Site Restoration Programme

Winfrith End State:
WINFRITH SITE DESCRIPTION

Project report – ES(18)P196 Issue 1, December 2024

WINFRITH END STATE:
Winfrith Site Description

Published in the United Kingdom by Nuclear Restoration Services, Hinton House, Birchwood Park Avenue, Risley, Warrington, Cheshire WA3 6GR.

Review/Revision Register

Document QA Grade 2

A review/change of this document was carried out as follows:

Version	Date	Amendments / Change
Issue 1	December 2024	Issue for application

Executive Summary

The Winfrith nuclear licensed site in Dorset was opened in 1957 to support the UK's civil nuclear research programme. The site has housed nine research and development reactors during its lifetime, including the prototype high-temperature gas-cooled reactor Dragon and the SGHWR (Steam Generating Heavy Water Reactor), as well as laboratories and support facilities. Decommissioning of the site started in the 1990s, and the last operational reactor shut down in 1995.

On-site disposal of radioactive waste at Dragon and SGHWR has been identified by NRS as the preferred option for the end state of the Winfrith site. In support of this, NRS is developing a suite of documents, including a Site-Wide Environmental Safety Case (SWESC) and Waste Management Plan (WMP), to underpin permit applications to the Environment Agency in accordance with the regulatory Guidance on Requirements for Release from Radioactive Substances Regulation and a Deposit for Recovery Permit.

As part of the disposal permit document suite, the overall objective of this report is to describe the characteristics of the site and collate the information necessary to support development of the SWESC, and radiological and non-radiological assessments. The study region includes the Winfrith site, including facilities operated by Tradebe Inutec Ltd and Scottish & Southern Energy, the region within the site perimeter fence (including some delicensed areas), the Winfrith Sea Discharge Pipeline and associated structures, and elements of the surrounding areas, including Blacknoll Reservoir. Where appropriate the site characteristics are placed in the context of the surrounding region and the rest of the UK.

The site characteristics discussed in this report include the site location and topography, the land use, geology, soils and resource potential in the area around the site and the climate. A summary of the site hydrogeology, described in detail elsewhere in the permit document suite, is provided together with a description of the regional hydrogeology, drainage and flood risk. The report also looks at the potential for the evolution of these characteristics following implementation of the Interim End Point (IEP), the point when decommissioning of the site and operations involving radioactive waste are complete. The evolution of the site from the IEP to the Site Reference State (SRS) is presented through the Stewardship Plan, with land use under planning controls only beyond this point. The interim end state for Winfrith is defined as heathland with public access, with buildings, hard-standing areas and non-native trees removed.

The site is located in close proximity to a National Landscape, and a region of nationally significant heathland in Dorset, near the towns of Wool and Dorchester, and experiences a temperate climate. The bedrock is a mixture of sands and clays overlying chalks, with the Poole, London Clay and Portsdown Chalk Formations being the dominant geological units. The Poole and Portsdown Chalk Formations act as aquifers, whilst the London Clay is an aquitard preventing flow between the two units. Surface water flow on the site is managed by a network of surface drains. The sand and clay formations have been exploited in the region for sand, gravel and Ball Clay extraction, which are used in a number of different industries.

The terrestrial section of the Sea Discharge Pipeline is 9.3 km long and crosses the London Clay and Portsdown Chalk Formation and passes through land owned primarily by the Lulworth Estate and the Ministry of Defence, before reaching the coast at Arish Mell, part of the Jurassic Coast Site of Special Scientific Interest. The Sea Discharge Pipeline then extends a further 3.7 km along the seabed.

The hydrology of the site will change after the removal of buildings and hard-standing areas and the decommissioning of drains on the site, which will all lead to greater infiltration and

groundwater recharge, thereby raising groundwater levels and increasing the risk of flooding on site. The removal of these features will also decrease the magnitude of surface flows on site.

Anthropogenic climate change is expected to lead to changes in temperature and precipitation in the region. Modelling identifies that summers are expected to get warmer and drier, whilst winters are expected to get warmer and wetter, again increasing the risk of flooding on site. Over longer timescales, climate changes will continue to affect the site, with the eventual onset of periglacial conditions resulting in more extensive changes on the site.

Information gaps and uncertainties are identified and are summarised for incorporation into the Uncertainties Management Plan.

Contents

1 Introduction ... 11
1.1 Background ... 11
1.2 Objectives ... 11
1.3 Scope ... 12
1.4 Report Structure ... 17

2 Site Description ... 18
2.1 Location ... 18
2.2 Topography ... 19
2.3 Land Ownership and Protections ... 21
2.4 Habits and Land Use ... 30

3 The Site at the Interim End Point ... 35
3.1 End Point Specification ... 35
3.2 On Site Disposals ... 36
3.2.1 Steam Generating Heavy Water Reactor (SGHWR) ... 36
3.2.2 Dragon Reactor ... 38
3.3 Land Quality Management ... 39
3.4 Other Site Features ... 40
3.4.1 A59 ... 40
3.4.2 Active Liquid Effluent System (ALES) ... 40
3.4.3 Drains ... 40
3.4.4 Landscaping ... 41
3.5 The Winfrith Sea Discharge Pipeline ... 41

4 Soils and Geology ... 45
4.1 Soils ... 45
4.1.1 Soil Type ... 45
4.1.2 Soil Chemistry ... 45
4.1.3 Soil Radiochemistry ... 47
4.2 Superficial Deposits and Bedrock Geology ... 48
4.2.1 Superficial Deposits ... 48
4.2.2 Bedrock Geology ... 50
4.2.3 Transport Properties ... 56
4.3 Resource Potential ... 57
4.3.1 Sand and Gravel ... 57
4.3.2 Ball Clay ... 59
4.3.3 Hydrocarbons ... 59
4.4 Natural Disruptive Events ... 60
4.4.1 Erosion ... 60
4.4.2 Seismic Events ... 61

5 Surface and Groundwater ... 64
5.1 Climate ... 64
5.2 Surface Water Flows ... 67
5.3 Hydrogeology ... 72
5.4 Hydrogeochemistry ... 76
5.4.1 Winfrith site ... 76
5.4.2 Palaeogene Sediments of the Wessex Basin ... 77
5.4.3 Dorset Chalk Aquifer ... 77

5.4.4 UK Groundwater Baseline 77
5.4.5 Nitrate Vulnerable Zones and Drinking Water Safeguard Zones 78
5.5 Water Use 79
5.6 Flood Risk 81

6 Future Evolution of the Site 84
6.1 Hydrology of the Site at the End State 84
6.2 Possible impacts due to Climate Change 87
6.2.1 Next Century 88
6.2.2 Long-term Climate Change 92
6.3 Summary 93

7 References 95

Appendix A Uncertainties, Assumptions and Gaps 102

Appendix B Land quality summary 108

Appendix C Groundwater Borehole Locations 119

1 Table of Figures

Figure 1: Winfrith End State GRR Permit Variation and Deposit for Recovery Application Report Hierarchy. 12

Figure 2: Principal features of the Winfrith Site 14

Figure 3: State of the site proposed for the Interim End Point (Ref. 95). 15

Figure 4: Ordnance Survey map showing the location of the Winfrith nuclear licensed site and the route of the Sea Discharge Pipeline. 16

Figure 5: Digital elevation map of the region surrounding the Winfrith site (route of pipeline shown in red) (modified from Ref. 13). 19

Figure 6: Digital terrain model of the Winfrith site, excluding buildings and stands of vegetation (Ref. 14, 15) 20

Figure 7: View of SGHWR and the Winfrith site from Blacknoll Hill (Ref. 16). 20

Figure 8: Land around the Winfrith Site covered by the 11 February 2019 environmental permit (Ref. 21). 22

Figure 9: The route of the sea pipeline covered by the 11 February 2019 environmental permit (Ref. 21). 23

Figure 10: Land areas covered by the ONR site licence (purple, bounded by the perimeter fence), and designated and de-designated land adjacent to the principal nuclear site following the 11 February 2019 relicensing (Ref. 22). 24

Figure 11: Location of the electricity sub-station in the south-west corner near SGHWR, in yellow, and the associated powerline, as well as the location of some of the old reactor buildings. 25

Figure 12: Land ownership along the route of the pipeline. 26

Figure 13: Location of Winfrith Heath SSSI (hatched) and the River Frome SSSI (hatched with solid colour background) (modified from Ref. 23). 27

Figure 14: Spatial distribution of NVC communities at Winfrith (Ref. 25). 28

Figure 15: The location of Groundwater Dependent Terrestrial Ecosystems (GWDTEs) on the Winfrith site (Ref. 40)....29

Figure 16: Land cover classification in the area around the Winfrith site (Ref. 31). 30

Figure 17: Agricultural land classification of the South West region of England focused on the Winfrith site, adapted from (Ref. 33). 31

Figure 18: The 2019 CEFAS radiological habits survey aquatic survey area, from Portland Bill to St Alban's Head (Ref. 32). 34

Figure 19: Site closure zones for Winfrith 36

Figure 20: The SGHWR reactor building in 2002. 37

Figure 21: Plan showing below-ground regions of the SGHWR reactor building. 37

Figure 22: Outside of the Dragon reactor building. 38

Figure 23: Schematic cross-section of the in-situ below-ground Dragon reactor building and mortuary hole structure (Ref. 7). 39

Figure 24: Image showing inner (active discharges) and outer (foul water discharges with some residual activity) pipeline (Ref. 6). 42

Figure 25: Cumulative fraction of the pipeline burial depth (Ref. 11). 43

Figure 26: Image showing the construction of the pipeline at Lulworth Castle (Ref. 11). 44

Figure 27: Map showing the soil types in the Dorset region (Ref. 55), with an indicative outline of the site location and route of the pipeline. 45

Figure 28: Sample location plan for Winfrith background soil samples (Ref. 100). 46

Figure 29: Map showing the regional superficial geology (Ref. 21). 49

Figure 30: Map showing the regional bedrock geology (Ref. 50). 52

Figure 31: Bedrock and superficial geology of the Winfrith site (Ref. 102). 53

Figure 32: Geological cross-section south-west to north-east across the Winfrith site illustrating both conceptual interpretations for the southern part of the site (Ref. 5). 54

Figure 33: Map showing the offshore geology along the route of the pipeline (Ref. 53). 55

Figure 34: Maps showing the current areas of aggregate resource in bedrock and superficial deposits, and the location of existing (safeguarded) and potential (allocated) sites for sand and gravel, Ball Clay, and oil and gas extraction in the region around the Winfrith site (֍) (Ref. 53). The locations of these areas are not precise (SD-012, SD-014). 58

Figure 35: Location of hydrocarbon wells in the region surrounding the Winfrith site and the pipeline (Ref. 50). 60

Figure 36: Map showing the historical (yellow) and instrumentally recorded (red) earthquakes in the region surrounding the Winfrith site (marked with a blue star) (Ref. 69), Modern instrument recorded earthquakes and historical earthquakes). 63

Figure 37: Decadal January and July average minimum temperatures for E381500 N086900. Year refers to the middle of the decadal span (i.e., 1955 is for the time span 1950-1959 inclusive) (Ref. 94). 66

Figure 38: Decadal January and July average maximum temperatures for E381500 N086900. Year refers to the middle of the decadal span (i.e., 1955 is for the time span 1950-1959 inclusive) (Ref. 94). 66

Figure 39: Decadal January, July and Annual average rainfall values for E381500 N086900. Peak in 2016 January data is due to extreme rainfall in 2014 and 2016. Year refers to the middle of the decadal span (i.e., 1955 is for the time span 1950-1959 inclusive) (Ref. 94). .67

Figure 40: Decadal January and July average hours of sunshine for E381500 N086900. Year refers to the middle of the decadal span (i.e., 1955 is for the time span 1950-1959 inclusive) (Ref. 94). 67

Figure 41: Map of the Winfrith site surface water and rubble drains; outfalls to the River Win are highlighted (Ref. 75). 69

Figure 42: Plan of surface water discharge points on the Winfrith site (Ref. 76). 70

Figure 43: Surface water drainage catchments and water courses on the Winfrith site (Ref. 5). 72

Figure 44: Hydrogeological interpretation of the Winfrith Site (Ref. 5). 74

Figure 45: Hydrogeology in the region around the Winfrith site showing the productivity of the aquifers (Ref. 59), Hydrogeology 1:625,000 scale). 75

Figure 46: Nitrate Vulnerability Map indicating Winfrith's location within a Nitrate Vulnerability Zone (NVZ) protecting Poole Harbour from eutrophication (Ref. 23). 79

Figure 47: Location of groundwater and surface water abstraction sites as reported by the EA in 2020 (abstraction maps no longer publicly available). 80

Figure 48: Groundwater protection zones in the region of the Winfrith site (Ref. 23). 81

Figure 49: Map showing the flood risk of the Winfrith region (Ref. 88). 83

Figure 50: Winfrith End State drainage proposals (Ref. 5). 85

Figure 51: Modelled hydrographs at the IEP of the SGHWR (Ref. 5). 86

Figure 52: Groundwater elevation contours (m AOD) and locations of groundwater emergence (blue diamonds) at the IEP assuming the highest modelled groundwater levels (Ref. 5). 87

Figure 53: Median extreme summer air temperature UKCP18 projections for each emissions scenario for the grid square 387500, 87500 (Ref. 92). 89

Figure 54: Median seasonal precipitation anomaly for UKCP18 projections for the grid square 387500, 87500 (Ref. 91). The period 1981-2000 is adopted as the baseline. 89

Figure 55: Modelled hydrographs for the 2080s at the SGHWR for two recharge scenarios – CCE (afixq) and RWC (afixh) (Ref. 5). 91

Figure 56: Groundwater elevation contours (m AOD) and locations of groundwater emergence (blue diamonds) for the highest modelled groundwater levels of the CCE simulation (May 2093). 91

2

Table of Tables

Table 1: Dimensions, materials and construction specifics of the pipeline, including normal conditions of the inner and outer pipes and notable exceptions to these values (Ref. 11). ..43

Table 2: Soil chemical concentrations for samples on the Winfrith site (Ref. 55) and rural soil concentrations (Ref. 57). 46

Table 3: Soil radiological concentrations for samples from the Winfrith site (Ref. 55) compared to the EPR23 exclusion levels (Ref. 50). 47

Table 4: The superficial and bedrock geology in the region of the Winfrith site in order of increasing depth (Ref. 5). 48

Table 5: Particle size distributions of selected bedrock and superficial sand and gravel deposits (Ref. 50). 51

Table 6: Transport properties of the River Terrace Deposits and the Poole Formation on the Winfrith site (Ref. 53). 56

Table 7: UKCP18 climate projections for E381500 N086900, data adapted from (Ref. 94). Long-term averages of maximum and minimum temperature, and rainfall, are taken from 1919–2020. Recent averages are taken over the period 2015–2020. 65

Table 8: Concentrations of major ions in the groundwater of selected boreholes on or near the site (Ref. 5). 76

Table 9: Ranges of values for selected parameters and analytes measured at the Winfrith site (Ref. 5), the Palaeogene sediments of the Wessex Basin (Ref. 82), the Dorset Chalk aquifer (Ref. 83) and the UK groundwater baseline values (Ref. 84). 78

Table 10: Classification scheme used to describe climate states. Adapted from (Ref. 101, 102). 92

Glossary and Acronyms

AEP	Annual Exceedance Probability
ALES	Active Liquid Effluent System
AOD	Above Ordnance Datum
APC	Area of Potential Concern
BGS	British Geological Survey
CEFAS	Centre for Environment, Fisheries and Aquaculture Science
CEH	Centre for Ecology and Hydrology
CCE	Cautious, central estimate
Defra	Department of Food and Rural Affairs
DGBP	Dorset Green Business Park
DWS	Drinking Water Standards
EA	Environment Agency
EAST	External Active Sludge Tanks
EPR23	Environmental Permitting Regulations 2016 (as amended)
ESC	Environmental Safety Case - A documented set of claims, made by the developer or operator of a disposal facility to demonstrate achievement of the required standard of environmental safety (also see SWESC)
GRR	Guidance on Requirements for Release from Radioactive Substances Regulation
GWDTE	Groundwater Dependent Terrestrial Ecosystem
HLW	High-Level Waste
Human intrusion	Any human action that unintentionally disturbs radioactive substances, or that impairs a barrier or measure providing an environmental safety function, after the release from radioactive substances regulation
HCA	Homes and Communities Agency
IEP	Interim End Point - the point in time at which the Winfrith IES is achieved
IES	Interim End State – the condition of the Winfrith site (or part thereof), following all physical decommissioning and clean-up activities required for the next planned use of the site (or part thereof)
ILW	Intermediate-Level Waste
LLW	Low-Level Waste
LOD	Level of Detection
m agl / bgl	metres above / below ground level
M_L	Local Magnitude (commonly referred to as Richter Magnitude)

MCZ	Marine Conservation Zone
MoD	Ministry of Defence
NBC	Normal Background Concentrations
NDA	Nuclear Decommissioning Authority
NIA65	Nuclear Installations Act 1965 (as amended)
NVZ	Nitrate Vulnerability Zone
OECD	Organisation of Economic Co-operation and Development
ONR	Office for Nuclear Regulation
ONS	Office for National Statistics
PIE	Post-Irradiation Examination
RCP	Representative Concentration Pathways
RSR	Radioactive Substances Regulation
RSRL	Research Sites Restoration Ltd
RWC	Reasonable worst case
SAC	Special Area of Conservation
SDADCAG	South Devon and Dorset Coastal Authorities Group
SGHWR	Steam Generating Heavy Water Reactor
SLC	Site Licence Company
SMP	Shoreline Management Plan
SPA	Special Protection Area
SSSI	Site of Special Scientific Interest
SWESC	Site-Wide Environmental Safety Case – a documented set of claims, made by the operator of a nuclear site, to demonstrate achievement by the site as a whole of the required standard of environmental safety. Where relevant, the SWESC includes the environmental safety case for any on-site disposal facility. The SWESC also takes account of contributions to the combined impact on representative persons from adjacent nuclear sites, and from areas of contamination and previously permitted disposals outside the site.
TCE	Trichloroethene
UKCP18	The UK future climate projections for land and marine regions as well as observed (past) climate data for the UK.
UNESCO	United Nations Educational, Scientific and Cultural Organization
VOC	Volatile Organic Compounds
WHO	World Health Organisation
WMP	Waste Management Plan – a documented plan, prepared by the operator of a nuclear site, which provides a comprehensive description of the current intent for dealing with all radioactive substances on or adjacent to the site and demonstrates how waste management has been optimised.

WSDP	Winfrith Sea Discharge Pipeline
ZEBRA	Zero Energy Breeder Reactor Assembly facility

1 Introduction

1.1 Background

The Winfrith nuclear site, located in Dorset, is a former nuclear power research and development site, which housed research and prototype reactors as well as laboratories. The site included nine experimental reactors in total, each with a unique design, with construction commencing in 1957 and the last operational reactor shut down in 1995 (Ref. 1). The site, owned by the Nuclear Decommissioning Authority (NDA) and operated by Nuclear Restoration Services Limited (NRS), is currently being decommissioned.

Activities involving radioactive substances at the Winfrith site are regulated by the Environment Agency (EA) under the Environmental Permitting (England and Wales) Regulations 2016 (EPR23) (as amended). Radioactive Substances Regulation[1] (RSR) includes the regulation of the disposal of radioactive waste (solid, liquid or gaseous). Permitted sites can only be released from RSR once site activities and disposals of radioactive waste on or from the site have ceased and any wastes or contaminated ground remaining on the site are authorised. Regulatory guidance was published in July 2018 in the Management of radioactive waste from decommissioning of nuclear sites: Guidance on Requirements for Release from Radioactive Substances Regulation (referred to here as the GRR) (Ref. 2).

The GRR requires operators to assess different options for the disposal of radioactive waste arising from decommissioning, including on-site disposal options. On-site disposal of radioactive waste has been defined as the preferred and optimised approach for managing some of the remaining wastes at Winfrith. A suite of documents, consisting of a Site-Wide Environmental Safety Case (SWESC) and a series of underpinning topic reports (Figure 1), are being produced to support the permit application to allow on-site management (disposal in-situ and for a purpose) under the GRR.

1.2 Objectives

The overall objective of this report is to describe the characteristics of the site and collate the information necessary to support development of the SWESC, and radiological and non-radiological assessments that demonstrate the overall safety of the proposals. This report is one of the Tier 2 topic reports required to support the disposal permit application (Figure 1). This report will also be a key supporting reference in relation to the application for planning permission to undertake operations.

---

1 Radioactive substances regulation is a generic term used by the environment agencies to cover the different regulations in force in the four different countries of the United Kingdom.

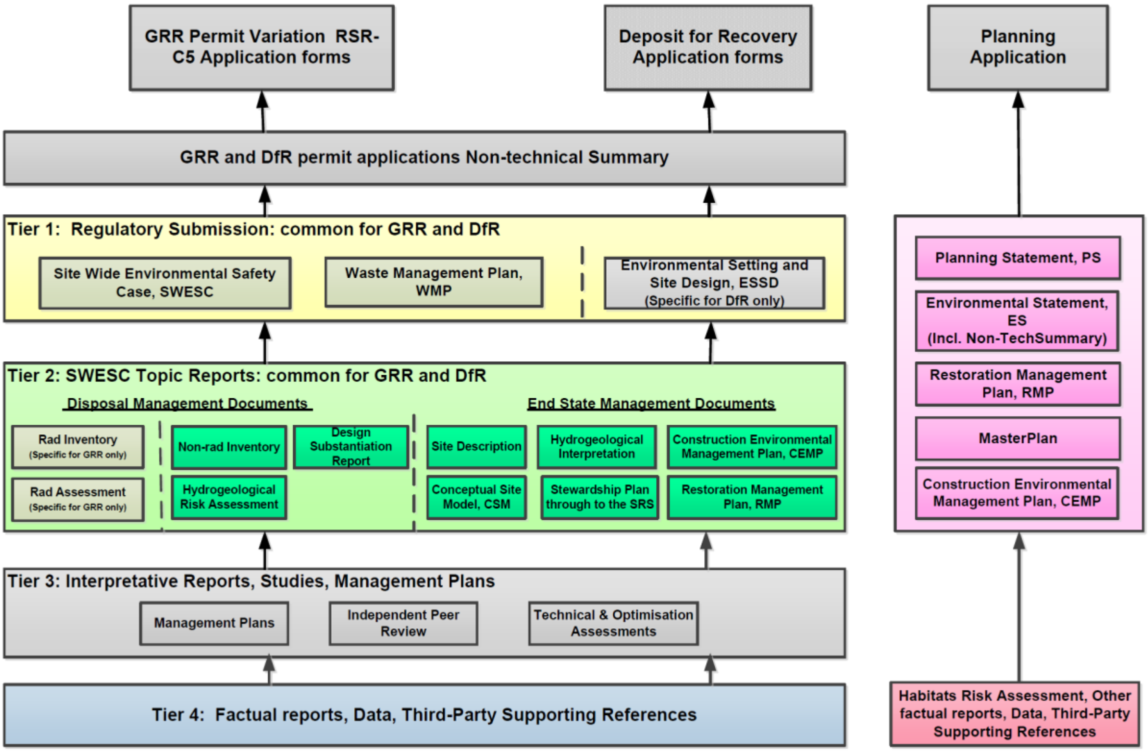


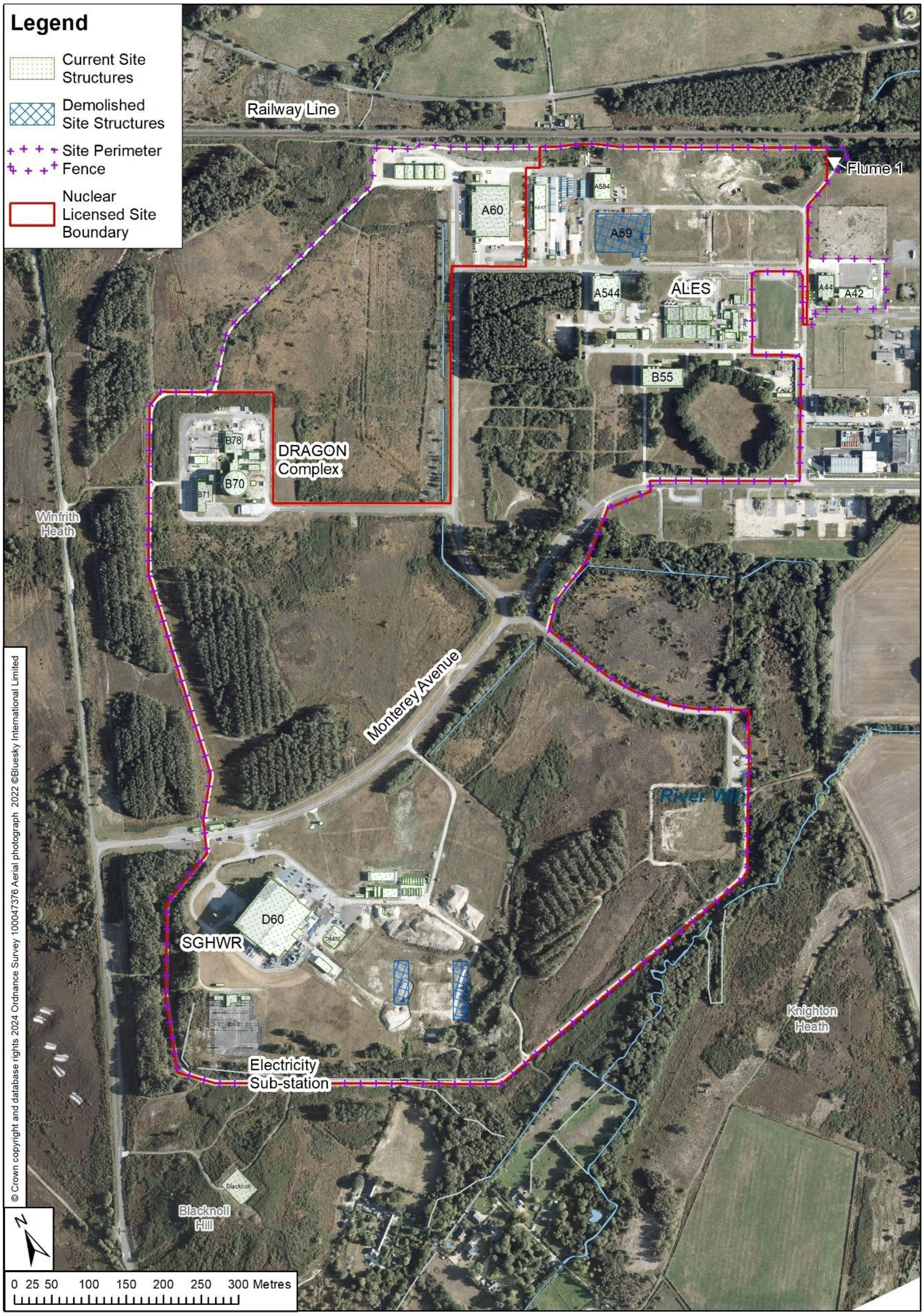
Figure 1: Winfrith End State GRR Permit Variation, Deposit for Recovery, and Planning Permission Application Reports Hierarchy.

