Appendix E3

Maelor Poultry Wrexham - Effluent Permit Modelling

Report Reference: UC11198 v1.1
October 2015

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Contents

List of Tables

List of Figures

Summary

A permit modelling assessment has been carried out for a proposed discharge by Maelor Poultry Ltd to the River Dee in Wrexham. The assessment used the EA's River Quality Planning (RQP) Monte Carlo tool to model the effect of the discharge on the downstream river quality, specifically for determinands: BOD, ammonia, total phosphate, total suspended solids and pH. A mass balance spreadsheet tool was used to model the resultant river temperature downstream of the discharge.

The river quality modelling using RQP showed that the predicted impact of the discharge on downstream river quality is small, with most quality determinands showing no change. Any predicted change in quality was small, especially in the context of uncertainty in the upstream data.

This was reflected in the monthly temperature modelling, which showed no increase in temperature except at the second decimal place under Q95 (low) flow conditions in the river, and at the third decimal place with average conditions in the river.

The results were based on proposed discharge flows of an average 1,200 m^3/d and a maximum 1,500 m^3/d, with quality based on the discharge concentrations previously permitted at the site when managed by First Milk Ltd. The results showed negligible impact at this loading (flow and concentration) from the discharge.

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1. Introduction

1.1 Background

Maelor Poultry, a subsidiary of Salisbury Poultry Ltd, is to open a new processing plant on the former First Milk creamery site in Wrexham.

WRc was commissioned to undertake a permit modelling assessment for the proposed discharge from the Maelor Poultry plant into the River Dee.

The approximate location of the site is shown in Figure 1.1.

1.2 Determinands

The assessment was required for the following determinands:

- BOD
- Total suspended solids
- Ammonia
- Phosphate
- Iron
- Aluminium
- Temperature
- pH

1.3 Modelling tool

The Environment Agency's (EA) River Quality Planning Monte Carlo modelling tool is the most appropriate way of completing the impact assessment for all determinands except for temperature. The tool can be used in two ways: firstly to predict the impact of point source discharges on receiving waters, and secondly to help derive permit conditions that ensure river water quality standards are met downstream of the discharge.

Temperature was modelled with a spreadsheet tool developed by WRc, rather than the River Quality Planning tool, as assessment of the impact of a discharge on temperature is required on a month-by-month basis and it is not possible to do this in RQP. A monthly assessment is required because the effluent is to be discharged above ambient river temperatures, which will vary throughout the year.

