

Aberthaw Power Station: Additional Information following Regulation 60 request (Permit Ref: EPR/RP3133LD)

RWE Generation UK

Environment & Chemistry

ENV/597/2015

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Aberthaw Power Station: Additional Information for Regulation 60 request (Permit Ref: EPR/RP3133LD)

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1 Introduction

This document is written to provide additional information as part of the Industrial Emissions Directive (IED) Regulation 60 process. The information provided is further information on the Open Cycle Gas Turbines (OCGTs) on site and information to allow two operational trials to take place at Aberthaw Power Station. The power station currently has an environmental permit EPR/RP3133LD.

2 OCGT information

For the OCGTs a nominal figure of 25% efficiency is used, reference the last graph in the original correction curve information in Appendix A of this document.

The maximum output is 18.5MW in winter, & 17.5 in summer so average 18 MW. This means that the rated thermal input would be 72 MWth for each GT, so total of 216 MWth for all 3.

The OCGTs do not operate for more than 500 hours per year, currently they are used for peak lopping and available for black start operation.

3 Information on short duration normal volatile coal trial proposal

To try to mitigate uncertainty, Aberthaw is considering alternative sources of coal for the future. Although Aberthaw's boilers are designed to burn exclusively coals or coal blends with a volatile matter content of between 9% and 14%, one of the possibilities being considered is a widening of the volatile matter content range for coals that Aberthaw can burn upwards to include the coals that are typically burnt at other coal-fired power stations in the UK and worldwide; bituminous coal, with a 'normal' volatile matter content between 20 and 30%. Options for this 'normal' volatile matter content coal would be to either burn it as delivered or, perhaps, as a blend with any low volatile matter content coal that is available, but at insufficient volumes to meet Aberthaw's requirements.

In order for Aberthaw to be able to take coals with higher volatile matter contents the station will not have to make any changes to its boilers beyond those already underway or planned as part of its ongoing programme of low NOx boiler modifications. As such, Aberthaw's boilers will remain as the original low volatile matter content coal design and the station would still be able to burn the low volatile matter content coals that it currently uses should they be available. However, to ensure that the higher volatile matter coals can be handled safely it is very likely that another multi-million pound upgrade project will be required that will include some physical reinforcement of the station's milling systems and the installation of mill safety detection and overpressure suppression systems.

To understand in more detail the issues surrounding the handling, milling and combustion of 'normal' volatile matter content coal, and so inform future coal procurement and site investment options, Aberthaw is proposing to undertake some short-duration trial burns of

'normal' volatile matter content coal during 2016. These trials, which will be planned following a full engineering risk assessment by internal experts and detailed in an Engineering Test Plan, will be carried out under strictly controlled conditions and will not involve any engineering modifications to either the station's coal handling and milling equipment or its boilers. Although the timing and number of these trials has yet to be determined, current thoughts are that an initial trial early in 2016 will, most likely, involve two parts; a trial on a single mill and then, shortly after, a single unit trial. Both trials will be of short duration, expected to be approximately 8 hours.

It is possible that the combustion of 'normal' volatile matter content coal could also lead to a further reduction in Aberthaw's NOx emissions beyond those that will be delivered by the low NOx boiler technologies currently being deployed. However, a pre-requisite of achieving these additional NOx benefits, which are anticipated by external equipment suppliers to be a reduction to < 300mg/NM³. Therefore, another aspect of the proposed trials is to understand the additional NOx reductions that the use of 'normal' volatile matter content coal would give when it is fired in a boiler equipped with low NOx boiler technology.

It is therefore requested that permission is given to go ahead with this short duration trials in 2016.

A copy of the Engineering Test Plan is attached for further detail in Appendix B.

4 Description of pH operational trial proposal

In 2008, to comply with the Large Combustion Plant Directive, the Aberthaw Power Station installed a Flue Gas Desulphurisation (FGD) process. This utilises the station's sea water cooling water to absorb approximately 95% of the sulphur dioxide gases generated in the coal combustion process. This results in an acidic effluent that is neutralised by the addition of oxygen in the Sea Water Treatment Plant (SWTP), before being released back into the Bristol Channel. The level of acidity is directly related to the sulphur content of the various coals fired by the Power Station.

The original FGD design reflected the quantity and quality of appropriate low volatile Welsh and internationally sourced coal available in the global coal market.

In recent years, the volume of available coal has decreased significantly with the decline of the Welsh coal industry and the expansion of the Chinese economy attracting many of the international coals previously readily available to Aberthaw.

Those coals remaining available to the Power Station typically have higher sulphur levels than the original FGD design, however via a series of controlled trials the Station has to date been able to accommodate the increasing coal sulphur levels by optimisation of the original SWTP / FGD operation.

It is now agreed however that the SWTP process is operating at maximum capacity within the discharge limits stipulated in the Station's operating permit.

From 2016 onward, the volume of appropriate low volatile coal is yet further constrained with the indigenous suppliers predicting increased sulphur levels and international supplies becoming limited to only one suitable supplier.

In order to address these constraints, RWE would like to propose a temporary variation to the Station's cooling water discharge pH of 5.6 (instantaneous) and 5.8 – 6.0 (95%ile of instantaneous measurements). To confirm this variation has no adverse impact to the environment, the Station wish first to propose a 3 month trial, January 1st to March 31st 2016 operating with the new pH limits alongside specifically designed chemical and environmental impact assessment monitoring programmes that would identify and prompt immediate cessation of the trial on the detection of any adverse environmental impact.

At the end of the 3 month period, the Station would cease the trial and review the results. During the review the Station would return to operating within current permit pH limits.

Following the review should results conclude no adverse impact whilst operating at the lower pH limits, a proposal will be submitted to Natural Resources Wales to consider a permanent amendment of the discharge pH limits to 5.6 (instantaneous) and 5.8 – 6.0 (95%ile of instantaneous measurements) accordingly.

It is envisaged that operation at the lower pH limits referenced above would support full year Power Station operation fuelled exclusively by indigenous coal at the increased sulphur levels predicted in future mining plans by the Welsh coal suppliers.

This document has been developed to investigate the predicted impact of the proposed pH variation to the local environment and to provide the necessary information to support the proposal of a 3 month trial period at the lower pH limits.

The table below details the current and proposed pH limits for a trial period of January to March 2016 inclusive.

Limit Type	Current pH ELV	Proposed pH ELV
Instantaneous	5.8 (min)	5.6 (min)
95%ile of instantaneous measurements	6.0-8.5	5.8-8.5

5 Site Boundary

There will be no change in the EP boundary as a result of the proposed trial.

6 Technical Standards

The standards discussed below are from EPR 1.00 "How to comply with your permit" and EPR 1.01 "Combustion Activities". The following information on operational techniques is provided in addition to that provided in the original application unless it is indicated that it is to replace information previously supplied.

6.1 Storage and Handling

There are no changes in relation to storage and handling as a result of this trial.

6.2 Point Source emissions to air

Whilst the average sulphur content of the coal is likely to be higher during the trial period, it is expected based on the historically excellent performance of the FGD process that any increased generation of sulphur dioxide will be readily removed in the FGD process and therefore there are no expected changes in relation to emissions of sulphur to air as a result of this trial.

The switch during the proposed trial to the use of all Welsh coal has the potential to change the concentration of material in the flue gas from that assumed during the atmospheric dispersion modelling undertaken for the permitting of the FGD process. This is because coal is not a homogenous product and its composition will vary between different mines. Differences in the concentration of trace materials are also found between the analyses of coal from the same mine.

Data from fourteen samples of Welsh coal analysed between 2009 and 2015 have been tabulated below alongside the concentration assumed in the air quality assessment (see Robinson 2006 & Hunter 2006 for details).

Table 1 Composition of Typical coal used in previous air quality studies and recent Welsh coals

Coal Analysis	Typical mg/kg	Recent Welsh Coal mg/kg
Arsenic*	15	18.95
Cadmium	0.11	0.3
Chromium*	30	40.9
Copper*	30	50.7
Lead	24	19.3
Mercury	0.09	0.1
Nickel	33	70.2
Zinc	25	39.9
Antimony*	1.6	n/a
Boron	28	37.3
Fluoride	75	80.6
Manganese	93	84.9
Selenium	2.1	1.5
Vanadium	51	70.7

Arsenic, Boron, Cadmium, Chromium, Copper, Fluoride, Nickel and Vanadium concentrations are higher in the Welsh samples than in the composition assumed for the FGD H1. The average lead content of the Welsh samples is lower than that assumed for the 2006 H1 as is Selenium and Manganese. The average Mercury content of the Welsh samples is very close to that assumed in 2006 (0.1mg/kg cf 0.09mg/kg).

The H1 air quality assessment undertaken for the PPC permit application (Hunter 2006) showed that both the short and long term process contributions from the plant burning the typical coal listed in Table 1 above were significantly below 1% of the relevant Environmental

Assessment Levels (EALs). The differences in the composition of the typical coal and recent Welsh coals would not change this conclusion. Hence there are not expected to be significant changes in air quality resulting from a switch to solely Welsh coals during the proposed trial.

6.3 Point source emissions to water

pH

The potential impacts of the proposed change in pH have been modelled, this is discussed in further detail in section 5 but the overall conclusion is that differences in the lowest pH between modelling using a discharge pH of 5.6 (proposed) and 5.8 (current) are observed within a small area (approximately 250m by 350m) of the Power Station outfalls and therefore the scale of any potential environmental impact is expected to be equally small (see section 7.2 and Appendix D for more detail).

Metals

The potential changes in metals are discussed in more detail in section 6.6 below but the predicted concentrations of metals in the discharge are within current permit limits, the annual masses of metals will be managed to be within the current permit limits.

Sulphite

The use of higher sulphur trial coals will increase the sulphur loading to the FGD SWTP, however analysis has shown that sulphite reacts very quickly with sea water and is virtually absent even before the effluent enters the SWTP. The environmental risk is therefore small with regard to Sulphite being present in the final discharge to sea. There is currently no Permit requirement to measure for sulphite but it will be prudent to obtain a weekly sample of FGD Absorber Effluent and Final CW Outlet to ensure that the above conditions prevail during the trial and hence such additional monitoring will be undertaken as part of the associated chemical monitoring programme of the trial.

Ammonia

The current Permit discharge limit for Ammoniacal Nitrogen in the final CW Outlet is 0.1mg/l above background. It is not envisaged that there will be an increase in Ammoniacal Nitrogen as a result of the trial. The current Permit monthly monitoring requirement for Ammoniacal Nitrogen presence in the final CW Outlet will be sufficient to monitor for any increase.

6.4 Fugitive emissions

There will be no changes in fugitive emissions from the site as a result of this trial.

6.5 Management

There will be no changes to the existing management systems as a result of the proposed trial other than additional monitoring proposed in section 6.11.

6.6 Raw materials

While the proposed trial is intended to test the predicted limited impact of a change in pH on the aquatic environment RWE have also considered whether or not the change in operation whereby all Welsh coal would be burnt over the winter period will result in other changes in discharge water quality.

The chemical composition of coal varies both between and within each mine. It is the higher sulphur content of Welsh coal compared to some international fuel that is the reason a lower pH limit is being requested. The coal diet will influence the chemical composition of the flue gas and fly ash and hence the concentration of trace metals in the FGD effluent. The analysis of the CW & FGD discharge undertaken for the IPPC H1 assessment in 2006 used a typical coal specification that was representative of the range of coals taken by Aberthaw.

In this section the previously assumed coal specification is compared to that which would be expected on the basis of burning all Welsh coal.

Data from fourteen samples of Welsh coal analysed between 2009 and 2015 have been tabulated in Table 2 below alongside the concentration assumed in the H1 assessment.

Table 2 Comparison of the composition of 2006 H1 and recent Welsh coal samples

Element	Unit	2006 H1		Welsh
Aluminium	mg/kg			29808.5
Arsenic	mg/kg	15		18.9
Boron	mg/kg	28		37.3
Cadmium	mg/kg	0.11		0.3
Chromium	mg/kg	30		40.9
Copper	mg/kg	30		50.7
Fluoride	mg/kg	75		80.6
Iron	mg/kg			9636.6
Lead	mg/kg	24		19.3
Manganese	mg/kg	93		84.9
Mercury	mg/kg	0.09		0.1
Molybdenum	mg/kg			5.6
Nickel	mg/kg	33		70.2
Selenium	mg/kg	2.1		1.5
Vanadium	mg/kg	51		70.7
Zinc	mg/kg	25		39.9

Arsenic, Boron, Cadmium, Chromium, Copper, Fluoride, Nickel and Vanadium concentrations are higher in the Welsh samples than in the composition assumed for the FGD H1. The average Lead content of the Welsh samples is lower than that assumed for the 2006 H1 as is Selenium and Manganese. The average Mercury content of the Welsh samples is very close to that assumed in 2006 (0.1mg/kg cf 0.09mg/kg).

Influence of the change in coal diet on discharge concentrations

Given the measured composition of Welsh coal listed above the discharge concentration of metals is predicted to be as listed in Table 3 below. The discharge concentrations are compared to Environmental Quality Standards (EQSs) where these are available in the table below. For a number of elements the draft River Basin Management Plan Phase (RBMP) 2 directions (expected to come into force soon) list a lower EQS than current applies. The lowest of the current and RBMP EQS is listed in the table.

Table 3 Predicted discharge concentration for an all Welsh coal diet

Component	Discharge Concentration	Units	Annual Average (EQS-AA)	Maximum Allowable Concentration (EQS-MAC)	Notes
Arsenic	0.25	µg/l	25		H1 document
Cadmium	0.06	µg/l	0.2	0.45 to 1.5	RBMP 2 Directions
Chromium	0.87	µg/l	0.6	32	Chromium VI
Copper	0.90	µg/l	3.76		RBMP 2 Directions
Lead	0.62	µg/l	1.3	14	RBMP 2 Directions
Mercury	0.04	µg/l	0.05	0.07	RBMP 2 Directions
Nickel	0.84	µg/l	8.6	34	RBMP 2 Directions
Zinc	0.48	µg/l	6.8		RBMP 2 Directions
Antimony	0.01	µg/l			
Boron	24.28	µg/l	7000		H1
Fluoride	180.16	µg/l	5000	15000	H1
Manganese	0.54	µg/l			
Selenium	0.83	µg/l			
Vanadium	0.65	µg/l			
NO3	474.86	µg/l			
Susp Solids	0.99	mg/l			

The predicted discharge concentrations listed in Table 3 above were calculated using the same process as used for the 2006 IPPC H1 study. The calculation uses the partition coefficients for the take up of flue gas constituents in the FGD process water recommended by the FGD system designer. These partition coefficients are expected to be valid with a switch to an all Welsh coal diet.

The predicted concentration in the CW discharge with a Welsh coal diet is less than the MAC concentrations for all the elements listed in Table 3. For Chromium the predicted discharge concentration is greater than the Annual Average EQS listed in Table 3 above. However the Chromium EQS is for Chromium VI whereas the predicted concentration is for all chromium species, it would be reasonable to expect that Chromium VI concentrations are lower than listed in Table 3 above..

The predicted discharge concentrations based on the all Welsh coal (Table 2) are lower than the current permit limits which are set for mercury ($0.5\mu\text{g/l}^{-1}$), cadmium ($0.2\mu\text{g/l}^{-1}$), lead ($4\mu\text{g/l}^{-1}$), and zinc ($10\mu\text{g/l}^{-1}$). The permit limits are set as increments above ambient based on monthly averages of daily samples.

The predicted metal concentrations in the FGD effluent are all lower than the BAT-AELs (achievable emission limits associated with Best Available Techniques) listed in the current draft of the LCPD BREF.

The permit also controls the annual mass emission of cadmium, lead, mercury and zinc to the sea. The proposed variation is for a three month trial and via the associated chemical monitoring programme RWE will continue to ensure that the mass of these elements remains within the annual limit.

It is noted that from 2016 onward, generation profiles will be significantly reduced compared to record generation in 2013, when a load factor of 70% was achieved via firing of approximately 3.5MTe of coal of which approximately 2.5MTe was Welsh Coal. It is envisaged that maximum generation will promote coal burns of approximately 2MTe and hence any perceived increase in concentration of individual metals will not cause the exceedance of the mass emission limits.

Other Legislation and Guidance

The BREF for large combustion plant is being reviewed with an expected publication date during 2016. In the current draft BREF there is no proposed BAT-AEL for pH. There is however a BAT-AEL for sulphite of 1-20 mg/l. As discussed in 6.3 above, it is not expected that sulphite will be present in the discharge from the site however monitoring will be carried out to confirm this during the trial.

In regards to The Bathing Waters Directive, the nearest bathing water is approximately 7km east of the outfalls and as is shown in section 6 the modelling predicts no change in pH at this point as a result of the trial.

The nearest Shell Fishery is at Porthcawl, which again the modelling predicts no change in pH at this point as a result of the trial.

6.7 Waste minimisation and handling

There will be no changes in waste minimisation and handling as a result of the proposed trial.

6.8 Energy efficiency

There will be no changes to energy efficiency as a result of the proposed trial.

6.9 Accidents

There will be no changes required in terms of accident management as a result of the proposed trial.

6.10 Noise

There will be no changes in noise as a result of the proposed trial.

6.11 Monitoring

Chemical Monitoring

The monitoring programme for the trial will follow the existing permit monitoring requirements for pH and metals (i.e. a representative aliquot of a monthly composite sample) in order to maintain consistency and for ease of comparison.

At present pH monitoring at the Seal Pit is hampered by “instrumentation drift” up to 0.2 of a pH unit on the existing main and back up pH probes. To ensure minimal compliance risk, the Operations team manage the system conservatively to the lowest of the pH readings and initiate additional aeration blowers as appropriate. Whilst this drift is deemed industry standard, it is envisaged that enhanced control can be achieved by installation of a third pH probe alongside the 2 current probes in the Seal Pit and use of a “2 out of 3” voting methodology, whereby the 2 closest readings are averaged and the FGD system operated accordingly. This is a typical measuring protocol for key parameters utilised within the FGD system e.g. sea water inlet flow rates to unit absorbers.

It is anticipated that the new monitoring system will be installed by January 2016 to provide enhanced control to the proposed trial.

In addition, it is proposed to install a pH probe at the outfall for the duration of the trial period to further increase knowledge of pH as the cooling water moves through to discharge.

A weekly sample will be obtained of an FGD Absorber effluent and Final CW Outlet and the sulphite content measured to monitor for any increase as a result of the trial.

Ecological Monitoring

A complementary ecological monitoring programme has been designed by Jacobs to assess potential ecological effects of the pH trial, this is made up of a number of surveys both before, during and after the trial at locations around the outfalls and at a control site at Ogmore. Full details can be found in Appendix D.

6.12 Closure

It is not anticipated that the proposed trial will have any effect on the current closure plan.

6.13 Installation Issues

The proposed trial will have no changes in the measures to be undertaken in respect of interactions with national grid and the on-site above ground installation.

7 Impacts

7.1 Modelling

To support the original PPC application for Aberthaw Power Station RWE undertook water quality modelling using a hydrodynamic model of part of the Severn Estuary.

The hydrodynamic model was obtained from Welsh Water and was accepted as fit for purpose by the then regulator EA Wales. The model is set up to run within Deltares' Delft3D software package.

A modified version of the same hydrodynamic model has been used to predict the change in water quality with the proposed pH limit. This section provides a summary of the output of the modelling, full details of the hydrodynamic and chemical modelling can be found in Appendix C.