1.3 Scope

To support development of the SWESC and safety assessments, this site description includes the current nuclear licensed site and some of the surrounding area where there are potential exposures of people and the environment to hazards on the site. The study region includes the Winfrith nuclear licensed site, including the neighbouring Tradebe Inutec Ltd site[2] and Scottish & Southern Energy (SSE) compound, the region within the site perimeter fence (including some delicensed areas), the Winfrith Sea Discharge Pipeline (pipeline) and associated structures, and elements of the surrounding areas including Blacknoll Reservoir. Where appropriate, the site characteristics are placed in the context of the surrounding region and the rest of the UK.

[2] Not that TradeBe Inutec own a neighbouring nuclear licenced site. They are included in this description as the GRR requires consideration of neighbouring sites in assessments.

The principal features of the site and its immediate surroundings are shown in Figure 2



(current state of the site) and Figure 3 (state of the site proposed for the Interim End Point

(IEP), the point when decommissioning of the site and operations involving radioactive waste are complete). The overall area considered, including the route of the pipeline, is shown in Figure 4.

Requirement R8 of the GRR states: *“Operators should carry out a programme of site characterisation and monitoring to provide information needed to support the [Waste Management Plan] WMP and SWESC. The programme shall include appropriate validation monitoring to provide technical confirmation that progress towards the site reference state is as expected or to validate that the site reference state has been achieved*.” (Ref. 2).

Requirement R8 also stipulates that site characterisation and monitoring need to establish in sufficient detail (Ref. 2):

i. The geological properties of the site, including the lithology, the stratigraphy, the geochemistry and the local and regional hydrogeology.
ii. The potential for, and effects of, dynamic geological processes that may be significant to the SWESC.
iii. The resource potential of the area under and near the site so as to assess the extent to which the site and its surroundings might in future be disturbed through exploitation of the resources.
iv. The nature, magnitude and distribution of the radiological hazards remaining on or adjacent to a site.
v. The nature, magnitude and distribution of any non-radiological hazards associated with, or potentially interacting with, the radiological hazards.
vi. Past and present rates of movement and diffusion of these hazards, if for example transported by groundwater, so that extrapolations can be made into the future.
vii. Uncertainties in each of the above.

This report aims to provide sufficient information on most of these topics to show compliance with Requirement R8, but some topics are reported elsewhere.

Radiological and non-radiological hazards currently on the Winfrith site and that may potentially remain at the End State are detailed in the inventory reports supporting the WMP and SWESC. Therefore, topics *relating to radiological and non-radiological hazards (iv and v)* above are excluded from the scope of this report and are reported separately (Ref. 3, 4). Similarly, the potential rates of movement of these hazards under different conditions will be described in the corresponding assessment reports and discussion of contaminant transport (topic *vi)* is therefore also excluded from the scope of this report but are reported separately (Ref. 5, 6, 7). Information is, however, provided on the potential future evolution of the site, including responses to climate change, which will be used in the assessments.

The hydrogeology of the Winfrith site is discussed in detail in the Hydrogeological Interpretation report (Ref. 5); consequently, the local hydrogeology and aspects of the natural geochemistry are only briefly discussed in this report. Relevant hydrogeological information beyond the Winfrith site boundary (e.g., relevant for the Sea Discharge Pipeline) is also presented.

Potential radiological impacts in the period prior to the IEP will be assessed as part of the decommissioning plans for the Winfrith site and summarised in the SWESC. Details of decommissioning activities and any other information required exclusively for assessments of the period prior to the IEP are outside the scope of this report.

Information presented in this report is provided at an appropriate level of detail to support assessments of the impact of on-site disposals in the period after the IEP, which in turn will support the SWESC. Any additional information gathered up until the time of release from RSR will be included in updates to this report, the SWESC and associated documents.

Gaps in the available information on site characteristics are noted within this report and a summary of the uncertainties associated with the site description is included in Appendix C for use in the Uncertainties Management Plan (Ref. 8). These uncertainties are noted within the report using an identifier of the form “SD-000”, which is an index to an entry in the Uncertainties, Assumptions and Gaps table in Appendix C.

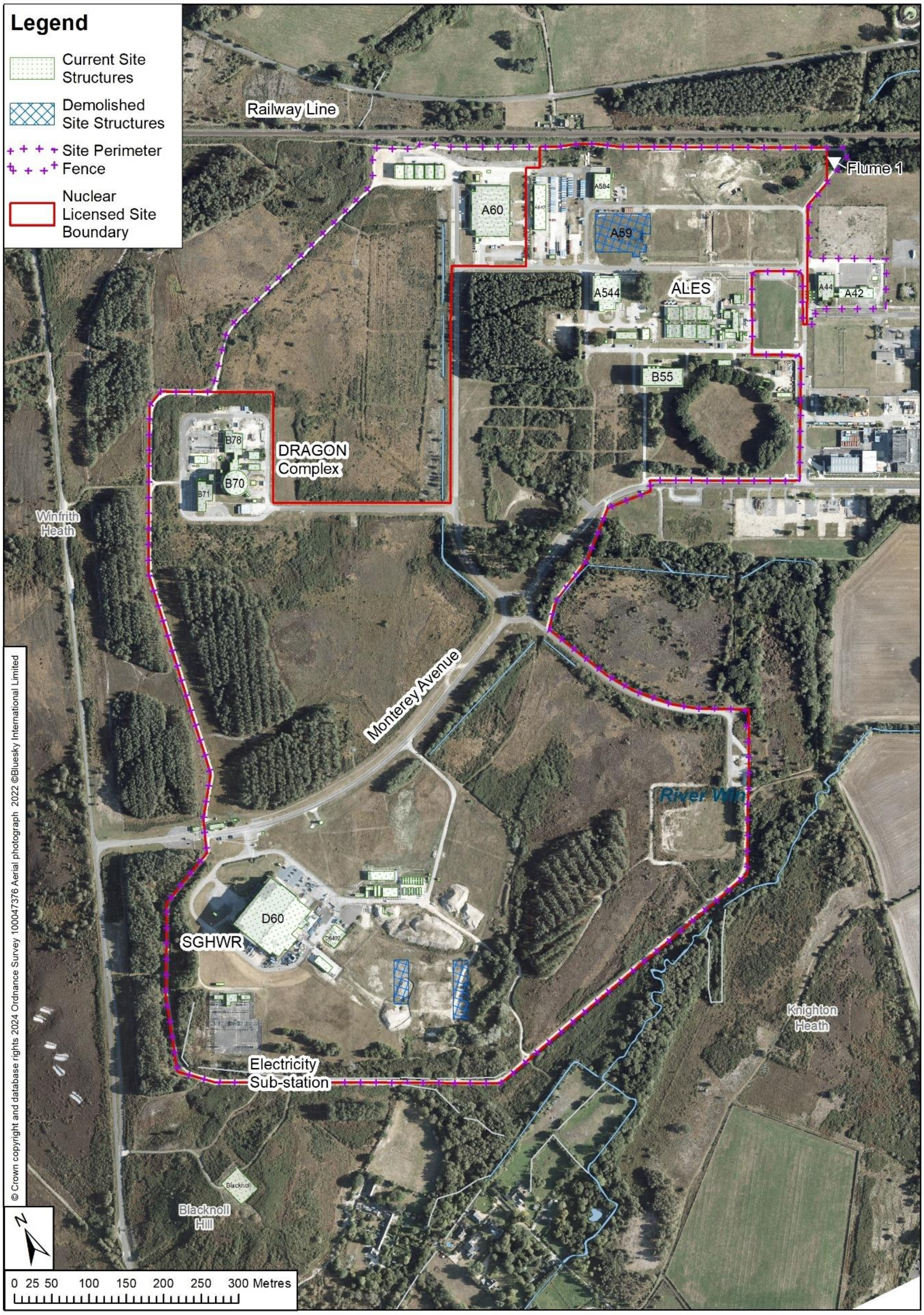


Figure 2: Principal features of the Winfrith Site

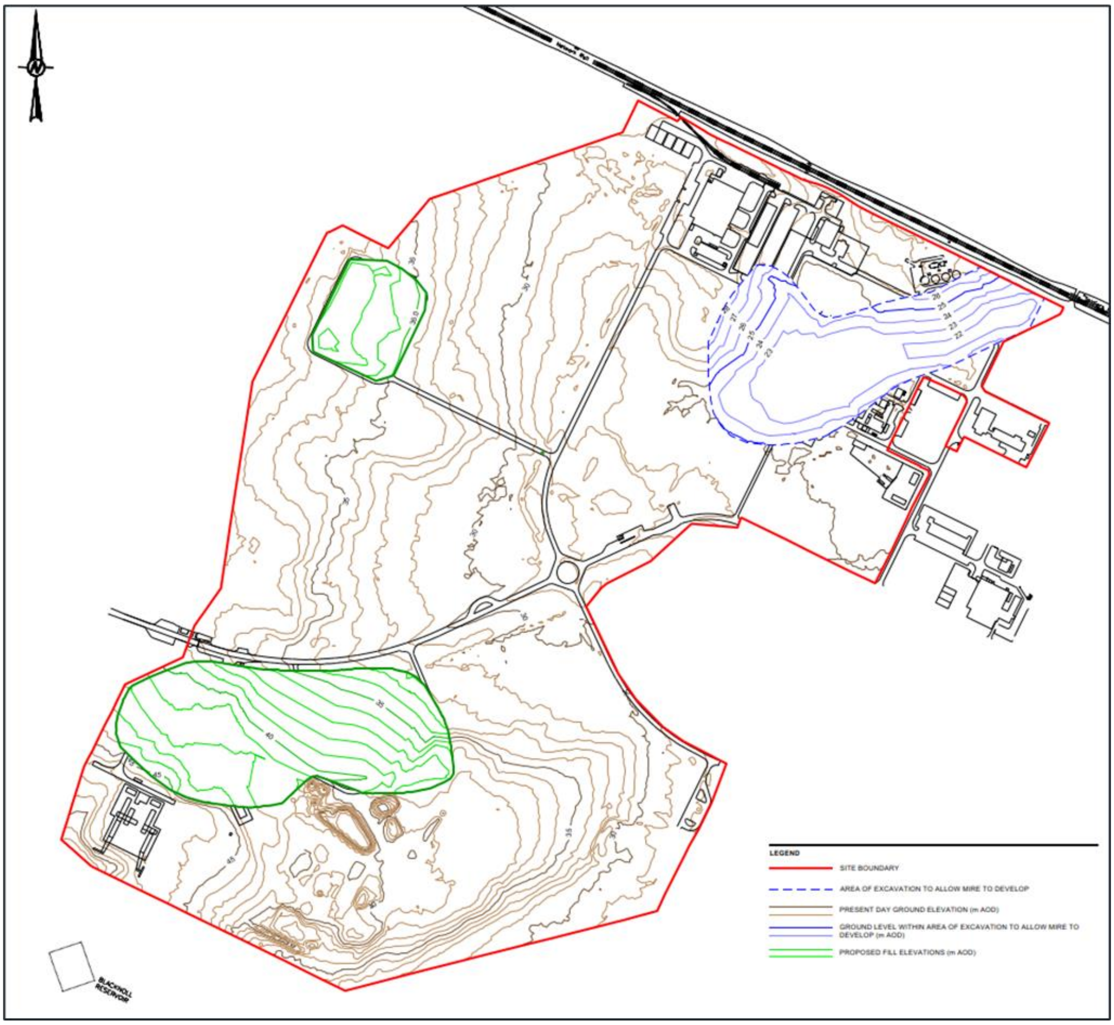


Figure 3: State of the site proposed for the Interim End Point (Ref. 95).

Figure 4: Ordnance Survey map showing the location of the Winfrith nuclear licensed site and the route of the Sea Discharge Pipeline.

1.4 Report Structure

The remainder of this report is structured as follows:

- Section 2 describes the location, topography, climate, land use and ownership of the site and the surrounding area.
- Section 3 describes the physical characteristics of the site at the IEP, including the voids beneath the reactor buildings, areas of contaminated ground and the Sea Discharge Pipeline.
- Section 4 describes the soils (including background radiation and contamination), geology, the resource potential of the surrounding region and the potential for disruptive events (erosion and earthquakes).
- Section 5 describes the hydrogeology, hydro-geochemistry, natural and managed surface flows, groundwater use and flood risk.
- Section 6 describes the potential evolution of the site following the IEP. This includes water management and flood risk, as well as climate change.
- Appendix C contains a summary table of the data gaps and uncertainties associated with the site description.
- Appendix B presents a list of land quality understanding of the Winfrith site. These areas will undergo further assessment and remedial works where required to ensure that the land at the site is in a satisfactory condition at the interim end point.
- Appendix C presents a map denoting the location of groundwater boreholes.

2 Site Description

This section describes the location of the Winfrith site (Section 2.1), the topography of the site and its surroundings (Section 2.2), current land ownership and protections in the area (Section 2.3), and the local land use and habits (Section 2.4).

2.1 Location

Winfrith is a site licensed for specific activities involving nuclear materials by the Office for Nuclear Regulation (ONR) under the Nuclear Installations Act 1965 (as amended). The site is also Permitted for listed activities under the Schedule 23 Radioactive Substances Activities under the Environmental Permitting Regulations (EPR). The site is near the south coast of Dorset, two miles west of the town of Wool and ten miles east of Dorchester, the approximate centre of the site is located at Easting 381328, Northing 086878 (Figure 4).

Formerly, the site encompassed the whole of this estate, but the eastern end has been decommissioned and now forms the Dorset Innovation Park[3] and the headquarters of the Dorset Police. A further adjoining area to the east of the site is owned by Tradebe Inutec Ltd following a sale of the land and licence transfer in 2019 (Ref. 9) and forms a separate but adjoining nuclear licenced site.

A perimeter fence runs around the Winfrith site, enclosing an area of 87 ha (purple line on Figure 2). The area of the nuclear licensed site is 71 ha (red line where it deviates from the perimeter fence on Figure 2). Some areas within the perimeter fence are outside the nuclear site licence.

Entry onto the Winfrith site is permitted to employees, their visitors and contractors who hold a properly authorised site pass. Access to the security-fenced site is via the main gate (Gate No. 1). Security and access is maintained in line with the existing requirements as set out in the Environmental Permit and nuclear site licence.

A full site pass will only be issued to persons who have been appropriately security cleared and have attended the site induction training. Visitor passes will only be issued if sponsored by an authorised employee who holds a full site pass and is resident on the NRS Winfrith site. Failure to provide suitable notification of a visit could delay access to the site.

Outside of the perimeter fence, the main south west London–Weymouth railway line runs along the northern edge of the site, with a railway siding by the perimeter fence. The River Frome flows to the north of the railway, while the River Win (a tributary of the Frome) runs close to the southern boundary of the site. A public bridleway follows the Western edge of the site perimeter from Blacknoll Hill in the South around to the railway sidings to the north.

This report also considers two facilities off the Winfrith site:

- The Blacknoll Reservoir, a concrete structure with a capacity of about 4,700m^3 situated to the southwest of the site, which was built to ensure adequate supplies of reactor process and emergency water (Ref. 10, 37). The reservoir was emptied in the early 2000’s and is awaiting decommissioning.
- The Winfrith Sea Discharge Pipeline (hereafter referred to as “the pipeline”), which consists of a pair of pipes, each containing an inner and outer pipe discharging effluent from the site to the sea. The outer pipe discharges foul water, with some residual activity, and the inner pipe discharges active effluent from the Active Liquid Effluent System

---

[3] This area has been re-named several times since release from the nuclear licensed site and parts of it have been known as the Winfrith Technology Park, Dorset Green Technology Park and the Winfrith Innovation Centre. For clarity the term “Dorset Innovation Park” has been used in this report.

(ALES). The pipeline extends for 9.3 km from the site on land, before extending 3.7 km out along the seabed (Ref. 11). The pipeline remains in use at current.

2.2 Topography

A digital elevation map (Figure 5) shows that the site is located within the low-lying valley of the River Frome. Between the site and the coastline, the land rises up to the Purbeck Ridge, a series of chalk downs (Section 4.2.2). The highest points along the ridge are the Ridgeway Hill (199 m) and Bindon Hill (168 m).

The Winfrith site itself is relatively low-lying, rising from between 20 m Above Ordnance Datum (AOD) in the north-east to about 50 m AOD in the south-west (Figure 6). Just south of the site the ground rises more steeply to the summit of Blacknoll Hill at 62 m AOD (Figure 7). Blacknoll Hill is a natural ridge with a series of six bowl-shaped Bronze Age “barrow” cemeteries (Ref. 12). These are mounds of earth, sand and turf, each surrounded by a ditch that is now largely infilled. The barrows are 11-22 m in diameter and between about 0.7-1.5 m high (Ref. 12).

Along the route of the pipeline the topography varies, generally increasing from an elevation of 25 m AOD at the start at the ALES pumphouse to an elevation of 90 m AOD at its highest point at the Break Pressure (Figure 4). From the Break Pressure Tanks, the topographic elevation generally decreases seawards towards Arish Mell, with the pipeline following a valley.

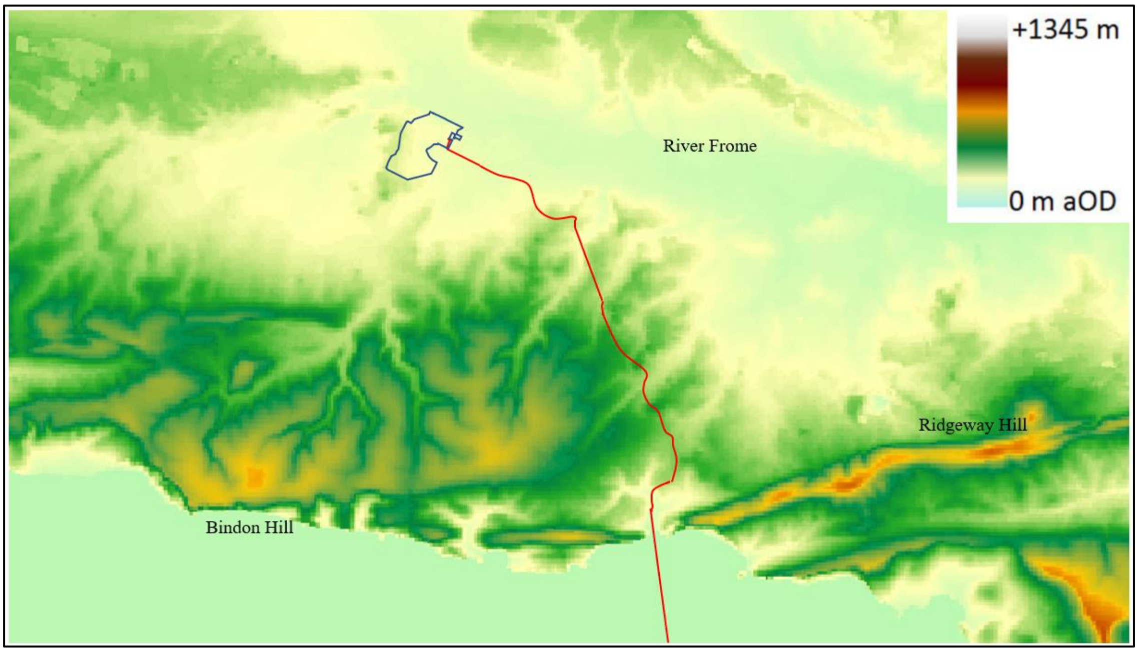


Figure 5: Digital elevation map of the region surrounding the Winfrith site (route of pipeline shown in red) (modified from Ref. 13).

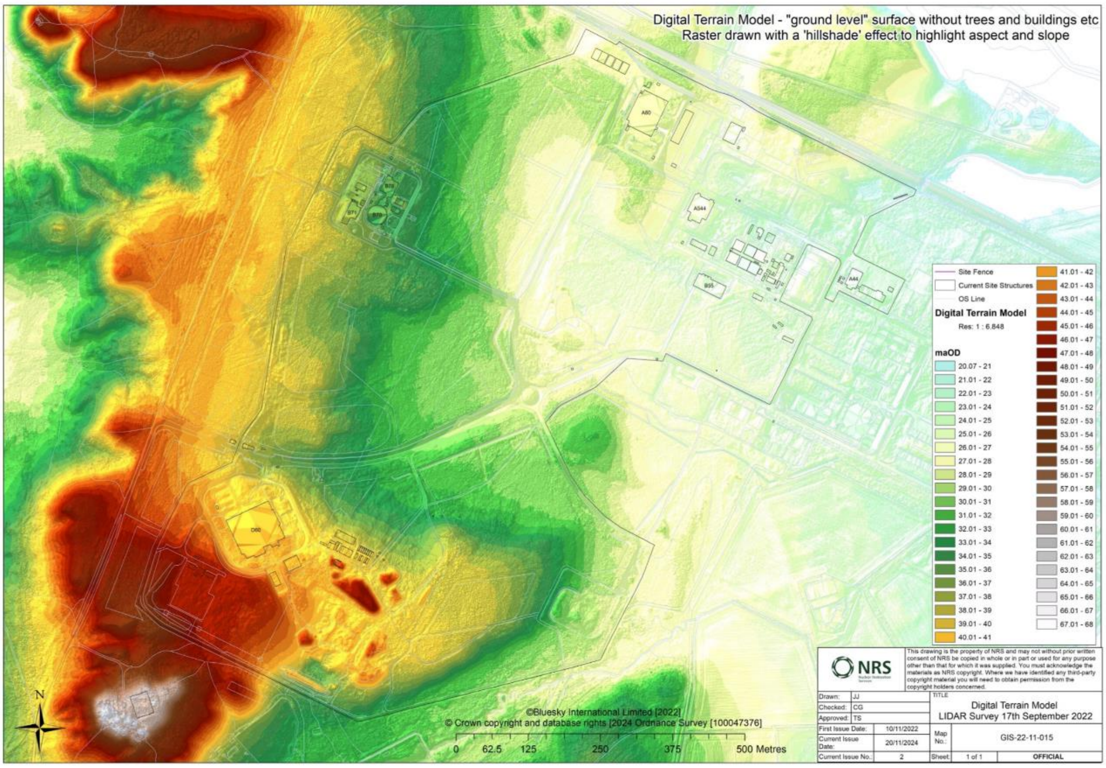


Figure 6: Digital terrain model of the Winfrith site, excluding buildings and stands of vegetation (Ref. 14,15)

Figure 7: View of SGHWR and the Winfrith site from Blacknoll Hill (Ref. 16).

2.3 Land Ownership and Protections

Land ownership at Winfrith, and the areas of the site covered by the Environmental Permit and the Nuclear Site Licence, has changed during decommissioning of the site. The land currently covered by the EA permit is shown in Figure 8 and Figure 9, and the area of the nuclear licensed site is shown in Figure 10.

The eastern end of the site that has been decommissioned and delicenced and now forms the Dorset Innovation Park[3], with areas owned by Dorset Council and Dorset Police (Ref. 17). Several technology companies operate on the Innovation Park and there are plans for further development.

Tradebe Inutec occupies three buildings which were formally part of the Winfrith site (B44, B45 and B48) and undertook radioactive waste management services under the Winfrith environmental permit and nuclear site licence. In 2019 the freehold for these areas of the site was sold by the NDA to Inutec Ltd (now Tradebe Inutec Ltd) and the environmental permit for these areas was subsequently transferred (Ref. 18). In addition, at the time of the sale, the Winfrith nuclear site was relicensed to exclude the transferred plots concurrently with a new nuclear site licence being granted to Inutec Ltd for the same area (Ref. 19). Tradebe Inutec Ltd continues to provide radioactive waste management services as a separate but adjoining nuclear licensed and permitted site.

An electricity sub-station that previously received electricity produced by SGHWR is located in the south-west corner of the Winfrith site, and high voltage overhead power lines from this head north across the site. Scottish & Southern Electricity own the power lines and the sub-station; the National Grid will continue to operate these after the IEP. The locations of these are shown in Figure 11.

The majority of the land between the Winfrith site and the coast along the route of the pipeline is owned by Dorset Council, the Weld Estate and the Ministry of Defence (Figure 12). The pipeline extends onto the seabed but remains within the 12 nautical miles owned by the Crown Estate (Ref. 20).

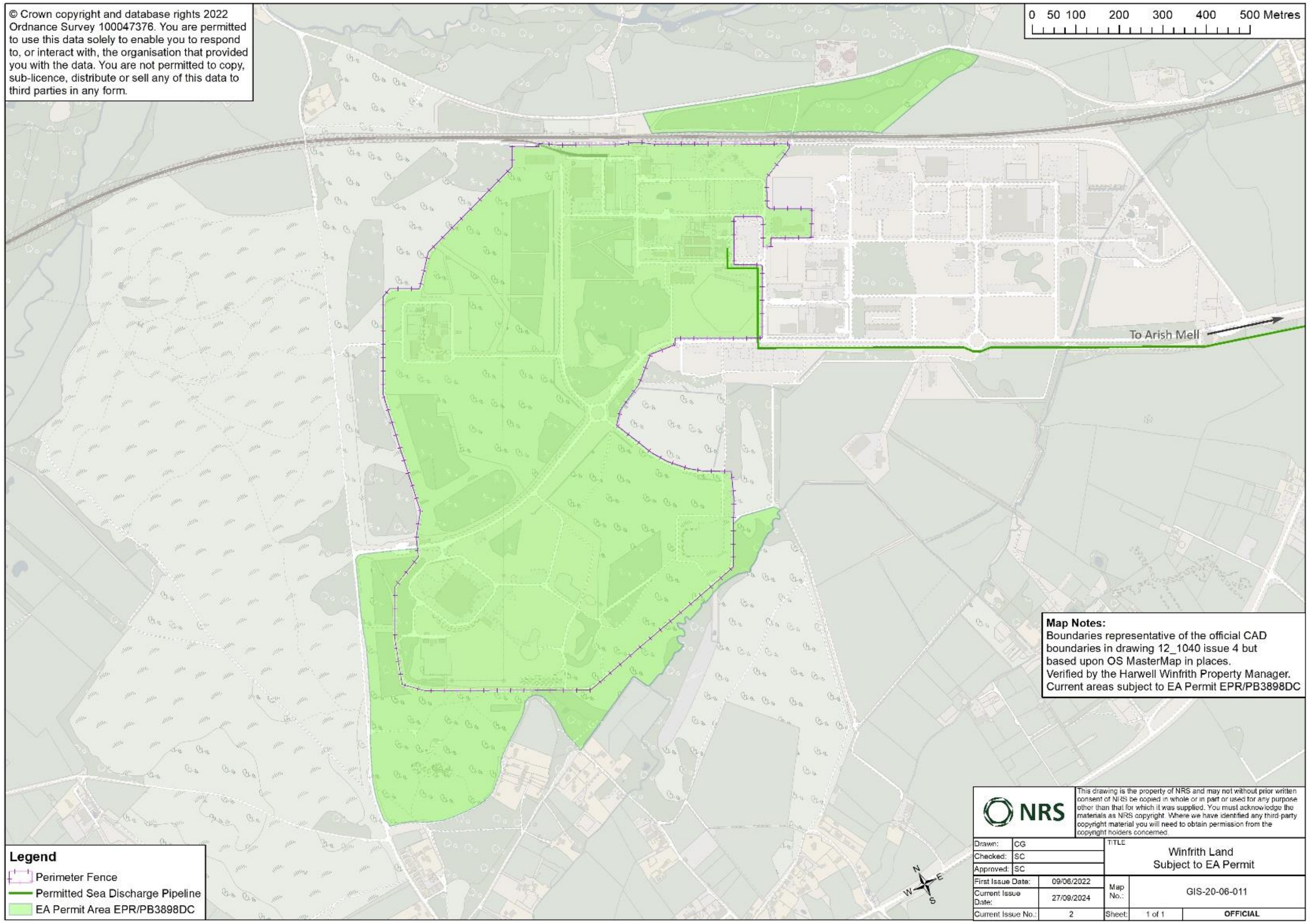


Figure 8: Land around the Winfrith Site covered by the 11 February 2019 environmental permit (Ref. 21).