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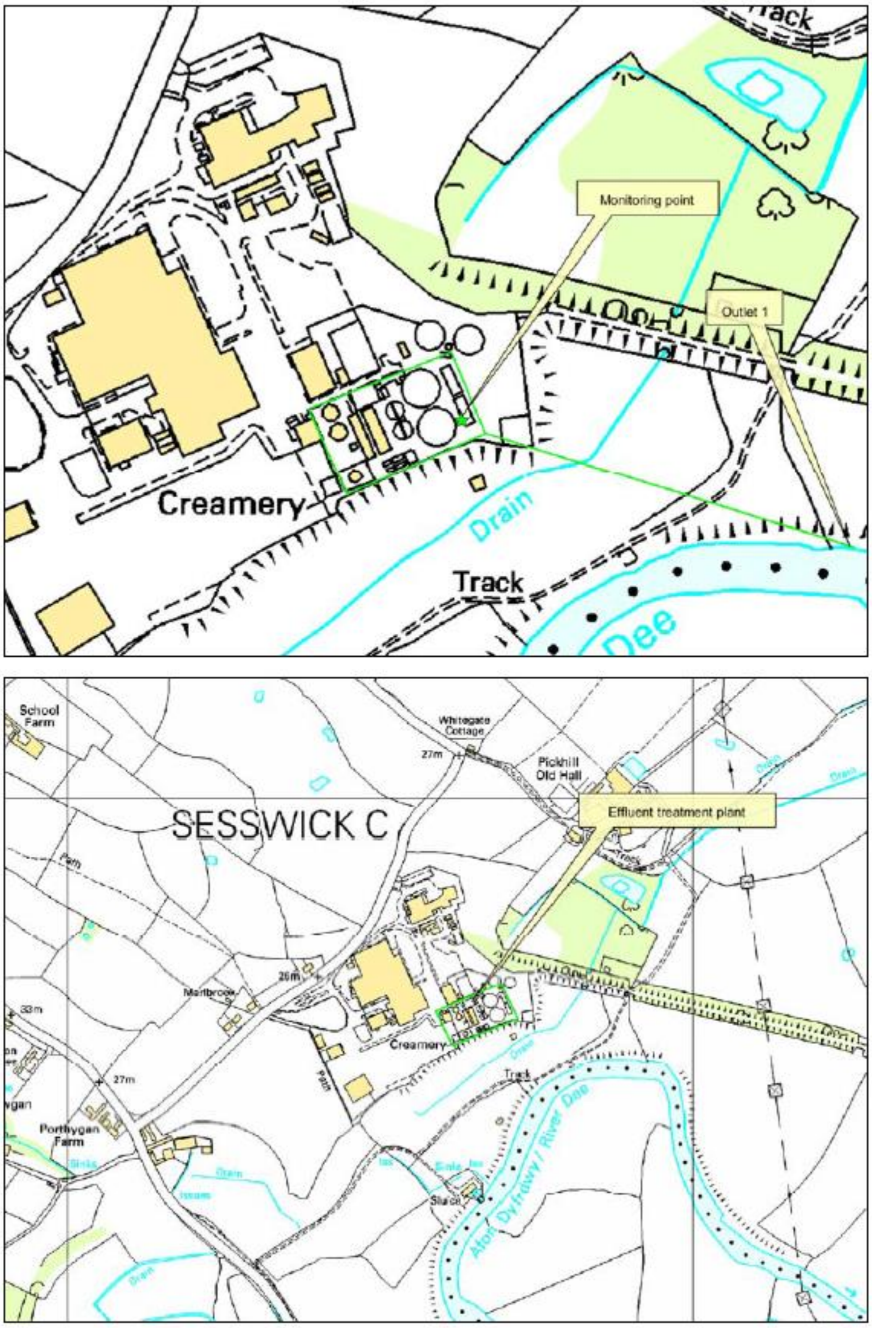
1.4 Structure of this report

Section 2 of the report outlines the data used to define flow and quality of the upstream river and the proposed discharge, and the methodology applied to identify the predicted downstream impacts. Section 3 presents the results of the River Quality Planning analysis and Section 4 gives the results of the monthly temperature modelling. The conclusions of the study are given in Section 5.

Figure 1.1 Site plan from previous permit



Source: Environment Agency

2. Data and Methodology

2.1 Upstream river flow and quality

Data on the flow and quality upstream of the proposed discharge were supplied by Natural Resources Wales (NRW) as a spreadsheet of approximately monthly values taken from two sampling points. The two sites were:

1. ID 87 – River Dee at Old Bangor Bridge. This is located immediately upstream of the proposed discharge.

2. ID 2 – River Dee at Overton Bridge.

The data provided covered the period 1 January 2000 – 19 August 2015. However, only samples from 1 January 2010 to 31 December 2014 were analysed to ensure that the statistics calculated best represented the current quality at the sites. Furthermore, samples with a purpose code of UI were excluded as this code relates to pollution incidents and so values may not represent the routine quality of the River Dee. No data were available for aluminium.

The data for site 2 included flow measurements, but the data for site 87 did not. However, the number of samples in the flow record was insufficient to produce monthly Q95[1] flows for the temperature modelling. Daily data for an upstream flow gauge on the River Dee at Manley Hall (ID = 67015) were downloaded from the CEH website and as the annual summary statistics were similar to those from Site 2, the study used the daily flow data to calculate all statistics by which the upstream river flow was defined.

Statistical analysis of the data derived mean and standard deviation for each determinand. Any ‘less than’ values were halved in accordance with the EA Codes of Practice for Data Handling (Ellis *et al*., 1993).

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[1] The Q95 (low) flow is the flow equalled or exceeded in 95% of the daily mean flows in a record and is a descriptor of the low flow of a river.