Proposed pH limit: lowest surface pH

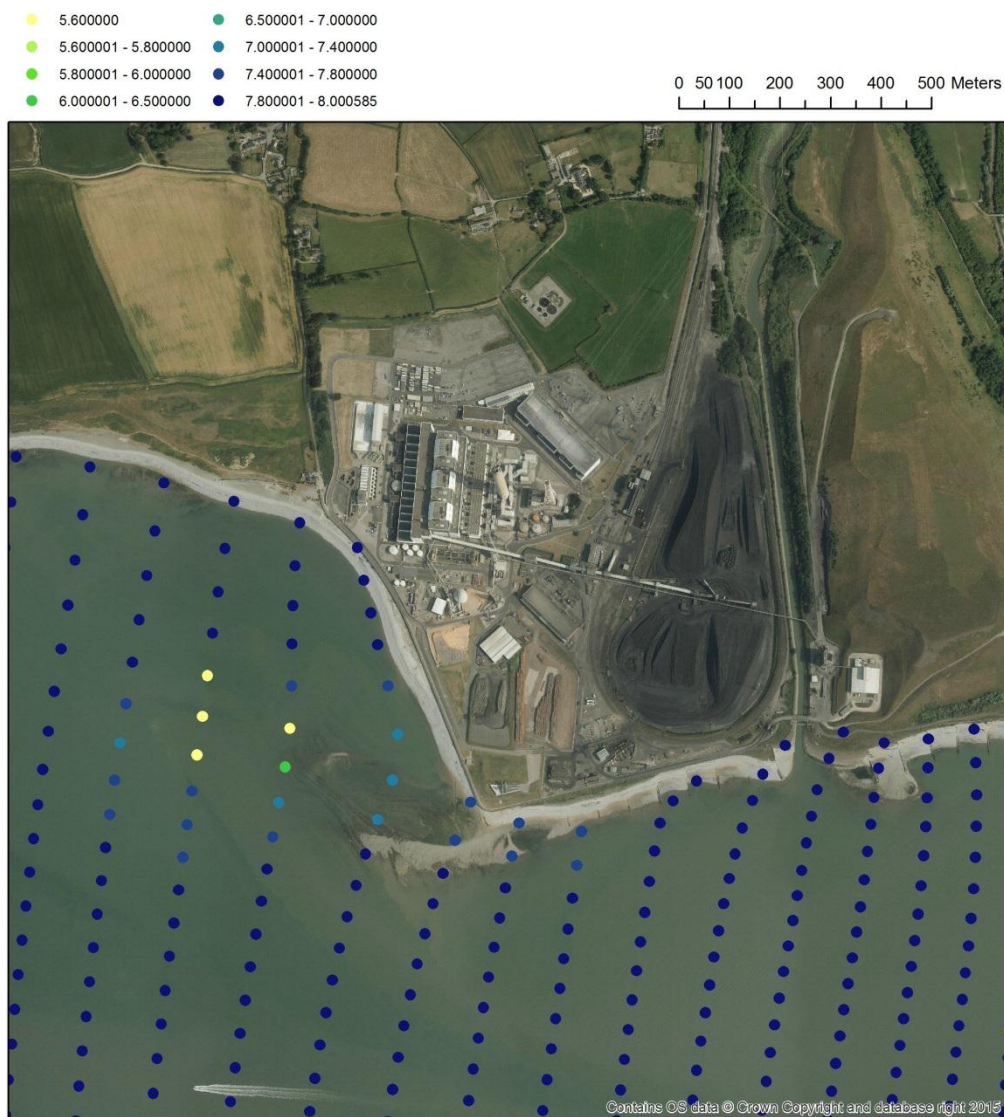


Figure A Predicted surface pH for a discharge pH of 5.6 - near outfall

The predicted surface pH for a CW discharge pH of 5.6 is plotted as Figure A above. Each point plotted corresponds to a model grid cell. Differences in pH from ambient extend for a length of approximately 900m and a width of approximately 400m.

Differences between the predicted surface pH with a discharge of 5.8 (current limit) and a discharge of 5.6 (proposed limit) are small and limited to the model cells adjacent to the outfall.

Proposed pH limit: lowest bed pH

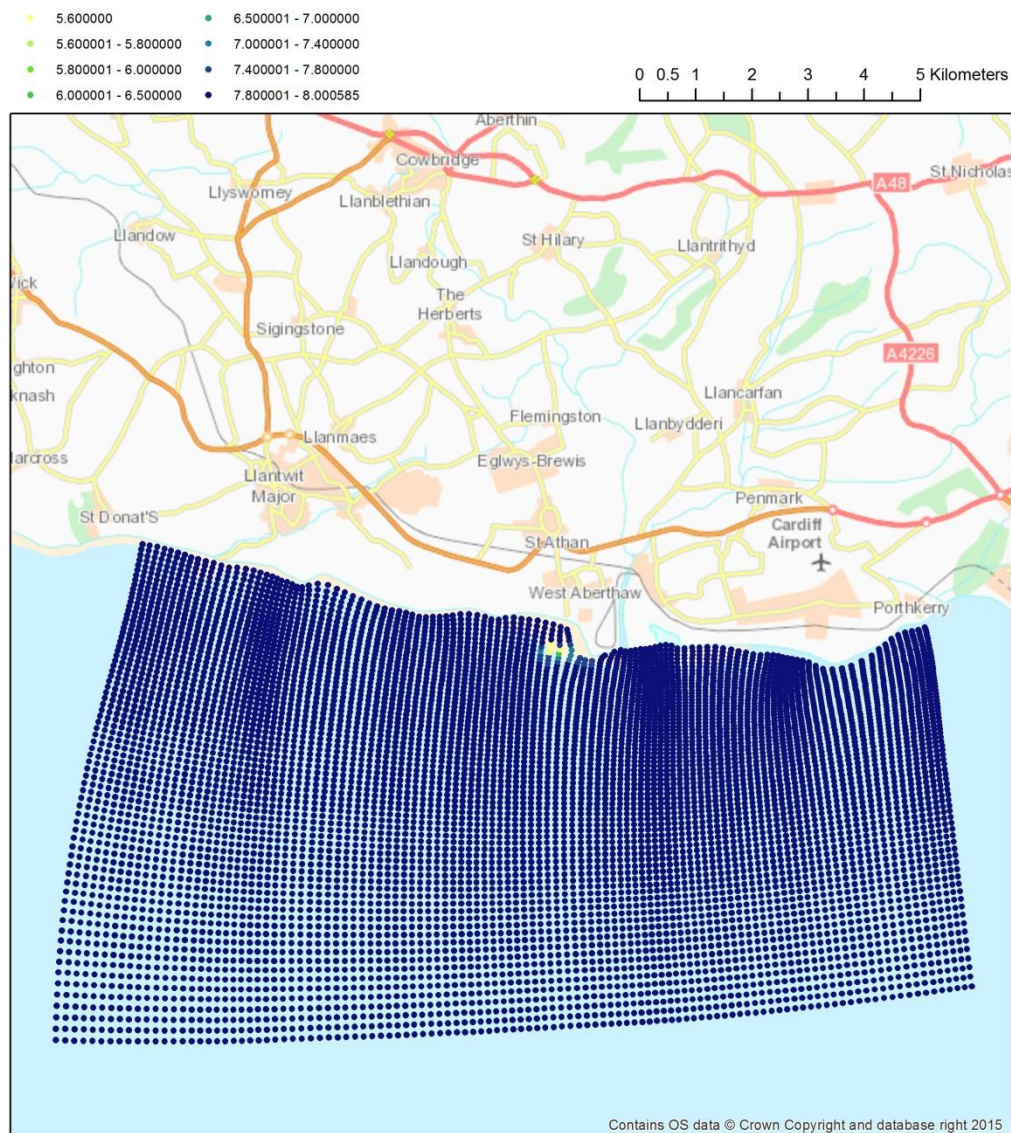


Figure B Predicted bed pH for a discharge pH of 5.6

The predicted bed pH for the proposed revised discharge limit of 5.6 is plotted as Figure B above. Changes in the pH from ambient are limited to the vicinity of the outfall.

Proposed pH limit: lowest bed pH

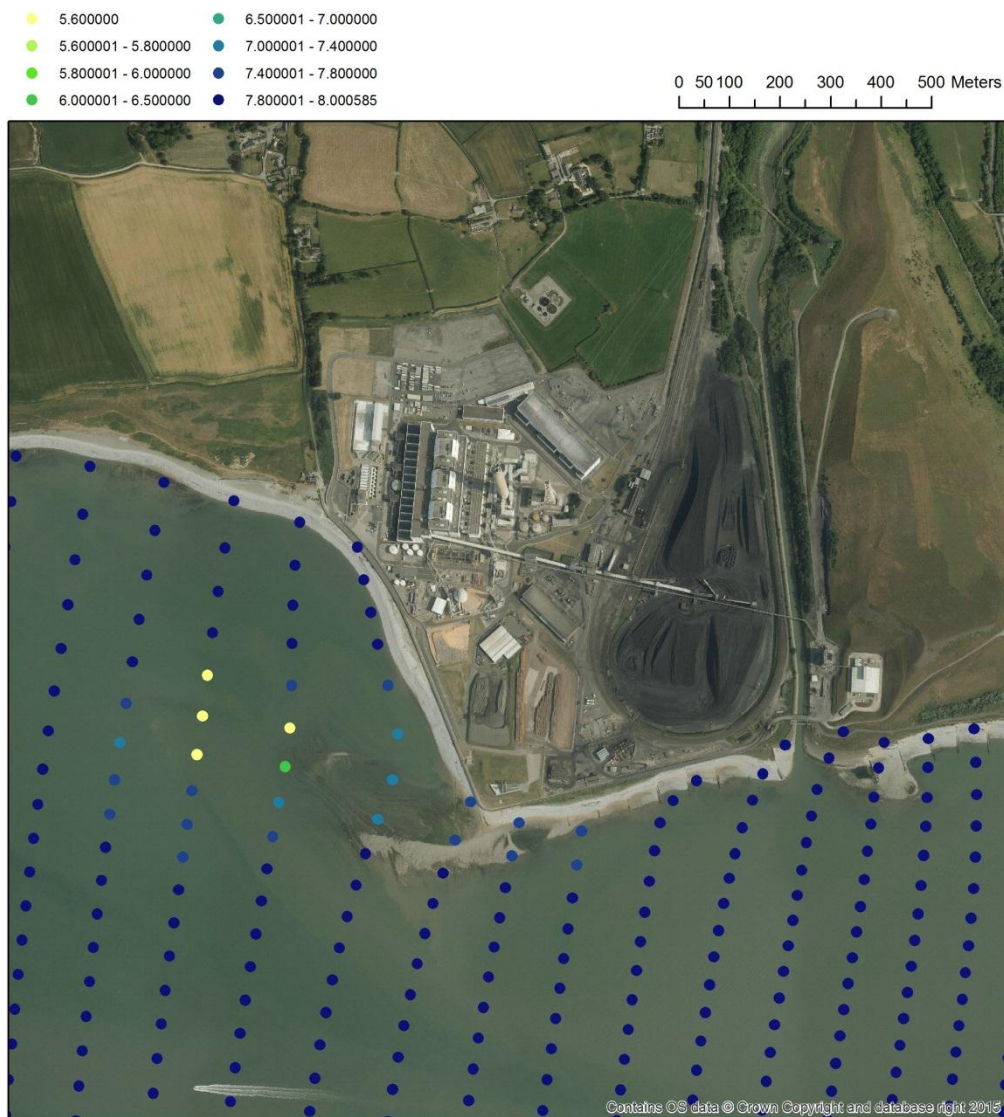


Figure C Predicted bed pH for a discharge pH of 5.6 - near outfall

The predicted bed pH for a CW discharge pH of 5.6 is plotted as Figure C above. Each point plotted corresponds to a model grid cell. Differences in pH from ambient extend for a length of approximately 900m and a width of approximately 400m.

Differences between the predicted surface pH with a discharge of 5.8 (current limit) and a discharge of 5.6 (proposed limit) are small and limited to the model cells adjacent to the outfall.

The hydrodynamic modelling predicts only localised differences in water quality with a reduction in of the discharge pH to 5.6 from 5.8. Differences are limited to the vicinity of the outfall away from which the pH is predicted to recover rapidly towards ambient.

Overall differences in the lowest pH between simulation using a discharge pH of 5.6 and 5.8 are observed within an area of approximately 250m by 350m and therefore the scale of any potential environmental impact is expected to be equally small (see section 7.2 and Appendix E for more detail.

7.2 Ecological Impacts -

RWE Generation provided information on the proposed operational trial and the modelling that had been carried out to Jacobs and asked them to carry out an ecological assessment of the potential impacts. The full report can be found in Appendix D, however the conclusions are also listed below:-

- Modelling indicates that an area of the intertidal ledges to the east and north-east of the outfall will be subject to the cooling water plume with no difference in pH between the current and proposed regime evident beyond 350 m from the outfalls. Consequently, changes to the pH of the discharge will not impact on any designated sites or features of conservation importance.
- Any impacts associated with lowered pH will be limited to the intertidal habitats in the immediate vicinity of the outfalls, and any such effects are likely to be minor in relation to those associated with the thermal attributes of the discharge.
- *Sabellaria alveolata* present to the west of the outfall are unlikely to be impacted by changes to the pH conditions of the discharge as pH conditions in the vicinity of the reefs will be unchanged from current conditions.
- Fish species, including migratory salmonids which utilise the River Thaw, are unlikely to be affected by a reduced pH in the discharge.
- No impacts on marine mammals are anticipated.
- Metal levels in the discharge are predicted to remain below relevant EQSs. Consequently, no impacts are anticipated.
- Dissolved oxygen levels in the discharge are predicted to remain high. If periods of low DO occur, any impacts will be in the immediate vicinity of the outfalls. However, these are predicted to be negligible.

Note - for the purpose of this report, that the pH of the actual CW discharge into the Bristol Channel remains as the Seal Pit discharge pH value. A limited data set obtained via “grab samples” at low tide of the discharge into the Channel suggest the pH is somewhat higher, typically 0.2 pH units higher due to the continued oxidation process that occurs during the passage of the effluent along the 300m Seal Pit discharge pipe to the Channel. This statement is yet to be fully qualified, however it would suggest that the assumption that no additional oxidation occurs during this pipeline passage is a cautious approach and the release of Seal Pit discharge of pH 5.6 remaining as pH 5.6 on entering the Channel conservative.]

8 References

“A chemical model of seawater including dissolved ammonia and the stoichiometric dissociation of ammonia in estuarine water and seawater from -2 to 40°C”, SL Clegg and M Whitfield, *Geochimica et Cosmochimica Acta*, Vol. 59, No. 12, 2403 – 2421.

Ammonia / ammonium dissociation coefficient in seawater: A significant numerical correction, TG Bell et al, *Environ. Chem.* 2008, 5, 258.

Environment Agency; How to comply with your Environmental Permit (EPR 1.00)

Environment Agency; How to comply with your environmental permit. Additional guidance for Combustion Activities (EPR 1.01)

Hunter G (2006) PPC: Air quality Impact Assessment for Aberthaw Power Station
ENV/075/2006

Robinson (2004) Aberthaw Power Station Desulphurisation Plant Addendum to Environmental Statement.
ENV/EMC/2004

Appendix A – OCGT correction curves

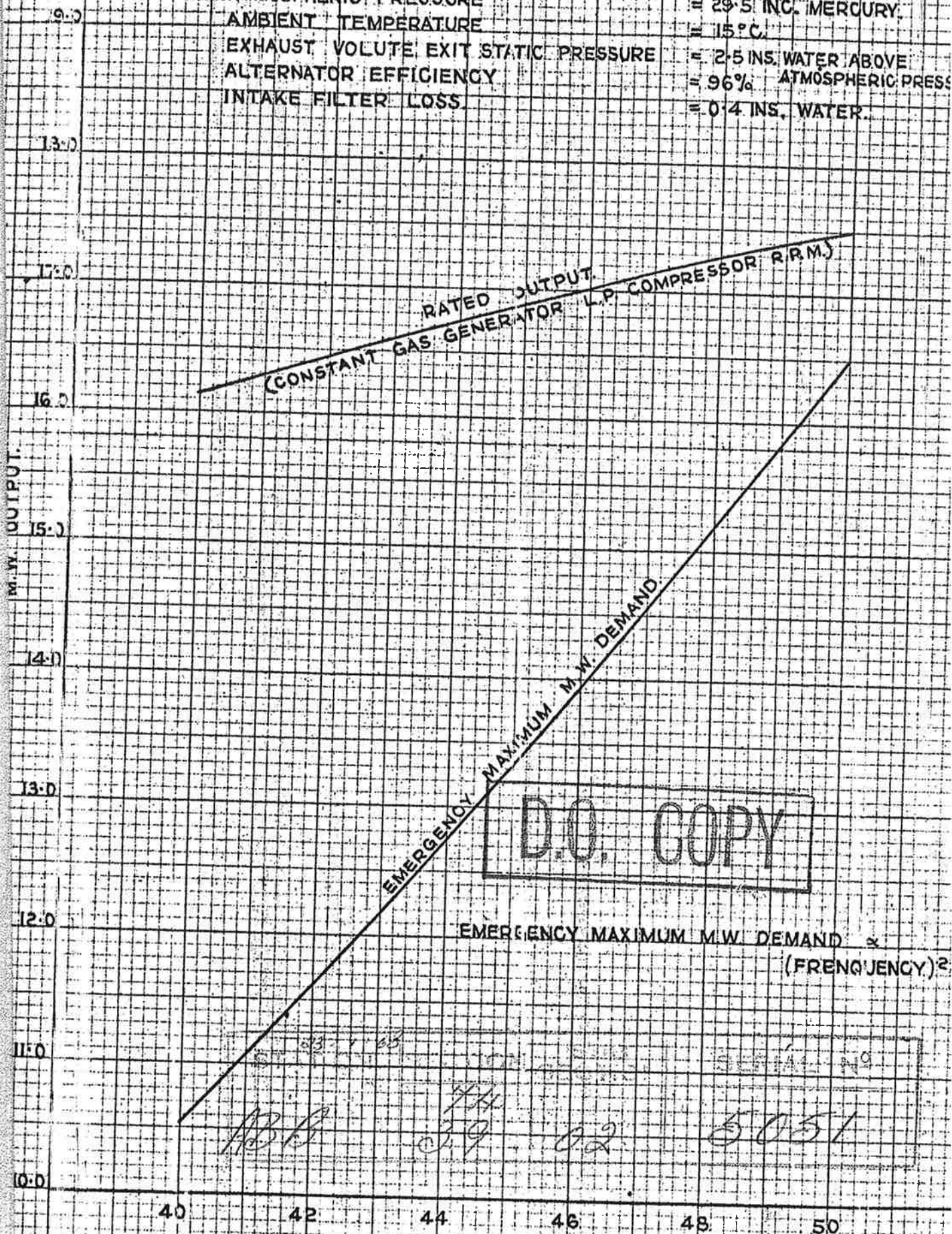
Gas Turbine Correction Curves

OLYMPUS INDUSTRIAL ENGINE

VARIATION OF RATED OUTPUT WITH FREQUENCY

VARIATION OF EMERGENCY MW DEMAND WITH FREQUENCY

ATMOSPHERIC PRESSURE = 29.5 IN. MERCURY
 AMBIENT TEMPERATURE = 15°C
 EXHAUST VOLUTE EXIT STATIC PRESSURE = 2.5 INS. WATER ABOVE
 ALTERNATOR EFFICIENCY = 96% ATMOSPHERIC PRESS
 INTAKE FILTER LOSS = 0.4 INS. WATER.



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OLYMPUS INDUSTRIAL ENGINE

VARIAION OF M.W. OUTPUT WITH AMBIENT TEMPERATURE.

ATMOSPHERIC PRESSURE = 29.5 INS. MERCURY
 EXHAUST VOLUTE STATIC PRESSURE = 2.5 INS. WATER ABOVE ATMOSPHERIC PRESSURE
 ALTERNATOR EFFICIENCY = 96%
 INTAKE FILTER LOSS = 0.4 INS. WATER
 POWER TURBINE R.P.M. = 100%

(CONSTANT L.P. COMPRESSOR R.P.M.) RATED OUTPUT

GUARANTEED RATED OUTPUT

D.O. COPY

(CONSTANT POWER TURBINE ENTRY TEMPERATURE)

SECTION

SERIAL

74

39 02

5052

ABB

20.0 19.0 18.0 17.0 16.0 15.0 14.0
 -15 -10 -5 0 5 10 15 20 25 30 35

ABERTHAW No. 8 17.5 MW GAS TURBINE PERFORMANCE

ENGINE No. 200624

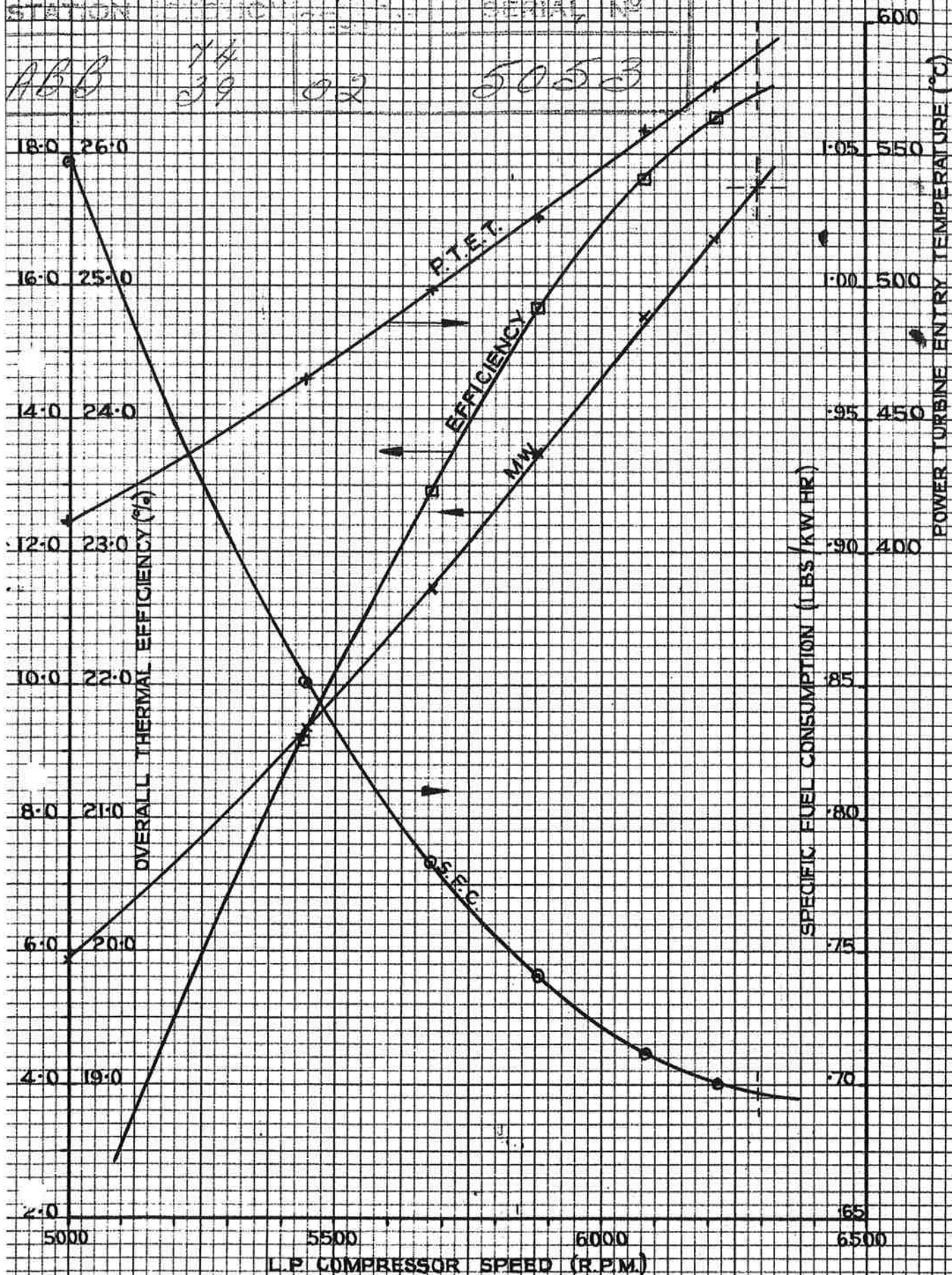
CORRECTED TO 29.5" Hg ATMOSPHERIC PRESSURE

15°C AIR INTAKE TEMPERATURE

BASED ON FUEL S.G. = 0.836

L.C.V. = 18,530 BTU/LB

STATION *ABB* *74* *39* *02* SERIAL No *5053*
23 1 65



Appendix B – Engineering Test Plan

Engineering Test Plan

Subject / Title:	High Volatile Coal Trials at RWE, Aberthaw Power Station
Document ref:	TECH/TEF/2345/15
Issue date:	01/12/15
Client:	Asset Development
Client contact:	Phil Cahill
Client contract ref:	ETS1054
Engineering & Technical Services Group/Team	Process and Fuel Technology
Prepared by	Niall Moroney, James Luxford
Reviewed by	James Luxford
Authorised by	Ed Jamieson

Background and Objectives

The feasibility of broadening the volatile matter (VM) content range of Aberthaw's coal diet was explored by RWE, with the intention of assessing capability to burn both low and normal VM coals at some point in the future. It was concluded that the use of "high VM" (i.e. bituminous) coals at Aberthaw was technically feasible subject to a number of safety measures.