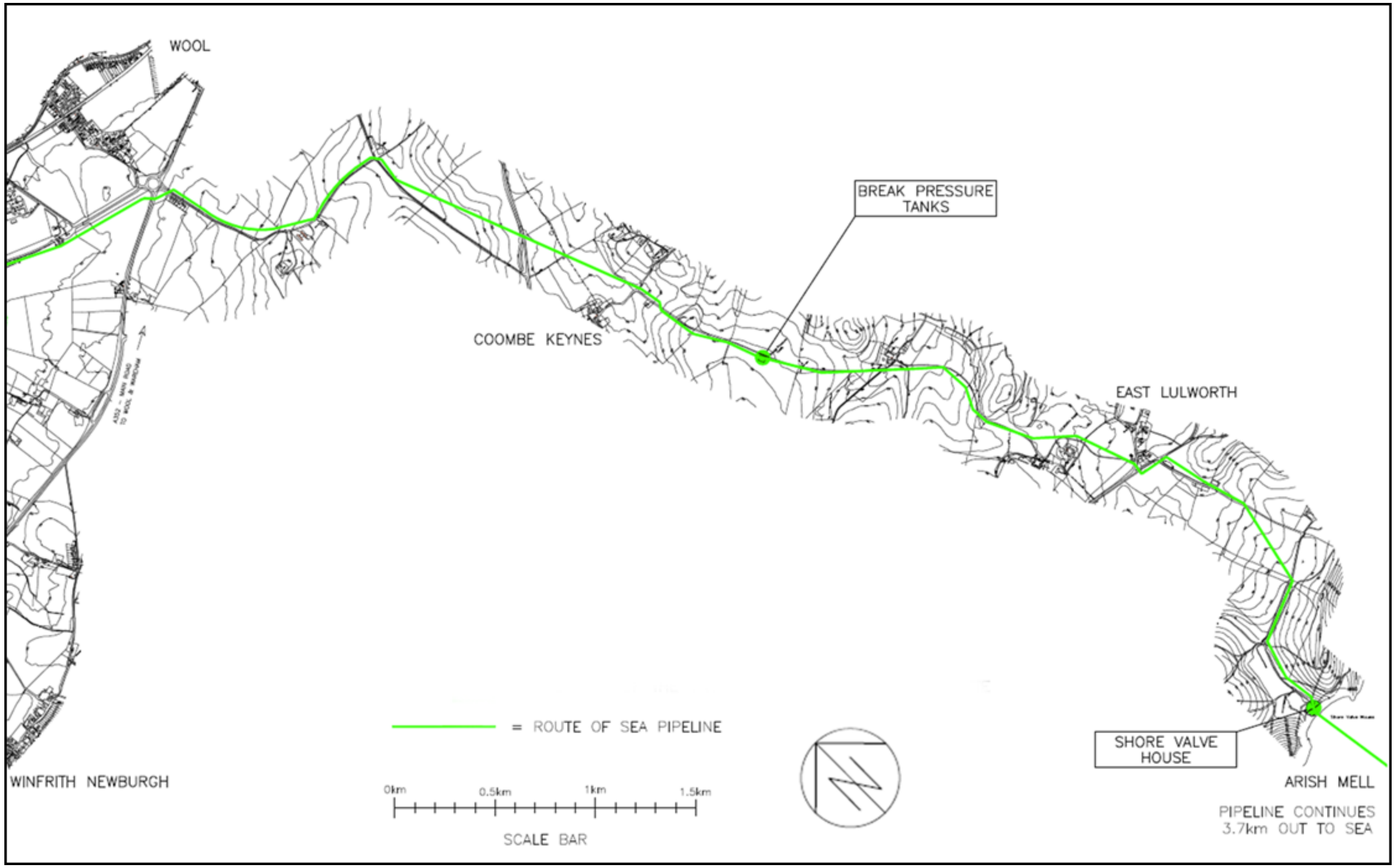


Figure 9: The route of the sea pipeline covered by the 11 February 2019 environmental permit (Ref. 21).

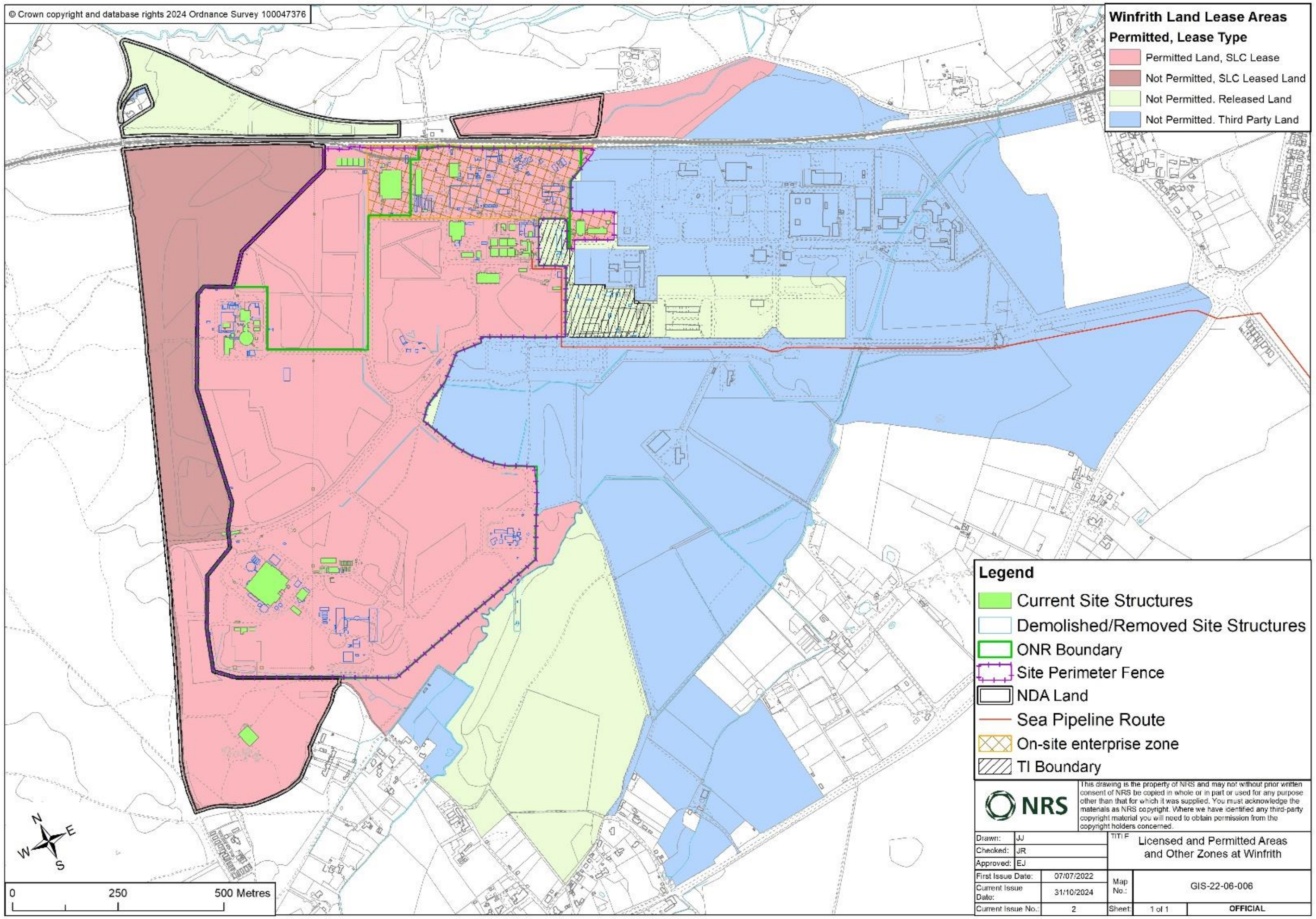


Figure 10: Land areas covered by the ONR site licence (purple, bounded by the perimeter fence), and designated and de-designated land adjacent to the principal nuclear site following the 11 February 2019 relicensing (Ref. 22).

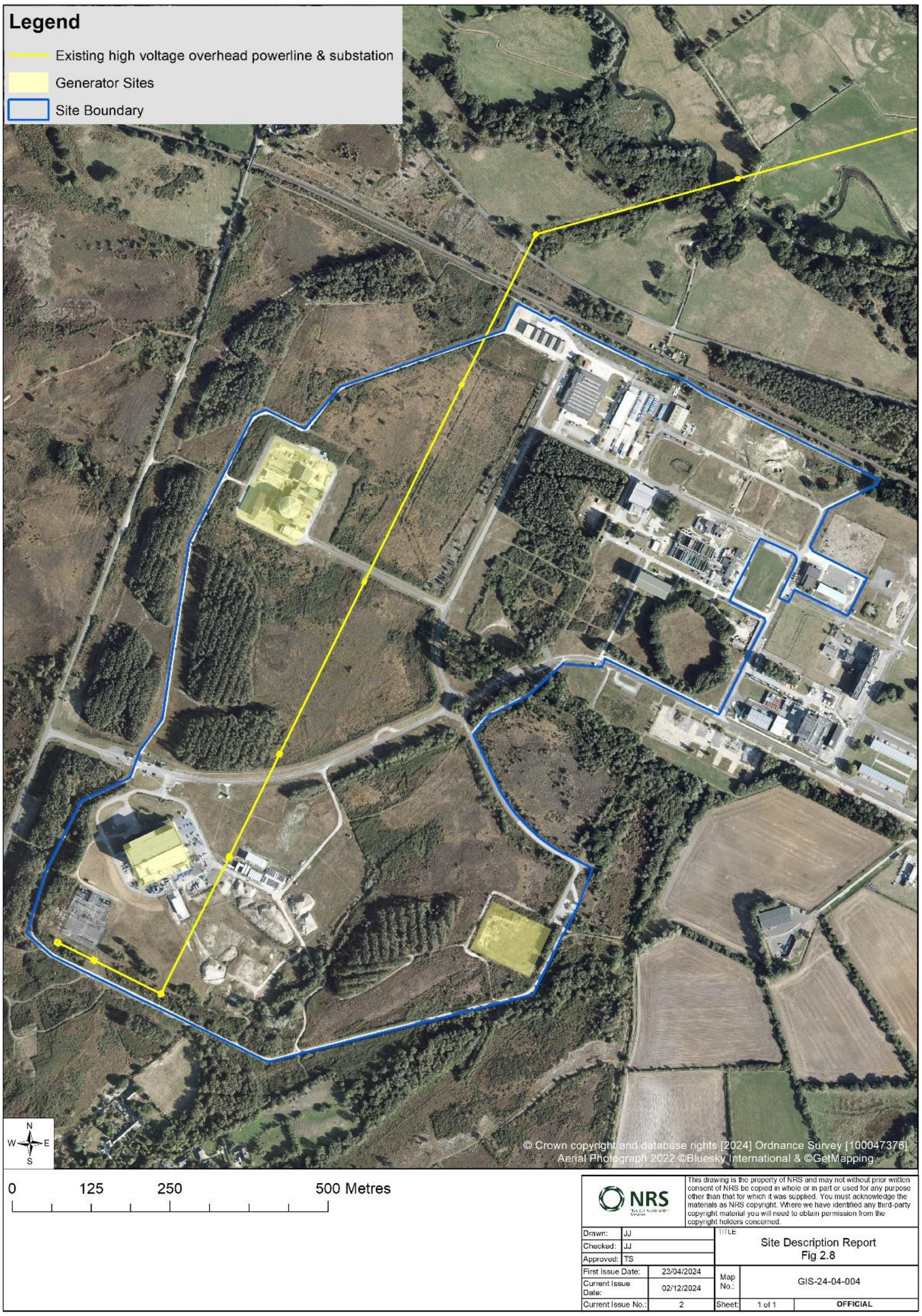


Figure 11: Location of the electricity sub-station in the south-west corner near SGHWR, in yellow, and the associated powerline, as well as the location of some of the old reactor buildings.

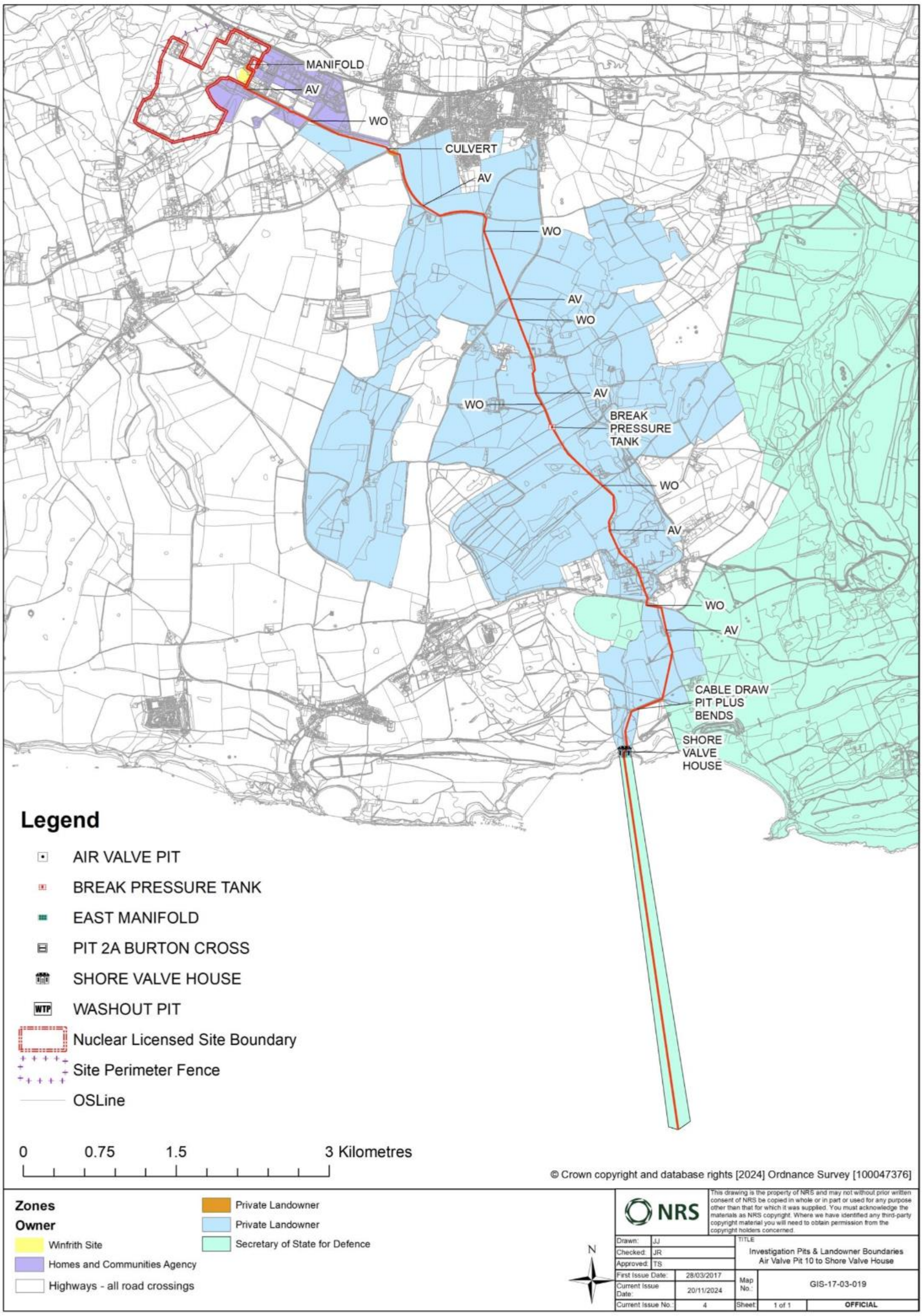


Figure 12: Land ownership along the route of the pipeline.

Most of the site is located within the Winfrith Heath Site of Special Scientific Interest (SSSI), although the areas around the SGHWR, ZEBRA and Dragon reactors are excluded (Figures 13 and 14). This SSSI includes both the Winfrith Heath and Tadnoll Nature Reserves and is also designated as the Dorset Heath Special Area of Conservation

(SAC), the Dorset Heathlands Special Protection Area (SPA) and the Dorset Heathland Ramsar[4] site.

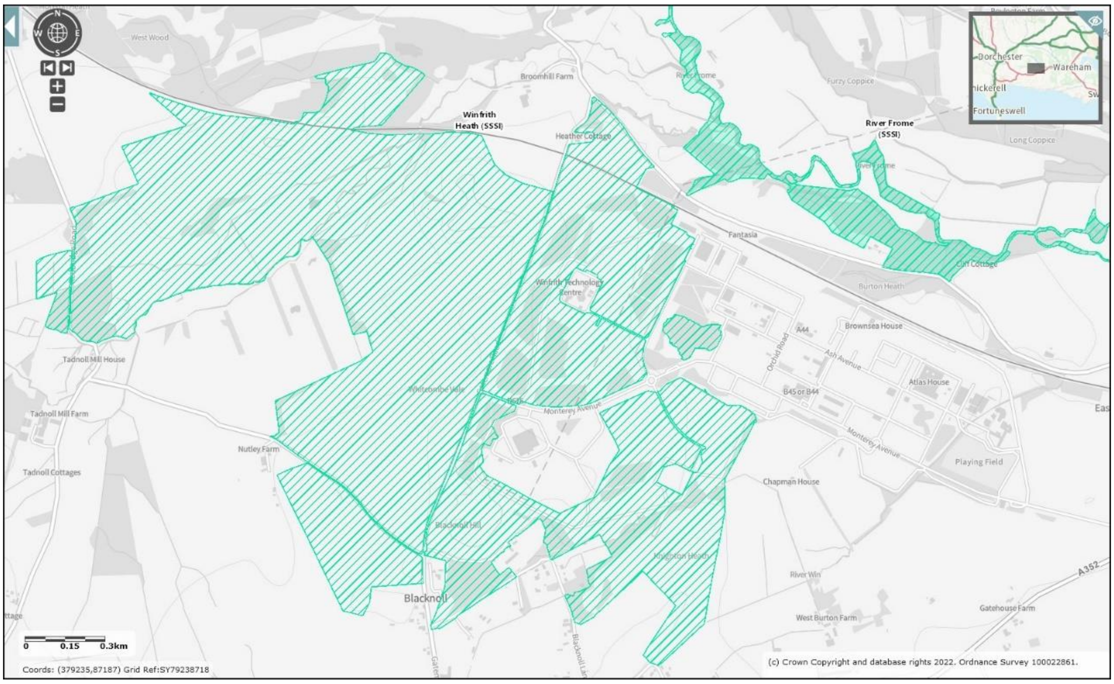


Figure 13: Location of Winfrith Heath SSSI (hatched) and the River Frome SSSI (hatched with solid colour background) (modified from Ref. 23).

The Winfrith Heath SSSI is a substantial and varied tract of heathland near the western limit of the Dorset Heaths. It encompasses a range of heath and mire ecological communities on the sides of the Tadnoll Brook and in the wet pastureland on the valley floor. The ecological habitats across the site, using the National Vegetation Classification (NVC) scheme, are shown in Figure 14. Within the designated parts of the site (i.e., those that are within the Winfrith Heath SSSI), there are three principal plant communities, types H2, H3 and M16, which have the following characteristics (Ref. 24):

- Ulex minor heath (H2). A lowland dry heath community that occurs on dry acid soils.
- Agrostis curtisii heath (H3). This is a transitional habitat between lowland dry heaths and wetter mire communities.
- Sphagnum compactum wet heath (M16). Wet heath usually occurs on acidic, nutrient-poor substrates, such as shallow peats or sandy soils with impeded drainage.

All three are associated with acidic environments, with M16 preferring wetter (seasonally waterlogged/flooded) conditions than H3 (moist) and H2 (dry) (Ref. 24).

[4] The Ramsar Convention of Wetlands of International Importance (1971) is an international treaty for the conservation and sustainable use of wetlands.

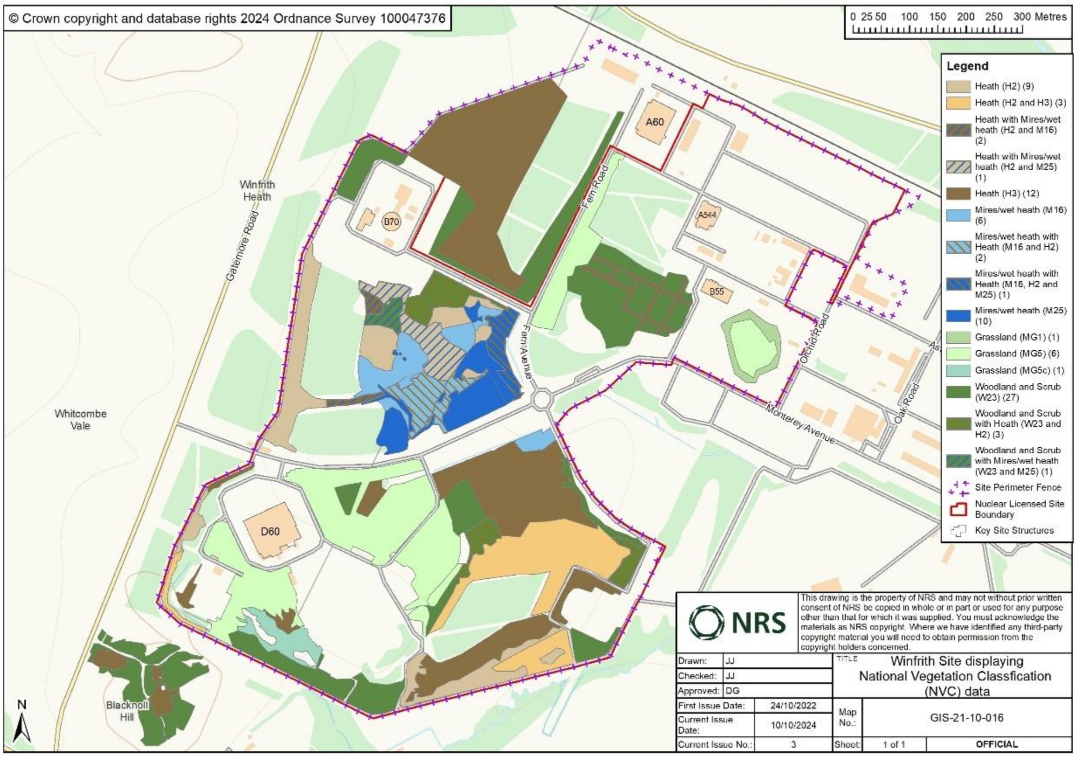


Figure 14: Spatial distribution of NVC communities at Winfrith (Ref. 25).

Within the site there is an ancient hedge marking the original boundary between agriculture and heathland (known as Coltsclose Corner). Parts of the site also sit within designated groundwater dependent terrestrial ecosystems (GWDTEs). GWDTEs are wetlands that are critically dependent on the groundwater. These ecosystems need to be assessed to ensure that the groundwater has not been significantly altered, leading to terrestrial damage. The location of the GWDTEs on the Winfrith site are shown in Figure 15.

The River Frome and adjacent land forms a separate SSSI to the north of the site (Figure 13). The River Frome is the most westerly example of a major chalk stream in England with species-rich aquatic and bankside vegetation (Ref. 26).

Beyond the site and along the route of the pipeline, the predominant land use is arable and horticulture, with lesser amounts of improved grassland and woodland (Figure 16). The route of the pipeline runs through the Dorset National Landscape. The pipeline also runs close to Lulworth Castle, the MoD Lulworth and Bovington Firing Range, and it reaches the coast at Arish Mell near Worbarrow Bay.

Lulworth Castle contains several scheduled ancient monuments and is sited in the Lulworth Park and Lake SSSI, whilst the MoD firing range and Worbarrow Bay are part of the South Dorset Coast SSSI (Ref. 27). Arish Mell is incorporated in the Isle of Portland to Studland Cliffs SAC.

The coastline across Dorset and East Devon, including Worbarrow Bay, is part of the Jurassic Coast UNESCO World Heritage Site and was designated as England's first natural World Heritage Site in 2001 (Ref. 28). The coastline is an internationally significant site for the Earth Sciences and especially palaeontology, with a nearly continuous outcrop of coastal exposure that covers nearly 190 million years of Earth's history (Ref. 29).

