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# Phosphate Mitigation Options – Bickton Fish Farm

## A feasibility assessment to mitigate residential development phosphate loading

Ricardo for Pennyfarthing Homes – ED15664

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# Executive summary

Following the European Court of Justice ruling known as the “Dutch N Case”, Habitat Regulations Assessments (HRA) of new residential developments now have a requirement to assess whether a development will result in increased nutrient (phosphate) loading to European designated sites, such as the Hampshire Avon Special Area of Conservation (SAC). Where a development will result in an increase in phosphate loading to the River Avon SAC, there is a need to mitigate these additional nutrients. Mitigation is required because the Avon SAC is currently failing its targets for phosphate concentrations that are required to bring the SAC up to ‘Favourable Condition Status’. Pennyfarthing Homes have various developments within the Avon SAC catchment that are in the planning phase and that will need phosphate mitigation to achieve HRA compliance.

Ricardo Energy and Environment have been supporting Pennyfarthing Homes to assess the feasibility of potential phosphate mitigation options. This report presents a feasibility assessment of the Bickton Fish Farm mitigation option. The feasibility assessment follows principles laid out in previous mitigation assessments for Herefordshire Council and is based on a set of key tests of HRA compliance.

The Bickton Fish Farm mitigation option consists of taking the fish farm out of production. Fish farms are known to be potential sources of additional phosphate to river systems as the food given to the fish and the resulting excreta can cause excess phosphate inputs to rivers that fish farms are connected to. The cessation of fish farming at Bickton may thus result in a reduction in phosphate loading to the River Avon, to which the farm is connected. The farm is located within the same reach of the River Avon SAC that the Fordingbridge wastewater treatment works (WwTW) outfall discharges into. Pennyfarthing Homes’ developments will connect to the Fordingbridge WwTW. Thus, this option would provide mitigation in the area of the Avon SAC that would be impacted by increased phosphate loading from Pennyfarthing Homes’ interests.

To assess the potential amount of mitigation the Bickton Fish Farm option may provide, open-source data from Environment Agency water quality compliance monitoring has been obtained for the inlets and outlets to the fish farm. The difference in concentration in phosphate between the inlets and outlets of the farm shows whether or not the farm is resulting in a net increase in phosphate loading to the Avon SAC. Analysis of all paired samples, i.e. samples taken on the same day, was conducted for two parts of the farm. These parts of the farm are named:

- Bickton Raceway
- Bickton Earthponds

The analysis showed that both the Bickton Raceway and Earthponds parts of the farm result in average increases in phosphate concentration between their inlets and outlets of 0.006 mg/l and 0.011 mg/l, respectively. In lieu of data on the flow rates exiting each part of the farm, data on abstraction rates to each part of the farm were used to calculate the phosphate load that is exported by the respective parts of the farm, on the basis that water abstracted to feed each part of the farm will need to be discharged. Thus, the abstraction rates provide a proxy for the required data on discharge rates. Combining the average increase in P concentrations caused by the farm with annual average abstraction rates for each part of the farm indicates that, combined, the Bickton Raceway and Earthponds parts of the farm contribute 920 kg P/year to the River Avon SAC.

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# Glossary

| Abbreviation | Definition |
|---|---|
| P | Phosphate |
| HRA | Habitats Regulations Assessment |
| EA | Environment Agency |
| NE | Natural England |
| CJEU | European Court of Justice |

# 1 Introduction

Following the 2018 ruling in the European Court of Justice (CJEU) known as the 'Dutch nitrogen case' or 'Dutch case', Natural England (NE) issued updated guidance in relation to Habitats Regulations Assessments (HRAs) of new interests that may result in increases in nutrient loading to European sites, such as the River Avon Special Area of Conservation (SAC). This guidance states that nutrient loading impact pathways would need to be screened into an HRA for new developments that could increase nutrient discharge to European sites. Where European sites are already in unfavourable condition or close to unfavourable condition due to nutrient loading, increases in nutrient loading from new residential developments that increase the number of overnight stays and thus increase wastewater production are "necessarily limited". Therefore, a new development is unlikely to be legally consented without mitigation for the increase in nutrient loading caused by the development. The River Avon SAC is currently under pressure due to phosphorous pollution from point and diffuse sources. It is in this context that there is a requirement for new residential development to mitigate the increase in phosphorous (P) loading to the River Avon SAC that will arise from increases in wastewater production.