The low volatile matter content coals that Aberthaw's boilers are designed to burn will become less available because lower volumes are being mined locally and equivalent imported fuels are economically unattractive. An additional ability to burn coals with a 'normal' volatile matter content would give Aberthaw a mitigation against this restriction in low VM supplies. The station is therefore proposing to undertake some short duration trial burns of bituminous coals with volatile matter contents of between 20% and 30% during 2016. The purpose of these trials is to gain initial insight into how world-traded, 'normal' volatile matter content coals might burn under low NOx boiler conditions. The increased understanding from the direct handling, milling and combustion of these coals is a prerequisite for the required investment to give Aberthaw some capability of burning 'normal' volatile matter content coal. The trials may also give an insight into additional ways the station could further reduce its NOx emissions, thereby also offering some mitigation against an adverse outcome to the ongoing Infraction between the European Commission and the UK Government.

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Single mill and Unit trials are planned to give further insight and thereby confidence to proceed. The following areas are of significant interest : -

- Furnace performance with high VM coal – steam temperatures, flue gas temperatures, metal temperatures, etc.
- The capability of Units to fire low VM coal whilst running with high VM burner and mill configurations (a scenario likely when switching between fuels).
- The impact of low NOx combustion set-up for NOx emissions. It is expected that burn-out of the high VM coal should be better than for low VM coals under equivalent combustion conditions due to the high proportion of volatiles in the coal and the relatively high reactivity of the coal remaining after volatiles are released.

Full unit high VM trials will be preceded by a high VM single mill trial which will be undertaken to gain ensure milling and initial combustion set-ups are appropriate. The high VM coal to be fired will be the same in both single mill and full unit trials. T

It is to be noted that the coal to be trialled is referred to as “high VM” to inform station staff of the change of coal type from the current low VM coal diet. It is the intention to trial a coal of approximately 26% VM, which would be a “normal volatile” coal for all other UK coal-fired power stations (towards the mid-point of their design VM specifications).

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1. Principles to Maintain Safe Operation

Compared to the semi-anthracite coals currently burnt by Aberthaw, clouds and layers of bituminous coal dust are easier to ignite and more liable to self-heat under certain conditions. Of most significance for coal-fired power plant is that unlike semi-anthracites, bituminous coals can produce, in the event of a mill pressurisation caused by ignition of a dust cloud, propagation leading to increased and potentially excessive pressures for in the pulverised fuel (PF) pipework. Although the VM content of the trial coal is expected to be at the mid-point of the range of the high VM project fuel specification it will be higher than the current station VM limit temporary – controls additional to those associated with normal operation will therefore be required to mitigate the.

Between maximum and minimum mill throughputs the air:fuel ratio is so low (i.e. the dust concentration is so high) that the conditions within the mill are not conducive to ignition and flame propagation and explosion propagation into the PF pipework is greatly inhibited.

Mill explosions typically occur if a fire is present when the conditions within the mill are conducive to ignition and flame propagation (at high air:fuel ratios). Depending on the conditions within the PF pipework propagation of the explosion from the mill may not occur; if it does damaging pressures in the pipework are a foreseeable, but not certain, consequence.

In the type of mills installed at Aberthaw high air:fuel ratios are present for very short periods of time at start-up, shut-down and trip. The most significant occasion is when the mill is being emptied: high air:fuel ratios are present for much longer and may be concurrent in both the mill and PF pipework; operational experience from other plant with similar mills is that this is when the most significant incidents have occurred. Consequently emptying of tube ball mills is an infrequent operation (even in high VM coal stations using these mills) which is typically only performed prior to a major outage (i.e. once every 4-5 years) and takes up to an hour to complete (compared to a few minutes on vertical spindle mills); thus operators have sufficient time to react to a coal flow failure before the mill empties significantly.

The main principles of the trials are therefore: -

- **to avoid operation at high air:fuel ratios (start-up, shut-down, emptying, very low mill levels);**
- **make provision for minimising the impact of adverse events;**
- **to operate all high VM mills at similar throughputs to ensure that the trial duration is as short as practical;**
- **exclusion of personnel from risk areas (outlined in Section 1.1).**

The trial plans satisfy this first principle by performing an on-load coal change from low VM coal to a high VM coal and back to a low VM coal. As described above avoiding operation during high risk periods will maintain very low air:fuel ratios (i.e. very high dust concentrations) in the mills and 24" pipework which significantly reduces the risk of a mill explosion and consequent propagation in to the PF pipework.

The first principle is also satisfied by: -

- Coal selection: by using coals of similar grindability (HGI value) the risks to operation at low mill levels during the change-over periods between low and high VM coals is reduced.
- Specified trial load: sufficiently high to obtain representative emissions and performance data whilst leaving margin to capacity on milling plant to reduce the

risk of plant trips (through limited primary air capacity) – of relevance when switching to a lower NCV coal and/or harder coal. The Unit will be frequency insensitive to give firing system stability

- Defect assessments prior to the trials: with sufficient notice allow plant defects to be identified and corrected prior to the trial date. The trials will be postponed if numerous or significant defects are identified.
- Information from the single mill High VM coal will provide valuable information on safety when undertaking the trial. The trial will provide experience of furnace indications during a fuel change-over.

The high VM mills will be operated with all burners in service as far as is possible in accordance with firing strategy for the LNBo technology.

It is acknowledged that whilst the measures above will confer a significant degree of safety, the residual risks associated with a mill trip and/or operating a mill during the high risk periods outlined above cannot be eliminated and will be managed through exclusion of personnel from areas of risk.

It is further noted that the single mill trial of high VM coal will be a short duration trial i.e. approximately 4 hours.

1.1. High VM Exclusion Zone

Risk areas will be confirmed in a revision to this test plan once the mills which will operate on high VM coals have been identified. Drawings showing the extent of the areas will also be provided. The duration of the exclusion zone is discussed in Section 2.

Outline exclusion areas are: -

- Unit 9 mill bay.
- Unit 9 operating floor in vicinity of feeders.
- Burner arches.
- Areas adjacent to PF pipework and dynamic classifiers.
- Burner arches.

2. Coal Specification for High VM trial

The exact coal to be purchased for the trial is to be will be known closer to the date of the trial. It is intended that the coal will be about 26% VM as received (i.e. bituminous) and have a similar HGI / NCV to coals currently burnt at Aberthaw (for reasons outlined in Section 1).

The high VM coal to be purchased should be sufficiently different in sulphur content to the coal used immediately prior to the trial to allow the flue gas SO_x indications to be used to estimate the proportion of coal being burned. This is essentially because of the way in which coal flow occurs within the coal bunkers. The coal purchasing specification is shown in Appendix A – note that the version for the trial will have a higher minimum HGI value.

3. Trial Plan

3.1. Requirements

- One train of high volatile (~26% VM) test coal, 1400-1500te (~8hrs full load operation)
 - 6 hours continuous running at 100% high VM at full load
 - with 1 hour at start and end of test for coal change over
- Ashing / sootblowing to be completed on the night before the trial
- AFW on site to assist with the trial
- External Testing House (LPS) required for gas analysis / grit collection at the electrostatic precipitator inlets
- Horiba gas analysis at the booster fan outlet
- Bunker levels to be run low the day before the trial and any accumulations of coal trimmed in line with standard procedures.
- Portable CO detection equipment to be used in bunker house – to be located above the bunkers
- Local fire team and fire-fighting arrangements confirmed
- HGI, proximate, petrographic analyses of test coal and assessment of handling properties.

3.2. Pre-test Checks and Actions

- Coal consignment specification is checked to be within agreed parameters
- Coal feeders to be cleared before the trial – tensioner condition checked
- External PF pipework inspection completed to confirm absence of PF leaks.
- Inspection and thermal image survey of conveyor route
- Conveyor route is to be cleaned
- Burner Shut Off Damper (BSOD) survey completed during week preceding the trial, this is to confirm that there are no passing BSODs or blocked PF legs.
- Bunker level indications are in working order and are logged on station's data recording system.
- Scaffold barriers in place to denote exclusion zone boundaries and signage ready for application when zones are in effect.
- Bunkers on non-trial units to be maintained at a high level.
- Operations and maintenance teams briefed with any temporary operating instructions.
- Sign-off and agreement that all pre-requisites have been fulfilled ahead of sending coal to bunkers – Production Manager, Ops Team Leader, Head of Materials Handling and ETS Test Coordinator

3.3. Test Overview

The test is split into several periods: -

- Operation on a standard low VM coal;
- The unit will be set up for high VM combustion (mainly modulation of dampers) and trial conditions;
- Subsequent assessment of low VM combustion with a high VM combustion set-up.
- Exclusion zone becomes effective.
- High VM test coal will be sent to the test Unit's bunkers – effects a coal change whilst the unit is on-load.
- Subsequent assessment of high VM combustion
- Standard low VM coal will be sent to the test Unit's bunkers – effects a coal change whilst the unit is on-load.
- Revert Unit settings back to pre-trial conditions.
- Exclusion zone ceases.

These sections are considered in detail below: -

Unit Operation before the Trial

- Unit to be operated with a low VM stock coal before the trial.
- Unit to be operating with 5 mills / 30 burners in service with throughput equalised across the mills.
- Out of service mill to be filled to the top with low VM stock coal (this mill will be used to supplement the five high VM mills if they cannot achieve the nominated test load).
- Bunkers for operating mills to be maintained at low levels with low VM stock coal.
- Biomass co-firing to be taken out of service to remain out of service for the period of the trial.

Unit set-up for High VM coal

- Unit load is reduced to ~500MWgen and fixed to provide margin on milling plant capacity.
- All six burners per mill are kept in service if possible with dynamic classifier speeds adjusted to maintain mill pressure: -
 - If required the number of burners in service can be reduced
 - Minimum Dynamic Classifier speed of 100rpm (similar HGI coal to current specification)
- The Unit's combustion settings are altered to high VM coal settings before the high VM fuel is bunkered up:-
 - Mill outlet temperature setpoint reduced to 75°C and stabilised, hot air to mills temperature to be lowered through closure of the hot gas tap and opening of the warm gas tap.
 - Primary and secondary air dampers set up to adjust air flows as required.
 - An improved understanding of the burner settings will be determined during the single mill high VM trial and through involvement of LNBo technology suppliers in trial planning.

Delivery of High Volatile Coal to the Unit

- **The start of the transfer of the high VM test coal to the bunkers brings the exclusion zone into force.**
- Coal is delivered to site by train and will be conveyed directly to the test Unit's bunkers (likely in two batches)
 - Avoids managing the high VM coal on the stockyard.
- The bunkering of high volatile coal will be undertaken manually by the coal plant and not by the automated system.
 - Conveying routes to be confirmed as correct prior to unloading from the train hopper.
 - Bunkers are topped up with high VM coal to target a 9am start for the high VM fuel coming through to the mills.
 - Coal to be tracked from train to bunker by test team personnel / CCTV.
 - Bunker levels to be monitored to ensure that the coal is fed to the correct unit and bunkers.
- Top of train unloading hopper to be cleaned down into hopper before high VM transfer to bunkers is finished.
- Train unloading hopper to be emptied of high VM coal.

High VM Coal is Fired on the Unit

- High VM coal is observed to come through due to change in SO₂ emissions, change in NO_x and flame scanner response.
 - (N.B. expected flame scanner response will be informed from single mill trial).

- If the mills have spare capacity the unit load is increased to 535MWgen or to maximum within the unit's capability but ensuring at all times that the mills have margin and the unit is immediately derated if the boiler has to overfire e.g. loss of a feed-heater, mill etc.
- The unit's combustion is optimised from the control room – lowest NO_x within acceptable CO range.
 - Emissions are monitored and recorded on high VM coal
 - LPS take extractive Carbon in Ash (CinA) samples from the precipitator inlets and undertake gas analysis (access to this area does not require entry into the exclusion zone).

Return to Low VM Coal

- Bunkers are topped up with low VM stock coal.
- Low VM coal is observed to come through on all mills – emissions and flame scanners
- The Unit's combustion settings are reverted to those for low VM coal
 - Mill outlet temperature remains at 75°C until the exclusion zone is lifted.
- The next low VM coal train which arrives after the trial is to be sent to stock. This is intended to dilute any residual high volatile coal which remains in the system.
- Conveyor route to be cleaned following the end of the trial
- **The exclusion zone will remain on the unit until 4 hours after the low VM fuel has been identified to come through on the unit (allows residual high VM coal in the bunkers to come through).**
 - **This may be extended if the SO_x emissions indicate that high VM is still present in the system.**
- After the exclusion zone has been lifted the mills may then be taken out of service and restarted normally if required.
 - If a mill is taken out of service prior to this it is to be assumed to contain high VM coal and to be washed out in line with the procedure in Aberthaw's Pulverised Fuel Code of Practice (PFCoP).

4. Actions in Abnormal Operation

High Volatile Coal Identified to be sent to the wrong unit or to the out of service mill on the test Unit.

Conveying route to be started empty prior to coal being unloaded from track hopper – test team / materials handling staff to confirm route is acceptable prior to unloading.

As the transfer will be under supervision use the pull key to halt the conveyors and cease the transfer. Precise actions will be determined once the quantity of coal has been identified. Bunkers not scheduled to receive high VM to be maintained at a high level to minimise the quantity that can be added.

High Volatile Coal Identified to be sent to stock

Conveying route to be started empty prior to coal being unloaded from track hopper – test team / materials handling staff to confirm route is acceptable prior to unloading.

As the transfer will be under supervision use the pull key to halt the conveyors and cease the transfer. Precise actions will be determined once the quantity of coal has been identified and whether it has gone to top load hopper or boom stacker.

Management of Residual High VM coal in the Track Hopper or Coal Conveyor System

High VM in the track hopper should be sent to the live pile, identified as high VM, embargoed and used as a blend coal under guidance from central technical support team.

Management of a tripped mill containing high VM coal

Treat as detailed in the “Out of Service Mill Fire” section below.

Single Feeder Trip

Attempt to restart the feeder. If that is unsuccessful then trip the mill and treat as detailed in the “Out of Service Mill Fire” section below. Shear pin replacement requires working in the exclusion zone which is not permitted. Single ended operation can result in high temperatures on the end supplied from the tripped feeder and this increases the fire risk.

Total Loss of Coal Feed to a Mill

Attempt to restart the feeders if they have stopped. If that is unsuccessful or feeders had not stopped then trip the mill and treat as detailed in the “Out of Service Mill Fire” section below. The instructions in the PFCoP require local operation of the bunker gates which requires entry into the exclusion zone which is not permitted.

High Final Steam Temperatures and High Metal Temperatures

On Unit 9 OFA settings should be adjusted to manage final steam temperatures. If steam temperatures cannot be controlled load should be reduced.

Low Bunker Level

Materials handling staff should inform the control room of low bunker levels; if coal cannot be supplied in time then the mill should be taken out of service and treated as detailed in the “Out of Service Mill Fire”

Bunker Funelling

Proceed in accordance with the instructions in the PFCoP.

Blowback in the Bunkers

Proceed in accordance with the instructions in the PFCoP.

Bunker Fire

A bunker fire will be identified from the CO detection equipment in the bunkerhouse. Dependent on the nature of the fire the associated mill should be taken out of service.

Fire in an Operating Mill

Proceed in accordance with the instructions in the PFCoP.

Out of Service Mill Fire

Leave until the exclusion zone has been lifted and manage in line with the instructions in the PFCoP unless fire-fighting can be effected without entering the exclusion zone. Feeder and bunker emptying will be required in line with existing operating procedures. The mill can then be returned to service once the bunker on low VM coal.

Appendix A – High VM Coal Specification for Trial

	basis	typical value	lower limit	upper limit
Proximate analysis				
total moisture	ar	8	6	12
inherent moisture	db	3.5		5
ash	ar	12.5	8	16
VM	ar	26	23	28
VM	db	28.3		
FC	ar	54	39	60
Ultimate analysis				
Carbon		66		
Hydrogen		3.7		
Nitrogen		1.5		1.5
sulphur		0.4	0	1.35
chlorine		0.04		0.1
Phosphorus			0.01	0.05
Oxygen		7.7		
Calorific value				
GCV		26.2		
NCV		25.2	23.5	28
Hardgrove Index				
HGI		70	65	100
Ash composition				
SiO ₂		50		
Al ₂ O ₃		35		
Fe ₂ O ₃		3.3		10
TiO ₂		1.8		
P ₂ O ₅		1.8		
CaO		4.5		6
MgO		1		
Na ₂ O		0.2		1.5
K ₂ O		0.4		
SO ₃		2.1		
Total		100.1		
Coal size				
% > 75 mm				0
% > 50 mm				3
% < 3.35 mm				30

Appendix C - Modelling

To support the original PPC application for Aberthaw power station RWE undertook water quality modelling using a hydrodynamic model of part of the Severn Estuary.

The hydrodynamic model was obtained from Welsh Water and was accepted as fit for purpose by the then regulator EA Wales. The model is set up to run within Deltares' Delft3D software package.

A modified version of the same hydrodynamic model has been used to predict the change in water quality with the proposed pH limit. This section provides full details of the hydrodynamic and chemical modelling.

Modelling the chemistry

The modelling undertaken to support the PPC application was carried out using Deltares' water quality module (Delwaq). The current approach is somewhat different as the chemistry modelling has been undertaken using a standalone chemistry modelling package and model output presented in GIS in order to enhance the interpretation of the modelling. The chemistry model predicts the pH of a mix of seawater and CW effluent and is described in detail below.

Modelling seawater pH change

The pH of the sea water as it is discharged from the seal pit is determined by the amount of alkalinity remaining after the FGD effluent combines with the remainder of the cooling water flow and is aerated in the SWTP. To calculate the pH of the sea water as the effluent mixes with local ambient seawater at the discharge point a mixing model was used in PHREEQC which is a geochemical modelling program. The PHREEQC¹ software is part of a suite of programs from the United States Geological Survey used by WRc to model surface and ground water for the Environment Agency.

The model was set up to mix water with a pH of 5.6 or 6.0 with ambient sea water with a pH of 8.0. For the purposes of modelling the pH in the cooling water discharge is varied by varying the alkalinity remaining in the discharge water to achieve the desired pH. It is important to realise that the model assumes all reactions are at equilibrium. Various ratios of ambient sea water to cooling water discharge were modelled and the pH mixing curve below is calculated. The pH mixing curves were fitted to a logarithmic curve (due to fact that pH is the negative logarithm of the hydrogen ion concentration) for use in the hydrodynamic model. The majority of the neutralisation of the discharge takes place within a mixing of 20% ambient sea water with the cooling water discharge.

