirming the suitability of our engineering designs in those areas where flood or landslip is highlighted as an issue. A separate briefing on this subject is available with more detail[12].

Despite these issues, our teams continue to deliver on what they can, as shown by recent informal surveys of the area engineers to gauge the level of issues they have been encountering. This found that, due to the prolonged wet weather and frequent storm events over the winter, they have suffered more problems with road surfaces in general. The south-west region in particular has had to carry out a lot of work in areas such as North Crychan and Brechfa, where haulage activity has been high. Looking at drainage infrastructure, some culverts that were in poor condition have worsened, but major

[11] https://gov.wales/sites/default/files/publications/2019-06/statutory-guidance.pdf

[12] https://cyfoethnaturiolcymru.sharepoint.com/teams/manbus/ManagingRegionsAndGroups/landstew/EstateStandardsTL/Scott%20Griffiths/SuDs/Project%20Management/SuDs%20Review%20May%202020.docx?d=w602e0008b68d4586a53d2eb9afebae47

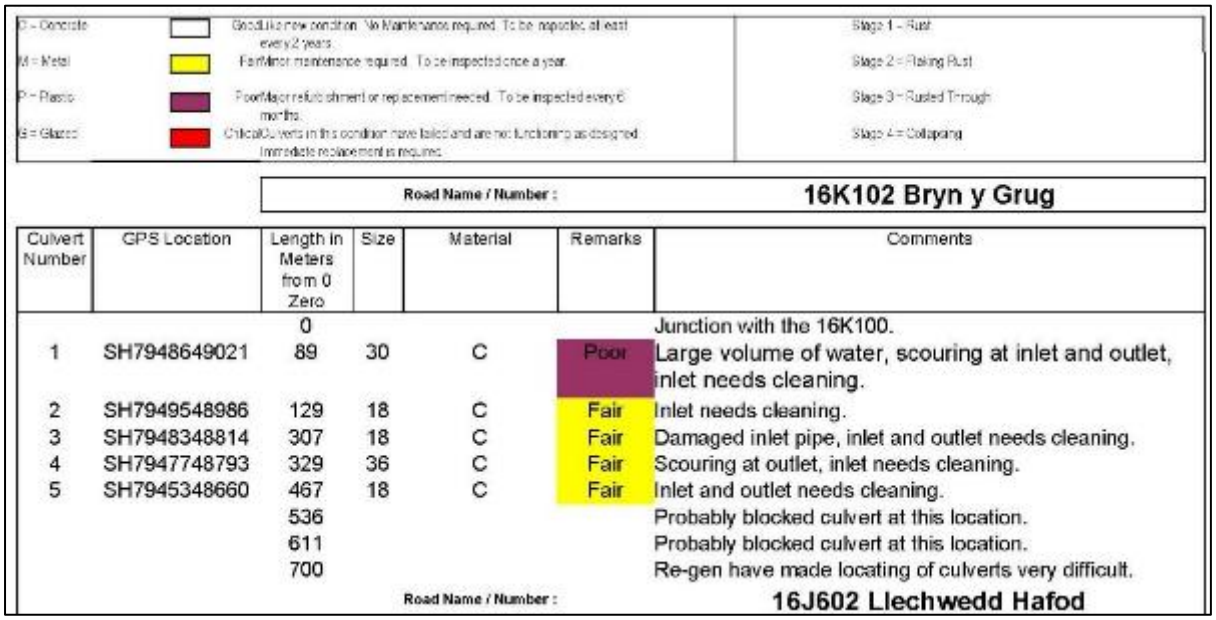
structures such as bridges have been less affected. All the major problems appear to have been identified and repaired, or an interim solution put in place. Where issues were less urgent, repairs have been identified and programmed for action as soon as is practicable. However, this reactive work has impacted on the ability to service the harvesting facility programme in some areas.

Infrastructure recording and inspection

Although parts of the organisation may have local records on some assets, in engineering terms, the only formal recording system in place is for bridges and major culverts, which is in the format of a centrally held spreadsheet. There has been a plan in place since 2015 to upgrade to a more sophisticated ICT solution for managing this information, which would include all the roads and structures that exist on the estate. This is called the Forest Assets Recording System and although work restarted on this towards the end of 2019, it is currently paused until September due to Covid-19 and ICT workload priorities. If this is restarted as planned, it will be in place in 2021. The function of this system will not just be to record those wider assets, but to allow for the building and tracking of work programmes based on maintenance schedules.

In general, there is currently no central recording of the condition of forest roads and roadside drains or any associated structures such as culverts (under 1metre in diameter), catch pits, tracks and landing bays. Some local initiatives have taken place as part of action plans relating to the Water Framework Directive. The example below at Fig 11 is from the North-West and was undertaken by local engineering staff in 2011. This is a good example of the detailed information that needs to be collected for the new system to work. However, unfortunately, in this case, the defects that were identified were not included in a programme of improvements due to a lack of available funds at the time. This has been an ongoing theme for many years, with surveys or estimates for culvert and water management requirements being undertaken and then shelved because of a lack of budget or other resource considerations. The cost of improvements is likely to run into millions of pounds over the whole estate but quantifying the problem and then prioritising some improvements based on risk is key.

Fig 11 – Extract from Gwydyr Forest Culvert Survey



C = Concrete
M = Metal
P = Plastic
G = Glazed

Good/Like new condition. No Maintenance required. To be inspected at least every 2 years.
Fair/Minor maintenance required. To be inspected once a year.
Poor/Major refurbishment or replacement needed. To be inspected every 6 months.
Critical/Culverts in this condition have failed and are not functioning as designed. Immediate replacement is required.

Stage 1 = Rust
Stage 2 = Flaking Rust
Stage 3 = Rusted Through
Stage 4 = Collapsing

Road Name / Number : **16K102 Bryn y Grug**

Culvert Number	GPS Location	Length in Meters from 0 Zero	Size	Material	Remarks	Comments
		0				Junction with the 16K100.
1	SH7948649021	89	30	C	Poor	Large volume of water, scouring at inlet and outlet, inlet needs cleaning.
2	SH7949548986	129	18	C	Fair	Inlet needs cleaning.
3	SH7948348814	307	18	C	Fair	Damaged inlet pipe, inlet and outlet needs cleaning.
4	SH7947748793	329	36	C	Fair	Scouring at outlet, inlet needs cleaning.
5	SH7945348660	467	18	C	Fair	Inlet and outlet needs cleaning.
		536				Probably blocked culvert at this location.
		611				Probably blocked culvert at this location.
		700				Re-gen have made locating of culverts very difficult.

Road Name / Number : **16J602 Llechwedd Hafod**

In the survey that has been carried out a total of 42 miles of FC roads in the Llanrwst forest district area have been completed with 451 culverts surveyed. The last time these were maintained and recorded on a regular basis was in 1997. Due to the acidity of the ground and the damage caused by the movement of stones, a corrugated steel pipe has a life expectancy of between 1 to 30 years before perforation. This corrosion allows the water to undermine the culvert, especially at the outlet, causing an unseen hazard to the stability of the road. These are the culverts most likely to cause problems in the near future. Concrete pipes set in concrete, which are among the earliert culverts built, have survived the best, but the cost of making these today is a lot higher compared with a plastic pipe. Of the 451 culverts surveyed only 1.33% were found to be in a critical condition and 11.53% in a poor condition. Most of these had not been regularly maintained over the last 15 years, but have held up well, apart from the corrugated metal which has shown a very fast state of deterioration and is the most likely to cause problems in the near future.

More resource is needed in integrated engineering to enable systematic planning of infrastructure maintenance. At present, all available resources are used for the planning and delivery of new infrastructure for specific harvesting coupes. Integrated engineering only has the resources to react to the most significant problems when informed. Defect reporting is informal and often relies on customers, contractors or even members of the public, rather than formal inspections by our staff, which can mean that problems have become more serious by the time they are reported. Ideally, a programme of planned maintenance should cover all the exit roads from a forest block at a frequency linked to the expected use and the wear characteristics of the roads themselves.

To illustrate the scale of work required we can show some of the output of our flood recovery work done in parallel with this review. As such, we have lifted this section from that report. We inspected storm damage to the high-risk assets in the three southern areas, with the summary of results as follows.

Following the identification of 173 high-risk assets on WGWE, visual inspections have been undertaken at 35 sites. The outcome from the visual inspections is that 77% or 133 assets

were found to have defects and remedial actions have been recommended. A high-level percentage breakdown of the recommended actions is as follows:

- No action required to 23% (40) of assets.
- General Maintenance works required to 51% (88) of assets.
- Civils works including investigation and modification required to 26% (45) of the assets.
- Estimated Expenditure identified: £800k of work identified, made up of:
    - £650k capital works on 10 sites
    - £150k revenue works on 23 sites.[13]

Infrastructure improvement and Water Framework Directive compliance

The work on Water Guidelines over many years and more recently on the Water Framework Directive (WFD) have highlighted that roadside drains should not discharge into natural watercourses and should be disconnected. While we were initially driven by water quality considerations, we judge that this principle will also have benefits for reducing flood risk. Along with forest drain realignment, roadside drain disconnection is the action that has the best chance of modifying water flow.

