WWNP Measure Group	WWNP Measure Types	Project WWNP GIS Categories	WRB	Funding Scale	Potential Water Resource Benefits	Evidence	Potential Water Resource Dis-Benefits	Evidence	Multiple benefits	Areas to avoid
Upper Catchment Land and Runoff Management	**Runoff attenuation storage features on hillslopes including ponds, bunds, infiltration trenches and swales**	**WWNP RAF WWNP CS**		**Small-scale capital construction**	1. Improves water storage, promotes infiltration and groundwater recharge where sited over permeable geology	1. Larson and Safferman, 2008 1. Hankin et al., 2018 1. Zhao et al., 2016	1. Reservoir Act 1975 regulates areas of significant storage volume and this threshold may reduce in future 2. Sedimentation can develop over time and result in clogging reducing infiltration 3. Surface ponding can result in poor soil aeration and restrict infiltration	1. GOV.UK, 2010 2. Larson and Safferman, 2008 3. USDA & NRCS, ND	Slow and attenuate surface runoff for flood risk reduction and delayed recharge Capture and filter sediment loads Capture and filter diffuse pollutants Improved biodiversity and habitat creation	In close proximity to contaminated land which may mobilise pollutants In close proximity to abstractions sensitive to groundwater quality eg. SPZs Generating storage volume >10,000m3
	Peatbog restoration including grip blocking and vegetation restoration	**WWNP RAF WWNP CS**		**Land management**	1. Sustains groundwater level and raises water table 2. Kinder Plateau, Derbyshire- water tables increased by 35mm over a 3-year period 3. Water tables raised by 20mm in Lake Vrynwy catchment, Wales	1. Krause et al., 2007 2. Pilkington et al., 2015 3. Wilson et al., 2010			Slow and attenuate surface runoff for flood risk reduction and delayed recharge Capture and filter diffuse pollutants Improved biodiversity and habitat creation Carbon sequestration	Careful management around SSSIs
	Tillage/ploughing and sub-soiling management	**WWNP SPS WWNP LCM**		**Farming Management**	1. Conventional tillage can increase soil infiltration rates compared to no tillage 2. Sub-soiling can increase infiltration by 10% through enhanced porosity after 2-years 3. Slot mulch can increase infiltration and increase water storage by 41% 4. Contour ploughing can retain surface runoff for recharge	1. Lipiec et al., 2006 1. Gomez et al., 1999 2. Sojka et al., 1993 3. McConkey ND 4. Harris et al., 2004	1. Conventional tillage can reduce soil infiltration rates compared to no tillage 2. Modifies soil properties by decreasing porosity and lowering hydraulic conductivity.	1. Elliott & Efetha, 1999 2. Carter and Colwick 1971	Conservation tillage can reduce soil erosion and diffuse pollution rates	Avoid conventional tillage in areas of fragile and erodible soils, particularly on steep hillslope gradients
	Peatbog drainage			**Land management**	1. Short-term initial drainage increases near-surface water storage capacity	1. Rogger et al., 2017	1. Increased soil moisture deficit reducing groundwater recharge and oxidation of peat will lower water tables and reduce peat thickness and reduce water storage	1. Rogger et al., 2017		Careful management around SSSIs
	Land and in-field drainage features	**WWNP SPS WWNP LCM**		**Farming Management**	1. Reduces local water table improving soil storage capacity Can divert surface water to more permeable areas	1. Blanc et al., 2012	1. Can promote rapid surface runoff and exacerbate diffuse pollution	1. Blanc et al., 2012	Improved crop yield	Areas susceptible to surface water flood risk or flashy fluvial flooding
