Narberth Mitigation Plan

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Contents

Summary

The Narberth housing development is proposed for a minimum of 143 homes and is predicted to produce 142.0 kg of phosphorus per year. The implementation of nature-based solutions that remove phosphorus from the wider catchment area have the potential to mitigate all of the phosphorus produced by the proposed housing development. Within the water catchment area there is the most ecological opportunity for the creation of riparian and hedgerow buffers to remove phosphorus from agricultural run-off. In addition, an artificially created, engineered waste water treatment wetland positioned downstream of the treatment works could remove up to 25% of the phosphorus produced from the new housing development.

Mitigation options

Following a literature review several nature-based mitigation options for phosphorus removal have been identified that would be relevant to the Narberth water catchment area. These are field buffers, riparian buffer strips, floodplain woodlands, and waste water treatment works (WWTW) constructed wetlands. These options can be implemented over a medium (1-5 years) or long-term (> 5 years) timescale and can provide phosphorus mitigation services for the medium (5-25 years) or long-term (> 25 years) if managed appropriately. In the short term to allow housing developments to proceed a phased approach may need to be considered whereby mitigation options that directly target agricultural practices are adopted in the first instance to allow mitigation to begin in a shorter-timescale while the proposed nature-based solutions have time to establish. A more detailed comparison of the nature-based solutions is shown in Table 1.

Field buffers

An in-field buffer strip is a vegetated strip of land, located along the land contour, on upper slopes or in valley bottoms. The strips act as a natural buffer to reduce the transfer of diffuse pollutants in surface run-off from agricultural land to water. The buffer strips reduce the length of the slopes, can act as a sediment trap, and help to reduce nutrient and pesticide losses in run-off (Schoumans et al. 2014). Grass buffers between 3-20 m in width have been reported to remove 39-90 % of phosphorus from agricultural run-off in silt, clay, and loam soils (Zabronsky 2016). Similarly, a study comparing the efficiency of grass versus vegetated (scrub, hardwood trees, wild hay and flower) buffers reported buffer strips as effective mitigation solutions in retaining phosphorus with a mean loss of total phosphorus reported as 0.3 and 0.2 ha ha^{-1} yr^{-1}, respectively in grass and vegetated buffers compared to a non-buffer zone that lost 0.6 kg ha^{-1} yr^{-1} (Uusi-Kamppa et al 2000). The width of the buffer, type of vegetation planted, slope of surrounding land and substrate type are all factors that will influence the phosphorus removing capacity of buffer strips, and should be carefully considered when implementing mitigation options.

Table 1 Summary of nature-based solutions for mitigating phosphorus pollution

Solution	Development timescale	Duration timescale	Phosphorus removal efficiency	Habitat/site considerations	Associated management activities	References
Field buffers (e.g. hedgerows)	Medium	Medium	0.3 - 4.8 kg ha^{-1} yr^{-1}	Most effective when placed next to areas with high phosphorus input	Sediment and vegetation removal (Cole et al. 2022)	Abu-Zreig et al 2003; Zabronsky 2016
Riparian buffer strips	Medium	Medium	11-21 kg ha^{-1} yr^{-1}	Most effective when placed next to areas with high phosphorus input	Sediment and vegetation removal (Cole et al. 2022).	Fortier et al 2015; Zabronsky 2016; Aguiar et al. 2015
floodplain woodlands	Long	Long-term	12-73 kg ha^{-1} yr^{-1}	Most effective when placed next to areas with high phosphorus input	Sediment and vegetation removal (Cole et al. 2022)	Kronvang et al. 2007; Johnston et al. 1984; Hoffman et al. 2009.
Waste water treatment work (WWTW) constructed wetlands	Long term	Long-term	Mean: 12kg ha^{-1} yr^{-1} Range: 5-50 kg ha^{-1} yr^{-1}	Should be placed downstream as close as possible to the waste eater treatment works	Sediment and vegetation removal (Cole et al. 2022)	Land et al. 2016; Weisner et al. 2020; Mitsch et al. 2000.

For the identification of opportunity areas for field buffers this report focuses on the establishment of hedgerows as field buffers. Two existing data layers were mapped that identify (1) opportunity areas suitable for hedgerow planting and (2) opportunity areas suitable for hedgerow planting in areas prone to flooding. Both may be considered suitable for the creation of field buffers, but the species composition will vary depending on hedgerow species ecological requirements (e.g tolerance of wetter conditions).