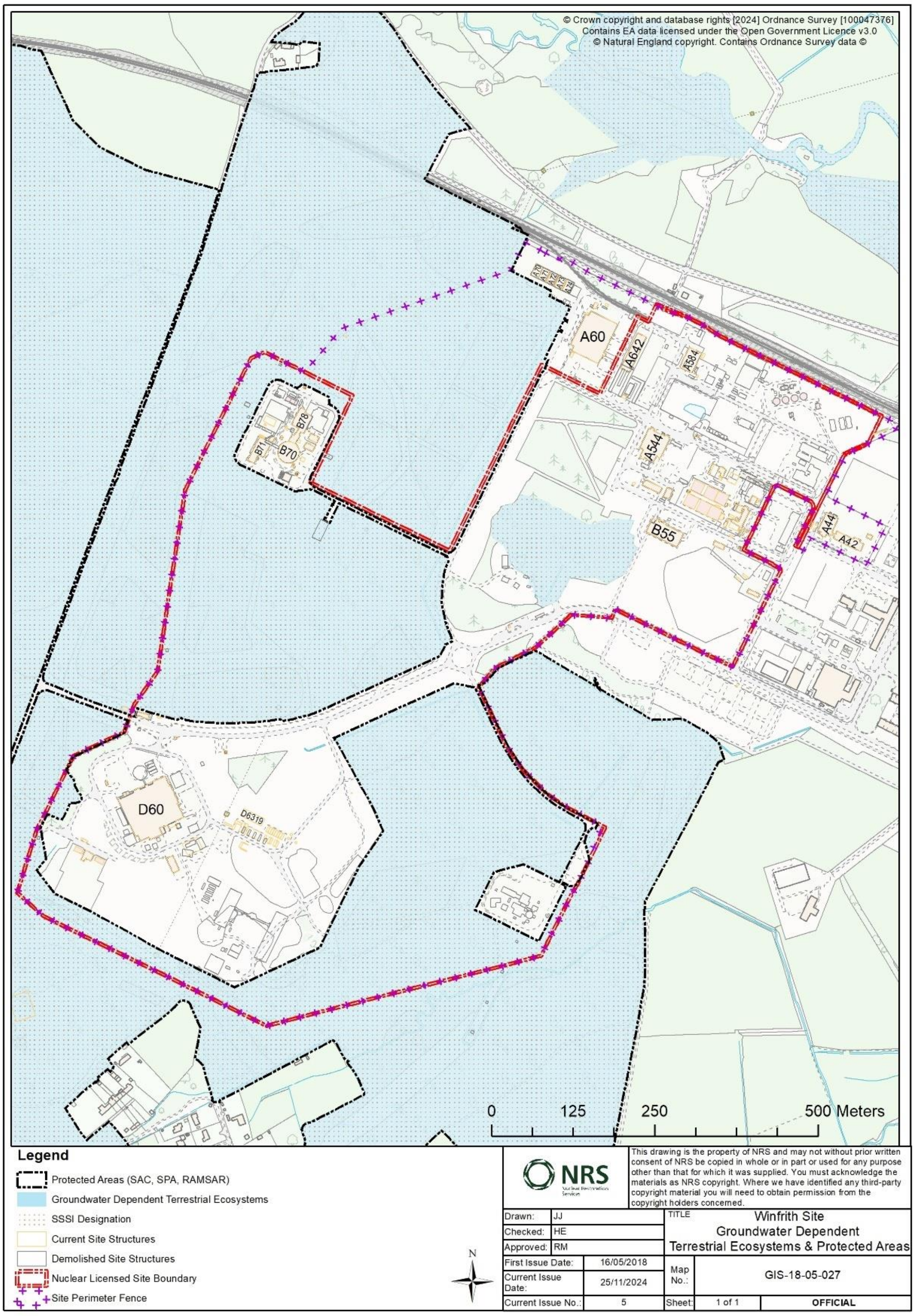


Figure 15: The location of Groundwater Dependent Terrestrial Ecosystems (GWDTEs) on the Winfrith site (Ref. 30).

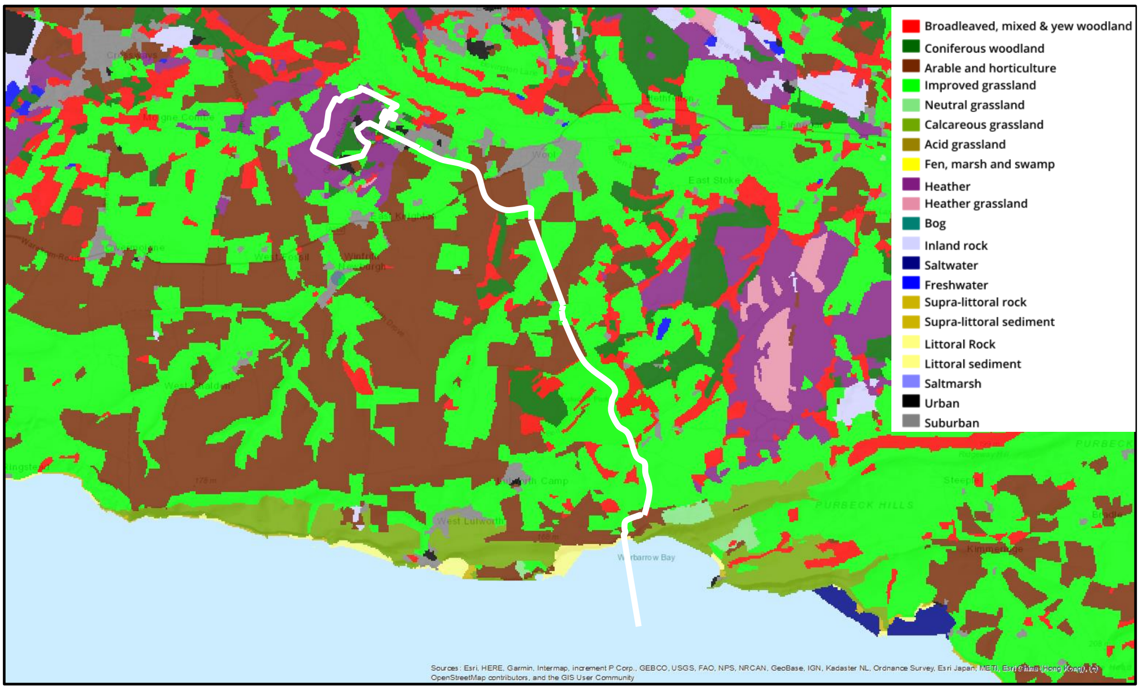


Figure 16: Land cover classification in the area around the Winfrith site (Ref. 31).

2.4 Habits and Land Use

A habits and land use survey for the Winfrith site was conducted in 2019 by the Centre for Environment, Fisheries and Aquaculture Science (CEFAS) on behalf of the EA (Ref. 32). The CEFAS terrestrial survey area covered all land and freshwater watercourses within 5 km of the site centre. The survey area is characterised by several small towns and villages, the closest to the site and pipeline being Wool and Winfrith Newburgh. Several small hamlets are within a kilometre of the pipeline, including Coombe Keynes, which is close to the pipeline Break Pressure Tanks. The rest of the land surrounding the built-up areas is predominately fields and a few small ponds. Within the area covered by the CEFAS survey, the route of the pipeline crosses two main roads, the A352 and the B3071, as well as several smaller roads.

The main use of land in this region is for farming. The agricultural quality is classified as good to moderate, as shown in Figure 17, although some areas that the pipeline crosses near the coast are primarily non-agricultural (i.e., the MoD Lulworth Firing Range).

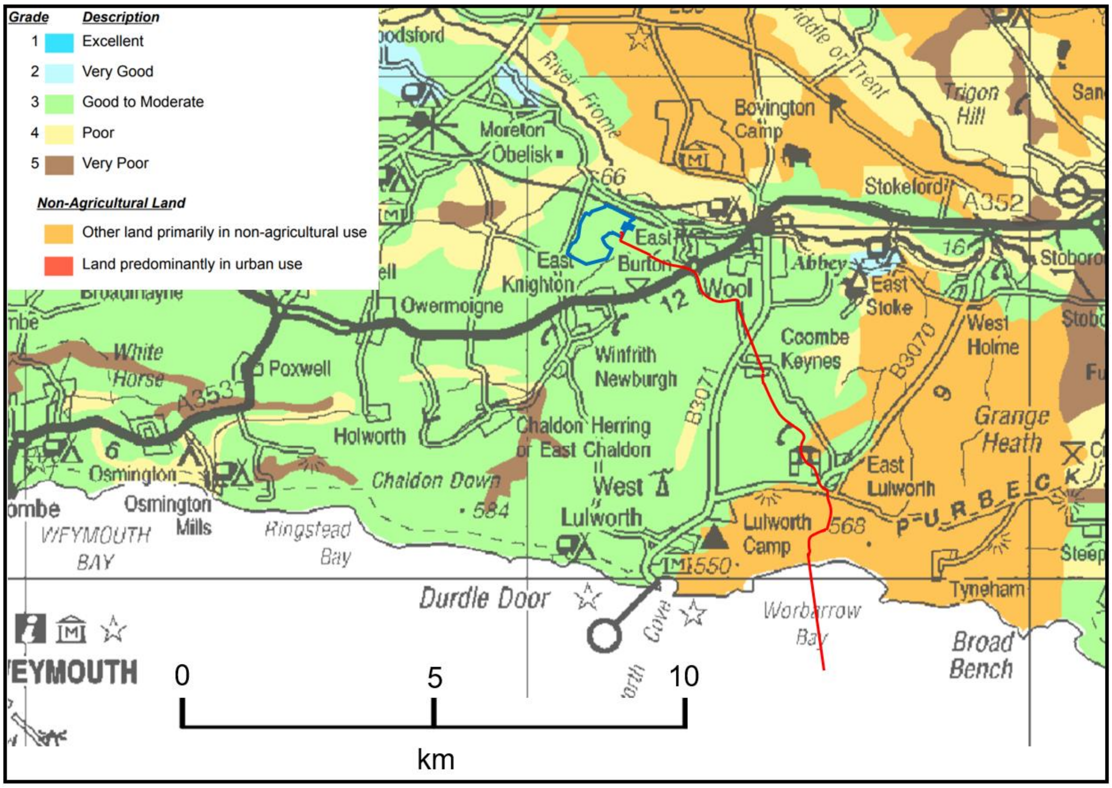


Figure 17: Agricultural land classification of the South West region of England focused on the Winfrith site, adapted from (Ref. 33).

The CEFAS survey identified 35 working farms and three smallholdings within the terrestrial survey area. Of these farms and smallholdings (Ref. 32):

- 11 farms produced milk (from dairy cattle), and raised dairy followers (young dairy cattle, intended to replace older dairy cattle) or dry dairy cows (waiting to calf).
- Six farms reared beef cattle (for fattening or stores), one of which also reared geese and turkeys.
- Six farms reared beef cattle and lamb.
- One farm reared lamb.
- Six farms produced arable crops for animal feed or stored animal feed.
- Four farms produced salad crops and one produced watercress.
- Two smallholdings reared pigs, lambs and chicken (for eggs), and one reared lambs.

The production of arable crops for human consumption was not identified (Ref. 32). Arable crops grown in the survey area for use as animal feed were grass (silage), wheat, barley, oats, beans and maize. Farmers, smallholders and their families were consuming milk, beef, lamb, watercress, pork, chicken eggs, goose and turkey produced commercially on their own farms or smallholdings.

Non-commercial production of fruit and vegetables was identified in private gardens within the survey area (Ref. 32). One allotment site of 50 individual plots was identified within the survey area, but survey access was not permitted. Four beekeepers were identified with a total of 25 mature hives in the survey area. Wild foods were collected and consumed, including blackberries, chestnuts, damsons, elderberries, elderflowers, rosehips, hawthorn fruit, hazelnuts, sloes and mushrooms. Game shooting was identified and pheasant, pigeon, partridge, rabbit and venison were consumed.

Human consumption of groundwater from boreholes was identified at several farmhouses (Ref. 32). Livestock were identified as drinking mains water and had access to spring, stream water and water from a borehole.

It was identified that foods produced for sale in the terrestrial survey area were largely sold locally at farm or butcher shops (Ref. 32). Lamb and beef were additionally sold to abattoirs and food processing companies, hotels, restaurants and public houses in Dorset, Wiltshire and Hampshire, and to national supermarket chains. Milk was sold to a dairy co-operative.

In addition to the terrestrial survey area, the aquatic survey area (Figure 18) covered all tidal waters and intertidal areas from Portland Bill in the west to St Alban's Head in the east, and the adjacent offshore sea area up to a direct line between these two points (Ref. 32). Fisheries within the East Fleet lagoon were also included in the aquatic survey area as seawater from Portland Harbour flows beneath Ferry Bridge into the lagoon.

The commercial fishermen in the area mainly targeted brown crab, common lobster, whelks, scallops and fish including plaice, bass, skate, cod and bream. Small quantities of prawns and black crab were also caught (Ref. 32). Approximately 30 commercial fishing vessels were based in the survey area, primarily in Weymouth harbour with a few in Portland harbour. These vessels were primarily potting, rod and line fishing (sustainable bass fishery) and netting; one fishing trawler was operating in the survey area.

A seaweed farm was identified in Portland Harbour and shellfish farm trials are being considered (Ref. 32). A shellfish farm was located in the East Fleet Lagoon. Diving for scallops took place on a commercial basis at Lulworth Banks and throughout the survey area.

Over the majority of the aquatic survey area (approximately 75%) bottom-towed fishing gear is prohibited from being deployed due to local byelaws applicable in the Purbeck Coast Marine Conservation Zone (MCZ) and Studland to Portland SAC (Ref. 32). A one-off incident is noted to have occurred where one of the Winfrith twin discharge pipelines had moved along the seabed and over the second pipeline; this was thought to have been caused by a snagged fishing net, but no nets were found or recovered. The pipelines are located within the Lulworth Ranges Sea Danger Area and during firing periods mariners are advised to avoid the area for their own safety. Fishermen operate in this area when firing is not taking place.

The majority of fish, scallops, brown crabs, common lobsters and common prawns were sold through fish merchants in Weymouth, sent to Brixham Market or sold to restaurants, pubs and hotels (Ref. 32). Whelks landed at Weymouth and Portland were sold in London, at fish merchants in Weymouth and to wholesalers for export to South Korea.

Non-commercial boat angling, spear fishing and collecting mussels were observed, and many sub-aqua divers were identified collecting and consuming large quantities of scallops (Ref. 32). Consumption of small quantities of winkles was also identified.

Seaweed was collected throughout the survey area on a small industrial scale to produce liquid fertiliser, which was sold commercially (Ref. 32). Foraging for wild foods was popular on the shoreline and some businesses offered foraging day courses for members of the public.

The CEFAS survey identified that all the beaches and coves along this section of coastline, where public access is possible and permitted, are visited frequently by tourists and locals (Ref. 32). In addition to walkers, the survey noted shore angling and edible seaweed collection were popular, and other intertidal activities included playing, coasteering, dog walking and collecting winkles.

Activities observed taking place in water5 by the CEFAS survey (Ref. 32) included kayaking, paddleboarding, kitesurfing, windsurfing, swimming, surfing, snorkelling, jet skiing, spear fishing, collecting mussels (while swimming), sub-aqua diving and collecting scallops whilst diving. Activities taking place on the water included sailing, commercial fishing (including gill netting, potting, trawling, and rod and line), boat angling, paddling, rowing, and various types of work taking place on boats and pontoons.

Differences of note between the 2019 habits survey and the preceding one in 2003 (Ref. 34) include:

- Between these surveys there was a change in conservation designations and fishing restrictions, which may have impacted commercial fisheries. Approximately 75% of the aquatic survey area is now included in an MCZ and SAC, where no bottom-towed fishing gear is permitted, and licence capping and bass restrictions has encouraged sustainable rod and line fishing for bass.
- The maximum and mean consumption rates of marine fish decreased significantly in the 2019 survey.
- A new human ingestion pathway identified in 2019 was the consumption of seaweed collected from Portland Harbour and from the shore in the aquatic survey area. Foraging for wild foods was popular on the shoreline in this area in 2019.
- Intertidal occupancy was recorded over rock and over stones in 2019 but not in 2003.
- In 2019, there were significant decreases in the consumption rates of potato, domestic fruit, wild/free foods, honey and wild fungi. Conversely, the consumption of sheep meat and eggs significantly increased.
- The consumption of goat meat and freshwater fish has ceased since the previous habits survey.

[5] CEFAS classified activities involving a high likelihood of an individual's face submerging under water as activities 'in water', as they are more likely to lead to ingestion of water. All other water activities were classified as activities 'on water'.

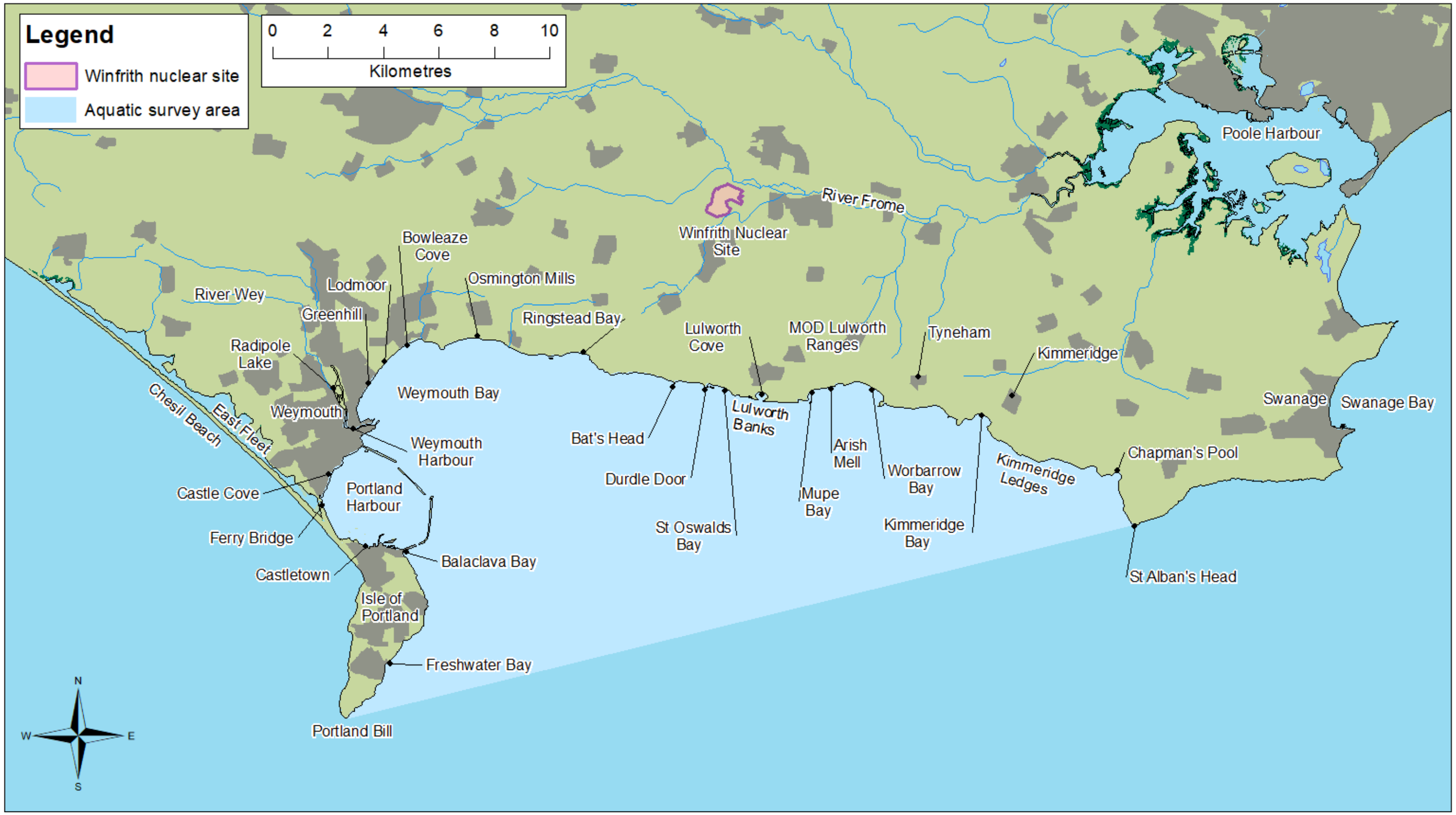


Figure 18: The 2019 CEFAS radiological habits survey aquatic survey area, from Portland Bill to St Alban's Head (Ref. 32).

3 The Site at the Interim End Point

This section summarises the general configuration of the site at IEP and the features expected to remain on site following the IEP. The NDA's strategy for Winfrith is to decommission the site as soon as reasonably practicable, taking account of life-cycle risks to people and the environment and other relevant factors (Ref. 35, 36). This strategy involves completing all physical decommissioning and demolition of all facilities remaining on the Winfrith site, followed by remediation and landscaping, to deliver its next planned use of land suitable for heathland with public access. Winfrith is expected to be the first UK site to reach such a significant milestone.

3.1 End Point Specification

The current state of the site is shown in Figure 1, with a number of buildings of various sizes and usages remaining, including portacabins, offices and stores. By the IEP, it is intended that all above-ground buildings and hard-standing areas will be removed.

The IEP for the Winfrith site will be reached when all physical decommissioning and clean-up activities required for the next planned use of the site are complete. At some time after this point, general public access to the site will be permitted, although access controls may apply to the protected zones (SSSI, SPA, SAC and Ramsar) to allow for the creation / regeneration of heathland habitats (Ref. 95, 98).

Following the IEP, a period of passive management will allow for residual radioactivity to decay and chemical contamination to degrade, and for validation monitoring. The site will be suitable for its next planned use as heathland with public access. The Stewardship Plan outlines what monitoring and management arrangements will be required up-to and beyond the IEP (Ref. 95). The Site is projected to be monitored for a number of decades beyond the IEP until it reaches the SRS, at which point the site will surrender its RSR permit.

An engineered cap will be constructed over the SGHWR and Dragon disposals/deposits to limit infiltration into the disposal structure. The engineered caps will be covered with approximately 1 m of site derived soils to permit the establishment of /heathland mosaic (Ref. 98).

Facilities that are expected to remain on or adjacent to the site at the IEP, but which do not require assessment, include the electrical sub-station (Figure 11). The Blacknoll Reservoir will be decommissioned before the IEP (Ref. 37).

For the purposes of managing land quality and achieving the End State, the site has been split into ten zones plus the on-site de-licensed areas and off-site areas still owned by the NDA (Ref. 19, 38):

- Zone 1 (8.09 hectares) – Heathland with Fire Training Area.
- Zone 2 (12.1 hectares) – Heathland with ZEBRA.
- Zone 3 (11.0 hectares) - Heathland with EAST and SSE station.
- Zone 4 (13 kilometres) - Sea Discharge Pipeline.
- Zone 5 (3.74 hectares) – Waste Management and Sewage Treatment.
- Zone 6 North (2.62 hectares) – Managed grassland.
- Zone 6 South (4.41 hectares) – Waste Management, ALES and Active Drain.
- Zone 7 (10.6 hectares) – Heathland.
- Zone 8 (2.34 hectares) – Ancient Field and woodland with Active Drain.
- Zone 9 (6.19 hectares) – Dragon and access road.
- Zone 10 (11.0 hectares) – SGHWR and access road with Active Drain.
- On-site de-licensed areas and off-site areas.

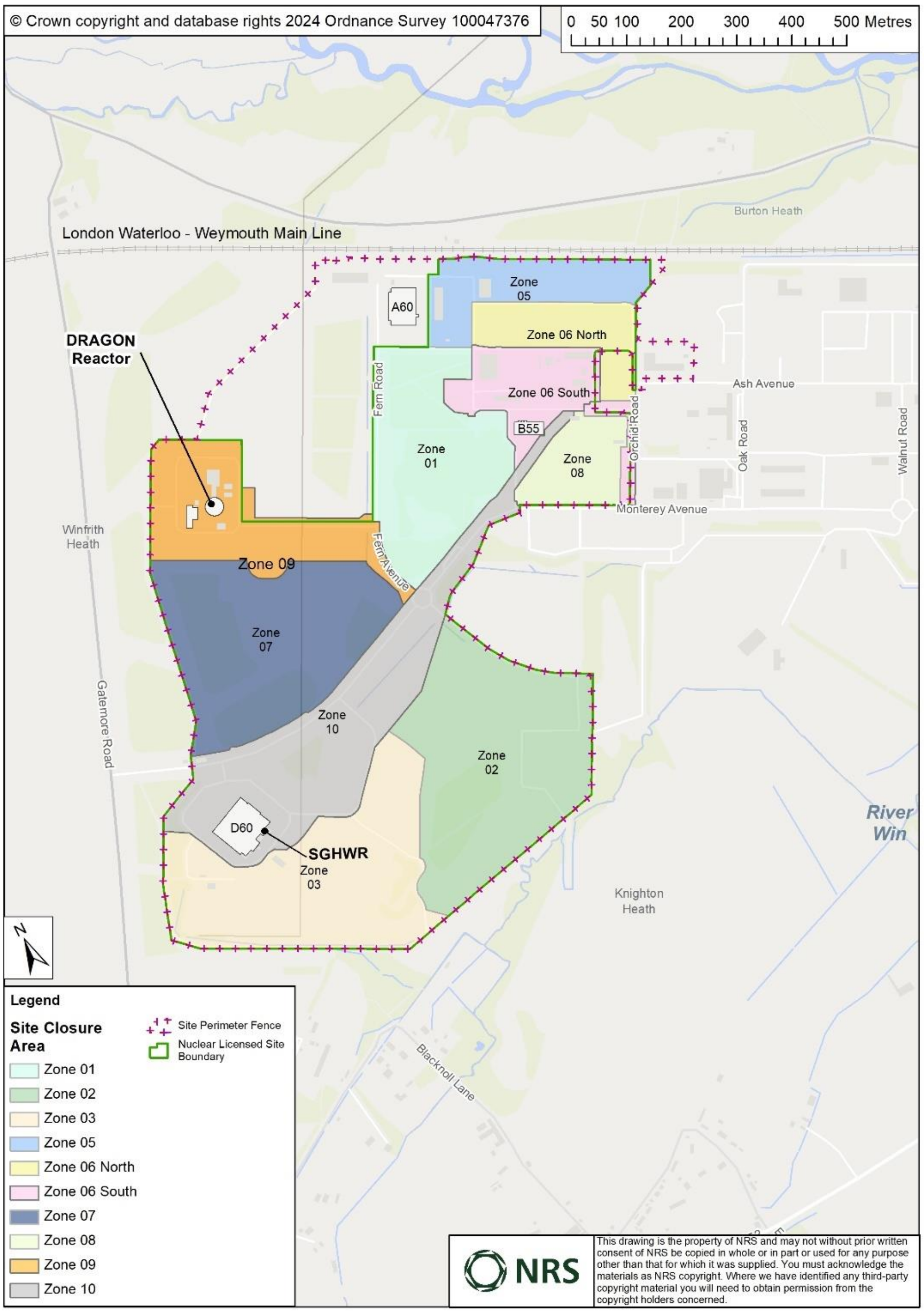


Figure 19: Site closure zones for Winfrith

3.2 On Site Disposals

The proposed end state for the reactor buildings includes leaving sub-surface structures in-situ and backfilling with demolition arisings from the above ground structures and material currently stored in the rubble stockpiles.

3.2.1 Steam Generating Heavy Water Reactor (SGHWR)

The SGHWR was a heavy-water moderated reactor, which used ordinary (light) water as the coolant, and deuterated water as the moderator. Construction of the SGHWR (Figure 20) was completed in 1967, with operations ceasing in 1990. As well as being an experimental reactor, the SGHWR was the only Winfrith reactor to supply electricity to the national grid.

The above ground structures are expected to be demolished and used to backfill sub-surface voids, along with demolition materials from other areas of site that are currently stockpiled (Ref. 6, 7).

An engineered cap will be constructed over the disposal to prevent water ingress and intrusion.

A plan of the below-ground regions of the SGHWR and the principal dimensions and elevations of these are shown in Figure 21 and Table 2.

Figure 20: The SGHWR reactor building in 2002.

