Eels Regulations IC35 Response: Cost Benefit Assessment for Aberthaw Power Station

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Environment & Chemistry

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Eels Regulations IC35 Response: Cost Benefit Assessment for Aberthaw Power Station

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Summary

This document is submitted to Natural Resources Wales in response to the requirement of Improvement Condition 35 within the Station's EP RP3133LD:

The Operator has undertaken a review of the existing screening arrangements with reference to the Eels (England and Wales) Regulations 2009 (SI 2009/3344) and the Environment Agency ''Safe Passage for Eel'' Regulatory Position Statement version 1 dated July 2012 (and as amended February 2013) in response to Improvement Programme reference 34.

Natural Resources Wales has determined that the site does not comply with the requirements for safe passage of eel and the Operator is now required to complete a cost benefits appraisal of best available technique with reference to the Environment Agency ''Safe Passage for Eel: Guidance on Exemptions'' as a screening tool.

a) *If the Cost Benefit Assessment shows that the benefits are greater than the costs by a factor of 1.5 or more, then the Operator shall submit to Natural Resources Wales for review a report setting out the costs and the technical and economic feasibility to introduce the improvements to achieve best available technique.*
b) *If the Cost Benefit Assessment shows that the benefits are not greater than the costs by a factor of 1.5 or more, then the Operator shall, with reference to the Environment Agency ''Safe Passage for Eel: Guidance on exemptions, assess which alternative measure, or combination of alternative measures, could be implemented under a case of a conditioned Exemption. The Operator shall submit a report to Natural Resources Wales setting out the costs and the technical and economic feasibility of implementing their proposed alternative measure or measures.*

In all cases, the submission shall contain relevant timescales in accordance with the Safe Passage for Eel Regulatory Position Statement version 1 dated July 2012 (as amended 2013).

The proposals shall be implemented following written approval from Natural Resources Wales.

Whilst undertaking this Improvement Condition, the Operator shall be operating under exemption from the requirements to place eel screen diversion structures pursuant to Regulation 17(5)(a) of the Eels (England and Wales) Regulations 2009. The exemption will remain in place until Natural Resources Wales has provided written approval that the Improvement Condition has been deemed complete.

The response will be submitted by 30th June 2015.

RWE Generation UK has undertaken a cost benefits appraisal (CBA) of best available techniques with reference to the Environment Agency ‘’Safe Passage for Eel: Guidance on Exemptions’’ as a screening tool. At Aberthaw the installation of best practise screening, as defined in the guidance, has been found to be not cost beneficial.

RWE Generation have therefore, with reference to the Environment Agency ‘’Safe Passage for Eel: Guidance on Exemptions”, assessed which alternative measure, or combination of alternative measures, could be implemented. None of the on-site alternative measures or combinations of alternative measures that were examined were found to be cost beneficial.

Following the process provided in “EA’s Safe Passage for Eel: Guidance on alternative measures (where best practise is not cost beneficial for existing sites)” document leads to the conclusion that the mitigation applicable at Aberthaw is an alternative measures by other means. This would entail Aberthaw funding measures, with a value of up to £50k, that benefit eel populations either locally or in the wider area. There is an expectation in the guidance that these measures will be agreed with the local Eel Management Plan staff.

RWE Generation UK have already committed to spend £36k over three years to part fund a PhD at Southampton University entitled “Protection of the critically endangered European eel: assessing the environmental and economic impact of alternative protection measures”. The output of this research will contribute to the protection of eel by increasing understanding of the pros and cons of the measures, available to station operations, that aim to benefit eel populations. All outputs will be shared with NRW/Environment Agency. RWE Generation consider that this funding should be taken into account by NRW when agreeing the alternative measures by other means for Aberthaw power station.

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1. Introduction

Natural Resources Wales (NRW) has issued an improvement condition that requires Aberthaw Power Station to complete a cost benefits appraisal of best available screening options with reference to the Environment Agency (EA 2014) ‘’Safe Passage for Eel: Guidance on Exemptions’’ as a screening tool.

This document is a report of that cost benefit screening. It also draws on previous studies detailing the feasibility and cost of implementing a best practise cooling water screening system at Aberthaw (Handley & Shay 2014) and a study of the potential impact of the current abstraction on eel populations (APEM 2013).

2. Regulatory Background

Aberthaw currently operates under permit EPR/RP3133LD. In order to address the requirements of the Eels (England and Wales) Regulations 2009 (SI 2009/3344) NRW have issued two variations with improvement conditions, EPR/RP3133LD/V008 on the 11th March 2013 and EPR/RP3133LD/V010 on 22nd December 2014.

In response to EPR/RP3133LD/V008 Aberthaw Power Station undertook a review of the existing screening arrangements with reference to the Eels (England and Wales) Regulations 2009 (SI 2009/3344) and the Environment Agency ‘’Safe Passage for Eel’’ Regulatory Position Statement version 1 dated July 2012 (and as amended February 2013). EPR/RP3133LD/V010 requires Aberthaw Power Station to complete a cost benefits appraisal of best available technique with reference to the Environment Agency ‘’Safe Passage for Eel: Guidance on Exemptions’’ as a screening tool.

From 1st January 2016, all large combustion plant including Aberthaw Power Station have to comply with the requirements of the Industrial Emissions Directive (IED). There are a range of compliance pathways available within the IED

- Compliance with Emission Limit Values (ELVs) specified in IED from the 1st January 2016. This includes derogations for low load factor (Limited Hours Derogation) and emergency use plant.
- Participation in the Transitional National Plan between 01/01/2016 and 30/06/2020. After this date plant must comply with IED ELVs.
- Take a Limited Lifetime Derogation and operate for no more than 17,500 hours between 01/01/2016 and 31/12/2023. Plants taking this option must close by the end of this period.

In November 2014, NRW issued a Regulation 60 notice to all plant that will fall into the scope of IED and asked them to specify which compliance route they would be taking and confirm ELVs. The response submitted at the end of March 2015 identified that Aberthaw will be either entering the Transitional National Plan, taking the Limited Lifetime Derogation or the Limited Hours Derogation. The decision on whether Aberthaw will enter the Transitional National Plan or take the Limited Lifetime Derogation has to be confirmed by 31st December 2015.

In addition to the requirements of IED the future operation of Aberthaw power station will remain influenced by regulatory and commercial pressures. These include the tax on carbon emissions and the market reforms introduced via the capacity market. The latter is intended to provide a means of ensuring fossil fuelled power plants remain available to provide back up for intermittent renewables.

The compliance route adopted will influence the potential load factor and life time over which the power station could operate. Load factor is a power sector term for the percentage of a period, typically a year, that a station operates. The load factor and station life time will influence the potential for operation of the cooling water system to impact on eel. The life of the station will also influence the total benefits calculated using EA's screening tool as these are calculated from a length of river considered to be improved by the screening measure being assessed and an assumed value per km of river per year.

3. Cooling Water System at Aberthaw

3.1. Existing System

Aberthaw power station is situated on the south coast of Wales near Barry in the Vale of Glamorgan. The station was designed to burn Welsh coal and now has the capability to co-fire biomass. It's three generation units can export around 1600 MW to the National Grid.

The three units are cooled by sea water extracted via tunnels from a Cooling Water (CW) intake caisson structure located half a mile off-shore (Handley & Shay 2014). The caisson was originally designed to feed both the original, now demolished, A station and the current B station.

From this caisson the water for Station B is brought along two tunnels (both having a horseshoe cross-section with an equivalent tunnel diameter of 15.4ft) to a forebay structure adjacent to the circulating water pumphouse.

The CW pumps draw water from the forebay and pass the water through strainers to the condensers and auxiliary plant. The system is arranged to allow any pump to serve the condensers of any unit.

The water flows from the condensers to an open seal pit and then through two outlet tunnels (both have a horseshoe cross-section with an equivalent diameter of 15.4ft) to the outfall structures on the foreshore. A seawater process Flue Gas Desulphurisation (FGD) system has been retrofitted at Aberthaw power station and now part of the water returned from the condensers is passed to an absorber tower to treat the flue gas. Water from the FGD absorber re-joins the main CW flow before discharge.

3.2. Impact of the existing system on eel populations

RWE Gen UK has commissioned a review of the potential for the Aberthaw Cooling Water abstraction to impact eel. The review (APEM 2013) included the use of the PISCES expert system. The PISCES expert system uses survey data and the characteristics and location of an intake to predict the number of fish that would be impinged on a typical power station screen.

For the Aberthaw intake it was predicted (APEM 2013) that approximately 97.4kg of eel would be impinged which is 0.02% of the 40% target for return from the Severn River Basin District. The predicted impingement at Aberthaw was estimated to be 0.13% of the loss of silver eel equivalents to the permitted eel fishery. Overall it was concluded that the abstraction was unlikely to have a significant impact on the adult eel population in the Bristol Channel or management targets in the UK Eel Management Plans.

4. The EA's Safe Passage for Eel: Guidance on Exemptions

Improvement Condition EPR/RP3133LD/V010 requires RWE Generation UK to complete a cost benefit appraisal with reference to the Environment Agency ''Safe Passage for Eel: Guidance on Exemptions''.

Environment Agency have developed and made available an Excel spreadsheet (Stage1 valuation sheet_v4.xlsx) to assist in the cost benefit appraisal (CBA) process.

At meetings between EnergyUK, the EA and NRW, station operators have raised concerns over the suitability of EA's CBA spreadsheet to value an impact on eel populations of an improvement measure. These concerns included the limited link between the detail of the abstraction arrangements and improvement measure under consideration and changes in eel populations and the methods used to put a value on the postulated impacts. These difficulties underlay the limitations of the methodology. Use by RWE Gen UK of the EA Methodology should not be taken as acceptance that it provides a means of predicting the impact of the power station on eel populations and the associated benefits of changes in power station abstraction arrangements.

4.1. Station Life and Load Factor Assumptions

Load factor is power sector terminology for a measure of a power station's operation. It usually refers to the percentage of a year for which a station operates. The EA CBA spreadsheet does not directly account for load factor although load factor will influence the potential for an abstraction to impact on eel populations. The default load factor assumption in the spreadsheet is effectively constant operation. Under the IED a plant may decide to take a derogation from the requirement to fit further stack gas abatement that limits the number of hours that it may run. Without accounting for the load factor EA's tool would give the same result for a station operating at high load factors as one that operates intermittently at low load factor. The low load factor station would have a reduced potential to entrain and impinge eel compared to the high load factor plant and therefore the benefit of improvements in screening arrangements would be expected to be lower too.