Table 2.1 River flow and quality in the River Dee upstream of the proposed discharge

Determinand	Upstream river conditions			
	Mean (mg/l)	SD (mg/l)	Q95 (flow only)	Source
Flow	32.0 (m^3/s)	32.9 (m^3/s)	8.6 (m^3/s)	Manley Hall
BOD	1.0	0.6	n/a	Old Bangor Bridge
Total suspended solids	6.5	6.8	n/a	Old Bangor Bridge
Ammonia	0.02	0.01	n/a	Old Bangor Bridge
Phosphate	0.02	0.02	n/a	Old Bangor Bridge
pH	7.7	0.3	n/a	Old Bangor Bridge
Iron	0.13	0.05	n/a	Overton Bridge*
Temperature	10.9	4.5	n/a	Old Bangor Bridge

*No data available at Old Bangor Bridge

2.2 Proposed discharge

The starting point for defining the discharge parameters was the concentrations permitted for the site when managed by First Milk Ltd (Table 2.2).

Table 2.2 Initial discharge limits applied in modelling

Determinand	Discharge limit	Units	Expressed as	Distribution applied in RQP	
				Mean (mg/l)	SD (mg/l)
Average daily flow	1200	m^3/d	Mean	0.014 m^3/s	0.003 m^3/s
Maximum daily flow*	1500	m^3/d	Maximum	0.017 m^3/s	0.000 m^3/s
BOD	30	mg/l	Maximum	14.95	4.93
Total suspended solids	45	mg/l	Maximum	22.43	7.40
Ammonia	10	mg/l	Maximum	4.98	1.64
Phosphate	2.5	mg/l	Maximum	1.25	0.41
pH	6 to 9	n/a	Minimum and maximum	7.50	1.29
Aluminium	1	mg/l	Maximum	0.50	0.16
Iron	n/a	n/a	n/a	n/a	n/a
Temperature*	30.0	°C	Maximum	n/a	n/a

*Only used in temperature modelling. The maximum temperature permitted for First Milk Ltd was 21.5°C.

As the limits were all maxima, these were treated as upper tier limits (99th percentile). Discharge quality is defined in the River Quality Planning (RQP) tool by a mean and standard deviation and these were calculated from the maximum values assuming a CofV of 0.33.

2.3 River quality standards

NRW provided details of the High and Standard physico-chemical Environmental Quality Standard (EQS) at two sites:

1. ID 87 – River Dee at Old Bangor Bridge. This is located immediately upstream of the proposed discharge.

2. ID 671 – River Dee at Farndon Bridge. This is located downstream of the proposed discharge (Figure 2.1).

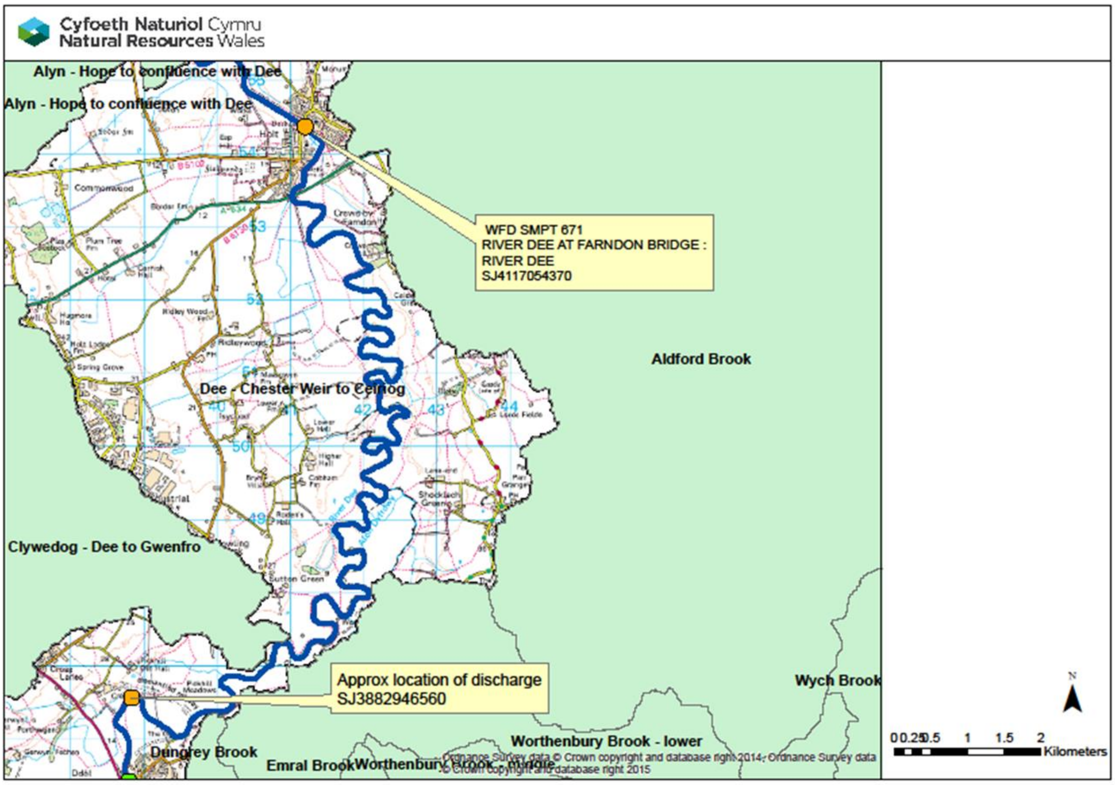
The standards at site 671 were applied in the modelling as this is downstream of the discharge, and are shown in Table 2.3. There are currently no EQS for total suspended solids at either site 671 or 87.