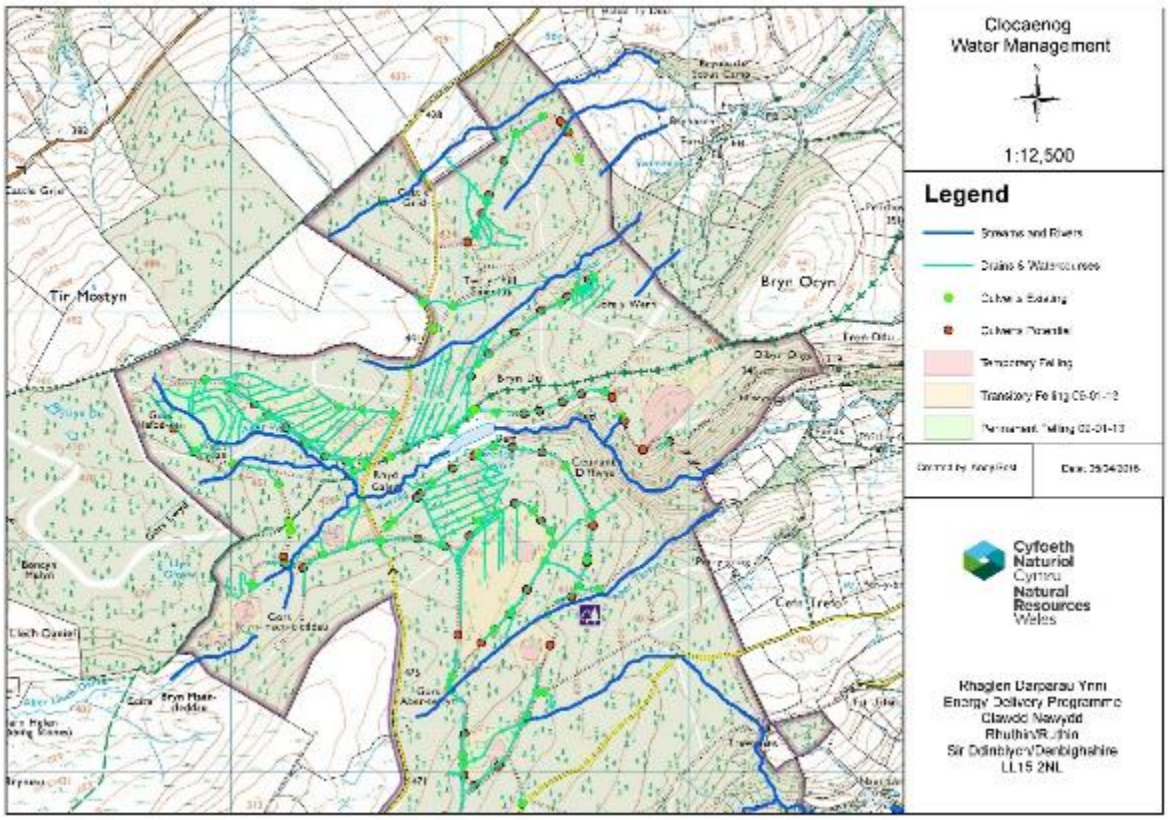
Due to their age, many of our roads, and their associated drainage and water management systems, are not compliant with WFD or our internal best practice guidelines. We have 4000km of roads of varying quality across the WGE. As a guide, if we estimated 10 culverts of varying sizes in a kilometre of road that would equate to 40,000 culverts. It is a massive task to locate them all, and an even bigger task and expense to replace, repair, upgrade, or add to this inventory. A very rough previous estimate for this was £11million, and many would argue that this was a large underestimate.

During the construction of facilities for harvesting or access road upgrades, drainage is dealt with on site and much of the improvement work is requested by forest ops staff as part of the facility build. Improvements will be made around the interface of the coupe and road, but few improvements will be made to the exit route drainage unless serious issues are identified. There is no overall planned programme for upgrading key access routes at the time when improvements relating to water management would be made. However, there may be individual examples, such as Esgair Dafydd, where an annual budget is allocated to carry out improvements for this route.

The infrastructure and asset recording discussed above are key to a move towards enhanced management of flood risk, but to achieve this we need to consider not only existing assets, but also what additional provision would be required. This would require a better understanding of the water pathways that exist. This requires another level of survey from that undertaken for the Gwydyr culvert work in Fig 11, and something along these lines was completed for the Clocaenog Forest Windfarm project in 2016 as illustrated in Fig 12.

[13] For further information see our associated flood recovery report.

Fig 12 Clocaenog Drainage Survey



The Clocaenog survey was completed using a combination of stock map assessment, past and present aerial photographs, and detailed ground inspection. It was commissioned to ensure the developers were aware of the potential for water issues and the limitations of the existing network of culverts. The map extract in figure 12 details an area in the north of the forest, and only highlights the drains and culverts in the areas affected by the proposed windfarm construction, which is now operational.

There are approximately 120 culverts mapped in this area, of which around half were pre-existing (green dots). No assessment was made of their condition or suitability, but the widening of roads would generally mean they would have to be replaced anyway. The other 60 culverts were proposals for new structures (red dots) that would be required to ensure work would be compliant with the WFD, reducing the risk of diffuse pollution during construction. The mapping of the drainage in those areas surveyed shows the scale of drainage that was undertaken when the forests were first established, and how they are still often directly connected to the watercourses. The drains are unmaintained and well vegetated, providing an element of filtering, but they still drain well during high rainfall events.

The cost of installing the 60 new culverts, and the associated work on bunds, catch pits, ponds, and drains, was estimated at over £50-£100k. This cost did not include the renewal of any existing structures, or additional work to modify and disconnect some of the forest drainage. This represents a limited survey of perhaps 200-300 hectares of a forest of 5000ha. If this was to be extrapolated across the WGWE, then the earlier estimation of £11 million for a programme of repair and improvement may be towards the lower end of the range.

There are other practical problems with undertaking such widespread improvement programmes than just obtaining the necessary funding. We need to be careful with blanket prescriptions, as culverts on steep ground can have the potential to create problems themselves if they are not carefully planned and designed. Adding more water in certain circumstances could trigger local landslips or create wet conditions that could affect forest operations.

Paths and trails

On our managed estate, we also have a network of over 900kms of waymarked paths and mountain bike trails that are managed by the local teams outside the arrangements for forest roads and facilities. Although they are smaller in scale and receive lighter traffic, these structures are still prone to many of the same issues described above; having the potential to intercept and concentrate water to create a rapid drainage channel.

They are generally subject to more inspection due to the health and safety implications for members of the public, but that does not automatically mean that specific water issues would be picked up before problems occurred. Information from local staff suggests that similar storm issues like the scouring of drains, washing out of culverts, and some misdirection of water have occurred and required repairs.

In the same way that other infrastructure may need to be reassessed in light of a new baseline for weather events, we may need to upgrade some of the features on these paths and trails too. We also have over 200kms of unofficial mountain bike trails on our land which are not surfaced or designed to allow for interception or drainage, and these are more challenging to deal with. One trail was shown through social media to have had at least 2000 users throughout the year, so they appear subject to some heavy use.

Conclusions and recommendations

There is an extensive and well-built road network that serves the multiple needs of forest management as well as public access and in some cases use by third parties. The rise in the harvesting of timber as forests have matured, and the scale of modern harvesting and haulage have put great pressure on this infrastructure. The number of built features on this network almost certainly has an impact on drainage from the forest which is significant enough to have an effect on flood risk, at least for medium scale, local flooding if not for the kind of extreme event we saw in February 2020. Climate change will almost certainly increase the pressure on this network and highlight the need for good design and maintenance.

We have a dedicated professional team that posseses the skills to effectively manage this network and carry out the additional work creating transient structures to facilitate harvesting such as tracks, ramps, and landing bays. There is a substantial cost involved in maintaining this network in good condition, but as the need for harvesting facilities is more pressing, budget cuts have tended to fall in this area. Consequently, the structure and capability of the forest engineering teams have also evolved to deliver only harvesting work and reactionary repairs. They would therefore struggle to manage maintenance in addition to this, even with increased capital available. While focusing on harvesting work and reactionary repairs is manageable in the short term, it is not sustainable on an ongoing

basis and maintenance work is now overdue. This approach makes our infrastructure less likely to contribute to reducing flood risk and more vulnerable to damage from flood events.

There is an ageing inventory of structures, including bridges and culverts, serving the road network. Aside from the larger ones, the majority of these structures are not recorded. Many of these structures are nearing the end of their service life and require repair or replacement. Similarly, when considering the latest standards of water management to many of the roads, it is also clear that many additional new structures are needed.

While the decisions that have led to this lack of maintenance and aging infrastructure may have been reasonable at the time, these issues are now adding up to an unacceptable level of risk. The increasing pressure due to machinery and the impact of climate change is likely to accelerate this deterioration and bring forward the tipping point where the rate and extent of deterioration is high enough to have widespread significant detrimental impact on our operations. The evidence that upgrading the infrastructure could help reduce flood risk makes this still more urgent.

