14 GROUNDWATER AND GEOLOGY

14.1 Introduction

14.1.1 This chapter of the Environmental Appraisal (EnvApp) examines the potential risks to groundwater resources and quality that may occur as a result of the proposed development. It also describes the geology of the Development Site and any potential effects that the HPC development may have with respect to geological interests.

14.2 Scope of Assessment

14.2.1 The work described in this chapter identifies and evaluates potential risks (or change) that may arise from activities primarily concerning groundwater resources and groundwater quality. However, it should be noted that because of interactions between groundwater and other environmental parameters (e.g. geology, hydrology, drainage, aquatic ecology) there is some overlap in the consideration of potential effects and their assessment. These areas of interaction are dealt with in the relevant EnvApp chapters, apart from geology which is dealt with here, and referred to in this chapter where appropriate. The geographical scope of the assessment for groundwater is confined to the land within the Development Site, although reference is made to adjacent areas where appropriate. The assessment has been undertaken with reference to the various parcels of land as described in the introductory chapters to the EnvApp and comprises namely the Built Development Area West, the Built Development Area East and the Southern Construction Phase Area.

14.2.2 With regard to geology, the baseline geology of the Development Site is described and assessment is undertaken with regard to the potential for the works to have an effect upon existing geological interests. Assessment focuses on the geological interest of the coastal cliff exposures fronting the Development Site and those to the west which fall within the Blue Anchor-Lilstock Site of Special Scientific Interest (SSSI).

14.3 Legislation - Groundwater

14.3.1 A summary of relevant policies and guidance relating to groundwater is provided below.

a) International Legislation

14.3.2 There is no international legislation that is considered relevant to the scope of the assessment work for groundwater issues.

b) European Legislation

14.3.3 A brief summary of European Legislation relevant to groundwater is presented below:

i) The Water Framework Directive (2000/60/EC)

14.3.4 The overall purpose of the Directive is to establish a framework for the protection of surface freshwaters, estuaries, coastal water and groundwater. The objectives of the Directive is to enhance the status and prevent further deterioration of aquatic ecosystems and associated wetlands, promote the sustainable use of water, reduce pollution of water (especially by 'priority' and 'priority hazardous' substances), and ensure progressive reduction of groundwater pollution. Among the main requirements of the Directive are:

- Member States should take all necessary measures to ensure that groundwater quality does not deteriorate and to prevent the input of pollutants into groundwater.
- Discharges of hazardous substances must cease or be phased out within 20 years of their identification as a priority hazardous substance.
- All inland and coastal waters within defined river basin districts must reach at least 'good' status by 2015. The Directive defines how this should be achieved through the establishment of environmental objectives and ecological targets for surface waters.

14.3.5 In England and Wales, the Directive is implemented through the Water Environment (Water Framework Directive) England and Wales Regulations 2003.

ii) Groundwater Directive (80/68/EEC)

14.3.6 This Directive, which was adopted in 1979, aims to protect groundwater against pollution caused by dangerous substances. The Directive requires the prevention of the discharge of List I substances to groundwater, and the investigation of List II substances prior to direct or indirect discharge. The Directive is due to be repealed in 2013 by the Water Framework Directive (2000/60/C). The Directive is implemented in England and Wales by the Environmental Permitting (England and Wales) Regulations 2010 (SI 2010/675).

14.3.7 The EU has now also adopted a new directive relating to groundwater, the Directive on the Protection of Groundwater Against Pollution and Deterioration (2006/118/EC). The aim of this Directive is to ensure good groundwater quality by 2015, in line with the requirements of the Water Framework Directive. The new Directive sets out specific measures for protecting and controlling groundwater against pollution and deterioration.

c) UK Legislation

14.3.8 All of the above EU Directives are implemented in the UK though a series of primary legislation (Acts) and secondary legislation (Regulations).

i) Water Resources Act 1991

14.3.9 Part II of the Water Resources Act covers the licensing of water abstractions (including groundwater). Section 29 of the Water Resources Act covers the exemption of construction dewatering from the abstraction licensing process by stating in S.29 (2) that the restriction on abstraction shall not apply to any abstraction of water from a source of supply in so far as the abstraction … is necessary (a) to prevent interference with any mining, quarrying, engineering, building or other operations (whether underground or on the surface); or (b) to prevent damage to works resulting from any such operations. The Environment Agency (on their website) also address the exemption of construction dewatering from the terms of Part II of the Water Resource Act, and state that: '*If, as part of your works, you are de-watering or pumping water that has gathered in an excavation, then you will not require an abstraction licence if the water is to be disposed of solely to prevent interference to your building operations. If you intend to* *use water from a de-watering operation for dust suppression or pressure testing on site, you may require an abstraction licence'.*

ii) Control of Pollution (Oil Storage) (England) Regulations (2001) (SI 2001/2954)

14.3.10 The Control of Pollution (Oil Storage) Regulations came into effect in 2002. The aim of the regulations is to reduce the risk of land contamination and water pollution from oil storage. They apply to anyone storing greater than 200 litres of oil in above ground tanks (underground storage is covered by the Groundwater Regulations). Oil is defined in the regulation as 'any kind of oil and includes petrol'. The regulations do not apply to:

- oil storage inside buildings;
- waste oil;
- oil refineries; or
- oil storage for the onward distribution of oil to other places.

14.3.11 The Regulations detail the construction requirement and bunding of tanks. New oil stores after 2002 had to meet all the requirements. Existing oil stores in use before 1 September 2001 had until 1 September 2005 to comply.

iii) Environmental Permitting (England and Wales) Regulations 2010 (SI 2010/675)

14.3.12 The Groundwater Regulations (1998) (SI 2902) came into force in 1999 and implement the 1980 EU Groundwater Directive. The regulations are designed to protect groundwater from pollution arising mainly from industrial and agricultural activities. These were replaced from 31 October 2009 by the 2009 Regulations, which harmonised the regulations with the Groundwater 'Daughter' Directive (2006/118/EC). On 6 April 2010, the 2009 Groundwater Regulations were repealed and replaced by the Environmental Permitting (England and Wales) Regulations 2010 during Phase 2 of DEFRA's Environmental Permitting Programme (EPP2).

14.3.13 The main changes (to the regime under the 1998 Regulations) brought in by the 2009 Regulations, and now contained in the 2010 Regulations, are:

- replacement of the prescriptive List I and List II dangerous substances in the 1980 Groundwater Directive with 'hazardous substances' and 'non-hazardous pollutants' respectively, to be determined by Member States;
- the scope and use of exemptions, as a result of which it has been necessary to make transitional arrangements to bring radioactive substances (and discharges from isolated dwellings not connected to the sewerage system (septic tanks)) within groundwater controls; and
- replacement of the four-yearly review of authorisations by a review at any time, with all permits granted before the coming into force of these Regulations being reviewed before 22nd December 2012. The Environment Agency must, on review, assess compliance with the conditions of the permit.

14.3.14 Activities likely to lead to a direct or indirect discharge of hazardous substances (formerly List I) or non-hazardous pollutants (formerly List II) require formal authorisation. Direct discharges of hazardous substances are prohibited. Activities which may result in indirect discharges (from tipping or disposal) of hazardous substances may only be authorised if prior investigation shows the groundwater is permanently unsuitable for other uses. Such authorisation should contain conditions to ensure that necessary technical precautions are taken to prevent an indirect discharge of hazardous substances. Non-hazardous discharges will only be authorised with conditions if prior investigation can demonstrate that groundwater pollution can be prevented. Where a discharge is authorised, the authorisation will specify the discharge to be made as well the quantities of any substances allowed in the discharge and monitoring requirements. Authorisations (permits) may be reviewed at any time.

14.3.15 A discharge may be taken to include leachate from waste materials or leakage from an above or below ground storage tank, or a soakaway etc. It is an offence to 'cause or knowingly permit' the discharge of hazardous substances or non-hazardous pollutants which might lead to them to enter groundwater without an authorisation (permit).

iv) Environment Agency Groundwater Protection: Policy and Practice (GP3) 2008

14.3.16 This guidance document provides a framework for the regulation and protection of groundwater resources. It comprises a number of parts; Part 1 outlines the EnvApp's approach to the management and protection of groundwater, Part 2 provides a technical framework which sets out key principles and concepts, Part 3 provides guidance in the tools available for analysing and assessing the risks to groundwater and Part 4 provides the EnvApp's position and polices in respect to developments and other activities which may present a risk to groundwater. It also provides guidance on the key groundwater legislation and how to interpret it.

14.3.17 The policy is risk based. To assist in this, the Environment Agency has developed a series of Groundwater Vulnerability Maps and Source Protection Zones (SPZs). Vulnerability maps identify where a groundwater resource is at risk from pollution (should a pollution source exist) due to the nature of the soil, unsaturated zone or inherent characteristics of the aquifer. SPZs show the level of risk to water quality at an abstraction due to activity on or in the ground.

14.4 Legislation - Geology

a) Wildlife and Countryside Act 1981

14.4.1 The Act covers the protection of wildlife, the countryside, National Parks, and includes provisions for the designation of protected areas and Public Rights of Way (PRoW). It provides for the designation of SSSIs, National Nature Reserves (NNRs) and Marine Nature Reserves (MNRs).

14.4.2 Under the Act, SSSIs are afforded specific protection in order to protect the special interest of the site from damage or deterioration, and consultation must be undertaken prior to proceeding with any development or activity which could impact the site. NNRs all lie within SSSIs, are designated for their national or international importance for nature conservation, and are subject to legal protection. They are managed to conserve their habitats or to provide special opportunities for scientific study.

b) Planning Policy Statement 9: Biodiversity and Geological Conservation (PPS9)

14.4.3 PPS9 sets out the government's approach to planning for the protection of biodiversity and geological conservation. The key objectives of PPS9 are to:

- promote sustainable development by ensuring that biological and geological diversity are conserved and enhanced;
- conserve, enhance and restore the diversity of England's wildlife and geology by sustaining and where possible improving the quality and extent of natural habitat and geological and geomorphological sites; and
- ensure that planning decisions should prevent harm to biodiversity and geological conservation interest.

14.4.4 PPS9 is supported by a Government Circular: Biodiversity and Geological Conservation – Statutory Obligations and their Impact within the Planning System (ODPM 06/2005, DEFRA

01/2005) and a good practice guide in relation to planning for biodiversity and geological conservation.

c) Regionally Important Geological sites/Local Geological Site

14.4.5 Features of regional or local geological interest can be designated as Regionally Important Geological sites (RIGS). It should be noted that since the publication of the DEFRA Local Sites Guidance report, the term Local Geological Site is often used for sites previously referred to as a Regionally Important Geological site. Other terms which are used to describe locally important geological/geo-morphological sites include: County Geological Site, Site of Nature Conservation Interest (SNCI) and Site of Importance for Nature Conservation (SINC).

14.4.6 Regionally Important Geological sites are selected by voluntary geo-conservation groups which, in England, are generally formed by county or unitary authorities. RIGS are currently considered the most important places for earth science outside statutorily protected land such as Sites of Special Scientific Interest (SSSIs) (see Wildlife and Countryside Act 1981 below) and are important as educational, historical and recreational resources.

14.4.7 The protection of RIGS is typically encouraged through the planning system and most local planning authorities regard RIGS as equivalent to non-statutory wildlife sites and thus list them in their local plan or emerging Local Development Framework (LDF).

14.5 Methodology

a) Introduction

14.5.1 The determination of potential effects of Hinkley Point C nuclear power station on groundwater has been undertaken with respect to identifying and, where practical, quantifying likely change to groundwater resources and groundwater quality. The standard assessment methodology **Chapter 5, Volume 1** has been adapted to provide an indication of the likely scale of change and to define the potential significance of any change. Specific data collected through a monitoring programme, together with available information from previous studies have been used in developing a conceptual groundwater model for the Development Site. This has then been combined with a mathematical model to determine the potential effects that the construction and operation of the nuclear power station would have on groundwater resources and quality within the Development Site and further afield. Where, through this analysis, potentially adverse effects have been identified options for managing the construction and operational works in order to minimise potential change to groundwater parameters have been identified.

b) Data and Sources of Information - Groundwater

14.5.2 The baseline information and the assessment work for the Built Development Area West are based on desk based information and site specific, qualitative and quantitative intrusive data (i.e. boreholes, groundwater monitoring and pumping tests etc). The baseline descriptions and assessments undertaken for the Built Development Area East and Southern Construction Phase Area are based primarily on desk based information.

14.5.3 The following principal information sources have been used to establish the groundwater baseline conditions:

- Ordnance Survey (2005) Explorer Map 1:25,000 scale 'Quantock Hills & Bridgwater' Sheet 140.
- British Geological Survey (BGS) 1:50000 BGS Sheet 279; Weston-Super-Mare.
- Whittaker, A and Green, G.W. (1983). Geology of the country around Weston-Super-Mare: Memoir for 1:50000 geological sheet 279, New Series, with parts of sheets 263 and 295. Institute of Geological Sciences. London.
- Rendel Palmer and Tritton (1986). Hinkley Point 'C' Power Station Pre-Application Studies, Volume 2 Geotechnical Report.
- Allot Atkins Mouchel (1988). Hinkley point 'C' Power Station Geotechnical Studies, Geotechnical Summary Report – Chapter 7. Report Ref: HPC 1101/57.
- Aspinwall & Company (1996). Analysis of Groundwater Conditions at Hinkley Power Station. Report Ref: NU5101B for Nuclear Electric.
- Structural Soils Ltd (February 2009). Factual Report on Ground Investigation: On Shore Investigations for Hinkley Site, Report Ref: 721763.
- EDF (8th May 2009). Onshore geological, geotechnical and hydrogeological interpretive report. Report Ref: EDTGG090141A1PREL.
- AMEC. Summary of Groundwater Quality (Campaign 5) Radiochemical Analysis Results Report Ref: 15011/TN/00066.
- AMEC. Summary of Groundwater Quality (Campaign 5) Non-Radiochemical Analysis Results Report Ref: 15011/TN/00060.
- AMEC. Desk Based Assessment and Synthesis Report for Complementary Lands. Report Ref: 15011/TR/00121.
- AMEC. Preliminary Conceptual Groundwater Model. Report Ref: 15011/TR/00092.

c) Groundwater Monitoring Programme

14.5.4 As part of the on-shore investigation works undertaken in 2008, 36 rotary cored and 23 rotary open holed destructive boreholes were drilled within the Built Development Area West. A total of 24 of these boreholes were completed with piezometers (a piezometer is a small diameter well used to monitor water pressure) to allow groundwater level monitoring (both shallow and deep) and sampling to be undertaken.

14.5.5 For groundwater level monitoring, transducers were installed to measure the pressure of the water column above them in the borehole. These readings were taken automatically every hour. Periodically (usually during sampling) the readings stored in the transducers' dataloggers were downloaded for processing. Manual water level readings were taken at this time to calibrate the transducers, and the automatic readings were converted to water level in metres below ground and above sea level datum. Correction for barometric pressure was carried out automatically. The transducers also record water temperature and electrical conductivity.

14.5.6 A groundwater quality monitoring programme for the Built Development Area West has also been undertaken. This comprised a total of five monitoring campaigns, in December 2008 and in January, March, April and June 2009. During each campaign, groundwater samples have been collected from eleven borehole piezometers installed as part of on-shore investigations. The boreholes included in the groundwater quality programme are indicated on **Figure 14.1**. Three of the piezometers sampled were screened to allow sample recovery from the deep groundwater (CBH11, CBH16, CBH29 - response zones ranging from 30m to 54m below ground level (bgl)), with the remaining eight piezometers being screened to sample the shallow groundwater (CBH20, CBH21, CBH24, CBH25, CBH27, CBH33, CBH35, DBH09 - response zones ranging between 3.5m bgl to 18.5 m bgl).

14.5.7 Determinands in the samples were analysed using standard test methods: mass spectrometry, titration, gravimetry and gas chromatography.

14.5.8 Five sampling campaigns for radiological analysis of groundwaters have also been undertaken, coinciding with the non-radiological sampling campaigns described in **Section 14.5.6**.

d) Risk Assessment and Screening

14.5.9 A Tier 1 groundwater risk assessment using the analytical results has been undertaken. This has involved the comparison of the groundwater concentration with relevant UK Drinking Water Standards (DWS) and the Marine and Freshwater Environmental Quality Standards (EQS). As part of the implementation of the WFD, in December 2009, Directions were issued by the UK government to the Environment Agency which allowed revised water environmental quality standards developed by UKTAG (United Kingdom Technical Advisory Group) for the WFD to be implemented. The WFD EQS values adopted for Hinkley (and validated by EDF) are presented in Table 14.5.1 alongside previous standards.

14.5.10 To assess the risks to groundwater and surface waters at Hinkley in line with the requirements of the WFD, the published Tier 1 screening values from The River Basin Districts Typology, Standards and Groundwater Threshold Values (Water Framework Directive) (England and Wales) Directions 2009 have been adopted. In addition, a review of the River Basin Management Plan for the south west (DEFRA/Environment Agency- Annex B Water Body Status Objectives) has been undertaken to determine if any specific threshold values were published for the controlled water receptors identified in the Conceptual Site Model (i.e. groundwater in the Secondary A aquifer (formerly Minor Aquifer) and the Hinkley C drainage ditch and Holford Stream surface water systems). This review of the water body status objectives set for the South West district indicated the following:

- The water body status objectives for the Secondary Aquifer in proximity to the study area confirmed that it is not located in a designated Groundwater Water Protection Area established under the Water Framework Directive. No trigger threshold values for the effects of changes in groundwater on surface waters have therefore been set for the underlying Secondary A aquifer underlying and in proximity to the study area.
- The on-site surface water receptors (Hinkley C drainage ditch and Holford Stream) have no water body status objections set under the WFD and the River Basin Management Plan (Annex B) for the South West. However, as Holford Stream is a tributary of the Stogursey Brook (albeit the confluence located at a downstream location), which has water body status objectives itself, the EQS values (for water chemistry) for Stogursey Brook have been adopted and the EQS values for 'good' quality water have been applied.
- Water body status objectives for Stogursey Brook have been specified in the River Basin Management Plan. The Stogursey Brook waterbody status is currently classified as an overall 'Poor' WFD standard with the objective of reaching 'Good Ecological Status' by 2015 for a select number of water chemistry parameters.

14.5.11 Where applicable these have been used, together with the target status of 'Good' to define appropriate EQSs under the WFD for the assessment of risk from groundwaters to surface water receptors. In each case, the highest available status score has been chosen, given that the WFD dictates no deterioration of any component water quality parameter should occur.

14.5.12 The WFD provides a range of EQS values which have to be adjusted to account for site specific conditions (e.g. hardness and alkalinity) and these have been taken into account in defining the site specific EQS values.

14.5.13 As the study area lies outside a groundwater water protected area, there are no water body status objectives (for groundwater effects on surface waters in accordance with Part 7 of the

WFD) specified for the aquifer underlying the study area. Therefore, in the absence of these values, the EQS values are based solely on the EQS values of ‘good’ standard for freshwater rivers (Part 4 specific pollutants) and EQS values for priority substances for inland waters (Part 5 priority substances) in accordance with Test 2 detailed in the Groundwater Classification System and its Application in Regulation document.

14.5.14 All EQS values have been revised in line with the WFD where applicable, with the exception of the values specified for Groundwater Drinking Water in test 4 and test 5. The current UK Drinking Water Supply Regulations (2000) are retained as screening values to assess the risks to groundwater, and using the test 4 screening value where no current drinking water screening values are available.

14.5.15 The main EQS values (for groundwater drinking water) are not adopted in total due to the study area not being located within a Groundwater Water Protected Area, for which these values apply; and that they are set at a percentile of the UK Drinking Water Supply Regulation Values which is not considered to be applicable to the environmental setting of the study area.