Table 2.3 Physico-chemical EQS at site 671, River Dee at Farndon Bridge

Determinand	EQS expressed as[2]	High Standard	Good Standard
BOD	90th percentile	4 mg/l	5 mg/l
Total suspended solids	90th percentile	N/A	N/A
Ammonia	90th percentile	0.3 mg/l	0.6 mg/l
Phosphate	Mean	0.028 mg/l	0.056 mg/l
pH Upper	n/a	9	9
pH Lower	n/a	6	6
Temperature	Maximum	25°C	28°C

2 The 90th percentile (or 90%ile) is the value for which 90% of the data points are smaller. It is a measure of statistical distribution.

Figure 2.1 Location of downstream sampling point



Source: Environment Agency

2.4 Methodology

2.4.1 River Quality Planning Monte Carlo modelling

The EA's River Quality Planning Monte Carlo modelling tool was used to determine the impact of the proposed effluent discharge to the River Dee for five determinands:

- BOD
- Total suspended solids
- Ammonia
- Phosphate
- pH

Aluminium data were not available for the River Dee and iron was not included in the permit for the previous use of the site by First Milk Ltd. Therefore, these determinands were not included in the modelling.

The following assumptions were applied to the modelling:

1. Upstream river concentrations were based on summary statistics from the observed data provided by NRW, as outlined in section 2.1.

2. Initial discharge concentrations were based on summary statistics calculated from the maxima issued within the site's previous permit, as outlined in section 2.2.

3. Mixing between effluent flow and river flow occurs instantaneously at the point of discharge.

4. All determinands have a maximum consent; pH also has a minimum limit.

2.4.2 Temperature modelling

The proposed Maelor Poultry discharge is likely to be at a higher temperature than the ambient temperatures of the River Dee. Modelling was required to identify by how much the downstream temperature would change compared to the upstream temperatures once the effluent was added.

The modelling was completed using WRc's in-house mass and energy balance spreadsheet tool, which assumes that the mixing between effluent and river waters occurs instantaneously. It does not include any representation of cooling through heat losses to the atmosphere, and therefore provides a conservative estimate of the temperature rise.

Results were calculated on a monthly average basis, with the observed temperature data from monitoring site 87 (River Dee at Old Bangor Bridge) and observed monthly river flow data from the gauge at Manley Hall. Temperature was modelled for a constant discharge flow of 1200 m^3/d and 1500 m^3/d, both at a constant temperature of 30.0°C.

Table 2.4 Average monthly temperature and flow in the River Dee upstream of proposed discharge

Month	Mean monthly river temperature (°C)	River flow (m^3/s)	
		Mean	Q95
January	5.0	59.2	17.0
February	4.7	54.2	15.0
March	7.7	16.4	8.2
April	9.9	23.6	8.5
May	11.5	20.0	8.3
June	15.5	18.1	8.5
July	17.4	17.4	8.9
August	16.2	14.3	8.7
September	14.6	22.4	8.5
October	11.6	28.6	9.8
November	8.5	56.5	12.7
December	4.5	55.0	12.4

3. River Quality Planning tool results

3.1 Results based on average flow from proposed discharge

The modelled impact of an average discharge flow of 1,200 m^3/d, expressed as mean of 0.014 m^3/s with standard deviation of 0.003 m^3/s, with discharge quality based on the site's previous permit, are summarised in Table 3.1.