At a meeting on the 8th April 2015 with EnergyUK EA's Eel Team confirmed that load factor could be used to adjust the life time of the station although EA also noted that such assumptions would be implemented in the resulting modified permit.

The CBA spreadsheet has a default lifetime for the improvement of 40 years. The CBA spreadsheet is intended to be used in many sectors and while the default life may be appropriate for some it is overly long for the power sector. The life of the project will influence the outcome of the assessment process as the calculated benefits of an option will increase with increasing station life. The CBA spreadsheet default improvement life is at odds with the assumptions in DECC's Energy Projections (DECC 2014) for the residual lifetime of existing coal-fired plant which predict coal fired generation without Carbon Capture & Sequestration ceases by, at the latest, the end of 2032. Based on the DECC Energy Projections a more realistic upper bound on life for a coal fired power plant, not fitted with carbon capture & sequestration, would therefore be 16 years.

As discussed previously the potential load factor and life of Aberthaw power station will depend on the compliance option taken under IED. The compliance option selected by RWE Generation UK and actual load factor will depend on the RWE's view of the future electricity market and subsequently the actual market occurring. At this stage RWE Generation UK has not decided which compliance option Aberthaw will follow and therefore what the appropriate load and life assumption for present purposes should be. The sensitivity of the cost benefit appraisal to the load and life of the station has been explored using three scenarios that cover the range of possible outcomes plus a fourth scenario where the EA/NRW default assumptions are adopted.

These scenarios are:

Short life-High load

This scenario assumes the station shuts at the end of the Transitional National Plan in 2020 but operates at a high load factor of 70% until that point. The effective (full load) life, used in the CBA spreadsheet, under this scenario is three years.

Low load factor-long life
This scenario assumes the default life in the CBA tool applies but that the load factor is low at 17%. The load factor is that which would apply under the limited hours derogation of the IED. The effective (full load) life, used in the CBA spreadsheet, under this scenario is seven years.

Medium load factor – medium life
This scenario assumes a 16 year station life with a high load factor of 70% between 2016 and mid 2020 (end of the Transitional National Plan) followed by a low 17% load factor until the end of 2032 which is the end of coal fired generation assumed in DECC 2014.

The average load factor under the medium load, medium life scenario is 32%. The effective (full load) life, used in the CBA spreadsheet, under this scenario is five years.

Default Life, Default Load
This uses the general default assumptions in EA's sheet which are for a 40 year life and 100% load factor.

The EA spreadsheet will calculate a benefit that is proportional to the effective station life therefore when using the spreadsheet to compare screening options it is only necessary to begin with the longest effective life. Options that screen out as not cost beneficial for the longest effective life will also screen out for the shorter life scenarios.

4.2. River Length Assumption

In order to use the spreadsheet it is necessary to enter a length of river improved by the measure under consideration. The spreadsheet multiplies this length with a value per river kilometre improved and the project life to calculate an overall value for the improvement to be used in the screening assessment. Environment Agency has provided all English & Welsh power plant operators a river length for use in the CBA methodology. In the case of Aberthaw power station this is 38.5km.

4.3. Costs

RWE Generation UK has undertaken a study into the cost of installing a best practise eel screen at Aberthaw power station (Handley & Shay 2014).

Handley & Shaw costed four screening options for improvement of the physical screens, these were:

Option 1 - New Drum Screen with fish return

Option 2 - New Band Screen with fish return

Option 3 – Passive Wedge Wire Cylinder (PWWC) screens

Option 4 - Caisson Intake Modifications with acoustic and strobe light behavioural fish deterrent

The study was undertaken to provide an initial cost estimate and has therefore focussed on the major costs for each option. Whilst Options 1 & 2 included a fish return system which will have significant design and cost requirements these were expected to be relatively small compared to those for the main civil & mechanical works. Therefore the fish return system costs were not included in Handley & Shaw's cost estimates.

The main costs with the drum and band screen options would be the need to construct a new forebay to house the screens. There are limits to the space available to construct a new forebay and construction would require the cooling water system to be shut down. It was estimated that the construction would require the station to be shut for up to two years. The civil engineering work required to create a new forebay was estimated at £32 million, with a further £8million for mechanical work associated with a drum screen. The shutdown was estimated to cost an additional £40 million. The total cost of a best practise screening solution is estimated as £80 million.

Handley & Shay did not consider a PWWC option to be suitable for Aberthaw. This was both because of the need to provide adequate water depth which would have required the screens to be positioned 200m further out to sea beyond the existing caissons and because of the lack of experience with the technology at open coast sites with UK coastal conditions at practical power station flow rates.

In addition to providing physical screening Handley & Shaw provided estimates of the cost to modify the intake caisson to provide a low velocity intake with an acoustic fish deterrent system. This would not be a best practise screening solution, as defined by EA's Eel Manual, but might offer a method of reducing the entrainment of some life stages. The costs were estimated as £20 million with a need to shut the station for a period of 8 months.

5. Use of the CBA Spreadsheet as an assessment tool

This section documents the output of the assessment process given in EA's ''Safe Passage for Eel: Guidance on Exemptions''.

5.1. Best Practise Option

The EA CBA spreadsheet (Stage1 valuation sheet_v4.xlsx) has been used to assess the options of modifying the Aberthaw intake to conform with Eel Manual best practise assumptions following Environment Agency's guidance (EA 2014b). This assumes a river length improved of 38.5km with a cost of £80 million to build a new intake system. For the purposes of this study a nominal £10k per year has been assumed as the operational cost of the system. Increasing the operational costs will reduce the Benefit Cost Ratio. The actual annual cost of managing a drum screen is likely to be higher than the £10k used in this assessment but given the very low Benefit Cost Ratio (BCR) of the options assessed a sensitivity study of outcome to operational costs is not appropriate. With an effective station life of 7 years installing best practise screening at Aberthaw option is ruled out. Even with the default life assumption of 40 years and 100% load factor the calculated BCR is 0.02 and building a new intake at Aberthaw is ruled out as an option.

Table 1 Summary of CBA sheet for Aberthaw: Best Practise Screening Options

Scenario	Capex (£k)	Opex (£k)	Life (col 17 & 19)	Risk of Failure (%)	BCR
1	80000	10	3	0	0.00
2	80000	10	7	0	0.01
3	80000	10	5	0	0.01
4	80000	10	40	0	0.02

Notes: Location ST0234066300, Catchment - Ogmore to Tawe, Western wales River Basin District. Capex costs include the cost of necessary outage

5.2. Alternative measures

In the process defined within EA's document Alternative Measures (where best practice screening is not cost beneficial for existing sites) (EA 2014c), which supports EA's ''Safe Passage for Eel: Guidance on Exemptions'' document, if an Eel Manual best practise screening solution is ruled out a number of different alternative measures should be considered. There are three groups of alternative measures. These are alternative measures by engineered solutions, alternative measures by changes to operational regime and alternative measures by other means. Within in the first two groups of measures there is an order of preference for each individual measure listed and engineered solutions are preferred over regime changes.

Depending on the engineered or regime measure selected the guidance suggests that additional alternative measures may be required to ‘top up’ the benefit.

Alternative measures by engineered solutions

Few of the measures listed in EA’s Alternative Measures document are applicable at Aberthaw.

Those alternative measures that use a mesh with spacing different to best practise would still require the construction of a forebay and would incur most if not all the costs required to achieve best practise. This option would therefore also be screened out from further consideration.

One potential alternative measure would be a bundle of measures that modified the existing intake to reduce intake velocities and installed a deterrent system. Handley & Shaw estimated a cost of £20million to modify the intake to create a low velocity intake system. An eight month outage would incur an additional cost of £13.3million.

EA Guidance indicates that for a low velocity intake the benefit calculated by the EA methodology should be reduced to 50% of that potentially obtainable.

Table 2 Summary of CBA sheet for Aberthaw Alternative Measures

Scenario	Capex (£k)	Opex (£k)	Life (col 17 & 19)	Risk of Failure (%)	BCR
1	33300	10	3	50	0.01
2	33300	10	7	50	0.01
3	33300	10	5	50	0.01
4	33300	10	40	50	0.03

Notes: Location ST0234066300, Catchment - Ogmore to Tawe, Western wales River Basin District. Capex costs include the cost of necessary outage (£20m + 8/12 of £20m).

The Benefit Cost Ratio for a £33.3 million modification assuming a 50% reduction of the benefit ranges between 0.01 to 0.03 for an effective station life of 5 to 40 years. Again this option is ruled out using the CBA tool.

Fish friendly pumps are listed in the guidance as a potential mitigation measure. These pumps are not currently available with the performance necessary for a once through cooled power station such as Aberthaw. The Aberthaw pumps pass approximately 16.7m^3s^{-1} at 17.7m head. Bedford Pumps offer relatively high flow rate fish friendly pumps but the maximum flow rate that they currently offer is only 8m^3s^{-1} with a head of 0.2m or 2m^3s^{-1} at a head of 14m (Bedford Pumps Ltd). Other fish friendly pump vendors such as Hydrostal are lower performance. It is possible that the design of fish friendly pumps, which are generally axial flow, limit the head available (M. McGrady Pers. Comm. 1/5/2015).

Alternative Measures by Regime Change

The EA's guidance lists adopting a Soft Start pumping regime in the list of alternative measures by changing the operational regime. This involves a gradual start of cooling water pumps to allow eel (and other fish) that have entered the intake system to escape before being entrained.

The starting process for the Aberthaw cooling water effectively ramps up the flow rate from zero to full flow over a relatively long period of time. If the system is being started from no flow it takes 45 minutes to prime the system and reach full flow on the pumps being used. If additional pumps are added to increase the flow through the cooling water system it takes 15 minutes for an individual pump to achieve full flow rate from off (A. Lavisher pers. Comm. 8/6/2015). Changes in intake velocity at Aberthaw with the current pumps and methods of operational are slow and therefore a soft start pumping system is not an appropriate alternative measure for the station.

Alternative Measures by Other Means

The list of alternative measures by other means in the EA's guidance (EA 2014c) is stated to be non-exhaustive and other measures can be considered in discussion with fisheries staff. The listed measures include trap and transport schemes, work to improve eel passage by means such as changes to tidal flaps and Research and Development Activities.