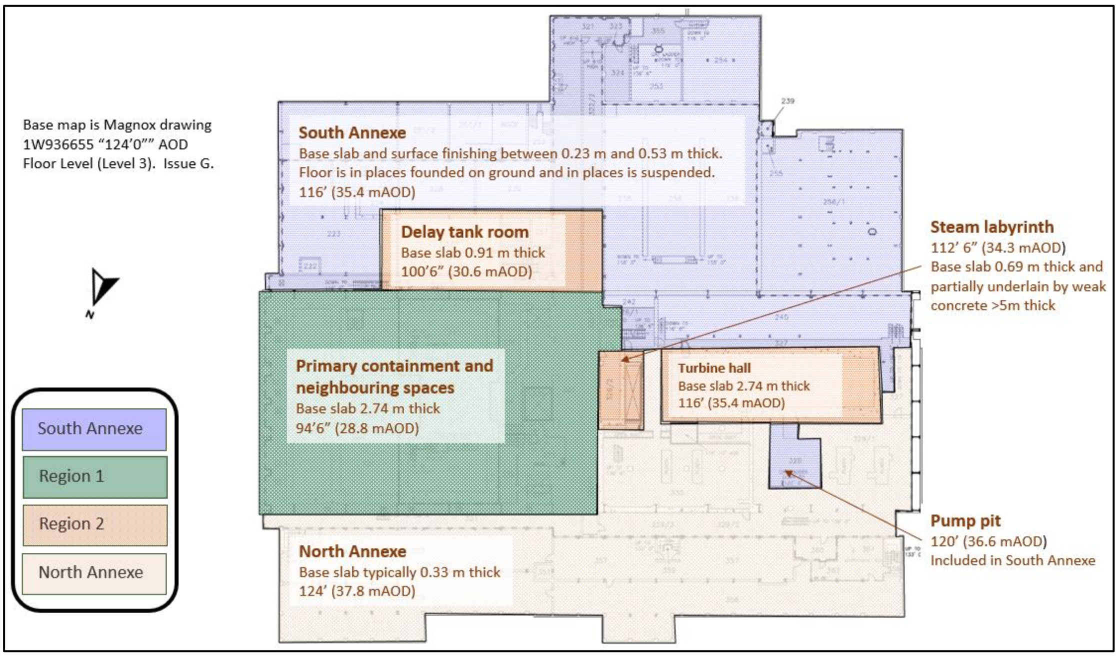


Figure 21: Plan showing below-ground regions of the SGHWR reactor building.

3.2.2 Dragon Reactor

The Dragon reactor, shown in Figure 22, was a prototype high-temperature helium-cooled reactor, built in 1960 as part of an Organisation of Economic Co-operation and Development (OECD) research project (Ref. 38). It achieved first criticality in 1965 and ceased operations in 1975). Early defueling and decommissioning was undertaken up to 1979. The adjacent mortuary hole structure was used during the operational phase for cooling spent fuel prior to transport off-site. After Dragon ceased operations, several Dragon buildings and the mortuary holes were re-purposed as temporary storage locations.

The current decommissioning plan for the Dragon reactor includes leaving sub-surface structures in situ, specifically the reactor bioshield and the associated mortuary hole structure (Ref. 39). The proposed end state for these structures was defined through multi-attribute comparison. Concrete and brick from the above-ground structure of the reactor will be demolished and used for filling the sub-surface voids (Ref. 5, 6, 40). The mortuary holes will be filled with clean grout and capped. The proposed disposals at both Dragon reactor (B70) and the mortuary holes (B78) will have an engineered cap.

A number of non-radioactive slabs in the vicinity of Dragon will also remain in place as part of the end state.

Principal dimensions and elevations associated with the Dragon reactor basement are summarised in Table 1 and a schematic cross-section of the anticipated structure at the IEP is shown in Figure 23.

Figure 22: Outside of the Dragon reactor building.

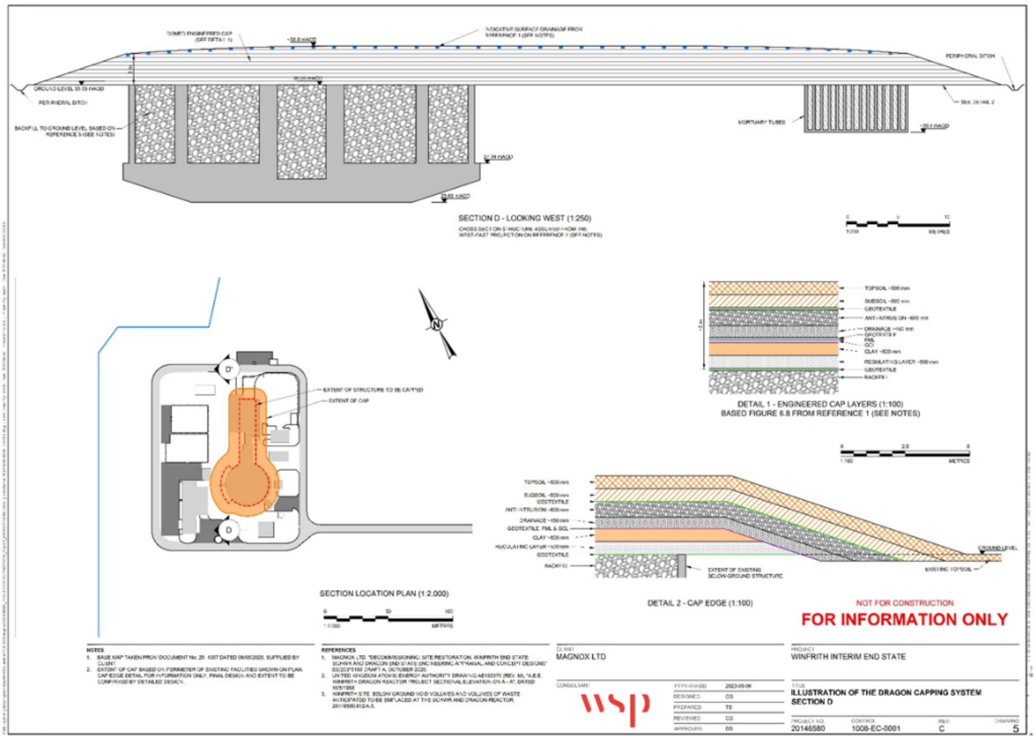


Figure 23: Schematic cross-section of the in-situ below-ground Dragon reactor building and mortuary hole structure (Ref. 7).

3.3 Land Quality Management

Land quality is assessed using historical data and knowledge of the site, remaining land quality and groundwater issues are assigned a level of environmental risk varying from ‘very low’ to ‘very high’ potential for contamination. Six areas of potential risk have been identified as being medium priority or above in the short-term or long-term, as follows (Ref. 41):

- Zone 3 is adjacent to the SGHWR zone (Zone 10) and contained the associated External Active Sludge Tanks (EAST). The demolished D69 (EAST pumphouse) facility had a short-term high-priority risk arising from radionuclides posing a potential hazard to groundwater. This area has been partially remediated during 2024 to address this issue, and will be completed prior to the IEP being achieved. Since the area will be remediated, there will be no hazard remaining at the IEP.
- Zones 5 and 6 North contained the main chemistry facilities, the ALES facility, the Post-Irradiation Examination (PIE) facility at A59 and the sewage treatment works (A57). Four high or medium-priority risks are located in this area:
    - Historical chlorinated hydro-carbon contamination in groundwater is high-priority risk. This risk is considered to be high priority in the short-term and medium priority in the long-term. NRS are continuing monitored natural attenuation of the chlorinated hydrocarbon contamination at the Winfrith Site. Ongoing monitoring will be undertaken, however concentrations of these contaminants are continuing to decline, and are below relevant Environmental Quality Standards. Zinc and Nickel was used in historical electroplating activities and is identified as having entered groundwater. This is considered a medium priority risk in the long-term.
    - The A56 diverter valve is a short-term medium-priority risk to groundwater from radionuclides. The contamination will be removed along with the remainder of the redundant active duct when the area is decommissioned. Preparation has started

for an investigation into the contamination in 2025, to guide further works. This issue will be resolved before the IEP with no contamination remaining beyond this point.

- Zone 9 houses the Dragon reactor complex. In the area of building B78 there is a short-term medium-priority risk to on-site workers from radionuclides in the B73 Fuel Store Facility / Mortuary Holes during decommissioning of the site. This has been designated as a low-priority long-term risk if no cleanup is undertaken. This area will be cleaned-up prior to the IEP as part of the implementation of the Dragon disposal.

Across the site a network of active and inactive drains is present. The active drains across the site posing a potential hazard to groundwater due to the potential presence of historical contamination. The drains will be assessed in line with the drains strategy (Ref. 96) and either demonstrated as meeting the end point criteria, or removed for off-site management.

3.4 Other Site Features

Optimisation assessment to ascertain the optimum end state have been completed for several other features on-site, which indicates all remaining contamination, excluding SGHWR and Dragon, should be removed based on current assumptions.

3.4.1 A59

Area A59 in Zone 6 North was the location of the Active Handling and Decontamination building, operational between the 1960s and 1990s. Until 1992 the building was used as a Post-Irradiation Examination (PIE) facility where reactor fuel assemblies and structural components from various reactors were examined. PIE operations finished in 1992 and the building was subsequently used for other active handling tasks until 1999, when post-operational clean out commenced (Ref. 42).

Decommissioning of the PIE facility began in 2001 with an initial clear out of the building, followed by remotely-operated and manual cleaning, before demolition (Ref. 42). Contaminated soil was excavated and the area remediated, but residual contamination remains below-ground (Ref. 43, 44).

The area is designated as a short-term medium-priority risk to groundwater. The A59 area is to be remediated to out-of-scope concentrations in the near term. Remediation will be completed prior to the IEP, with only Out of Scope (OoS) levels remaining. Consequently there will be no remaining issue beyond this point.

3.4.2 Active Liquid Effluent System (ALES)

The ALES system at the Site is to be decommissioned prior to the IEP being achieved. Optimisation assessments of the sub-surface structures at the ALES facility have concluded that in-situ disposals are not optimised for this area (Ref. 97).

The proposals for decommissioning at ALES concludes with above ground structures to be removed and disposed of off-site. Sub-surface structures are to be demonstrated as free from contamination, before being provided with 1 m of cover soils.

Land quality surrounding ALES is largely unassessed due to access being limited at current (Ref. 97). Decommissioning of the ALES facility will be required prior to land quality assessment commencing; however, any remediation works required to be undertaken will be completed prior to the IEP.

3.4.3 Drains

The Drains Strategy (Ref. 96) outlines the proposals for the remaining drains across the Winfrith Site including: Active Drains, Active Foul Systems, Non-Active Drains and surface water drains and soakaways.

Where radioactive contamination within a drain exceeds OoS criteria, then the drain will be removed and/or cleaned to meet safety and environmental justifications. If any soils are contaminated surrounding these drains sections then remediation of these soils will be undertaken.

Where drains meet OoS criteria, these drains are not required to be removed. In the event of drains not being removed, access manholes are required to be plugged to enable the establishment of a natural hydrograph on the site to meet the requirements of the Restoration Management Plan (Ref. 98). Any drains left in-situ must be free from any chemical contamination.

3.4.4 Landscaping

Landscaping of the site is proposed to be commence in the early 2030s, with completion later in the same decade. Landscaping to be completed at the site is presented in the Restoration Management Plan (Ref. 98). Following decommissioning and demolition operations, and following the completion of any land remediation activities, final site landscaping will be undertaken. Where appropriate, landscaping works will be undertaken on an area by area basis.

Landscaping will include the re-profiling activities to manage surface water or minimise risk to the public post-IEP. Landscaping also includes the removal of all redundant asphalt road materials. Final site landscaping will be undertaken in accordance with the Restoration Management Plan (Ref. 98) and Environmental Impact Assessment (EIA). There is no current requirement for large scale landscaping / re-profiling.

The site permitter fence will be removed following confirmation with the EA that the IEP has been achieved. The fence removal will likely be removed in the late 2030s as one of the last pieces of physical works prior to public access to the site being permitted.

The tarmac surface course and binder course for most of the internal roads on site will be removed before the IEP, especially where they present a potential hazard (e.g. hazardous organics) (Ref. 7). The sub-base layer will be broken to alowl the establishment of habitats (Ref. 98). Some roads may be retained in part to allow access to the electricity sub-station.

3.5 The Winfrith Sea Discharge Pipeline

The route of the pipeline is shown in Figure 4 and a detailed description is given in the report on options for decommissioning the pipeline (Ref. 11). The pipeline consists of two pipes running in parallel underground, each with a smaller internal pipe (Figure 24). The internal pipes carry active effluent, whilst the external pipes carry lower active effluent. Construction commenced in 1959 and completed in 1960. The pipeline remains in use until such a time as an Alternative Discharge Route (ADR) can be put in place. The lease for the land is owned by the NDA and has no termination date.

The pipes are buried to various depths through the terrestrial section at the time of construction (Figures 25 and 26). Through the majority of the terrestrial section there was a nominal depth of 1.2m below ground level (assumed to be three plough depths), with some shallower sections associated with ducts and roadways. Through the Ministry of Defence firing range there was a minimum of 3.6m below ground level, with one section also being encased in concrete. The marine section is surface laid and weighted for the majority of the length, with the intertidal section being concrete encased and protected.

There are concrete structures at intervals along the pipeline: six air valves, six wash-out pits, the Break Pressure Tanks and the Shore Valve House (Figure 4). The Break Pressure Tanks are located near the high point of the pipeline route, and between the site and these tanks the effluent is pumped. From the tanks to the shore the effluent travels under gravity, with its discharge to the sea controlled by valves at the Shore Valve House.

At the Shore Valve House, the two pipelines each split into a further two pipelines, leading to four separate pipes on the seabed. The two lower active water pipes discharge 15 m out to sea, below the mean low water springs, while the two active pipes continue 3.7 km (2 nautical miles) out to sea. Diffusers are set on the end of the active pipes, which are in about 30 m depth of water. The submarine pipelines have a vertical undulation of 4.5 m following the contours of the seabed and reefs (Ref. 11). Details of the construction and dimensions of the pipeline are given in Table 2. Discharge volumes through the pipeline have been reducing as the site is decommissioned and, as part of the Alternative Discharge Route (ADR), the operation of the pipeline will be terminated, with decommissioning to follow. The pipeline is being removed in its entirety (Ref. 103).

Figure 24: Image showing inner (active discharges) and outer (foul water discharges with some residual activity) pipeline (Ref. 11).

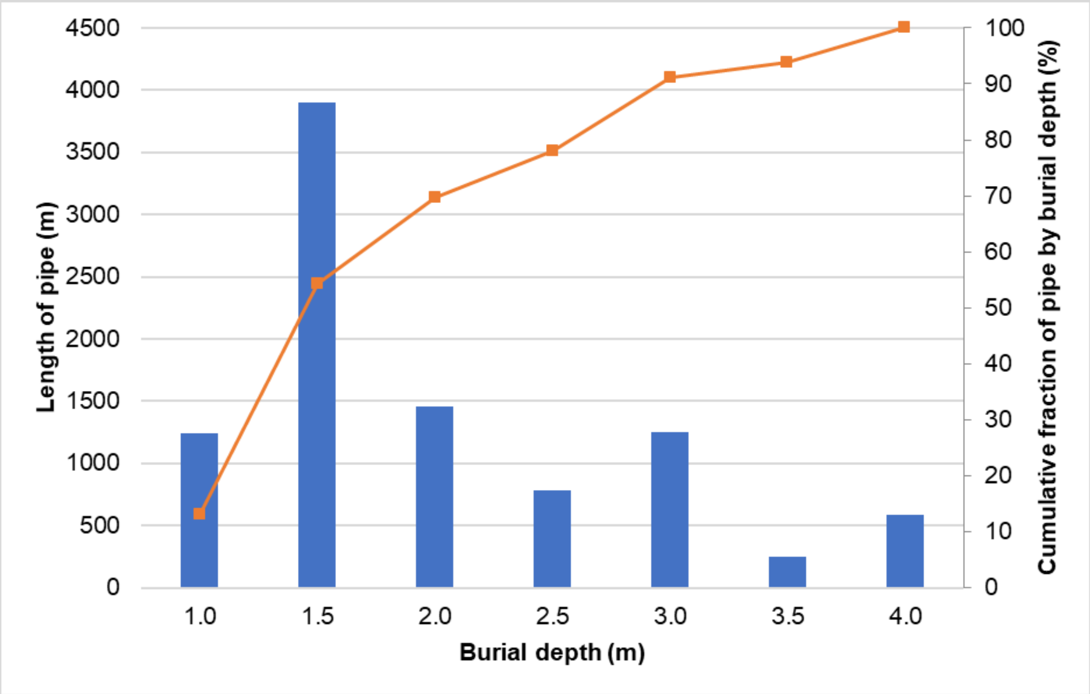


Figure 25: Cumulative fraction of the pipeline burial depth (Ref. 11).

Table 1: Dimensions, materials and construction specifics of the pipeline, including normal conditions of the inner and outer pipes and notable exceptions to these values (Ref. 11).

Statistic	Normal Conditions		Exceptions
	Inner Pipe	Outer Pipe	
Diameter (mm)	152.4 (pumphouse to Break Pressure Tanks), 203.2 (Pressure Break Tanks to Shore Valve House)	304.8 (pumphouse to Break Pressure Tanks), 406.4 or 457.2 (Break Pressure Tanks to Shore Valve House)	152.4 (at Shore Valve House each pipeline splits into two further pipes)
Pipe wall thickness (mm)	9.5	9.5	12.7 (at sea)
Materials	Mild steel tubes – American Petroleum Institute Specifications API-5L Grade B		Same, extra heavy, out at sea
Depth (m)	0.91 (minimum at construction) – seen in Figure 26, during construction under Lulworth Castle		2.44 at MoD gunnery range, 3.05 at region in direct line of fire
Covering	Backfilled with soil		Concrete slabs under A352, minor roads and tracks, 0.61 m concrete slab at MoD gunnery range

Figure 26: Image showing the construction of the pipeline at Lulworth Castle (Ref. 111).

4 Soils and Geology

4.1 Soils

The understanding of soil composition and contamination are important in developing models of the biosphere.

4.1.1 Soil Type

Soil types on the Winfrith Site

The types of soils covering the site and surrounding region are shown in Figure 27. The soils underlying the site are defined as the "Shirrell Heath 1 Formation", comprising well-drained, acid, sandy soils, with a bleached subsurface horizon (Ref. 55). In general terms, this formation is a podzol, which are typified by a leached sandy layer and are often associated with heathlands.

Across the site, during successive phases of construction, soils have been turned over leaving few areas of un-affected soils. Soils have also been imported onto the site. For example, following the demolition of the PIE facility in area A59, the excavation area was backfilled using soils sourced from off-site (Ref. 43).

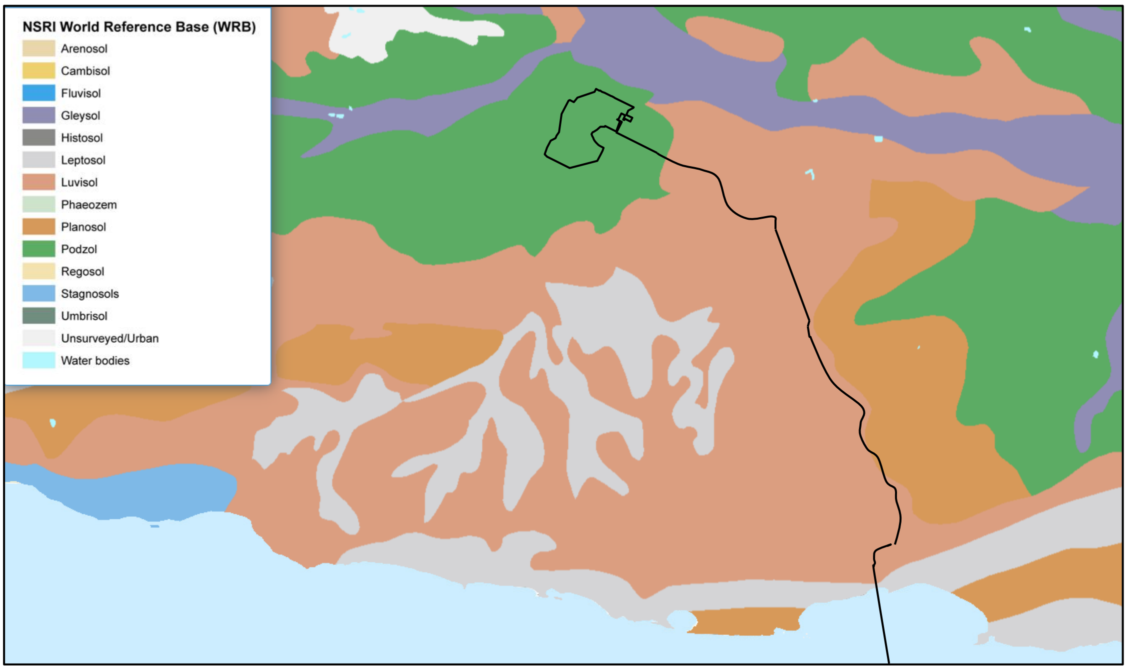


Figure 27: Map showing the soil types in the Dorset region (Ref. 31), with an indicative outline of the site location and route of the pipeline.

Soil types of the pipeline route

Along the route of the pipeline the soils are predominantly luvisols. These are marked with a surface accumulation of humus and a sub-surface horizon enriched in clay that has migrated from the leached layer.

4.1.2 Soil Chemistry

An assessment of the background concentrations of chemicals and radionuclides in the soil on the Winfrith site was made initially in 2004 and then supplemented by additional samples taken across the 'un-developed heathland' areas of the site, including samples collected from off-site areas (Ref. 45). Soil samples were taken at depths of between 0.0 m and 1.0 m below ground level (bgl) at the locations shown in Figure 28. A statistical methodology (Ref. 46) was used to reduce the bias associated with the presence of samples with concentrations below the limit of detection (LOD) and the consequent average concentrations for key analytes are presented in Table 2. These samples were also analysed for cadmium, mercury and selenium, but all but a very few analyses were below the LOD.

The chemical concentrations for Winfrith soils have been compared to mean concentrations of heavy metals and metalloids in rural UK soils. Mean concentrations have been determined by the EA as a baseline for assessing pollutant levels in UK soils and herbage (Ref. 47). Comparison of the measured Winfrith soil concentrations (Ref. 45) with the EA's reported rural soil concentrations from (Ref. 47) show that all measured analytes are lower than these concentrations defined by the EA baseline.

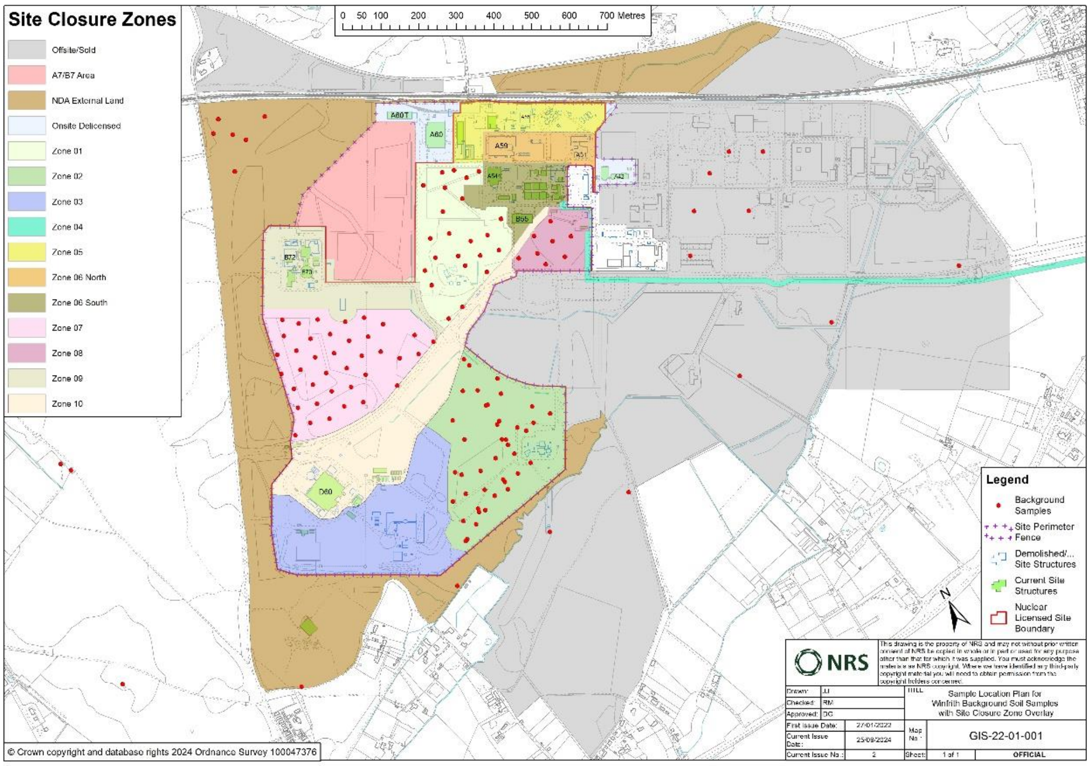


Figure 28: Sample location plan for Winfrith background soil samples (Ref. 100).

Table 2: Soil chemical concentrations for samples on the Winfrith site (Ref. 55) and rural soil concentrations (Ref. 57).

Analyte	**Average on-site soil concentration (mg kg^{-1}) (Ref. 45)**	***Mean UK Rural Soils concentration (mg kg^{-1}) (Ref. 47)***
Arsenic	1.7	*10.9*
Chromium	5.8	*34.4*
Cobalt	0.94	
Copper	2.9	*20.6*
Lead	5.1	*52.6*
Nickel	2.9	*21.1*
Zinc	8.6	*81.3*

4.1.3 Soil Radiochemistry

Samples from the boreholes on and around the Winfrith site assessed as being representative of natural heathland conditions were analysed for the naturally occurring radionuclides, and for positively identified anthropogenic and cosmic radionuclides (Ref. 45). A statistical methodology (Ref. 46) was used to reduce the bias associated with the presence of samples with concentrations below the LOD and activities of radionuclides resulting from historical weapons testing and nuclear accidents were decay-corrected to a common date. The average measured activities for selected radionuclides are given in Table 3 and are compared to the EPR23 exclusion levels (Ref. 48). The natural series are believed to be in secular equilibrium (Ref. 46) whereby background concentrations of daughter radionuclides, for example 234U and 226Ra, are identical to the parent radionuclide, for example 238U.

In almost all instances the Winfrith sample averages are below the EPR23 exclusion levels, with the exception of 232Th. The reason for these concentrations is unclear. 232Th is a primordial radionuclide with a half life in the order of 14-billion years. Given that 232Th is the main naturally occurring isotope of Thorium, it is hypothesised that the 232Th is naturally occurring.

Anthropogenic radionuclides from sources such as historical weapons testing and nuclear accidents, including 137Cs and 239/240Pu, show higher concentrations in shallower samples. Activities in shallow soils samples are consistent with those found elsewhere nationally (Ref. 104). In undisturbed soils from background sample locations, anthropogenic radionuclides are restricted to depths <0.3 m. Their presence in deeper samples is attributed to mixing in areas of made ground (Ref. 46).

Table 3: Soil radiological concentrations for samples from the Winfrith site (Ref. 55) compared to the EPR23 exclusion levels (Ref. 50).