For BOD, ammonia phosphate and pH, the impact on the 90^{th} percentile river quality is negligible (0% change). For total suspended solids, there is an increase in the mean and a decrease in the 90^{th} percentile but these changes are small (<2%), especially given the inherent uncertainty in the observed data.

Table 3.1 Summary of the River Quality Planning Monte Carlo modelling – average discharge flow

Determinand	Observed upstream river concentration		Modelled discharge permit		Modelled downstream river concentration		% change in downstream river concentration	
	Mean	90%ile (from RQP)	Limit	Type	Mean	90%ile	Mean	90%ile
BOD	1.0	1.7	30 mg/l	Maximum	1.0	1.7	0.0	0.0
TSS	6.5	13.5	45 mg/l	Maximum	6.6	13.3	1.5	-1.0
Ammonia	0.02	0.03	10 mg/l	Maximum	0.02	0.03	0.0	0.0
Phosphate	0.02	0.04	2.5 mg/l	Maximum	0.02	0.04	0.0	0.0
pH (lower limit)	7.7	8.0	6	Minimum	7.7	8.0	0.0	0.0
pH (upper limit)	7.7	8.0	9	Maximum	7.7	8.0	0.0	0.0

3.2 Results based on maximum flow from proposed discharge

The modelled impact of an average discharge flow of 1,500 m^3/d, expressed as a constant flow of 0.017 m^3/s with discharge quality based on the site's previous permit, are summarised in Table 3.2.

Table 3.2 Summary of the River Quality Planning Monte Carlo modelling – maximum discharge flow

Determinand	Observed upstream river concentration		Modelled discharge permit		Modelled downstream river concentration		% change in downstream river concentration	
	Mean	90%ile (from RQP)	Limit	Type	Mean	90%ile	Mean	90%ile
BOD	1.0	1.7	30 mg/l	Maximum	1.0	1.7	0.0%	0.0%
TSS	6.5	13.5	45 mg/l	Maximum	6.6	13.3	1.5%	-1.0%
Ammonia	0.02	0.03	10 mg/l	Maximum	0.02	0.04	0.0%	33.3%
Phosphate	0.02	0.04	2.5 mg/l	Maximum	0.02	0.04	0.0%	0.0%
pH (lower limit)	7.7	8.0	6	Minimum	7.7	8.0	0.0%	0.0%
pH (upper limit)	7.7	8.0	9	Maximum	7.7	8.0	0.0%	0.0%

For BOD, phosphate and pH, the impact on the 90th percentile river quality is very small and is only observed at the third decimal place. For total suspended solids, there is an increase in the mean and a decrease in the 90th percentile but these changes are small (<2%) and are the same as the predicted impact of the average discharge flow (Section 3.1).