The value of these alternative measures by other means depends on the abstraction volume and the location of the abstraction in relation to the tidal limit. For a coastal site with Aberthaw's abstraction rate the value listed is £50k.

RWE Generation UK have already committed to spend £36k over three years to part fund a PhD at Southampton University entitled "Protection of the critically endangered European eel: assessing the environmental and economic impact of alternative protection measures". The output of this research will contribute to the protection of eel by increasing understanding of the pros and cons of the measures, available to station operations, that aim to benefit eel populations. RWE Generation consider that this funding should be taken into account by NRW when agreeing the alternative measures by other means for Aberthaw power station.

6. Conclusions

The impact of Aberthaw power stations cooling water abstraction on eel population is predicted to be very small compared to the local Eel Management Plan area populations.

The installation of best practise screening at Aberthaw, as defined in EA's Eel Manual, would require significant expenditure and a long outage. Using the process provided in the EA "Safe Passage for Eel: Guidance on Exemptions" the installation of such best practise screening has been ruled out using EA's Cost Benefit (CBA) spreadsheet screening tool.

The alternative measures listed in EA's guidance documents are either not available for Aberthaw or are also ruled out using the CBA screening tool.

Following the process provided in EA's "Safe Passage for Eel: Guidance on exemptions" document leads to the conclusion that the mitigation applicable at Aberthaw is alternative measures by other means. This would entail Aberthaw funding measures, with a value of up to £50k, that benefit eel populations either locally or in the wider area. There is an expectation in the guidance that these measures will be agreed with the local Eel Management Plan staff. RWE Generation UK are currently supporting a PhD research project the output of which will contribute to the protection of eel by increasing understanding of the pros and cons of the measures, available to station operations, that aim to benefit eel populations. Outputs will be shared with NRW/Environment Agency. RWE Generation consider that this funding should be taken into account by NRW when agreeing the alternative measures by other means for Aberthaw power station.

7. References

APEM (2013) Aberthaw Power Station Entrainment Desk Study
February 2013
Report Number 412642

Bedford Pumps Ltd
(http://www.bedfordpumps.co.uk/downloads/DAF%20DBF%20Range.pdf)

DECC (2014) Updated energy and emissions projections 2014
(https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/368021/Updated_energy_and_emissions_projections2014.pdf)

Environment Agency (2014) ''Safe Passage for Eel: Guidance on Exemptions''
63_13_SD01.pdf

Environment Agency (2014b) Guidance on the completion of Benefit Cost Analysis Stage 1 Valuation spreadsheet for eel passage and screening requirements
July 2014 version 003

Environment Agency (2014c) Alternative Measures (where best practice screening is not cost beneficial for existing sites)
Alternative_Measures_Final_V6 September 14 version.docx

Environment Agency Screening at intakes and outfalls: measures to protect eel
The Eel Manual – GEHO0411BTQD-E-E

Handley, P. & Shay, T. (2014) Feasibility options for installation of fish screening
TECH/JTE/2126/14

Appendix Aberthaw Screening Feasibility & Initial Cost Estimates

Engineering Report
Feasibility options for installation of fish screening

Prepared for: Aberthaw Power Station

Reference Number: TECH/JTE/2126/14
Date: March 2014
Issue: 1
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Feasibility study to consider the options for installation of fish screening at Aberthaw Power Station

Prepared for:

Aberthaw Power Station	
Client Contact :	Andy Moores
Contract No. :	

Prepared by:		
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Summary

The RWE npower civil engineering group were requested by the Environment and Chemistry team on behalf of Aberthaw power station to provide feasibility and construction cost estimates for options to improve fish and eel screening on the main cooling water (CW) intake system.

The need for this study arises because of the introduction of the Eels Regulations (2009) which require an abstractor of greater than 20m^3 per day to fit an eel screen to intake and outfall by January 2015 unless they are issued with an exemption. Environment Agency has developed guidance on screening options that is likely to be adopted by Natural Resources Wales (NRW). The current guidance is that power station outfalls are unlikely to require screening under Eel Regulations.

This report provides feasibility and cost information that could be used within a cost benefit analysis for improved eel screening at Aberthaw power station.

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1 Introduction

This study has been undertaken to provide information on the feasibility & cost of options to improve the screening of eel at Aberthaw power station.

The need for a feasibility & cost study arises because of the introduction of the Eels Regulations (2009) which require an abstractor of greater than 20m^3 per day to fit an eel screen to intake and outfall by January 2015 unless they are issued with an exemption.

Environment Agency has developed guidance on screening options that is likely to be adopted by Natural Resources Wales (NRW). Current operational guidance (http://cdn.environment-agency.gov.uk/LIT_7888_3a0b71.pdf)(Ref 5), is that power station outfalls are unlikely to require screening under Eel Regulations.

It is RWE npower's understanding that there will be a need to provide screening cost information to the regulator. The cost data will be used in a cost benefit analysis of different screening options. The regulator will use the cost benefit analysis as input into a decision on what changes are required of an operator.

This report considers the cost & feasibility of adopting a number of screening options at Aberthaw as referenced in Environment Agency publications: -

Screening at intakes and outfalls: measures to protect eel (Ref 1), and
Screening for intake and outfalls: a best practice guide (Ref 2).

In particular this report considers the feasibility and construction estimates of options for new screen system with fish return and intake improvements with fish deterrent.

This report provides an initial estimate of costs for each option considered. Further work would be required to provide a detailed breakdown of cost and duration of works.

1.1 Background to Aberthaw B Power Station

Aberthaw B is a coal-fired power station. The station began full operation in 1971 and is located to the west of Cardiff, in the Vale of Glamorgan, on the north bank of the Bristol Channel.

Aberthaw can generate around 1600MWe of electricity for the National Grid System and operates as an opted in station under the Large Combustion Plant Directive (LCPD). Aberthaw has taken the Limited Life Derogation under the Industrial Emissions Directive (IED). This limits the number of hours that the station can operate to 17 500 and sets a date of 2023 when it must close. However the IED also allows an operator until the end of 2015 to decide to comply with IED emission limits or enter the Transitional National Plan. Either of these options would extend the life of the station. Both would require large scale investment at the station. Hence the life of the station will be a commercial decision that will depend on the economics of generation. Economic factors include the cost of compliance with IED and Eel Regulations amongst other factors.

1.2 Environment adjacent to Aberthaw

To the east of the power station is a Special Area of Conservation (SAC), as shown in the 'Report to the National Assembly for Wales on Marine Protected Areas in Wales (Ref 4) on their map of Marine Protected Areas in Wales, as shown in Figure 2 in Appendix A.

The 'East Aberthaw Coast SSSI' site is located to the east of the power station as shown on the coastal map in Figure 1 below, which also shows the location of the existing cooling water (CW) intake caisson.

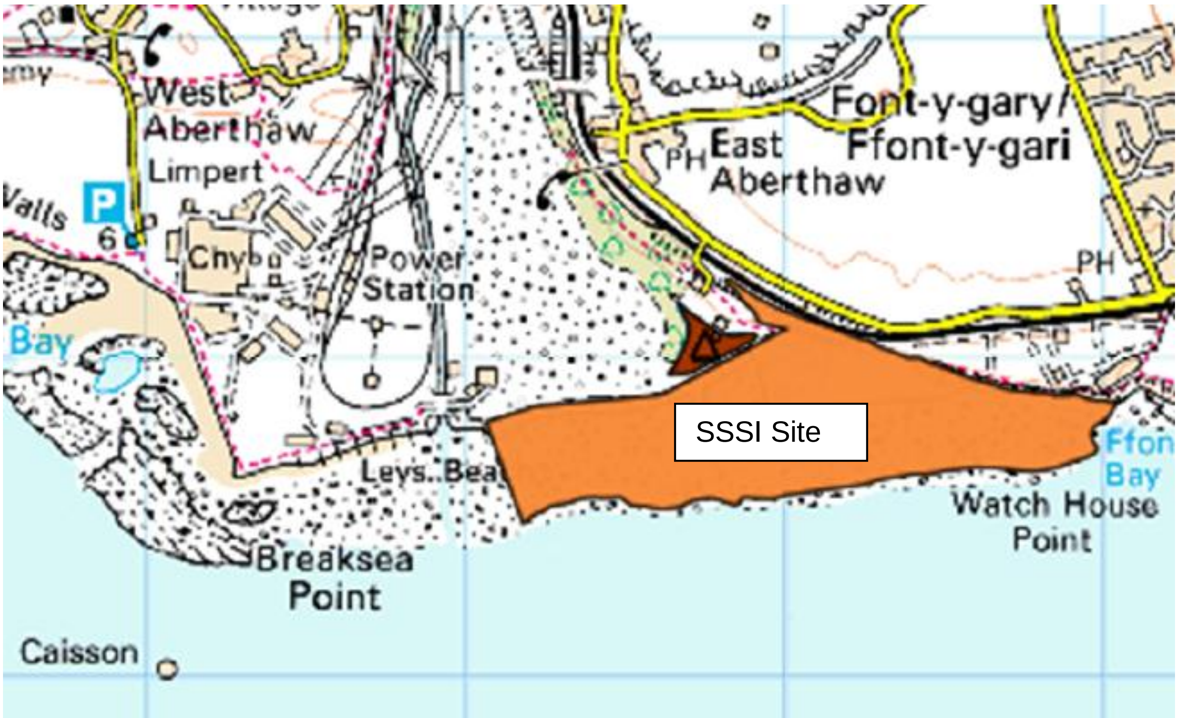

Figure 1. Coastal Map adjacent to Aberthaw

1.3 Fishery Details

Aberthaw is one of the most productive shore angling venues in south-east Wales as reported by – www.fishing.visitwales. For the most part the entire area consists of rock though there are a few sandy patches and other areas of fairly clean ground to fish. The power station is the overriding feature at Aberthaw and is in part the reason why the fishing in the area is reported as good. Offshore the concrete dome marks the cooling water intake for the power station and the outfall structure discharges warm water back out into the bay through the outfalls which are situated at the low tide mark.

Fish species are reported as: -

strap conger - April until well into the autumn;

smoothounds - end of May and stay until September;

ray, dogfish, wrasse, rockling and an occasional triggerfish - summer months;

cod and whiting appear - autumn and winter;

big cod - December through to the middle of February;

mullet - May through to October;

1.4 Existing Cooling Water System

Circulating cooling water for the main condensers and auxiliary coolers is taken from the sea, full load requirements being approximately 50 m^3s^{-1}, or 660 000 gallons per minute (40 million gallons per hour) quoted in original design data.