14.5.16 Where no EQS value (saltwater or freshwater) exist in the WFD, the previous EQS values specified have been used as screening criteria

e) Development and Use of Groundwater Models

14.5.17 In order to evaluate the potential effects of the HPC on groundwater conditions, notably flow directions and levels.

i) Conceptual Model

14.5.18 Using the available information on the geological structure and succession and data from groundwater studies of the development area a preliminary conceptual and qualitative groundwater model has been produced, as shown in **Figures 14.2** and **Figure 14.3**. This conceptual model has also taken account of hydrogeology work previously undertaken by Aspinwall & Company (1996) and Allott Atkins Mouchel Power Consultants (1988).

ii) Mathematical Model

14.5.19 A numerical groundwater model has been developed to represent as closely as possible the observed baseline regime and provide a basis for assessment of future scenarios.

14.5.20 The model has been developed using the United States Geological Survey (USGS) MODFLOW code running under Groundwater Vistas v5. The architecture and boundary conditions have been determined in association with EDF CEIDRE.

14.5.21 An important part of model development has been calibration. Options for calibration of the model were limited to i) a single short-duration pumping test carried out as part of the Built Development Area West onshore investigation in December 2008, and ii) the groundwater hydrograph records from about 12 months of data (between December 2008 and January 2010) collected from the transducers installed in many of the monitoring boreholes.

14.5.22 The calibration process has been further constrained by the interdependence of hydraulic conductivity and infiltration recharge variables in generating a water table surface. The former is estimated from permeability and pumping tests which sample very small volumes of aquifer material, whilst the latter is subject to temporal and spatial variability in a parameter that cannot be measured directly. Moreover, the multi-layered nature of the Lower Lias aquifer makes the comparison of equivalent monitoring points difficult.

14.5.23 Nevertheless, it has been possible to develop a reasonable fit for the model and to make development scenario projections which are considered valid for environmental assessment purposes. The model development is an ongoing process, and it is expected that further evolution will take place on finalisation of additional ongoing investigation programmes in the Built Development Area East.

f) Assessment of Potential Groundwater Effects

14.5.24 The basic assessment methodology adopted for assessing the potential effects on groundwater resources and quality arising from the proposed development is set out in **Chapter 5, Volume 1**.

14.5.25 With respect to groundwater, the following subject specific criteria for determination of impact magnitude and receptor importance have been utilised in the assessment process, as set out in Table 14.5.1 and Table 14.5.2.

14.5.26 Importance can be most readily defined from the Environment Agency designated aquifer status; the presence within the aquifer on and around the development site and of groundwater Source Protection Zones (Inner, Outer, Catchment); and the presence of any other specific groundwater uses (abstraction, baseflow support to surface drainage). With specific respect to groundwater, aquifers are more sensitive to changes in quality than level because of the timescales involved in groundwater flow and natural flushing/attenuation of any groundwater quality (contamination).

Table 14.5.1: Guidelines Used in the Determination of Magnitude of Change for Groundwater Resources

Magnitude	Guideline
High	Very significant certain or likely change to key groundwater regime characteristics to the extent that UK and European legislation is contravened. Change in groundwater level, quality or available resource usefulness is chronic, permanent or prolonged significantly beyond the activity causing the change, and irreversible. Permanent loss of aquifer as useful groundwater resource. Changes are spatially extensive beyond the area in which the effect may occur, e.g. drawdown into adjoining areas or contamination down gradient of site into adjoining areas.
Medium	Significant likely change to key groundwater regime characteristics to the extent that UK and European legislation may be contravened. Groundwater quality may be affected permanently or at least for 10 years. Change in groundwater level, quality or available resource usefulness is prolonged more than two years beyond the activity causing the change, and only reversible after significant remediation activity. Permanent or long term loss of aquifer as useful groundwater resource. Changes are spatially extensive beyond the area in which the effect may occur, e.g. drawdown into adjoining areas or contamination down gradient of site into adjoining areas.
Low	Possibility of noticeable but insignificant changes in groundwater levels or quality for more than two years, or significant changes for more than six months but less than two years, or barely discernible changes for more than two years. Reversible without external action required. Changes confined largely to the area of effect only. No contravention of UK or European legislation.

Magnitude	Guideline
Very Low	Barely discernible changes in groundwater levels or quality for more than two years, or noticeable but insignificant changes for more than six months but less than two years. Changes confined largely to the area of effect only and reversible without external action. Changes of lower magnitude than baseline seasonal changes. No contravention of UK or European legislation.

Table 14.5.2: Guidelines Used in the Determination of Importance for Groundwater Resources

Value and Sensitivity	Guideline
High	Principal Aquifer with significant public water supply abstractions. Site is within Inner or Outer Source Protection Zones.
Medium	Principal Aquifer with significant public water supply abstractions. Site is within Catchment Source Protection Zone; or Minor Aquifer with significant water supply abstractions. Site is within Inner or Outer Source Protection Zones.
Low	Secondary A Aquifer with water supply abstractions. Site is within Catchment Source Protection Zone.
Very low	Secondary A/B Aquifer without abstractions in area of activity; or Unproductive.

g) Data and Sources of Information - Geology

14.5.27 The geology of the Development Site and surrounding area has been determined with reference to the series of recent and historical investigations and reports produced by third parties, detailed above. These sources have relied upon evidence from the British Geological Survey (BGS) published maps and Memoirs, the commercially available Groundsure Geology and Ground Stability report and direct evidence derived from intrusive investigations and geological field mapping.

14.5.28 Given the potential for loss of exposure of the rock sequence exposed in the cliff section due to construction of the proposed sea defence and impacts on the exposed rock pavement due to construction of both the sea defence and the temporary jetty, consultation was undertaken with Natural England to determine their perspective and potential concerns with respect these aspects of the proposed development.

14.5.29 Natural England stated that if the stratigraphy exposed in the cliffs could be found elsewhere then this would be likely to remove any concerns relating to loss of geological interest. Specifically, Natural England requested that the geological beds found at any alternative site should contain the same rock units as referred to in the relevant geological memoirs. In respect of this, the exposed geological sequence at Hinkley Point and to the west has been examined and mapped in order to determine similarity with the exposures that would be lost due to the proposed construction works. The report on the mapping exercise is provided at **Appendix 14a.**

h) Limitations and Assumptions

14.5.30 At the time of writing, intrusive investigations, including sampling testing and monitoring of environmental media within the Built Development Area East and Southern Construction Phase Area are scheduled or underway. As such, the current assessment of effects on groundwater within these areas is based principally on desk study information.

14.6 Baseline Environmental Characteristics

a) Introduction

14.6.1 This section presents the baseline environmental characteristics for the proposed Development Site and surrounding areas with specific reference to groundwater. The general location of the proposed development is shown in **Figure 2.2.1**.

14.6.2 The geographical extent of the area under consideration includes that within the boundary of land nominated for nuclear new build at Hinkley Point for the Strategic Siting Assessment (SSA) process. Reference throughout is made to the three separate areas of land delineated within the Development Site (the Built Development Area West, Built Development Area East and Southern Construction Phase Area), as described in **Chapter 2** of the EnvApp.

b) Topography

14.6.3 In general terms, the topography around Hinkley Point comprises undulating countryside, terminating at Bridgwater Bay to the north at a natural cliff line which descends to a shingle beach.

14.6.4 Across the Development Site ground elevations range from approximately 10 m above ordnance datum (AOD) to 35 m AOD and across the Southern Construction Phase Area ground elevations range from approximately 5 m AOD to 28 m AOD.

14.6.5 Within the Built Development Area West and Southern Construction Phase Area are a series of east-west trending ridges and depressions. The lowest terrain within the study area is formed by a shallow east-west trending valley which runs along the boundary between the Southern Construction Phase Area and the Built Development Area West. The base of the depression is occupied by a small watercourse (Holford Stream) lying at an elevation ranging from 4.1 m AOD to 5.1 m AOD.

14.6.6 North of this shallow valley, within the Built Development Area West, the ground rises sharply towards a ridge which crests at a maximum elevation of 35.3 m AOD. North of the ridge, the topography comprises a series of west-east trending undulations and the ground generally falls towards the north before it is intercepted by the path of an agricultural drainage ditch which runs from west to east before changing course to head north towards the coastline, along the boundary of the Built Development Area West and Built Development Area East. To the north of the west-east trending length of the drainage ditch the land rises at a moderate gradient from around 19 m AOD to 22 m AOD and then gently falls again to the coastline. Elevations near the cliff edge adjacent to the Built Development Area West are typically around 15 m AOD. In the north eastern area of the Built Development Area West, the land surface reduces in height and a lower elevation along the cliff line is maintained through the Built Development Area East area (ranging from 10.7 m AOD to 13.3 m AOD).

14.6.7 Within the Southern Construction Phase Area the gently undulating relief continues southwards from the shallow valley, with the land gently rising to around 5.8 m AOD and then increasing in gradient to a maximum of between 21.1 m AOD and 24.8 m AOD. The land then gently falls towards the southern boundary where elevations typically range between 15 m AOD and 16 m

AOD adjacent to Bum Brook. A small hillock is located towards the south-west corner of the Southern Construction Phase Area where the land crests at an elevation of 28.7 m AOD.

14.6.8 The topography of the Built Development Area East comprises areas of variable relief. The southern boundary is occupied by higher ground peaking at 26.2 m AOD. The relief then falls northwards and levels out with a large proportion of the area lying at elevations ranging between 14 m AOD and 16 m AOD.

14.6.9 A number of minor surface watercourses are present within the study area. Holford Stream runs west to east within the northern part of the Southern Construction Phase Area. This watercourse flows under Wick Moor Drove and drains into Wick Moor to the east. There are also a series of agricultural drainage ditches present on site, running along field boundaries. Two drainage ditches are present within the Built Development Area West, one running west to east along a field boundary in the northern part of this land parcel before turning northwards towards the coastline (as referred to above). The other, drains west to east at the base of the shallow valley forming the boundary between the Built Development Area West and Southern Construction Phase Area.

c) Geology

14.6.10 The study area is located within the Bristol Channel Basin which is a WNW - ESE trending basin approximately 30 km wide and 150 km long and contains a depth of approximately 3,000 m of both Tertiary and Mesozoic sediments.

14.6.11 The solid geology in the locality of the study area predominantly comprises the Lower Lias of the Lias Group (Lower Jurassic) and the Triassic Penarth and Mercia Mudstone Groups. The local area geology is shown within **Figure 14.4** and is taken from the 1:50000 BGS Sheet 279; Weston-Super-Mare.

14.6.12 The structural geology of the area, based on BGS Sheet ST24NW (1:10,560 scale) shows the study area to be located on the northern flank of an anticline with a crest orientation running generally east to west. Strata are seen to generally dip gently (10°) in a direction ranging northwest through northeast. A major northeast-southwest trending faulted zone crosses the footprint of the existing Hinkley Point Power Station Complex, with part of this structure utilised as the cooling water outfall of the existing Hinkley Point Power Station Complex. To the northwest of this fault zone, Whittaker and Green (1983), as reported in the Geological Survey and Mapping report, recorded that contours on the base of the Lower Lias bed are parallel to the outcropping strata on the foreshore with a dip between 5° and 10° to north north-east.

14.6.13 **Figure 14.4** is a detail of the 1:50,000 scale published geological map which includes Hinkley Point. It also shows the Development Site boundary and the significant surface watercourses in and around the site. **Figure 14.5** shows the lines of section presented in detail in **Figure 14.2** and **Figure 14.3**, which are south-north cross sections illustrating the principal features of the geology across the Built Development Land West (**Figure 14.2** details the site itself, **Figure 14.3** incorporates the underlying geology from Stogursey northwards).

14.6.14 Fault zone drag is noted in the BGS Memoir to have resulted in the slight deflection of these strata towards an east-west trend. To the southeast of the fault zone the strata are noted to be folded into a slightly asymmetrical anticline, which plunges to 070°. The fault zone is indicated in the Memoir to be poorly exposed on the foreshore, masked by the outflow channel. The net throw of the fault is recorded as approximately 4.5 m at the foreshore with the downthrow to the southeast. The Memoir further asserts that the net throw on the fault increases to 10.6 m further inland (NGR 2128 4624).

14.6.15 Prior to any confirmatory intrusive investigations the available information indicates that:

- The Southern Construction Phase Area is underlain by the Penarth Group Langport Member, Blue Lias and Charmouth Mudstone Formations **Table 14.6.1** with the exception of a small area in the western section of the Southern Construction Phase Area. This area is underlain by an inlier of the Mercia Mudstone and Blue Anchor Formations and corresponds with a topographic low to the immediate west of the Southern Construction Phase Area.
- To the immediate north of the Southern Construction Phase Area an uplifted linear exposure trends east-west and comprises mudstones and halite-stone of the Triassic Mercia Mudstone Group and Penarth Group (Blue Anchor Formation) mudstones. This area corresponds with the linear depression in the local topography.
- The Built Development Area East is underlain by the Penarth Group Langport Member, Blue Lias and Charmouth Mudstone Formations.

14.6.16 Intrusive investigations undertaken as part of the first on shore investigation, within the Built Development Area West have confirmed and characterised the sequence of geological strata present within this part of the study area. The proven geological sequence comprises a basement of the Mercia Mudstone Group overlain by the Penarth Group, which is in turn overlain by Blue Lias. These deposits subcrop on the site and are covered by a thin veneer of superficial drift which is of variable thickness as detailed above.

14.6.17 The solid geology of the Built Development Area West area dips to the north by a relatively uniform 7-9°. Upthrown strata of the Mercia Mudstone Group outcrop in the southernmost part of the Built Development Area West, in the fields to the south of the main east-west agricultural track which crosses this part of the study area. Penarth Group strata outcrop north of this on the east-west ridge of high ground, forming a steeper rock scarp outcrop succeeded northwards by the Blue Lias Formation which forms the geology all the way to the coastline. The mean dip direction of Blue Lias strata in Built Development Area West (northern part) identified during mapping is 010˚. Slight deviations to this dip direction will be controlled across the site related to the fault bounded inlier formation and small scale faults exhibiting drag/folding.

14.6.18 The geology of the Built Development Area East has largely been determined with reference to site investigations undertaken by Rendell Palmer and Tritton (1986) and subsequent cross sections presented within the Allot Atkins Mouchel report. The geology has been identified as similar to that underlying the Built Development Area West comprising varying thicknesses of Made Ground and natural soils overlying Blue Lias rocks (subcropping in a north to south direction, controlled by the northerly dip of the strata). Underlying the Blue Lias are rocks of the Lilstock and Westbury Formations of the Penarth Group which in turn overlie the Blue Anchor Formation of the Mercia Mudstone Group.

14.6.19 Intrusive investigations undertaken as part of the second onshore investigation on the Built Development Area East have confirmed the presence of Blue Lias deposits, at depths starting from 0.1 m below ground level (bgl) to 9.0 m bgl. The deposits comprise an interbedded sequence of mudstone and limestone units. The upper mudstone units were frequently noted to have been significantly weathered to clay like deposits. Underlying the Blue Lias the top of the Penarth Group has been confirmed at depths of 9.3 and 11.1 m bgl towards the southern boundary of the Built Development East Area. This increases to confirmed depths of 68.6 and 71.8 m bgl towards the coast. The top of the Mercia Mudstone Group was confirmed at depths of 80.2 and 83.9 m bgl near the coast, decreasing to 23.45 m bgl further inland.

14.6.20 The foreshore cliffs adjoining the study area provide exposure through part of the Lower Jurassic Blue Lias Formation.

14.6.21 Some uncertainties remain about the geological structure of the site. Some east-west trending linear Penarth Group outcrops may exist at about half a kilometre south of the coastal cliff edges.

14.6.22 The Charmouth Mudstone Formation (referred to above) has not been identified in the cliff sections or during the on-shore investigations of the Built Development Area West or East. This formation is noted to be younger than the Blue Lias with the lower boundary taken as the top of the Blue Lias Formation (i.e. next formation within the regional stratigraphic sequence). The dip of the strata to the north and the topography noted within the Southern Construction Phase Area may mean this formation may be observed during planned drilling works within this area.

14.6.23 A summary of the lithostratigraphical sequence identified within the study area is provided in **Table 14.6.1** and further described below.

Table 14.6.1: Lithostratigraphical Sequence for the Post-Variscan Rocks of the East Bristol Channel Basin Identified within Study Area (modified from Whittaker, A and Green, G. W. 1983[15])

Stage and Formation			'Up-to' thickness (m)	Lithology
Lower Lias	Blue Lias		140	Alternation of shale/mudstone/limestone/mudstone sequences
Penarth Group	Lilstock Formation	Langport Member	2	Pale grey limestones with interbedded grey to bluish grey mudstones
		Cotham Member	2	Pale grey to greenish grey calcareous mudstones, limestones, siltstones and sandstones
	Westbury Formation		14	Very dark shaly mudstones and dark grey argillaceous limestones
Mercia Mudstone Group	Blue Anchor Formation		38	Thin dark grey mudstone beds and green to greenish grey mudstone and siltstone beds. Some are dolomitic in part.
	Undifferentiated		484	Upper units are reddish brown mudstones and siltstones (occasionally greenish grey) with halite, gypsum and anhydrite as minor components

14.6.24 **Lower Lias, Blue Lias:** The Blue Lias comprises very weak to medium strong, thinly laminated to thinly bedded calcareous mudstone, alternating with weak, thinly laminated fissile mudstone and medium strong to strong thinly bedded argillaceous limestone.

14.6.25 **Penarth Group, Lilstock Formation** (subdivided into Langport Member and Cotham Member): The Cotham Member of the Lilstock Formation comprises weak to medium strong, thinly to thickly laminated, green-grey calcareous mudstone with some strong thinly bedded limestone beds, whilst the Langport Member comprises medium strong to strong, thinly bedded argillaceous and micritic limestone.

14.6.26 **Penarth Group, Westbury Formation**: The Westbury Formation mainly comprises very weak to weak, thinly laminated, fissile, dark grey-black calcareous mudstone and siltstone with limestone bands.

14.6.27 **Mercia Mudstone Group, Blue Anchor Formation**: The Blue Anchor Formation comprises mainly grey-green mudstone and siltstone. The siltstone is generally weak to strong thinly laminated to medium bedded, light grey-green with some gypsum and anhydrite and occasional halite. The mudstone is generally weak to strong thinly laminated to thinly bedded, grey (locally dark grey), sometimes calcareous, with some gypsum and anhydrite inclusions as veins or possibly of depositional origin. The Blue Anchor Formation also includes some dolomitic bands.

14.6.28 **Mercia Mudstone Group (Undifferentiated)**: The undifferentiated component of the Triassic Mercia Mudstone Group has been found to comprise mainly reddish brown mudstones and siltstones. The mudstones are generally weak to strong thinly laminated to thinly bedded, red-brown with some grey colour. The siltstones are generally weak to strong thickly laminated to medium bedded, reddish brown, occasionally green-grey, with localised calcareous and occasionally gypsum veining and/or anhydrite.

d) Superficial Geology

14.6.29 The majority of the study area is shown not to be overlain by significant superficial deposits. From intrusive investigations, drift deposits within the Built Development Area West have been confirmed to depths of between 0.26 m and 5.5 m below ground level. These deposits are classified typically as slightly gravelly locally sandy silty clay to a sandy silt/clay. Investigations within the Built Development Area East identified superficial drift deposits to depths of between 0.3 and 4.0 m, typically comprising slightly sandy slightly gravely clay.

14.6.30 Also, within the Built Development Area East apparent sediment deposits, believed to be associated with former infilled ponds, were encountered at two isolated locations at depths of between 2.3 m and 5.0 m.