¹ User's guide to PHREEQC (version 2)—A computer program for speciation, batch reaction, one dimensional transport, and inverse geochemical calculations, Parkhurst and Appelo, US Geological Survey, 1999

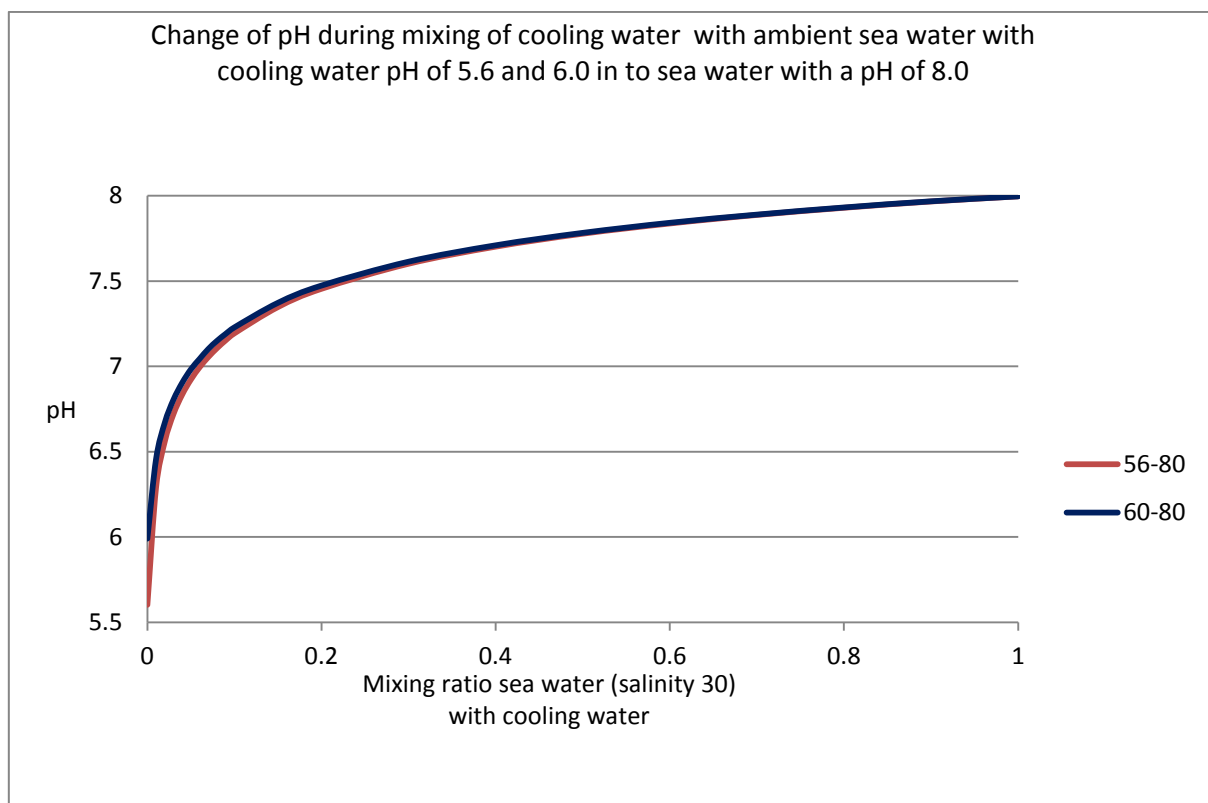


Figure 1 Predicted pH of FGD discharge (pH 5.6 & 6.0) mixed with ambient seawater (pH 8)

The assumption that the rate of the alkalinity neutralisation is much faster than the mixing and can therefore be assumed to be instantaneous from a modelling perspective (i.e. the equilibrium assumption above) was confirmed by laboratory measurements. Samples of ambient seawater were reacted with cooling water taken from the seal pit and mixed in various ratios from 10 to 50% and the change in pH was monitored. The results are shown in the figure below.

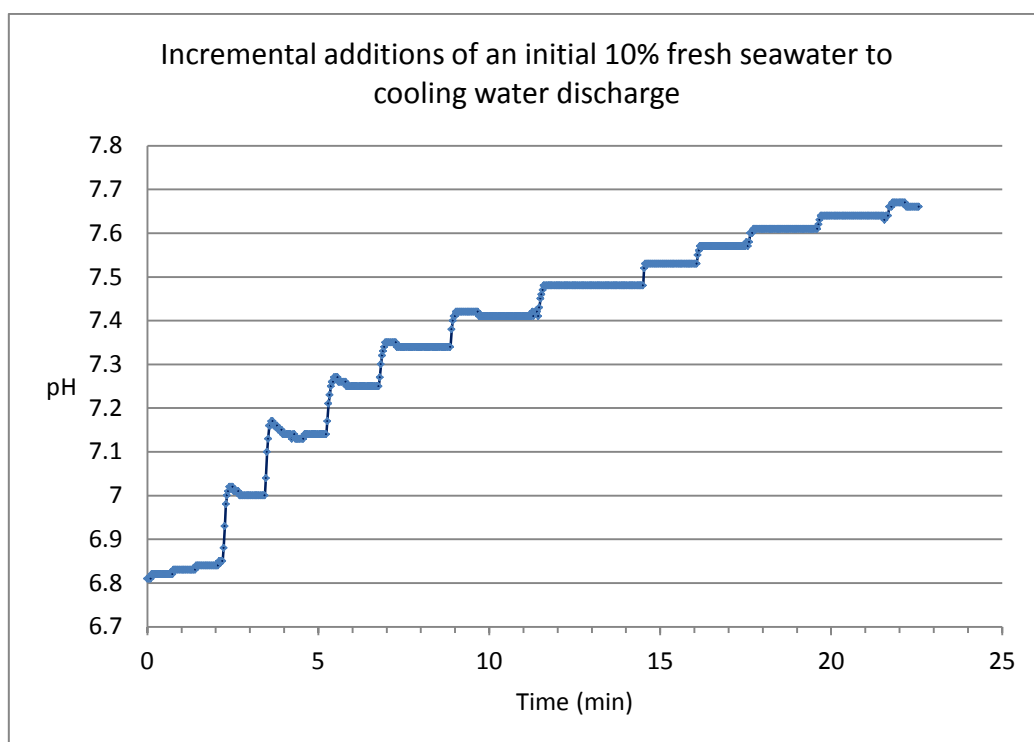


Figure 2 Sequential dilution of cooling water sample with ambient seawater

In the graph (Figure 2) above data points are 2 seconds apart and it can be seen that the reaction is complete within 10 to 14 seconds after each dilution.

On-line data at the seal pit discharge sampling point indicates that the oxygen saturation level is at 100%. The absolute concentration of oxygen will however vary with temperature and salinity and is shown in the figure below. This shows the percent change in the absolute oxygen content for a 13.5°C temperature increase across the cooling water system. This shows that for the maximum temperature difference the absolute dissolved oxygen content will change by approximately 15% assuming the oxygen saturation level is kept at 100%. As part of the trial it is proposed to measure the sulphite concentration at the inlet and exit to the de-aeration pit to confirm the model of the FGD system. Since the level of sulphite in the pit is a measure of the oxygen demand this will provide an early indication of any changes to the oxygen saturation level.

In conclusion, it is not expected there will be any reduction if dissolved oxygen levels released in the Power Station's cooling water discharge.

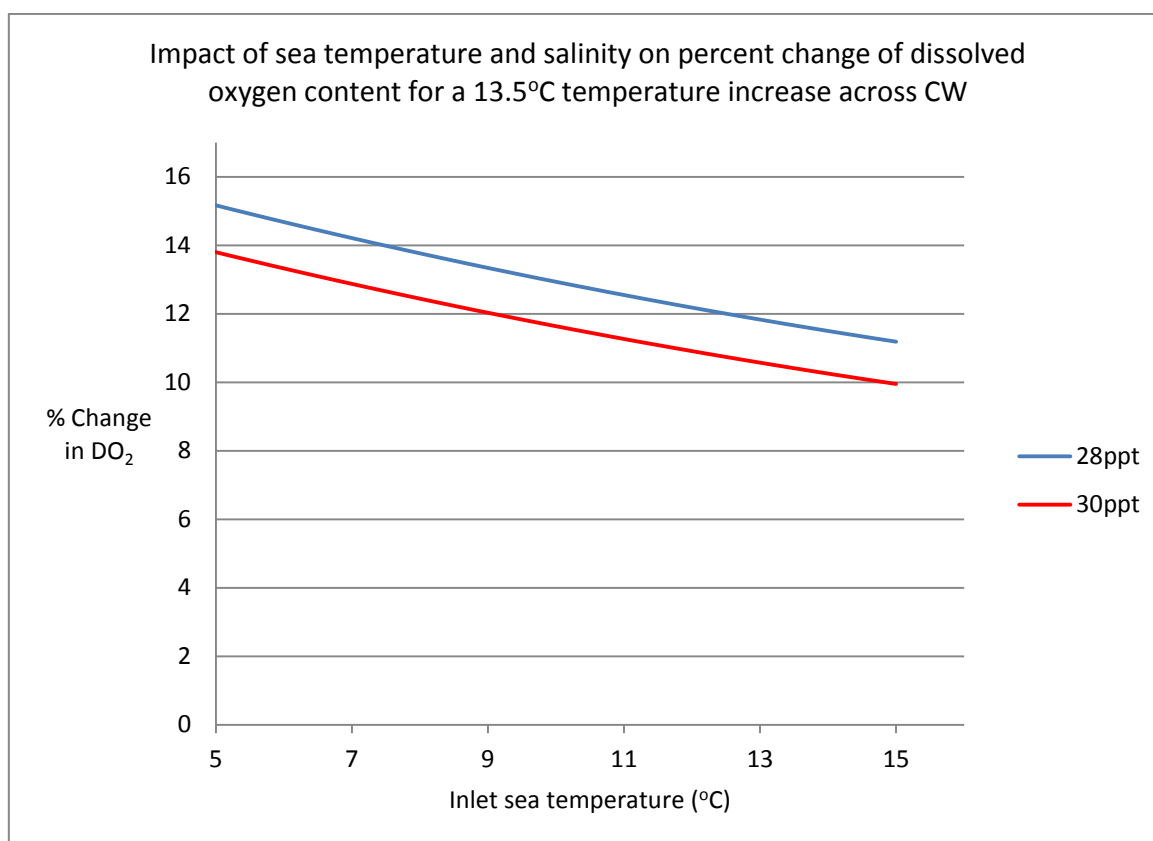


Figure 3 Predicted influence of salinity and intake temperature on % dissolved oxygen content with the permitted condenser temperature rise.

Solubility of Oxygen and Ozone in liquids, R Battino et al, J. Phys. Chem. Ref. Data, Vol. 12, No. 2, 1983, 163 – 178.

The condenser rise assumed to calculate the data plotted as Figure 3 is the permitted maximum rise between intake and outfall for Aberthaw (the permitted maximum is a 98%ile daily average).

Ammonia speciation

The figures below display the changes in the concentration of the ammonium ion with pH, the speciation was calculated using the equation from the paper of Bell et al referenced below. The pKa which is both temperature and salinity dependent shifts to higher pH with the resulting effect of a small drop in the ammonia concentration as the pH is lowered. The changes in the $\text{NH}_4^+/\text{NH}_3$ ratio is very small and in the pH region of 5 to 7 is less than 0.5% even at 25°C.

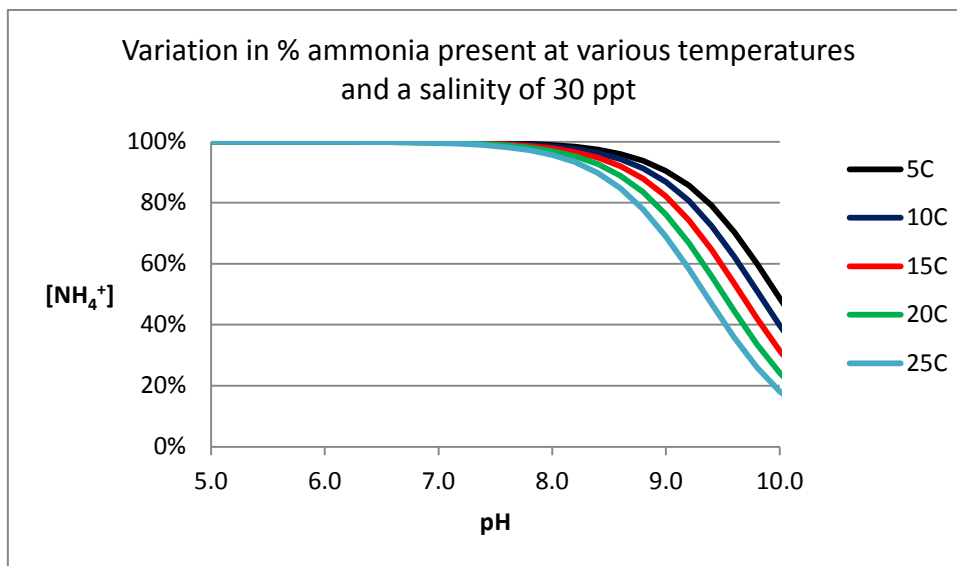


Figure 4 Predicted variation in % ammonia with temperature, salinity and pH (5 to 10)

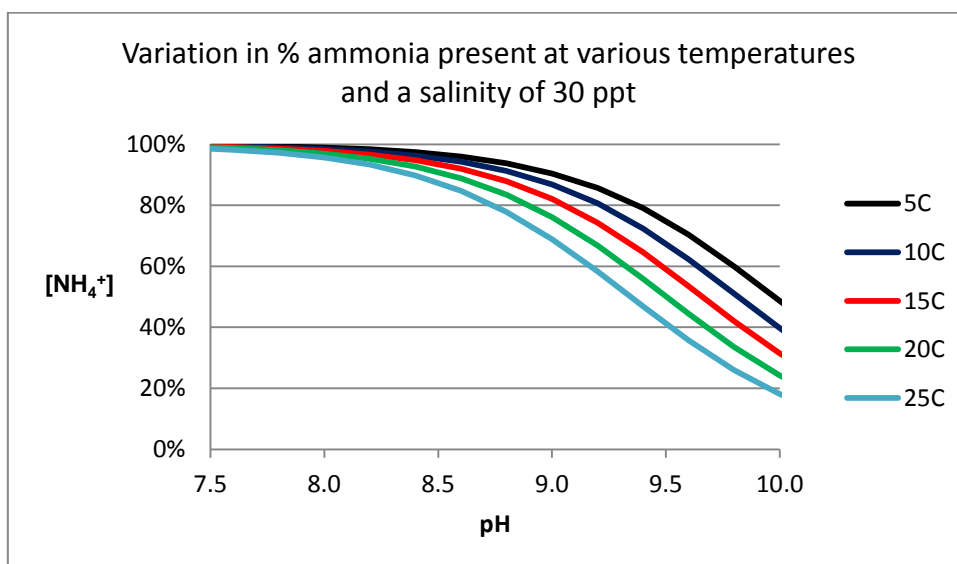


Figure 5 Predicted variation in % ammonia with temperature, salinity and pH (7.5 to 10)

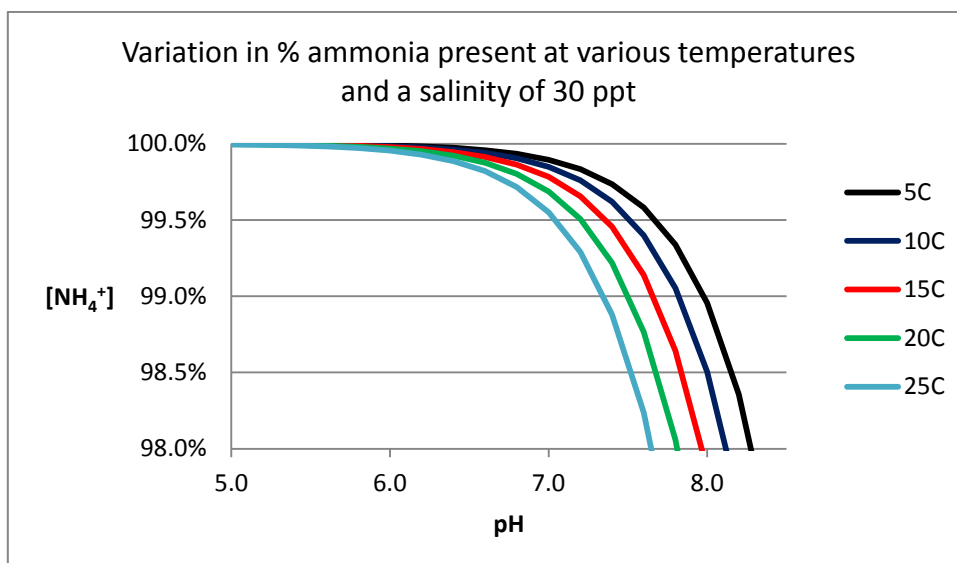


Figure 6 Predicted variation in % ammonia with temperature, salinity and pH (5 to 8.5)

Hence in conclusion, it is not expected that any significant variation in ammonia / ammonium ion concentration will occur in the Power Station's discharge associated with the operation at the lower pH levels.

Metal speciation

As the pH of seawater decreases both hydroxide and carbonate ion concentration will decrease. Both of these ions form strong complexes with di and trivalent metal ions. The lower pH will affect the adsorption of metals to organic particulate. As a general rule most metals are more soluble as the pH is lowered. The table below details the changes in metal speciation with pH, but does not consider metal organic complexation reaction which for the Bristol channel is likely to be significant.

Metals that form strong complex's with chloride will see little if any change in speciation as the pH varies because the concentration of chloride remains constant. Those metals which are strongly complexed to carbonate will see a significant decrease in the carbonate form and a corresponding increase in the free metal form. Species in the table below which significantly increase with a decrease in pH are highlighted in bold.

Table 4 Speciation of metals for pH 8.1 to 7.4

pH	8.1	8.0	7.9	7.8	7.7	7.6	7.5	7.4
Cd^{2+}	20.15	20.17	20.18	20.19	20.20	20.21	20.21	20.22
CdCl^+	43.71	43.75	43.78	44.10	43.82	43.80	43.85	43.86
CdCl_2	27.70	27.72	27.74	28.07	27.77	27.78	27.79	27.79
CdCl_3^-	7.95	7.95	7.96	7.97	7.96	7.97	7.97	7.97
HgCl_2	11.80	11.80	11.80	11.80	11.80	11.80	11.80	11.80
HgCl_3^-	88.20	88.20	88.20	88.20	88.20	88.20	88.20	88.20
Zn^{2+}	80.58	84.41	87.45	89.85	91.74	93.22	94.38	95.29
ZnOH^+	5.65	4.70	3.87	3.15	2.56	2.06	1.66	1.33
ZnCO_3	7.16	6.10	5.10	4.20	3.47	2.82	2.28	1.83
Pb^{2+}	2.89	3.29	3.70	4.13	4.56	4.99	5.39	5.77
PbOH^+	4.24	3.83	3.40	3.03	2.66	2.31	1.98	1.68
PbCO_3	59.03	54.53	49.72	44.71	39.64	34.65	29.88	25.43
PbCl^+	13.09	14.86	16.74	18.68	20.63	22.54	24.37	26.07
PbCl_2	14.09	16.00	18.02	20.10	22.21	24.60	26.23	28.06
PbCl_3^-	6.40	7.27	8.19	9.14	10.09	11.03	11.93	12.76
Cu^{2+}	7.67	9.64	12.04	14.92	18.32	22.26	26.75	31.76
CuOH^+	4.70	4.70	4.66	4.59	4.47	4.30	4.12	3.88
CuCO_3	66.98	68.51	69.25	69.14	68.14	66.25	63.50	59.96
$\text{Cu}(\text{CO}_3)_2^{2-}$	18.34	15.26	12.49	10.05	7.95	6.18	4.70	3.55
Fe^{2+}	65.99	70.42	74.57	78.36	81.76	84.75	87.33	89.53
FeCO_3	32.00	27.78	23.81	20.16	16.89	14.00	11.51	9.39
FeOH	1.40	1.20	1.01	0.84	0.69	0.57	0.47	0.38
Ni^{2+}	68.29	72.48	76.37	79.91	83.10	85.79	88.15	90.12
NiCO_3	30.29	26.15	22.30	18.80	15.69	12.97	10.63	8.64
Co^{2+}	92.58	93.81	94.84	95.69	96.39	96.97	97.44	97.82
CoCO_3	5.30	4.37	3.57	2.91	2.35	1.89	1.51	1.21
CoOH	1.45	1.16	0.93	0.75	0.60	0.48	0.38	0.30
$\text{Al}(\text{OH})_3$	32.18	37.34	42.76	48.32	53.82	59.10	63.98	68.30
$\text{Al}(\text{OH})_4^-$	65.53	62.24	56.63	50.81	44.96	39.22	33.72	28.59
Mn^{2+}	97.34	97.70	98.08	98.36	98.60	98.77	98.93	99.05

The fraction forms of metal in seawater as a function of pH at 25°C and salinity 35 ppt from "Effects of Ocean Acidification on the speciation of metals in seawater", FJ Millero et al, Oceanography, Vol 22, No4, 72 – 85.