The absence of high silt content in the water and the virtual elimination of floating debris by the intake caisson design, have maintained the CW system relatively trouble-free.

The CW intake caisson structure is located half a mile off-shore and was originally designed to serve both Station A and Station B. From this caisson the water for Station B is brought along two tunnels (cross-section – horseshoe with equivalent diameter of each tunnel 15.4ft) to a forebay structure adjacent to the circulating water pumphouse. Eight of the twelve caisson wall inlets serve the two tunnels for Station B, and measure 15 ft high by 8.2 ft minimum wide. This gives an existing velocity of 0.55 ms^{-1}, as calculated in Appendix B.

There is a third man access tunnel from Station A to the caisson.

The CW pumps draw water from the forebay and pass the water through strainers to the condensers and auxiliary plant. The system is arranged to allow any pump to serve the condensers of any unit.

The water flowed from the condensers to an open seal pit and then through two outlet tunnels (cross-section – horseshoe with equivalent diameter of 15.4ft) to the outfall structure on the foreshore. A seawater process Flue Gas Desulphurisation (FGD) system has been retrofitted at Aberthaw power station and now a fraction of the water is passed to absorber tower to treat the flue gas.

The location of the intake and outfalls of the cooling water (CW) system is shown in Figure 3.

The hydraulic gradient through the CW system (excluding the FGD) is shown in Figure 4, which also illustrates the depth of construction on the existing intake structures.

Figure 5 shows the existing structure details.

The scale of the forebay construction and tunnels is shown in photographs in Appendix C.

1.5 CW Design Improvement Requirements

The original design document for the B station CW system provides the following system description. The circulating cooling water for the main condensers and auxiliary coolers is taken from the sea, with full load requirements being approximately 50 m^3s^{-1}.

The Environment Agency (EA) has produced a number of documents that can be used to infer Best Practise in terms of screening options for fish and eel. These guidance documents are understood to have been adopted by Natural Resources Wales (NRW) as well.

EA 2012 - Screening at intakes and outfalls: measures to protect eel (Ref 1), in particular Page 18, Table 3.1; and EA 2005 - Screening for intake and outfalls: a best practice guide (Ref 2), in particular page 122, Table 6.2; suggest the following screening options at intakes to protect eel as being applicable to a thermal power station with off shore intake: -

Option 1 - rotary drum screens with fish return
Option 2 - band screens with fish return
Option 3 - PWWC screens where feasible

EA 2005 - Screening for intake and outfalls: a best practice guide (Ref 2), in particular page 122, Section 6.2, suggests **non physical screening** fish deterrent solutions to be considered for intake improvements. These have been considered with caisson intake modifications in this report as: -

Option 4 – to reduce water velocity at existing caisson intake with – addition of acoustic and strobe light behavioural deterrent

Figure 3 shows the location of options considered on the layout of the existing CW system.

2 Options

The options selected for consideration in this study are shown on the following figures –

Figure 6 - Option 1 - New Drum Screen with fish return

Figure 7 - Option 2 - New Band Screen with fish return

Figure 8 - Option 3 - PWWC screens

Figure 9 - Option 4 - Caisson Intake Modifications with acoustic and strobe light behavioural fish deterrent

This study has been undertaken to provide an initial cost estimate and has therefore focussed on the major costs for each option. Whilst Options 1 & 2 include a fish return system which will have significant design and cost requirements these are expected to be relatively small compared to those for the main civil & mechanical works. Therefore the fish return system costs have not been included in the current cost estimates.

Estimates in section 3 of the report are based on the following described options.

2.1 Fish and Eel Screening

2.1.1 Option 1 – New Drum Screen outside sea wall

This option is the construction of a drum screen structure located before the CW forebay structure, as shown in Figure 6.

This could be located either at the first intake point, or in addition to the intake improvement, the drum screen could be located before the forebay.

The CW system would have to be isolated to allow for break in to the tunnels and during these phases of the construction process the power station would not be able to generate electricity. This lost generation opportunity is an additional cost in addition to the civil and mechanical capital costs.

It has been assumed that a drum screen large enough for the CW supply of 50 m^3s^{-1}, would be approximately 40m x 80m in plan, by 42m deep. The drum screen structure for the second location option (which would be easier of the two to construct) would partially have to be built external to the existing sea wall structure due to it's size. Therefore within the scope of the construction consideration is also required for the construction of a new sea wall and re-routing of the road that runs adjacent to the sea wall. This road would be needed for both construction and permanent operational access.

2.1.2 Option 2 – New Band Screen adjacent to forebay

This option is the new construction of a band screen structure immediately before the existing CW forebay structure, as shown in Figure 7.

The available space for construction of a new structure chamber between existing structures, existing outfall tunnels and the forebay is very limited. The CW tunnels would require isolation and removal of section, before the new structure could be constructed and before the CW system returned to service.
Photographs in Appendix C illustrate the depth of construction of the existing forebay. The new band screen chamber would be constructed to the same depth.

The approximate size of a band-screen structure means that it could in theory be situated within the sea wall structure, but the limited space would make construction very difficult and disruptive. The depth of new excavation as shown on Section B-B in Figure 7 is not advised so close to the existing principal structure of the forebay.

As the CW system would be out of service during the construction period the power station would not be able to generate electricity.

Construction costs are likely to be similar to those for the band screen options and have not been developed further at this stage.

2.1.3 Option 3 – PWWC (Passive Wedge-Wire Cylinder) Screens

From reference to Concord-screen data (Ref 6), the PWWC screens would be extensive, with the screen positioning criteria leading to new construction further into the estuary beyond the existing intake structure, as shown in Figure 8.

Considering a course slot screen size of '3mm plus', and using Concord data, and layout based on EA 2012? – Screening at intakes and outfalls: measures to protect eels – section 4.2.2.6 – screen diameter and spacing from surfaces; the minimum provision would be: - 1.5 metre diameter screens would need a minimum of 256 metre length of screen tube. This is shown in Figure 8, as four rows of 1.5m diameter screens, each of about 70m in length. With spacing between screens at 3metres to ensure free water flow, the area taken by screens, manifold and support structure would be approximately 20m by 70m. To achieve a minimum submergence of 2m and bed clearance of equal to diameter 1.5m, then overall water depth needed is about 5 metre at extreme low water level. This new intake manifold and structure would be approximately 200 metres further into the estuary to ensure uniformity of water flows. Twin pipe connections would be needed between the manifolds and existing tunnel pipework. There would be an on going maintenance requirement for screen clearance and the plant to achieve this, and to ensure reliability of water intake. The civil engineering work would need to include systems to warn vessels away from the intake array.

This demonstrates the extensive construction work necessary to retrofit PWWC cumbersome screens to the existing intake.

The construction installation itself would be environmentally damaging to the coast line.

There are a number of issues which make the PWWC screens not suitable for installation or reliability of uninterrupted water supply, these are documented in the Environment Agency guidance documents:-

EA 2012? - Screening at intakes and outfalls: measures to protect eel (Ref 1), Page 47 to 49;
EA 2005 - Screening for intake and outfalls: a best practice guide (Ref 2), page 45 to 49: –

PWWC screens are not suited for retrofitting to existing intakes, and would require a purpose 'bulkhead structure' to be created to fit a screen manifold (Ref 1 - Section 4.2.2.9)

The large number of PWWC to meet the flow intake requirement, as demonstrated above, would be impractical, and collective size could cause blockage risk, interrupting water supply; it is recognised PWWC are not suited for large flows, i.e. 50 m^3s^{-1}.(Ref 1 - Section 4.2.2.7, and Ref 2 – Section 3.2.1.12 – Applications)

PWWC screens remain an unproven technology anywhere in the world in marine waters as hostile as those offshore in the UK, with significant tides, waves and currents. 'EA 2010 - Cooling water options for the new generation of nuclear power stations in the UK – page 64', Ref 3.

Therefore for reasons of the difficulty with construction and unproven reliability this option is not considered further.

2.2 Non physical screening

2.2.1 Option 4 – Caisson Intake Modification with acoustic and strobe light behavioural fish deterrent

The first of the proposed options is a modification to the intake structure. The aim of this type of modification is to attempt to reduce the water intake velocity to below 0.3m/s, preventing the local fish population entering the intake structure.

The existing intake structure has 4 openings for each of the 2 intake pipes to the B station, as shown in Figure 3. Assuming a uniform flow across the openings with approximate size 15ft high x 8.2ft (minimum width on inside face of caisson), gives a velocity in the order of 0.55 ms^{-1} . It may be possible to change the central bulkhead dividing walls, opening and enlarging the apparent existing 'bulkhead gates' to bring water in from the A station gates, which reduces the flow velocity to 0.36 $ms^{-1.}$

This would not change or solve the problem of the high tidal range (11m) and maximum tide current speed at mean spring tide of between 2.5 - 3 ms^{-1}

In order to provide a low intake velocity a new caisson could be constructed around the exiting intake structure as shown in Figure 9. This additional caisson could also incorporate acoustic and strobe light behavioural fish deterrent.

3 Cost Estimates

3.1 Fish and eel screening

3.1.1 Option 1 – Drum screen outside sea wall

From the detailed cost estimate given in Appendix D –

Creating a drum screen chamber and new surge chamber/fore bay excavation -
- construction period is estimated at 2 years;
- works estimate of £32 million.

Installation of drum screens plant within structure etc -
- construction period is estimated at 1 year
- works estimate of £ 8 million

Regardless of if the band screen and new surge chamber are built online of the intake tunnels or off-line with tunnel diversion; the station could be expected to be out of service for about 2years. One reason being the safety case of integrity of an uninterrupted water intake and discharge during generation. This loss of generation needs to be considered within the overall cost estimate of the project. The value of lost generation will vary with market conditions but is estimated to be approximately £20million per year.

The overall cost of this estimate is £80m.

3.1.2 Option 2 – Band screen adjacent to forebay

This is not estimated as discounted in section 2.1.2.

3.1.3 Option 3 – PWWC (Passive Wedge-Wire Cylinder) Screens

It is noted from – 'EA 2012? - Screening at intakes and outfalls: measures to protect eel' (Ref 1), page 24, Table 3.5 gives indicative capital purchase cost for PWWC intake screens only, at £430k per 10 m^3s^{-1}. From section 2.1.2 of this report, sizing the PWWC screens, with a maximum flow intake of 50 m^3s^{-1}, the PWWC purchase is about £2.2million, plus installation.