14.6.31 There are certain areas where the drift geology differs from the general classification described above. These include:

- A linear expanse of alluvial deposits which is orientated approximately east-west along the boundary between the Built Development Area West and the Southern Construction Phase Area. This area of alluvium correlates with the alignment of a fault and is the in the area of Holford Steam. Further alluvial deposits are associated with Bum Brook which runs along the southern boundary of the study area.
- Undifferentiated tidal flat deposits are shown within three areas including the coastal area to the northwest; to the northeast (northwest of the existing power station complex); and on a large expanse to the east of the study area in Bridgwater Bay.
- Tidal flat deposits to the east of the study area within North Moor and Wick Moor.
- Drift deposits identified during the studies for the former proposed Central Electricity Generating Board (CEGB) Hinkley Point C included head deposits around 1 m in thickness, and estuarine alluvium up to 5 m thick, comprising soft to firm organic clays. To the east of the Hinkley Point B Power Station, fluvioglacial sands between 2.4 m and 5.2 m thick were found beneath the alluvium (Aspinwall & Company 1996) as well as a series of peaty deposits.

i) Made Ground

14.6.32 Intrusive investigations of the Built Development Area West confirmed the absence of any Made Ground in this area (with ground conditions largely comprising topsoil over natural deposits), with the exception of one isolated area of shallow made ground associated with the historical farm buildings (Benhole Farm) in the northwestern area of the Built Development Area West.

14.6.33 As part of the Phase 2 supplementary investigation one location in the Built Development Area West identified made ground deposits comprising slightly gravely cobbly sandy clay with occasional gravel, bricks, glass and clay tile, to a depth of 0.33 m. Further investigations, conducted as part of the second on shore investigation, identified further deposits at two locations in this area, comprising soft dark brown slightly gravely clay with rare fragments of red brick and mortar to between 0.25 m and 0.3 m, underlain by a layer of limestone gravel and cobbles to between 0.3 m and 0.4 m.

14.6.34 The investigations conducted as part of the Preliminary Phase 2 Contamination Assessment of the Built Development Area East, identified varying depths of made ground across this area, ranging from absent to proven depths of 9.0 m within the mounds. Made ground deposits have been found to typically comprise either reworked natural soils (weathered Blue Lias formation deposits comprising mudstone and limestone), or demolition and construction waste materials.

14.6.35 There are no known made ground deposits on the Southern Construction Phase Area, which is consistent with the recorded agricultural and use in this area. However this has yet to be confirmed through intrusive investigations.

ii) Designated Geological Interests

14.6.36 The eastern extent of the ‘Blue Anchor to Lilstock’ Site of Special Scientific Interest (SSSI) extends into the Built Development Area West frontage by approximately 40 m (based on co-ordinates within English Nature ‘Geological site documentation/management brief, Blue Anchor to Lilstock Coast’, 1993. The SSSI designation is for the unique cliff stratigraphy which comprises interbedded limestones, shale and mudstones of the Lower Blue Lias units. The exposed stratigraphic units are considered to be amongst the best examples of the Blue Lias outcrop in Europe. Furthermore, the SSSI also has a geomorphological designation for the exposed rock pavement on the foreshore.

e) Hydrogeology

14.6.37 The baseline hydrogeology of the site and its immediate surroundings is described in terms of

- hydrology;
- aquifers and aquifer characteristics;
- groundwater levels and flow;
- groundwater quality; and
- groundwater use.

14.6.38 Each of the above aspects of hydrogeology is described and data from current investigations is used together with any relevant data from previous investigations. The adequacy and relevance of historic data is reviewed and any limitations and assumptions in its use noted where appropriate.

f) Hydrology

14.6.39 Available information and published studies indicate that rainfall recharge provides the driving mechanism for groundwater flow within the local area. Groundwater then springs out at outcrops of lower permeability strata and also provides baseflow to surface watercourses. **Figure 14.4** shows the main surface watercourses around Hinkley Point. It is likely that the watercourses are structurally controlled, with those flowing west to east following the trends of the strike faults and fold axes, and those flowing SW-NE following structures parallel to the Hinkley Point Fault (as well as merely following the topography to the Bristol Channel). It appears that one of these streams on Wick Moor may follow an unmarked extrapolation of the Hinkley Point Fault.

14.6.40 Given the topography and likely groundwater flow regime it is likely that the surface watercourses are in at least partial hydraulic continuity with the groundwater, probably with significant groundwater contributions to baseflow and possible groundwater recharge in places. Streams to the south of Stogursey running off the Mercia Mudstones some 2 km to the south of the Hinkley Point **Figure 14.4** could contribute to groundwater recharge under some circumstances (e.g. runoff during low water table conditions).

14.6.41 Rainfall recharge provides the principal input to the groundwater regime. Discharges from the groundwater regime can occur as springs at outcrops of lower permeability strata, where the water table intersects the surface (onshore or offshore), and also as baseflow to surface watercourses.

14.6.42 Where the Blue Lias Formation outcrops, the aquifer responds rapidly to recharge by precipitation. This is explained by the fact that the aquifer has a low storage capacity. Rainfall data from the Centre for Ecology and Hydrology (CEH) has been used in previous groundwater studies with the mean annual rainfall in this area being taken as 947 mm/year, although recharge to the aquifer is considerably lower than this, due to evapotranspiration, run-off and crop uptake. Recharge to the aquifer is also dependent upon the vertical hydraulic conductivity (K) and the Transmissivity (T) of the drift deposits. As the values of K and T of the drift deposits are relatively low at this site, the maximum effective recharge to the aquifer at outcrop has been estimated to be one third of the mean annual rainfall, which is 315 mm/year. In areas where the site is underlain by clay and silty clay to a depth of around 5 m, the effective recharge to the aquifer will be significantly lower than that of the outcrop area **Figure 14.6**.

14.6.43 In previous modelling studies by Allott, Atkins and Mouchel (1988) and Aspinwall & Company (1996), recharge was calculated as a percentage of rainfall, depending on land use or presence of drift deposits. A value of 50 mm/year for effective recharge was used by Aspinwall & Company (1996), i.e. a quarter of the value of effective rainfall used in their study. However, it is considered that this value is low, especially in the area of outcrop.

14.6.44 Rainfall data acquired from the Meteorological Office provide daily rainfall records from 1962 until 1996 at Brymore School, some 8 km from the Hinkley Point C site. Average annual rainfall from Met Office HM33 data is 763 mm, lower than the estimate of 947 mm used in previous work, although the average will vary depending on the length and period of data concerned. Actual recharge rates will depend on the soil characteristics, slope and nature of the surface at any given time.

14.6.45 Rainfall data from December 2008 have been available from a weather station installed on the Development Site. **Figure 14.7** shows this data for December 2008 to January 2010, with fill-in data obtained from the Met Office from radar analysis for periods in January and March/April 2009 when the site station was experiencing technical problems. Highest daily rainfall recorded on site was 37.84 mm on 3 November 2009. The annual total recorded on site in 2009 was 740.4 mm (including some radar data fillin). Monthly totals for 2009 are shown in **Table 14.6.2**. More detailed data on rainfall patterns can be found in the EnvApp chapter on Hydrology **Chapter 15**.

Table 14.6.2: Monthly Rainfall (mm) for 2009

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
67.0	58.3	54.8	34.8	39.2	73.9	96.1	34.9	25.6	57.2	140.1	58.5	740.4

14.6.46 The annual total for 2009 is 78% of the average 947 mm quoted above. Of particular note in 2009 is the 140.1 mm (19% of the annual amount) in November. This is shown clearly in the responses in many of the borehole hydrographs (**Appendix 14b**) where a rapid rise in November follows a recession of about eight months with little apparent recharge despite high rainfall also in June and July. This is a typical condition with most potential recharge in the summer months being absorbed by soil moisture deficit.

g) Aquifer Characteristics - General

14.6.47 Groundwater flow in the Lower Lias occurs predominantly via bedding planes, joints and fractures in the more competent limestone horizons within the formation. Rocks of the Penarth Group, especially the mudstone and limestone of the Westbury Formation (the lower component) are considered to be generally impermeable, although fault and fracture zones in the Lilstock Formation (the upper 4 m approximately) may have minor transmissivity. The mudstones of the Mercia Mudstone Group (including the Blue Anchor Formation) are likely to be of insignificant permeability.

14.6.48 The Environment Agency 1:100,000 scale Groundwater Vulnerability Map (Sheet 42, Somerset Coast) indicates the site as being situated on a Minor Aquifer (now re-defined, see 14.5.32, below). Such aquifers were defined as fractured or potentially fractured rocks, which do not have a high primary permeability, or other formations of variable permeability including unconsolidated deposits. Although these aquifers will seldom produce large quantities for abstraction, they are important both for local supplies and in supplying base flow to rivers. The distribution of the previous Environment Agency designations in and around the Developed Area is shown on **Figure 14.8**, as presented in the GroundSure Environmental Data Report. The Lower Lias formations which outcrop over most of the area were designated as Minor Aquifers, with varying degrees of leaching potential due to presence of drift deposits. The Penarth and Mercia Mudstone formations were designated as Non-Aquifers, shown in white on **Figure 14.8**.

14.6.49 From 1 April 2010 new aquifer designations were introduced in accordance with the requirements of the Water Framework Directive. These designations were assigned both to superficial and bedrock formations, with separate maps being made available on the Environment Agency website, the new designations are:

- Principal (generally equivalent to Major Aquifers): Layers of rock or drift deposits that have high intergranular and/or fracture permeability – meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale.
- Secondary A (generally equivalent to Minor Aquifers): Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers.
- Secondary B (generally equivalent to water-bearing parts of Non-Aquifers): Predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering.
- Unproductive: These are rock layers or drift deposits with low permeability that have negligible significance for water supply or river base flow.

14.6.50 As far as Hinkley Point is concerned, the Lower Lias is now Secondary A, and the similar lithologies of the Lilstock Formation of the Penarth Group are also likely to be Secondary A. The

Westbury, Blue Anchor and Mercia Mudstones are Secondary B due to their yielding limited amounts of groundwater from minor fractures or thin permeable horizons.

14.6.51 River alluvium in the Holford Stream is designated as Secondary A, and the marine alluvium south and east of Hinkley Point A and B (North Moor, Wick Moor etc) is designated as Secondary Undifferentiated, meaning it is not definitively attributable to either Secondary A or B.

14.6.52 The published Groundwater Vulnerability maps are still valid for the definition of soil leaching potential, which is not covered by the new maps.

14.6.53 The lower boundary on the effective groundwater regime in the area may be the base of the Lilstock Formation of the Penarth Group, possibly less than 4 m below the base of the Lower Lias.

h) Aquifer Characteristics - Relevant Earlier Studies

14.6.54 A number of studies and investigations have been undertaken, particularly in relation to the determination of hydrogeological conditions for HPA and HPB stations and baseline data for the original CEGB Hinkley C proposal (e.g. Aspinwall & Company (1996) and Allott Atkins Mouchel Power Consultants (1988)).

i) Hinkley Point A

14.6.55 Tests reported by Foundation & Exploration Services Ltd (1989) provide permeability data for the Lower Lias derived from constant head, single packer and double packer tests in three boreholes, all sited immediately to the west of the Hinkley Point A turbine hall and reactor buildings and which are therefore fairly close to the shoreline.

14.6.56 The recorded permeability values were all low to very low (ranging from 2×10^{-6} m/s to no flow) and generally decreased with depth, although it is recognised that these type of tests may not be very reliable for groundwater model scales since they sample a very localised volume of 'aquifer'. SERCO (2004) referred to matrix hydraulic conductivity of the Blue Lias of less than 1×10^{-11} m/s, with formation permeability typically in the range 10^{-5} to 10^{-6} m/s, generally decreasing with depth but with no direct relationship with formation lithology.

14.6.57 The SERCO interpretive report for Hinkley Point A of October 2005 provided similar order of magnitude data from small-scale pumping tests. These tests provided data indicating that the Blue (Lower) Lias exhibits permeabilities in the range 5.9×10^{-4} to 9.2×10^{-7} m/s, and in the Hinkley Point Fault zone a permeability of $1.1\text{-}6.4 \times 10^{-6}$ m/s. From this work it was concluded that the aquifer properties of the Hinkley Point fault zone were no different to those of surrounding strata.

ii) Hinkley Point B

14.6.58 Rising head tests carried out by Foundation Engineering Ltd (1979) exhibited relatively low permeability values between 4.3×10^{-3} and 2.06×10^{-7} m/s, while packer tests exhibited values between 0 and 4.79×10^{-5} m/s.

14.6.59 Golder Associates (2007) carried out a number of falling head tests in shallow boreholes in the Lower Lias on Hinkley Point B, the results of which gave a mean permeability value of 1.2×10^{-5} m/s (range 3.2×10^{-6} – 2.5×10^{-5} m/s).

iii) Hinkley Point C (former CEGB proposed PWR station)

14.6.60 The groundwater conditions, as determined from a number of investigations, in the vicinity of Hinkley Point are reported on and summarised by Aspinwall & Company (1996) in relation to the former CEGB proposed Hinkley C station.

14.6.61 Aspinwall & Company (1996) report that permeability tests undertaken in boreholes at Hinkley Point during previous investigations were carried out for different depth ranges with the average hydraulic conductivity (K) values calculated from the testing results ranging from 10^{-6} m/s to 10^{-5} m/s.

14.6.62 Values of hydraulic conductivity (K) at shallow depths ranged from 10^{-6} to 10^{-4} m/s, whereas below this zone the aquifer is described as being only slightly permeable, with K values reported to range from 10^{-8} to 10^{-7}m/s. As flow at depth is restricted, discharge to the sea occurs by upward vertical movement through mudstone horizons via fractures. As vertical groundwater movement is restricted by the lower permeability mudstones and shales, the aquifer is considered to be under semi-confined to confined conditions. As such, the aquifer has low storage coefficients ranging from 0.001 to 0.00008, which are reported to be typical of semi-confined to confined conditions (Aspinwall & Company (1996).

14.6.63 The BGS physical properties of minor aquifers in England and Wales reports that six analyses from outcrop samples at Hinkley Point gave porosities ranging from 1.9 % to 3.1 %.

iv) Southern Construction Phase Area

14.6.64 There is no specific data yet available for aquifer properties on the Southern Construction Phase Area. Similar intrusive borehole studies to those undertaken for the BDAW are planned and will be completed prior to the DCO application being submitted. It is anticipated that permeability and storage values will show a similar range to equivalent strata elsewhere on Hinkley Point.

i) Aquifer Characteristics - Current Studies

14.6.65 **Table 14.6.3** summarises the average permeabilities for different rock formations under the Built Development Area West from Lugeon testing.

Table 14.6.3: Indicative Permeabilities for Different Formations

	Permeability (m/s)		
Formation	0-20 m depth	20-40 m depth	>40 m depth
Blue Lias	4.9×10^{-6}	1.3×10^{-6}	4.5×10^{-8}
Lilstock (Penarth Group)	4.0×10^{-7}	2.5×10^{-7}	1.7×10^{-7}
Westbury (Penarth Group)	1.4×10^{-6}	7.5×10^{-7}	3.2×10^{-7}
Blue Anchor Formation		7.0×10^{-7}	6.0×10^{-7}
Mercia Mudstone Group			6.0×10^{-7}

14.6.66 The results of development specific pumping tests carried out in November and December 2008 provided a range of transmissivity values and storage coefficients. The constant rate test provided a mean transmissivity of 7.7×10^{-4} m2/s (67 m2/d) and the recovery test 4.3×10^{-4} m2/s (37 m2/d). The mean storage coefficient was 0.0015. For an assumed aquifer thickness of

13 m, the above transmissivity value from the constant rate test equates to a permeability of 6 x 10^{-5} m/s.

j) Groundwater Levels

i) Built Development Area West

14.6.67 Groundwater levels, both strikes and static water levels, were recorded during the Structural Soils investigation and are now being monitored in selected boreholes installed with dataloggers.

14.6.68 Minimum levels were usually reached on or about 1st November 2009 after the summer recession, with maxima on or about 1st December after the very heavy November rain, although levels in some boreholes continued to rise into January 2010. **Table 14.6.4** shows the shallow Lower Lias water levels on these two dates, which are contoured in **Figures 14.9** and **14.10**. It is apparent that the main groundwater flow regime on the site is controlled by local rainwater recharge and topography, with the contours echoing the general features of the land surface. The small watercourse crossing the Hinkley Point C site from west to east and then turning north to the shoreline clearly receives groundwater baseflow and can be seen from **Figures 14.9** and **14.10** to exert significant control on groundwater levels. Average gradient from these contours is around 0.02 but varies in detail with the level condition and the location on the site.

14.6.69 Hydrographs from the shallower Lower Lias piezometers (**Appendix 14b**) show a clear correlation with the rainfall hydrograph **Figure 14.7**. Water tables rise in response to the sustained rainfall during the second half of January and early February and then fall away again as recharge declines. Rainfall periods in spring and summer do not show a groundwater response because available recharge is taken up by the growing soil moisture deficit and does not reach the unsaturated zone or the water table. The soil moisture deficit is only reversed at the end of October when recharge can start again.

Table 14.6.4: 2009 Low and High Borehole Groundwater Levels

Borehole	Low (m AOD) c 1st November 2009	High (m AOD) c 1st December 2009	Difference (m)
CBH10	11.58	16.40	4.82
CBH11	10.77	12.11	1.34
CBH17	10.96	14.26	3.30
CBH18	10.38	13.24	2.86
CBH19	10.13	11.09	0.96
CBH21	10.74	15.14	4.40
CBH24	9.69	14.70	5.01
CBH25	14.46	20.16	5.70
CBH26	12.01	13.61	1.60
CBH27	10.93	16.95	6.03

Borehole	Low (m AOD) c 1st November 2009	High (m AOD) c 1st December 2009	Difference (m)
CBH33	11.54	15.88	4.34
DBH06	8.15	12.84	4.69
DBH07	11.12	12.69	1.56
DBH08	8.93	14.00	5.07
DBH09	11.42	14.06	2.64
DBH10	13.30	16.99	3.69
DBH11	11.84	16.03	4.19

14.6.70 The artesian boreholes, two of which (CBH20 and CBH33) are included in the monitoring programme, exhibit their characteristics entirely due to topography and not to any special groundwater condition.

14.6.71 Piezometers installed deeper in the Lower Lias tend to show a higher piezometric level than the shallower boreholes when shallow piezometer heads are low, so upward leakage of deeper groundwater is possible at these times. This is illustrated in cases where shallow and deeper piezometers are installed adjacent to each other, for example at DBH08 (shallower) and CBH11 (deeper); and DBH06 (shallower) and CBH18 (deeper). Differences are around 2 m when levels are generally low, with an upward vertical groundwater gradient resulting from the deeper water in the Lower Lias being derived from recharge from further away (but still within the Hinkley Point C site). In times of high shallow groundwater levels the difference is removed or even reversed, e.g. in early December the level in DBH08 is nearly 2 m higher than that in CBH11. This is due to DBH08 preferentially receiving rapid infiltration recharge compared with CBH11.

14.6.72 There is not enough groundwater data from boreholes in the Blue Anchor Formation and Mercia Mudstone Groups to form reliable contours. However, groundwater/piezometric levels are all significantly lower than the Lower Lias levels, typically by around 6-8 m. Therefore there is no evidence of a tendency for any upward groundwater flow into the Lower Lias from deeper formations, and no apparent significant hydraulic continuity between the Lower Lias and either the Blue Anchor or Mercia Mudstone Groups.

ii) Hinkley Point A, Hinkley Point B and Built Development Area East

14.6.73 Relatively recent available groundwater level data for the area outside of the Hinkley Point C Development Site is limited. SERCO (2004) and SERCO (2005) show a northerly groundwater flow under Hinkley Point A, consistent in general with the flow for the Hinkley Point C site, with a gradient of around 0.03, from 13 m AOD to 5 m AOD. This is a lower elevation than the level in most of the monitoring boreholes at Hinkley Point C, but cannot be compared directly because of the different dates for which the data were collected.

14.6.74 Golder Associates (2007) and subsequent monitoring updates up to February 2009 report on water levels below ground level at Hinkley Point B, which vary between 0 and 6 m bgl approximately.