Analyte	Average Activity ($Bq\ g^{-1}$)	EPR23 Exclusion Levels ($Bq\ g^{-1}$)
Gross Alpha	0.122	-
Gross Beta	0.123	-
^{238}U	0.0126	*1*
^{232}Th	0.0099	*.01*
^{235}U	0.0006	*1*
^{40}K	0.035	-
^{3}H	0.017	*100*
^{14}C	0.004	*10*
^{137}Cs (<0.3m)	0.0020	*1*
^{137}Cs (all samples)	0.0013	*1*
^{238}Pu	0.00003	*0.1*
$^{239/240}Pu$ (< 0.1m)	0.00088	*0.1*
$^{239/240}Pu$ (Full Depth)	0.00047	*0.1*

4.2 Superficial Deposits and Bedrock Geology

An understanding of the bedrock and superficial geology is needed to support modelling of groundwater flow and radionuclide transport. The superficial and bedrock geology in the region of the Winfrith site, in order of increasing depth, is summarised in Table 4 (Ref. 5). The superficial deposits and bedrock geology of the site are discussed in more detail in the hydrogeological interpretation report (Ref. 5).

Table 4: The superficial and bedrock geology in the region of the Winfrith site in order of increasing depth (Ref. 5).

Geological Group	Formation	Description	Approx. Thickness
Quaternary Deposits	Head	Poorly stratified clay, silt, sand, gravel and chalk	Up to 4 m. Locally absent
	River Terrace Deposits	Mainly angular flint gravel in a sandy, locally clayey, matrix	
	Alluvium	Soft, organic mud	
Bracklesham Group‡ (Palaeogene)	Poole Formation	Sand and clay	8 m or thicker to the south of the Winfrith site, and 30 m to the north-east
Thames Group (Palaeogene)	London Clay Formation comprising the West Park Member	Sandy clay and sand, locally pebbly	10 m or thicker to the south of the Winfrith site, thickness not proven to the north-east
White Chalk (Cretaceous)	Portsdown Chalk Formation	Chalk, soft, marly near base, flintier in upper part	Up to 130 m thick regionally

‡ Historically referred to as the Bagshot Formation / Bagshot Beds.

4.2.1 Superficial Deposits

Superficial Deposits on the Winfrith Site

Head deposits are present across much of the current site with River Terrace deposits extending across much of the eastern part of the site that has been decommissioned. Borehole logging has ascertained that the superficial geology on-site is 2-4 m thick (Ref. 5).

The River Terrace deposits present in the vicinity of the site are composed of sand and gravel and were formed in long-lived fluvial systems. Rivers deposit alluvium during flooding and later river incision erodes these layers forming terraces. Head deposits are composed of clay, silt, sand and gravel. They formed in sub-aerial slope environments, with down-slope layers and fans accumulating detrital material.

Superficial Deposits off the Winfrith Site

Off-site to the north, alluvium deposits are present along the River Frome. Alluvium consists of very fine-grained sheet-like deposits, which formed during periodic flooding of the rivers. Along the route of the pipeline there are a series of valleys containing head deposits, and the higher ground is characterised by “Clays with Flints”. These latter deposits are composed of clays, silts, sands and gravels formed from weathering of soils.

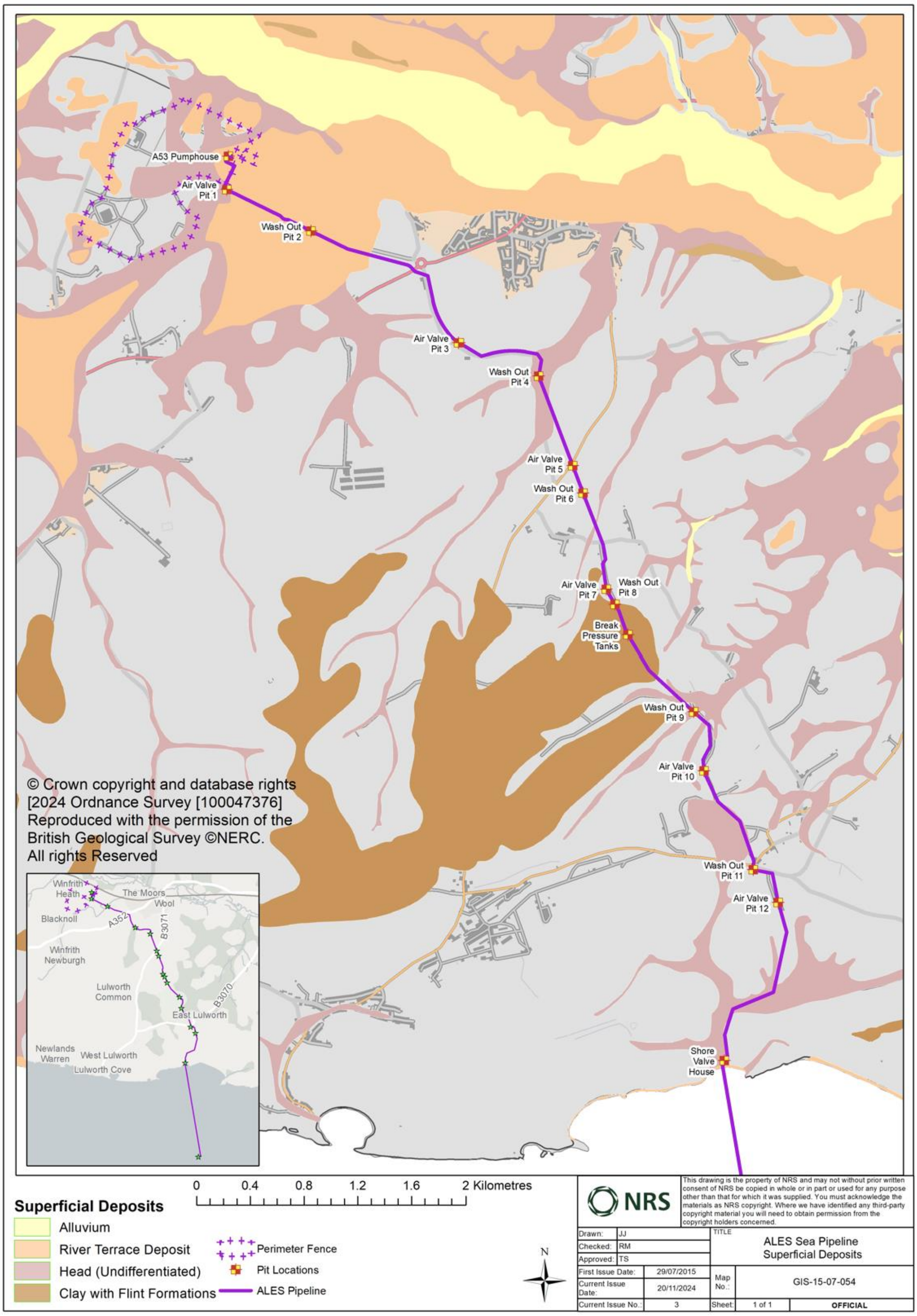


Figure 29: Map showing the regional superficial geology (Ref. 101).

4.2.2 Bedrock Geology

Bedrock Geology at the Winfrith Site

The bedrock geology of Dorset is dominated by Cenozoic and Mesozoic formations that are folded in a broad synclinal basin, termed the Wareham Basin. The southern half of this basin, which includes the Winfrith site, is shown in Figure 30. This folding is due to crustal compression in the Alpine orogenic foreland during the Cenozoic and has resulted in a large number of folds including the Purbeck Monocline, which forms the Purbeck Ridge (Figure 5). The main Cenozoic Groups underlying the Winfrith site are the Bracklesham and Thames Groups, of which the Poole and London Clay Formations are the main units (Figure 31) and these are underlain by the Mesozoic age White Chalk, of which the local formation is termed the Portsdown Chalk Formation. The Winfrith site is on the southern limb of a fold that plunges to the east so that locally the units dip to the north-east and regionally the units thicken eastwards (Ref. 5)

Regionally, bedrock units progressively increase in age southwards with the Poole Formation being the youngest (shown in Figure 30). The Poole Formation is between 30-40 m thick, although the spatial variation in thickness is poorly defined (SD-04). Beneath the Poole Formation is the London Clay Formation, similarly 30-40 m thick, which in turn overlies the Portsdown Chalk Formation. The base of the Chalk beneath the Winfrith site has not been observed, but boreholes adjacent to the site show the thickness to be greater than 100 m (Ref. 50).

The Poole Formation is a sequence of alternating clays and fine to coarse sands that formed in the Early to Mid-Eocene. The thickness of the sand units within the formation are 10-15 m thick on average (Ref. 49), with average particle sizes of 0.4-0.6 mm (Ref. 49), whilst clay units are 6–16 m thick on average (Ref. 49).

The London Clay Formation contains thin sand units with particles finer than the Poole Formation (0.22 mm on average) (Ref. 49) . The members of the London Clay Formation include the sandy West Park Farm sand and clay members (Figure 30), and the Warmwell Farm sands (Figure 30). Both the Poole and London Clay Formations were formed in environments dominated by swamps, estuaries and deltas.

Table 5 shows the physical properties of the Poole and London Clay Formations in the region, as well as for the superficial river deposits of the River Frome (River Terrace and Alluvium deposits are discussed in Section 4.2.1) (Ref. 5).

The Poole and London Clay Formations are underlain by the Portsdown Chalk Formation, which was formed in marine environments during the Cretaceous. The Portsdown Chalk Formation is part of the White Chalk which extends throughout Dorset (Ref. 52). The Chalk is underlain by progressively older marine sediments.

Bedrock Geology along the pipeline

Along the route of the pipeline, the dominant surface geology is the sandy member of the London Clay Formation (West Park Farm Member) and the Portsdown Chalk Formation, with the pipeline crossing the Chalk near Wool and again close to the coast.

At the coast, a sequence of progressively older Lower Cretaceous and Upper Jurassic sediments outcrop in the cliffs of Worbarrow Bay and these underlie the offshore route of the pipeline beyond Arish Mell (Figure 30 and 33). The sequence of Lower Cretaceous and Upper Jurassic sediments are partially overlain by Quaternary marine sediments.

During the installation of the pipeline, a series of reef formations that were formerly present at the surface as part of the Lower Cretaceous and Upper Jurassic formations were removed.

The bedrock formation where the pipeline terminates off-shore is the Kimmeridge Clay Formation.

Table 5: Particle size distributions of selected bedrock and superficial sand and gravel deposits (Ref. 50).

Geological Unit	Fines (<65 μm) wt. %	Fine Sand (65 μm-0.25 mm) wt. %	Med. Sand (0.25-1 mm) wt. %	Coarse Sand (1-4 mm) wt. %	Fine Gravel (4-16 mm) wt. %	Coarse Gravel (16-64 mm) wt. %
Poole Fm. (East)	12	36	48	2	2†	-
Poole Fm. (West)	6	19	65	8	2†	-
London Clay sands	16	49	32	2	1†	-
High level Frome Terrace	12	6	20	12	24	26
Low level Frome Terrace	5	5	22	13	25	30
Sub-alluvial Frome	5	5	28	14	21	27

† *Refers to all gravel >4 mm in size.*

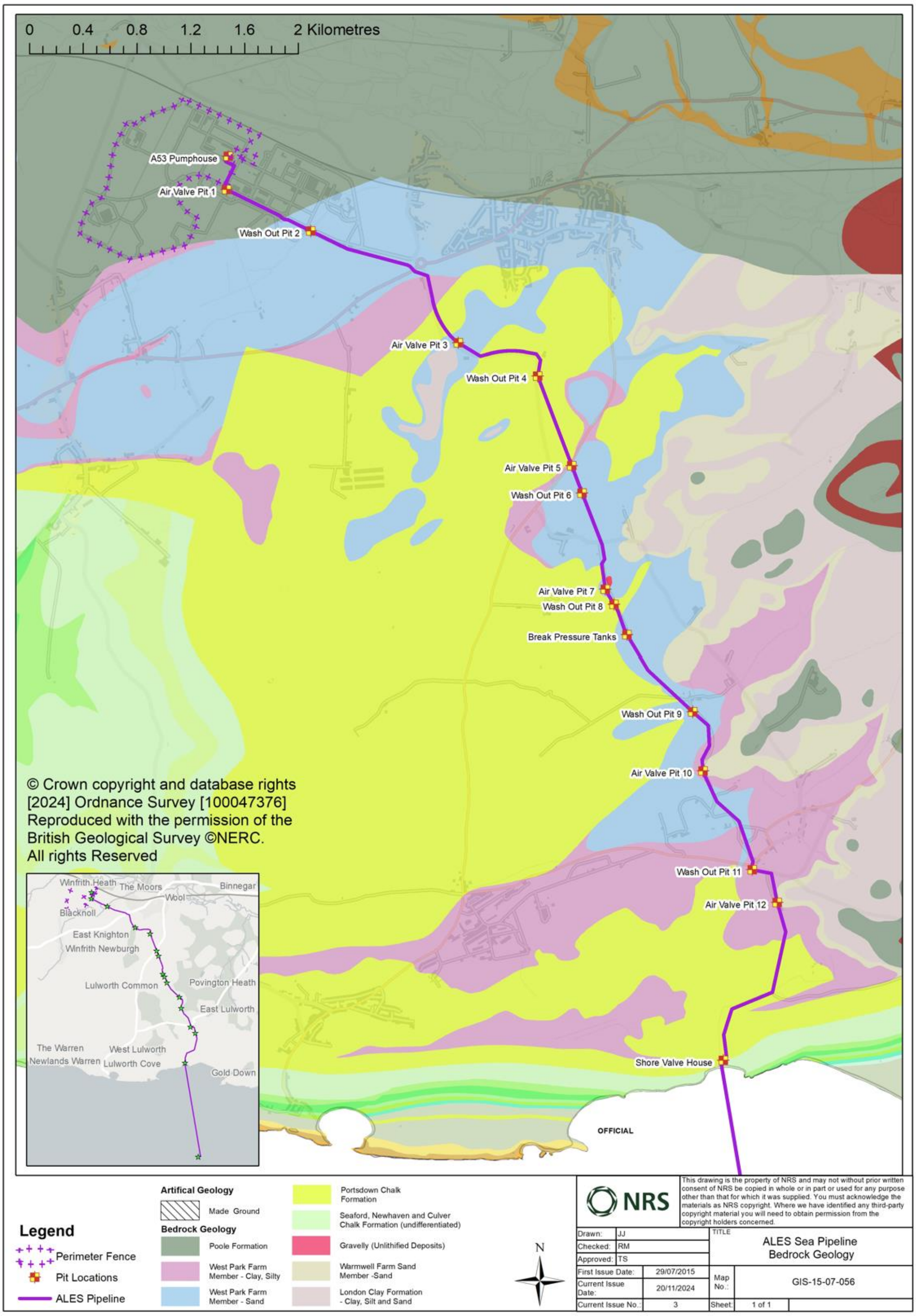


Figure 30: Map showing the regional bedrock geology (Ref. 50).

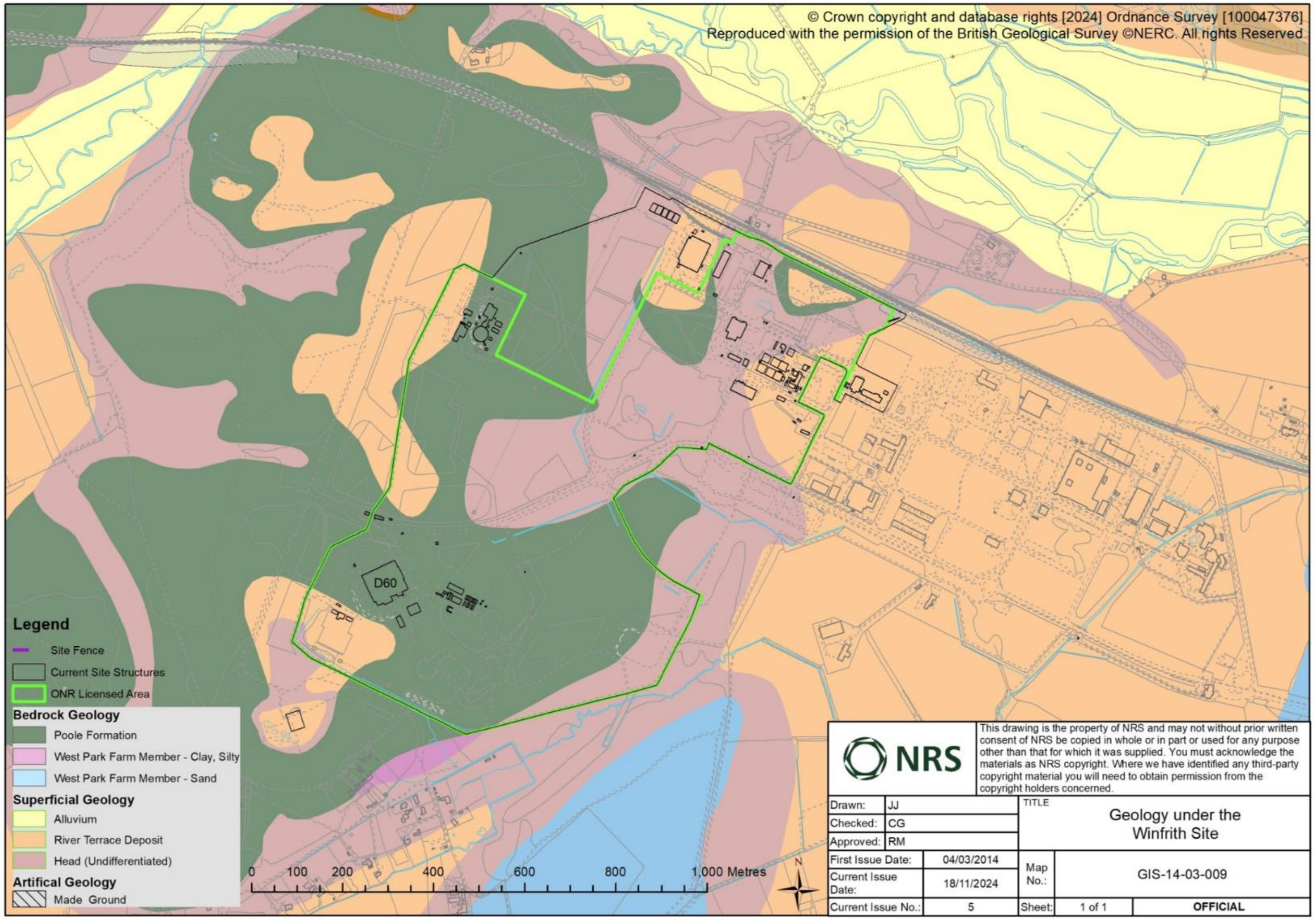


Figure 31: Bedrock and superficial geology of the Winfrith site (Ref. 102).

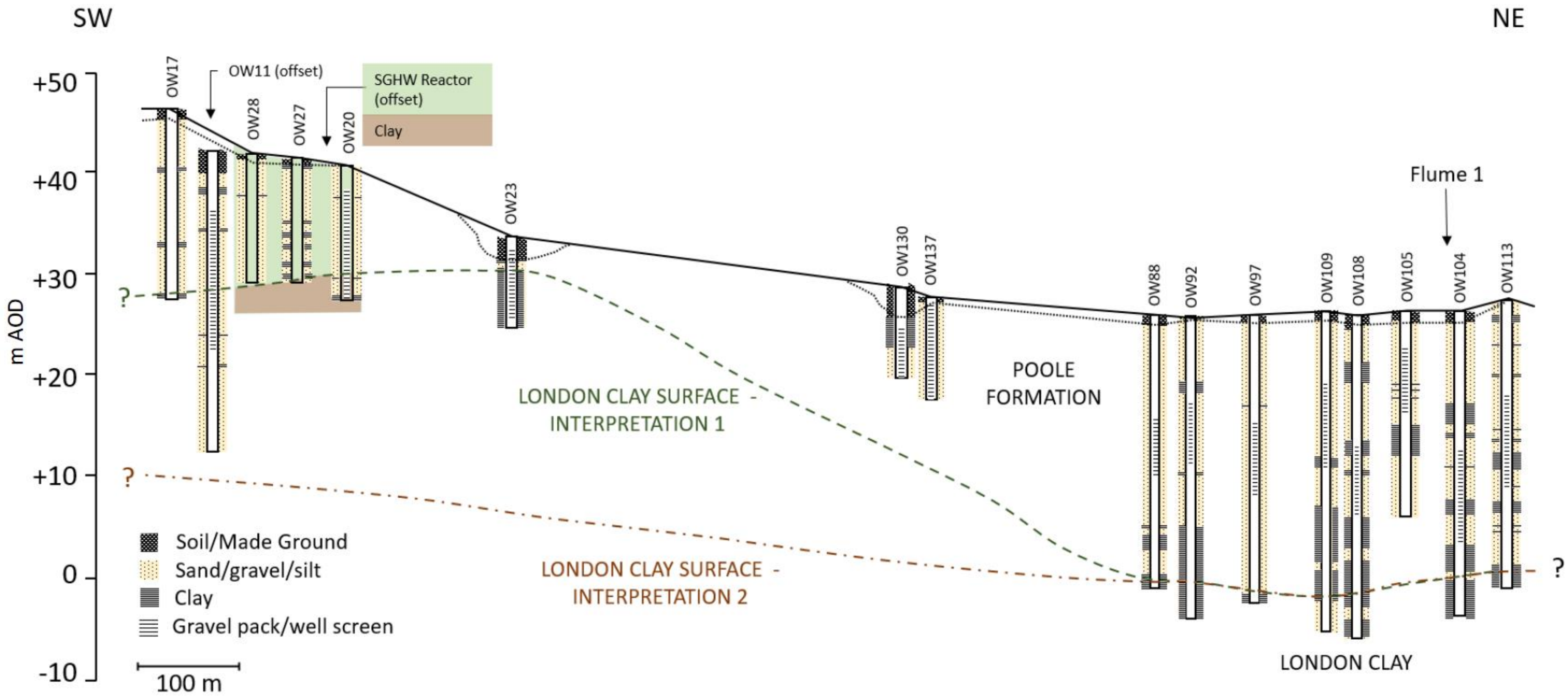


Figure 32: Geological cross-section south-west to north-east across the Winfrith site illustrating both conceptual interpretations for the southern part of the site (Ref. 5).

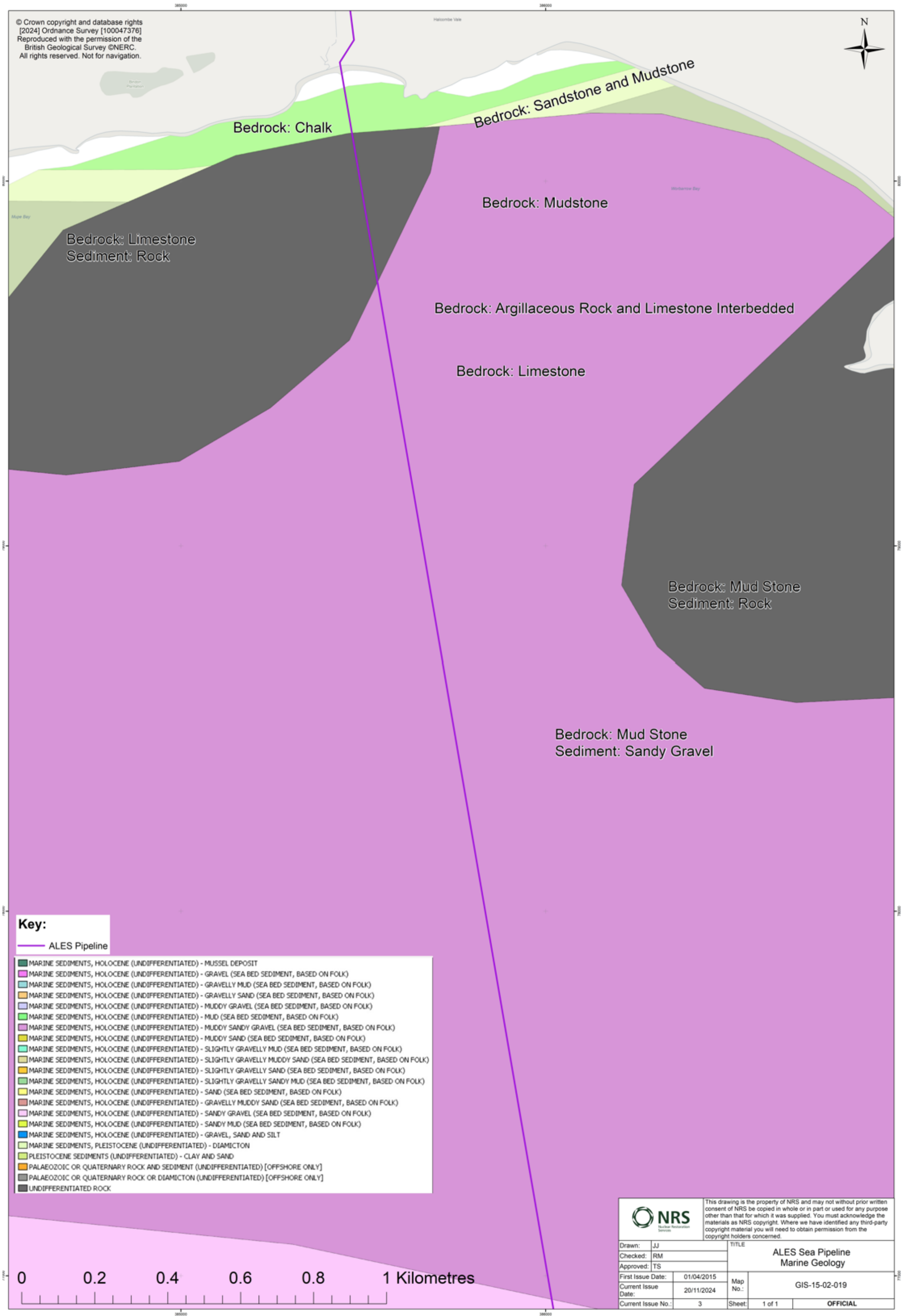


Figure 33: Map showing the offshore geology along the route of the pipeline (Ref. 51).

4.2.3 Transport Properties

Contaminant transport properties for different units of the geosphere on site (the Poole Formation and the River Terrace Deposits) are key inputs into radiological and non-radiological risk assessments. The hydrological properties of these units are described in the hydrogeological interpretation report (Ref. 5). A set of elemental sorption coefficients have been derived for the site (Ref. 52) and are reported in Table 6. These sorption coefficients are not measured using samples from the site but are measured using analogue geosphere materials. The values in Table 6 are assumed to be representative values for the formations beneath the Winfrith site (SD-06). Most of the sorption coefficients reported are identical for the two units (the Poole Formation and the River Terrace Deposits), with only Ni, Sr, Cs, Eu, Pb and Ra having different values.

Table 6: Transport properties of the River Terrace Deposits and the Poole Formation on the Winfrith site (Ref. 53).