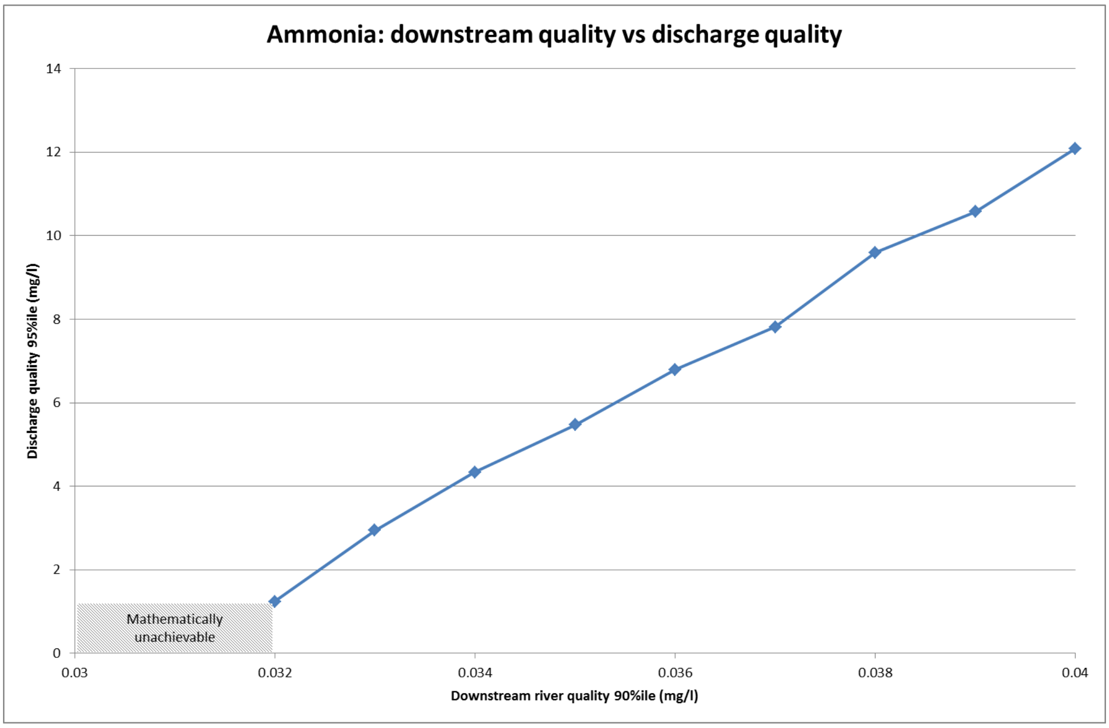
3.2.1 Ammonia

The predicted impact on ammonia is an increase in the 90th percentile of 0.01 mg/l i.e. very small, however due to the low concentration of ammonia in the river this rise equates to 33%.

In light of this result, further simulations were undertaken to calculate discharge concentrations that bring about small changes in downstream river quality, based on the maximum flow from the proposed discharge. The RQP software does not give results to more than 2 decimal places but it was possible to use the 'downstream quality target' parameter and set this to be worse than the upstream quality at the third decimal place and then calculate the required discharge to achieve this change. The required discharge quality was calculated to achieve downstream river quality in incremental steps from 0.032 mg/l to 0.040 mg/l (Figure 3.1).

It was not mathematically possible to obtain results for downstream quality of 0.030 or 0.031 mg/l because of the very small increase in concentration, the shape of the discharge distribution and the statistical nature of the Monte Carlo simulation used for this type of analysis.

Figure 3.1 Downstream river ammonia 90th percentile against 95th percentile discharge concentrations for maximum proposed discharge flow



The results reflect the magnitude of the available dilution in the river, i.e. larger changes in discharge quality still result in small absolute increases in downstream river quality. However, because the river upstream is clean and ammonia concentration is low, a large percentage difference in the resultant downstream quality can be in reality only a small change in the concentration value.

4. Monthly temperature modelling results

Temperature modelling was undertaken using a mass and energy balance spreadsheet tool.

4.1 Monthly average river flows

The modelling showed that the predicted impact of both the average discharge flow of 1,200 m^3/d and the maximum flow of 1,500 m^3/d, at 30.0°C, is small (Table 4.1), with changes only at the second or third decimal place.

Table 4.1 Summary of the impact of the proposed discharge on temperature in the River Dee – average river flow

Month	Temperature (°C)				
	Upstream	Average discharge flow		Maximum discharge flow	
		Downstream	Differential	Downstream	Differential
January	5.0	5.0	0.0	5.0	0.0
February	4.7	4.7	0.0	4.7	0.0
March	7.7	7.7	0.0	7.7	0.0
April	9.9	9.9	0.0	9.9	0.0
May	11.5	11.5	0.0	11.5	0.0
June	15.5	15.5	0.0	15.5	0.0
July	17.4	17.4	0.0	17.4	0.0
August	16.2	16.2	0.0	16.2	0.0
September	14.6	14.6	0.0	14.6	0.0
October	11.6	11.6	0.0	11.6	0.0
November	8.5	8.5	0.0	8.5	0.0
December	4.5	4.5	0.0	4.5	0.0

The results are illustrated in Figure 4.1. This graph demonstrates the seasonal variability of observed upstream river temperatures.