14.6.75 Groundwater levels for BDAE will be obtained from an onshore investigation programme that is currently being progressed for the Built Development Area West.

iii) Southern Construction Phase Area

14.6.76 At present there is no groundwater level data on the Southern Construction Phase Area. As with the BDAE, information will be obtained from the programme of site investigation that is being progressed for this area. It is anticipated, however, that groundwater levels will be at or slightly higher than the surface water levels in the Holford Stream and Bum Brook, and will exhibit a muted version of the ground topography.

k) Groundwater Chemistry – Built Development Area West

i) General and Major Ion Chemistry

14.6.77 The groundwater sampling campaign demonstrated that the pH of the groundwaters within the Built Development Area West was found to be quite consistent throughout the monitoring campaign across the shallow piezometers **Table 14.6.5**. More variation was identified across the deep piezometers with one location (CBH16) showing lower pH levels (ranging from pH 6.3 to 6.5) and one location showing significantly higher pH levels (CBH29 ranging from pH 7.0 to 9.7). Groundwater in CBH16 has a very high (non-sea water) salinity (see below) whilst CBH29 groundwater is very low in bicarbonate alkalinity and therefore has limited buffering capacity against pH changes.

14.6.78 Electrical conductivity (EC) values from the transducer/dataloggers are plotted on **Figure 14.9** and **Figure 14.10**. In general values are in the range 700-1000 µS/cm in the shallow Lower Lias piezometers, but higher values occur in the deeper Lower Lias boreholes and these waters infiltrate the shallower groundwaters when shallow levels are low and so these can have temporarily elevated conductivities. For example, at DBH08 EC rose to 1780 µS/cm by 1 November 2009 as shallow levels fell through the groundwater recession, then back to 620 µS/cm by 1 December 2009 as recharge caused the shallow levels to rise again.

14.6.79 However, comparison with the laboratory determinations of EC shows that the datalogger values are consistently lower by an amount that increases with salinity. Relatively fresh groundwaters such as at CBH25 show datalogger EC values around 600-700 µS/cm, but laboratory values between 872 and 964 µS/cm. The saline waters in CBH11 show datalogger EC values up to 16,000 µS/cm, but laboratory values between 40,900 and 57,200 µS/cm. At CBH16 in the Blue Anchor Formation, EC values are between about 2000 and 4500 µS/cm and laboratory values over 150,000 µS/cm. These discrepancies are likely to relate to the water in the borehole columns as measured by the dataloggers being exposed to freshwater recharge compared to the formation groundwater that is sampled after purging and also there may be a limit to the EC range capable of being measured reliably by the dataloggers.

14.6.80 In terms of general groundwater quality in the shallow Lower Lias groundwaters, CBH20 and CBH24 are the only ones that show signs of elevated concentrations of determinands related to sea water such as EC, chloride and sodium. Otherwise they represent typical hard calcium-bicarbonate type groundwaters.

14.6.81 Highly saline groundwaters are found in the deep piezometers CBH11 and CBH16. CBH11 is nearest to the shoreline and at a similar distance to CBH24 and has chloride concentrations around 16,000 mg/l and sodium around 12,000 mg/l. At CBH16 chloride concentrations reached around 70,000 mg/l and sodium around 56,000 mg/l (though these high values were not consistently recorded).

14.6.82 At CBH11 chloride concentration is similar to slightly diluted sea water (as would be typical for the estuarine waters of the Bristol Channel) but sodium is higher and sulphate is very low. This suggests a principal formation mineral source for the salinity, presumably the presence of distributed halite (NaCl) within the rocks, although sea water could still be a component. At CBH16 sulphate and potassium concentrations are similar to typical sea water but the chloride and sodium concentrations are much higher and calcium concentrations are also very high (up to 7,367 mg/l). This is also indicative of a formation mineral or interstitial groundwater origin (halite and gypsum/anhydrite) rather than modern sea water.

Table 14.6.5: Groundwater Major Ion Chemistry on Built Development Area West

Borehole	Campaign	Total Hardness (mg/l as $CaCO_3$)	pH Value (Units)	Electrical Conductivity (µS/cm)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Ammonium (converted to NH4-N) (mg/l)	Chloride (mg/l)	Sulphate (mg/l)	Bicarbonate (mg/l as $CaCO_3$)	Nitrate (mg/l)
CBH20	Dec-08		7.4	1167					0.13	143	56.9		<1
	Jan-09	471	7.7	2400			189		0.79	287	25		<1
	Mar-09	355.3	7.6	1229	91.4	30.9	83.0	3.44	0.51	111	48	261	1
	Apr-09	376	7.3	1125	99.0	31.4	89.1	3.5	0.09	133	53	231	<1
	Jun-09	343	7.4	1170	98.0	23.9	109.7	2.7	0.07	131	54	243	<1
CBH21	Dec-08		6.7	992					0.07	88	68.8		<1
	Jan-09	332	7.6	842			48		0.26	54	40		24
	Mar-09	331	7.8	847	86.7	27.8	46.9	3.3	0.18	63	60	194	21
	Apr-09	364	8.3	920	79.9	40.0	113.7	6.9	0.14	80	57	254	17
	Jun-09	356	6.8	1019	80.1	37.9	101.2	6.2	0.09	87	82	265	<1
CBH24	Dec-08		7.0	971					0.11	66	63.3		6.2
	Jan-09	432	7.4	918			52		0.31	58	58		16
	Mar-09	402	7.7	936	93.8	40.7	42.6	4.3	0.42	56	71	219	11
	Apr-09	434	7.4	1298	70.0	62.9	151.2	8.6	0.89	132	30	353	<1
	Jun-09	458	7.4	1194	112.1	43.1	126.5	5.5	0.92	101	50	341	<1
CBH25	Dec-08		7.1	940			85		<0.01	63	70		6
	Jan-09	349	7.3	888			74		0.26	55	71		9
	Mar-09	320	7.7	872	72.2	33.9	66.6	6.1	0.44	64	72	212	25
	Apr-09	378	7.9	945	80.5	43.1	63.9	7.8	0.23	55	65	251	25
	Jun-09	392	7.6	964	77.8	48.0	69.8	8.9	0.09	61	70	280	<1
CBH27	Dec-08		6.2	976			44.7		0.05	55	89.6		32.9
	Jan-09	480	7.3	974			36		0.16	30	85		34
	Mar-09	486	7.9	1755	143.7	30.9	112.0	4.7	0.23	141	88	306	29
	Apr-09	452	7.1	992	133.1	29.0	35.3	4.4	0.03	43	111	238	17
	Jun-09	379	6.9	965	112.1	24.1	55.0	5.1	<0.01	13	156	229	8
CBH33	Dec-08		6.4	847			41		<0.01	40	76		14
	Jan-09	320.0	6.6	860			46		<0.01	46	75		13.2
	Mar-09	367.4	8.2	2410	136.0	17.9	75.2	2.7	0.09	50	76	264	13
	Apr-09	383	7.2	835	121.2	19.6	32.5	2.4	0.03	39	89	207	8
	Jun-09	365	7.2	841	116.7	17.8	67.6	2.8	<0.01	30	91	231	2
CBH35	Dec-08		7.4	880			409		0.05	38	20		92
	Jan-09	425	7.5	835			34		0.04	29	79		13
	Mar-09	356	7.8	793	103.6	23.7	22.5	3.2	0.18	26	16	194	93
	Apr-09	367	7.3	862	103.1	26.6	28.2	4.2	0.03	29	18	195	96
	Jun-09	473	7.3	845	138.2	31.2	36.1	7.2	0.02	22	19	240	103

Borehole	Campaign	Total Hardness (mg/l as $CaCO_3$)	pH Value (Units)	Electrical Conductivity (µS/cm)	Calcium (mg/l)	Magnesium (mg/l)	Sodium (mg/l)	Potassium (mg/l)	Ammonium (converted to NH4-N) (mg/l)	Chloride (mg/l)	Sulphate (mg/l)	Bicarbonate (mg/l as $CaCO_3$)	Nitrate (mg/l)
DBH09	Dec-08		7.0	1006			29		0.15	279	81		30
	Jan-09	511	7.2	1011			47		0.03	49	72		<1
	Mar-09	438.5	7.5	1371	113.9	37.4	89.2	6.5	0.37	150	77	268	1
	Apr-09	414	7.2	1180	101.6	39.0	45.6	7.6	0.23	72	77	244	<1
	Jun-09	489	7.2	1014	142.1	32.7	44.0	8.7	0.34	65	84	289	<1
CBH11 (Deep)	Dec-08		7.1	40900			9406		3.73	14078	24		<1
	Jan-09	1925	7.1	50000			12050		17.53	15465	8		<1
	Mar-09	2098	7.4	52700	236.4	366.2	13030	53.8	14.88	15389	<5	548	<5
	Apr-09	2428	7.1	56800	200.3	468.2	12512	67.9	12.20	16521	19	591	2
	Jun-09	2034	7.2	57200	258.2	337.4	11340	41.5	7.96	17033	7	591	<1
CBH16 (Deep)	Dec-08		6.3	154100			42630		4.33	11785	9002		290
	Jan-09	11211	6.5	151900			56239		1.07	70593	2963		<1
	Mar-09	9847.1	6.5	157000	7367.0	715.9	42210	336.9	30.35	50781	2484	140	<1
	Apr-09	18361	6.4	162700	5900.0	881.3	47830	246.0	29.94	72315	2541	146	<1
	Jun-09	7345	6.5	161400	2130.0	492.0	29820	164.2	25.87	61936	1195	159	2
CBH29 (Deep)	Dec-08		7.0	4460			255		1.42	638	1317	n/t	2
	Jan-09	2213	8.1	4430			240		0.89	682	1420	n/t	2
	Mar-09	1966	9.3	4050	735.4	31.6	201.9	35.8	2.21	571	1333	46	<5
	Apr-09	2261	9.7	4380	814.8	54.9	112.0	40.9	2.03	663	1355	30	1
	Jun-09	1880	9.3	4270	658.7	57.0	220.1	30.1	0.79	667	1584	20	<1

ii) Potential Contaminants

14.6.83 The samples collected during the monitoring campaigns have been analysed for potential non-radiological and radiological contaminants. A summary of the non-radiological analytical results is provided in Table 14.6.6. Full analytical results are included in the Summary of Groundwater Quality Reports.

Table 14.6.6: Summary of Non-Radiological Groundwater Analytical Results

Determinand	Units	Pre-WFD Screening Values			WFD Screening Values			Range of concentrations in deep piezometers	Range of concentrations in shallow piezometers
		DWS	EQS Salt	EQS Fresh	DWS	Saltwater EQS	Freshwater EQS		
Dissolved Arsenic*	(µg/l)	10T	25AD (f)	50AD (f)	10T	25A (GC)	50A (G15R)	<1-6	<1-3
Dissolved Cadmium*	(µg/l)	-	2.5AD (e)	-	5T	0.2A/1.5MAC	0.2A (C5)/ 1.5MAC	<1-2	<1
Dissolved Chromium*	(µg/l)	50T	15AD	250AD#	50T	15AD	250AD#	<1-12	<1-3
Dissolved Lead*	(µg/l)	25T	25AD	250AD#	25T	7.2A	7.2A	<1-8	<1
Dissolved Nickel*	(µg/l)	20T	30AD	200AD#	20T	20A	20A	<1-46	<1-16
Dissolved Copper*	(µg/l)	2000T	5AD	28AD#	2000T	5A (GC)	28A (G15#)	<1-137	<1-3
Dissolved Zinc*	(µg/l)	-	40AD		5000T	40A (GC)	-	<5-64	<5-12
Dissolved Mercury*	(µg/l)	-	0.3AD (e)	-	1T	0.05A/0.07MAC		<0.1-29.7	<0.1
Dissolved Boron	(µg/l)	1000T	7000AT	2000AT	1000T	7000AT	2000AT	101-4420	<5-1887
Dissolved Iron	(µg/l)	200T	1000AD	1000AD	200T	1000A (GC)	1000A (G15)	<10-1375	<1-2218
Dissolved Vanadium	(µg/l)	-	100AT	60AT#	-	100AT	60AT#	<5-8	<5
Total Zinc	(µg/l)	5000T (a)	-	500AT#	5000T (a)	-	125AT# (G15)	<5-102	<5-371
Total Cadmium	(µg/l)	5T	-	5AT (e)	5T	-	5AT (e)	<1-2	<1
Total Mercury	(µg/l)	1T	-	1AT (e)	1T	-	1AT (e)	<0.1-37.3	<0.1-4.9
Total Boron	(µg/l)	1000T	7000AT	2000AT	1000T	7000AT	2000AT	663-4892	262-2390
Total Hardness	(mg/l as $CaCO_3$)	-	-	-				1880-18361	320-511
pH Value*	(Units)	6.5-9.5	6.0-8.5 p	6.0-9 p	6.5-9.5	6.0-8.5	6.0 (5P, H) 9.0 (95P, H)	6.3-9.7	6.2-8.3
Electrical Conductivity	(µS/cm)	2500	-	-	2500	-	-	4050-162700	793-2410
Sulphate*	(mg/l)	250	-	400A (b)	250	-	400A (b)	<5-9002	16-156
Chloride	(mg/l)	250	-	250A (b)	250	-	250A (b)	571-72315	13-287
Nitrate	(mg/l)	50	-	-	50	-	-	<1-290	<1-103
Nitrite	(mg/l)	0.5	-	-	0.5	-	-	<1	<1
Ammonium (NH4)	(mg/l)	0.5	-	-	0.5	-	-	1.02-39.02	0.03-1.19
Ammonium (converted to NH4-N)	(mg/l)	-	-	1.3 (c)	-	-	-	0.89-30.35	<0.01-0.92
Unionised Ammonium (converted from NH4-N)	(mg/l)	-	-	0.021 (c)	-	-	-	0.001-0.979	<0.001-0.007
Phosphate	(mg/l)	-	-	-	-	-	-	<5	<5
Sodium	(mg/l)	200	-	170A^	200	-	170A	112-56239	22.5-408.8
Calcium	(mg/l)	250 (h)	-	-	250 (h)	-	-	200.3-7367.0	70.0-143.7
Magnesium	(mg/l)	50 (h)	-	-	50 (h)	-	-	31.6-881.3	17.7-62.9
Potassium	(mg/l)	12 (h)	-	-	12 (h)	-	-	30.1-336.9	2.4-8.94
Suspended Solids	(mg/l)	-	-	25 (g)	-	-	25 (g)	<5-1176	10-710
BOD	(mg/l)	-	-	6 (c)	-	-	5 (90P, T7 G15)	<2-8.0	<2-7

Determinand	Units	Pre-WFD Screening Values			WFD Screening Values			Range of concentrations in deep piezometers	Range of concentrations in shallow piezometers
		DWS	EQS Salt	EQS Fresh	DWS	Saltwater EQS	Freshwater EQS		
COD	(mg/l)	-	-	-	-	-	-	‹2-168.0	‹2-165
Total Cyanide*	(µg/l)	50.0	1A/5MAC (b*)	1A/5MA C (b*)	50.0	1A/5P (GC FPN)	1A/5P (G15 FPN)	‹5	‹5-8
Bicarbonate	(mg/l as $CaCO_3$)	-	-	-	-	-	-	20 -591	194-353
Total Petroleum Hydrocarbons*	(µg/l)	10 (a)	-	50 (i)	10 (a)	-	50 (i)	‹10	‹10 except one instance of 29 µg/l in CBH27
PAHs (speciated)	(µg/l)	0.1^^			0.1^^	-	-	‹0.01	‹0.01
VOCs	(µg/l)	-	-	-	-	-	-	‹1	‹1

Based on hardness value ›250 mg/l CaCO3 - reported average hardness value (399mg/l CaCO3 for the Hinkley C Drainage Ditch and 258 mg/l CaCO3) for the Holford Stream) recorded during monitoring in 2009).

D = Dissolved, T = Total, A= Annual Average, P = 95% of results, * UKAS accredited, MAC=Maximum Allowable Concentration

Pre-WFD DWS = Drinking Water Standard based on Water Supply Regulations (Water Quality) Regulations 2000 **unless stated**

Pre-WFD EQS = National Environmental Quality Standards (EQS) - For List II substances. Source DoE Circular 7/89 **unless stated**. (Salt EQS = Saltwater concentration, Fresh EQS = Freshwater other aquatic life - cyprinid fish)

WFD values from River Basin Districts Typology, Standards and Groundwater Threshold Values (Water Framework Directive England and Wales Directions 2009 - Part 3 (General Physico-chemical parameters, Part 4 (Specific Pollutants) or Part 5 (Environmental Quality Standards for Priority Substances) as appropriate).

(a) Drinking Water Standard based on Water Supply Regulations (Water Quality) Regulations 1989 N.B. these regulations have been superseded by the 2000 regulations therefore there is no current UK guidance for these determinands

(b) Environment Agency Non-Statutory (Operational) Environmental Quality Standards. Source Table B11 Environment Agency EPR H1 Environmental Risk Assessment Part 2 Assessment of point source releases and cost benefit analysis. Source Table B11 Environment Agency EPR H1 Environmental Risk Assessment Part 2 Assessment of point source releases and cost benefit analysis.

(b)* As no value available for Total cyanide the value for Free cyanide has been used.

(c) River Ecosystem Classification RE3 - The Surface Waters (River Ecosystem) (Classification) Regulations 1994

(d) Proposed EQS for Priority Substances and Certain other Substances (COM 2006/397)

(e) The Surface Waters (Dangerous Substances) (Classification) Regulations 1989

(f) The Surface Waters (Dangerous Substances) (Classification) Regulations 1997

(g) 2006/44/ EC Fish Directive - Cyprinid Fish Guideline.

(h) The Private Water Supply regulations 1992 N.B. These regulations were superseded by 2008 regulations therefore there is no current UK DWS for these determinands.

(i) The Surface Water (Abstraction for Drinking Water) (Classification) Regulations 1996. DW1 treatment (i.e. simple physical treatment and disinfection limit).

^ Guideline Value - Non statutory/proposed EQS, but EQS never adopted in UK.

^^ Relates to a suite of specific PAHs (i.e. sum of the concentrations of benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(1,2,3-cd)pyrene detected and quantified in the monitoring process).

C5 Cadmium EQS based on class 5 hardness (›200 mg/l CaCO3), corrected based on the reported average hardness value (399 mg/l CaCO3 for the Hinkley C Drainage Ditch and 258 mg/l CaCO3 for the Holford Stream) recorded during monitoring in 2009)

P90 90-percentile (defined as a standard that is failed if the measured value of the parameter to which the standard refers (e.g. concentration of a pollutant) is greater than the standard for 10% of the time or more).

P5 5-percentile (defined as a standard that is failed if the measured value of the parameter to which the standard refers (e.g. concnetration of a pollutant) is less than the standard for 5% of the time or more).

T7 River Type 7 (alkalinity › 200 mg/l as CaCO3)

G15R Threshold value based on 'good standard' to meet objective of WFD for Stogursey Brook to achieve good status by 2015.

GC Threshold value based on 'good standard' for transitional and coastal waters to meet objective of WFD for Bridgewater Bay to achieve good ecological status by 2027 (no chemical criteria target thresholds specified).

FCN Threshold value for free cyanide (as HCN)

H Threshold value for high standard based on current WFD Status

l) Results of the Tier 1 Groundwater Risk Assessment

14.6.84 The groundwater results showed generally low concentrations of inorganic contaminants, below the relevant screening values **Table 14.6.6**, across all shallow piezometers, with the exception of some isolated exceedances of specific contaminants, with subsequent monitoring having identified the return of concentrations to below the relevant screening values. The exceptions to this are the elevated nitrate concentrations, probably resulting from agricultural activity, which have been identified at one location (CBH35) during four out of the five monitoring campaigns, elevated concentrations of dissolved and total boron in CBH24, slightly elevated ammonium which were identified in CBH24 and CBH20 and total suspended solids which have been identified during two or more of the campaigns.

14.6.85 In the deep piezometers, elevated concentrations of dissolved heavy metals (nickel, copper, mercury and zinc) and total mercury have been identified (elevated does not necessarily mean that guideline values are exceeded, see **Table 14.6.7** for details). Elevated concentrations of ammonium were consistently identified across all deep locations along with elevated sodium, calcium, magnesium, potassium, chloride, suspended solids and electrical conductivity in excess of the relevant screening values. The concentrations of the major ions recorded in the groundwater of the deeper aquifer indicate it to be highly mineralised.