Hence in conclusion, it is not expected that any significant variation in metal levels will occur in the Power Station's discharge associated with the operation at the lower pH levels.

Modelling the mixing

As noted previously RWE have a hydrodynamic model of part of the Severn Estuary. The model was developed for Welsh Water for use in understanding water quality impacts of marine discharges. The model is fully 2D and covers the estuary from a line between Porthcawl/Lynmouth and Chepstow/Oldbury.

The model was originally developed by Hyder Consulting Ltd for Dwr Cymru Welsh Water (DCWW). The model domain is approximately 90km long extending from the Severn Bridge in the east to Porthcawl in the west. A curvilinear grid was used to give higher model resolution in key areas (between Cardiff and Barry and a 2km strip along the north coast of the Bristol Channel). Grid resolution varies from 30m to 200m being about 60m in width in the area of the outfall. The model was developed in 2D because of the strong vertical mixing in the Bristol Channel. The DCWW Cardiff Coastal model was subject to extensive testing by its developers and independent peer review.

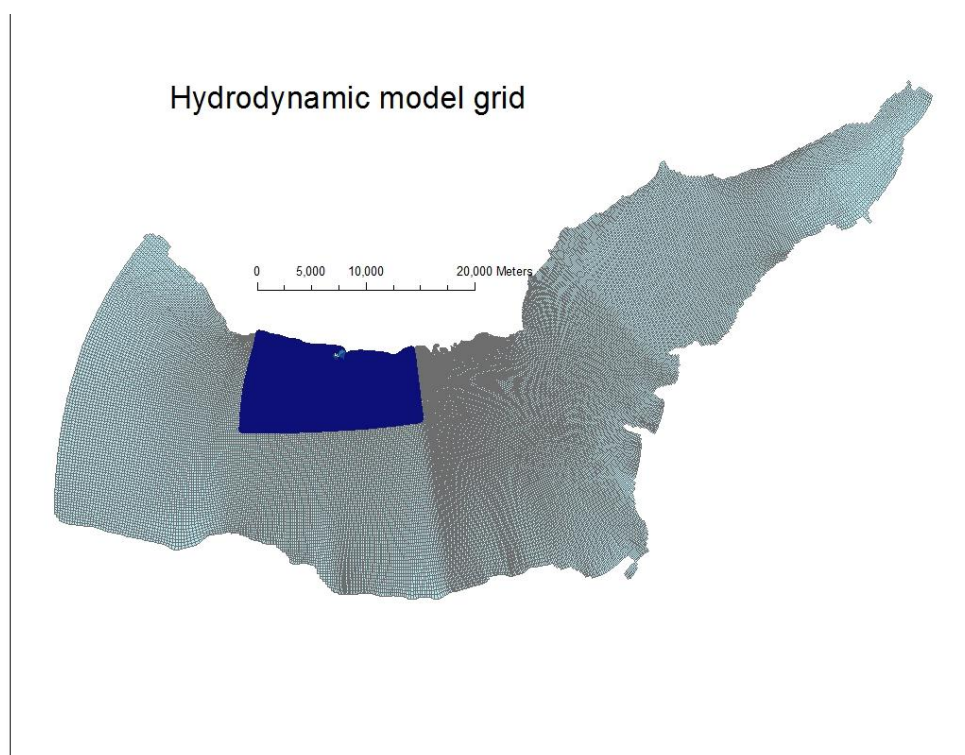


Figure 7 Overall hydrodynamic model grid in light blue (3D mesh in dark blue)

Whilst the model has previously been accepted as fit for the purpose of predicting mixing in the Severn recent Environment Agency guidance for modelling large power station discharges suggest the use of a 3D model to reproduce the influence of the buoyancy of the cooling water discharge in the mixing process.

In order to ensure that the modelling was consistent with current guidance a decision was taken to modify the model by incorporating a 3D zone around the outfall. The extent of the 3D domain was chosen to ensure that mixing of the cooling water plume over the vertical

was achieved within the 3D domain. The area of the nested 3D grid is shown in dark blue in Figure 7 above.

The following cooling water discharge conditions were simulated. A constant discharge flow of $50\text{m}^3\text{s}^{-1}$ typical of high load factor with a cooling water temperature rise of 14.5°C (for consistency with previous modelling). The intake and outfalls were linked in the model to reproduce the influence of recirculation on the discharge.

A conservative tracer was applied to the discharge to allow the dilution to be determined. Tracer concentrations were recorded every 20 minutes over a spring-neap cycle and the data processed in Matlab to generate a map of the dilution. The model was allowed to run for five spring-neap cycles before collecting map data. Plotting the predicted temperature at a number of sites in the estuary demonstrated that the warm up period was adequate to ensure that concentration, especially in the areas of interest, had fully developed.

The chemistry model discussed below was used to predict the final pH for a mix of discharge and ambient seawater. A curve was then fitted to tabulated dilution/pH data and used to convert the dilution maps into a map showing the pH with the discharge in operation. The chemistry model was used to predict the pH resulting from a discharge of water with a pH of 5.8 (current limit) and 5.6 (proposed limit) with seawater (pH of 8).

Plots have been produced showing the worst case (lowest) surface and bed pH with the current pH limit (5.8) and the proposed limit of 5.6

Current pH limit: lowest surface pH

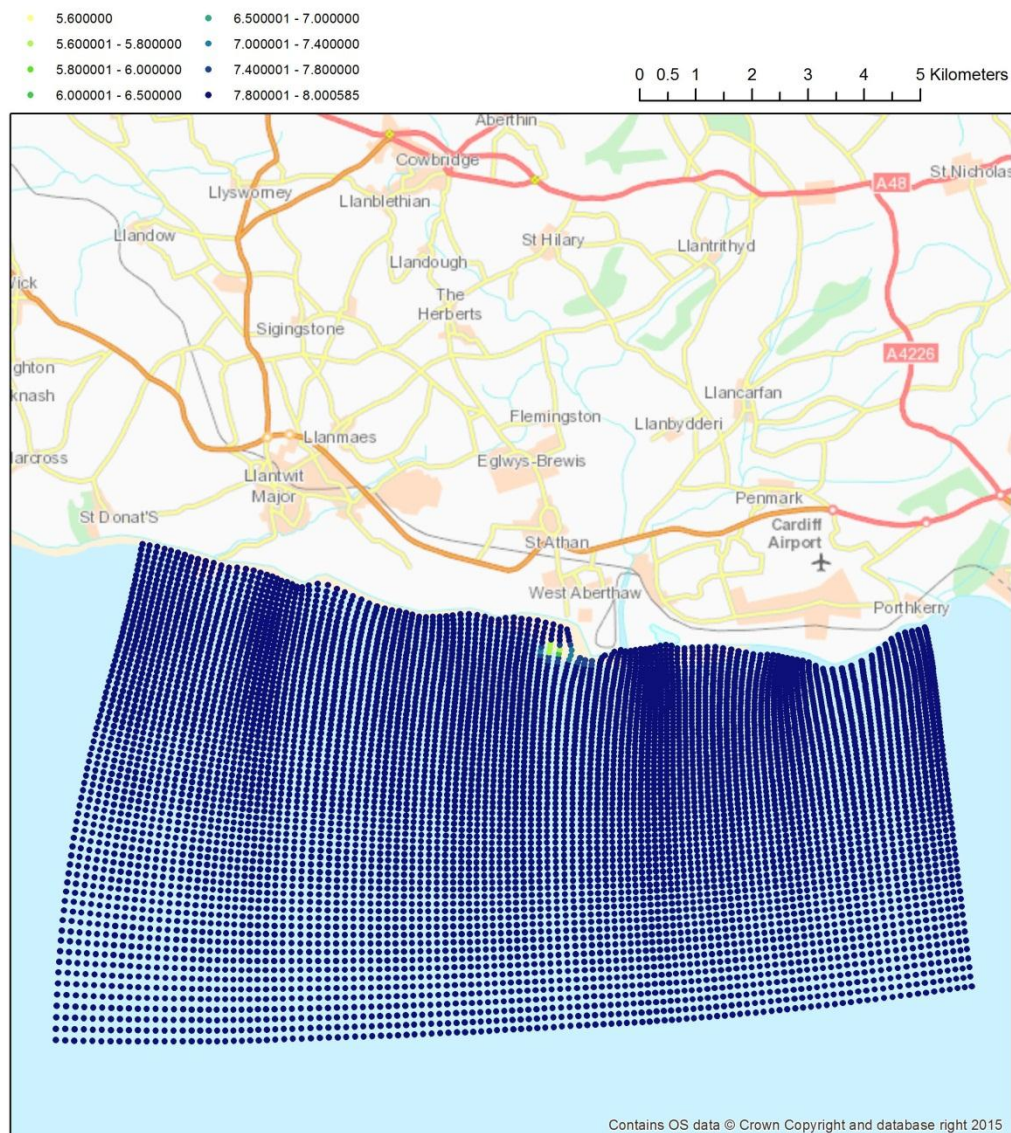


Figure 8 Predicted surface pH with a discharge of pH 5.8

The predicted change in surface pH plotted as Figure 8 for a discharge pH of 5.8 is limited to the vicinity of the outfall.

Current pH limit: lowest surface pH

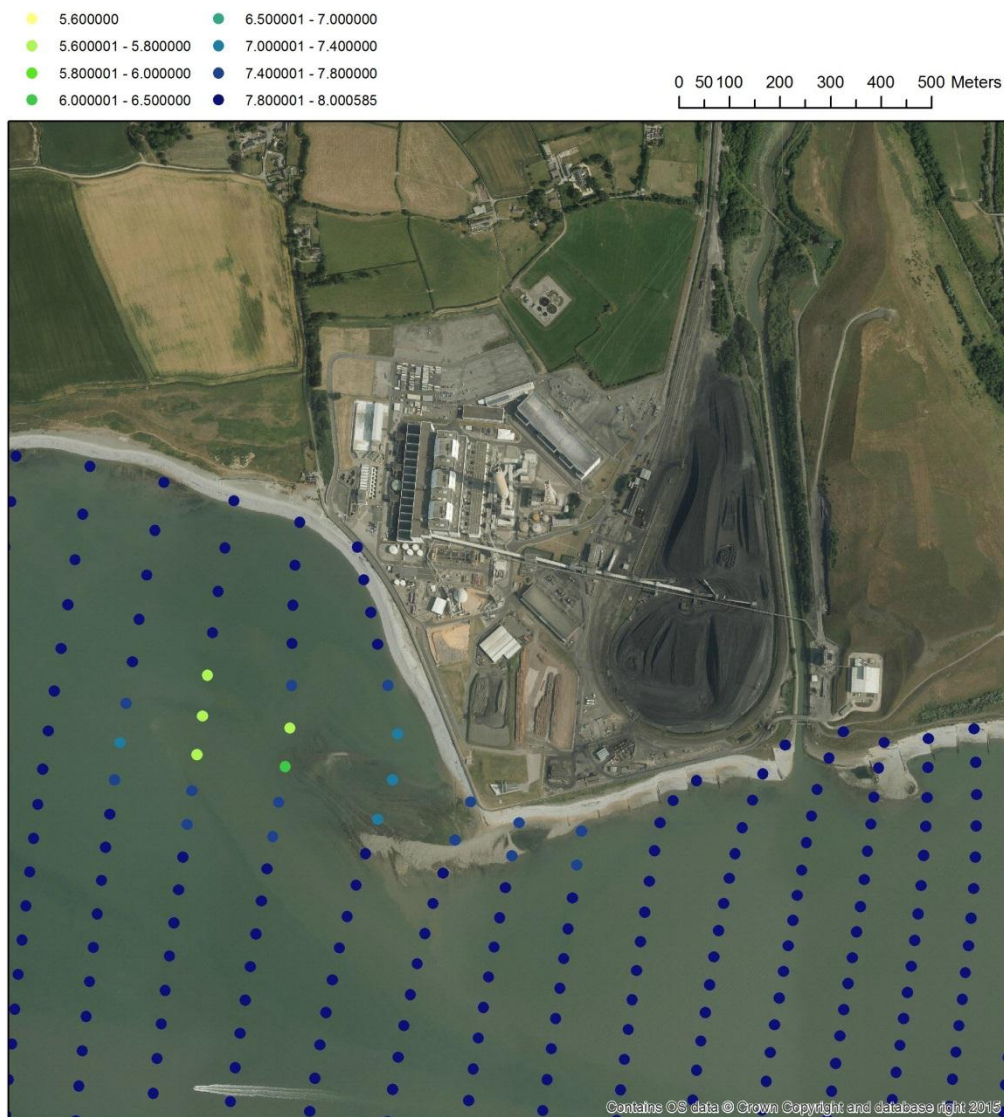


Figure 9 Predicted surface pH for a discharge of 5.8 - near to outfall

The predicted surface pH for a CW discharge pH of 5.8 is plotted as Figure 9 above. Each point plotted corresponds to a model grid cell. Differences in pH from ambient extend for a length of approximately 900m and a width of approximately 400m.

Current pH limit: lowest bed pH

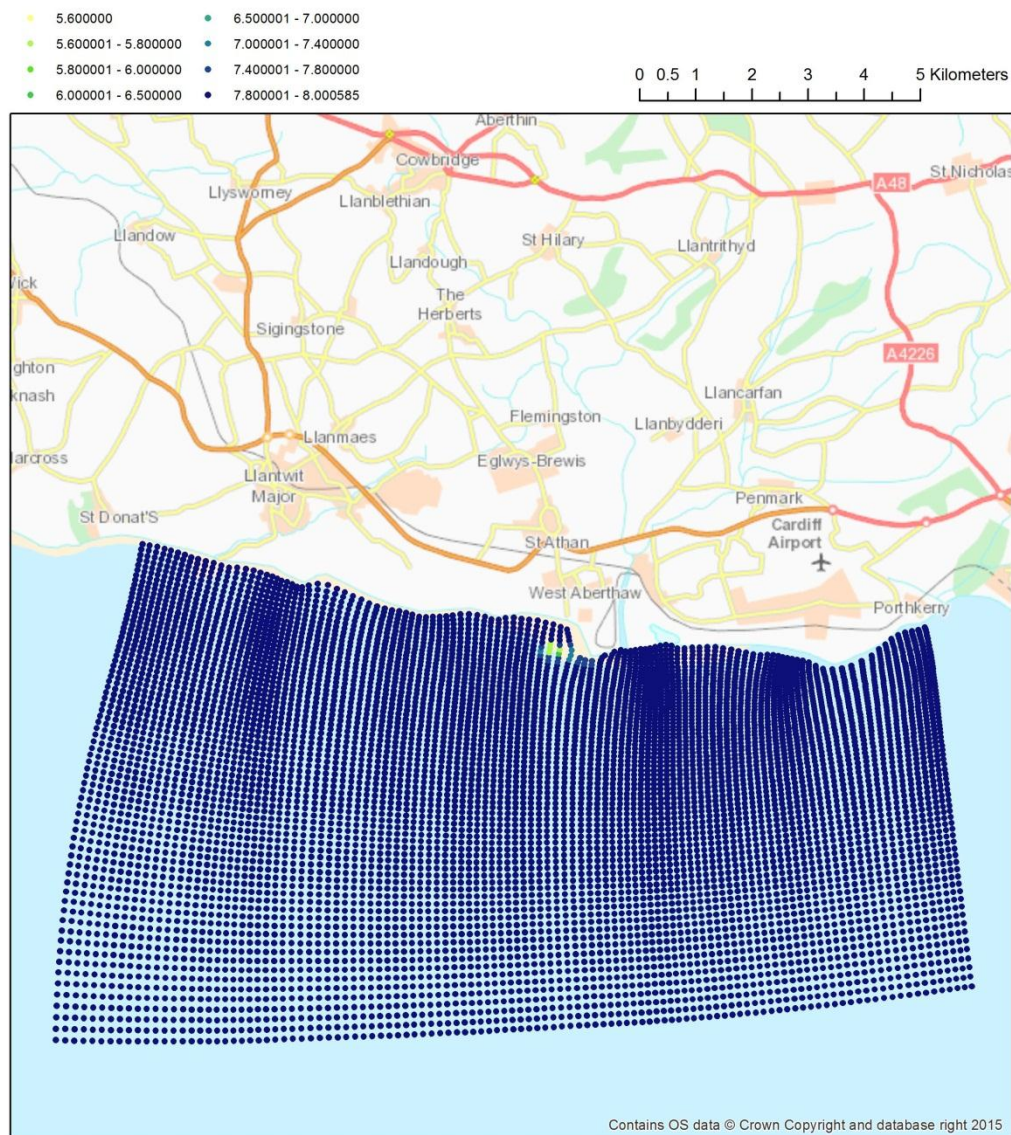


Figure 10 Predicted bed pH of a discharge of pH 5.8

The predicted change in bed pH for a discharge pH of 5.8 plotted as Figure 10 above is limited to the vicinity of the outfall.

Current pH limit: lowest bed pH

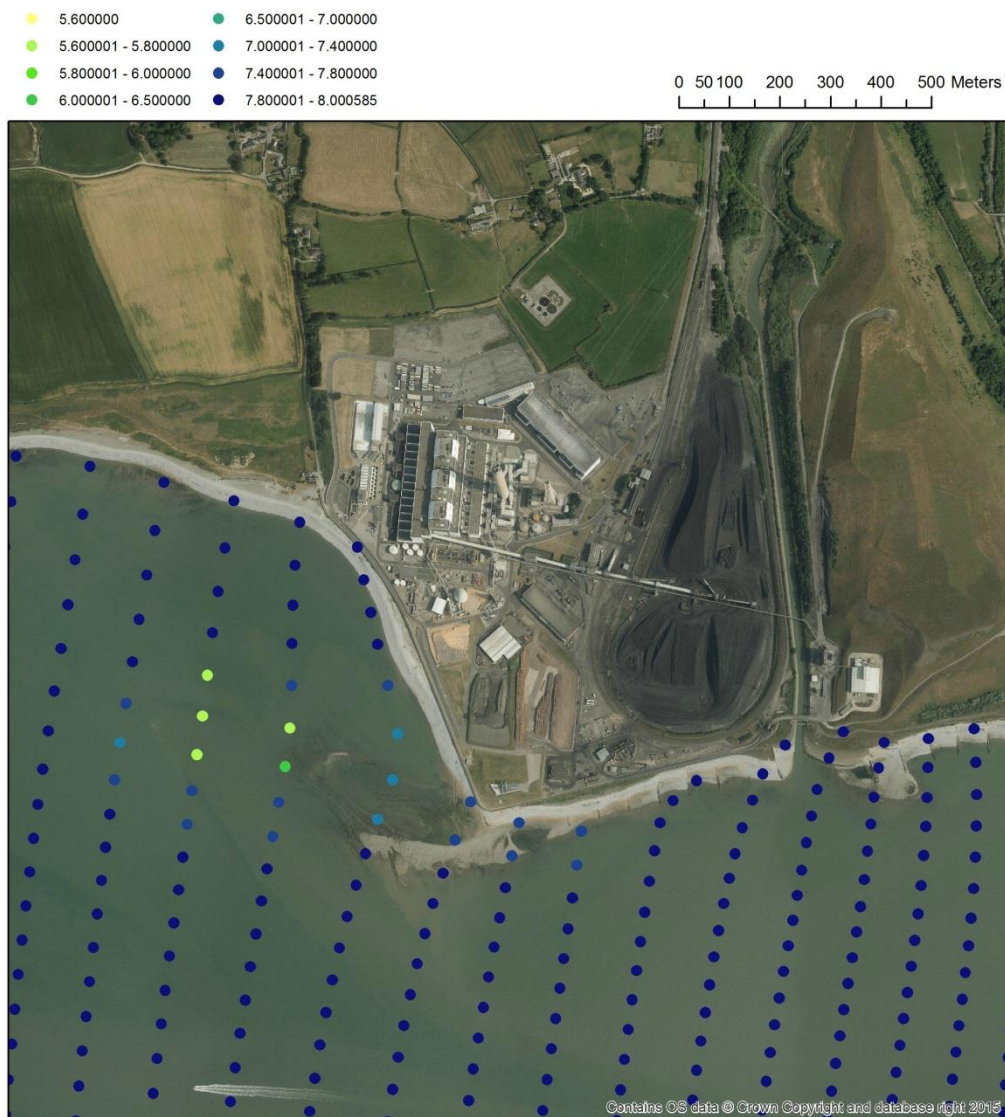


Figure 11 Predicted bed pH for a discharge of pH 5.8 - near outfall

The predicted surface pH for a CW discharge pH of 5.8 is plotted as Figure 10 above. Differences in pH from ambient extend for a length of approximately 900m and a width of approximately 400m. The predicted bed pH is similar to that at the surface.