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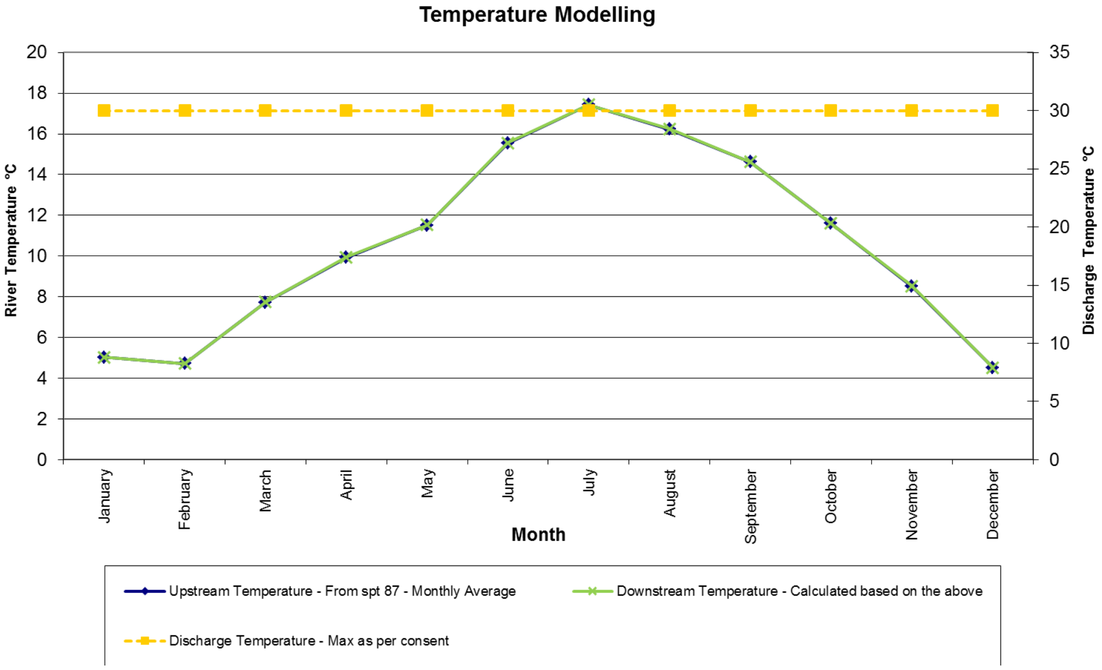
Figure 4.1 Comparison of observed upstream and modelled downstream river temperature profiles with discharge flow of 1,200 m³/d at 30.0°C – average monthly river flows



4.2 Monthly Q95 river flows

The modelling showed that the predicted impact of the average discharge flow of 1,200 m³/d and the maximum flow of 1,500 m³/d, at 30.0°C, is still small (Table 4.2). Increases in the downstream river temperature were observed at only the second decimal place.

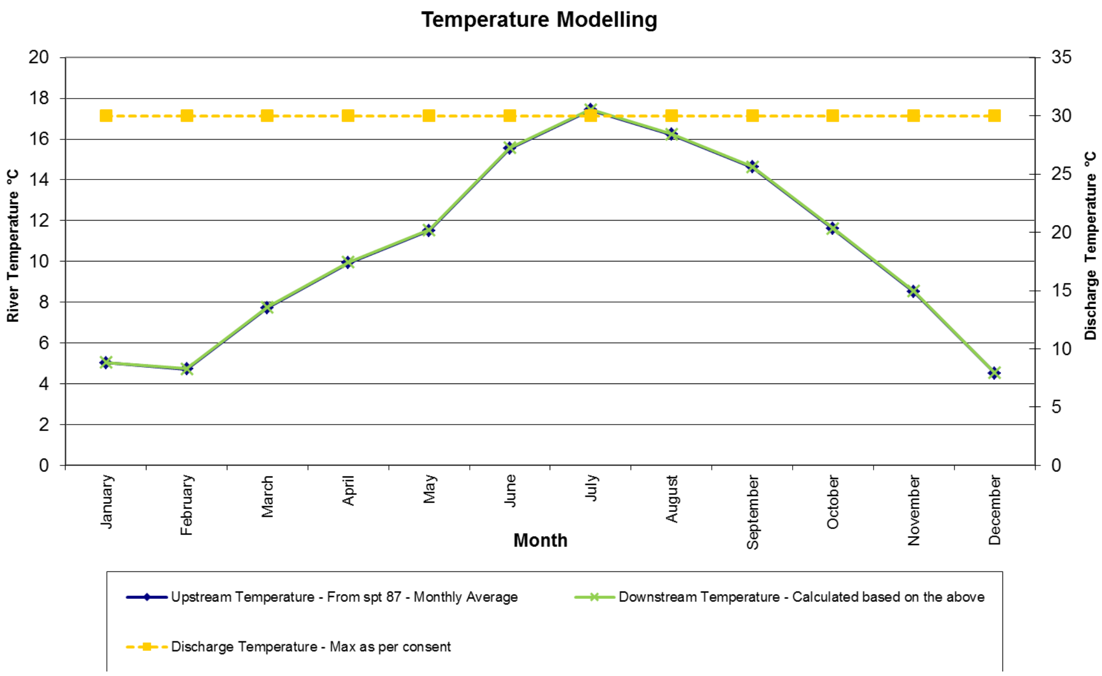
Table 4.2 Summary of the impact of the proposed discharge on temperature in the River Dee – Q95 river flow