Pennyfarthing Homes (PfH) are actively seeking mitigation options that can be used to prevent impacts on the River Avon SAC as a result of increases in P loading from their residential interests that are currently seeking planning permission. Feasible mitigation options will be used to underpin the nutrient neutrality components of the HRAs for these interests. However, whilst there are various potential options that, in theory, can provide P mitigation, site-specific environmental and operational factors may mean that certain options fail to deliver the required P mitigation at either the required scale or over the required timeframe, or both.

In order to determine a mitigation option or options that will be sufficient to mitigate the P loading that will result from PfH's upcoming development portfolio, there is a need to assess the potential feasibility of different mitigation options. This report presents a feasibility assessment of an option to purchase a fish farm and take it out of production. Fish farms can be significant sources of P pollution to rivers due to excess inputs of P from fish food and fish excreta. However, not all fish farms results in increased P loading to rivers systems and where a farm is resulting in P pollution, there is a need to quantify how much and thus the number of P 'credits' a farm could offer for use in offsetting the P loads that will come from PfH's prospective interests.

The following sections of the report present an overview of the nutrient budgets for PfH's upcoming development portfolio in Section 2. These nutrient budgets provide the basis for the amount of P mitigation that PfH need to achieve. Section 3 provides an assessment of the potential reduction in P loading that could be delivered from the Bickton Fish Farm option, including an overview how the option will remove P loading from the Avon SAC and data to support the feasibility of the option, as well as further evidence required to support the feasibility assessment.

## 1.1 Feasibility assessment principles

Assessment of mitigation feasibility will be based on the key HRA tests for mitigation schemes, as applied to the assessment of the theoretical potential of mitigation options in Herefordshire (Ricardo, 2021a). This approach was supported by Natural England, who have gone on to recommend the Herefordshire mitigation report as a reference to support mitigation planning. For a mitigation scheme to be deemed compliant with the Habitats Regulations, it will be required to pass the following tests:

1. The scale of phosphorous reductions that can be achieved by a mitigation scheme are based on *best available evidence*.

2. The available evidence for a mitigation scheme suggests the scheme will be effective *beyond reasonable scientific doubt*.

3. The estimates for phosphorous reductions suggested for the scheme are *precautionary*, in line with the Precautionary Principle.

4. The reductions in phosphorous loading can be secured *in perpetuity* which, for the purposes of a housing development, is considered to be 80-125 years.

Tests 1 and 2 will be used to guide the interrogation of the theory and available data that underpins the mitigation option. Test 3 and 4 are intended to provide scrutiny on the estimates of mitigation potential and whether it will be able to provide mitigation over the required timescales for a development to remain nutrient neutral.

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# 3 Assessment of the Bickton Fish Farm Mitigation Option

The following subsections provide an overview of each option that highlights the theoretical potential of the option to remove P from the Avon SAC. This theoretical potential was then used in the context of the baseline operation of the option to assess the potential reductions in P load in the River Avon SAC that the option can achieve. If required, recommendations for further investigations to qualify the option were provided.

## 3.1 Overview of option

Bickton fish farm is located on the River Avon approximately 1 km downstream of Fordingbridge (Figure 3-1). It is noted that the Fordingbridge WwTW outfall discharges into the same reach of the Avon as the outfalls from Bickton Fish Farm and thus removal of the P load from the farm will provide mitigation for the reaches of the Avon that will be affected by PfH's interests.

The current operation of Bickton fish farm abstracts water from the River Avon. The abstractions supply water to the ponds and lakes in which fish are reared. As detailed in the Hampshire Avon SAC Nutrient Management Plan (NMP), fish farms can be a large source of P loading to the Avon (Bryan, 2015). Increases in P loading due to fish farming are caused by decomposition of food that is not ingested by

the fish, as well as increases in P emissions caused fish excreta. Thus, water that is abstracted to Bickton fish farm may be enriched in P from fish farming activities. On discharge, this P enriched water has the potential to result in increased P loading to the River Avon SAC.