When considering the number of PWWC screens, the manifold assembly, supporting marine submerged structure, physical protection and warning to sea vessels, the combined construction would be extensive.

This is not estimated further, as also discounted in section 2.1.2 on technical reliability and environmental impact reasons.

3.2 Non physical screening

3.2.1 Option 4 – Caisson Intake Modification with acoustic and strobe light behavioural fish deterrent

Possible CW intake improvements would be to limit the intake velocity to below 0.30 ms^{-1}, as well as including a fish deterrent acoustic and strobe light system.

The cost of such works could be considerable, at the very least an electrical supply would be required to the intake structure, if not a compressed air supply as well.

- Estimated at £20 million, and construction period estimated at 8 months or longer.

To increase the primary inlet area to reduce velocity before the existing caisson inlet, a new cofferdam would be constructed around the existing intake. For safety reasons this would probably require that the station to be offline during construction. For the costing we have assumed similar construction to existing - reinforced concrete caisson resting on rock. It may be possible to use precast segments, float them out and drop into place which should shorten the construction time.

It looks as if it may therefore be necessary to put at least an outer baffle to reduce velocities. It appears from some of the literature that the tide currents may not have a uniform direction so more investigation work would be required before concluding that a simple baffle plate system would be acceptable.

3.3 Notes to Estimates

We note that the use of drum screens may not be the most appropriate solution in this instance. The other stations within RWEnpower that have looked at installing fish upgrades already had at least some drum screen infrastructure and have intakes on more restricted locations.

At Pembroke there was already some drum screen infrastructure in place and it appears that some other options were unlikely to work with the intake location. Pembroke already had drum screens, therefore the requirement was to add 1 new screen unit. Most of the cost for the additional drum screen at Pembroke was for the drum screen itself (of the order of £13M). Aberthaw would require 4 drums of a comparable size to serve the volume of water required; a total cost of £52M. It is assumed that this price must have included the civil engineering works.

For Fawley there are drum screen chambers in place and other screening options do not seem suited to any feasible intake location.

Where construction works are outside the sea wall it is expected that additional construction restrictions will apply to protect the environment of the SSSI.

4 Discussion

The existing design of the intake caisson has maintained the CW system relatively trouble-free through out the station operation from 1971.

The construction of option 1, new drum screens, and option 4, caisson intake modifications, would involve substantial works and significant changes on the coast line, and disrupt the operation of the power station.

Options 2, new band screens, is discounted due to scale of construction between existing structures.

Option 3, PWWC screens, is discounted on technical reasons due to scale of off-shore construction and unreliability.

4.1 Environmental Issues

The organisation 'fishing-visit Wales' report good fishing in the area and a variety of fish species, as detailed in section 1.3.

This is not to say that there is no effect by the CW system, however the potential benefits from flow reduction and/or additional screening on the fish populations should be compared with the environmental impacts of the substantial constructions on the surrounding natural habitats.

It is safe to assume that with the construction of any of the outlined options there is going to be a considerable degree of disturbance to marine species, with alterations within and development beyond the existing intake structures, and sea wall. With managed marine works there remains an increased risk of pollution as a result of construction activities.

An environmental impacts assessment is likely to be required for off site works. The costs of these studies are outside the scope of this report.

4.2 Health and Safety Issues

Any works involving deep excavations or construction in the marine environment carry increased risks, relating to health and safety, potential programme extensions and therefore additional unexpected costs.

Whilst the risk to human life would be managed, it could be argued that this increased risk should be taken into account when discussing the need and possible benefits of installing fish protection measures on an existing system.

The reasons for the marine works, and justifying the safety case for such works, might be difficult to justify, against the perceived benefits, and in principle may not be allowed to progress.

The need for an uninterrupted water intake and discharge during generation would result in the power station not operating during the construction period.

5 Conclusion

A review of options for fish screening and fish deterrent has been carried out for Aberthaw Power Station.

The report illustrates that the scale of alterations to the existing CW system, which has operated relatively trouble-free from 1971, would be disruptive to both the operational power station and the environment.

Option 1, the installation of drum screens is the main option for direct fish screening, with a total estimate of construction cost plus loss of production of £80million.

The costs to construct a new intake are very high and should be considered against the potential benefits to the passage of eel.

6 References

1. EA 2012? - Screening at intakes and outfalls: measures to protect eel.
2. EA 2005 - Screening for intake and outfalls: a best practice guide.
3. EA 2010 - Cooling water options for the new generation of nuclear power stations in the UK.
4. www.fishing.visitwales.
5. EA - http://cdn.environment-agency.gov.uk/LIT_7888_3a0b71.pdf) – Operational Guidance.
6. Concord Screen – Intake screen data for PWWC (http://www.concordscreen.com/technical.html)

Appendix A. Drawings

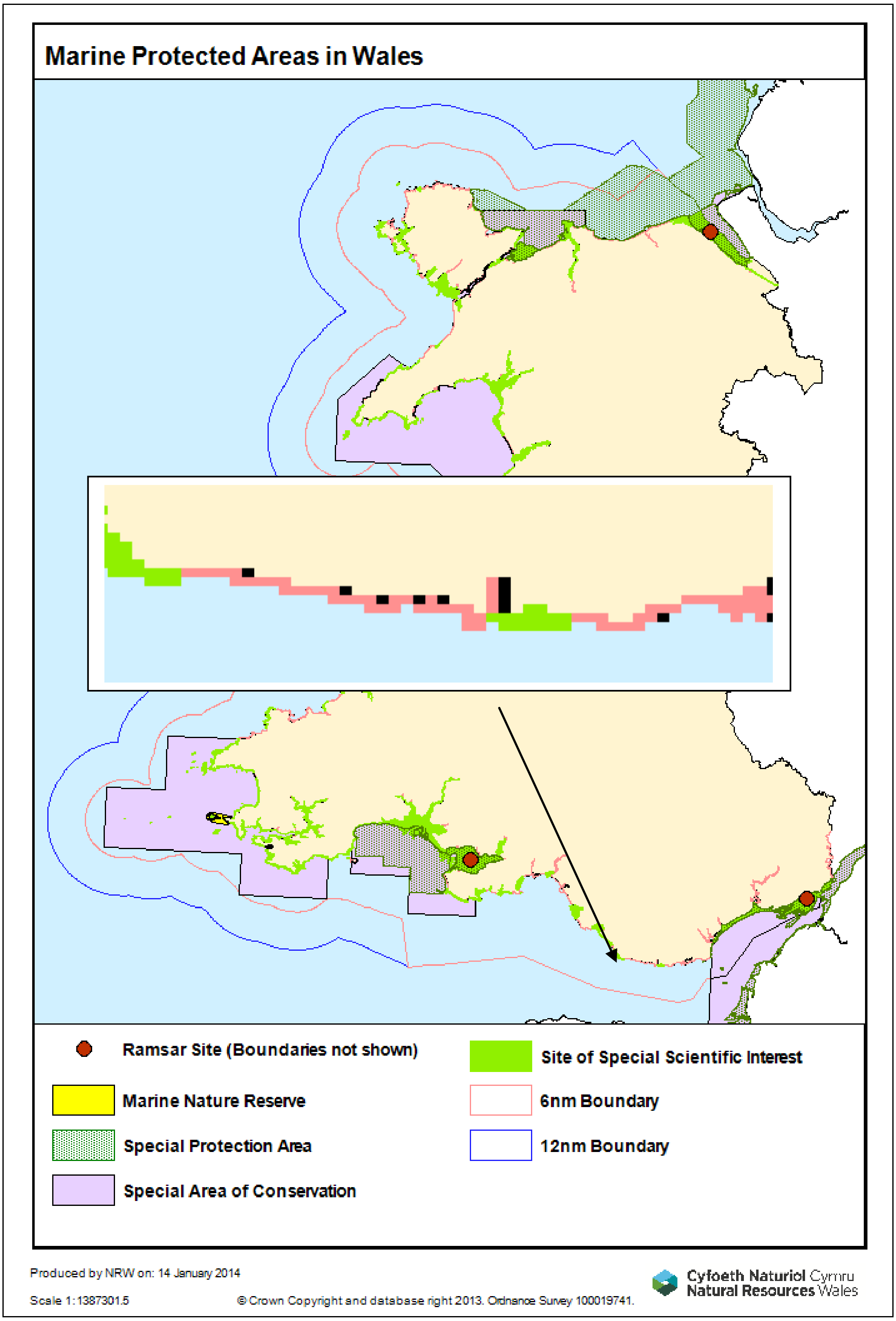

Figure 2. Welsh Government - Report to the National Assembly for Wales on Marine Protected Areas in Wales - February 2014