Riparian buffer strips

Riparian buffers are areas in the transition zone between the border of cultivated fields (e.g. croplands, grazing lands) and the hydrographic network (e.g. ditches, brooks, rivers and lakes. These buffer strips 'filter' pollutants contained in surface flow originated from the fields (Schoumans et al. 2014). In a meta-analysis of 30 studies phosphorus removal efficacy of riparian buffers was reported as 55 % (confidence interval 46-61 %) (Tsai et al. 2021). Buffer width has been reported to be the most predominant determinant for phosphorus retention efficiency in clay soil riparian buffers, whereas in sandy soils slope is the leading factor (Aguiar et al 2015). The composition of vegetation may influence phosphorus retention properties; in one study buffer strips planted with tree species were more effective in retaining phosphorus than those with grass or grass plus trees (Zhang et al 2020) while another study reported that buffers planted with grass, grass mixed with tree, and tree riparian buffers were equally effective in removing phosphorus (Tsai et al 2022). In contrast other studies have reported that poplar and willow buffer strips store 3-7 × more biomass phosphorus; than nearby herbaceous buffers (Fortier et al. 2015).

Floodplain woodlands

In the past, most lowland rives were accompanied by riparian woodlands that were inundated during periods with high water levels. However, many of these woodlands have been transferred into agricultural land. Reestablishment of the riparian floodplain woodlands, by stopping their agricultural use and removing dikes has the potential to restore these wetlands (Schouman et al. 2014). Similar to riparian buffers, the role of riparian floodplain woodlands in water quality management is to increase hydraulic roughness, which slows flow velocities and allows sediment and particulate bound pollutants to fall out of suspension and enter storage on the floodplain. Studies have reported that Inundation of floodplains with river water can deposit particulate phosphorus at rates of up to 128 kg P ha^{-1} yr^{-1}, whereas plant uptake within wetland areas may temporarily immobilise up to 15 kg P ha^{-1} yr^{-1} (Luderitz et al. 2001). Further studies have reported lower but still significant values, for example a study of four woodland floodplains reported the deposition of sediment and particulate phosphorus as between 12 and 73 kg P ha^{-1} yr^{-1}, respectively (Kronvang et al. 2007). In another study the average annual phosphorus accumulations over a floodplain were reported as 26 kg P ha^{-1} yr^{-1} Johnston et al. 1984).

Waste water treatment works constructed wetlands

Constructed wetlands, while not strictly nature-based solutions are artificial wetlands installed downstream of waste water treatment plants designed with the aim to optimise the removal of nitrogen and storage and removal of phosphorus. Constructed wetlands can be made both on high-lying areas and low-lying areas (Schouman et al. 2014). This is opposed to natural wetlands, which are situated in low-lying areas. The closer they are located to waste water treatment plants the more effective they will be. In a review of a variety of constructed wetland types in different countries one study reported typical removal rates for total phosphorus of 40 % - 60 %, depending on wetland type and inflow loading (Luderitz et al. 2001). Similarly, in other studies medium removal rates of 12 kg ha^{-1} yr^{-1} were achieved, with a removal efficiency of 41-46 % (Land et al 2017). The retention of phosphorus by constructed wetlands increased with the surface-area / watershed-area ratio (Usai-Kamppa et al 2000) and macrophyte diversity and abundance (Maucieri et al 2020). Phosphate reduction potential can vary as it is dependent on factors such as wetland size, flow velocity, retention times, vegetation type, input concentrations, depth, aspect ratio and sediment removal potential (Land et al 2016).

Calculation of phosphorus removal potential

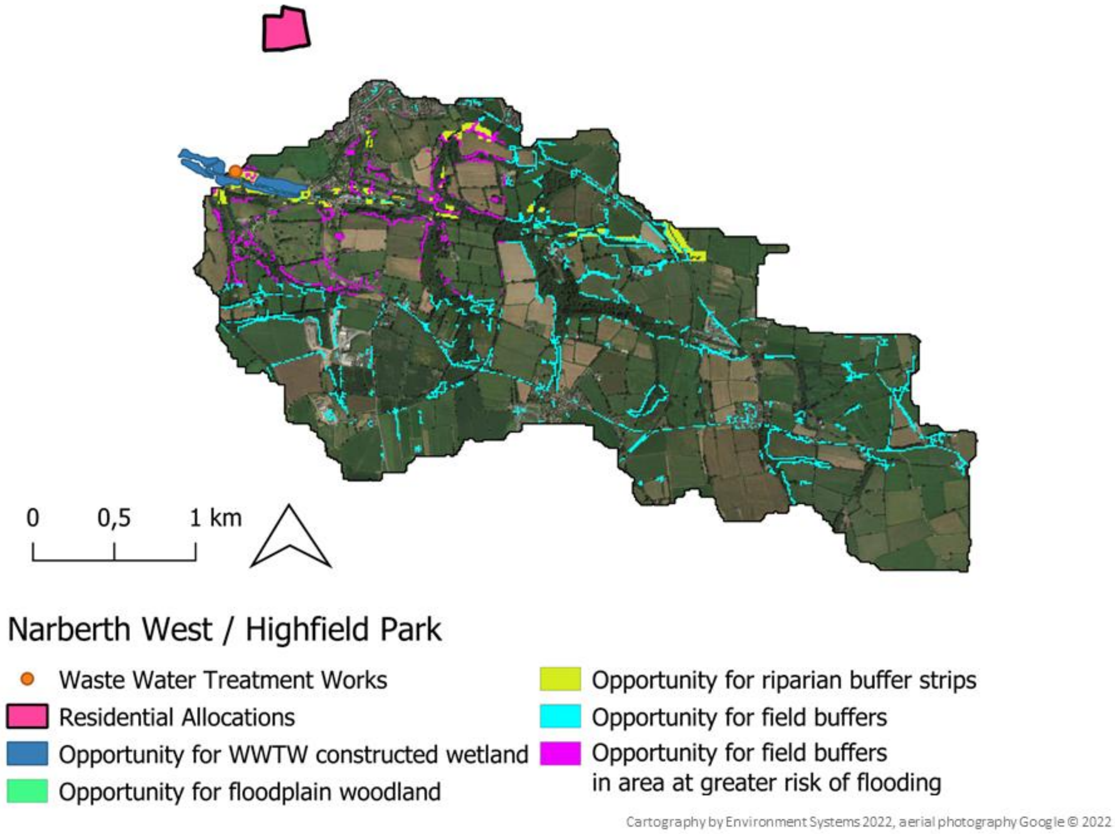
Using the total area identified for mitigation opportunity in the catchment area the phosphorus removal efficiency reported from previous literature was applied to estimate the amount of phosphorus that could potentially be removed by the proposed nature-based solutions. However, it should be noted that these previously reported phosphorus mitigation efficiency values have been sourced from a range of different field scenarios; which will be based on environments that have different climates, soil types, slopes, agricultural processes and intensity (Gruau et al 2017).