Cessation of fish farming at Bickton fish farm would remove the two key sources of P loading associated with the farm, namely decomposition of non-ingested food and fish excreta. Thus, PfH are seeking to assess the scale of P loading reductions that could be achieved by taking Bickton fish farm out of production.

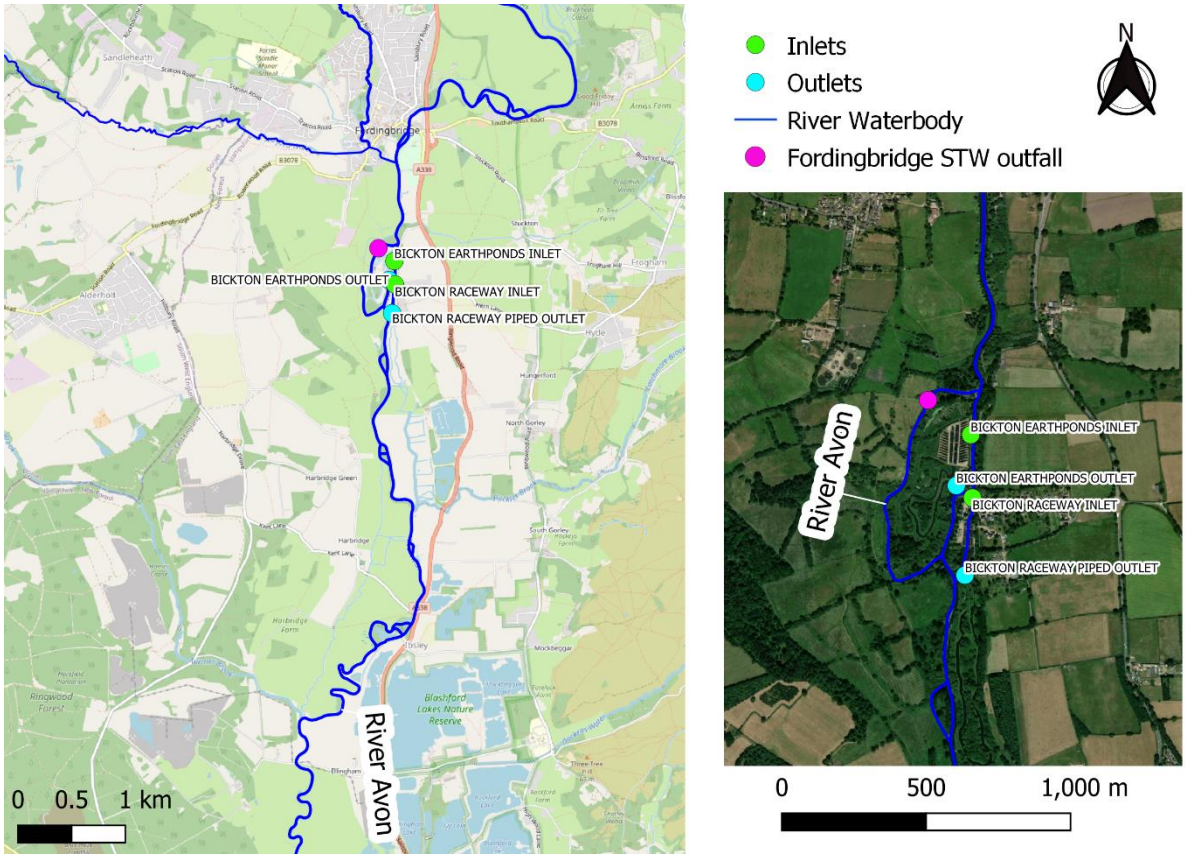


Figure 3-1: Location of the Bickton fish farm in relation to the River Avon.