14.6.86 Concentrations of organic contaminants, i.e. Polycyclic Aromatic Hydrocarbons (PAHs), Total Petroleum Hydrocarbons (TPHs) and Volatile Organic Carbons (VOCs) were below the limit of detection and below the relevant screening values across all deep and shallow groundwater locations, with the exception of an elevated TPH concentration identified in one shallow piezometer (CBH27, 29 µg/l) during the first monitoring campaign. However, all subsequent campaigns have recorded concentrations below the limits of detection (‹10 µg/l).

m) Groundwater Chemistry Outside of the BDAW

14.6.87 Information on groundwater chemistry from the other (existing) Hinkley Point Power Station sites and the Built Development Area East, and the Southern Construction Phase Area, has been obtained from a range of reports and documents made available for the former CEGB Hinkley Point C EIA. A summary of the key findings from the site investigations and monitoring studies undertaken for land at HPA and HPB is provided below:

14.6.88 The following areas of groundwater contamination were identified in the Built Development Area East and HPA and HPB sites from the above-mentioned reports (locations of significant groundwater contamination shown on **Figure 14.11**).

- North west corner of Built Development Area East: minor exceedances of heavy metals, no hydrocarbons.
- HPA: Diesel Range Organics up to 800,000 µg/l (800 mg/l) in southeast corner of investigated area, and concentrations of TPH exceeding 1000 µg/l in several areas. Light non-aqueous phase liquid (LNAPL) in five boreholes. The extent of hydrocarbon plume in the groundwater (including deeper groundwater) has not been delineated. Hydrocarbon plumes inferred in the groundwater are considered to be attenuated, although only a small amount of monitoring data is available. There are also minor exceedances of ammonium and heavy metals.
- HPB groundwater: Free oil product, and TPH up to 50 mg/l, PAH up to 2900 µg/l.
- Hinkley Point B landfills: Slightly elevated ammonia, TOC and other leachate-related mineral ions.

i) Southern Construction Phase Area

14.6.89 There is at present no information on groundwater quality for the Southern Construction Phase Area. The land is agricultural and has never been used for industrial purposes. General major ion groundwater chemistry is anticipated to be similar to that found on the Built Development Area West.

14.6.90 Potential controlled water receptors on the Southern Construction Phase Area include groundwater (e.g. the underlying Minor Aquifer) and the surface water courses that cross the site and are present along the southern boundary of the site (e.g. Bum Brook). The desk study has not identified any groundwater or surface water abstractions (e.g. boreholes and wells) on the site itself, however, there are two groundwater abstractions identified at one location 400 m to the west of the Southern Construction Phase Area (see also under Groundwater Use below).

14.6.91 Information on groundwater quality from the investigation in the Southern Construction Phase Area (not available at the time of writing) will be considered in the final Groundwater Technical Note later in 2010.

n) Groundwater Chemistry – Radiological

i) Built Development Area West

14.6.92 The samples from the monitoring campaigns were scheduled for analysis with the following radiochemical suite (analytical methods included in **Appendix 14c**). The sample screening values and background values are provided in **Table 14.6.7**:

- High Resolution gamma spectrometry.
- Gross alpha, (calibrated with Am-241), and Gross beta, (calibrated with K-40).
- Tritium (as tritiated water).
- Carbon-14.

Table 14.6.7: Summary of Radiological Groundwater Screening Values and Background Values (background values as defined by HMIP and RIFE)

Determinand	Screening Value			Background Values	
	RSA93[1] (Bq/kg^{-1})	DWI[2] (Bq/l^{-1})	WHO[3] (Bq/l^{-1})	HMIP[4] (Bq/l^{-1})	RIFE[5] (Bq/l^{-1}) (mean and range)
Gross Alpha (as Am-241)		0.1	0.5	0.0041 – 0.42	0.024 (0.02-0.029)
Gross Beta (as K-40)		1	1	0.026-0.52	0.086 (0.061-0.12)
Ac-228	37				
Ag-110m			100		
Be-7			10000		
Bi-212					
Bi-214					
Ce-144			10		
Co-57			1000		

Determinand	Screening Value			Background Values	
	RSA93[1] (Bq/kg-1)	DWI[2] (Bq/l-1)	WHO[3] (Bq/l-1)	HMIP[4] (Bq/l-1)	RIFE[5] (Bq/l-1) (mean and range)
Co-58			100		
Co-60			100		‹0.7 (‹0.37-‹1.1)
Cs-134			10		‹0.21 (‹0.28-‹0.97)
Cs-137			10		‹0.21 (‹0.001-‹0.86)
Eu-152			100		
Eu-154			100		
Eu-155			1000		
I-131			10		
K-40				0.013-3.6	0.071 (0.063-0.083)
Mn-54			100		
Nb-95			100		
Np-237			1		
Pa-233			100		
Pa-234m	11.1				
Pb-210	0.93	0.2	0.1	0.0085-0.23	
Pb-212	0.93				
Pb-214	0.93				
Ra-226	0.093		1	0-0.98	‹0.01 (‹0.01)
Ru-106			10		
Sb-125			100		
Th-234	6.2		100		
Tl-208					

Determinand	Screening Value			Background Values	
	RSA93[1] (Bq/kg^{-1})	DWI[2] (Bq/l^{-1})	WHO[3] (Bq/l^{-1})	HMIP[4] (Bq/l^{-1})	RIFE[5] (Bq/l^{-1}) (mean and range)
U-235	247		1		<0.01 (<0.01)
Zn-65			100		
Zr-95			100		
C-14			100		
H-3		100	10000		<4 (<4)

1. RSA93 (Radioactive Substances Act 1993) - threshold values for individual isotopes of the RSA93 Schedule 1 elements.
2. DWI (Drinking Water Inspectorate) - Drinking Water Directive (Council Directive 98/83/EC) sets standards for drinking water quality and presents indicator parameter values for radioactivity indicator parameter values. Have been adopted in the United Kingdom in the Water Supply (Water Quality) Regulations 2000 (SI 3184) as amended and can be considered as screening values with no regulatory status.
3. WHO (World Health Organisation) - guidance levels for radionuclides in drinking water
4. HMIP (Her Majesty's Inspectorate of Pollution) - Department of Environment Report 'Natural Radionuclides in Environmental Media. (Ref Doe/HMIP/RR/93/063).
5. Reported in the RIFE reports 8 to 13 from 2002-2007 (RIFE 8 being the first report that includes specific data for Ashford Reservoir near Bridgwater).

14.6.93 Tables and graphs presenting the summary results across all campaigns for Gross Alpha, Gross Beta, Tritium and Carbon-14 are included in Appendix 14c. A summary of the results is also given in the paragraphs below.

Anthropogenic Radionuclides

14.6.94 No anthropogenic radionuclides measurable by gamma spectrometry were detected in any of the samples throughout the sampling campaign indicating that there is no significant contamination of the groundwater in the sampling locations included in this monitoring campaign. However, the presence of anthropogenic alpha- and beta-emitting radionuclides that do not have a significant gamma-emission cannot entirely be discounted.

Comparison of Results with Screening Values

14.6.95 Comparison of the gross alpha, gross beta and tritium results with the requirements of the Drinking Water Directive (Council Directive 98/83/EC) and Water Supply (Water Quality) Regulations 2000 has provided several examples of screening value exceedances. These screening value exceedances were associated with the three deep piezometer locations: CBH11, CBH16 and CBH29. There were no examples of Drinking Water Directive (Council Directive 98/83/EC) and Water Supply (Water Quality) Regulations 2000 screening value exceedances observed for the shallow piezometers (DBH09, CBH20, CBH21, CBH24, CBH25, CBH27, CBH33 and CBH35).

14.6.96 Sampling location CBH16 consistently provided gross beta results of 1.8 to 6.6 Bq Kg $^{-1}$, all above the Drinking Water Inspectorate (DWI) screening value of 1 Bq l-1. The elevated gross beta values can largely be attributed to the elevated potassium-40 content of the samples. The mean value for the monitoring programme was 4.1 Bq Kg $^{-1}$ which was calculated using all values, including any 'less than' values.

14.6.97 Guidance in the application of the DWI screening values permits the subtraction of potassium-40 from any gross beta result that exceeds the DWI screening level. The contribution of potassium-40 to the mean gross beta value has been calculated as 3.7 Bq kg^{-1}; hence the mean gross beta excluding potassium-40 is 1 Bq kg^{-1}, which is equivalent to the DWI gross beta screening value.

14.6.98 The analytical data do not permit further analysis of the constituents of the gross beta value to be established. The absence of anthropogenic nuclides measurable by gamma spectrometry indicates that the gross beta signal is likely to be due to natural radionuclides; although the presence of anthropogenic beta-emitters that do not have a significant gamma emission, for example, strontium-90, cannot entirely be discounted.

14.6.99 Four of the gross alpha results for CBH16 were 'less than' values that exceeded the DWI screening value (0.1 Bq l-1). For campaign 4, a positive result was reported (5.6 ± 4.0 Bq kg^{-1}), although the high relative uncertainty indicates that the result is close to the limit of detection. The high 'less than' values reported for the samples from this location are due to the high dissolved solids associated with the water as indicated by the high major ion content.

14.6.100 Sampling location CBH29 provided gross beta results that were consistently close to the DWI screening value (1 Bq l-1). The mean gross beta activity concentration is just below the DWI screening value (1 Bq l-1). In this case, it is not possible to establish whether or not that the gross beta values can largely be attributed to potassium-40 because the results for this radionuclide are all 'less than' values that exceeded their associated gross beta values.

14.6.101 In addition, location CBH29 provided three positive gross alpha results that exceeded the DWI screening value of 0.1 Bq l-1 but were below the WHO screening value of 0.5 Bq l-1. In addition, the mean gross alpha result for the monitoring programme is above the DWI screening value, but below the WHO screening value.

14.6.102 The analytical data do not permit further analysis of the constituents of the gross alpha value to be established. The absence of anthropogenic nuclides measurable by gamma spectrometry indicates that the gross alpha signal is likely to be due to natural radionuclides; although the presence of anthropogenic alpha-emitters that are not accompanied by any significant gamma emission cannot entirely be discounted.

14.6.103 Sampling location CBH11 provided one gross alpha result that exceeded the DWI screening value (0.1 Bq l-1) in campaign 1, although based on the high relative uncertainty, the result (0.76 ± 0.71 Bq kg-1) was close to the limit of detection. All other gross alpha results were 'less than' values that exceeded the DWI screening value.

14.6.104 The gross beta results for CBH11 in campaigns 2 and 4 (1.39 ± 0.75 and 2.32 ± 0.96 Bq kg-1 respectively) exceeded the DWI screening value (1 Bq l-1). In addition, the gross beta results for campaigns 3 and 5 were 'less than' values for exceeded the DWI screening value.

14.6.105 The analytical data do not permit further analysis of the constituents of the gross alpha and gross beta values to be established. As was the case for CBH16, the elevated gross alpha and gross beta 'less than' values reported for the samples from CBH11 are due to the high dissolved solids associated with the water.

14.6.106 The tritium results covering the monitoring programme were all significantly below the DWI indicator parameter value of 100 Bq l-1. Only three positive tritium results were reported. These were for samples DBH09, CBH25 and CBH27 from campaign 4. In each case, the results (2.5 ±

2.5, 2.6 ± 2.6 and 4.7 ± 2.8 Bq l-1 respectively) were close to the limit of detection and were of the same order of magnitude as the adopted RIFE background value (‹ 4.0 Bq l-1).

Naturally Occurring Radionuclides

14.6.107 Naturally occurring radionuclides detected in the samples throughout the monitoring programme were carbon-14, potassium-40, lead-214, bismuth-214 and lead-212.

14.6.108 Carbon-14 was detected in sample CBH11 in campaign 2 at a level close to the limit of detection (4.9 ± 4.6 Bq kg-1) and significantly below the WHO guidance value (100 Bq l-1).

14.6.109 Potassium-40 was detected in samples from location CBH16 in campaigns 1, 4 and 5. Its presence makes a significant contribution to the elevated gross beta results observed for this sample location.

14.6.110 Bismuth-214 and lead-214 were detected in a number of samples throughout the monitoring programme. These radionuclides are decay products of radon-222; hence in accordance with the Drinking Water Directive (Council Directive 98/83/EC), these radionuclides are excluded from the assessment of total indicative dose. This exclusion also applies to lead-212, which is a decay product of radon-220.

o) Hinkley Point A

14.6.111 SERCO (October 2005) reported the following in relation to radiological constituents in groundwater at Hinkley Point A:

- In shallower groundwater monitoring boreholes, slightly elevated gross beta activities were found in boreholes close to the R1 and R2 Cooling Ponds (Sr-90 was determined to be the cause of this.
- Elevated tritium activity (1910 Bq/l at the source and up to 520 Bq/l in downgradient land drains) was detected in boreholes adjacent to and down-gradient of the R1 and R2 Cooling Ponds and south of the decontamination building in January and March 2005 (see **Figure 14.11**). This plume extends to the seaward boundary of the HPA site. Although significantly above background (3-5 Bq/l), all tritium activities are below the WHO guideline value for drinking water of 10,000 Bq/l and so are not considered to be of environmental concern.

p) Hinkley Point B

14.6.112 Golder Associates (May 2007) reported the following in relation to radiological constituents in groundwater at Hinkley Point B:

- Tritium ›100 Bq/l; and
- Gross beta activity 1.33 Bq/l

q) Built Development Area East and Southern Construction Phase Area

14.6.113 Data are not presently available for these areas, but will be included following investigations in documentation to accompany the final DCO application.

r) Groundwater Use

14.6.114 Within the area shown in **Table 14.6.8**, including the 2 km search radius there are no potable water abstractions and no associated Source Protection Zones.

14.6.115 In the nominal 2 km search area 17 licensed groundwater abstractions were identified. These are shown in **Table 14.6.8** with distances adjusted to show nominal distance (to nearest 5m) and direction from the boundary of the Build Development Area East and Built Development Area West combined (the developed area).

Table 14.6.8: Licensed Groundwater Abstractions

Grid Reference	Licence no. and Details of Use	Nominal Distance (m) and Direction from Developed Area Boundary
319400E 144600N	16/52/007/G/109 General farming and	650 m SW; 400 m W of Southern
319400E 144600N	16/52/007/G/10 General farming and domestic, well, Stogursey	650 m SW; 400 m W of Southern Construction Phase Area
321300E 143480N	16/52/007/G/178 General farming and domestic, Farringdon Hill Farm	1950 m SSE; 1175 m SSE of Southern Construction Phase Area
323200E 145800N	16/52/007/G/109 General farming and domestic, borehole, Stogursey	2340 m E
323200E 145800N	16/52/007/G/109 General farming and domestic, borehole, Stogursey	2340 m E
323110E 145090N	16/52/007/G/105 General farming and domestic, well, Yearmoor Lane	2295 m E
323110E 145090N	16/52/007/G/105 General farming and domestic, well, Yearmoor Lane	2295 m E
323600E 145400N	16/52/007/G/108 General farming and domestic, well, Stogursey	2735 m E
323600E 145400N	16/52/007/G/108 General farming and domestic, well, Stogursey	2735 m E
323000E 143500N	16/52/007/G/154 General farming and domestic, Stogursey	2920 m SE
323800E 144300N	16/52/007/G/062 General farming and domestic, well, Stogursey	3200 m ESE
323800E 144300N	16/52/007/G/062 General farming and domestic, well, Stogursey	3200 m ESE
320300E 142300N	16/52/007/G/116 General farming and domestic, well, Stogursey	3200 m S
320300E 142300N	16/52/007/G/116 General farming and domestic, well, Stogursey	3200 m S

Grid Reference	Licence no. and Details of Use	Nominal Distance (m) and Direction from Developed Area Boundary
321000E 142300N	16/52/007/G/077 General farming and domestic, well, Stogursey	3200 m S
321000E 142300N	16/52/007/G/077 General farming and domestic, well, Stogursey	3200 m S
320940E 141960 N	16/52/007/G/180 General farming and domestic, borehole, Higher Monkton Farm	3320 m S

14.6.116 All these wells and boreholes are for general farming and domestic purposes. The nearest abstraction is 650 m southwest of the Built Development Area West site boundary (and 400 m west of the Southern Construction Phase Area). All the others are over 1.9 km distant from the Development Site.

14.7 Modelling of Groundwater Conditions and Development Scenarios

a) Conceptual Model

14.7.1 Using the available information on the geological structure and succession and data from groundwater studies of the development area a preliminary conceptual and qualitative groundwater has been produced, as shown in **Figures 14.2** and **14.3**. This conceptual model has also taken account of hydrogeology work previously undertaken by Aspinwall & Company (1996)13 and Allott Atkins Mouchel Power Consultants (1988).

14.7.2 In the area covered by **Figure 14.3**, groundwater in the fractures of the Lower Lias is shown being fed by rainfall recharge, with flows approximately south to north from the Mercia Mudstone outcrop, with eventual discharge into the Bristol Channel, either directly or following baseflow discharge to the surface water system. The Penarth Group/Mercia Mudstone forms a lower boundary to the system.

14.7.3 Within the Development Site itself, however, this general natural flow regime is intercepted by the upfaulted inlier of Mercia Mudstone on the southern margin of the site. This bedrock barrier might effectively 'dam' the groundwater flow sufficiently for water tables to rise and groundwater flow to be diverted into the surface water system as baseflow, especially (in relation to the Southern Construction Phase Area) to Holford Stream. Estimated groundwater levels on **Figure 14.3** show how the groundwater is likely to discharge to Holford Stream, which is at an elevation of about 5 m AOD at this point, and well below the groundwater levels south of the Mercia Mudstone inlier at the Hinkley Point C site itself **Figure 14.2**. It is possible that the rapid response of groundwater levels to rainfall in the vicinity of Holford Stream could also be a factor in the flood characteristics of the stream.

14.7.4 The Development Site is therefore likely to be largely self-contained as a groundwater system, bounded by the Mercia Mudstone/Penarth Groups beneath, the faulted inlier to the south, and the Bristol Channel to the north. To the east and west under natural conditions groundwater is expected to flow northwards in general, but those conditions may be altered in the short term during the construction dewatering phase. There are some minor reversals of groundwater flow due to the geological structure and topography with some groundwater flowing south into the site drainage on the Hinkley Point C site. The structural fault, which is located between CBH29 and CBH12 on **Figure 14.1** may provide for further compartmentalisation within the Lower Lias underlying the Hinkley Point C site, depending on the detailed aquifer properties, weathering and fissuring across the upper parts of the Blue Anchor and Penarth lithologies. There does not seem to be a discontinuity in groundwater levels between these units so this may not form a further constraint on the groundwater regime.

14.7.5 The areas south of the HPA and HPB stations are not bounded on the south side by the faulted inlier as within the Development Site. However, Holford Stream and other more southerly watercourses may still present a partial barrier by collecting shallow groundwater as baseflow and restricting the effective groundwater catchment leading to HPA and HPB.

14.7.6 This model is clearly preliminary, nevertheless, it includes the significant features likely to control the groundwater system in and around the Development Site. The conceptual model may evolve as more data become available, for example from further site investigations on the Built Development Area East and Southern Construction Phase Area, which will enable the use of site-specific data to enhance the validity of the model in areas currently inferred or lacking in validation.

b) Groundwater Numerical Model

i) Introduction

14.7.7 In order to improve upon the analytical assessments described in the previous section, a numerical groundwater model has been developed to represent as closely as possible the observed baseline regime and provide a basis for assessment of future scenarios.

14.7.8 The model has been developed using the United States Geological Survey (USGS) MODFLOW code running under Groundwater Vistas v5.