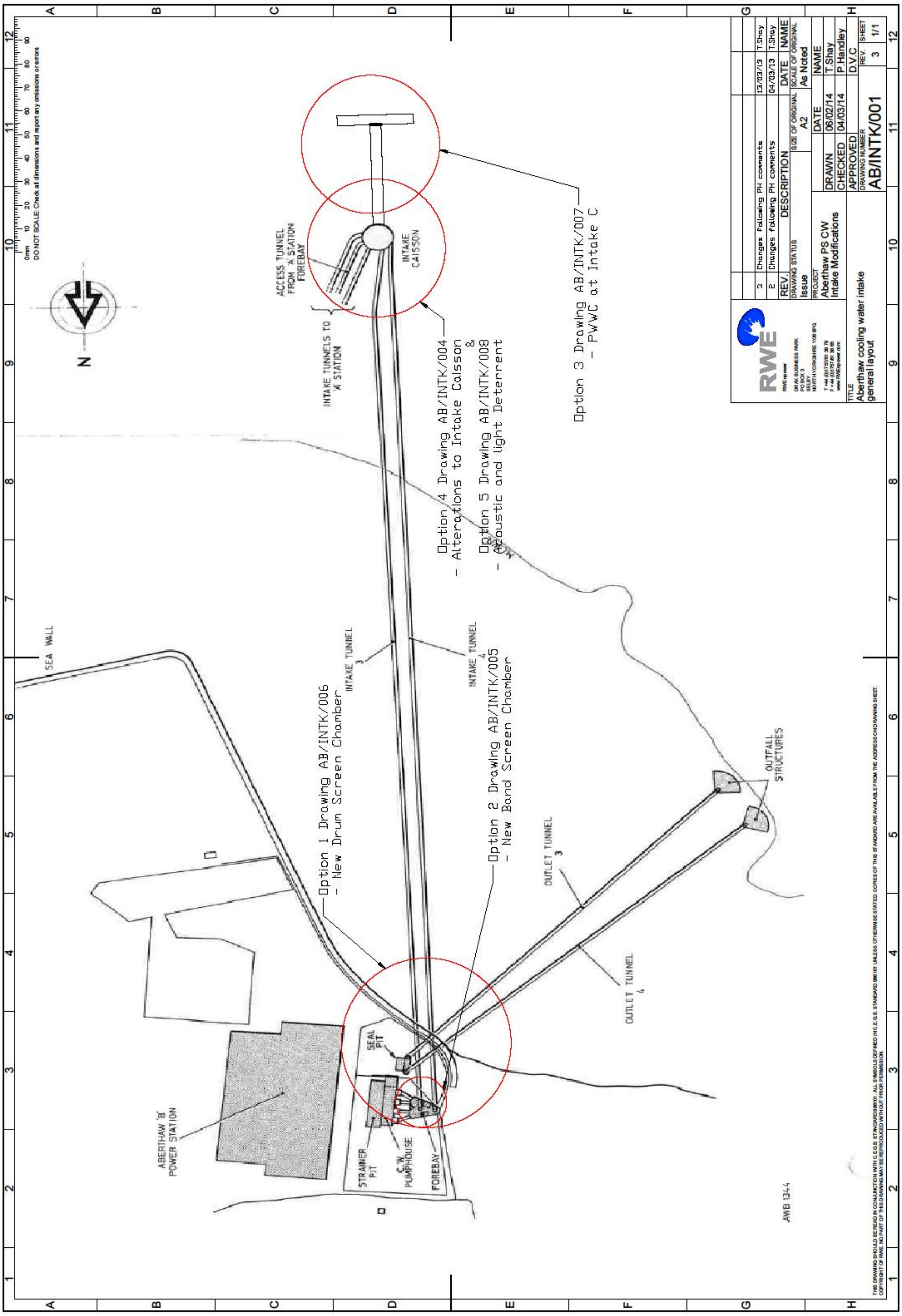

Figure 3. Layout of existing cooling water (CW) system

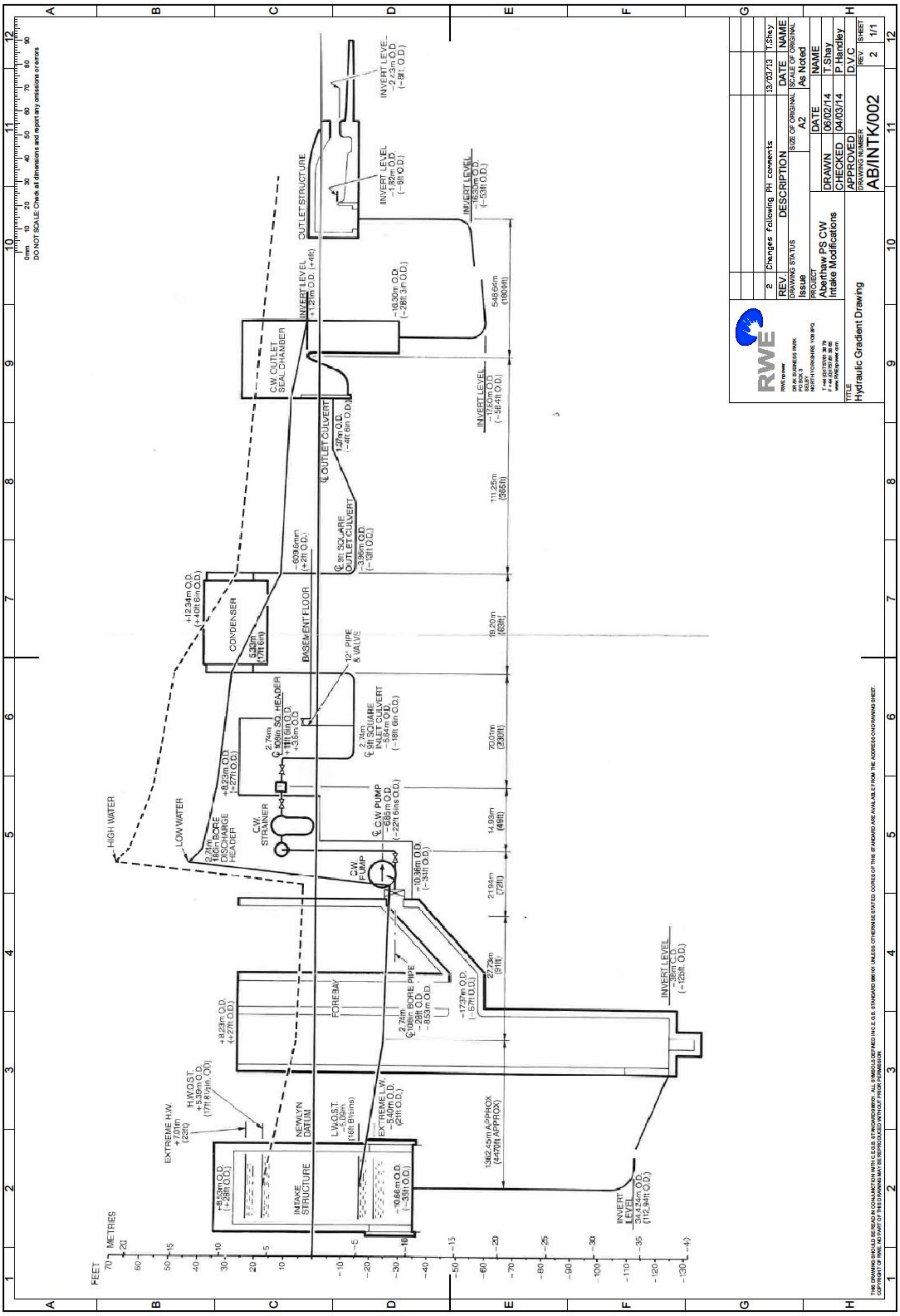

Figure 4. Hydraulic gradient through cooling water (CW) system

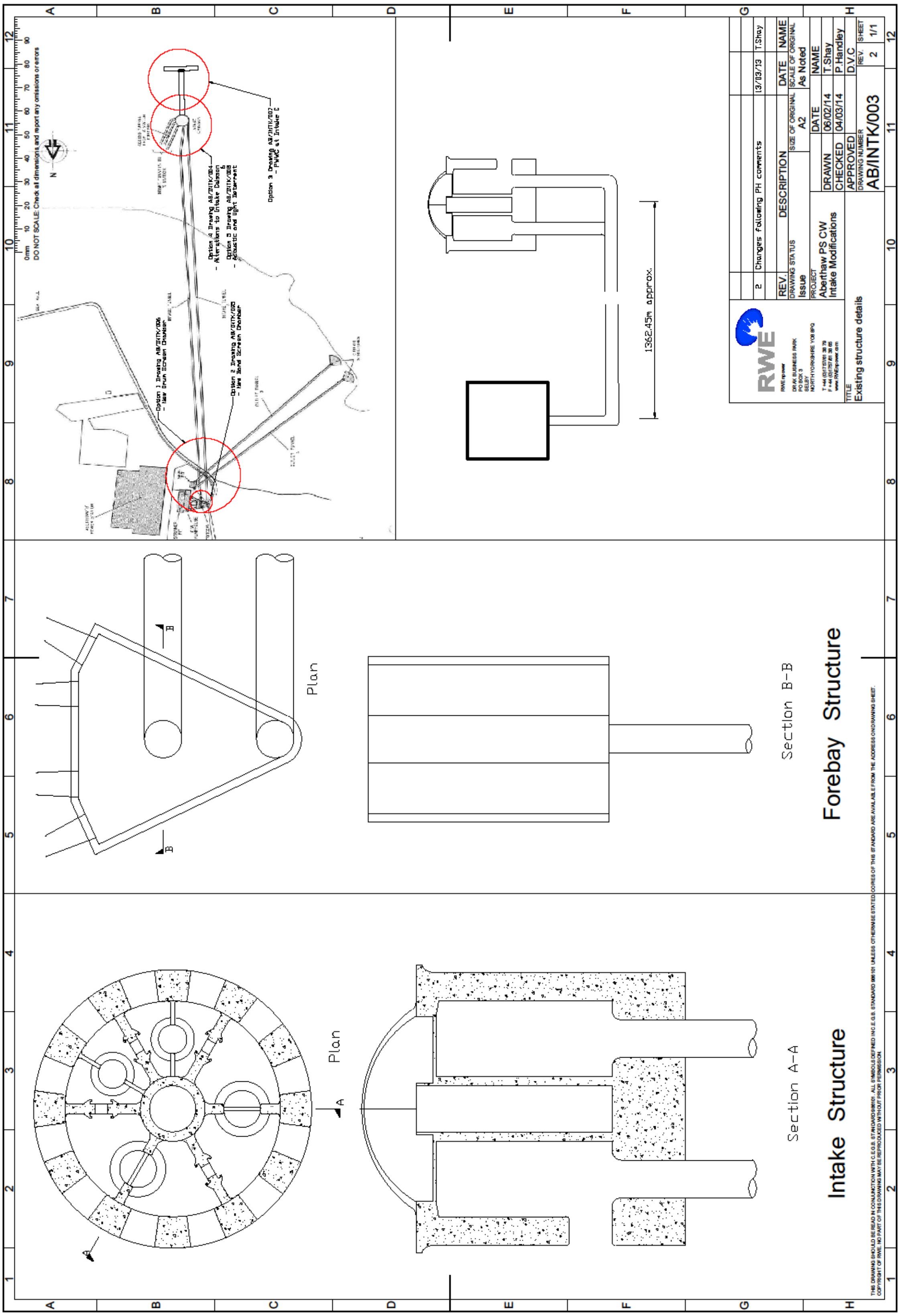

Figure 5. Existing structure details

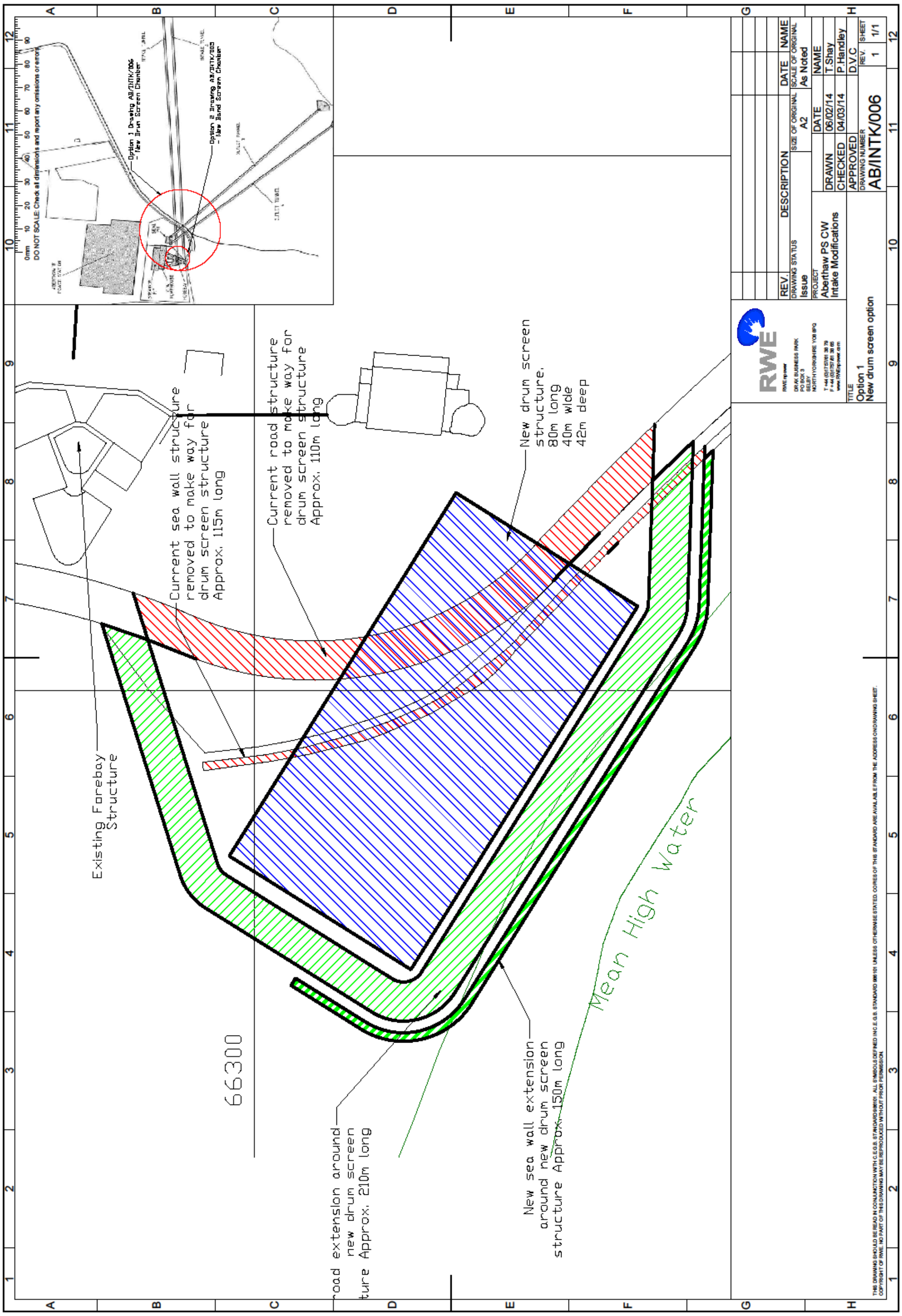

Figure 6. New drum screen with fish return

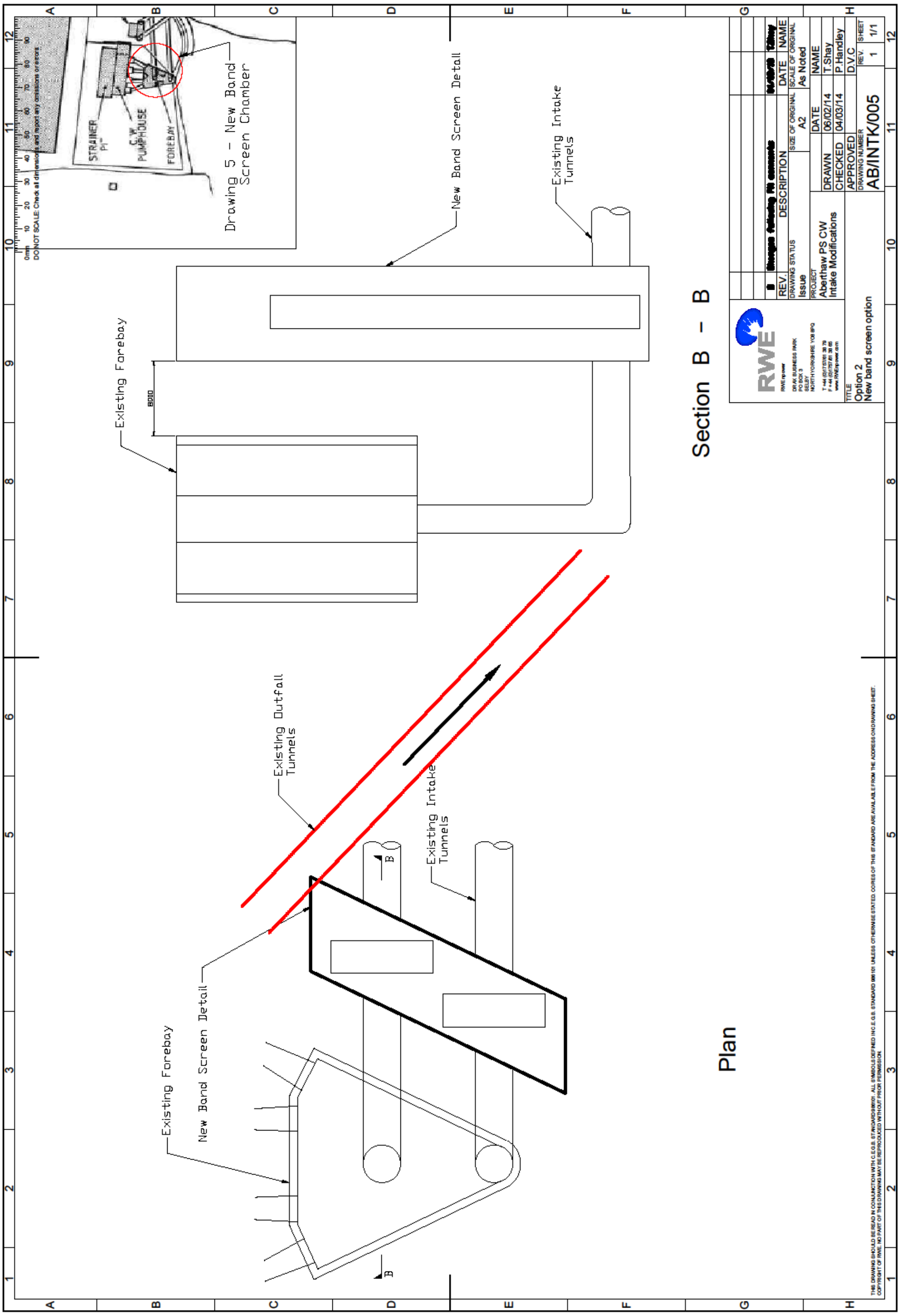

Figure 7. New band screen with fish return

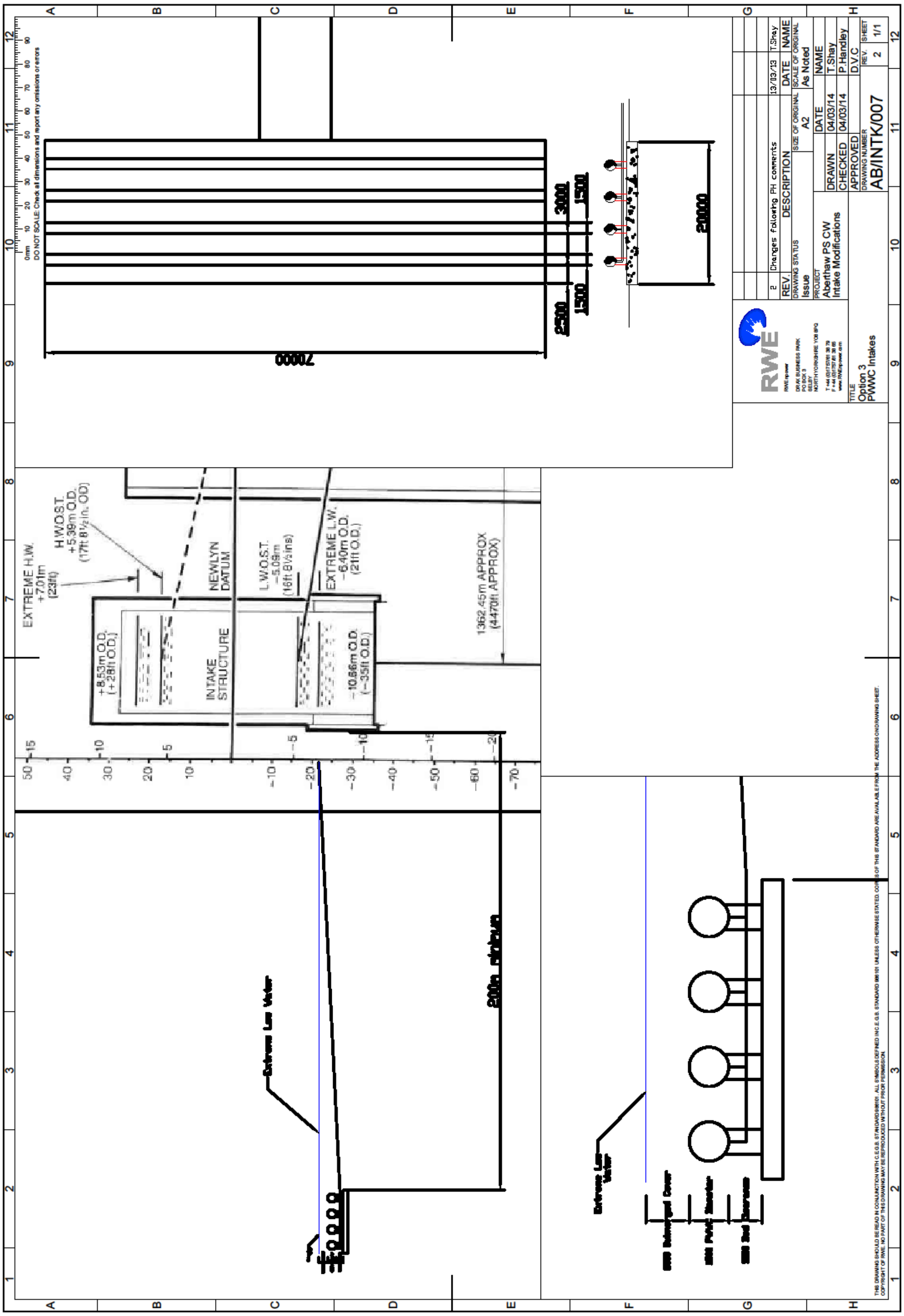

Figure 8. PWWC screens

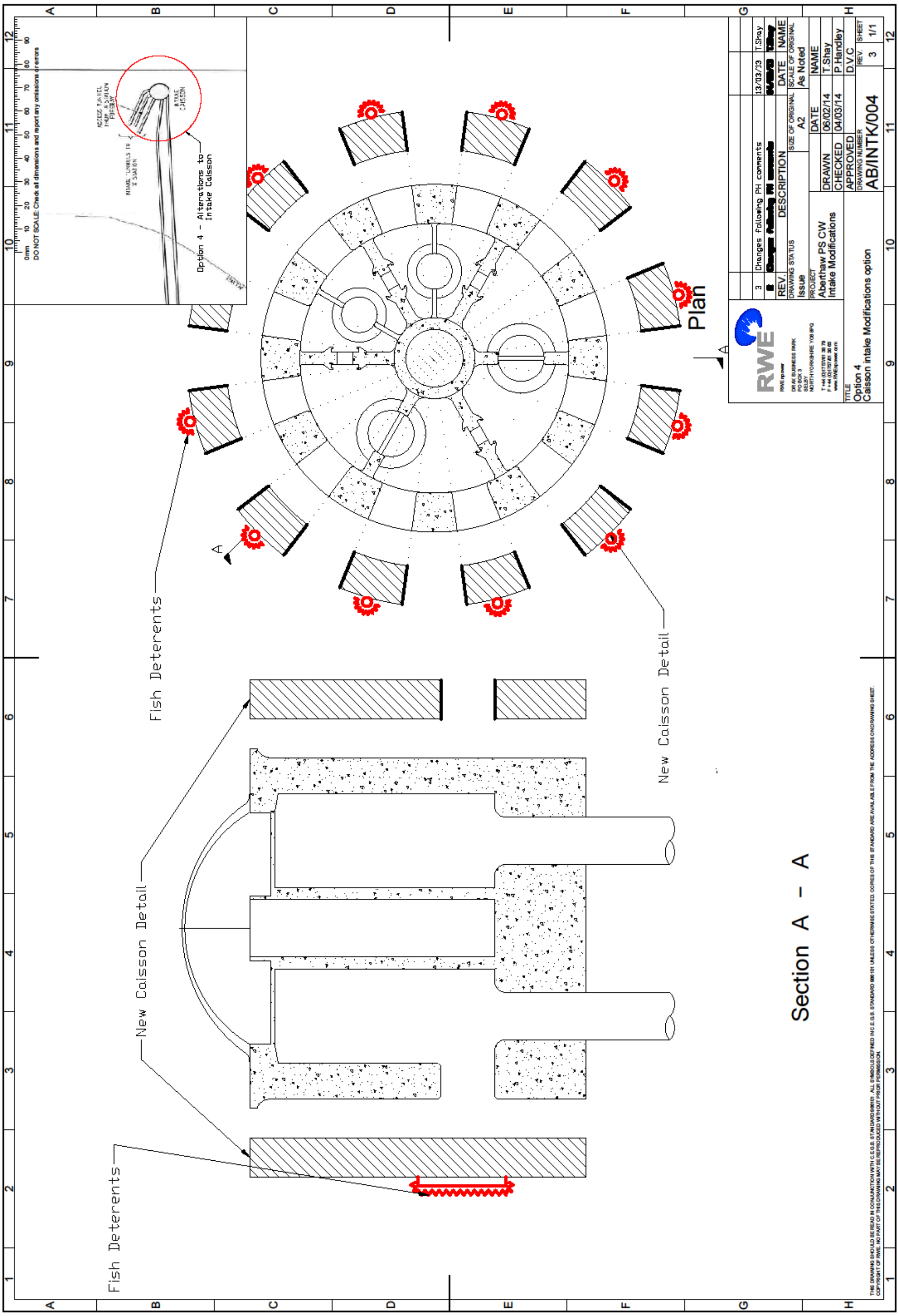

Figure 9. Caisson intake modification with fish deterrent

Appendix B. Calculations

To establish size of existing caisson inlets

From figure 5 –

the caisson diameter on the inside face of the 10’ wall is 85’ less 20’ = 65’

circumference = 3.14 x 65’ = 204.1ft x 0.3048 = 62.21m

Opening height = 15’ x 0.3048 = 4.572m

opening proportion of wall circumference = 7/(7+7.5) = 0.4827 (by scaling)

Opening area = 62.21 x 0.4827 x 4.572 = 137.29 m^2

Station B inlets only –

net opening area = 8/12 x 137.29 = 91.53 m^2

velocity = 50 m^3s^{-1} / 91.53 m^2 = 0.55 ms^{-1}

Station B and A inlets –

opening area = 137.29 m^2

velocity = 50 m^3s^{-1} / 137.29 m^2 = 0.36 ms^{-1}

Minimum width of each inlet opening, inside face = 204.1 x 0.4827 = 98.52ft / 12 = 8.2ft

Appendix C. Photographs

ABB.33. ABERTHAW B POWER STATION. 15.7.64.
C. W. Pumphouse, Forebay Excavation. C3h.

C.1. Forebay Excavation

ABB.49. ABERTHAW B POWER STATION. C.W. Pumphouse. C3h. 24.9.64.

C.2. Pumphouse Excavation

ABB.62. ABERTHAW B POWER STATION. 28.10.64.
C.W. Pumphouse Forebay. C3h.

C.3. Forebay Excavation

ABB.101 ABERTHAW 'B' POWER STATION 25.3.65
C.W. Pumphouse Fore Bay C3h

C.4. Forebay Excavation

Appendix D. Cost Estimates

Aberthaw Power Station								
Feasibility options for installation of fish screening								
Cost Estimates								
Option 1								
	Item/Task	Duration in months			Direct Estimate		**Totals, £**	Notes
		£1m/m	other		m			
	Site prep, set up		1		0.25			
	Diversion of services	2						1