Proposed pH limit: lowest surface pH

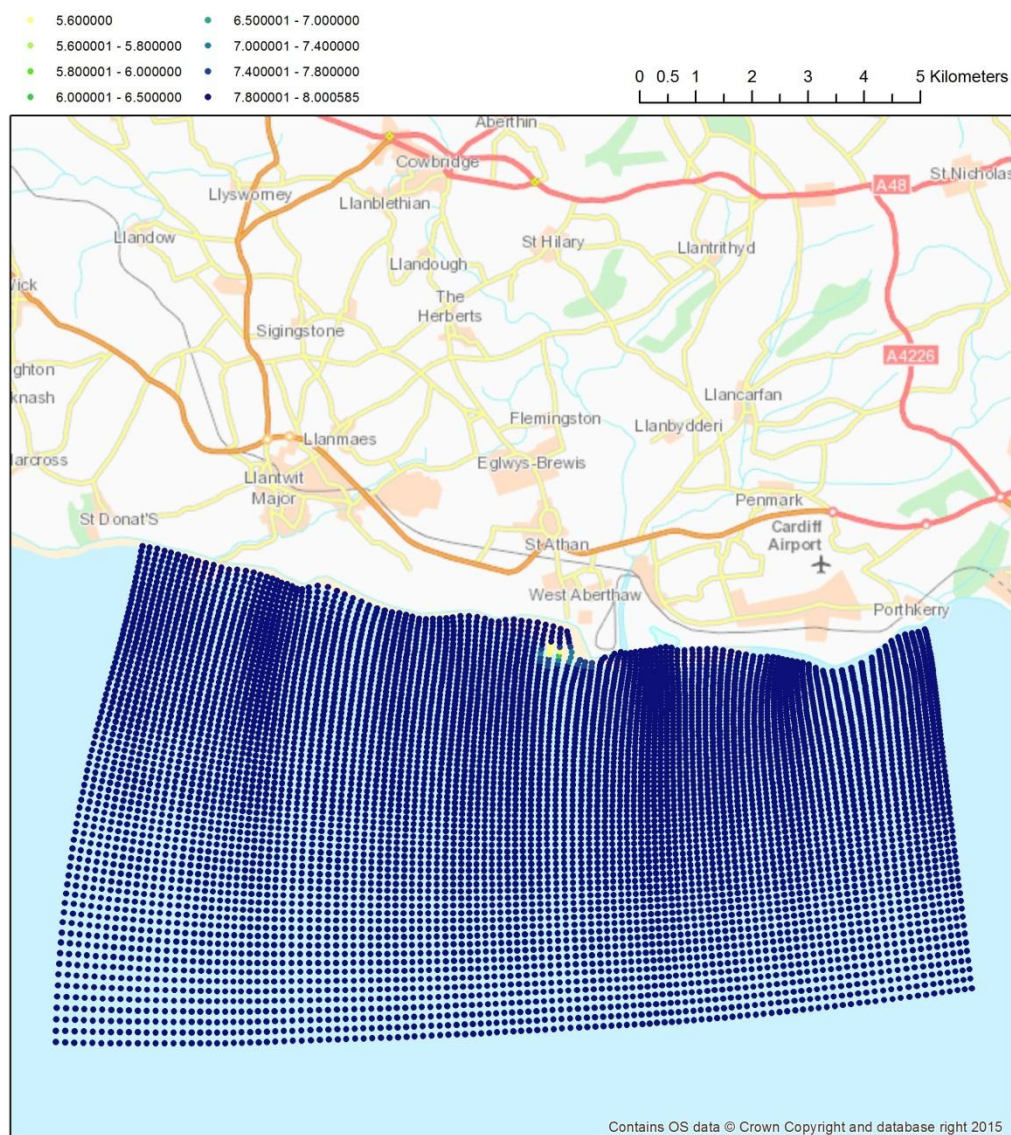


Figure 12 Predicted surface pH for a discharge of pH 5.6

The predicted surface pH for the proposed revised discharge limit of 5.6 is plotted as Figure 12 above. Changes in the pH from ambient are limited to the vicinity of the outfall.

Proposed pH limit: lowest surface pH

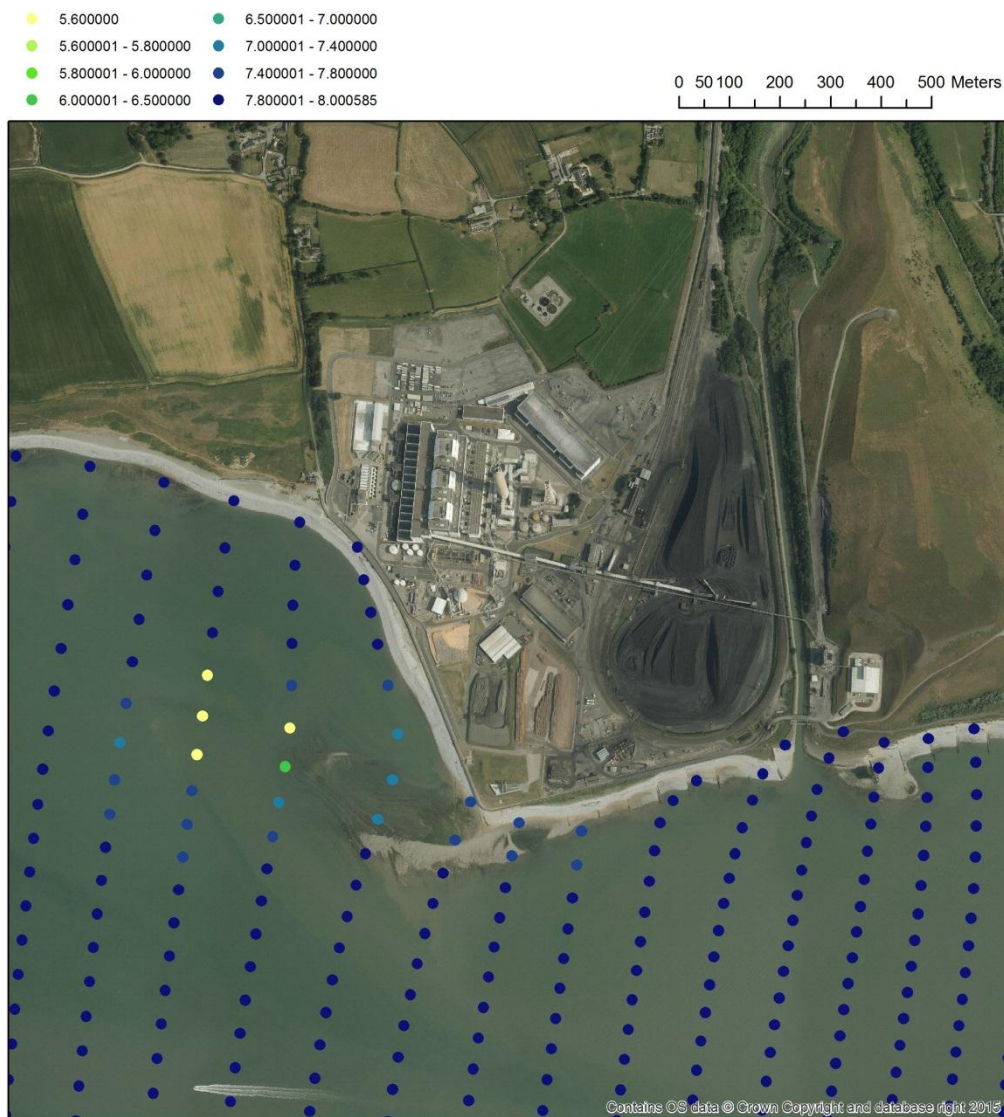


Figure 13 Predicted surface pH for a discharge pH of 5.6 - near outfall

The predicted surface pH for a CW discharge pH of 5.6 is plotted as Figure 13 above. Each point plotted corresponds to a model grid cell. Differences in pH from ambient extend for a length of approximately 900m and a width of approximately 400m.

Differences between the predicted surface pH with a discharge of 5.8 (Figure 9) and a discharge of 5.6 (Figure 13) are small and limited to the model cells adjacent to the outfall.

Proposed pH limit: lowest bed pH

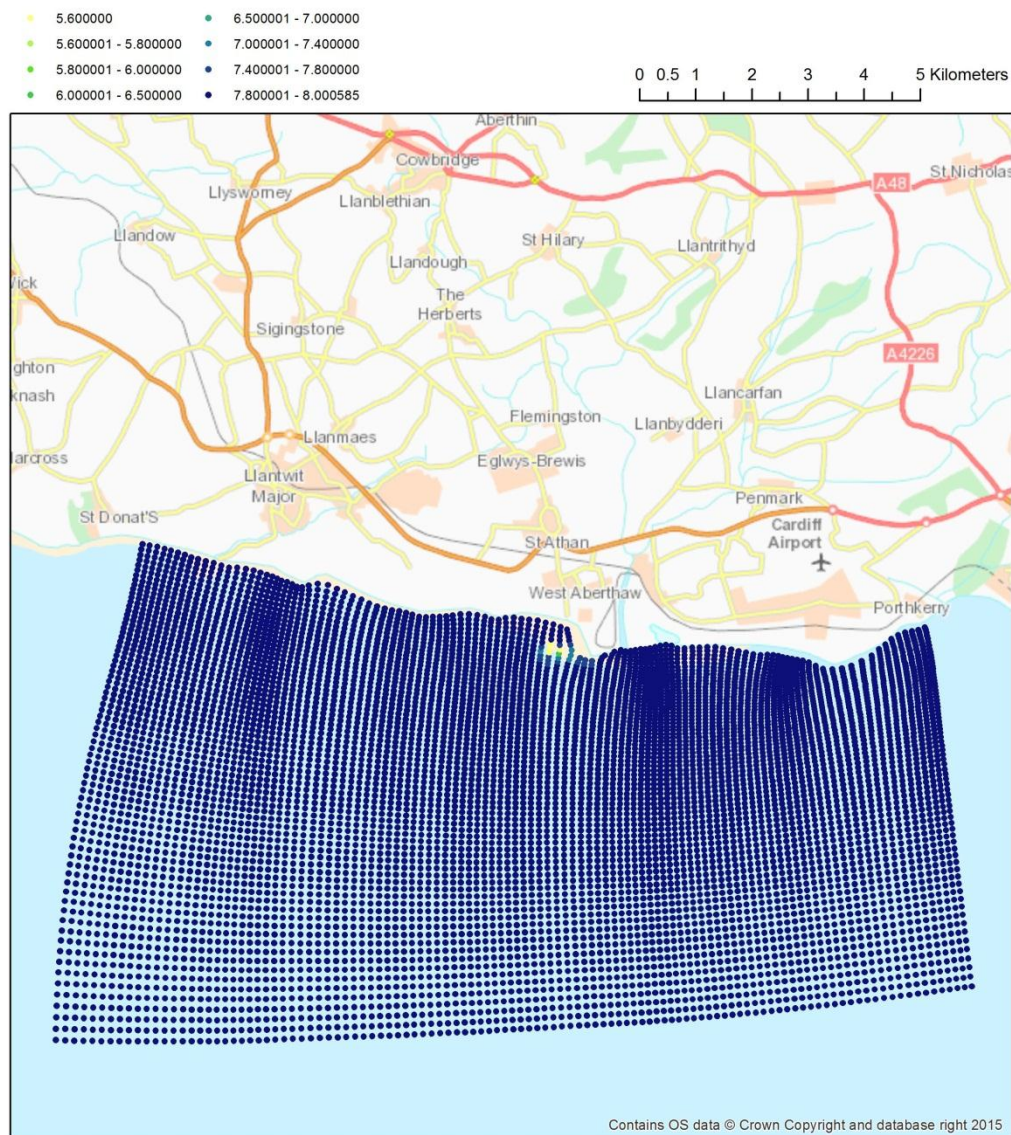


Figure 14 Predicted bed pH for a discharge pH of 5.6

The predicted bed pH for the proposed revised discharge limit of 5.6 is plotted as Figure 14 above. Changes in the pH from ambient are limited to the vicinity of the outfall.

Proposed pH limit: lowest bed pH

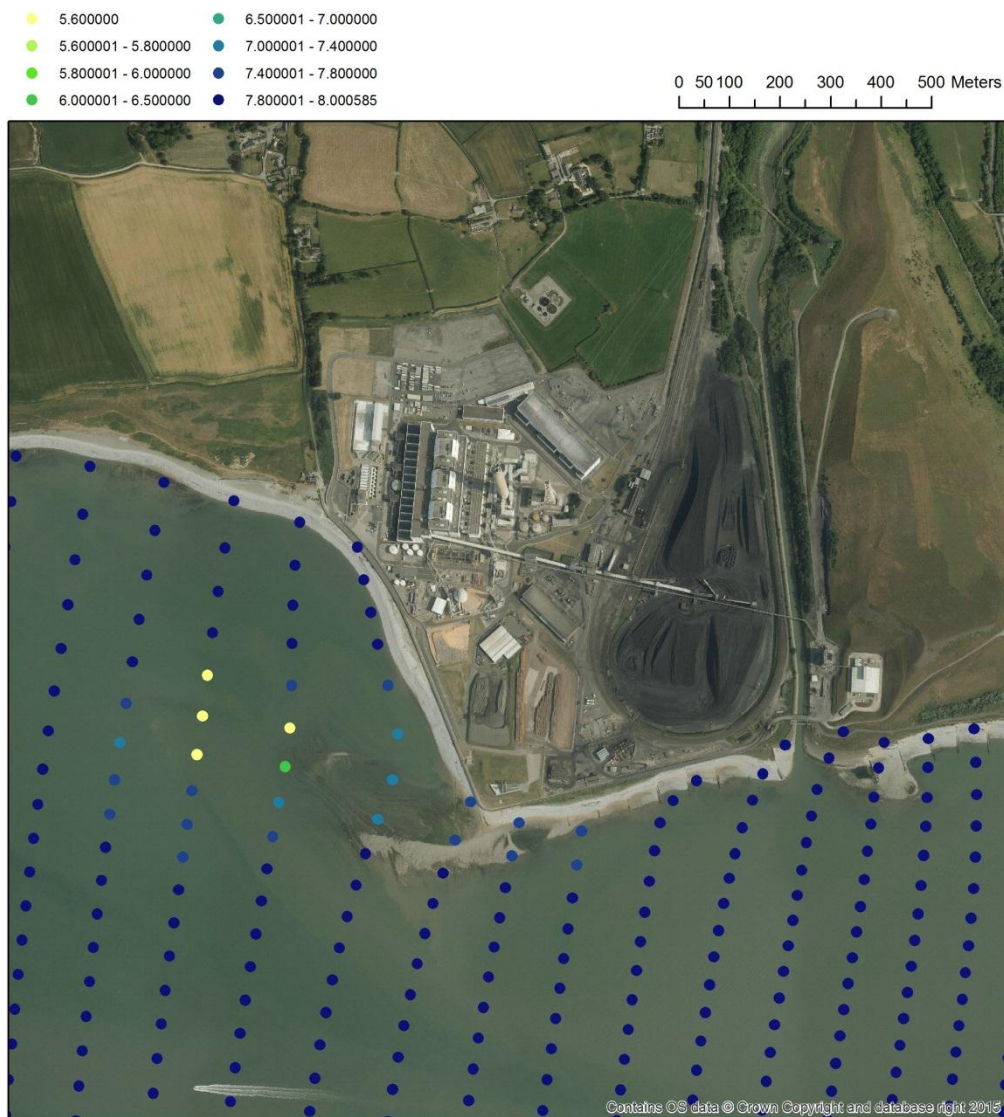


Figure 15 Predicted bed pH for a discharge pH of 5.6 - near outfall

The predicted bed pH for a CW discharge pH of 5.6 is plotted as Figure 15 above. Each point plotted corresponds to a model grid cell. Differences in pH from ambient extend for a length of approximately 900m and a width of approximately 400m.

Differences between the predicted surface pH with a discharge of 5.8 (Figure 11) and a discharge of 5.6 (Figure 15) are small and limited to the model cells adjacent to the outfall.

The hydrodynamic modelling predicts only localised differences in water quality with a reduction in of the discharge pH to 5.6 from 5.8. Differences are limited to the vicinity of the outfall away from which the pH is predicted to recover rapidly towards ambient.

The overall conclusion is that differences in the lowest pH between modelling using a discharge pH of 5.6 (proposed) and 5.8 (current) are observed within a small area (approximately 250m by 350m) of the Power Station outfalls and therefore the scale of any potential environmental impact is expected to be equally small (see section 7.2 and Appendix E for more detail).

Appendix D – Proposed Monitoring Proposal



Aberthaw Power Station Cooling Water pH Modification Project

RWE Generation UK Plc

Ecological Support Proposal

November 2015



Aberthaw Power Station Cooling Water pH Modification Project

Project no: tbc
Document title: Ecological Support Proposal
Document No.:
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Date: November 2015
Client name: RWE Generation UK Plc
Client no: n/a
Project manager: Matt Robson
Author: Chris Nikitik
File name:

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Document history and status

Revision	Date	Description	By	Review	Approved
0	09/11/15	Aberthaw pH variation – ecological assessment methodology	Chris Nikitik	Matt Robson	Matt Robson

1. Introduction

1.1 Background

Aberthaw Power Station is a 1500 MW coal-fired plant located on the South Wales coast 9 km west of Barry. It abstracts cooling water (CW) from, and returns it to, the Bristol Channel via two outfalls at mean low water near Breaksea Point.

In order to comply with new sulphur dioxide (SO₂) emissions limits introduced with The Large Combustion Directive, RWE npower installed a flue gas desulphurisation (FGD) operation using a sea water washing process which was commissioned in 2008. After passing through the condensers some 20% of the CW flow is diverted to the FGD absorber tower where it strips out most of the acidic gases from the flue gas, together with trace quantities of metals. This FGD stream is then recombined with the other 80% of the flow and aerated before discharge through the existing outfalls.

The pH levels of the discharge comply with discharge requirements established by the Environment Agency and currently regulated by Natural Resources Wales. However, due to possible changes in the coal supply it is anticipated that sulphur levels in the coal will increase which will result in lower pH of the of the discharge. In advance of this RWE are seeking a variation of their discharge conditions to accommodate the possible lowering of pH of the discharge with an initial trial period. To support the discharge consent variation application, an assessment of the likely impacts of the modified discharge on marine receptors is proposed.

The work involves targeted ecological surveys the results of which, in combination with desk studies, will inform the assessment. This document provides detailed methodology to be employed during the targeted field studies.

2. Targetted Ecological Survey Methodology

2.1 *Sabellaria alveolata*

There is concern that reduction in pH of the discharge may impact on populations of the honeycomb worm *Sabellaria alveolata* inhabiting areas influenced by the plume. Areas of Limpert Bay populations of this species, particularly to the west of discharges where significant areas of shore are colonised with the worm tubes forming biogenic reef structures. These *S. alveolata* populations will be monitored in order to determine any influence of any change of the discharge.

The extent of these reefs will be mapped and their condition assessed. Reference will be made to historical studies, particularly CCW biotope maps, in order to target areas of the shore where *S. alveolata* is present. These areas will be surveyed in and reefs mapped and assessed. Other areas identified during field surveys will also be mapped and assessed. A suitable reference site has been identified at Nash Point - the *Sabellaria* reefs here have previously been assessed and this information will be used as a historical baseline in combination with CCW biotope maps to assess any temporal change in character of reefs prior to proposed trial.

(i) Mapping – the presence of *Sabellaria* biotope will be determined in Limpert Bay and these will be mapped with the periphery of the identified areas walked and with all data logged on hand held GPS. Where smaller areas <25m² are identified these will be recorded as target notes and their positions recorded.

All data will be subsequently plotted on maps and extent of biotope compared to historical data.

(ii) Reef Assessment – the characteristics of the *Sabellaria* reefs will be examined with the forms of the reef determined in relation to “reefiness” which is defined by the extent, coverage and height of the colonies with the following colony types identified:

1. Well developed individual reefs forming colonies or platforms (>90% coverage, >10m² in area, >30cm in height);
2. Well developed individual reefs forming colonies or platforms (>90% coverage, <10m² in area, generally >30cm in height, but at least 10cm);
3. Recognisable area of *S. alveolata* over 10m² with patchy distribution (>50% coverage). Individual patches are of varying size but form recognisable reef structures (e.g. >10cm diameter/height), together forming recognisable area as opposed to discrete individual reefs as in type 2 reef (above);
4. Areas >10m² with very patchy distribution (<50% cover) but forming recognisable area of reef structures (>10cm diameter/width);
5. Low lying areas of *S. alveolata* forming barnacle like coverage on substrate and may include juvenile forms following settlement. This type may be prevalent at edges of well developed reefs and may be low abundance and patchy cover,
6. Low lying heavily silted and predominantly dead areas of relict *S. alveolata*.

An initial survey will be undertaken prior to the proposed trial in order to determine baseline conditions, further work will be undertaken in January and February to identify any possible acute impacts. If any detrimental impact to the relevant ecological system is identified this will prompt cessation of the trial. A subsequent survey will be undertaken in March to assess possible impacts over the period of the trial. If no adverse environmental impact results from the trial, these results may support a subsequent proposal by RWE for permanent application of the lower pH trial limits.

2.2 Community Study

Intertidal communities will be quantitatively assessed to determine any impact of the modified discharge on intertidal communities. A quadrat survey will be undertaken in the upper, mid and low shore zones with all biota enumerated with five quadrats assessed at each shore height; sites will be located in habitat representative of the shore height. Sites will be marked so that the same quadrats will be assessed on subsequent surveys. Abundance of all biota will be converted to relative abundance using the SACFOR scale. Sites will be arranged on four transects which will correspond with sites used for ongoing bioaccumulation studies. Communities will also be assessed at a reference site at Nash Point.