It is important to note that although most fish farms will contribute a net increase in P loading to a river, there have been cases of fish farms acting as a P sink, i.e. resulting in net decrease P loading to rivers in the Avon catchment (Bryan, 2015). This occurs primarily through the sedimentation of particulate P and emphasises the need to understand the baseline operation of each fish farm in order to determine the scale of P reductions that could be achieved by taking a farm out of production.

## 3.2 Baseline operation of the option

Fish farms are, in general, required to have environmental permits on their discharges. These permits place limits on the increase in P concentration between the inlets and outlets from a farm, as well as on the max abstraction and discharge rates to and from a farm. Monitoring data are required to evidence that a fish farm is complying with their permit requirements. These monitoring data can provide a good understanding of the increases in P loading that a fish farm is causing.

In order to quantify the current P loading from a fish farm, data on the discharge flow rate from the farm and the increase in P concentration between the farm's inlet and outlet can be combined to calculate the load; P load from a fish farm being the product of the increase in P concentration in effluent from the farm and the discharge flow rate. Thus, if Bickton fish farm is causing a large increase in P concentration in between its influent and effluent flow but the discharge flow rate to the River Avon is consistently very low, then the overall P load from the farm will not be very high. Conversely, a high

outflow rate coupled with a small increase in P concentration between influent and effluent flows may still result in a notable increase in P loading to the River Avon.

Data on the differences in P concentration between inlets and outlets at Bickton fish farm have been obtained from the Environment Agency's (EA) open-source WIMS water quality monitoring dataset. These monitoring datasets are used to show compliance with P permits placed on the farm by the EA. Bickton fish farm has two operational areas that are used for rearing fish, and that subsequently have discharge permits and associated monitoring datasets. These areas are referred to with the following names in the EA P monitoring datasets:

- Bickton Raceway
- Bickton Earthponds

Analysis of the potential P load that each part of the farm is generating is provided in the subsection below.

### 3.2.1 Bickton Raceway baseline phosphate loading

Data are available for the Bickton Fisheries Raceway inlet and outlet phosphate concentrations between 2012-2021 (Figure 3-2). Data for 2020 and 2021 are lacking, likely due to both the fish farm and the EA reducing operations during the Covid-19 pandemic. As such, data from 2020 and 2021 were excluded from further analysis as they are not representative of the standard operations at the farm. The P concentration series in Figure 3-2 indicates that the inlet concentration is the main driver of the outlet concentration, as the majority of spikes in the outlet concentration coincide with spikes in the inlet concentration. However, it was also observed that the concentration of P in the outlet generally elevated above the inlet concentration (Figure 3-2). This observation is supported by Figure 3-3, showing a scatter plot of the Bickton Raceway inlet and outlet P concentrations, with a 1-in-1 reference line. Most of the data points in Figure 3-3 plot above the 1-in-1 line, indicating that the phosphate concentration in the outlet is higher than the phosphate concentration in the inlet.