Managing this risk is challenging, as it applies across the NRW Estate to a large number of assets. Prioritising the most pressing programmes of work will be key. Flood risk is one element of prioritisation, while health and safety is another. The two usually point to the same assets being the priority.

The following are specific actions to be considered for delivering change:

- Better targeting and enforcement of haulage restrictions on weak roads especially during adverse weather to protect our assets. Our contracts allow us to specify haulage restrictions and to enforce them, but staff need to be trained and empowered to do this. We could also consider going further in some circumstances by restricting weight or vehicle configuration, which would have the greatest impact. However, there would be cost and logistical implications with this and it would need liaison with the trade and customers.

- Carry out cost and benefit analysis of planned upgrade and maintenance as opposed to the current, largely reactionary strategy. Based on this, reinstate an element of planned maintenance linked to the level of risk and use required to fulfil their function for all forest use, including harvesting programmes.

- Programme infrastructure and facilities much further in advance to allow them to be completed in good time, and to be able to realise the efficiencies and wider environmental benefits of including other work in the area. Specifically, completing coupe planning and facilities requests two years ahead of when required would take pressure off the engineers, allowing for more effective procurement settlement of structures prior to use.

- An asset recording system completed, implemented and widened to allow for all our assets, not just bridges and culverts. Train more engineers to the required level of competence or employ contractors to keep on top of inspection regimes. Use more non-technical staff to inspect assets and report on maintenance issues. Consider loss and damage reporting of assets that would focus managers on the cost incurred by lack of investment and avoidable damage.

- Look at creating a coordinated system of defect reporting that is accessible to all forest road users, ideally linked to the asset recording system.

- Better use of WMPs, as recommended in the planning section above, with a more holistic approach at early planning stage, widening the focus from a specific coupe or operation to forest block or transport network level.
- Commission surveys for all forest blocks and their road networks to check for compliance on disconnection and target high risk areas for initial investment.
- Procure a more flexible and better functioning civil engineering framework contract to deliver the work from 2021 onwards, looking at different ways of packaging up work to make it more effective.

These can be consolidated into the following key recommendations for changing our current approach to infrastructure and civil engineering (ICE):

- ICE1: Use prioritisation based on water management and other key considerations, such as health and safety, to plan, resource and deliver a long-term (10–60 year) programme of upgrades and maintenance of forest infrastructure. This should include survey for disconnection of road networks from forest drainage.
- ICE2: Move from a 'just-in-time' approach to constructing new infrastructure for harvesting to a 'build well in advance" (two years) approach including, for example; advance commissioning of infrastructure requirements for harvesting coupes and renewing the civil engineering framework contract.
- ICE3: Develop an asset management system including an on-line database, guidance on reporting standards, and resourcing for a continual inspection regime.
- ICE4: Increase enforcement of haulage restrictions, particularly on vulnerable roads and at vulnerable times.

Forest operations

Background

In the context of this report, forest operations refer to felling, thinning, and ground preparation work to establish new tree crops. As these operations are the most visible part of what we do, any local incidents are often assumed to be directly connected to these operations despite this not necessarily being the case. In terms of reducing the risk of flooding, the planning and engineering requirements described previously have the most influence on how these operations are delivered and the outcomes. Although there are issues arising from our management of forest operations, they are more likely to relate to areas such as ground damage, diffuse pollution, fire risk, disruption to access, wildlife, and changes in the landscape rather than flooding. As a result, the following sections may repeat to some extent things already highlighted in the sections on planning.

Contingency planning is an important element of dealing with flood risk. However, it is out of scope for this review as it is covered in the other elements of our review of the February 2020 event. Partly as a result of this review, we have further strengthened incident response capabilities and capacity for incidents on the NRW Estate.

Staffing and training

There are staff issues to consider around forest operations. There is a shortage of trained and experienced professionals in the forest industry in general, and NRW has seen a reduction of these skills within its workforce through staff retiring or moving onto other employment. Not all the teams are at full strength post OD, and the balance of experience and knowledge within them is marginal in some areas and could easily be upset by further staff moves. The loss of the technical training provision previously available to all three countries has also been problematic. Although we have managed to organise training in recent years to cover our immediate needs, this has tended to cover compliance with standards rather than offering an opportunity to learn more deeply about sustainable forest management. Our Learning and Development Team is small and hasn't got the capacity to do more than help schedule training and related procurement. The work of identifying requirements and drawing up course content falls to a mixture of other staff and could be better coordinated. After a tough few years for those involved in forestry in NRW, especially in harvesting, we need to build confidence in this area and show that we value these skills within the organisation. Making the roles and structures attractive, and ensuring they are balanced properly in terms of workload, will help avoid a continued drain of skilled staff into other areas of the business or into the private sector.

Timber harvesting

Timing - Forest operations, particularly harvesting work are carried out throughout the year. This is crucial to be able to physically deliver our large programmes, and to maintain a steady supply of timber to the industry. Having to work around half our sites over the Autumn and Winter period makes it impossible to allocate all operations to the slightly drier months that they would be ideally suited to. Larch woodland presents specific problems as the branches and foliage are light and brittle and don't protect the ground from damage in the same way as spruce and other conifer species. Having a programme of felling in some areas dominated by larch due to disease compounds the issue of winter working. April to September also coincides with the breeding season for many birds which further restricts the ability to allocate work to the drier months. As a result of all these interacting factors managers often have little real choice over scheduling in all but a few key operations and prioritising sites for summer working are the exception.

Contract management -The history of custom and practice in the UK forestry industry together with ageing contract documentation and processes has resulted in difficulties in enforcing contract conditions consistently and effectively. The recent work of the Timber Governance Project has provided new contracts and guidance that now make it possible to specify, and better enforce standards on site. This still requires staff to manage the process but with many being relatively new to areas of work they are having less in the way of contract management experience. There will be room for further improvement here. We currently have an internal project ongoing to write guidance and provide detailed training for staff on contract management. This along with the new contract templates should start to address any shortcomings in this area. It is particularly key to have better management of contracts when weather events are likely to affect our operational sites and have the capability for wider impact. This requires us to have the systems in place, as well as the confidence in our ability to act.

There are two elements to this, firstly having identified the risk and having monitoring in place to alert when problems occur or give advanced warning. This monitoring already happens to an extent where local staff know of problem structures such as culverts and have an inspection system to regularly check these for blockage but needs to be extended to cover work sites and access routes in general. Our customers and contractors are also best placed to monitor what is happening on the ground in real time and need to be more engaged in preventing issues or reporting them swiftly as their contracts require them to do.

Secondly, we need to have the confidence to stop operations, which can be a difficult decision when it affects the businesses of our customers and contractors. We need to be more pro-active, suspending work before things have gone too far.

Working Methods- Most mature crops contain undisturbed original drainage beneath the canopy, that was designed 40 or more years ago and which feeds into adjacent roadside drains and watercourses, providing it has not already been disconnected. Harvesting operations can affect drains and water courses on site by crossing and disturbing them several times. Although there is no evidence of direct links between this work and increased water flow during flood events, harvesting does have the potential to create new pathways for water, channelling it into inappropriate areas.

Choosing the optimal working method will reduce the potential for problems, but we must be careful not to be overly prescriptive as this can restrict competition and compromise the safe working of the site. What we can do is specify the methods that will not be accepted if these can be identified. The difficulty is that although ruts caused by wheeled or tracked machines are an obvious and visible sign of disturbance, there are many other ways in which problems can arise. Wire rope systems can also create enough ground disturbance to result in channelling and erosion. Avoiding the construction of new tracks is often seen as a way of preventing issues arising during or after harvesting but if properly constructed facilities may have less impact on a site overall and ensure the most effective working methods are used. This may also provide an infrastructure for implementing lower impact and more diverse silvicultural systems in the future.

As manual felling work remains the greatest risk to safety in forestry operations the desire to further mechanise this work has driven the development of tethered or winch assisted machines working on steep slopes where manual felling has been necessary. On steep slopes, with dying larch as the crop, this could pose a particular risk of creating erosion if not managed carefully but this must be balanced against the serious risk to life posed by the alternative. If there is careful management of winch assisted mechanical harvesting with extracted loads limited in weight, extraction routes frequently moved and a commitment to using some small diameter timber to protect the ground there can be safety, environmental and efficiency benefits.

The important factor here is not the working method itself, but that water management and locally identified risk factors are considered fully during the planning and execution of this work. To do this, staff need to understand the drainage on site and the potential effects of operations. They also need to be prepared for this in a situation where extreme events are more frequent and unpredictable.

Ground preparation and establishment

The most important aspect of establishment work that influences water flow on a site is the ground preparation phase post harvesting. Ground preparation will take place after a coupe is felled and a WMP will have already been drawn up and implemented for the engineering or harvesting works. There may or may not be a handover after harvesting is completed, depending on the local team structure, but the WMP will be updated as required to reflect any new work identified. This may include crossing points being removed or the reinstatement of tracking, but generally, the water control measures already in place are left in situ.