14.7.9 An important part of model development is calibration. Options for calibration of the model were limited to i) a single short-duration pumping test carried out as part of the Built Development Area West onshore investigation in December 2008, and ii) the groundwater hydrograph records from about 12 months of data (between December 2008 and January 2010) collected from the transducers installed in many of the monitoring boreholes.

c) Model Architecture and Boundary Conditions

14.7.10 The model configuration is shown in **Figure 14.12**. A rectilinear finite difference grid is made up of 172 columns and 119 rows. These vary in resolution from 50 m at the margins to 10 m both in the central area, and also to the north where the rock layers dip relatively steeply and a tight grid is required to ensure that sloping layers are sufficiently continuous from one row to the next.

14.7.11 The total model domain extends 4800 m east-west and 1500 m north-south. To place the model in geographical context, **Figure 14.13** shows the grid overlain by an outline map of the Hinkley Point area.

14.7.12 The model comprises five geological layers, two in the Lower (Blue) Lias, and one each in the Lilstock, Westbury and Blue Anchor formations. The base of the model is defined by the top surface of the Mercia Mudstones aquiclude below the Blue Anchor formation.

14.7.13 Figures 14.12 and 14.13 indicate inactive cells and no-flow boundaries in black. The natural regime discharge of groundwater to the Bristol Channel is represented by fixed heads along the north of the model domain at 0 m AOD. The groundwater surface is still at an elevation of up to 10 m at the cliff line, so it is assumed that the discharge of the natural groundwater flow regime into the Bristol Channel takes place several hundred metres offshore – in the model the fixed head cells are generally about 300 m from the cliff line.

14.7.14 Holford Stream and its associated surface drainage system in the south-east corner of the model is in reality supported at least partially on lower premeability marine/estuarine alluvium which could result in the Lower Lias being semi-confined or confined in this area. This means that the groundwater heads in this part of the model could justifiably be above ground surface level since the alluvium is not explicitly modelled; moreover, this cover will also restrict aquifer recharge in this zone.

14.7.15 The precise nature of the interaction between the surface and groundwater regimes in the area of Holford Stream is unknown since there is no available piezometric or flow data. Under these circumstances it is therefore desirable to run some sensitivity checks using a variety of different boundary conditions in order to confirm that there is no significant effect in the Development Site if the south-east model boundary conditions are changed. The following options were evaluated during this process:

- Fixed heads at 5 m AOD (in eastern part of the model this generated a permanent flux in Layer 1 between the south east boundary and the northern sea discharge at 0 m AOD).
- Fixed heads in the Holford Stream varying downstream from 5 m AOD in the west to 0 m AOD at the coast in order to obviate the above.
- Holford Stream represented as a drain using a hydraulic conductivity of 1 m/d and default geometry (little difference from no-flow boundary condition).
- Holford Stream represented as a river using a river bed hydraulic conductivity of 1 m/d and default geometry (little difference from fixed head condition).
- No-flow boundary with reduced recharge on alluvial area (finally adopted condition).

14.7.16 Across the Built Development Area the existing drainage ditches (which control some of the borehole groundwater levels, see **Figures 14.9** and **14.10** are represented in MODFLOW by internal boundary conditions in the form of drains, with stage elevations between 10 and 16 m AOD, derived from the surface topography. This also includes a former drain channel now buried beneath made ground on the Built Development Area East which joins the extant drain where it alters course from east to north. In the absence of any other property data, the drains are allocated hydraulic conductivity values of 1 m/d (about twice the highest initial Lower Lias permability in Layer 1), with assumed thickness and width of 1 m.

14.7.17 The model layer geometry has been developed as follows:

- Existing borehole information from the Built Development Area West and the former CEGB Hinkley Point C investigation were imported and gridded in SURFER.
- For the base of the Blue Lias (base of Layer 2) this gridded data was replicated directly to east and west (as far as the Hinkley Fault), and extrapolated to north and south in accordance with the geological formation dips identified from cross-sections through the Built Development Area West boreholes.
- The base of Layer 1 was derived from the surface topography since the geotechnical interpretation of the onshore investigation data concluded that there was a change in degree of weathering (and therefore permeability) related to depth below ground surface. The surface topography was gridded in SURFER from site survey data augmented by 1:25,000 Ordnance Survey data on the model margins (**Figure 14.14**), and the base of Layer 1 was set at 40 m below ground level, thereby wedging out to the south on the west side of the Hinkley Fault.
- East of the Hinkley Fault the base of the Lias was modified according to downthrow and structural information in the British Geological Survey sheet memoir to incorporate variable downthrows and an anticline with an axis running west-east.

- MODFLOW requires that all layers are in sequence throughout the model domain, so for example Layer 1 could not be situated directly on Layer 3 in the areas to the south where the 'real' Layer 2 is absent (total Blue Lias thickness less than 40 m). In order to preserve model functionality therefore, Layer 2 was extended across the whole model so that it remained at a 5 m thickness at the base of Layer 1 (a value of 5 m was chosen so that cell-to-cell continuity would be maintained in the areas of steeper layer gradients), Layer 2 was allocated the same aquifer properties as Layer 1 in these areas.
- The average thicknesses of Layers 3 (Lilstock), 4 (Westbury) and 5 (Blue Anchor) were determined from evaluation of the Built Development Area West borehole logs, giving, thicknesses of 2.7 m, 9.7 m and 33.1 m respectively. These thicknesses were subtracted from the base of Layer 2, although the thickness of Layer 3 was subsequently increased to 5 m in the model to preserve cell-to-cell continuity in the areas of steeper dip (as was done with the quasi-Layer 2 in the south. Hydraulic conductivity was decreased in proportion so that the layer transmissivity remained the same.

14.7.18 Layers 1 and 2 are assigned as unconfined, with transmissivity variable depending on saturated thickness, and Layers 3, 4 and 5 as confined. For convenience, starting head values in the initial steady state models were set at a flat 15 m AOD

d) Initial Parameters and Calibration

i) Initial Parameters

14.7.19 For an initial steady state model, the following parameters were used, based on investigation data and previous documentation.

ii) Hydraulic Conductivity (K):

- Layer 1 (Weathered Blue Lias) 4.9×10^{-6} m/s (0.42 m/d)
- Layer 2 (Fresh Blue Lias) 4.5×10^{-8} m/s (0.0039 m/d)
- Layer 3 (Penarth – Lilstock) 5.0×10^{-6} m/s (0.43 m/d)
- Layer 4 (Penarth – Westbury) 5.0×10^{-7} m/s (0.043 m/d)
- Layer 5 (Blue Anchor) 5.0×10^{-7} m/s (0.043 m/d)

14.7.20 In the absence of any other data, vertical hydraulic conductivity K_z was assumed to be 10% of horizontal.

iii) Recharge

14.7.21 A recharge value of 315 mm/a was used initially for the general land areas at Hinkley Point as a basis for further calibration and refinement. Data from the Meteorological Office Surface Exchange System (MOSES) database for the period 1961-2001 provides for an analysis of rainfall, evaporation and soil moisture deficit through the year, which can then inform the likely temporal distribution of groundwater recharge for the transient calibration process. The following components were included in the determination of recharge:

- PE (potential evapotranspiration) and AE (actual evapotranspiration) monthly average values for average rural land use surfaces.
- SMD (soil moisture deficit) which increases through the late spring and summer and declines in early autumn.
- EP (effective precipitation) which is the rainfall available after evaporation for runoff and potential groundwater recharge.
- Actual rainfall monthly averages (for the period 1962-1995) for the Brymore School rain gauge.

14.7.22 Annual average totals are 452 mm AE, 383 mm PE and 759 mm rainfall. SMD reaches a cumulative maximum of 77 mm in July and August.

14.7.23 The seasonal distribution of rainfall, evaporation and soil moisture deficit restricts the periods during which aquifer recharge is likely to the late autumn and winter when the soils are at field capacity and a proportion of the effective precipitation can recharge. In spring the higher temperatures result in a build up of soil moisture deficit which lasts until at least early autumn; during this period groundwater recharge is unlikely unless there is enough persistent precipitation to remove the soil moisture deficit. Consequently, and as shown in the borehole data collected during 2009, groundwater levels exhibit a steady recession lasting from around March/April through to late October when the final removal of soil moisture deficit coincides with a period of intense rainfall and the groundwater levels show a sudden rise. Rainfall events during June, July and August, some of which are quite significant, are not reflected in the groundwater levels because of the prevailing high SMD. In the model this means that the total annual recharge is concentrated in the period between November and February in order to best emulate the borehole hydrograph pattern, and weighted particularly in November/December.

14.7.24 The apportionment of effective precipitation (ER) between runoff and groundwater recharge is uncertain It is possible to derive an approximation for the potential recharge by subtracting the SMD from the effective precipitation in the autumn and winter months when SMD is zero or low enough to be overcome by the rainfall – this gives a total groundwater recharge of 217 mm, and may represent a lower bound on total recharge values (subject to corroboration in the transient model calibration below).

14.7.25 The area of HPA and HPB stations was initially allocated a reduced recharge of 25 mm in view of the hardstanding and engineered drainage. There is no basis for refining this value, but it represents approximately 10% of the ‘standard’ recharge applied to the Lower Lias outcrop areas. The reduced recharge alluvial flood plain area in the south-east of the model was allocated a recharge of 50 mm following transient calibration as described below. No recharge was allocated to the areas of sea.

iv) Steady State Calibration

14.7.26 The overall calibration process performed to achieve a representative groundwater model for the Built Development Area involved both steady state and transient regimes. In summary, the calibration process involved the following steps:

- A steady state model was constructed in order to determine the general piezometric head pattern across the model and to explore the influences of the Holford Stream boundary condition.
- The recharge associated with the alluvial flood plain in the east of the model was then modified in order to represent likely heads on the Hinkley Point B site which are believed to be in the order of 4-6 m AOD (but no piezometric data from 2009 has been made available).
- A transient model was then constructed to represent the 2008 pumping test by matching the maximum drawdowns in a selection of monitoring wells in the model to those observed in the field. This was achieved by varying model hydraulic conductivity values in all three principal axes (K_x, K_y and K_z) in Layer 3 (as detailed below).
- A second transient model was then constructed using the calibrated hydraulic conductivity values for Layer 3 from the pumping test model. The second model was designed to investigate the appropriate general recharge value assumed in the model, and its temporal distribution throughout the year by attempting to match modelled heads in a selection of boreholes on the Built Development Area site with observed field hydrographs. This model allowed both the total annual recharge value and its monthly distribution to be modified. The best transient recharge calibration achieved used a total annual recharge value of 220 mm/a for the majority of the site outside of the existing power stations and alluvial flood

plain. This annual recharge was distributed between the four winter months (January, February, November and December.

e) Modelled Development Scenarios

i) Construction Works Drainage

14.7.27 Additional drains were added to the model to represent the spine drains planned in the Built Development Area to facilitate construction of the site working platforms. These are shown in **Figure 14.15** together with a steady state contour plot of Layer 1 heads. The spine drains make little discernable influence on the groundwater regime.

ii) Unmitigated Deep Dewatering

14.7.28 The planned deep dewatering for the nuclear islands, and in particular for the excavations for the cooling water pumping stations, has been simulated in the model. This has been done by introducing fixed heads in Layers 1 and 2 at the locations of the cooling water pumping stations at elevations of -25 m OD to allow for non-dewatered sections between the borehole cones of depression and also for depressurisation beneath the excavation floor. The modelled scenario therefore represents a maximum dewatering depth. Recharge was restored to an average daily equivalent of 315 mm/a and the model was run in transient mode for four years.

14.7.29 The initial water level conditions for Layer 1 are represented by **Figure 14.16**. Dewatering impacts after 30 days, 60 days, 1 year and 4 years are shown in **Figures 14.17-14.20**. The influence on the groundwater regime in terms of modification of gradients establishes quickly and the condition away from the immediate vicinity of the pumping does not change significantly after the 30 day period. 'Pumping rates' generated by the fixed heads are 12 l/s (43 m3/hr) after 30 days, declining to 11 l/s after four years.

14.7.30 Of particular note is that the groundwater gradient across HPA, which is to the NNE under baseline conditions, alters to north-west under the influence of pumping and groundwater under HPA could migrate into the dewatering cone of depression. The groundwater ridge between HPA and Holford Stream is not significantly affected however.

14.7.31 Gradients and flow directions are similarly altered in Layer 2 **Figures 14.21-14.24** compared with the baseline shown in **Figure 14.25**). Permeabilities in Layer 2 are much lower than Layer 1 however, and significant change in groundwater flux is considered unlikely.

iii) Curtain Walling Around Pumping Station Excavations

14.7.32 It is currently planned to emplace curtain walls on the north, west and east sides of the deep pumping station excavations. It is proposed that the walls will be approximately 1.8 m in thickness and have a permeability in the range of 10^{-8} – 10^{-10} m/s. Figures 14.26 and 14.27.

14.7.33 The effect of these walls on the groundwater regime during dewatering is shown in and 14.27 for Layer 1 after 30 days and 4 years; and in **Figures 14.28** and **14.29** for Layer 2. The change in groundwater flow direction under Hinkley Point A is delayed but still occurs eventually. Pumping rates are reduced to around 3-4 l/s (10.8-14.4 m^3/hr).

14.7.34 A model run was also undertaken to simulate the influence of an additional wall running north-south just to the east of EPR1. The modelled location of the various walls is shown on **Figure 14.30**. **Figures 14.31** and **14.32** indicate that such a barrier would be likely to effectively mitigate any groundwater movement from beneath HPA towards the Development Site.

14.8 Assessment of Potential Changes to Groundwater Conditions

a) Introduction

14.8.1 A description of the stages, infrastructure and methods to be used in the construction of the development is contained within the project description and construction sections of the EnvApp **Chapters 2 and 3**.

14.8.2 The main effects on groundwater conditions are likely to be:

- Dewatering during the construction phase;
- Modification of the natural groundwater regime during the operational phase; and
- Potential contamination of groundwater during both construction and operational phases.

14.8.3 These effects are described and detailed in the following sections based on available information and data obtained during the site investigation works to date, together with the conceptual and mathematical models developed using this survey data and other available information sources.

14.8.4 The assessment work focuses on the potential for the development during both construction and operation to alter the existing groundwater conditions.

i) Dewatering during the Construction Phase

14.8.5 Dewatering of the excavations for buildings is required to enable safe and efficient construction of foundations and the construction of any section of the building(s) below the baseline water table. Dewatering operations will start in advance of excavations so that the working areas are as dry as possible.

14.8.6 The assessment detailed (without a diaphragm wall) in this Chapter can be regarded as worst case; any containment is likely to ameliorate the effects of changes in groundwater levels on the outside of the containment during dewatering, by the same means by which it prevents water entering the excavation. In turn, this would reduce the potential for any associated changes in water quality that may occur with the dewatering cone of depression and that would otherwise apply.

14.8.7 Most of the dewatering abstraction volume will arise from drainage of the fractures and larger pores in the saturated zone in its area of influence; but some water will still be present in the unsaturated zone above the water table as transitional recharge water moving downwards or held in small pores and pore connections by capillary forces in the pre-dewatering saturated zone – this latter comprises the 'specific retention' component of effective porosity which cannot drain by gravity and will be released into the excavation as the material is broken up and removed.

14.8.8 During construction, the installation of dewatering plant is scheduled as part of site preparation, with the need for dewatered conditions in the excavations continuing through until completion of the underground construction works for EPR Unit 2. As such a dewatering programme lasting 4-5 years is anticipated.

14.8.9 Ongoing work on the foundation design for the deep excavations indicates that the extent of the deep excavations will cover an area of some 350 x 350 m on the 'nuclear island'. This area is shown on the deep excavation plan in Figure 3.3 chapter 3 and extends to within about 100 m of the shoreline. The northernmost 100 m or so of this deep excavation area are for the cooling water pumping stations referred to above, nearest to the shoreline, which will be excavated the deepest to around 29 m below the 14 m OD platform level, i.e. to around to -15m OD. The rest of the ‘nuclear island’ will be excavated to various depths but for dewatering purposes a depth of 17 m below the 14 m OD platform level is assumed, i.e. to -3 m OD.

ii) Modification of the Natural Groundwater Regime during the Operational Phase

14.8.10 Once the sub-water table buildings are in place and the site is operational the baseline groundwater regime will be altered. Proportions of the baseline aquifer system will be replaced by effectively impermeable blocks which will possibly result in localised rises in the groundwater level on the upgradient side, drops in groundwater level on the downgradient side, and attendant changes to localised groundwater flow directions.

14.8.11 The preferred design for the sea wall comprises a concrete structure with a base nominally at 1.8 m AOD at its lowest point which is within the likely range of active groundwater heads but does not completely penetrate the aquifer. It is not considered likely at this stage that the sea wall will have a significant effect on groundwater conditions.

iii) Activities that May Cause Contamination of the Groundwater Resource

14.8.12 Other than direct and indirect modification of the characteristics of the groundwater system, as highlighted above, general activities and processes during the construction and operation of the power station may influence groundwater quality, largely through the introduction of potential contaminants.

14.8.13 During construction the key effect would be the potential mobilisation of existing contaminants present within the Development Site or adjacent areas by construction activities e.g. through groundwater dewatering, soil disturbance during earthworks.

14.8.14 Assessment of the potential risk of contamination of the groundwater as a result of accidental release of fuels, oils and other chemicals from plant and storage tanks during either construction and/or operation is considered as an environmental management issue and is covered in **Chapter 3** of the EnvApp. Measures to prevent or minimise the potential for any accidental releases of pollutants that could affect groundwater quality will be contained and described in the Environmental Management and Monitoring Plan (EMMP) for the project.

b) Effect of Site Preparation Works on Groundwater Conditions

14.8.15 The initial components of site construction largely focus on site clearance (i.e. vegetation), earthworks and formation of the final construction platforms. A description of these works is provided in **Chapter 3** of the EnvApp. While it is not anticipated that these components are likely to have any effects as significant on groundwater as those associated with the deep excavation works, their potential implications are briefly described and determined below as they represent a distinct phase in the construction works. In relation to potential effects on groundwater resources and quality it is assumed that, other than the accidental release of potential pollutants during construction, that within the context of the overall planned construction works, the installation of the perimeter fence, vegetation removal and topsoil stripping would not lead to any change in groundwater conditions.

14.8.16 To date there is no evidence of any significant volumes of contaminated soils in the topsoil areas to be stripped on the Built Development Area West. Conditions in the Built Development Area East remain to be determined from the ongoing site investigation programme. In any event any contaminated soils would be segregated from clean soils and subjected to appropriate management which may involve remediation to render the soil suitable for re-use or alternatively off site disposal. Accordingly there is **no potential** for groundwater contamination arising from the topsoil stockpiles.

i) Site Levelling/Terracing

14.8.17 **Figure 14.9** and **Figure 14.10** show the nominal groundwater contours derived from water table levels in the shallow Lower Lias piezometers installed on the Built Development Area West. Of these, the highest water levels are shown in **Figure 14.10**, based on water table data from 1st December 2009.

14.8.18 The lowest excavation area for the preliminary earthworks is for a formation level at 10 m AOD. Comparison with the information shown in **Figure 14.11** indicates that, at the highest observed groundwater levels, this formation level will be up to 6 m below natural groundwater levels, which vary between 11.0 and 16.0 m AOD in this locality.

14.8.19 The remainder of the Hinkley Point C site excavations for the preliminary earthworks over the main nuclear island area results in a platform level of 14.0 m AOD. In the strip south of the 10.0 m AOD formation level, and in the area to the east, it is also likely that parts of the platform will be below the highest natural groundwater levels by 2-3 m.

14.8.20 The remaining platforms appear to be above the likely maximum groundwater levels, although conditions in the Built Development Area East are not fully known (investigation is ongoing which will confirm this).

14.8.21 Without additional water management, the presence of high groundwater levels would make the cut and fill operations in the low areas of excavations difficult and potentially unsafe. However, the surface water drainage component of the initial phase of construction will incorporate deep drains running south-north (see **Chapter 2** of the EnvApp) either side of the 10.0 m AOD formation level, at a level which will drain most of the groundwater to that level and intercept future groundwater flows. These drains are currently proposed to discharge to the foreshore at an invert level of 9.0 m AOD.