	create jetty access bridge/road' ---							
	around chamber outside sea wall	4						
	alterations to sea wall	2						
	create cofferdam to top of and into rock	2						
	Excavate main chamber all assumed in rock		8		12			2 & 3
	line out chamber concrete walls, slabs etc	5						
	prep and tie-in to tunnels	4						
	fish return pipe/mini tunnel 500mm dia x 400m long		4		0.5			4
	fish return ends				0.25			
	4no drum screens; 2 per tunnel @ £2m each				**8**			
	total task duration @ £1m/month	19					19	1
					21		21	
	total estimate drum screen and chamber						**40**	
	duration in months	**13**	**10**	**23**				
Option 4								
	Caisson Intake structure improvements	8			12		**20**	5
	see Figure 11 for further details							
Notes								
1	Main contracting rate assumed at £1m/month							
2	Excavation 42m deep x 40m wide x 80m long = 134,400m3							
3	rate for excavate, dispose, land tax of rock/reuse -							
	£50/m3 + £4/m3 + £72/m3x 50% density/m3 =		90		12060000	say 12	see check Figure 11	
4	rate £1000/m							
5	To limit intake velocity to 0.3m/s, and fish deterrent system							
6	Station have advised that all excavated material will have to be disposed of off site.							
	From Spons 2012 disposal 15km away, no double handling, tipping fee land tax 20+ 46+4 = £70/m3 - covered above?							
	p169 spons £58; p171 £3 to 8/m3							
rev 3								
2014								

Figure 10. Cost Estimates for Option 1 and Option 4

Aberthaw Power Station											
Feasibility options for installation of fish screening											
Option 4											
Caisson Intake structure improvements											
	Combined for A and B station. 12 outer opening in total. Each intake pipe has a separate chamber.										
	There are small openings between the chambers.										
	4 outer gates for each of the 2 B station intake tunnels. Clear opening 15' x 8.2' (estimated from drgs)										
	Assume laminar flow across the gate surface										
						The size of openings need to be verified for accurate velocity calculations!					
1 large intake, 4 gates											