In fact, a coupe may only be partly ground prepared as the introduction of elements such as broadleaved species, graded edges, open ground, and riparian areas are often part of the new coupe design. These elements can be achieved without the need for ground preparation. Existing drains can be cleaned out or altered as ground prep takes place. If it is necessary, these would be redesigned and disconnected at the required distance from any watercourses or roadside drains in line with the requirements of the WMP in place. As mounding is now the predominant ground preparation method in use on the WGWE, the resulting raised planting position largely negates the need to lower the existing water table and therefore the need for extensive draining work.

Current practice is unlikely to have had a significant effect on water flow in the forest, but it is potentially missing an opportunity to create some further benefits. This stage of intervention offers the biggest opportunity to implement natural flood management options such as woody debris dams without adversely affecting the stability of stands (Appendix 4).

Disconnecting drains and creating ponds and wet woodland areas can most easily be achieved at this stage, after clear felling. It is also the best time to ensure there is a resilient diversity of species arranged in a way that could minimise large scale disruptions from future pest and disease epidemics implemented on the ground. There may be opportunities to consider how the ground preparation operation can best manipulate brash and harvesting woody debris to minimise over land flow and encourage infiltration. Examples include creating brash rows across the slope and building dams that encourage water to spill out onto suitable areas during the build up to peak flows. If the further disconnection of drainage systems within future riparian areas or the wider site were identified at the coupe planning stage, and incorporated into WMPs, then that could be easily implemented at this stage.

There is no evidence that opportunities to carry out such proactive work are being taken, other than for specific areas such as Cwrt in North Wales where Pearl Mussel research in the adjacent Afon Eden, has identified a benefit. Replanting quickly to reinstate the benefits of woodland and vegetation cover is known to have a positive effect on normal water flows after felling. The speed at which we replant areas depends on a variety of factors and can vary from a year or two to several years. We plan to reduce the area currently held fallow to a slightly lower level, but it would be sensible to target this effort to restock quickly in areas where this would be most beneficial.

Feedback from staff involved in restocking concluded that as everyone settles into the new team structures and takes on more multi-disciplined roles, future control or implementation should become more consistent. All believed that a structured implementation from the coupe planning stage (as described above) would be the correct approach to realise these environmental benefits.

Brash management

Much of the emphasis for including brash management in this review is driven by issues around fire rather than a flood, but there are some crossovers, including a link to the incident at Pentre, which makes it worth considering.

Brash is a term traditionally used to describe the branches and other woody material, created by harvesting, that is not subsequently sold. It can consist of everything from large sections of timber to twigs and branches. Depending on the working method, some of this material may be gathered into dense concentrations for machines to travel on, or left along roadsides when whole trees are extracted before being processed, In either case, there will always be an element of this material spread across site.

Brash and wider deadwood have an important role to play in the forest and its retention on site is part of good practice particularly in creating a platform for machinery and reducing ground damage, but also as part of the wider ecosystem, nutrient re-cycling and soil acidity regimes. Our plan for management[14] is based on UK practice guide Managing Deadwood in Forests and Woodlands[15] which states “Dead and decaying trees are vital components of a properly functioning forest ecosystem and play a key role in sustaining biodiversity, soil fertility and energy flows such as hydrological processes in streams and rivers. Deadwood also plays a part in mitigating the effects of climate change by acting as a medium-term sink for carbon.” One of the other benefits of leaving brash within the coupe, but not immediately adjacent to the watercourses is the ability to intercept rainfall to partly compensate for the role that would have been played by the trees until the next rotation matures and closes canopy. However, this material can also cause problems especially when large amounts build up particularly in linear features and close to roads and paths where it can be unsightly and cause a wildfire hazard.

If considering removing brash from site then in addition to preventing the possible benefits noted above, it might create further problems. The accumulation of large amounts of brash in one place, if not dealt with, is already clear but another issue is that we currently have no reliable market for brash products. Retrospective removal of brash by machinery can cause severe ground damage as there is less support for the machinery on used or older brash. This will be compounded if brash is removed from steep sites which could be technically difficult and very expensive to achieve.

On the other hand, an operational benefit of brash removal can mean that direct planting is possible, and the cost of ground preparation is avoided. There are several research papers on the management and removal of brash including Managing Brash on Conifer Clear-fell Sites[16] and the Brash Residue Protocol.

Standard UKFS Water guidelines say: “Keep streams and buffer areas clear of brash as far as practicable”. This is ambiguous and provides a lack of clarity if distances and expectations are not explicitly stated in contracts. In sensitive areas, we need to ensure that contract prescriptions on brash are realistic and fulfilled, to avoid any such ambiguity.

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14 https://cyfoethnaturiolcymru.sharepoint.com/teams/landman/wgwe/Deadwood/Forms/NRW%20View.aspx?id=%2Fteams%2Flandman%2Fwgwe%2FDeadwood%2FDeadwood%20Guidance%2FDeadwood%20Management%20Plan%20April%202020%20v2%2E0%2Epdf&parent=%2Fteams%2Flandman%2Fwgwe%2FDeadwood%2FDeadwood%20Guidance

15 https://www.forestresearch.gov.uk/research/managing-deadwood-in-forests-and-woodlands/

16 https://www.forestresearch.gov.uk/research/managing-brash-on-conifer-clearfell-sites/

There is also a general understanding among practitioners that keeping buffer areas clear of brash is intended to minimise compounds released during brash decomposition from leaching into watercourses, rather than to mitigate the risk of brash entering water-courses during flood events. There are grey areas with what customers are responsible for, as elements like drains may already contain branches, stems and whole tree material prior to the operations.

Greater consideration of the pre-existing woody debris, water-course specific flood risk indicators, downstream targets and infrastructure could be made as part of the coupe planning, contract specification and pre-commencement process. Including flood risk indicators and brash management in relation to this in the WMPs may be beneficial.

We have good frameworks in place for ground preparation in both normal conditions and on steep ground, as well as for the chipping and mulching of timber and brash material. If the correct site brash management conditions cannot be realised as part of the felling contracts, there is no ground preparation planned or the risks are too great to wait for this phase, then we should instigate specific operations to deal with problem brash as soon as possible post-harvesting.

Communicating with the local community

We already do a lot of communication with people who live and work close to our land estate. It is a requirement of UKWAS and a key part of how we work on the sustainable management of natural resources. It is also a benefit of our regionalised, Place based model. It is not limited solely to the communication of information; we also enable deeper engagement by community groups in some areas such as the Rhondda Skyline project.[17]

We need to be realistic about how much we can do and recognise that any communications process has to be two ways and active. For example, we publish information on our FRPs online and need people to engage with this.

However, evidence suggests that in communities that are particularly vulnerable to flooding, where the WGWE is a large and visible part of the local land use, NRW and its contractors should be more active with communications around the work we are doing and why we are doing it, both before and during forest operations. For example, at Pentre, local residents had expressed concerns prior to February 2020 about timber stacks being present on site some months after harvesting. As explained above, this is normal practice, and did not contribute to the February 2020 flooding in the area.

Nevertheless, it shows we need to do more to explain and reassure people about the nature of our forest operations in such communities. We make a recommendation on this in the FRP section recommendations.

Much of our general work on this is being organised via our Customer Programme to deliver the seventh Wellbeing Objective – a “first class organisation and customer service excellence”.

[17] https://www.bbc.co.uk/news/uk-wales-53834679.

Conclusions and recommendations

The internal guidance and procedures around forestry, along with industry standards, provide detailed and wide ranging information on health and safety and environmental issues. If all these are followed, then apart from inevitable unforeseen events, operations should run smoothly.

The key to problem free operations is the pre-planning that goes into them from the strategic level downwards. If planning actions identified earlier in the report are implemented, there should be less in the way of change required at the operational stage, other than ensuring works are carried out to expected standards. Along with these changes to planning procedures, promoting greater awareness and focus on flood risk as a factor, rather than just water quality, has the potential to make a difference.

There are also human factors to consider, our staff group is relatively inexperienced and they do not always have a background in forestry. We need to find ways to allow staff to develop into professionals in their field and retain talent as well as improve our ability to recruit successfully when required. On the other hand, we believe that our integrated model is powerful. As the UK's only fully integrated state environmental body, we are well placed to take holistic solutions across a range of types of intervention.

The other human factor is communications with people who live and work close to the woods that we care for (see recommendation in the FRP section).

The following are specific actions to be considered for delivering change:

- Make staff aware of flood risk and ensure the actions set out under land use and coupe planning are incorporated into operations. Instigate a more proactive programme of disconnection of forest drains and other natural flood solutions when drawing up coupe and water management plans. Our integrated teams and working is designed to enable this.
- Additional training and awareness raising amongst staff to ensure effective contract management is in place.
- Need for assessment of high risk sites and structures during adverse weather, including more proactive involvement from our contractors and customers. This could be achieved by arranging training or toolbox talks, and through a better reporting system. Existing operations working groups to consider options, and standards team will produce instruction and guidance as necessary.
- Although the new team structures may resolve this naturally over time, we need to look at the handover from harvesting to establishment to ensure sites are left in a condition that avoids any issues occurring in the gap between felling and subsequent replanting. Existing operations working groups can consider options, and standards team will produce instruction and guidance as necessary.
- Designated person or team to:
    - Review training and education needs, develop course content, and look at coordinating provision with the other countries and the private sector in Wales.
    - Review of current skills within the forest ops and land management teams, consider succession planning, and highlight areas of concern.