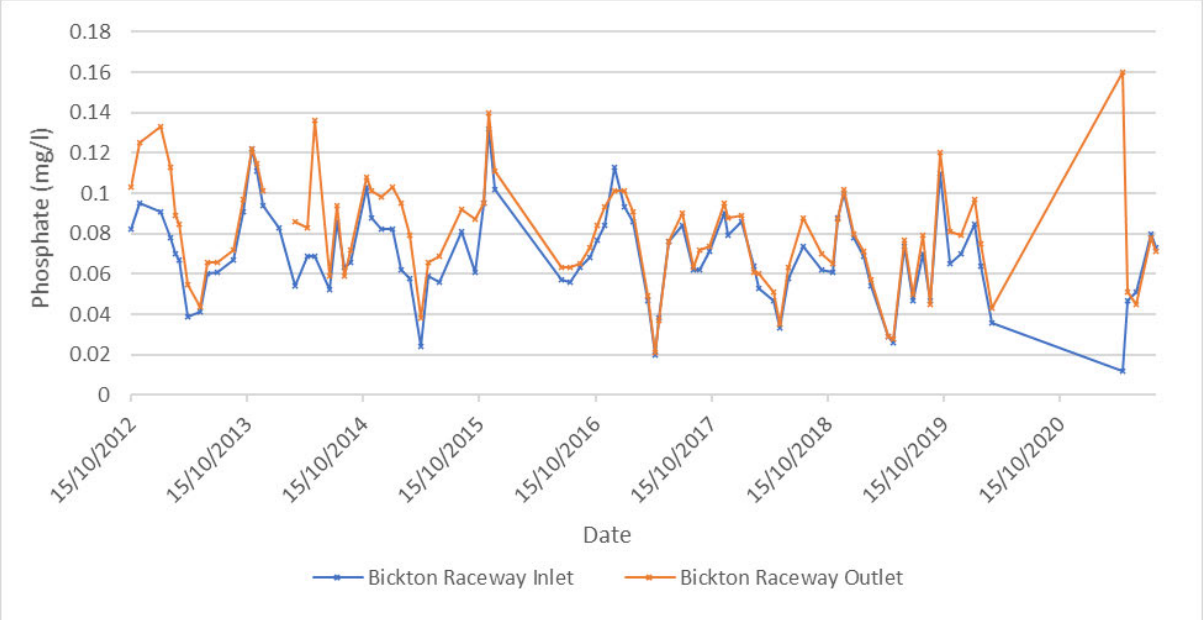


Figure 3-2 Bickton Fisheries Raceway inlet and outlet phosphate concentration timeseries.

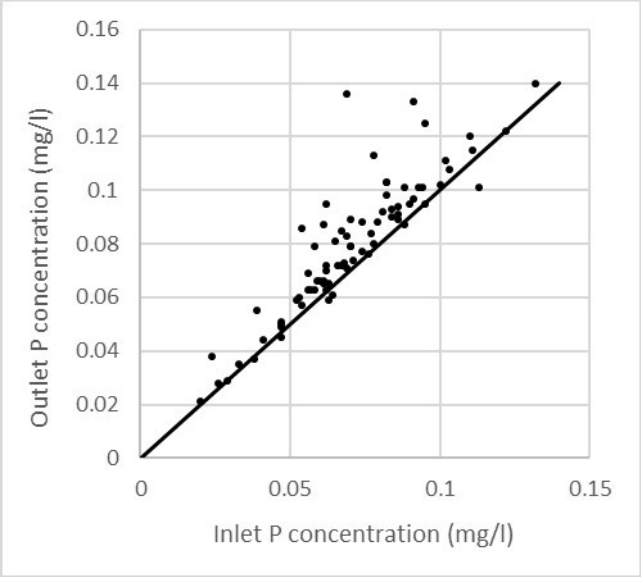


Figure 3-3 Bickton Raceway inlet phosphate concentration vs outlet phosphate concentrations shown with a 1-in-1 reference line. Points plotting above the line show outlet concentrations > inlet concentrations and vice versa.

To quantify the increase in P concentration between the Bickton Fisheries Raceway inlet and outlet flows, all inlet and outlet P samples taken on the same day were paired and the difference between the inlet and outlet concentrations was calculated. Summary statistics for these differences are provided in Table 3-1. As can be seen from the minimum and maximum differences, and the standard deviation, there is a large range in concentration differences seen between the inlet and outlet from this part of the farm. As such, the median concentration difference is deemed as a suitable average to describe the increase in P concentration caused by rearing fish in this area of the farm and shows that the Bickton Fisheries Raceway area of the farm results in an average increase in P concentration of 0.006 mg/l between its inlet and outlet.

The average increase in P concentration between the inlet and outlet of the Bickton Fisheries Raceway area of the fish farm can be combined with the likely annual discharge rate. Assuming that all abstracted water is discharged, this will provide an estimate for the potential annual increase in P loading that this area of the farm will contribute to the River Avon. Abstraction data provided by the EA provides a constant average daily abstraction of 118,866.5 $m^3$/day for the period on record between 2017-2019, with a lack of reliable records preceding 2017. The Bickton Fish Farm operators informed this study that they are currently abstracting at a rate of 1372 l/s (118,540.8 $m^3$/day), which is very close to the daily abstraction rate shown by the measured data between 2017-2019. This indicates that the current 1372 l/s abstraction rate suggested by the farm operators is accurate. Discharge from the farm is not monitored, however due to the geology of the site, it is highly unlikely that there are significant losses of water to an alluvial aquifer. Superficial geology shows the fish farm to be located upon alluvium consisting of clay, silt, sand and gravel that is unlikely to provide significant connectivity to an alluvial aquifer. Evaporation losses are assumed to be cancelled out by rainfall in winter months. It is therefore assumed that all abstracted water is discharged, as otherwise the site would flood. This in turn suggests that the available abstraction data is a good proxy for discharge.