14.8.22 Overall, although it is clear that the formation of the construction platforms will intercept existing groundwater levels, the effect on groundwater resources would be negligible. This is largely due to the fact that the groundwater body concerned is designated as a Secondary Aquifer and there is no apparent current use of the resource meaning that it is of low sensitivity with regard to potential construction influence. Any effects on groundwater would also be restricted to the northern part of the Development site (i.e. in the vicinity of the platforms themselves).

14.8.23 Some groundwater held in the non-drainable pores and joints in the unsaturated zone, and recharge water in process of vertical migration above the water table, will be released by the excavation process and will need to be discharged to the drainage system via suitable arrangements for removal of suspended solids prior to final discharge to the natural environment.

14.8.24 The groundwater quality in the Built Development Area West does not show any indication of sustained contamination except in the case of nitrate and so discharge of groundwater captured by the deep drains is not expected to present any groundwater quality issues. The nitrate is presumed to originate from agricultural activities.

14.8.25 The ongoing investigation on the Built Development Area East will confirm whether or not groundwater contamination issues are a significant factor in the eastern part of the Development Site. It is possible that incidences of existing groundwater contamination may be encountered in relation to areas of possible contaminated soil identified or suspected in the Built Development Area East. Should there be any groundwater that presents problems with respect to final discharge due to its quality, then additional measures would be required to contain or treat it.

14.8.26 There is not expected to be any groundwater contamination issue associated with any relocated contaminated soil or rock material. No significant volumes of contaminated soil have been identified on the Built Development Area West. The contamination status of soils within the Built Development Area East and Southern Construction Phase Area is subject to confirmation from ongoing investigations. Should contaminated soils be identified they would be segregated and subjected to appropriate management such that they would not be re-used without remediation or alternatively removed for disposal off-site.

14.8.27 The temporary stockpiling of superficial deposits and rock material may result in a reduction in direct recharge to the stockpile footprint in areas where the Lower Lias minor aquifer outcrops. This results from the enhanced runoff from the stockpile slope faces. However, this enhanced runoff could then recharge the aquifer away from the stockpile footprint if not carried directly to surface water drainage – which in any event is contributed to from groundwater baseflow.

14.8.28 At present it is assumed that the water table in the Lower Lias in the Southern Construction Phase Area reflects the surface topography and is controlled by the levels of Bum Brook and Holford Stream to which it discharges as baseflow **Figure 14.3**. Between the watercourses the natural water table is likely to be slightly higher than the surface drainage, by an amount dependent on permeability, storage and recharge rate. Because of the likely recharge and underflow from the south this condition is likely to remain. It is however possible that stockpiling will compress the in situ lithology beneath and result in a local lowering of permeability and storage. Whilst this may result in some localised modifications to groundwater flow in the stockpile area, it is not expected to be significant in the context of groundwater flows/levels in the wider area. As such, a **negligible** influence on groundwater resources as a result of stockpiling is predicted.

ii) Drainage

14.8.29 The groundwater conceptual model suggests that Holford Stream is at least partially fed by groundwater baseflow where the Lower Lias water table intercepts the surface, although in the absence of site-specific groundwater data (until the scheduled site investigation on the Southern Construction Phase Area is carried out) it is not possible to confirm the groundwater flow rates involved nor where the ‘gaining’ and ‘losing’ sections of the Holford Stream are.

14.8.30 However, if the culverted section does not adequately allow for the inflow of groundwater baseflow from the Lower Lias during periods of high groundwater levels and flow, then it is possible that groundwater heads will rise in the vicinity of the culverted section. This could lead to localised temporary flooding and/or saturation of the lower parts of stockpiled materials that have been placed in this area.

14.8.31 Any such effect would be confined to the culverted section of Holford Stream and its immediate vicinity. In reality, although this effect stems from the interaction between drainage and groundwater flow, the impact of temporary flooding is a hydrology and drainage issue. There would be insignificant changes in groundwater levels and on the basis of the low sensitivity of the resource itself (Secondary Aquifer) it is considered that the influence on the groundwater component of this interaction would be **negligible**.

c) Excavation Works and Dewatering

14.8.32 The key aspects of the construction works that have been identified as having the potential to influence groundwater behaviour and conditions are related to the deep excavation works and are as follows:

- the generation of dewatering cone(s) of depression creating new gradients under buildings in adjacent areas, notably the Hinkley Point A and B power stations;

- the generation of dewatering cone(s) of depression creating new gradients which result in the flow of potentially contaminated groundwater from adjacent areas into the abstraction point(s);
- discharge of potentially contaminated water from the dewatering abstraction; and
- the generation of dewatering cone(s) of depression creating reversal of the baseline groundwater gradient to the Bristol Channel and incursion of saline water to the Minor Aquifer.

14.8.33 The assessment work that addresses the above issues is described in the following sections and covers:

- the likely volumes and rates over time of water needed to be removed from the aquifer for effective dewatering (this will be a function of excavation depth, saturated aquifer characteristics, recharge and construction timescale);
- the worst-case extent of the dewatering cone(s) of depression using the numerical groundwater model;
- range of worst-case differential groundwater gradients across the footprints of existing buildings falling within the cone(s) of depression, and their comparison with the range of prevailing natural gradients and geotechnical consideration of the implications; and
- from the gradients and the aquifer characteristics, estimates of the possible ranges of groundwater flux rate from potential contaminated groundwater sources to the dewatering abstraction, i.e. how far would any contaminated water or sea water be able to migrate during the dewatering programme.

i) Dewatering

14.8.34 This section addresses the following main topic areas:

- water levels;
- sea water incursion; and
- contaminated groundwater transfer.

ii) Influence on Groundwater Levels

14.8.35 The dewatering activity will cause the drawdown of groundwater to create a zone of influence (cone of depression). This drawdown is assumed to reach a maximum of - 25 m OD.

14.8.36 It is likely that the dewatering cone of depression will extend beyond the Development Site into adjacent land during the 4-5 year dewatering programme, resulting in localised groundwater level change within the aquifer. There is no apparent current use of the aquifer resource at or adjacent to the site and therefore the overall sensitivity of this resource to the predicted change is assessed as low.

14.8.37 While it is clear that groundwater drawdown would occur during construction, the effect would be temporary and groundwater levels within the aquifer would recover (through recharge) after completion of the construction works.

14.8.38 Given the localised nature of the predicted change and the temporary and reversible nature of the drawdown in groundwater levels the overall magnitude of the impact is assessed as low. On the basis of this and the low sensitivity of the aquifer (i.e. it has no resource usage) the predicted change in groundwater levels is determined as **not significant** and no effect specific control is considered to be required or suggested to address this effect.

iii) Influence on Groundwater Quality

14.8.39 Dewatering will lead to the movement of groundwater in the zone of influence (cone of depression) towards the abstraction point, i.e. the deep excavations. As described above the cone of depression will extend into adjacent land during the 4-5 year dewatering programme. This means that there would be sufficient time for any non-attenuated contaminants in the groundwater within the cone of depression to migrate to the site of the abstraction within the time frame of the dewatering activity.

14.8.40 This potential effect is provisional in that no significant contamination is identified on the Built Development Area West and the status of any groundwater contamination in adjacent areas is uncertain. Further investigations on the Built Development Area East and Southern Construction Phase Area will resolve some of the uncertainties. More recent information from the HPA and HPB sites will be obtained if possible to further reduce uncertainty.

14.8.41 There is no significant groundwater contamination under the Built Development Area West. There are, on the basis of available information, however, potential contamination sources within the existing HPA and HPB sites, and some evidence of groundwater contamination by organic and inorganic constituents. The current detailed scale and distribution of any contamination is uncertain and requires further assessment – some of this assessment is in process on the Built Development Area East.

14.8.42 The groundwater body concerned is designated as a Secondary Aquifer with no apparent current use of the resource at or adjacent to the site in the likely area of dewatering drawdown influence. Therefore, the potential migration of contaminants into the aquifer via dewatering and drawdown could be considered to have no effect on the water quality status of the groundwater resource.

14.8.43 The likelihood of this effect occurring depends on the presence of potential contaminants within the groundwater in the area of influence. If contaminants are present, then the movement of groundwater containing them is likely. The dewatering activity would be temporary (4-5 years), however the effect could be permanent because the groundwater flow would not reverse when abstraction stopped, and would revert to its pre-abstraction condition, thus leaving any introduced contaminants in place. The potential exists for the contaminants to be removed from the groundwater through natural groundwater flow or active removal if concentrations were deemed significant.

14.8.44 As the aquifer resource is designated as a Secondary Aquifer and there are no apparent current uses of it within the zone in which contaminant levels could be increased, the potential change in groundwater quality is assessed as of **not significant**.

iv) Effect of Dewatering on Fows in Holford Stream

14.8.45 It is probable that there is a groundwater divide (watershed) in the natural groundwater regime south of the existing HPA and HPB station complex. Groundwater to the north of the divide would flow northwards to the Bristol Channel, and groundwater to the south of the divide would flow southwards or to the southeast to the Holford Stream, contributing to baseflow to that stream.

14.8.46 The dewatering cone of depression could reduce the groundwater levels at the divide and thereby reduce gradients and baseflow rates to the stream. The potential for this effect to occur and its overall significance is difficult to establish at the present time. The additional data on groundwater levels and the groundwater flow regime within the SCPA that will be obtained from the planned site investigations will contribute towards defining this potential effect. It is also not known what proportion of the normal flows in Holford Stream derive from baseflow in this area. However, it is clear that because the dewatering would be temporary that any effect would be reversible. The overall issue is also complicated by the proposed culverting of a section of Holford Stream and the additional interaction with groundwater flows that this may introduce.

v) Potential to Effect Groundwater Abstractions

14.8.47 In theory, dewatering during construction could alter water levels within the local aquifer and therefore influence the yields of any licensed abstractions in the area of influence.

14.8.48 The only licensed abstractions in the study area are to the south of the development site and outside of the Southern Construction Phase Area. These licensed abstractions are located outside of the likely dewatering zone of influence. Potentially, the aquifer at the abstraction sites could be sensitive to fluctuations in groundwater levels if this were to occur, particularly at times when recharge was limited (e.g. under low rainfall conditions). It should be taken into consideration that natural variations in the groundwater levels at the abstraction sites would be likely to far exceed any variation in levels caused by drawdown as a result of the construction works and the added effect of drawdown with natural variation would be unlikely to be discernible if it were to occur. It is therefore assessed as unlikely that an effect would occur because of both the distance of the licensed abstractions from the zone of dewatering and the hydrogeological separation due to the upfaulted impermeable Mercia Mudstones barrier between the development site and the Southern Construction Phase Area. Dewatering would be temporary (i.e. during construction) and any related effects would therefore also be temporary as the groundwater regime would revert to its pre-dewatering configuration following the cessation of construction.

14.8.49 Taking into account the above aspects, it is considered that any changes in groundwater conditions would be unlikely to be discernible and **no significant change** in groundwater levels or resource outside of the Development Site would be likely to occur.

vi) Influence on Buildings and Infrastructure

14.8.50 If groundwater gradients under a structure increase significantly it is possible that stresses can be generated due to the differential hydrostatic pressures under the structures and lead to damage to the foundations due to differential settlement. Potentially dewatering and the drawdown of groundwater levels could have an influence on buildings with shallow foundations (e.g. those present within the HPA and HPB sites). However, the analysis work presented in previous sections suggests that groundwater level changes due to dewatering on land adjacent to the HPC Development Site would not be significantly different to those groundwater levels that occur naturally (i.e. within the range of natural variation).

14.8.51 This potential effect is therefore presently considered **unlikely to be significant**. However, as complete details of the dewatering programme and its influence have yet to be determined and the groundwater conditions outside of the Built Development Area West are uncertain and/or not validated, this conclusion is presently provisional. Some of the uncertainties associated with this potential effect will be resolved by site investigations currently in progress.

d) Construction of the Seawall

14.8.52 The seawall will be founded on the Lower Lias rock formation at approximately 1.8 m AOD at its lowest point. This is likely to be below the current groundwater level, although the additional drainage provided for the Built Development Areas East and West may reduce groundwater levels behind the Sea Wall. Nevertheless, the drainage preferred concept drainage design provides for perforated collector pipes behind the seawall feeding to two main outfalls in order to drain and relieve any pressure from groundwater behind the wall. The drains will be sufficient to store groundwater and other drainage flows during high tide conditions and flap valves will prevent backwash.

14.8.53 No dewatering is required for Sea Wall construction, so the only potential effects are related to increased groundwater levels behind the wall and the use of mechanised plant during construction. The former is obviated by the drains incorporated in the design. As such, **no significant** effect on groundwater resources as a result of construction of the seawall is forecast.

e) Effects on Groundwater Conditions during Operation

14.8.54 Key aspects of the operational phase of the project that may lead to changes in groundwater conditions include:

- placement of new building foundations, resulting in a change to groundwater flow and a localised rise in groundwater levels; and
- a longer term increase in the incursion of sea water due to the altered groundwater flow regime

14.8.55 The likely maintenance overall of an operational phase groundwater regime that is little changed from the baseline is not expected to result in any significant changes to distribution of any contaminated groundwater.

i) Modification of Baseline Groundwater Regime

14.8.56 A change in the baseline groundwater regime may result in localised rises in groundwater level within the development site due to the placement of what will effectively be impermeable blocks formed by new building foundations. This would be more likely to occur if the same total groundwater flux through the system was maintained, i.e. if the same rainfall recharge to the groundwater system continued. In relation to this it should be noted that the aquifer at Hinkley Point is compartmentalised to the extent that its footprint is virtually coincidental with the Hinkley Point C site, i.e. it is effectively isolated from the Southern Construction Phase Area.

14.8.57 However, effective recharge by rainfall would itself be reduced because of the change in surface cover over the site from open soil and vegetation to a surface with a high proportion of low permeability hardstanding and buildings that will intercept much of the rainfall that previously formed the basis of groundwater recharge. Accordingly, any tendency for a rise in groundwater levels due to loss of aquifer volume through which groundwater flow would be offset, or possibly even reversed, by the reduction in groundwater recharge feeding the system.

14.8.58 The new 'equilibrium' condition for the groundwater system at HPC can be evaluated in general by qualitative and analytical methods. The assessment described below considers in sequence:

- distribution of new structures and changes in surface cover and evaluation of reduction in effective rainfall and groundwater recharge;
- loss of aquifer volume due to sub-water table impermeable structures; and
- analytical assessment of new average groundwater gradients through the reconfigured system using simple 'models' as an augmented analytical tool for sensitivity analysis. This identifies and semi-quantifies any areas that might be subject to groundwater level rise.

14.8.59 The groundwater model that was used to approximate baseline conditions prior to dewatering has been used to assess the potential influence on the natural groundwater regime of those parts of the EPR buildings that would be located beneath the water table. This was carried out by:

- replacing the 'nuclear island' area that was the subject of fixed head abstraction for the dewatering assessment with inactive cells, i.e. making an impermeable block; and
- addressing the reduced infiltration on the remainder of the site (because of increased hardstanding areas and installation of a managed drainage system) by replacing the baseline effective rainfall with an assumed lower value of 25 mm/yr.

14.8.60 The resulting groundwater head distribution indicates that under the aquifer conditions 'modelled' the change in distribution of groundwater heads is minor, generally around 1 m. This is less than the baseline variation due to seasonal/rainfall temporal variation.

14.8.61 Changes in groundwater flow pattern are insignificant except immediately up-gradient of the building foundations where flow diverts to west or east to rejoin the main flow regime.

ii) Modification of Baseline Groundwater Regime on the Aquifer

14.8.62 As set out in the section above, the new impermeable sub-water table structures could cause a very localised rise in groundwater level on their up-gradient side. This change in groundwater level is likely to be around 1 m, which is similar to the changes (seasonal etc) in the natural groundwater regime. While the affected groundwater forms part of a Secondary Aquifer, its sensitivity is assessed as very low since the resource is not used in the Development Site and the effects of the change in levels would not extend beyond the immediate vicinity of the buildings. The localised change would, however, be permanent and irreversible. Overall this effect is therefore assessed as **not significant** with respect to groundwater resources.

iii) Sea Water Incursion

14.8.63 If the baseline groundwater flux through the system is reduced, because of reduced recharge via rainfall, then the equilibrium condition between the 'fresh' groundwater and sea water may be disturbed and tend to allow further sea water incursion to take place.

14.8.64 As described above, the modelling work undertaken indicates that during the operational phase the groundwater regime would be little changed from the baseline. Changes in groundwater gradients and flow rates are not likely to be significantly altered except immediately down-gradient of structures. Those structures close enough to the shoreline and where enhanced sea water incursion into the 'fresh' groundwater might be expected, would themselves prevent incursion by their presence (i.e. deep foundations). It is therefore unlikely that the groundwater flux would be altered to the extent that significant sea water incursion would be facilitated.

14.8.65 Some small-scale, localised incursion might be expected as impermeable structures would replace parts of the permeable aquifer. In this instance, and within the localised areas where structures occurred below the water table, any small-scale incursion would effectively constitute a permanent and irreversible change. In overall terms of groundwater quality, such small-scale change would be highly unlikely to have any discernible effect on wider groundwater conditions and as such this effect is **not considered significant**.

14.9 Potential Measures to Control the Predicted Effects on Groundwater Conditions

a) Introduction

14.9.1 Although it is apparent from the work presented in the previous sections that potential effects of the development on existing groundwater conditions are unlikely to be significant, there is still uncertainty regarding the potential scale and nature of potential change. Further investigations are ongoing and will be reported upon in the Environmental Statement accompanying the DCO application. These investigations will provide data that will enable better definition of the significance of any effects to be determined and confirm the need for appropriate control measures to be put in place.

14.9.2 In the absence of this additional site data it is assumed that, on the basis of the work undertaken to date, that there are two main issues that may require measures to be implemented in order to ensure that the development does not adversely influence groundwater conditions. These are both linked to the dewatering associated with the deep excavation works during construction and are:

- the migration of potentially contaminated groundwater; and
- reduction in baseflow to Holford Stream and alteration of its hydrological characteristics.

14.9.3 The assessment work did not determine any groundwater effects that would require management measures to be implemented during the operational phase of the development.

14.9.4 The objective with regard to the potential for contaminants to be transported via groundwater flow during construction would be to reduce propagation of the dewatering cone(s) of depression and/or reduce potential concentrations of groundwater contaminants to acceptable levels. Should any contaminated groundwater reach the dewatering abstractions then, prior to discharge, the water may need treatment to meet acceptable concentrations/loads in accordance with standard EQS's and in agreement with any thresholds or values set by the Environment Agency for the discharge (see **Chapter 15** on water quality for further information on this).

14.9.5 Should it be determined that there is a significant groundwater component to the baseflow of Holford Stream the main outcome of any management measures would be to minimise the potential for a reduction in baseflow that could result from the dewatering process.

14.9.6 The following sections describe the types of measures that could be implemented if, following further analysis and assessment of additional data, it is considered that the effects listed above are significant. It should be stressed at this point that the information presented here is purely to outline the measures that could be employed and to provide an initial indication of their suitability in the event that such a measure is required.

b) Management/Control Options

14.9.7 The measures required essentially fall into two categories for the construction phase:

- groundwater flow/level management; and
- groundwater quality management.

14.9.8 For groundwater flow management, general options include:

- hydraulic control of groundwater gradients by selected pumping and recharge; and
- engineered control of groundwater gradients by construction of impermeable or semi-permeable barriers.

14.9.9 For groundwater quality management, general options include:

- natural attenuation and associated monitoring;
- prevention of unacceptable migration of contaminated water (either anthropogenic contamination or 'natural' contamination, i.e. seawater) by a) hydraulic control or b) engineered control as above; and
- pump and treat coupled with source removal.

14.9.10 These management measures should, ideally, be integrated as far as possible rather than applied ad hoc to specific locations during the construction phase (i.e. for the duration of the potential effect that requires addressing).