- Coordinate formal forestry education and make available for all staff to give them the core skills and understanding they need to develop as professionals in this field.
- Encourage membership and interaction with bodies such as the Institute of Chartered Foresters and the Royal Forestry Society and promote the need for continuing professional development (CPD).

These can be consolidated into the following key recommendations for changing our current approach to forest operations (FO):

- FO1: Training, awareness raising and capability and capacity building on current, and to be revised, approaches to flood risk management at both planning and operational stages for all relevant staff.
- FO2: Further improve the handover from harvesting to establishment functions to minimise risks and maximise opportunities between felling and replanting.

Concluding remarks and resource needs

We have concluded that any conceivable largescale changes to the NRW Estate would be unlikely to make a significant contribution to reducing the risk of floods such as those we saw in February 2020. This will, perhaps, be disappointing to some who believe that having land with or without trees of a particular type, or changes to felling practices can in themselves solve the kinds of challenges that society faces due to the changes in rainfall caused by climate change. However, we have concluded that there are changes we could, and should, make to how we plan our forests, how we design and look after our forest infrastructure and how we undertake forest operations, which would help to reduce the risk of small to medium scale flooding at a local level.

We have found much to encourage us and many of the actions we identify are already underway, such as the existence of tools and information we need on flood risk, the programme of upgrading Forest Resource Plans and much of the work on recovery from the February 2020 floods. We have been reminded on several occasions of the strengths of our integrated model which has expertise on forestry, incident response, civil engineering, and water management all within the same organisation. While this is certainly a benefit, there is still much work to be done. The requirement to accelerate the upgrading and maintenance of forest infrastructure is probably the biggest challenge we have identified.

The main cost of implementing the changes we recommend would be in the asset inspection, maintenance and upgrade work. The cost of other recommendations is relatively minor compared to this. We already allocate considerable resources to this with a typical annual spend of about £4M. In 2020/21 we plan to spend £8.38M on this area of work:

- Civil engineering: £4.4M
- NRW Estate reservoir capital investment: £2.5M
- NRW Estate reservoir inspection and maintenance: £0.480
- Bridge replacement: £1M.

The basic further improvement that we recommend is an enhanced long-term, regular forest infrastructure inspection and maintenance regime. We estimate this will cost an additional £1.4M per year. Such a programme should stabilise our infrastructure and generate the information we need to plan a programme of investment to bring our assets into line with the recommendations we make in this report. We estimate that the total additional one-off investment required to bring all our assets into line with the recommendations would be £35.8M (Table 2).

How quickly we do this and the extent to which we prioritise particular areas of the WGWE will depend on wider choices we make related to the level of service we wish to provide and trade-offs with other important public benefits. We also need to be realistic about our capacity, and that of the sector, to increase the rate of delivery. If an additional £35.8M investment programme took 10 years to implement, along with the enhanced inspection and maintenance programme, it would represent an approximate doubling of the current typical annual expenditure on civil engineering. Ten years is probably the fastest feasible timescale to implement such a programme. On the other hand, climate change is happening and the need to implement these recommendations is becoming more urgent. Most of the NRW forest estate operates on a 60 year forest rotation. 60 years could therefore be the maximum credible timescale for the investment.

In practice, the annual size of any investment programme we bid for would depend on a combination of factors including the prioritisation of sites and suggested time for delivery. We would need to do further work to develop a fully costed programme but adopting a 10-60 year assumption gives us a rate of spend of between £3.58M and £0.597M per year. Including the enhanced inspection and maintenance programme, the total costs of implementing these recommendations, if they are agreed, would be between £4.98M and £2M per year.

Table 2. Estimated cost of implementing the recommendations on asset inspection, maintenance, and upgrade.

Area of Work	Resourcing assumptions	Additional capital investment needed	Additional revenue costs needed
Survey and recording of existing assets	Additional 4 FTE years needed	£150k	
Planning of Improvements	Additional 12 FTE years needed	£450k	
Maintenance/replacement of existing and construction of new assets.	Based on 4 new or replacement standard culverts per km of road	£12million	
Repair and Replace Existing Major Assets	100 structures @ £150k/each	£15 million	
Additional planning and supervisory resources to deliver the increased capital expenditure	Mixture of staff and contract resource equiv. to approx. 20% of additional capital expenditure	£8.2 million	
Total investment needed		£35.8M	
Planned preventative maintenance of forest road system			£1.4m/annum
Total additional annual capital investment	Assuming 10 year programme	£3.58M	
	Assuming 60 year programme	£0.597M	

NB: Estimates assume working asset recording system with field data capture capability.

Achieving this level of work will require additional resources overall for NRW and potentially, the redeployment of resources away from other, highly beneficial activities. We will need to prioritise our activity to the areas most at risk of flooding where the NRW Estate can make the greatest contribution. However, we must bear in mind that this contribution will be to help reduce the risk of small to medium scale flood events, not the kind of extremes we saw in February 2020. Given the negative impact that flooding has on society and the economy – particularly those in our most vulnerable communities – and with the increased risk of flooding due to climate change, we believe these changes are worth making.

Appendices

Appendix 1: List of main research papers and related documents read during development of the report

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Appendix 2: Land Stewardship Report Pentre Flooding February 2020

Background

At Pentre, we assessed the implications of the flooding for our forestry operations in the days after the incident. This informed our immediate recovery work, helped us communicate with the local community, and also provided some of the evidence for this review. We include the report here for this reason. We are working with Rhondda Cynon Taff Borough Council and Dwr Cymru Welsh Water to work out the causes of the flooding at Pentre to help us all understand how to protect this community. In the meantime, we fed the recommendations arising from the rapid assessment below into the overall review.

Following a site visit on the 5 March 2020 we drew up the following brief report to provide a viewpoint that was independent from the team managing the site to feed into the investigations surrounding this incident.

Planning phase

The coupe area is dominated by larch which was subject to a statutory notice to fell as a result of *P. ramorum* (PR) infection. Some other species such as Lodgepole pine are also included as part of the coupe.

The Coupe plan adequately identifies risks, as does the harvesting plan. The watercourses are noted as high risk but in my view conditions on site prior to felling would have suggested they were generally benign. Without the benefit of hindsight, that assessment would have been reasonable as there would have been no evidence from within the coupe that they had ever risen to any significant level.

There was a Water Management Plan (WMP) prepared by the harvesting team which identified measures associated with the engineering and sampling points to check water quality during active operation. However, there was no wider WMP for the site in the agreed format which is a common issue throughout forest ops.

The expectations for brash management were clear in the Coupe Management Plan (CMP) and the harvesting contract documents specify keeping brash mats, lop top and processed timber at least five metres away from watercourses. However, there is scope for some ambiguity on the ground with customers during operations and contract managers often struggle to effectively implement some of these contract conditions.

Harvesting and engineering

The engineering carried out prior to harvesting was completed to a high standard, and looks to have been well maintained since. It is still in good condition with no scouring or degrade of surface and no impact on the site.

Harvesting was carried out mainly over winter 2018/19 with some of the final tidying up taking place around July 2019, although dispatch of timber from the site continued until

quite recently. The site was visited as part of NRW's UK Woodland Assurance Scheme (UKWAS) external audit last summer and there were no issues or corrective actions flagged up from this visit, supporting the view that it was being managed to accepted standards.

The upper area closest to the forest road was worked by harvester/forwarder, leaving the majority of the site - which is inaccessible due to the steep gradient in the mid-section - to be worked by skyline. There is no evidence anywhere on the site of ground damage of any type, including scouring from the skyline runs, and certainly nothing that would modify the natural pattern of run-off from the site.

As the presence of brash is an issue that has been brought up, it is worth noting how this crop and the working method (correctly specified in our view) would influence things. This was an un-thinned 50-year-old larch crop which would contain a significant amount of dead and dying stems regardless of anything succumbing from infection from PR; some of which would already have been on the ground. Also, larch branches are very brittle and the act of felling and dragging the whole trees away would have broken off many of the branches before they got to the skyline bays for processing which is evident from the lack of large amounts of material at these points. Winching material across the narrow ravine of stream 1 would have potentially pulled more branches and dead material from the surrounding area into this location. Larch brash is light compared to other species and relatively quick to break down into the soil and disappear.

From talking to the contract manager there was an issue with getting the customer to remove brash from both the footpath area and the streams, and although they were confident that the streams themselves were eventually clear some additional work was commissioned to clear the footpath more effectively. Due to the steep sided nature of the gully in the area of Stream 1, it would have been a significant piece of work to remove all small branches and debris from this area as it would have been a labour-intensive manual operation.