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2.3 Population Study

As an indicator of population “health” the condition of suitable target species will be assessed – suitable species will be limpets and winkles which are present in sufficient numbers across the shore at Aberthaw to support sampling. Sampling will be on the four transects identified and at the reference site with animals sampled where most abundant, although away from both quadrat sites and sites used for Aberthaw bioaccumulation study so as not to influence future work.

Sub-lethal responses of molluscs to chemical or environmental stressors can influence physiological processes such as tissue and/or shell growth. Such changes can be detectable by examining various size and weight relationships which can be employed as Condition Indices (CI). The CI of a target animal can be used as an integrated indicator of ‘health’, with higher values indicating better health status. From each transect the body metrics of 50 individuals of each target species will be measured and used to provide a condition index which can be used as a measure of population health. Animals will also be collected from a reference site at Nash Point. CI will be calculated using the following relationship between tissue weight and shell size.

$$CI = (\text{Tissue dry weight (g)} \times 1000) / (\text{shell height (cm)})^3$$

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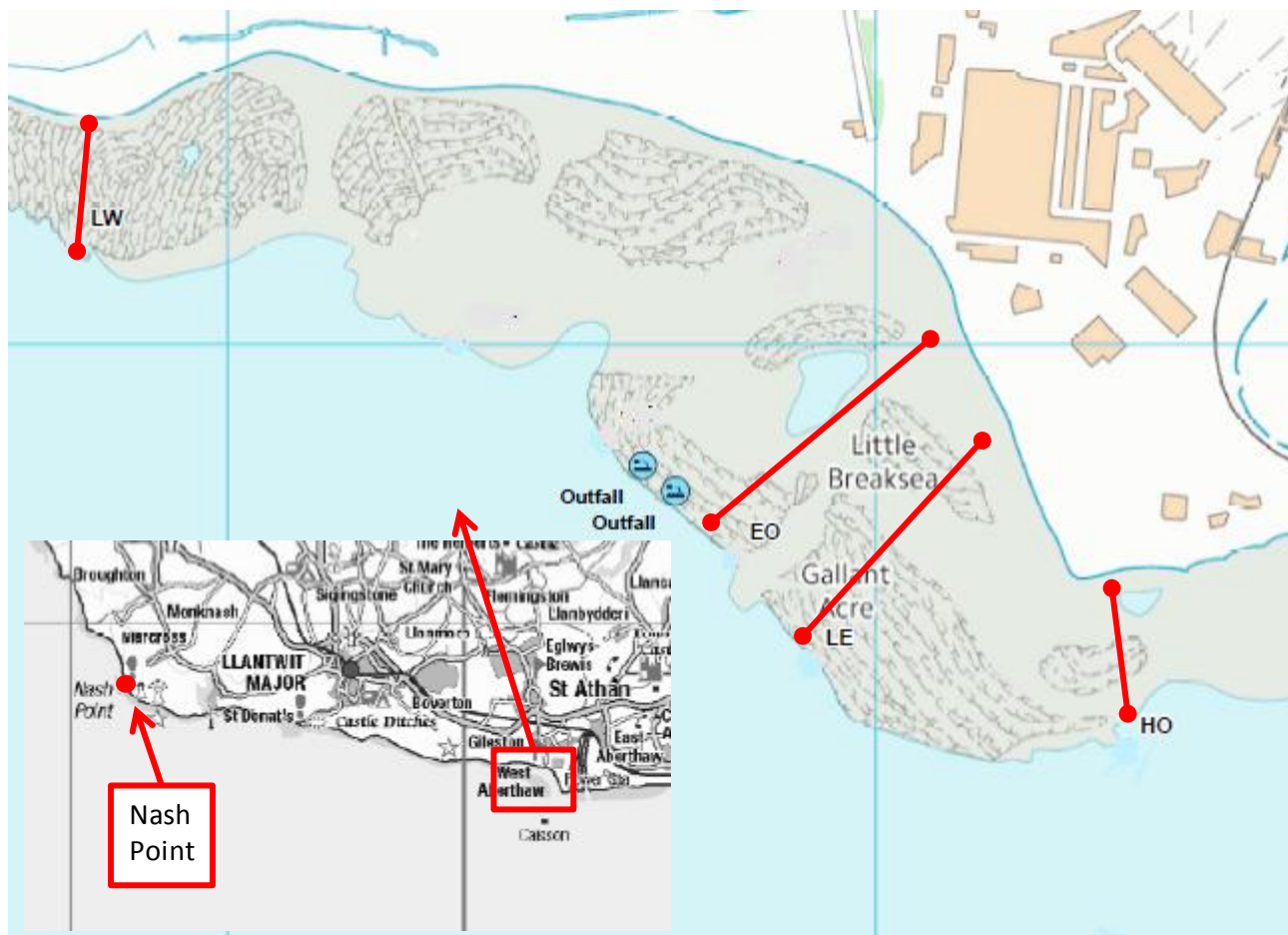


Figure 1. Survey sites/transects.



Aberthaw Power Station Cooling Water pH Modification Project

RWE Generation UK Plc

Ecological Support Proposal

November 2015



Aberthaw Power Station Cooling Water pH Modification Project

Project no: tbc
Document title: Ecological Support Proposal
Document No.:
Revision: 0
Date: November 2015
Client name: RWE Generation UK Plc
Client no: n/a
Project manager: Matt Robson
Author: Chris Nikitik
File name:

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Document history and status

Revision	Date	Description	By	Review	Approved
0	09/11/15	Aberthaw pH variation – ecological assessment methodology	Chris Nikitik	Matt Robson	Matt Robson

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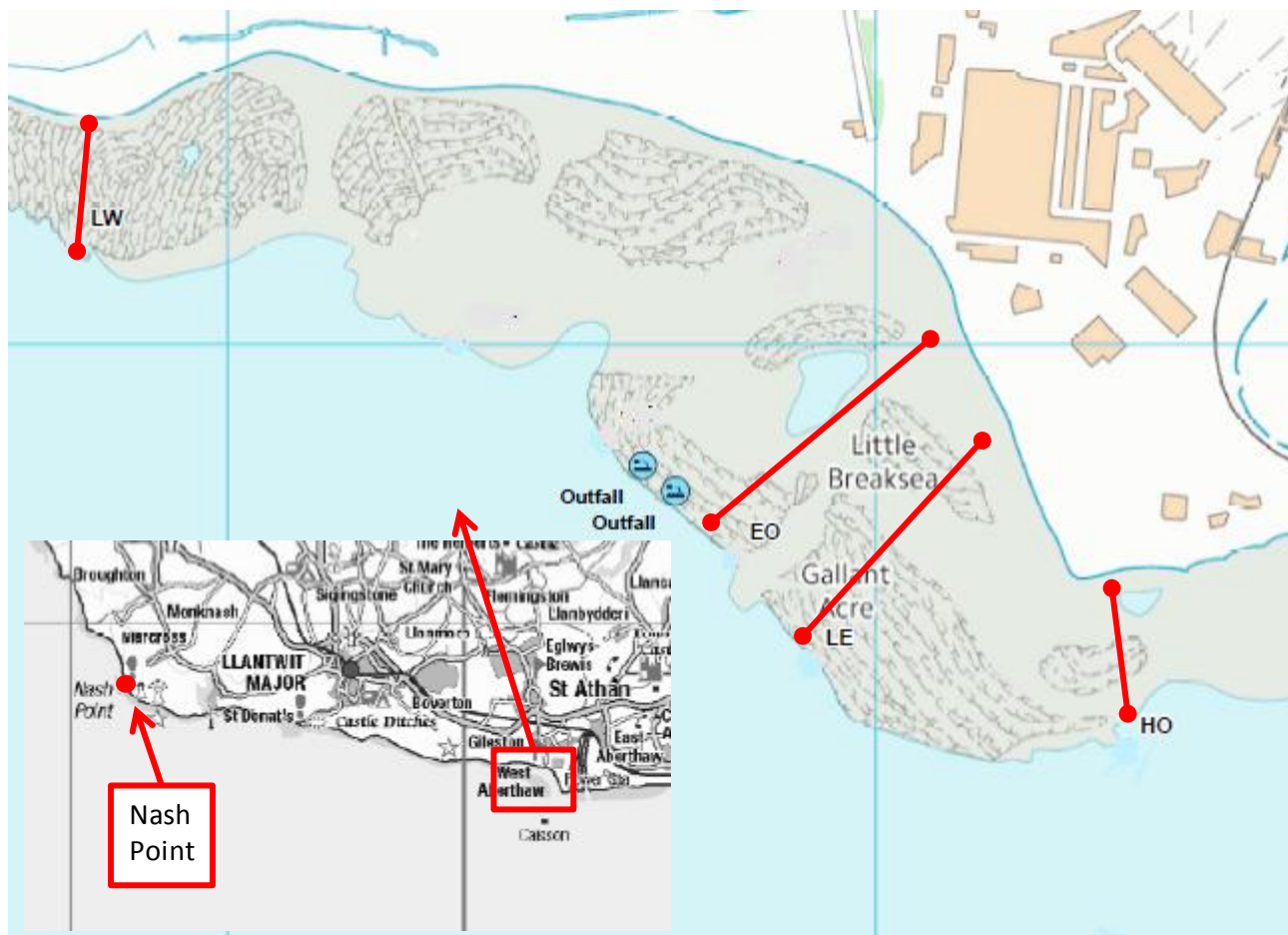


Figure 1. Survey sites/transects.

Appendix E – Ecological Impact



Aberthaw Cooling Water Discharge pH Variation

RWE Generation UK Plc

Environmental Report

| 0.1

30 November 2015



Aberthaw Cooling Water Discharge pH Variation

Project no: -
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Document No.: -
Revision: 0.1
Date: 30 November 2015
Client name: RWE Generation UK Plc
Client no: -
Project manager: Matt Robson
Author: Chris Nikitik
File name: -

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Document history and status

Revision	Date	Description	By	Review	Approved
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1. Introduction

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The pH levels of the discharge comply with discharge requirements established by the Environment Agency (now National Resources Wales - NRW). However, due to possible changes in the coal supply it is anticipated that sulphur levels in the coal will increase which will result in lower pH of the discharge. In advance of this RWE are seeking a variation of their discharge conditions to accommodate the possible lowering of pH of the discharge, with an initial trial period between January and March 2016 proposed. The current permit allows for an instantaneous pH of 5.8, with the proposal seeking a reduction of this to 5.6. As part of this process RWE are looking to support the variation application with an assessment of the likely impacts of the modified discharge on marine ecological receptors.

This document describes the current understanding of the ecology of the receiving environment and discusses the potential effects of the proposed change to the discharge on the ecological receptors. The report will be updated following completion of a pre-trial baseline survey. Further monitoring will be undertaken during and after the trial in order to determine any impacts.

The aims of the report are to:

- describe the baseline ecology of the surrounding area;
- identify important ecological receptors; and
- identify and assess the potential impacts on habitats, flora and fauna and designated areas of conservation importance.

2. Baseline Conditions

2.1 Marine Statutory Designations

Aberthaw Power Station is located in the upper Bristol Channel just downstream of what is considered as the mouth of the Severn Estuary, i.e. the line between Lavernock Point in the north and Brean Down in the south. Although not located within any designated conservation area, Aberthaw is close to a number of sites of conservation importance. The site is 16 km to the west of the Severn Estuary Special Area of Conservation (SAC) which includes five Habitats Directive Annex I habitat types, three of which are primary reasons for site designation: estuaries, mudflats and sandflats not covered by seawater at low tide and Atlantic salt meadows. Two further Annex I habitat types which are present but do not qualify as primary reasons for site designation are sandbanks which are slightly covered by seawater all the time and reefs. Annex II species that are a primary reason for designation of the site are the sea lamprey (*Petromyzon marinus*), river lamprey (*Lampetra fluviatilis*) and twaite shad (*Alosa fallax*).

The Atlantic salmon (*Salmo salar*) is also an Annex II species though is not a primary reason for the site designation of the Severn Estuary SAC. It is however a primary reason for SAC designation of both the rivers Wye and Usk, and fish migrating to and from these sites will migrate through the Severn Estuary and Bristol Channel.

The site is also to the west of the Severn Estuary Special Protection Area (SPA), designated under the EC Directive on the Conservation of Wild Birds, and the Severn Estuary Ramsar site under the Convention on Wetlands of International Importance, the nearest points being Flat Holm Island and Steep Holm Island which lie approximately 20 km from Aberthaw. The site supports an internationally important population of the Annex I species Bewick's swan (*Cygnus columbianus bewickii*) and also of the European white-fronted goose (*Anser albifrons*), dunlin (*Calidris alpina alpina*), redshank (*Tringa totanus*), shelduck (*Tadorna tadorna*), curlew (*Numenius arquata*) and pintail (*Anas acuta*). The site is also important for the ringed plover (*Charadrius hiaticula*) on passage during its winter migration.

2.2 Benthos

The seabed in the upper Bristol Channel lower Severn Estuary is predominantly hard with rock outcrops and areas of clean sand or mixed sand/gravel with muddy habitats present in the shallow sublittoral between Cardiff and Newport, and extensively off Bridgwater Bay. The hard substrates support an impoverished fauna characterised by the anemone *Sagartia troglodytes* and amphipod *Gammarus zaddachi*, while the muddy substrates also support an impoverished community characterised by polychaete species such as the cirratulid *Aphelocheata marioni* and the tube building *Melinna* sp. (Warwick & Davies, 1977). In the sublittoral areas off Aberthaw the exposed rock and hard gravelly sediment supported a community characterised by the honeycomb worm *Sabellaria alveolata*, the polychaetes *Eulalia tripunctata* and *Syllis armillaris*, and bivalve mollusc *Sphenia binghami* (Mettam *et al.*, 1994). These impoverished communities are a result of the naturally high turbidity which restricts light penetration, the variable or low salinity conditions and the strong tidal currents.

The intertidal habitats in the vicinity of Aberthaw are predominantly formed of rocky pavement, ledges and outcrops, interspersed with sandflats. The intertidal communities here are characterised by macroalgae such as *Fucus serratus*, *F. vesiculosus*, *Corallina officinalis* and *Ulva lactuca*; the fauna include the limpet (*Patella vulgata*) periwinkle, (*Littorina littorea*) top shell (*Gibbula cineraria*) dog whelk (*Nucella lapillus*) and barnacle (*Semibalanus balanoides*) (Bamber, 1997).

The honeycomb worm (*Sabellaria alveolata*) is also present in intertidal habitats at Limpert Bay. Aggregations of this tube dwelling species can result in reefs of considerable size which in turn support diverse communities. Although not a species of specific conservation importance the reef habitat is included on the Section 42 list of habitats of principal importance for conservation of biodiversity in Wales under the Natural Environment and Rural Communities (NERC) Act 2006. Countryside Council for Wales (CCW) biotope maps indicate the presence of the biotope LS.LBR.Sab.salv (*Sabellaria alveolata* reefs on sand-abraded eulittoral rock) to the west of the discharges, reflecting work reported by Innogy (2003) which indicated a similar distribution. This latter report stated that the condition of the reefs were a mixture of low encrusting veneer growth, 'ball'

formation, and the beginnings of taller reefs. In general the reefs were reported as being smaller than might be expected under optimal growing conditions, though generally in good condition and it was assumed that its proliferation in Limpert Bay was due in part to the elevated temperatures caused by CW discharge. However, it was noted that growth was noticeably poorer in the immediate vicinity of the western outfall. The honeycomb worm *S. alveolata* is also known from subtidal habitats in the Bristol Channel with reefs present 3 km south of Aberthaw (Innogy, 2003).

2.3 Fish

The waters of the upper Bristol Channel and lower Severn Estuary are home to a diverse range of fish, with 111 species recorded (Potts and Swaby, 1993). This list includes seven migratory species which is more than any comparable environment in the UK. Catches at power stations in the area indicate that fish communities are dominated by 10 species which make up 90% of all fish caught on intake screens (Bird, 2008). At Hinkley Point, 80 species have been caught on the stations intake screens with whiting (*Merlangius merlangus*), bass (*Dicentrarchus labrax*) and sprat (*Sprattus sprattus*) the most commonly reported; dab (*Limanda limanda*) was the most commonly reported flatfish (Henderson *et al.*, 2007). Generally, the intake biomass is dominated by juveniles, probably due to their weaker swimming speeds. Considering the extensive habitat available in the upper Bristol Channel and Severn Estuary it is accepted that this area represents an important nursery area for juvenile fish (Langston *et al.*, 2003).

The Bristol Channel and Severn Estuary is a vital route used by migratory fish species. These species are features of statutory designations, both in the Severn Estuary and its tributaries. Both the twaite shad and the allis shad (*Alosa alosa*) are known to return from coastal waters to the tributaries of the Severn in spring to spawn. Spawning stocks of the twaite shad are only known from a few rivers in Wales and on the England/Wales border, particularly the Usk and Wye. Similarly, the allis shad has been reported from the Severn catchment, although this is no longer considered to be a viable breeding population.

The river lamprey is widespread in the UK, although the main populations are reported as those which migrate into the Severn Estuary from the Bristol Channel and adjacent offshore waters. The sea lamprey is less common in the UK and although found around the coast, the main population centres are concentrated on the Bristol Channel (Bird, 2008). Both species migrate up rivers to spawn with the important period for river lamprey being late autumn while sea lamprey migration occurs in spring.

The Atlantic salmon utilise the Severn Estuary and Bristol Channel as a migratory route as they return from the sea in spring and summer to spawn in the Severn and its tributaries, particularly the Usk and Wye. Similarly, smolt use the same route as they migrate to the sea, usually in late spring. The River Thaw has a small but sustainable run of sea trout (*Salmo trutta*) and salmon are occasionally recorded in the lowermost reaches of the river (Innogy, 2003). Both species are known to run up the Taff from Cardiff, and are likely to be present in other rivers in the area, so it is likely that they frequently occur in the sea off Aberthaw.

In late autumn adult eel (*Anguilla anguilla*) migrate from freshwater to spawn in the Sargasso Sea, with elvers returning in early spring. Eel are common in the Severn Estuary, although numbers have been declining in recent years (Langston *et al.*, 2003). Historically there was an important eel fishery in the Severn and the River Parrett still supports a small commercial fishery.

2.4 Marine Mammals

The greatest number of cetaceans in southern UK waters are reported in the Western Approaches although diversity and abundance decrease up the Bristol Channel towards the Severn Estuary with only odontocetes (i.e. toothed whales) being recorded (www.seawatchfoundation.org.uk). The harbour porpoise (*Phocoena phocoena*) is relatively common around UK coasts and has been reported from the Bristol Channel (Reid *et al.*, 2003) usually being observed in small groups close to the shore between October and March (www.seawatchfoundation.co.uk). Although not commonly recorded in the Severn Estuary, this species has been reported as far upstream as Elmore, only 7 km from the tidal limit at Maisemore Wear (www.bdmlr.org.uk). Other cetaceans recorded in the Bristol Channel are bottlenose dolphin (*Tursiops truncatus*), short-beaked common dolphin (*Delphinus delphis*) and Risso's dolphin (*Grampus griseus*). Although these three species are

generally common in waters around Wales and south west England (DeBoer & Simmonds, 2003), they have only been rarely reported from the Bristol Channel (Reid *et al.*, 2003).

The grey seal has been reported in the outer Bristol Channel, particularly around Lundy Island where there is a breeding colony (Westcott, 2009). However, seal sightings are rare in the upper Bristol Channel and Severn Estuary where there are no known haul out or breeding sites, although seals have been reported as far upstream as Purton in Gloucestershire (www.glaucus.org.uk).

Data on marine mammals (primarily seals, dolphins and porpoises) in the vicinity of Aberthaw are sparse; it can be assumed that such species, if not resident, are at least occasional visitors.

2.5 Water Quality

The Bristol Channel/Severn Estuary system is dominated by the second largest tidal range observed in the world resulting in high water velocities which are orientated parallel to the channel axis and locally parallel to coastlines, high mixing rates and high sediment loads. Vertical stratification is not observed in the Bristol Channel/Severn Estuary due to the intense vertical mixing (Uncles, 1983). The water quality of the Bristol Channel/Severn Estuary is relatively homogeneous, with gradients in pH and metals being small to negligible. This is probably due to a combination of high lateral mixing rates, high sediment loads influencing dissolved concentrations and the general improvement in water quality since the early 1990's (Ellis, 2002; Langston *et al.*, 2003).

The high sediment loads within the water column result in low light penetration, a situation that limits total biological production. As a result of the limited biological production, nutrient concentrations, though showing anthropogenic enrichment, also show relatively restricted depletion compared to other estuaries. The low salinity, high current speeds and low light penetration also provide a range of relatively uncommon habitats which contribute to the conservation importance of this environment. Anthropogenic influence on water quality has historically included both industrial and diffuse sources of metals and nutrients. However, distinguishing the anthropogenic influence from the natural background is complicated by a number of factors. Despite anthropogenic influence on the water quality, there is no evidence of widespread influence on the fauna and flora in the Severn Estuary; the composition of which is related principally to current velocities, suspended sediments and sediment particle size (see Langston *et al.*, 2003).