	Arable land management including cover crop, crop choice, reduced intensification, grass seeding, hedgerow planting	**WWNP SPS WWNP LCM**		**Farming Management**	1. Application of crops with reduced water demand to reduce impact on water balance and resulting recharge 2. Cover crops can reduce surface runoff and increase soil water capacity. 3. Reduced intensification of managed grassland can increase soil water capacity Crop rotation can increase soil hydraulic properties	1. Defra, 2013 1. Wheater and Evans, 2009 2. Patto et al., 1979 3. Puttock & Brazier, 2014	1. Maize fields left bare in early autumn increase hillslope and silt runoff, diverting potential recharge away from aquifers 2. Cover crop can increase soil moisture deficits in rain-scarce regions reducing recharge potential	1. Palmer & Smith, 2013 1. FWAG SouthWest, ND 2. Dabney et al., 2007	Slow and attenuate surface runoff for flood risk reduction and delayed recharge Soil retention Reduced diffuse pollution rates Enhanced soil organic matter content Improved biodiversity and habitat creation	Cover crop in rain-scarce regions which may reduce proportion of rainfall recharging into aquifers
	Reduced grazing stock density	**WWNP SPS WWNP LCM**		**Farming Management**	1. Reduced soil compaction improving soil porosity and potential recharge	1. McGinty et al., 1978 1. Marshall et al., 2014			Slow and attenuate surface runoff for flood risk reduction and delayed recharge Soil retention Reduced diffuse pollution rates Enhanced soil organic matter content Improved biodiversity and habitat creation	Areas of high agricultural land classification
	Agricultural Managed Aquifer Recharge onto permeable soil/geology	**WWNP CS**		**Major intervention**	1. Recharge of excess surface water increased groundwater recharge by between 9 and 12% and raised groundwater levels up to 7-metres (USA)	1. Kourakos et al., 2019	1. Groundwater mounding can waterlog crops and damage overlying land use e.g. crop growth Groundwater is prone to movement so pumping down water into aquifers for subsequent re-use is likely to have moved elsewhere when it is needed to be redrawn to the surface	1. Kourakos et al., 2019	Slow and attenuate surface runoff for flood risk reduction and delayed recharge	Areas of high agricultural land classification Areas of significant groundwater movement which may shift groundwater resources away from target areas

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Middle Catchment Runoff Interception and Attenuation	**Gully blocking**	**WWNP RAF WWNP CS WWNP RZ**		**Small-scale capital construction/ Land management**	1. Double as effective than revegetation for increasing water residency post rainfall 2. Reduces fluctuations in groundwater level close to surface water such as rivers	1. Wilson et al., 2010 2. Krause et al., 2007			Slow and attenuate surface runoff for flood risk reduction and delayed recharge Water quality improvements Improved biodiversity and habitat creation	Areas of high agricultural land classification
	Leaky barriers and large woody material/ engineered log-jams	**WWNP RAF WWNP CS WWNP RZ**		**Small-scale capital construction**	1. Improves floodplain reconnection and storage Increases potential for recharge on permeable soils/geology 2. Creation of scour pools can regulate low flows during dry periods 3. Increased shading may promote enhanced downwelling into groundwater	1. Nisbet et al., 2011 2. Booth et al., 1997 2. Gurnell 2013 3. Sawyer & Cardenas, 2012	1. During high magnitude events, backwater rise can reduce storage available	1. Geertsema et al., 2017	Successional growth of shorter vegetation where local trees have been felled. Sediment traps and improved downstream water quality Slow and attenuate surface runoff for flood risk reduction and delayed recharge Improved biodiversity and habitat creation to create a diverse physical habitat Enhanced carbon net store	Large rivers - aim to restrict to watercourses <2m wide Upstream of urban areas sensitive to structure blockage. To reduce mobility of the wood choose wood that is twice the length of the channel width Areas sensitive to fish migration. Follow Environment Agency (2019) guidance
	Riparian planting for friction and creation of backwater to connect storage on floodplain	**WWNP RZ WWNP FROP WWNP FZ**		**Habitat creation/ restoration**	1. Raising channel water levels to re-direct high flows onto floodplain for potential recharge on permeable geology	1. Nisbet et al., 2011	1. Certain species (eg. Willow) and high planting density may increase water demand and reduce available water resources	1. Nisbet et al., 2011	Bank stabilisation and reduced sediment loads Watercourse shading reducing fish thermal stress Improved biodiversity and habitat creation Slow and attenuate surface runoff for flood risk reduction and delayed recharge Aestheric and cultural activity benefit	Upstream of urban areas sensitive to structure blockage Careful management around SSSIs