Based on the constant abstraction rate of 1372 l/s and the median increase in P concentration between the inlet and outlet of 0.006, **an annual average P load from this part of the farm is estimated at 260.5 kg P/year.**

The calculations to derive this annual average P load are shown below:

1. 1372 l/s * 86400 seconds = 118,540,800 l/day
2. (118,540,800 l/day * 0.006 mg P/l) / 1,000,000 = 0.713 kg P/day
3. 0.713 kg P/day * 365.25 days = 260.5 kg P/year

Table 3-1 Summary statistics for the increase in P concentration between the Bickton Fish Farm Raceway inlet and outlet.

| Statistic | Increase in P concentration between inlet and outlet (mg/l) |
|---|---|
| Minimum | -0.012 |
| 1st Quartile | 0.003 |
| Median | 0.006 |
| Mean | 0.009 |
| 3rd Quartile | 0.013 |
| Maximum | 0.067 |
| Standard Deviation | 0.012 |
| Number of paired samples | 78 |

### 3.2.2 Bickton Earthponds baseline phosphate loading

Data are available for the Bickton Fish Farm Earthponds inlet and outlet phosphate concentrations between 2012-2021 (Figure 3-4). The same issues with sparse data for 2020 and 2021 have been observed and thus these data were excluded from further analysis as they are not representative of the standard operations at the farm. As with the Bickton Raceway area of the farm, the P concentration series in Figure 4-4 indicates that the inlet concentration is main driver of the outlet concentration in the Bickton Earthponds. However, it was again noted that the concentration of P in the outlet is generally elevated above the inlet concentration for the Bickton Earthponds data series (Figure 3-4). This observation is supported by the Bickton Earthponds scatter plot of inlet vs outlet P concentrations (Figure 3-5). All of the data points in Figure 3-5 plot above the 1-in-1 line, indicating that the phosphate concentration in the outlet is higher than the phosphate concentration in the inlet.