Month	Temperature (°C)				
	Upstream	Average discharge flow		Maximum discharge flow	
		Downstream	Differential	Downstream	Differential
January	5.0	5.0	0.0	5.0	0.0
February	4.7	4.7	0.0	4.7	0.0
March	7.7	7.8	0.0	7.8	0.0
April	9.9	9.9	0.0	10.0	0.0
May	11.5	11.5	0.0	11.5	0.0

Month	Temperature (°C)				
	Upstream	Average discharge flow		Maximum discharge flow	
		Downstream	Differential	Downstream	Differential
June	15.5	15.6	0.0	15.6	0.0
July	17.4	17.4	0.0	17.4	0.0
August	16.2	16.2	0.0	16.2	0.0
September	14.6	14.6	0.0	14.6	0.0
October	11.6	11.6	0.0	11.6	0.0
November	8.5	8.5	0.0	8.5	0.0
December	4.5	4.5	0.0	4.5	0.0

The results are illustrated in Figure 4.2. This graph demonstrates the seasonal variability of observed upstream river temperatures.

Figure 4.2 Comparison of observed upstream and modelled downstream river temperature profiles with discharge flow of 1,200 m^3/d at 30.0°C – Q95 monthly river flows



4.3 Summary

The temperature modelling showed that discharges of 1,200 m^3/d and 1,500 m^3/d with a temperature of 30.0°C would not increase the river temperature under average or Q95 river flow conditions.

However, it should be noted that this assumes that the discharge and river flows are fully mixed across the river at the point of discharge. In reality, the discharge is unlikely to be fully mixed until further downstream with the effluent plume possibly hugging one side of the river. This may result in local temperature variation across the channel of a higher temperature differential.

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5. Conclusions

A permit modelling assessment has been carried out for a proposed discharge by Maelor Poultry Ltd to the River Dee in Wrexham. The assessment used the EA's River Quality Planning (RQP) Monte Carlo tool to model the effect of the discharge on the downstream river quality, specifically for determinands: BOD, ammonia, total phosphate, total suspended solids and pH. A mass balance spreadsheet tool was used to model the resultant river temperature downstream of the discharge.

The river quality modelling using RQP showed that the predicted impact of the discharge on downstream river quality is small, with most quality determinands showing no change. Any predicted change in quality was small, especially in the context of uncertainty in the upstream data.

This was reflected in the monthly temperature modelling, which showed no increase in temperature except at the second decimal place under Q95 (low) flow conditions in the river, and at the third decimal place with average conditions in the river.

The results were based on proposed discharge flows of an average 1,200 m^3/d and a maximum 1,500 m^3/d, with quality based on the discharge concentrations previously permitted at the site when managed by First Milk Ltd. The results showed negligible impact at this loading (flow and concentration) from the discharge.

References

Ellis, J.C., van Dijk, P.A.H. and Kinley, R.D. (1993) Codes of Practice for Data Handling. NRA Report No. R&D 241.

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