Lower Catchment Storage and Attenuation	**Floodplain reconnection including flood meadows over permeable soil/geology and river restoration**	**WWNP RZ WWNP FROP WWNP FZ**		**Small-scale capital construction/Major intervention**	1. Increased infiltration and enhanced groundwater recharge 2. Reduced channel incision and superficial aquifer loss 3. Enhanced overland flow onto floodplain and enhanced infiltration of water into underlying chalk aquifer, raising groundwater levels local to river	1. Acreman et al., 2009 2. Hickson 2017 3. Cliverd et al., 2013			Improved biodiversity and habitat creation Slow and attenuate surface runoff for flood risk reduction and delayed recharge Low flow benefits (maintaining a flow within channel) Aestheric and cultural activity benefit	Impermeable geologies Urban areas or land of high value In close proximity to contaminated land which may mobilise pollutants In close proximity to abstractions sensitive to groundwater quality eg. SPZs
	Beaver introduction over permeable soil/geology	**WWNP FROP WWNP FZ**		**Habitat creation/ restoration**	1. Improves water storage over permeable areas and maintains baseflow	1. Puttock et al., 2017	1. May increase surface water flood risk and be complex to manage	1. Butler & Malanson, 2005	Improved biodiversity and habitat creation Slow and attenuate surface runoff for flood risk reduction and delayed recharge Capture and filter sediment loads Capture and filter diffuse pollutants Enhanced carbon net store	Upstream of urban areas sensitive to structure blockage
	Washlands, wetlands and offline storage ponds overlying permeable soil/geology	**WWNP FROP WWNP FZ**		**Small-scale capital construction/Major intervention**	1. + 2. Improved aquifer recharge 1. Retaining water at subsurface levels during low-flows	1. Brunet et al., 2003 2. Bullock and Acreman 2003	1. Water shortages downstream due to wetland evaporation and low flows 2. River-controlled groundwater levels may make storage short-lived and drain aquifers once river levels drop below groundwater table 3. The Reservoir Act 1975 and Flood and Water Management Act 2010 legislation, regulating waterbodies of 25,000m3 or greater, which may reduce to 10,000m3 volume in the future	1. Bullock and Acreman 2003 2. O'Docharteigh et al., 2019 3. GOV.UK, 2010	Recreational amenity Improved biodiversity and habitat creation Flood risk benefits Low flow benefits - although conflicting Aestheric and cultural activity benefit	Generating storage volume >10,000m3 Impermeable geologies In close proximity to contaminated land which may mobilise pollutants River-controlled groundwater levels In close proximity to abstractions sensitive to groundwater quality eg. SPZs Careful management around SSSIs and GWDTEs
	Floodplain planting for friction and surface water retention	**WWNP FROP WWNP FZ**		**Habitat creation/ restoration Land Management**	1. Increases surface water retention and ability to maintain low flows	1. Burgess-Gamble et al., 2018	1. Certain species (eg. Willow) and planting density may increase water demand and reduce available water resources	1. Nisbet et al., 2011	Slow and attenuate surface runoff for flood risk reduction and delayed recharge Bank stabilisation and reduced sediment loads Watercourse shading reducing fish thermal stress Improved biodiversity and habitat creation	Upstream of urban areas sensitive to structure blockage Downstream of urban areas sensitive to increased backwater water levels Areas with groundwater levels close to surface where aquifers may deplete Careful management around SSSIs