Element	Elemental sorption coefficient ($m^3\ kg^{-1}$)	
	River Terrace Deposits	Poole Formation
H	0	0
C	0	0
Ni	0.1	1
Sr	0.02	0.07
Tc	0.0001	0.0001
Cs	0.5	0.4
Eu	0.4	2
Pb	0.2	10
Po	0.2	0.2
Ra	2	40
Ac	1	1
Pa	1	1
Th	3	3
U	0.2	0.2
Np	0.02	0.02
Pu	1	1
Am	1	1
Cm	1	1

Protection to the principal aquifer of the Portsdown Chalk formation is provided by an extensive thickness of London Clay. The sorption of contaminants (both radionuclides and chemical) on to is expected to lead to their retardation within the London Clay.

4.3 Resource Potential

The history of resource exploitation in the region is of importance in understanding the potential for future human intrusion on the site, as future generations may wish to further explore or exploit these resources.

Across Dorset a number of different minerals and resources have been exploited and several of these are subject to minerals policy and planning controls to ensure that they remain available. These include sand and gravel, industrial (silica) sand, Ball Clay, common clay, limestone, marble, chalk and some hydrocarbons. In the East Dorset region, the main resources are: sands and gravels (Section 4.3.1), Ball Clay (Section 4.3.2) and hydrocarbons (Section 4.3.3). These resources are considered due to the proximity of current extraction to the Winfrith site. Groundwater is a potential resource and is abstracted in the region; this is discussed in Section 5.5.

4.3.1 Sand and Gravel

The Cenozoic Poole and London Clay Formations, and Quaternary River Terrace deposits, provide extensive sources of exploitable sand and gravel in the region. In this case, sand and gravel are defined as:

- Gravel: material coarser than 5 mm, maximum size 64 mm.
- Sand: material coarser than 0.075 mm, finer than gravel (Ref. 49).

The physical properties of bedrock and superficial sand and gravel deposits are shown in Table 5.

The Poole Formation is the major bedrock sand resource in Dorset, containing a large proportion of medium sand. A number of quarries are in operation in the region surrounding the Winfrith site to extract sand and gravel (Figure 34), with the majority of quarried sand and gravel used to produce aggregate for concrete (Ref. 49). The London Clay has been less heavily worked due to the finer grain size (Table 5). The Poole Formation has also been exploited for silica sands (sands with a high proportion of quartz) to be used in industrial processes (Ref. 49). The distinction between sand and silica sand extraction locations has not been made in Figure 34 (SD-07, SD-08).

Superficial deposits in river terraces, including terraces of the River Frome, are the principal resource of gravels in Dorset. Table 5 shows that the deposits of the River Frome have a very high proportion of fine and coarse gravel, accounting for roughly 50% of the sediments in the units.

Figure 34 shows that there are no current plans for the extraction of sand or gravel on the Winfrith site. However, the presence of the Poole Formation and River Terrace Deposits at the site and along the route of the pipeline could potentially lead to exploration or exploitation in the future.

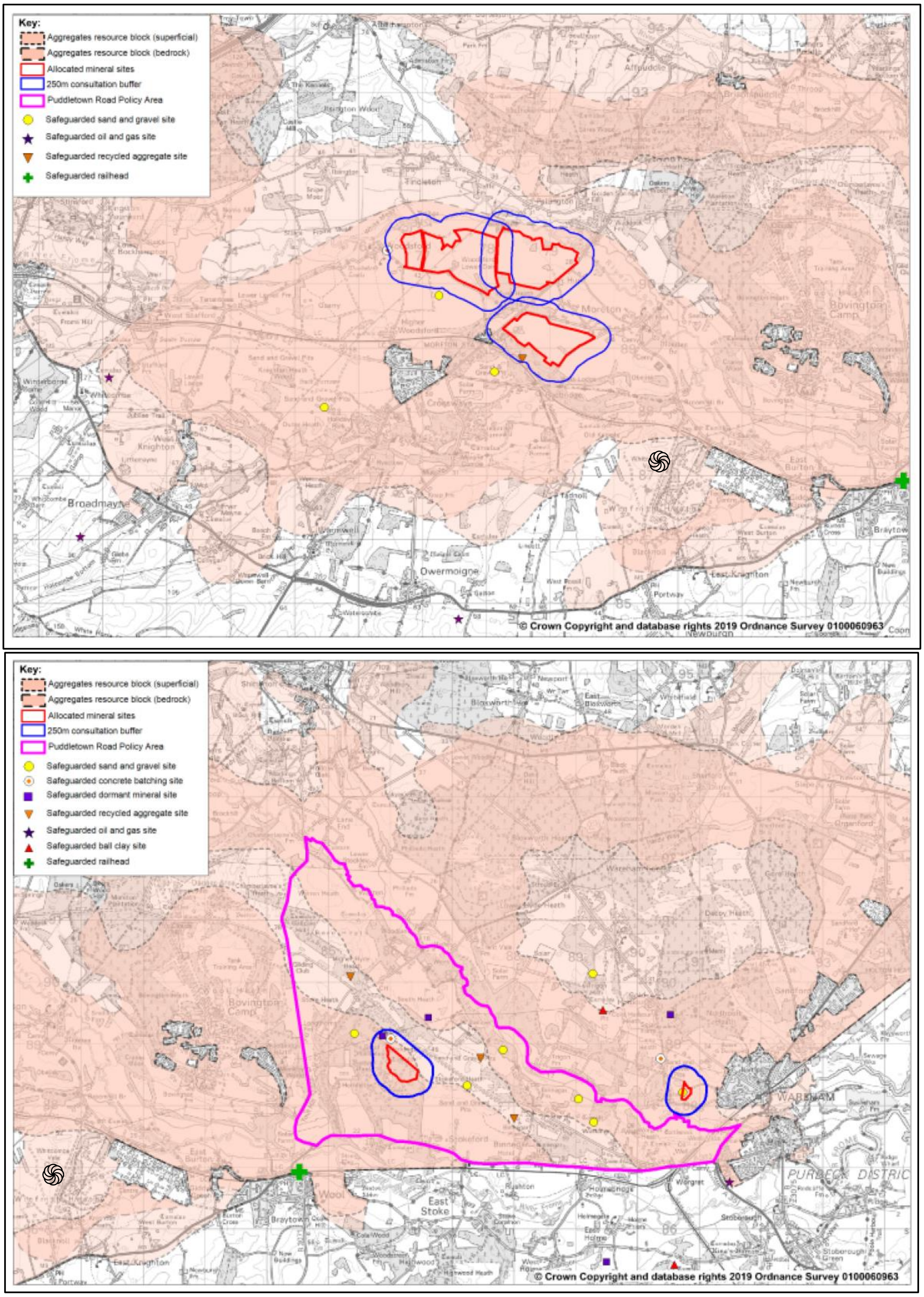


Figure 34: Maps showing the current areas of aggregate resource in bedrock and superficial deposits, and the location of existing (safeguarded) and potential (allocated) sites for sand and gravel, Ball Clay, and oil and gas extraction in the region around the Winfrith site (֍) (Ref. 53). The locations of these areas are not precise (SD-08).

4.3.2 Ball Clay

Ball Clay, a mixture of kaolinite, mica and quartz, has been extensively mined in Dorset. The name comes from the method used for mining, where the clay is mined as cubes, which become rounded during handling and storage. The Wareham Basin produces roughly half the total sales of Ball Clay in Dorset (Ref. 54) and accounts for 20% of national production (Ref. 49). The clay units of the Poole Formation (Parkstone Clay, Broadstone Clay, Oakdale Clay, and Creekmoor Clay Members) have the desirable properties for good quality Ball Clay (Ref. 49):

- High kaolinite content (>30 wt.%).
- Light-firing properties (low Fe-Ti oxides <3 wt.%).
- High plasticity (high proportion of fine kaolinite particles).
- Low carbon content (<0.3 wt.%).

Ball Clay is used in the ceramics industry (tiles, tableware, electrical insulators), and also as a filler in rubber and plastic products due to its high plasticity and strength properties. Ball Clay is mined at Trigon Hill, roughly 5 km away from the Winfrith site (shown in Figure 34). Future expansion of Ball Clay mining in the Wareham Basin is uncertain as only 1 million tonnes of permitted reserves remain, compared to 44.7 million tonnes in the Bovey region of West Dorset (as of 2011) (Ref. 54).

The Poole Formation on-site and in the region surrounding the pipeline is dominantly sandy rather than clay-rich, which will limit its potential use, future demand for Ball Clay may lead to more unconventional resources to be sought after. However, given the SSSI status of much of the Winfrith site and the pipeline, this resource is unlikely to include any on-site clay units.

4.3.3 Hydrocarbons

Oil and gas have been extracted on the Dorset Coast since the 1930s. Oil production is currently occurring at the Wytch Farm, Kimmeridge and Wareham fields. The Mesozoic-age Bridport Sands and Sherwood Sandstone are the principal units in which hydrocarbon shows have been observed (Ref. 49). The locations of boreholes for hydrocarbons are shown in Figure 35. The closest well to the Winfrith site was at Coombe Keynes (around 3 km from the site) where in 1989 minor oil shows were seen in the Bridport Sands and the Sherwood Sandstone (Ref. 49). This borehole has now been plugged and abandoned (Ref. 49). Close to the route of the pipeline, two other exploratory boreholes were drilled, the Chaldon Down 1 and 2 boreholes. Chaldon Down 2 is the closest borehole to the route of the pipeline (1.5 km west of the pipeline) and was drilled in 1939, with no oil shows observed. This borehole was plugged and abandoned in 1951 (Ref. 49, 55). Chaldon Down 1 (4 km west of the pipeline) was drilled in 1938 and abandoned in 1944, with no oil shows observed (Ref. 55).

The Wytch Farm field to the south-east of Wareham was discovered in 1974 and was Western Europe's largest onshore field, producing more than 100,000 barrels per day in 1997, although now reduced to about 13,000 barrels per day (Ref. 56).

The Wareham oilfield was discovered in 1964, with production starting in 1991. This field produced between 2,000–3,000 barrels per day from two well sites located west of Wareham (Ref. 49, 56), production has since dropped to far lower levels.

Beyond the currently producing fields, exploration drilling has produced limited oil shows, suggesting that large reserves do not exist elsewhere in Dorset (Ref. 49). Nevertheless, there is a potential for future exploration of specific targets such as stratigraphic traps. The Kimmeridge Clay, which is present at depth below parts of the pipeline route (Figure 33), contains oil shales which in places have been suggested as a potential target for gas production using fracking. In this part of Dorset, however, this formation is considered to be too shallow for fracking and the underlying Lower Lias has not been shown to have the oil shale quality of the Kimmeridge Clay.

Despite a number of exploratory boreholes being drilled in the region, there have been no significant finds and so there is unlikely to be much future exploitation near the site. However, if there is increased demand for oil and gas in the Dorset region, there may be potential for further exploration in the region.

Figure 35: Location of hydrocarbon wells in the region surrounding the Winfrith site and the pipeline (Ref. 50).

4.4 Natural Disruptive Events

Natural disruptive events that could potentially affect the Winfrith site or the pipeline in the short-term are erosion (Section 4.4.1) and earthquakes (Section 4.4.2). Flood events are also potential natural disruptive events on the same timescales. These are considered in association with the description of surface and groundwater systems in Section 5.6.

The potential increase in natural disruptive events due to climate change is discussed in Section 6.

4.4.1 Erosion

Erosion may refer to coastal or surface erosion, and both are considered in this section.

Coastal Erosion

Coastal Erosion on the Winfrith Site

The proposed on-site disposals are approximately 6km from the coast and coastal erosion is excluded from assessment.

Coastal Erosion on the Winfrith Pipeline

The South Dorset coast comprises a range of rock types and geomorphological features, so that rates of coastal erosion are variable along the coast. The section that includes Arish Mell and the outfall of the sea pipeline is characterised by rocky cliffed shorelines, with erosion risks assessed as generally low due to the resistant nature of the cliffs (Ref. 57). There are, however, sections dominated by clay-rich cliffs, which experience episodic landslide events, causing tens of metres of retreat as a result of a single event.

Sea-level rise is expected over the next few centuries because of increasing global temperatures and thermal expansion of the oceans. Estimates of the extent of this rise are dependent on the assumptions made about greenhouse gas emissions and consequent climate change. Guidance from the EA and ONR (Ref. 58, 59) encourages use of the UKCP18 credible maximum climate change scenario for assessing sea-level rise. For the Dorset coast, the central estimate for this scenario is a rise of 0.7 m by 2100, with a range from 0.45 m to 1.05 m (Ref. 60). Using the exploratory post-2100 sea level rise dataset (Ref. 60), the corresponding estimate for 2300 would be 2.6 m with a range of 1.4 m to 4.3 m. Such rises, potentially exacerbated by increased storminess as a further consequence of climate change, may increase the rates of coastal erosion through under-mining of cliffs.

Sea-level rise will lead to inundation of the valley leading to Arish Mell. There may be associated erosion of unconsolidated materials along the beach, but there is no cliff at the point where the pipeline reaches the coast and erosion of the underlying rocks is expected to be limited. Current Shoreline Management Plans (Ref. 57) indicate that there are no planned interventions along this stretch of coast.

Surface Erosion

The principal types of surface erosion are soil erosion, through wind or rainfall, and fluvial erosion, through incision or migration. Soil erosion is of considerable concern across the UK and is of concern in the Winfrith region due to the agricultural land use (Section 2.4), although mapping by the European Soil Data Centre (Ref. 61) indicates rates of less than 5 te ha^{-1} yr^{-1} for soil erosion by water in the Dorset region (SD-11). Erosion is also of concern for heathlands, with special consideration being given to understanding heaths near urban areas in Dorset (Ref. 62, 63). One of the main causes of erosion is public access and associated trampling of soils (Ref. 64). The clay-to-silt content of soils will affect erosion, with more silty soils more susceptible to erosion, while more clay-rich soils are less susceptible (Ref. 26).

Heathlands are susceptible to fire (Ref. 65). Hot, dry summers and arson are the most common causes of heathland fires. It is understood that five heathland fires have occurred within a 5 mile radius of the site in the last 10 years. Fires not only damage the local environment, but they may also be a hazard to people and fauna in the area, may damage infrastructure on site, and can lead to significant erosion, as bare soils will be more readily eroded by winds. Heathland fires affecting the site cannot be ruled out but are not expected to significantly increase surface erosion as burned heather should continue to protect the soil until regrowth is established.

Erosion along the River Frome can be significant. On 16 February 2018 part of the wall foundation of the Grade II* listed Wool bridge slumped due to erosion (Ref. 66). Erosion at meander bends has also been observed (Ref. 26). Both the site and the pipeline are far enough away from the River Frome and any other large water course that river erosion is assumed not to have any effects over the timescales of concern (SD-12).

4.4.2 Seismic Events

The UK is in a geologically inactive setting at present, situated far from any plate boundaries, and levels of seismicity are characteristically low. However, the UK does experience a few earthquakes of local magnitude ML > 4 per decade. The largest instrumentally recorded earthquake close to the Winfrith site was a ML = 2.9 event that occurred on 23 March 1998 near Weymouth. Figure 36 shows a map of all earthquakes measured in the region (1970-2022) and historic data (1700-1970). Future earthquakes are predicted to be ML < 4 (Ref. 67).

The chance of future earthquakes in the UK was assessed by splitting the region into a series of 23 seismic zones, with Winfrith located in V1L, a region of low seismic hazard, covering Devon, Somerset and Dorset (Ref. 68). For each zone the mean number of events with moment magnitude MW ≥ 4.5 was modelled for a 300 year period and then compared to the number of observed events in the past 300 years (Ref. 69). Seismic zone V1L is expected to experience 0.06 MW ≥ 4.5 events in the next 300 years, while the region has experienced no events of such magnitude in the last 300 years. This zone is the joint least active of the seismic zones considered, alongside Zone SC3M (containing the Midland Valley of Scotland).

Predicted peak ground acceleration rates for Dorset are also expected to be low, with accelerations of 0.00-0.02 g for a 475-year return period, and 0.02-0.04 g for a 2,500-year return period (Ref. 69), where g is the acceleration due to gravity (9.81 m s-2). The low likelihood of large earthquakes occurring in the area coupled with only minor ground motions means that seismic hazard is likely to be insignificant at Winfrith.

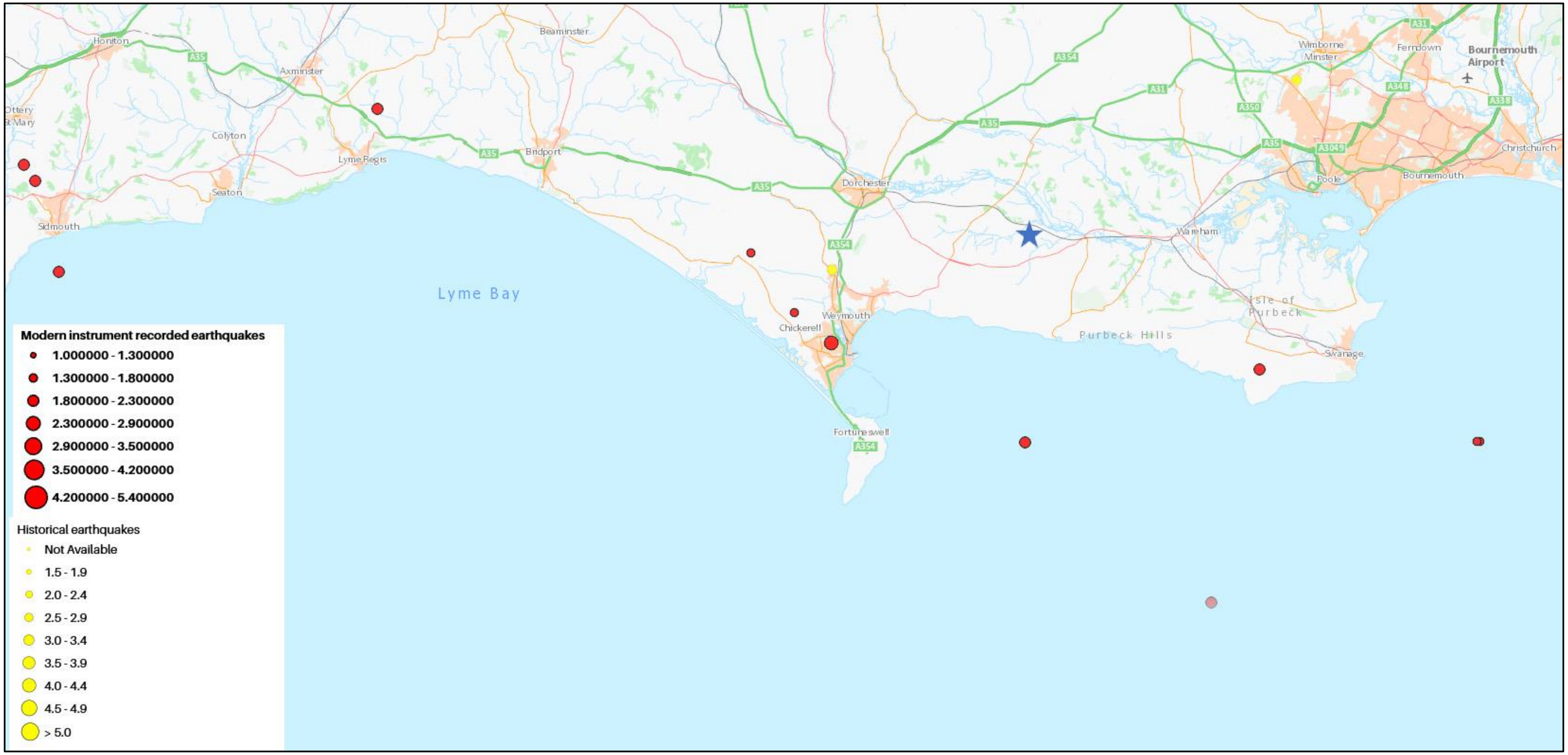


Figure 36: Map showing the historical (yellow) and instrumentally recorded (red) earthquakes in the region surrounding the Winfrith site (marked with a blue star) (Ref. 69), Modern instrument recorded earthquakes and historical earthquakes).

5 Surface and Groundwater

The location and behaviour of surface and groundwaters is of importance in understanding the potential migration of contaminants from waste disposals. This section provides information on the historical and current climate conditions that influence the present-day hydrology and hydrogeological conditions. The potential for future changes in the climate and associated changes in water movement are presented in Section 6.

A summary of the conditions on the site is provided, based on the hydrogeological interpretation presented in (Ref. 5), and this is extended to include the region around the site relevant to the pipeline.

5.1 Climate

Historical rainfall data is available for the site from a rain gauge located adjacent to ALES that operated between 1961-2008 (Ref. 70). More recently, a tipping bucket rain gauge was installed, becoming operational in August 2022. The data from this gauge is downloaded monthly.

The average annual rainfall over the period 1961-2008 was 919 mm, with average winter (November–February) monthly rainfall of 100.2 mm and average summer (June–September) monthly rainfall of 58.5 mm[6].

The UK Government, via the Met Office and Department of Food and Rural Affairs (Defra), produces climate records and projections in order to understand and assess plausible future climate projections. The most recent data sets that are publicly accessible (UKCP18) (Ref. 71) have been used here. As part of these studies, past climate variables (e.g. mean daily maximum temperature, mean daily minimum temperature, precipitation) are available for the UK at up to 1 km × 1 km resolution. Data for the site are obtained through the UKCP user interface using the coordinates E381500 N086900 for the site. Confidence in the UKCP09 model is discussed in SD-19 in Appendix C.

Using the UKCP18 data (Ref. 71), average monthly values of maximum and minimum temperature, rainfall and sunshine have been derived for the Winfrith location as presented in Table 7. Long-term averages are derived using data for the interval 1919-2020 inclusive. Recent averages, over the period 2015–2020, are also included for comparison. The long-term average for annual rainfall gives a value of 926.3 mm, consistent with the published annual rainfall total of 919 mm for the Winfrith site (Ref. 70).

Decadal averages for January and July have also been derived and these are presented in Figure 37 to Figure 40, with the decadal average annual rainfall also included in Figure 39. In general, temperature variation is limited (Figure 37 and Figure 38), although there has been an increase in minimum and maximum temperatures for both June and January since the 1950s. Annual rainfall has been variable over the previous century, with an extreme low of 495 mm yr^{-1} corresponding to the drought of 1921 and an extreme high of 1,346 mm yr^{-1} in 1960. The January and July monthly averages broadly mirror one another (Figure 39). Variation in hours of sunshine is limited (Figure 40).

6 The hydrogeological interpretation (Ref. 5) uses a slightly shorter rainfall record (1961-2004), but the corresponding average values of 919.5 mm, 97.9 mm and 58.9 mm are effectively the same as for the longer record.

Table 7: UKCP18 climate projections for E381500 N086900, data adapted from (Ref. 94). Long-term averages of maximum and minimum temperature, and rainfall, are taken from 1919–2020. Recent averages are taken over the period 2015–2020.

Month	Long-term Ave. Max. Temp (°C)	Recent Ave. Max. Temp (°C)	Long-term Ave. Min. Temp (°C)	Recent Ave. Min. Temp (°C)	Long-term Sunshine (hours)	Recent Sunshine (hours)	Long-term Rainfall (mm)	Recent Rainfall (mm)
Jan	8.3	9.5	2.5	2.8	61.6	76.2	103.7	120.2
Feb	8.3	9.4	2.4	2.8	78.8	107.5	73.2	82.2
Mar	10.4	11.2	3.0	4.0	127.8	135.3	68.7	79.4
Apr	13.2	14.5	4.4	5.2	176.4	208.6	57.1	46.2
May	16.3	17.5	6.9	7.6	211.5	247.8	53.8	46.1
Jun	19.2	19.9	9.8	10.8	218.8	214.1	48.7	46.5
Jul	21.0	22.1	11.5	12.3	218.0	239.4	54.7	40.3
Aug	20.8	21.3	11.5	12.3	201.8	197.2	66.2	70.7
Sep	18.6	19.1	9.7	10.1	153.8	170.3	75.4	85.0
Oct	15.1	15.5	7.4	7.9	112.7	116.3	101.6	105.5
Nov	11.2	12.1	4.2	5.4	75.5	85.7	111.8	112.2
Dec	9.0	10.8	3.0	4.8	56.0	59.8	111.7	121.7
Annual					**1692.6**	**1858.1**	**926.3**	**956.1**

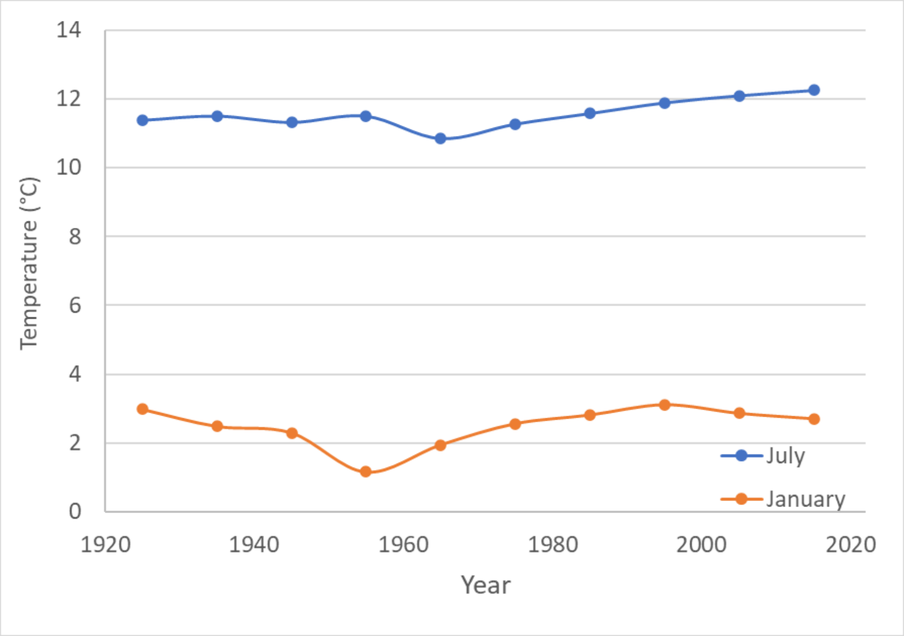


Figure 37: Decadal January and July average minimum temperatures for E381500 N086900. Year refers to the middle of the decadal span (i.e., 1955 is for the time span 1950-1959 inclusive) (Ref. 71).