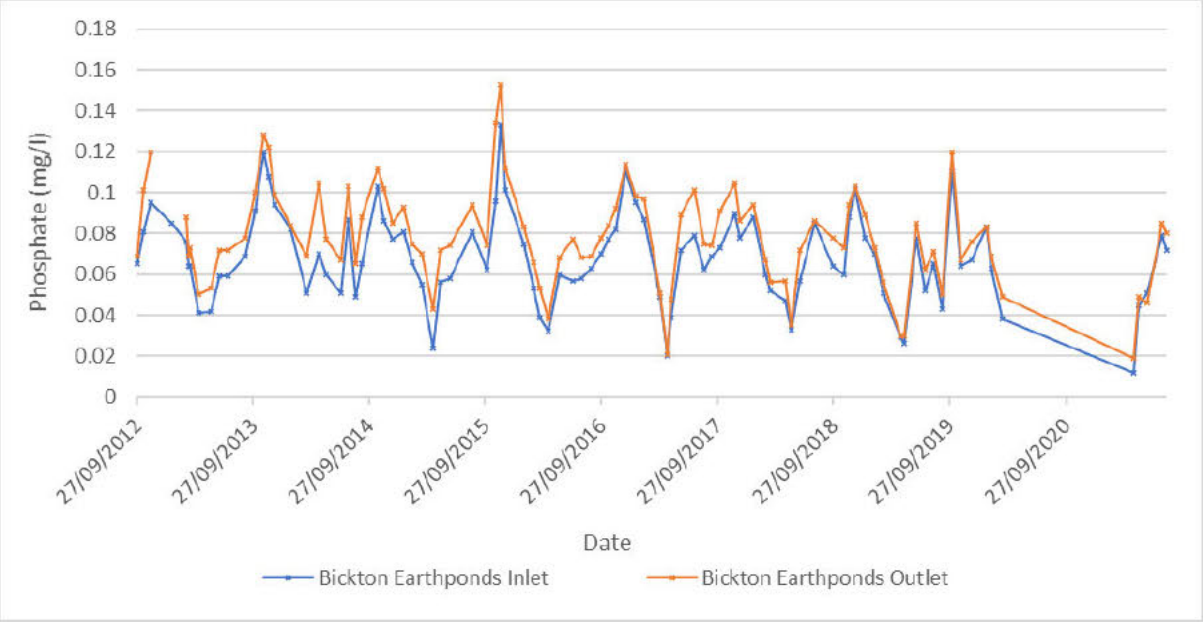


Figure 3-4 Bickton Earthponds inlet and outlet phosphate concentration timeseries.

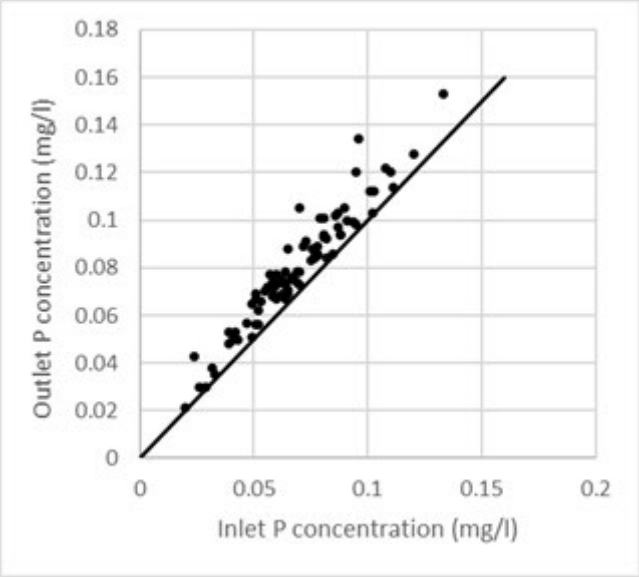


Figure 3-5 Bickton Earhtponds inlet phosphate concentration vs outlet phosphate concentrations shown with a 1-in-1 reference line. Points plotting above the line show outlet concentrations > inlet concentrations and vice versa.

To quantify the increase in P concentration between the Bickton Earthponds inlet and outlet flows, all inlet and outlet P samples taken on the same day were paired and the difference between the inlet and outlet concentrations was calculated. Summary statistics for these differences are provided in Table 3-2. As can be seen from the minimum and maximum differences, there is a relatively large range in concentration differences seen between the inlet and outlet from this part of the farm. The range in this instance is not as great as it was for the Raceway section of the Fish Farm (Table 3-1), however it is still significant. Given that the standard deviation is lower than the mean and that the 1st and 3rd quartiles suggest a lack of significant skewness in the data, the mean concentration difference is a suitable average to describe the increase in P concentration caused by rearing fish in this area of the farm. This shows that the Bickton Fish Farm Raceway area of the farm results in an average increase in P concentration of 0.011 mg/l between its inlet and outlet.

The average increase in P concentration between the inlet and outlet of the Bickton Fish Farm Earthponds area of the fish farm can be combined with the likely annual discharge rate to estimate the potential increase in P loading that this area of the farm will contribute to the River Avon. Daily abstraction rates were provided by Bickton Fish Farm for the period between April 2020 – March 2021, providing a calculated average daily abstraction of 165.9 Ml. These data were supported by data provided by the EA on abstraction volumes that are provided by the fish farm operators to show abstraction licence compliance. Reliable abstraction data in the EA records is available from April 2017 to March 2018 and shows that during this period, abstractions to the Earthponds area of the farm were consistent at 165.6 Mld, which suggests that abstractions rates to this part of the farm have been constant over time.