3. Potential Impacts

3.1 Marine Ecological receptors

For the purposes of this assessment the following are considered sensitive aquatic receptors that occur within the vicinity of the proposed project:

- Honeycomb worm (*Sabellaria alveolata*) reefs;
- intertidal habitats;
- diadromous fish;
- other fish fauna of conservation and/or commercial interest; and
- marine mammals.

The presence of these features was determined through a combination of desk based study i.e. scientific literature; ecological datasets, and focused baseline survey work.

3.2 Identification of Impacts

The potential impacts on ecological receptors are related to changes in water quality associated with possible changes to:

- pH
- dissolved oxygen (DO); and
- metal loading.

The temperature regime of the cooling water discharge will not change. Consequently, temperature effects are not discussed further.

3.3 pH

Typical pH levels in UK estuaries range from 7.0 to 8.3 (Wolff *et al.*, 1988). The pH of waters in the Bristol Channel/Severn Estuary remain fairly constant between 8 to 8.2 throughout the entire estuary (Ellis, 2003). This is essentially the pH of seawater in equilibrium with atmospheric carbon dioxide. Variations in seawater pH of a few tenths of a unit are possible on a diurnal and seasonal scale associated with algal photosynthesis with maximum pH values occurring at or slightly after the time of maximum illumination with highest values in the summer months. This is related to photosynthetic activity with bicarbonate used as a source of carbon dioxide. The degree of photosynthesis is affected by the supply of nutrients, organic carbon and turbidity (www.ukmarinesac.org.uk).

Effluents containing acids and alkalis are discharged into the marine environment but generally the high buffering capacity of saline waters ensures that pH levels are returned to the normal range. Any variations arising from the discharge are therefore likely to be local to the discharge point. This is reflected in modelling undertaken for the Aberthaw discharge which indicates that under the current conditions with a discharge of pH 5.8 the differences in pH from ambient extend for a length of approximately 900m and a width of approximately 400m throughout the water column.

The direct effects of a change in pH in the marine environment include:

- the potential for the release of CO₂ following the rapid release of acids;
- influence on the speciation and toxicity of substances, such as ammonia, silicate, phosphate, borate, some metals and some phenolic organic compounds; and
- lethal and sub-lethal effects on marine organisms.

At pH 8, bicarbonate is the predominate carbonate species, but below pH 6, CO₂ predominates, so that the rapid discharge of acids to tidal waters may be able to liberate sufficient CO₂ to be lethal to aquatic life. pH affects the equilibrium position of other systems, such as that for silicate, phosphate, borate and ammonia in a similar way. At high pH the proportion of the toxic unionised form of ammonia increases and may cause water quality problems. Low pH can increase the solubility of toxic metals, such as cadmium, copper, lead, aluminium, mercury and zinc but the degree of mobilisation in high alkalinity saline waters is low compared to that of freshwaters.

Modelling undertaken for the Aberthaw discharge under the proposed pH indicates that with a discharge of pH 5.6¹ the differences from ambient extend for a length of approximately 900 m and a width of approximately 400 m throughout the water column; a similar pattern to that modelled for the existing discharge conditions (i.e. pH 5.8). The model also indicates that differences between the predicted surface pH with a discharge of 5.8 (current limit) and a discharge of 5.6 (proposed limit) are small and limited in the immediate vicinity of the outfall with pH ≥ 7 predicted within 350 m of the discharge. At the location of the honeycomb worm (*Sabellaria*) reefs there is no measurable difference between the current discharge pH conditions, with a range at the surface of between 7.95 and 7.98 compared to proposed pH conditions with a range of 7.93 to 7.98. Similarly, at a site approximately 300 m to the east of the outfall the model predicts a surface pH range of between 7.92 and 7.97 which is not measurably different from the current conditions where the model predicts a pH range of 7.94 to 7.98. This would indicate that the pH of the discharged CW is rapidly mixed and buffered within a short distance of the outfalls.

As a result of the monitoring undertaken and the localised mixing zone it is considered that a discharge with a lower pH (as proposed) will not be an important issue in the context of the wider geographic area of the Severn Estuary and Bristol Channel. It is also considered that the proposed change in the discharge will not impact on any marine ecological receptors and or sites of conservation importance.

3.3.1 Benthic Communities

The immediate vicinity of the outfalls will be exposed to effluent of a lower pH, particularly at low water due to the reduced amount of surrounding seawater available for mixing and buffering the effluent at this period of the tidal cycle. At low tides and shortly thereafter, limited mixing is expected to result in a small area in the immediate vicinity of the outfalls at pH 5.6. The modelling indicates that an area of the intertidal ledges to the east and north-east of the outfall will be subject to the plume on the rising tide. However, the area influenced will be the same as that experiencing reduced pH under the current discharge conditions and no difference in pH between the current and proposed regime will be evident beyond a distance of 350 m from the outfalls. Consequently, any impacts associated with changes to the pH of the discharge will be limited to this area.

Threshold pH values for fish and other marine organisms are given in Table 1. Although not all the species listed are present at Aberthaw, the data presented indicates the potential for impacts associated with low pH seawater. The limpet (*Patella vulgata*) shows behavioural responses when exposed to seawater of pH 5.5, although once normal seawater conditions return, normal behaviour is re-established (Bibby *et al.*, 2007); similar responses are observed in the periwinkle (*Littorina littorea*) at a pH of 6.6 (Bonner *et al.*, 1993). Occasional shoreline impingements of water below the pH threshold for some species are predicted (under worst-case conditions), although due to shifting current direction and velocity through the tidal cycle, and continued mixing and buffering by surrounding seawater, it is unlikely that impingement of the lower pH water on any given stretch of the shoreline and intertidal zone will be for an extended period of time. From this information it is evident that within the immediate vicinity of the outfalls low pH may impact on invertebrates, although any impacts are likely to be at the sub-lethal level and transient.

¹ For the purpose of this report the pH of the actual CW discharge into the Bristol Channel remains as the Seal Pit discharge pH value. A limited data set obtained via "grab samples" at low tide of the discharge into the Channel suggest the pH is somewhat higher, typically 0.2 pH units higher due to the continued oxidation process that occurs during the passage of the effluent along the 300m Seal Pit discharge pipe to the Channel. This statement is yet to be fully qualified, however it would suggest that the assumption that no additional oxidation occurs during this pipeline passage is a cautious approach and the release of Seal Pit discharge of pH 5.6 remaining as pH 5.6 on entering the Channel conservative.

A wide range of tolerance exists for different marine algal species, with different optima for different physiological or reproductive processes, so that no overall trends or conclusions can be drawn. At low pH, the increased free CO₂/bicarbonate ratio may favour some species, but hinder growth/reproduction in others (www.ukmarinesac.org.uk). Several species show reduced calcification as the pH is reduced towards 6.0, and toxicity of copper may increase as pH is reduced. For molluscs, adverse effects are seen at pHs greater than 8.5 and less than 7.0, including shell dissolution at lower pH values (see Wolff *et al.*, 1988). Some crustaceans survive at well below pH 6.0, but others experience acute pH effects when values are in the range of 5.5-6.7 (Wolff *et al.*, 1988).

Table 1. Reported critical pH levels for lethal and sub-lethal effects. Data from Bamber (1985, 1987, 1990), Batten and Bamber (1996), Langford and Bamber (1984), Bibby *et al.* (2007) and Bonner *et al.* (1993).

Species	Threshold of lethal effects	Threshold of sub-lethal effects
King ragworm (<i>Nereis virens</i>)	-	≤ 6.5
Mussel (<i>Mytilus edulis</i>)	6.6	≤ 7
Native oyster (<i>Ostrea edulis</i>)	6.9	≤ 7
Pacific oyster (<i>Crassostrea gigas</i>)	6.0	≤ 7
Grooved carpet shell (<i>Ruditapes decussata</i>)	-	≤ 7
Common limpet (<i>Patella vulgata</i>)	-	5.5
Common periwinkle (<i>Littorina littorea</i>)	-	6.6
Bass (<i>Dicentrarchus labrax</i>)	5.6	6.3
Rock goby (<i>Gobius paganellus</i>)	5.0	5.85
Plaice (<i>Pleuronectes platessa</i>)	5.5	6.0
Dab (<i>Limanda limanda</i>)	5.5	5.5
Thick-lipped grey mullet (<i>Chelon labrosus</i>)	5.17	5.17
Sea trout (<i>Salmo trutta</i>)	6.0	6.0

Bamber (1997) reported that in the vicinity of the outfalls at Aberthaw growth of furoid algae and *Ulva lactuca* was poor, and that they were replaced by encrusting coralline algae as the dominant seaweed species, while the densities of barnacles and dog whelks were also reduced. This pattern was attributed to the effect of the heated effluent water lifting across the rocks on the rising tide. The extent of this impacted area was estimated as being a radius of 50 – 100 m from the CW outfall structures and was skewed to the east and north-east due to the direction of the incoming tide. The area to the west of the CW outfalls, dominated by *Fucus serratus*, with a variety of other algal and faunal species, was regarded by Bamber as being of a relatively normal condition for this kind of rocky intertidal habitat. Although no quantitative monitoring of the intertidal communities has been undertaken since commissioning of the FGD plant, observations made during routine biota sampling associated with bioaccumulation studies associated with the FGD plant indicate that there has been no significant change from the conditions reported by Bamber (C. Nikitik – *pers. obs.*). Consequently, it would appear that operation of the FGD plant has had negligible influence on the communities in the immediate vicinity of the outfalls and that the major influence remains the thermal character of the discharge rather than pH. Due to rapid mixing it is likely that the spatial extent of any influence of lower pH will be limited as discussed and that any associated impacts on benthic communities within this area will be minor and are likely to be masked by the impacts already observed in relation to the thermal effects of the discharge.

3.3.2 Honeycomb Worm *Sabellaria alveolata*

There is insufficient information available in current scientific literature to determine with absolute certainty the sensitivity of *S. alveolata* to changes in pH. However, various studies carried out on *S. alveolata* have, like the congeneric *S. spinulosa* (Ross worm), indicated that these sabellariid worms are tolerant of a wide range of

conditions and, provided that suitable substratum is available, can rapidly recolonise areas that have been disturbed (Jackson, 2008).

Although the predominantly intertidal *S. alveolata* differs in its ecological niche from the subtidally occurring *S. spinulosa*, the worms have similar life strategies and where information is available on the sensitivity of the worms to specific physical, chemical and biological factors, they have shown comparable levels of tolerance (Jackson, 2008).

A study by Hoare and Hiscock (1974) investigating the distribution of marine organisms around the outfall from a bromide extraction plant in North Wales, recorded *S. spinulosa* closer to the outfall than any other organism. The effluent at the outfall had a pH of 4 and, among other contaminants, contained free halogens. Although caution should be applied when suggesting that this tolerance might also be true of *S. alveolata*, it is considered that, in the absence of studies specific to *S. alveolata*, some indication of its sensitivity can be derived from studies carried out on *S. spinulosa*.

Despite the limited information available on the sensitivity of either sabellariid worm to specific changes in water chemistry, there is additional evidence that suggests a reasonable level of tolerance to outfall discharges. For example, work by Bamber and Irving (1997) at the cooling water outfall at Hinkley Point, Somerset, found that the growth of *S. alveolata* tubes in winter was considerably greater where water temperature was raised by approximately 8-10°C, than at the control site.

Furthermore, observations at Aberthaw have noted the presence of low lying *S. alveolata* reef adjacent to the western outfall, with reefs also present further west in Limpert Bay (C. Nikitik – *pers. obs.*). As the area over which any lowered pH would be experienced is limited to the immediate vicinity of the outfalls and skewed to the east, it appears unlikely that, considering the predicted tolerance of this species to reduced pH, *S. alveolata* reefs in Limpert Bay would be affected by the proposed changes to the discharge pH.

3.3.3 Fish

Marine fish species have been shown to be sensitive to both low and high pH levels with LC50 values being reported below 5.4, and above 9.0 (www.ukmarinesac.org.uk). Some adult fish are reported to be unaffected at pH values above 9.0, but for the larval stage effects are noticeable above 8.5, while fish larvae feeding appears to be affected at pHs below 6.0 and above 8.4 (Wolff *et al.*, 1988).

Langford and Bamber (1984), referring specifically to fish, summarise a range of effects, from avoidance behaviour beginning at pH 6.5 and discolouration and eye damage at around pH 6. Furthermore, it is likely that the combined stresses of low pH, heat and the presence of heavy metals is more harmful than low pH alone, since low pH can increase the toxicity of substances, including ammonia, phosphate, borate, and some metals. However, it is well-known that fish exhibit avoidance behaviour and are likely to avoid harmful waters if possible. Harmful effects of low pH are proportional to the length of time of exposure.

It is likely that the low pH effluent will cause fish to avoid waters in the immediate locality of the outfall. Any effects are likely to be localised to the immediate vicinity of the discharge where pH values below 7.0 may occur. Reduced pH of water in the vicinity of the mouth of the River Thaw has the potential to affect the sea trout run in to the river, however, trout are tolerant of pH levels well below 7.0, so would be unaffected by the discharge plume. It should be noted that modelling indicates that pH conditions in the vicinity of the River Thaw will be close to ambient.

Salmonid olfactory senses can be affected by lowered pH with reduced response to olfactory stimuli occurring at a pH of 6.6 and being lost at 4.6 (Potter and Dare, 2003). As olfactory senses are important for fish returning to their natal river there is a potential for the plume to influence the sea trout run to the River Thaw. However, this would appear unlikely as pH levels within 300m offshore of the outfalls and in the approaches to the mouth of the River Thaw are likely to be above the threshold levels which may influence olfactory response with predicted pH levels close to 8. The potential impact on salmon will likely be less important as this species is less frequently encountered in this area. Consequently, no impacts on fish are likely in relation to lowering the pH of the discharge.

3.3.4 Marine Mammals

Due to the nature of the plume and the mobile nature of marine mammals, exposure to the plume will be minimal. The area over which lowered pH is predicted is limited and as such no impacts on marine mammals are anticipated.

3.4 Heavy Metals

The Bristol Channel/Severn Estuary is a highly dispersive environment. Much of this dispersion results from the very high tidal range and axial velocities that occur in this environment. Horizontal and vertical mixing are very intense. As a result, higher than ambient concentrations (e.g. resulting from the discharge) are rapidly dispersed. This may partially account for the highly homogenous baseline condition observed in this environment. An additional influence is the high suspended sediment concentration and suspended sediment gradient from the Severn to the Irish Sea. This acts to sequester metals from the dissolved phase where their concentrations might otherwise be high (e.g. the Severn Estuary). As dissolved trace elements concentrations in the discharge are not anticipated to exceed the EQSs, the discharge will not result in significant changes to background levels in the receiving environment.

Seawater contains a very wide array of trace metals and other substances, from both natural and anthropogenic sources. As with excess acidity, some form of equilibrium is rapidly reached, through buffering, chelation, reaction to form insoluble salts, and inclusion in sediment layers. Nonetheless, trace metals, with their ability to be concentrated up through the food chain are a group of contaminants of some concern. Many of these substances are liable to bioaccumulation, with potentially serious consequences for higher trophic levels in the food web (including man). In addition, raised levels of trace contaminants can lead to growth inhibition and many other sublethal effects in marine algae, phyto- and zooplankton and macro-invertebrates, and promote changes in the food web by favouring the growth of species and forms tolerant of raised trace metal levels. All of these substances already occur in seawater in minute quantities, so the primary concern is the potential increase over existing levels attributable to FGD process effluent and any changes in pH, and compliance with guidelines for maximum permissible concentrations in discharges and the background environment.

Owens (1984) reviewed metal concentrations in the Severn Estuary and Bristol Channel and concluded that while concentrations were higher than in some other estuaries, there was no evidence of any impact on the zooplankton community and metal concentrations in some commercial fish and shellfish were no higher than in other coastal waters. However, in some non-commercial species, such as limpets and winkles, increased metal concentrations have been recorded while elevated levels of mercury were also recorded in dogwhelks, limpets and fucoid algae from the immediate vicinity of the discharge at Aberthaw (Nikitik, 2015).

The predicted concentration in the CW discharge with a Welsh coal source is less than the MAC (Maximum Allowable Concentrations) concentrations for all the elements listed in Table 2. For Chromium the predicted discharge concentration is greater than the Annual Average EQS listed. However, as the chromium EQS is for chromium VI, whereas the predicted concentration is for all chromium species, it is anticipated that chromium VI concentrations will be lower than the level listed in Table 2.

However, as dissolved trace element concentrations in the discharge are not anticipated to exceed the EQSs, the discharge will not result in significant changes to the background levels in the receiving environment. Consequently, it is considered that any change in the characteristics of the metal loads in the discharge will not result in any increased effects on any of the marine receptors identified.

Table 2. Predicted discharge concentration for an all Welsh coal diet.

Component	Discharge Concentration	Units	AA	MAC	Notes
Arsenic	0.25	µg/l	25	-	H1 document
Cadmium	0.06	µg/l	0.2	0.45 to 1.5	RBMP 2 Directions
Chromium	0.87	µg/l	0.6	32	Chromium VI
Copper	0.90	µg/l	3.76	-	RBMP 2 Directions
Lead	0.62	µg/l	1.3	14	RBMP 2 Directions
Mercury	0.04	µg/l	0.05	0.07	RBMP 2 Directions
Nickel	0.84	µg/l	8.6	34	RBMP 2 Directions
Zinc	0.48	µg/l	6.8	-	RBMP 2 Directions
Antimony	0.01	µg/l	-	-	-
Manganese	0.54	µg/l	-	-	-
Selenium	0.83	µg/l	-	-	-
Vanadium	0.65	µg/l	-	-	-

3.5 Dissolved Oxygen

The FGD Process technology employed at Aberthaw Power Station uses seawater and its natural capacity to absorb and neutralise a high percentage of SO₂ from the flue gases. After seawater passes through the plant it is aerated to reduce chemical oxygen demand (COD) and acidity before being returned to the sea. The process operates by using the natural alkalinity of seawater to convert the acidic components of the flue gas into the minerals sodium and calcium sulphate and sodium and calcium chloride; the sulphates are naturally occurring minerals and are already present in seawater at high concentrations, while the chlorides are naturally present at very high levels. Using a coal source with increased sulphur load will result in higher levels of sulphites thus increasing the COD of the effluent from the plant. This could have implications of lowering the dissolved oxygen of the final discharge to sea.

The lethal and sub-lethal effects of reduced levels of dissolved oxygen are related to the concentration of dissolved oxygen and period of exposure of the reduced oxygen levels. A number of animals have behavioural strategies to survive periodic events of reduced dissolved oxygen. These include avoidance by mobile animals, such as fish and macrocrustaceans, shell closure and reduced metabolic rate in bivalve molluscs and either decreased burrowing depth or emergence from burrows for sediment dwelling crustaceans, molluscs and annelids. Stiff *et al.* (1992) and Nixon *et al.* (1995) identified crustacea and fish as the most sensitive organisms to reduced dissolved oxygen levels with the early life stages of fish and migratory salmonids as being particularly sensitive.

On line data from the station seal pit discharge sampling point indicates that oxygen saturation levels are at 100% prior to discharge to sea under current conditions. However, dissolved oxygen levels will vary with temperature and salinity. For a maximum temperature change of 13.5°C across the cooling water system the dissolved oxygen content will change by approximately 15% assuming the oxygen saturation level is kept at 100%. It is predicted that this will not change with the proposed changes.

As with pH, intertidal habitats to the east and north-east of the outfall will be subject to any decrease in dissolved oxygen in the discharge. However, due to mixing and dilution, the area will be limited and, if as predicted, there is no change in dissolved oxygen discharge conditions, no increased impacts are expected in the intertidal habitats. As indicated above mobile species, particularly fish and mammals, will show avoidance response to areas of low dissolved oxygen, consequently no increased impacts on fish or marine mammals are anticipated.

4. Conclusions

- Modelling indicates that an area of the intertidal ledges to the east and north-east of the outfall will be subject to the cooling water plume with no difference in pH between the current and proposed regime evident beyond 350 m from the outfalls. Consequently, changes to the pH of the discharge will not impact on any designated sites or features of conservation importance.
- Any impacts associated with lowered pH will be limited to the intertidal habitats in the immediate vicinity of the outfalls, and any such effects are likely to be minor in relation to those associated with the thermal attributes of the discharge.
- *Sabellaria alveolata* present to the west of the outfall are unlikely to be impacted by changes to the pH conditions of the discharge as pH conditions in the vicinity of the reefs will be unchanged from current conditions.
- Fish species, including migratory salmonids which utilise the River Thaw, are unlikely to be affected by a reduced pH in the discharge.
- No impacts on marine mammals are anticipated.
- Metal levels in the discharge are predicted to remain below relevant EQSs. Consequently, no impacts are anticipated.
- Dissolved oxygen levels in the discharge are predicted to remain high. If periods of low DO occur, any impacts will be in the immediate vicinity of the outfalls. However, these are predicted to be negligible.

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