	4.57				15'		8.2ft is the minimum width on inside face of caisson.				
	2.5				8.2'						
		11.425									
		4									
			45.7	25	assume even flow split across the gates (unlikely as central gates nearer the intake pipe).						
				0.547046	m/s						
1 large intake, 2 gates											
	4.57										
	2.5										
		11.425									
		2									
			22.85	15	assume 2 middle gates take 60% of flow						
				0.656455	m/s						
May be able to change the central openings to bring water in from the A station gates which may drop the flow below 0.32m/s.											
But this would not solve the problem of the high tidal range (11m) and maximum tide current speed at mean spring tide (											between 2.5 - 3 ms^{-1}
It looks as if it may therefore be necessary to put a minimum of an outer baffle to reduce velocities											
Note - It appears from some of the literature that the currents may not have a uniform direction so more work than a simple baffle may be required.											
assume similar construction to existing - reinforced concrete caisson resting on rock.											
Outside diameter of intake structure = 95'				28.956	m						
	walls 10' thick			3.048	m	!					
	height -42 to +35'			23.4696	m						
new structure - say 2m outside existing				39	m						
	walls 3m thick			3	m						
	height			24	m						
	volume concrete			28655.64				(price based on Spons 2012 p94 water & treatment facilities)			
			-	20516.76							
				8138.88	m3	500	4	£M			
	ancillaries						2	£M			
	double as marine						12	£M			
	if take 8 months @ £1M/month						8	£M			
							20	£M			
<u>check on price for drum screen chamber</u>											
assume 1m thick section sizes.											
	base	3200	m3								
	wall	3360	m3								
	walls	6720	m3								
	int walls	5040	m3								
		18320	600	11	£M	(price based on Spons 2012 p94 water & treatment facilities)					
					note this excavation is very deep and likely to have high water table so costs will be more						
2014											

Figure 11. Option 4 Caisson intake structure improvements

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