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Wider Catchment Planting Management	**Birch and alder shelterbelts over permeable soils**	**WWNP SPS WWNP LCM**		**Habitat creation/ restoration Land Management**	1. Increased infiltration of 60% compared with grazed pasture although under young woodland 2. Introducing shelterbelts into agricultural landscapes can provide shelter to reduce evapotranspiration over adjacent fields and improve recharge in these areas	1. Bird et al., 2003 2. Kedziora, 2015	1. Increased evapotranspiration directly over tree shelterbelts	1. Kedziora, 2015	Slow and attenuate surface runoff for flood risk reduction and delayed recharge Improved biodiversity and habitat creation Air and water quality improvements Carbon sequestration Aestheric and cultural activity benefit Natural capital	Areas with groundwater levels close to surface where aquifers may deplete Regions of rainfall scarcity where water balances are particularly sensitive
	Wider beech woodland overlying cretaceous chalk			**Habitat creation/ restoration Land Management**	1. Drainage increased by 17-25% compared with grassland although linked with underlying soil/geology	1. Calder et al., 2008	1. Reduced recharge	1. McCulloh & Robinson, 1993	Slow and attenuate surface runoff for flood risk reduction and delayed recharge Improved biodiversity and habitat creation Carbon sequestration Aestheric and cultural activity benefit Natural capital	Regions of rainfall scarcity where water balances are particularly sensitive Areas with groundwater levels close to surface where aquifers may deplete
	Wider beech woodland overlying clay			**Habitat creation/ restoration Land Management**			1. Reduced recharge by 1.4% compared to grassland	1. Harding et al., 1992 McCulloh & Robinson, 1993	Slow and attenuate surface runoff for flood risk reduction and delayed recharge Improved biodiversity and habitat creation Carbon sequestration Aestheric and cultural activity benefit Natural capital	Regions of rainfall scarcity where water balances are particularly sensitive Areas with groundwater levels close to surface where aquifers may be depleted
	Wider oak woodland overlying sandstone			**Habitat creation/ restoration Land Management**			1. 45% reduction in annual recharge 2. 1.4-3.2% reduction in groundwater recharge with 10% increase in oak woodland.	1. Zhang and Hiscock, 2010 McCulloh & Robinson, 1993 2. Green et al., 2006	Slow and attenuate surface runoff for flood risk reduction and delayed recharge Habitat creation and improved biodiversity Air and water quality improvements Carbon sequestration Aestheric and cultural activity benefit Natural capital	Regions of rainfall scarcity where water balances are particularly sensitive Areas with groundwater levels close to surface where aquifers may be deplete
	Wider conifer afforestation			**Habitat creation/ restoration Land Management**			1. 40mm decrease in water yield with 10% increase in planting 2. 7-10% reduction in water yield with 10% increase in forest cover	1. Bosch and Hewlett, 1982 2. Calder et al., 2003 McCulloh & Robinson, 1993	Slow and attenuate surface runoff for flood risk reduction and delayed recharge Improved biodiversity and habitat creation Air and water quality improvements Carbon sequestration Natural capital	Areas of grazing and fuelwood harvesting because inputs of organic material into the soil are prevented and reduces infiltration Regions of rainfall scarcity where water balances are particularly sensitive Areas with groundwater levels close to surface where aquifers may be deplete
	Wider broadleaf afforestation			**Habitat creation/ restoration Land Management**			1. 25mm decrease in water yield with 10% increase in planting	1. Bosch and Hewlett, 1982 McCulloh & Robinson, 1993	Slow and attenuate surface runoff for flood risk reduction and delayed recharge Improved biodiversity and habitat creation Air and water quality improvements Carbon sequestration Aestheric and cultural activity benefit Natural capital	Areas of grazing and fuelwood harvesting because inputs of organic material into the soil are prevented and reduces infiltration Regions of rainfall scarcity where water balances are particularly sensitive Areas with groundwater levels close to surface where aquifers may deplete

Further explanation of this table including a full list of references is available within the main project report.