Analysis of incident

Despite the final position it is worth noting that the site made it through much of a very wet autumn and winter without incident. We were informed that the Land Management team had continued to check the site and main culvert throughout this time with no problems found.

The issues appear to have been almost entirely related to stream 1 (see figs 1-5 below). Strong flow appears to arise from a point with no additional catchment pressure suggesting abnormal flow from a spring. The other, stream 2, which we have identified on the figures, has by far the largest catchment area and has not suffered any scouring even retaining small twigs and other debris still within the stream bed. Stream 1 would also appear to have the lowest normal flow of all watercourses in the area, based on the evidence of my visit.

It is possible to speculate that in the upper reaches of stream 1 below point A there may have been an initial blockage of material, causing a dam effect that, when it eventually burst, caused the more catastrophic problems at the confluence of the two streams, making it even more likely that material would be carried further down towards the culvert.

However, we can find no credible evidence of brash moving on site because of surface water flow outside of the immediate stream channel, except at confluence of the two

streams where water had spread over the small plateau area. All brash mobile in the channel has come from the vicinity of the watercourse and been directly picked up by the water flow within that channel.

We do not believe that the act of felling trees on its own would have played a part in this event, and we would suggest that the lack of scouring in the largest catchment area on site would support this. What we know about interception and the behaviour of forested catchments would also support this conclusion, as per the information provided separately by NRW's Specialist Advisor for Forests and Water.

In conclusion , we would accept that the brash left within the area of stream 1 and the lower reaches is likely to have been part of the material washed down to the area of the culvert. Although this may not have been present in significant volumes in any one place, the accumulated debris over a hundred or so metres would soon build up. There was a significant level of silt and stone that ended up in that area, and we couldn't conclude that brash was the primary factor in causing the blockage.

Recommendations and lessons learnt

Firstly, it would be useful to have an assessment of the area by a Geomorphologist, being clear about the other factors at play before looking seriously at any recommendations on changes to harvesting or general forestry practice.

While not wanting to portray brash as the primary factor there is evidence that we could have treated the brash better in this case, and that had we done so, any ambiguity over the primary cause of the blocked culvert would have been avoided.

A useful lesson learnt regardless is that our requirements for treatment of brash needs to be reviewed. In circumstances where this is deemed to be of particular importance, then it should be explicitly expressed in the contract documents and in the pre-commencement process. This is not a criticism of the way this particular operation was organised but more a reflection of a general tension that exists between the different expectations of landowner and customer. We should also be prepared to allow for and carry out separate remedial action to clear any problem areas post harvesting if that is the most effective way to proceed.

Water Management Plans also need to be drawn up in more detail as per the format provided by our in-house advisor and some further training has already taken place on this in the last year. Although not necessarily a significant factor in this case it might have provided more focus on the management of the stream areas themselves. This practice needs further embedding within Forest operations and Integrated Engineering teams.

There should not be an overreaction to the presence of brash on our sites. It forms an important part of the site ecosystem providing nutrients and, in most cases, helping with interception and reduction of surface water flow rather than causing problems.

Report produced by Team Leader Forest Standards 06th March 2020, reproduced here with minor modifications for clarity.