Previous scientific studies have reported phosphorus removal efficiencies of field buffers ranging from 0.3 - 4.8 kg ha^{-1} yr^{-1}, and riparian buffers values ranging from 11-21 kg ha^{-1} yr^{-1}. The range in values can be attributed to these studies focusing on buffers of different widths (ranging from 2.5 - 30 m), with different species compositions and species present (e.g. grass, herbaceous or tree) that were located on a variety of soil, slope and agricultural types. Every site will be different and the most important factors that influence phosphorus removal capacity will need to be investigated on a site-by-site basis to better inform the areas selected for mitigation solutions and to create recommendations for best practice implementation. As a precautionary principle we have applied the minimum phosphorus removal values reported in the literature per hectare of identified opportunity area for each of the proposed nature-based solutions.

Results of opportunity mapping reveal that even if all of mitigation solution are employed, there is still insufficient mitigation available within the boundary of the catchment. (Table 2, Map 1). To mitigated the proposed development, additional areas outside of the catchment will need to be found.

Table 2. Areas of opportunity (ha) within the Narberth water catchment for the creation of nature-based solutions and the estimated amount of phosphorous that will be removed from this water catchment if all opportunity areas are used. When all potential opportunity areas for each of the solutions are combined then up to 135 kg yr^{-1} of phosphorus can be removed from the water catchment, this is less than the required 142 kg yr^{-1} of phosphorus estimated to be produced annually by the proposed housing development.

	Riparian buffer strips	Floodplain woodland	Field buffers	Field buffer in areas of greater flood risk	Waste water treatment works constructed wetlands	Total
Areas of opportunity for mitigation (ha)	8.5	0.03	35.8	11.4	5.5	61.2
Estimated phosphorus removal efficiency (kg yr^{-1})	93.2	0.3	10.7	3.4	27.5	135



Map 1. Location of opportunity areas for riparian buffer strips, floodplain woodland and field buffers along with the location of a waste water treatment constructed wetland, within the Narberth water catchment.

Considerations for placement and development of solutions

The opportunity maps created for each mitigation solution highlight all ecologically-suitable areas where each nature-based solution could be implemented. However, we understand that the entire extent of these areas may not be suitable based on various site-specific factors such as landowner support and their business objectives and additional or alternative opportunities these areas might deliver for the landowner. In addition, the potential sensitivities of the sites, such as historic, cultural and biodiversity values, and also how the proposed measures fit with any local nature recovery plans/partnerships should be considered.

Before planning permission is granted for the housing developments the next phase of this work will require further identification and prioritisation of areas for the implementation of the proposed solutions. This phase will require more in-depth stakeholder consultation and site visits to allow the most acceptable and effective mitigation solutions to be designed and implemented. In addition, site-specific monitoring and management plans should be established to monitor and evaluate local phosphorus removal efficiencies that will help to inform future management and ensure that phosphorus mitigation requirements are being met into the future. The costs and timeframe for the next stage of this process should be agreed between interested stakeholders.

There are various sources available that can be used to help Inform the best-practice implementation of riparian and hedgerow buffers and riparian floodplain woodlands such as those detailed in the Glastir Management Verifiable Standards (2016). In the case of field and riparian buffers the width of the buffer and species composition should be carefully considered following site visits and consultation with local stakeholders, and would be best guided by national guidelines as mentioned above. The creation of WWTW artificial wetlands will need to be designed and implemented by specialist engineers/consultants.

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