Based on the 165.9 Mld daily abstraction rate as per the most recent available data the Earthponds part of the farm and applying the same assumption that all abstracted water is discharged back to the Avon (see Section 3.2.1), **an annual average P load from this part of the farm is estimated at 659.5 kg P/year.**

The calculations to derive this annual average P load are shown below:

1. 165.9 Mld = 165937472.9 l/day
2. (165937472.9 l/day * 0.011 mg P/l) / 1,000,000 = 1.806 kg P/day
3. 1.806 kg P/day * 365.25 days = 659.5 kg P/year

Table 3-2 Summary statistics for the increase in P concentration between the Bickton Fish Farm Earthponds inlet and outlet.

| Statistic | Increase in P concentration between inlet and outlet (mg/l) |
|---|---|
| Minimum | 0.001 |
| 1st Quartile | 0.006 |
| Median | 0.011 |
| Mean | 0.011 |
| 3rd Quartile | 0.015 |
| Maximum | 0.038 |
| Standard Deviation | 0.001 |
| Number of paired samples | 84 |

# 4 Conclusion

This report presents a feasibility assessment of the Bickton Fish Farm P mitigation option. Bickton Fish Farm is located just downstream of Fordingbridge and abstracts water from and discharge water to the River Avon. This mitigation option consists of the purchase of the farm by PfH and the subsequent cessation of fish farming at the site. Fish farming can be a significant source of P pollution to river systems and thus by halting fish production at Bickton, a substantial source of P pollution could be removed from the River Avon, providing a mitigation opportunity.

In order to determine whether the Bickton fish farm has the potential to provide a P mitigation for the Hampshire Avon SAC, a set of tests designed to determine likely HRA compliance were applied to this mitigation option. The outcome of each of these tests is detailed below.

*Will the option provide P mitigation beyond reasonable scientific doubt?*

The theoretical P mitigation benefit that can be achieved by the cessation of fish farming is sufficient to show that, if a farm can be shown to be a source of P pollution to a river, removal of the farm would deliver P mitigation *beyond reasonable scientific doubt.*

*Is the assessment of potential P mitigation benefit from the options based on best available evidence?*

Data on the impact of the farm on P concentrations between the inlet flows to the farm and the outlet flows from the farm to the River Avon SAC have been provided by open-source EA data that is collected to show compliance with the farm's water quality permit. This dataset has been collected since 2012 and provides 78 and 84 observations of the difference in concentration of P between the inlets and outlets of the Raceway and Earthponds parts of the farm, respectively. Data on abstraction rates, used as a proxy for discharge from the farm, were provided by the EA and the farm operators. Combining the data on concentration differences caused by the farm with the likely discharge rate from the farm, it has been estimated that the farm adds 920 kg P/year to the River Avon. The datasets used to arrive at this estimate are the *best available evidence* to underpin this assessment.

*Has any estimate of P mitigation from the option been made using the precautionary principle?*

The analysis of data has also been done in accordance with the *precautionary principle.* A lower, median average concentration difference was selected for the Bickton Raceway part of the farm to avoid using a mean that is likely skewed upwards by outlying high values in the dataset that the average was taken from. It is also noted that the P data used to derive the loading estimates for the farm are measurements of orthophosphate, which does not capture dissolved organic and particulate phosphate fractions. As such, the total phosphorous output from the farm is likely to be higher than the 920 kg P/year estimated here.

*Can the P mitigation option be delivered in perpetuity?*

It is recognised that there is a requirement for a robust management plan that will ensure that the current site of the farm does not have any additional P inputs once it is no longer in use for fish production. This management plan should be used to provide the confidence that the mitigation option will deliver P mitigation *in perpetuity*.

# 5 References

Bryan, G. (2015). *Annex 4: Phosphorus in the Hampshire Avon Special Area of Conservation Technical Report.* Exeter: Envrionment Agency.

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Ricardo. (2021b). *Herefordshire Council Interim Phosphate Delivery Plan: Stage 1 - Guidance for calculating phosphate budgets for new developments draining to the River Wye SAC.*

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