14.10 Options during Construction

a) Hydraulic Control

14.10.1 Hydraulic control involves the focussed reversal of groundwater gradients by creation of recharge mounds to prevent migration of undesirable groundwater to the abstraction (i.e. contaminated groundwater or sea water). Boreholes would need to be put in place in order to receive a proportion of the dewatering abstraction, and be located between the abstraction and the source of potential contamination. Additional monitoring piezometers would be required to verify that the desired outcome was being realised. Recharge boreholes would need to avoid low-lying areas so that there would be sufficient available head for the recharge up-coning. The main advantages of hydraulic control are that:

- **It is a simple technology** - Essentially the requirements are similar to an abstraction wellfield in as much as a series of boreholes are constructed and equipped with delivery pipework and pumps to bring the water from the dewatering abstraction to the recharge field for recharging of the aquifer. Pressurised re-injection is not envisaged – if the permeability is sufficiently low for pressurised re-injection to be required then it would be less likely that the dewatering cone of depression would extend a great distance in the first place.
- **The pumping/recharge regime can be refined during initial design and in real time to maximise effectiveness** - With sufficient monitoring in place the configuration of the abstraction cone of depression and recharge 'ridge' can be managed so that the benefit is focussed where it is needed. Dewatering itself will be managed as far as possible to minimise volumes whilst ensuring that excavations are kept dry.
- **It operates in the same timespan as the (temporary) effect** - Once the excavations and associated buildings are complete, the need for dewatering and the associated potential influence of recharge boreholes also ceases. There is no permanent installation remaining apart from the boreholes themselves (which can be decommissioned and backfilled or kept in use for future pumping/monitoring if required).

14.10.2 The disadvantages of hydraulic control are that:

- **Recirculation of some recharged water may add to overall pumping requirement** - The recharged water will create an uplift cone which, in combination with the cone of depression generated from the abstraction, may result in a steeper gradient to the abstraction and the recirculation of some of the water. Total pumping throughput may therefore increase.
- Given the sea water component of the dewatering abstraction, recharge may in itself result in an increase in the effect, with regard to derogation of groundwater quality and introduction of saline water to Holford Stream - The presence of the deep excavation for the two EPRs close to the shoreline and the associated dewatering to keep the excavations (base at -15 m OD) dry, means that it is likely that sea water will be a significant component of the water entering the excavations via the Lower Lias formations. Although there is no evidence from the baseline data of significant sea water incursion under natural conditions, the imposition of a head difference of 15 m or more between sea level and the excavation base places a significant stress on the groundwater system and generates a steep gradient which could induce sea water incursion.

14.10.3 If the hydraulic control option is considered, it is therefore likely that water of brackish to saline condition (depending on the degree of dilution from other fresher components of the dewatering inflow) would then constitute the water recharged to the aquifer. This would inevitably result in the introduction of poorer quality water to the aquifer than is already present, which could be unacceptable. Moreover, despite the current lack of information on groundwater conditions outside the development site, and the lack as yet of final dewatering programme details, it is also possible that this recharge could drive either saline water or intervening contaminated groundwater in the direction of Holford Stream. Equally, the potential of the measures themselves to have an additional or lead to an exacerbated effect would be unacceptable. On a provisional basis therefore, the hydraulic control option is not favoured.

i) Engineered Control

14.10.4 Engineered control involves the construction of a temporary (ground freezing) or permanent barrier feature ('grout curtain') to reduce or eliminate groundwater movement across it. A ground freezing barrier is impermeable, preventing both flow and, therefore, potential contaminant migration; a grout curtain barrier can either be essentially impermeable or it can be semi-permeable incorporating reactive materials such as e-clays that would also provide a contaminant attenuation function.

14.10.5 It is currently planned to emplace curtain walls on the north, west and east sides of the deep pumping station excavations. The walls will be approximately 1.8 m in thickness and have a permeability in the range 10-8 – 10-10 m/s. Because the model cell size is 10 m, the permeability used for the marginal cells around the excavations is a factor of five less (2 x 10-8 m/s) than the average quoted figure thereby giving the same equivalent effect.

14.10.6 The effect of these walls on the groundwater regime during dewatering is shown in **Figure 14.26** and **Figure 14.27** for Layer 1 after 30 days and 4 years; and in **Figures 14.28** and **Figure 14.29** for layer 2. The change in groundwater flow direction under Hinkley Point A is delayed but still occurs eventually. Pumping rates are reduced to around 3-4 l/s (10.8-14.4 m3/hr).

14.10.7 A model run was also undertaken to simulate the influence of an additional wall running north-south just to the east of EPR1. The modelled location of the various walls is shown on **Figure 14.30**. **Figure 14.31** and **Figure 14.32** indicate that such a barrier would be likely to effectively mitigate any groundwater movement from beneath HPA towards the HPC Development Site.

14.10.8 Grout curtains or curtain walls are commonly used in major construction projects to eliminate significant external groundwater-related effects and/or eliminate unwanted incursions of external groundwater or sea water. The Sizewell B nuclear power station benefited from a complete encircling curtain wall to avoid sea water incursion and avoid groundwater drawdown within adjacent marshland and other structures such as the adjacent Sizewell A nuclear power station. The advantages of engineered control are:

- **Ground freezing** - Frozen ground would provide an impermeable barrier which would maintain groundwater levels at or near 'natural' levels on the side away from the dewatering. This in itself would prevent any significant migration of contaminated groundwater by restricting advective movement. Ground freezing is a temporary condition. When it is no longer required (i.e. following establishment of building foundations and dewatering), the ground would be allowed to thaw and the original groundwater regime would then be restored.
- **Grout curtain** - A grout curtain is a permanent feature requiring little post-construction attention apart from monitoring Once installed, a 'grout curtain' should need no maintenance and so its benefits could extend beyond the construction phase into operation and even into decommissioning and post-closure. Such benefits, in this instance, have not been sought or identified however.

14.10.9 An impermeable/low permeability barrier would maintain groundwater levels at or near 'natural' levels on the side away from the dewatering. This in itself would prevent any significant migration of any potentially contaminated groundwater by restricting advective movement. A semi-permeable barrier will allow some advective flow though it but with the additional benefit of providing some treatment/attenuation for any contaminated groundwater flowing across it.

14.10.10 The disadvantages of engineered control are:

- the material selection, design and emplacement are crucial to the performance of a 'grout curtain'. This especially applies to semi-permeable barriers if contaminant treatment is to be required/included in the design;
- as a continuous engineered linear feature there needs to be access along its whole route to avoid any compromise in its performance;
- the grout curtain barrier is designed and installed to fulfil a specific function which is only temporary. Once the design function is fulfilled the barrier remains in place and may be of limited (or no) further use. This does not apply to the ground freezing option; and
- s grout curtain is a permanent solution to what may only be a temporary problem during dewatering.

ii) Natural Attenuation of Groundwater Contaminants (not seawater)

14.10.11 Natural attenuation relies on any groundwater contaminants being attenuated during migration to concentrations that do not place a constraint on either the groundwater resource itself or the dewatering discharge. Some contaminants attenuate more readily than others, for example the heavier fractions of Diesel Range Organics may physically adhere to pores in the aquifer rock formation once the lighter fractions have volatilised or preferentially separated. On the other hand, ammonium (ion) is relatively conservative and does not attenuate significantly during advective groundwater flow. The advantages of natural attenuation are that it is inexpensive and non-invasive. The disadvantages of natural attenuation are:

- uncertainty over its effectiveness, so other contingency measures may be required anyway; and
- allows for possible limited movement of contamination during the dewatering programme which could be regarded as contrary to groundwater regulations.

iii) Pump and Treat

14.10.12 This would not assume that contaminants reached the dewatering abstraction, but that a separate operation took place focussed on specific areas of contaminated groundwater. The basis of pump and treat is the removal of groundwater contaminants by pumping, either by scavenging off the water table surface in the case of free-phase light hydrocarbons or more frequently the abstraction of (usually much larger volumes) of groundwater containing the contaminant in solution. In either case the pumped water then has to be removed for disposal and/or treated on site to remove the contaminant. The advantages of pump and treat are that it:

- keeps potential groundwater contamination areas isolated from the construction area; and
- provides for additional/alternative hydraulic control.

14.10.13 The disadvantages of pump and treat are that:

- activities may have to take place away from the development site;
- dealing with a problem that, *in situ*, may not be an EDF responsibility (i.e. the source of contamination lies within land held by another landowner);
- need to provide above ground storage and treatment facilities (or major transportation operation); and
- difficult to define an end-point.

iv) Residual Effects

14.10.14 The only significant potential effects relate to the control of the dewatering cone of depression and the influence of this on the movement of potentially contaminated groundwater into the aquifer and baseflow conditions of Holford Stream. Whilst the groundwater conditions outside the development site are uncertain and the dewatering programme details have yet to be finalised, any management in respect of one or more of these effects, if determined significant, will incorporate, as a design objective, measures to ensure that groundwater conditions are maintained within acceptable limits and in compliance with the applicable legislation. On the basis of the available data to date and the assessment work undertaken it is therefore considered that there would be unlikely to be any significant residual effects.

14.11 Construction Phase - Effects on Geological Interests

14.11.1 The Phase 1 (desk studies) and Phase 2 (intrusive) investigations, mapping and surveying have enabled a thorough understanding of the baseline geology to be achieved.

14.11.2 Although some of the construction works, e.g. site levelling for the platforms and tunnelling work, would lead to disruption to and the loss of geological material, these activities are not considered to have any significant impact on intrinsic geological interest. This judgement is based on the following reasons:

- the rocks and geological sequence affected by these site works are not exposed within the development area and therefore are not available for examination and study; and
- the rocks form part of a stratigraphic sequence that subcrops extensively in the wider area.

14.11.3 The value of the geology of the Development Site is therefore effectively confined to the visible outcrops forming the cliff and foreshore platform along the northern boundary of the site. All potential impacts on geological interests therefore relate to the effects of the construction of the proposed nuclear power station on these existing exposures.

a) Loss of Geological Exposure due to Construction of the Sea Wall

14.11.4 The preferred option for the new sea wall is a solid concrete wall founded on bedrock which would be built along a similar alignment to the current coastline and the existing sea wall to the east in front of the A and B stations. Construction would require the rock platform to be cut along the alignment of the structure to install and properly found the toe of the structure. This alignment would set the sea wall slightly back from the existing cliff line which would result in a minor increase in the area of exposed foreshore rock.

14.11.5 The total length of the new sea defence from the western to eastern extremities has been approximated at 760 m and would rise to a crest height of 13.5m above OD. The new wall would completely cover the existing cliff exposures of the Blue Lias along its entire 760m length. As the defence would have a design life of approximately 100 years the impact on the existing cliff exposures and foreshore environment is considered to be permanent. The new defence would not at any point extend into the Blue Anchor to Lilstock geological/geomorphological SSSI. However, the entire cliff section that would be obscured by the sea wall is considered by Natural England to expose a rock sequence of significant value.

14.11.6 The mapping exercise undertaken to determine the stratigraphic extent of the sequence exposed in the cliff section (see **Appendix 14a**) confirmed that there are exposures of the same sequence of geological beds to the west of Hinkley Point. Similarly, there are several examples of rock pavement exposed to the west of Hinkley Point that are similar to those present in front of the HPC development. Where such features exist they are equally accessible to the public as they are at Hinkley Point.

14.11.7 While it is apparent that the current exposures through part of the Blue Lias sequence at Hinkley are of value, it is clear from the work undertaken that no part of the exposed sequence is unique and that other sections on the foreshore and to the west provide expsoure through the same part of the succession. Thus, the loss of the cliff exposures as a result of construction of the seawall would not lead to the loss of any part of the available geological sequence. As such, and in the wider context, while this is essentially a permanent impact, the magnitude of the loss is rated as medium (due to the complete loss of 735m of available exposure) but the value of the sequence is rated as low, due to the fact that no loss of succession would occur. Overall, it is therefore determined that the impact of the works on the geological interest is of **minor adverse** significance.

14.11.8 With regard to the foreshore geomoprhological interest of the area it is important to note that the seawall would not impinge upon the foreshore platform within the designated SSSI to the west. While the construction of the seawall would lead to the loss of part of the upper most section of the foreshore, this largely comprises semi-mobile material (cobbles and pebbles) overlying currently unexposed strata. The direct loss of foreshore environment under the footprint of the seawall is therefore very limited in extent and would not take up any of the existing platform features that occur on the foreshore. Given the above, the value and sensitivity of the foreshore environment from a geomorphological perspective is therefore assessed as 'low' and the overall degree of significance of the geomorphological impact is assessed as **negligible**.

b) Construction of the Temporary Jetty

14.11.9 The temporary jetty for the unloading of construction materials during the construction phase would be constructed immediately to the west of the western end of the sea wall. The jetty would extend a distance of around 500 m from the cliff line into the Bristol Channel along an approximate south-east to north-west axis.

14.11.10 For the approach bridge, steel tubular piles will be installed into the bedrock layer approximately 4 m to 5 m. It is anticipated that either a 'drill and drive' or a 'pre-drilled and socket' technique will be used to install the piles. Those piles located on the foreshore will be installed using land based plant gaining access down a temporary ramp cut into the cliff and across the beach. The piles beyond the foreshore would be installed from a jack-up barge. In order to decommission the jetty the steel tubular piles will be cut off at rock head/bed level and the internal void in-filled with concrete. The construction works for the approach bridge will result in a permanent and direct impact on the foreshore and the cliff section proposed for the temporary ramp. The area of foreshore to be impacted would be restricted to the footprints of each pile and the impact on the cliff limited to the area of the temporary ramp.

14.11.11 The impacts of the temporary jetty on existing rock exposures and the foreshore platforms will be site specific but confined to the footprint of the piles and the route of the temporary ramp on the cliff. Given the relatively small footprint of the piles on the foreshore and the fact that the jetty would be removed following its use during the construction process, the magnitude of the impact is considered to be very low. While the affected exposures and platforms are part of the same overall assemblage of landforms as those within the SSSI to the west, it is apparent that the intrinsic geomorphological interest of the assemblage would not be adversely affected by the loss (temporary) of those areas of the shore platforms under the footprint of the jetty piles. Additionally, the processes that form and maintain these platforms would not be influenced to such a degree that would lead to modification of the platform structures during the operation of the jetty (see Chapter 16 for more detail on the potential hydrodynamic effects of the jetty). Overall, it is therefore concluded that the jetty would have a **negligible** effect on either the interest of the foreshore exposures or the geomorphology of the foreshore platforms and the processes that support that these features.

c) Mitigation Measures

14.11.12 Although it is apparent that a relatively long (760m) stretch of cliff line exposing part of the Blue Lias sequence will be lost due to construction of the sea wall, there are no mitigation measures that can be practically implemented to deal with this loss. The findings of the mapping exercise undertaken following consultation with Natural England have confirmed that there are extensive exposures of the same sequence of geological strata exposed in the cliff section at Hinkley to the west (i.e. within the SSSI). This indicates that, from a scientific perspective, there would be no significant loss of interest as a result of the construction of the seawall and as such no further measures to deal with this loss are suggested.

14.11.13 Similarly there are several examples of the rock pavement exposed within the foreshore environment at Hinkley Point elsewhere to the west. The loss of the small area of platform under the footprint of the jetty piles, particularly given that this loss would effectively be temporary, would therefore not require mitigation.

References

Allot Atkins Mouchel (1988). Hinkley point ‘C’ Power Station Geotechnical Studies, Geotechnical Summary Report – Chapter 7. Report Ref: HPC 1101/57.

AMEC (5th March 2009). Summary of Groundwater Quality (Campaign 2) Radiochemical Analysis Results Report Ref: 15011/TN/00030.

AMEC (27th March 2009). Summary of Groundwater Quality (Campaign 3) Non-Radiochemical Analysis Results Report Ref: 15011/TN/00037.

AMEC (1st April 2009). Summary of Groundwater Quality (Campaign 2) Non-Radiochemical Analysis Results Report Ref: 15011/TN/00027.

AMEC (2nd April 2009). Summary of Groundwater Quality (Campaign 3) Radiochemical Analysis Results Report Ref: 15011/TN/00040.

AMEC (May 2009). Scoping Sheet 8 Earthworks Volumes Optimisation Report.

AMEC (11th May 2009). Summary of Groundwater Quality (Campaign 4) Non-Radiochemical Analysis Results Report Ref: 15011/TN/00053.

AMEC (5thJune 2009). Desk Based Assessment and Synthesis Report for Complementary Lands, Rev A. Report Ref: 15011/TR/00121.

AMEC (23rd June 2009). Preliminary Conceptual Groundwater Model, Rev D. Report Ref: 15011/TR/00092.

AMEC (26th June 2009). Summary of Groundwater Quality (Campaign 4) Non-Radiochemical Analysis Results Report Ref: 15011/TN/00060.

AMEC (15th July 2009). Topography, Geology and Contaminated Soils, Preliminary Environmental Impact Assessment Technical Note. Report Ref: 15011/TR/00128.

Aspinwall & Company (1996). Analysis of Groundwater Conditions at Hinkley Power Station. Report Ref: NU5101B for Nuclear Electric.

British Geological Survey (BGS) 1:50000 BGS Sheet 279; Weston-Super-Mare.

CEGB (August 1987). Proposed Hinkley Point 'C' PWR Power Station - Environmental Statement

Drever, J.I. (1997). The Geochemistry of Natural Waters, Prentice Hall.

EDF (8th May 2009). Onshore geological, geotechnical and hydrogeological interpretive report. Report Ref: EDTGG090141A1PREL.

Environment Agency 1:100,000 scale Groundwater Vulnerability Map (Sheet 42, Somerset Coast).

Foundation and Exploration Services Ltd (April 1989). Hinkley Point 'A' Power Station Somerset - Report on Groundwater Investigation Volume 1.

Foundation Engineering Ltd (1979). Hinkley Point - Factual Report on Site Investigation.

Golder Associates (May 2007). Hinkley Point B Power Station - Establishment of Groundwater Monitoring Network and Allied Investigations.

Golder Associates (August 2007). Groundwater Monitoring at Hinkley Point B Power Station - Monitoring Round 1, July 2007.

Golder Associates (August 2007). Landfill Monitoring at Hinkley Point B Power Station - Monitoring Round 1, July 2007.

Golder Associates (February 2009). Landfill Monitoring at Hinkley Point B Power Station - Monitoring Round 7, December 2008.

Golder Associates (February 2009). Groundwater Monitoring at Hinkley Point B Power Station - Monitoring Round 7, December 2008.

GroundSure (25th June 2008). Environmental Data Report.

Kruseman, G.P. and de Ridder, N.A. (1994). Analysis and Evaluation of Pumping Test Data, International Institute for Land Reclamation and Improvement.

Ordnance Survey (2005) Explorer Map 1:25,000 scale 'Quantock Hills & Bridgwater' Sheet 140.

Rendel Palmer and Tritton (1986). Hinkley Point 'C' Power Station Pre-Application Studies, Volume 2 Geotechnical Report.

Royal Haskoning (January 2009). Geological and Hydrogeological Review Hinkley Point C Power Station.

SERCO (July 2004). Hinkley Point A Power Station Contaminated Land and Geotechnical Investigations. New Build Contaminated Land Investigation.

SERCO (October 2005). Interpretive Report of the Combined Phase 2 and 3 Contaminated Land Investigation at Hinkley Point A Power Station.

SERCO (August 2006). Baseline Survey of an Area of Land to be leased from British Energy at Hinkley Point. Report Ref: SA/Env/ 0878/ Issue 1 for British Nuclear Group Magnox Electric Ltd.

Structural Soils Ltd (February 2009). Factual Report on Ground Investigation: On Shore Investigations for Hinkley Site, Report Ref: 721763.

Whittaker, A and Green, G.W. (1983). Geology of the country around Weston-Super-Mare: Memoir for 1:50000 geological sheet 279, New Series, with parts of sheets 263 and 295. Institute of Geological Sciences. London.