Fig 1 – Site Layout and location of watercourses

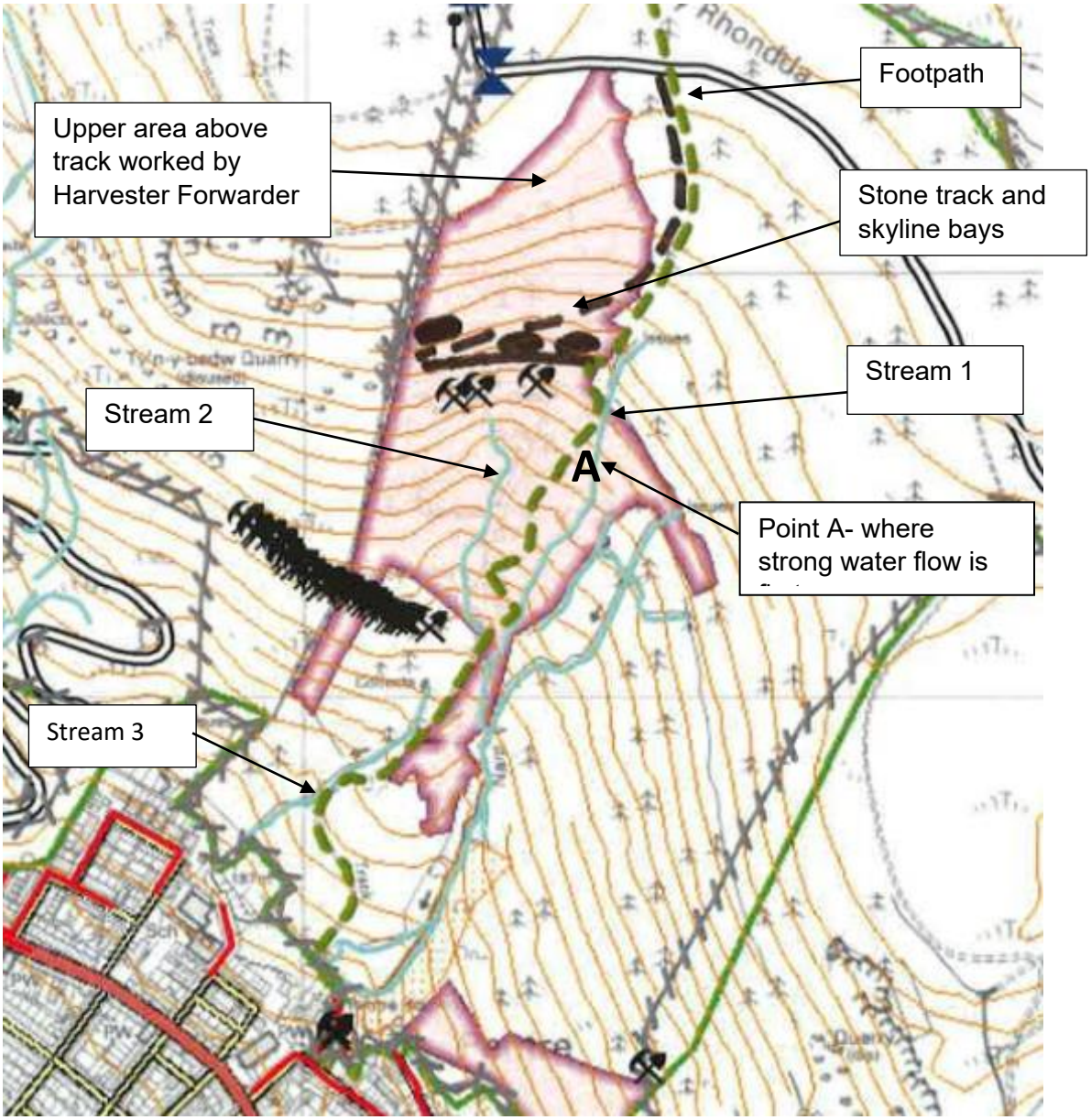


Fig 2 – Relative catchments within felled area

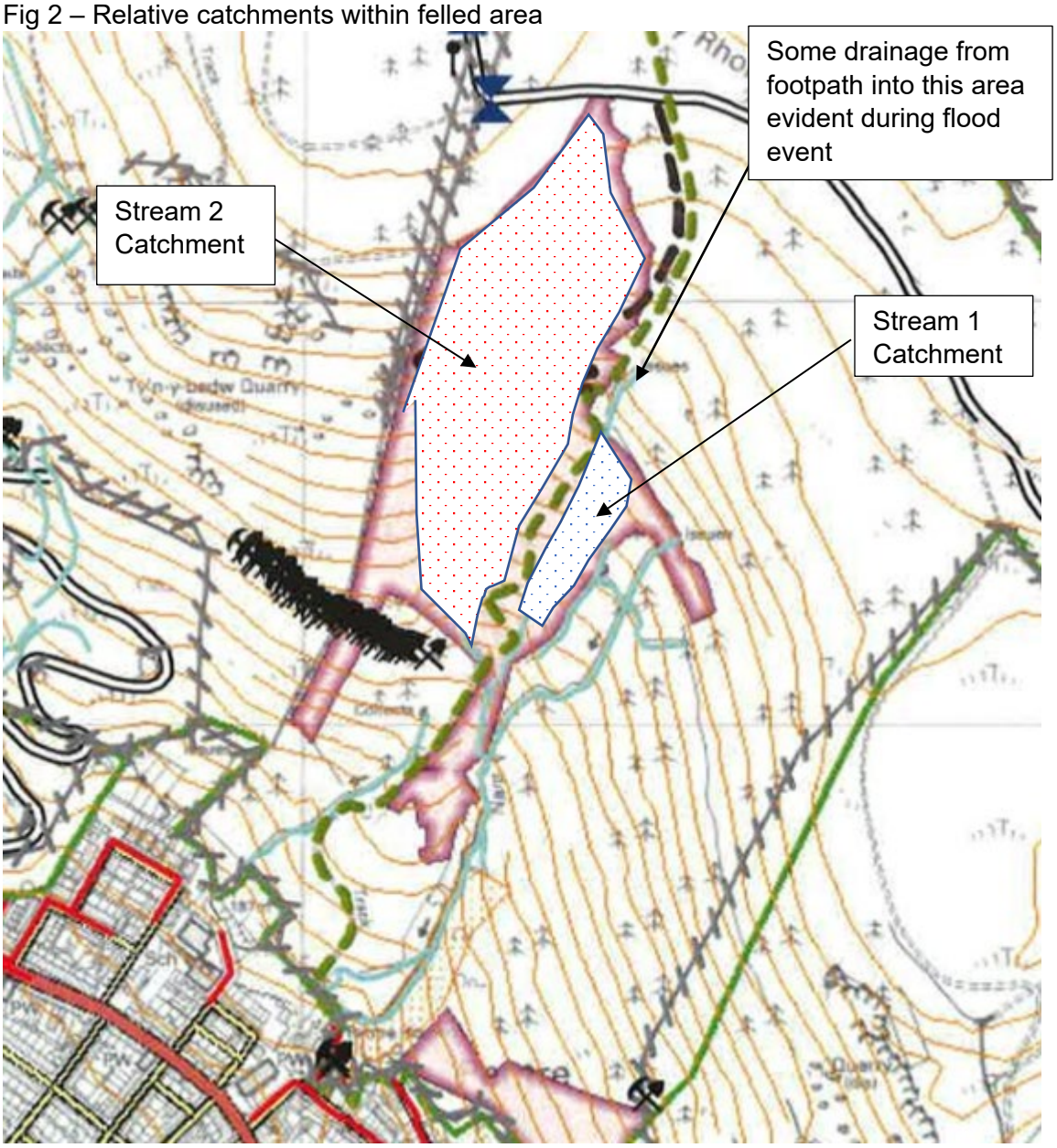


Fig 3 – View down eastern edge watercourse Stream 1

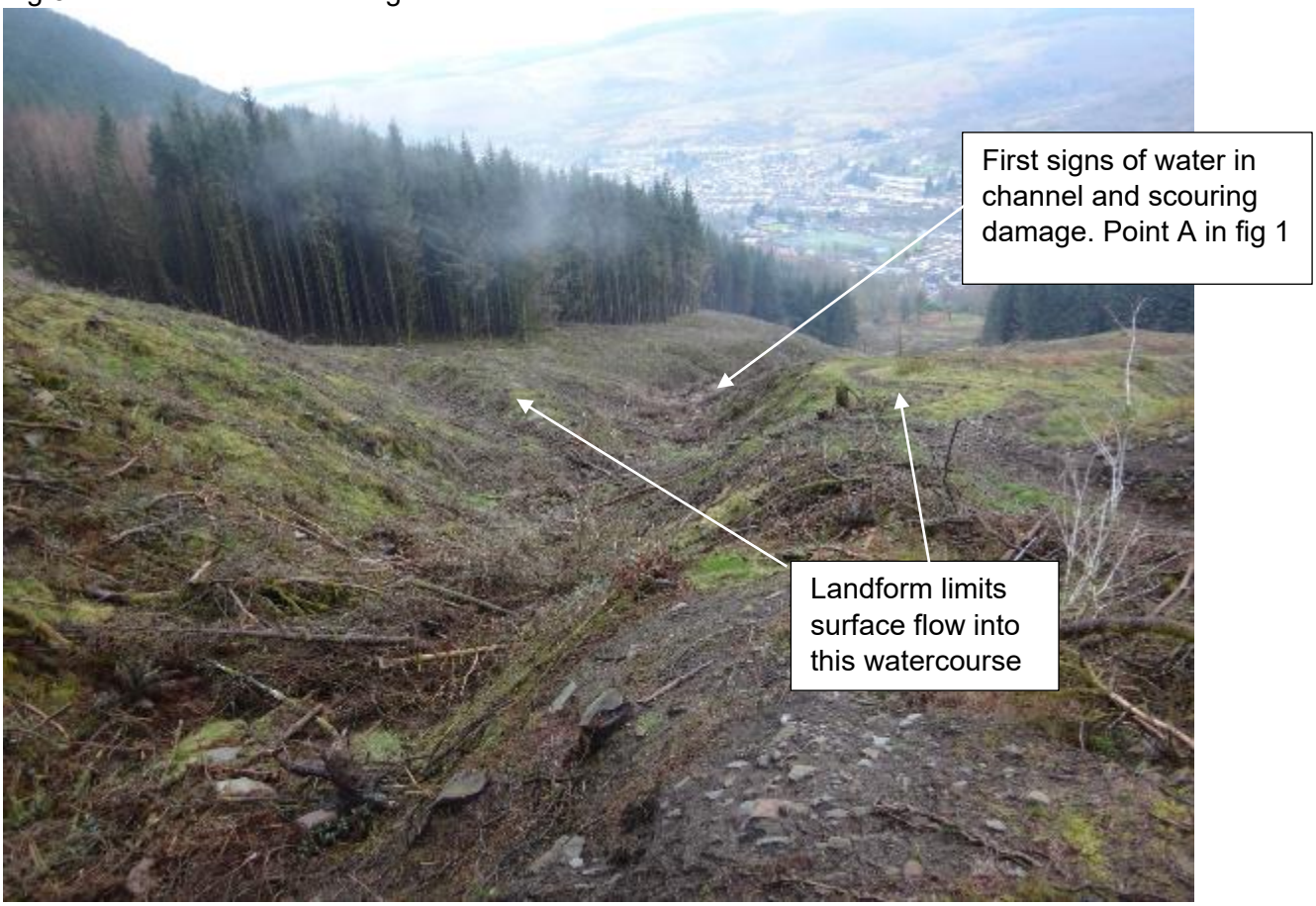
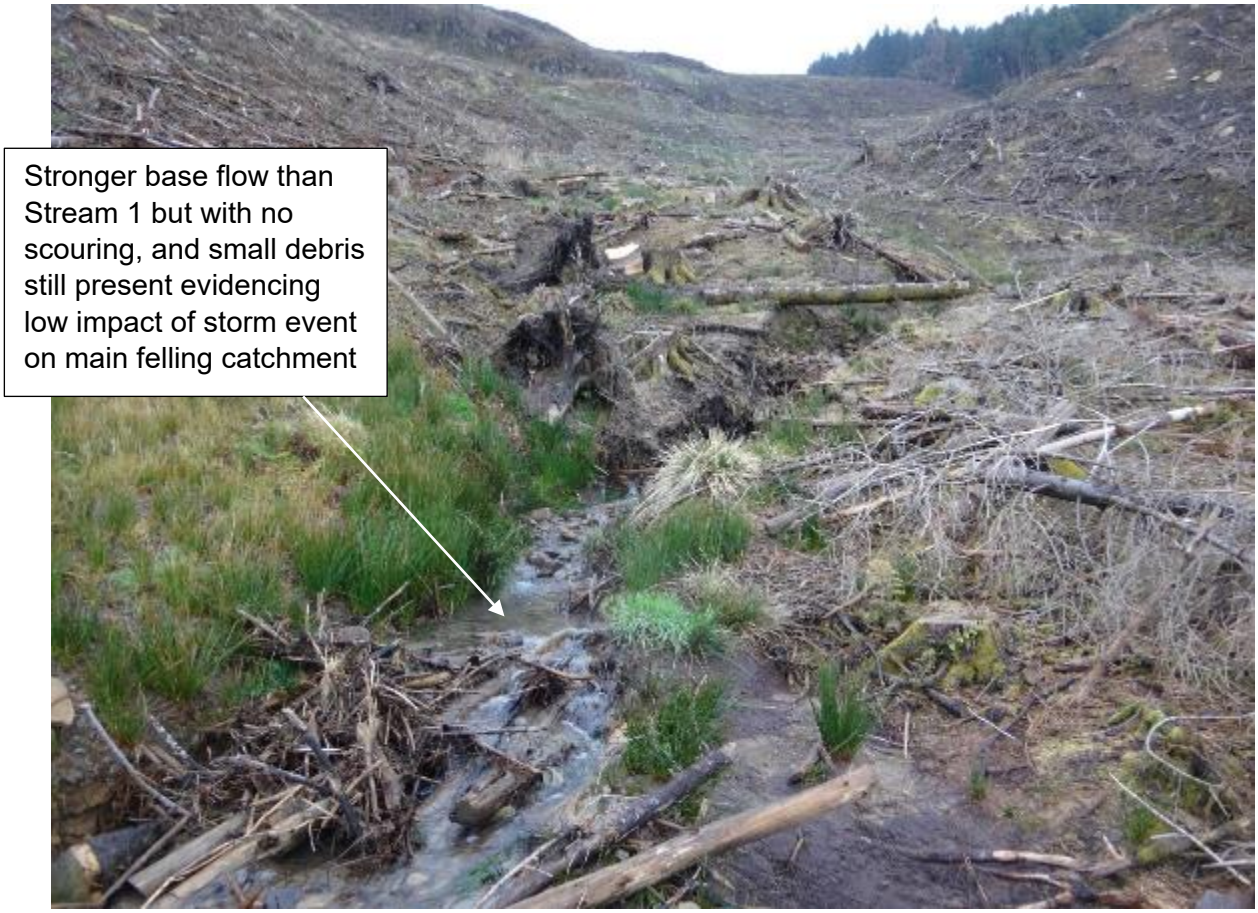


Fig 4 – View over main of the site and catchment of Stream 2

Fig 5 – View Looking back up Stream 2 and its catchment from close to confluence with Stream 1



Appendix 3: Briefing note: Restocking on the Welsh Government Land Estate

"Restocking" is replanting clear-felled woodland plantation sites after harvesting. It is an important part of sustainable forest management to maintain the potential to grow harvestable timber The Welsh Government Woodland Estate (WGWE) is certified as sustainably managed to international standards using the UK Woodland Assurance Standard.

The total area restocked in 2019/20 was 1,260 ha, which is 70% of the 1,800 ha target. The reasons for the shortfall were delays while we secured compliance by our contractors with regulations on welfare provision and latterly Covid19 impacts on plant availability.

On the WGWE we leave most sites fallow for up to four years to control a weevil that otherwise eats the young spruce trees and also to allow harvesting residues to break down, which in turn facilitates certain types of ground preparation, e.g.: scarification. In addition, many of our larch sites cleared due to *Phytophthora ramorum* infection require a fallow period to reduce the risk of susceptible replacement species such as oak becoming infected. This is good practice and there will always be a small proportion of the WGWE awaiting restocking. At Sept. 2019 this was 5,456ha, 5.3% of the productive forest area and we had aimed to reduce it to <4% by end 2022/23. Following the challenges in 2019/20 and the Covid19 incident we now believe this to be achievable in 2023/24.

In 2020/21 we have the plant supply contract and other resources in place to restock 1,586ha at a cost of £3.9M. This is achievable provided contractor resource is available following recovery from the Covid19 incident. We are assessing whether we can further increase the output to catch-up from 2019/20; 1764ha appears possible at present.

If we continue with the momentum from 2020/21 and restock 1,800ha in 2021/22 and 2022/23 the area awaiting restocking will be reduced to <4% of the total productive area in 2023/24.

The role of state forestry in the domestic timber sector is to predict and then provide a reasonably large and stable volume of timber to give confidence to invest. A small % of land awaiting restocking has little impact on future timber supply as supply smooths out over the whole WGWE and in the decades it takes for the timber crop to mature.

Further detail

Issue: It is important that we restock our clear-felled sites to maintain future timber supply and that we are seen to do this to maintain confidence in our contribution to the low carbon economy.

Further background

From 2006, restocking rates fell below that required to replace trees removed on clear-fell. While it is often good practice to delay restocking for biosecurity reasons, and while the overall impact on Welsh timber supply is small, the commercial timber sector criticised us. This led us to commit to the "land bank" (clear-felled sites not yet restocked) being <4% of the productive WGWE by 2022/23.

In 2018/19 we increased resources for restocking but drought reduced tree supply and then extreme cold cut short the planting season and we did not reach target. In 2019/20 the increased resources remained in place and we made better progress than in 2018/19 but ultimately missed the target due to issues set out above. [18]

Area awaiting restocking: the area awaiting restocking is determined by the rate of clear-felling, the rate of restocking and the impact of forest restructuring on productive area. It is thus a complex measure that only covers production on clear-fell sites. This has become known as the "land bank" but we recommend not using this term as it has become associated with failure when it is mainly about good forestry practice. We have devised a simpler and more complete way of measuring maintenance of timber supply in 2020/21 and beyond.

Securing supply of trees: restocking 1,800ha would use 3.194M small trees. We have supply secured for 2020/21 (3.915M trees). Climate heating will increase the frequency of drought but weather events of the intensity that reduce supply will remain infrequent; the 2018/19 incident was the first UK wide shortfall in supply in the past 15 years. At present, the UK nursery industry appears stretched with high demand as we all expand woodland. To help investor confidence and to secure our supply, we are tendering for supply of plants from 2022/23 to 2030/31. We plan to make this more secure with forward commitments of budget over three to five years so nurseries can plan with confidence. We will also offer the contract in more lots and with greater flexibility to enable smaller nurseries to compete, including those based in Wales.

Quality: Restocking is compliant with the UK Woodland Assurance Standard (UKWAS). To grow tall, straight trees which are easier to harvest and more likely to meet the requirements of the construction industry we aim to establish at least 2,500 evenly spaced stems per ha of commercial species. The average rate of planting is above the target while the rate of establishment at year 5 is below target – an average 2,300 trees per ha. This is tolerable, but we have various measures in place to improve it, like treatment of *Hylobius* (a weevil that attacks young plants), and the culling of deer. All trees are UK sown and grown for biosecurity reasons. We are increasing the range of species we plant to adapt to climate heating and reduce the risk caused by tree diseases. We have long played a leading role in development of forest management practices, particularly with regard to reducing pesticide use (Annex 1).

Welfare standards: The law on welfare provision has been in place for years, as set out in the Workplace (Health, Safety and Welfare) Regulations 1992 but the forest industry has generally not complied. In 2019, we further clarified expectations that all our contractors comply with the law. This was as part of our leadership on health and safety in forestry as a member of the Forest Industries Safety Accord, and alongside a Health and Safety Executive (HSE) initiative. The timing for our restocking contractors was awkward, coming at the start of the season. In addition, the investment required was challenging due to most restocking contracts being relatively low value. We were unable to change the price structure as the framework contract was already in place, with compliance with the law a known requirement. Nevertheless, contractors responded well with most of the 12 contractors on our framework able to comply albeit one of the larger contractors has

[18] Note that the Wales restocking figures reported at https://www.forestresearch.gov.uk/tools-and-resources/statistics/forestry-statistics/ tend to be slightly higher than reported in the NRW corporate performance report, this is because the Forestry Statistics figure includes a factor for open space for consistency

withdrawn from the framework. The HSE visited us on 21 – 24 January. and we appear to have shown the improvement needed.

Hot planting: Many private sector harvesting sites are planted immediately after felling ("hot planting"). This usually requires more pesticide use to control weevils and is better suited to smaller estates where influx of weevils from neighbouring sites is less likely, or to private commercial operations where accounting for income and costs in the same year is often important. On the WGWE, we use hot planting where appropriate but we usually use the fallow period to minimise pesticide use. Welsh state forestry has pioneered reduced pesticide use in the UK. Felling licence conditions for private sector clear-fell sites usually stipulate restocking in two years and we would consider extending this if requested. We receive very few requests for extensions and have no records of ever having refused an extension request.

Author: Dominic Driver, Head of Land Stewardship **Date:** 28 July 2020

Appendix 4: Considerations for natural flood management using leaky wood dams

Extract from UK Forestry Standard document on designing and managing forests to reduce flood risk.

- Check with Local Lead Flood Authority (LLFA) if downstream structures (at least within 10 km) such as bridges and culverts are at risk of blockage from woody material and if so, whether this would increase flooding to property, assets or land. Where there is a risk of increased flooding, design structures to withstand washout or avoid installing.
- Check if leaky woody dams will back-up or divert flows onto neighbouring land or affect access routes and if so, seek agreement or reject site.
- Check accessibility of leaky woody dams to public and where contact is likely, design structures to minimise risk of accidental injury and install appropriate signage.
- Select locations for building leaky woody dams that will be effective for storing flood waters and/or slowing the flow; obtain formal Consent from lead local flood authority before any works begin.
- In general, restrict structures to watercourses that are <5 m wide or to those designated ‘Ordinary’ watercourses.
- Favour locations with bankside trees or riparian woodland, which will generally help to improve the stability of structures (e.g. by bracing against or securing to trees or stumps), sustain and increase their effectiveness (e.g. by inputs of deadwood) and trap washed-out material.
- Avoid sites where flood flows are already controlled or throttled by existing culverts and bridges, especially where the structures would be ‘drowned-out’ by flood water backing-up from these.
- In general, avoid steep watercourses and those with vulnerable or sensitive banksides where scour or undercutting could threaten the stability of adjacent man-made structures or routeways.
- Select a design that is appropriate to the location and leave a gap below the structure to allow low and moderate flows to pass unhindered.
- Install structures perpendicular to the watercourse where there is a need to avoid flows being deflected into and undercutting stream banks.
- Use local trees to construct structures and favour species that are more resistant to degradation, such as oak, chestnut, beech, ash, willow and alder.
- Do not use veteran or dead trees and minimise ground damage when constructing structures.
- Construct a network of leaky woody dams to increase their contribution to reducing downstream flood risk.
- Conduct annual survey of structures, especially after any significant flood events, and repair or replace to maintain effectiveness.
- Follow published guidance on assessing the potential hazards of installing leaky woody dams within watercourses, including how to strengthen structures to reduce the risk of washout.
- Avoid watercourses with a high sediment load as the leaky dam could quickly fill or become blocked by sediment.