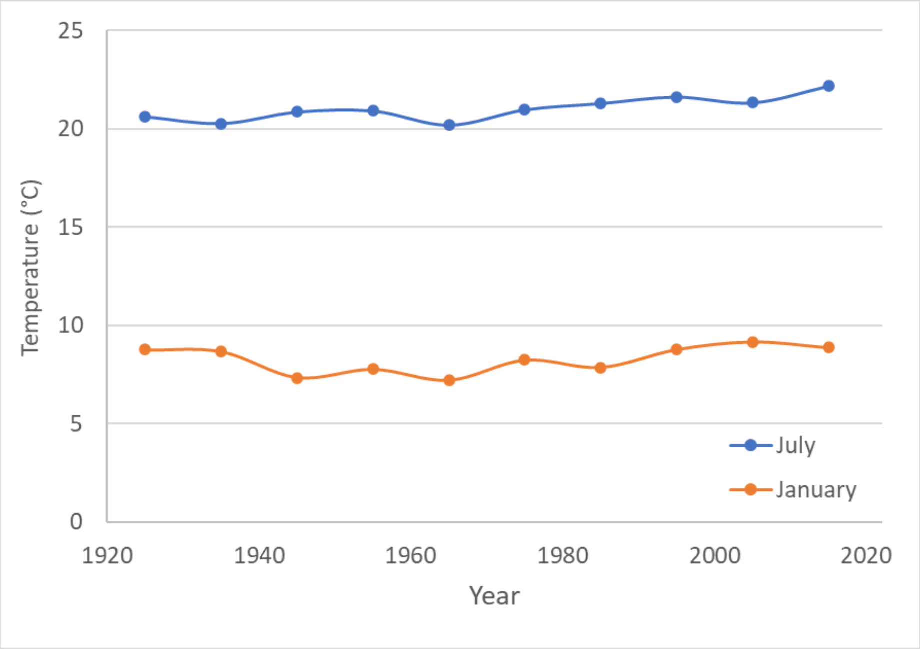


Figure 38: Decadal January and July average maximum temperatures for E381500 N086900. Year refers to the middle of the decadal span (i.e., 1955 is for the time span 1950-1959 inclusive) (Ref. 71).

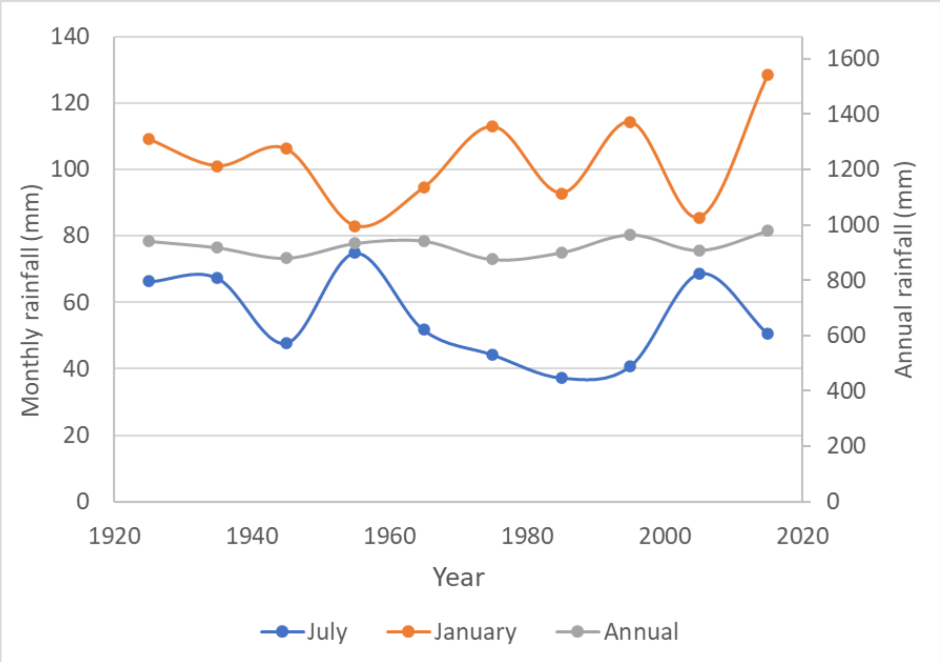


Figure 39: Decadal January, July and Annual average rainfall values for E381500 N086900. Peak in 2016 January data is due to extreme rainfall in 2014 and 2016. Year refers to the middle of the decadal span (i.e., 1955 is for the time span 1950-1959 inclusive) (Ref. 71).

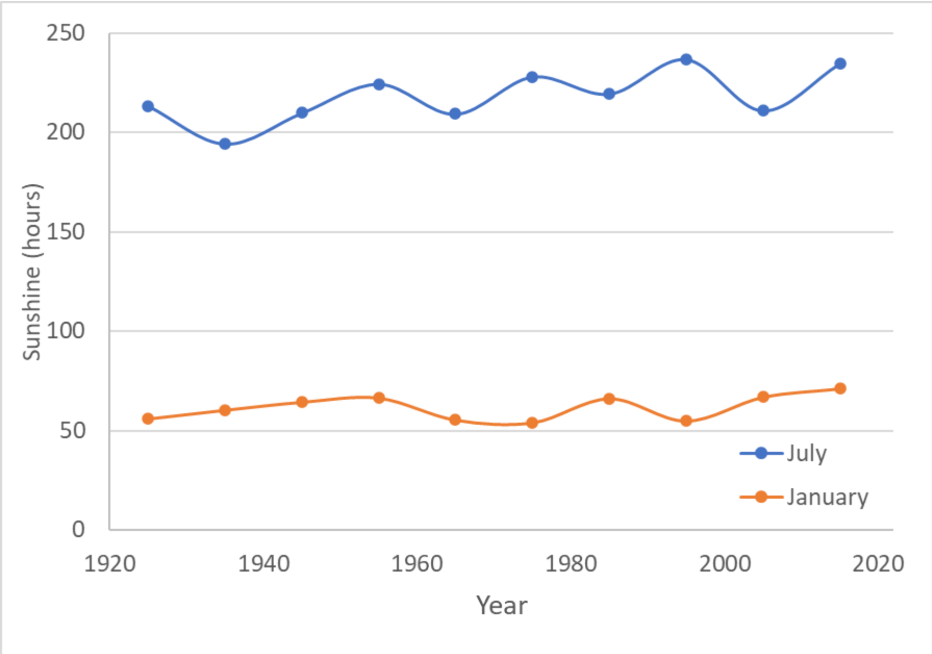


Figure 40: Decadal January and July average hours of sunshine for E381500 N086900. Year refers to the middle of the decadal span (i.e., 1955 is for the time span 1950-1959 inclusive) (Ref. 71).

5.2 Surface Water Flows

The two main rivers close to the site are the River Frome, located approximately 300 m to the north of the site and which flows towards the east, and its tributary, the River Win, located south and east of the site and which flows roughly north east towards the River Frome.

Flow data for the River Frome are available for the flow gauging station at East Stoke, approximately 6 km downstream of the site (Ref. 72) (EA Station No. 44001). Based on the data in the period 1965 to 2021, the mean daily flow rate is 6.72 m^3/s. The River Win has been gauged for flow by the Environment Agency (EA Station No. 445930 Win) and the estimated daily mean flow near the site for the period 1975 to 2022 is 0.038 m^3/s (Ref. 73). The River Win meets and discharges into the River Frome around 1.5 km east-north-east of the site.

Rainfall runoff at the site is primarily drained through an extensive network of surface water and land drainage systems that were emplaced during the late 1950s. These can be broadly categorised into three groups (Ref. 5):

- Surface water drains (Figure 41), consisting of a series of salt-glazed clay pipes (Ref. 74), which collect rainfall runoff from impermeable areas, such as the roofs of buildings, and discharge it into either the local watercourses (in some cases via flumes, Figure 42) or soakaways.
- Surface French drains, that encourage direct infiltration of rainfall-runoff into the soil.
- Buried rubble drains / open-channel ditches (Figure 41) that collect, store and convey drained surface water into local watercourses (in some cases via flumes, Figure 42). The open-channel ditches are subject to maintenance that involves clearance of vegetation.

Surface water and rubble drains reduce the areas of waterlogging and the risk of flooding on the site (Ref. 74). The rubble drains are particularly important for controlling groundwater elevations in regions where they intersect groundwater. Other drainage structures are only likely to interact with groundwater levels when structurally degraded. Based on groundwater contours there is no indication that significant leakage to groundwater is occurring from below-ground pipes. Some of the surface flow at the site is often routed along the roads, especially Monterey Avenue (the main north-east to south-west road by SGHWR). Across the site, depressions in the land surface lead to surface water ponds, which are mostly fed by rainfall and some by shallow groundwater (Ref. 10).

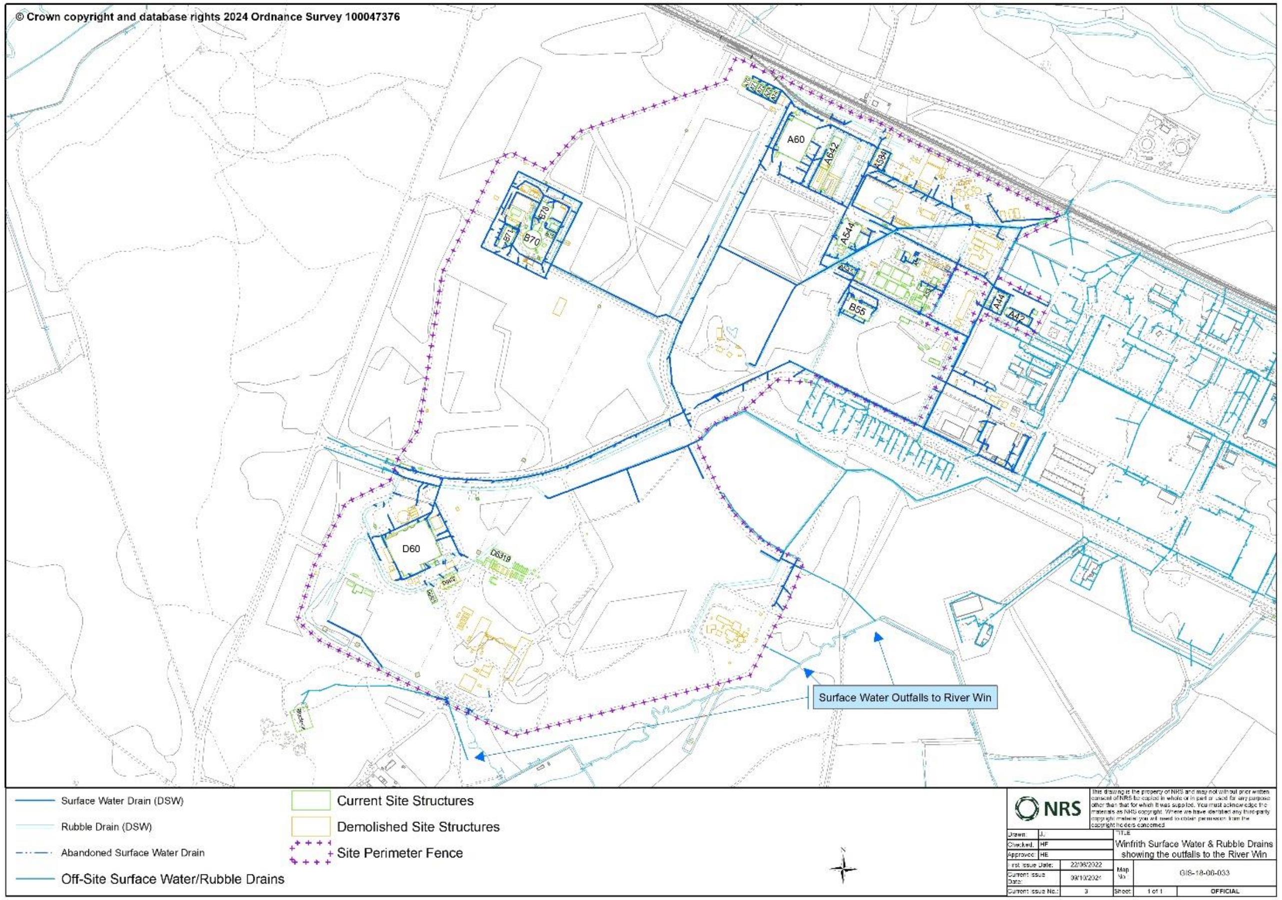


Figure 41: Map of the Winfrith site surface water and rubble drains; outfalls to the River Win are highlighted (Ref. 75).

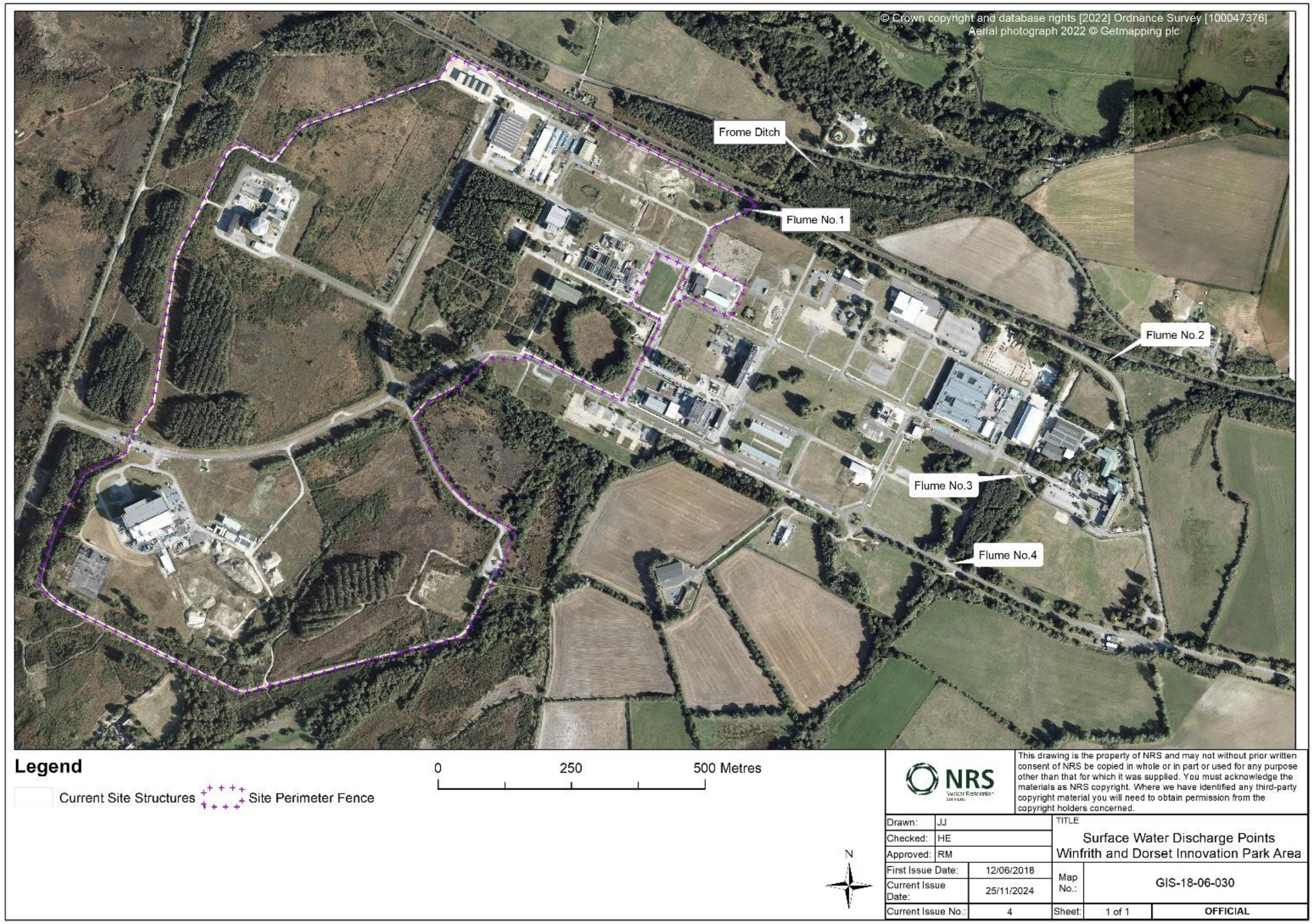


Figure 42: Plan of surface water discharge points on the Winfrith site (Ref. 76).

The site can be split into two rainfall catchments; the majority of the site is drained to the north and north-east towards the River Frome and a small portion to the south of the site drains south and south east towards the River Win (Ref. 5). The approximate divide between the southern and northern catchment areas is shown in Figure 43. The water collected by the surface water drainage network in the northern catchment is directed through the main 48" drain into Flume 1, which travels under the railway track and discharges into the Frome Ditch and then into the River Frome itself. In a risk assessment of tritium and other contaminants in discharges from the site, a comparison of flow rates in Flume No. 1 and the River Frome indicated a dilution factor of 2,500 (Ref. 77).

Surface water discharges to the River Win through a number of surface water outfalls to the south and east of the site or via the surface water drainage system of Dorset Innovation Park (Figure 41 and Figure 42).

ALES and the transient foul system are known to intercept some groundwater through degraded pipe joints. The intercepted groundwater is accounted for in models (Ref. 5, 7). The groundwater is not used for any active processes. Some surface water is also intercepted and discharged from the site by ALES through the pipeline.

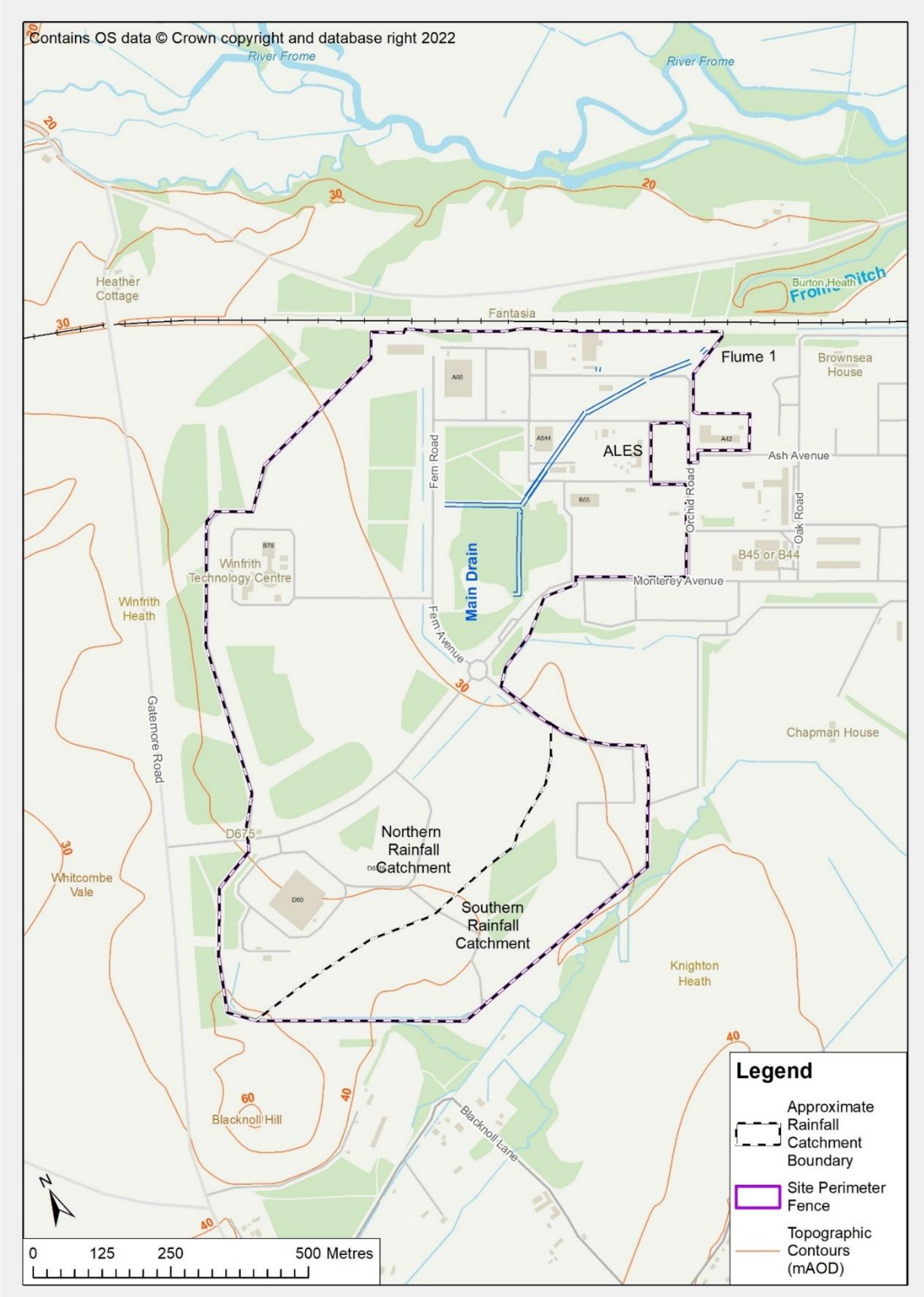


Figure 43: Surface water drainage catchments and water courses on the Winfrith site (Ref. 5).

5.3 Hydrogeology

Groundwater flow in the Chalk aquifer is controlled by the topography of the region, with recharge dominating where the Chalk outcrops on higher ground. To the west of the Winfrith site, groundwater from the Chalk discharges in the lower-lying areas of the Frome and Piddle valleys. Beneath the site and to the east, however, the Chalk is confined beneath the Palaeogene deposits.

Groundwater flow in the Poole Formation is typically controlled by the synclinal basin structure, with recharge occurring at the edges and discharge in the lower-lying areas of the Frome and Piddle valleys. In the region of the site, this pattern is shown in Figure 32 with the units dipping towards the north-east (Ref. 5). Groundwater recharge has been calculated in the hydrogeological interpretation report which adopts the BGS recharge projections for the Lower Frome and Piddle catchment. This approach yielded an average recharge of 279 mm/year for 2020, with a range of 252 to 319 mm/year (Ref. 5).

The hydrogeology of the region in terms of aquifer productivity is shown in Figure 45. The productivity of the aquifers matches the geology of the region, with the Poole Formation being classified as a moderately productive aquifer (Figure 45), where transport through the intergranular matrix dominates. The Portsdown Chalk is classified as a highly productive aquifer, where flow is dominantly through a fissure network. The impermeable London Clay is classified as a formation with essentially no groundwater. Close to the coast, the layered Mesozoic sediments beneath the Portsdown Chalk alternate with productive and unproductive aquifers.

Across the Winfrith site the groundwater is generally less than 4 m below the surface, with a seasonal range between 0.5m and 1.0m (Ref. 10). The hydrogeology of the site is dominated by the near-surface sands of the Poole Formation and the Quaternary deposits that affect shallow groundwater flow. On a small scale, local flow is difficult to predict due to lateral discontinuities in sandy and clay beds within the Poole Formation. Perched aquifers are found within the Poole Formation, where locally clay-rich layers hinder infiltration and lead to perching of groundwater. The hydrogeological interpretation of the site that is used in the hydrogeological interpretation and modelling is shown in (Figure 44).

Most of the groundwater beneath the site flows in a north and north-easterly direction towards the River Frome while a portion flows more easterly towards the River Win (Ref. 5). The groundwater divide between these flows is positioned south of the SGHWR in the vicinity of the former EAST facility (Figure 43). Modelling predicts that as groundwater levels become lower the groundwater divide moves in a southerly direction, such that in drought conditions all groundwater flow on site is towards the River Frome.

The hydrogeology of the site including groundwater level, flow and discharge is discussed in further detail in the hydrogeological interpretation report (Ref. 5).

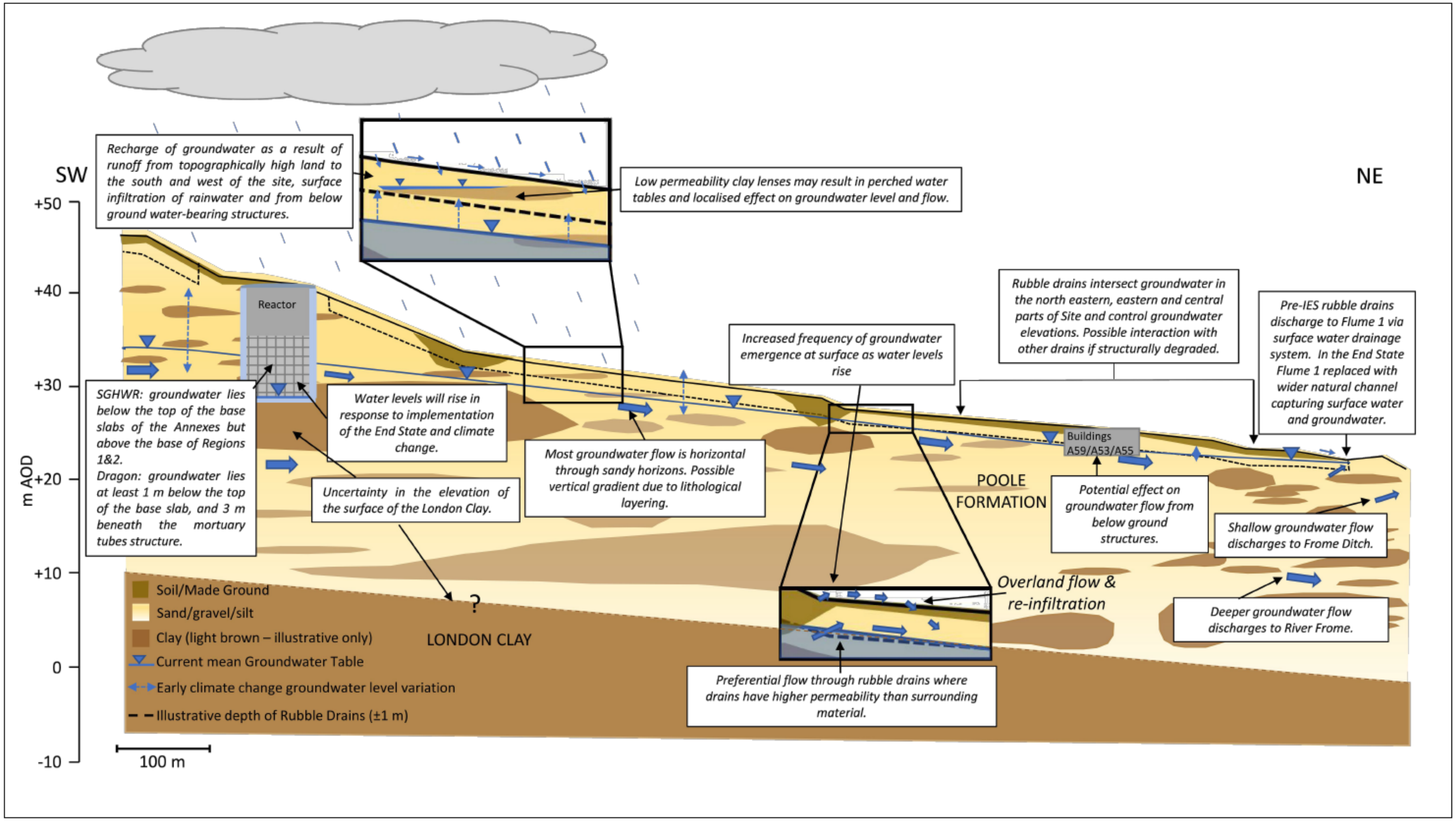


Figure 44: Hydrogeological interpretation of the Winfrith Site (Ref. 5).

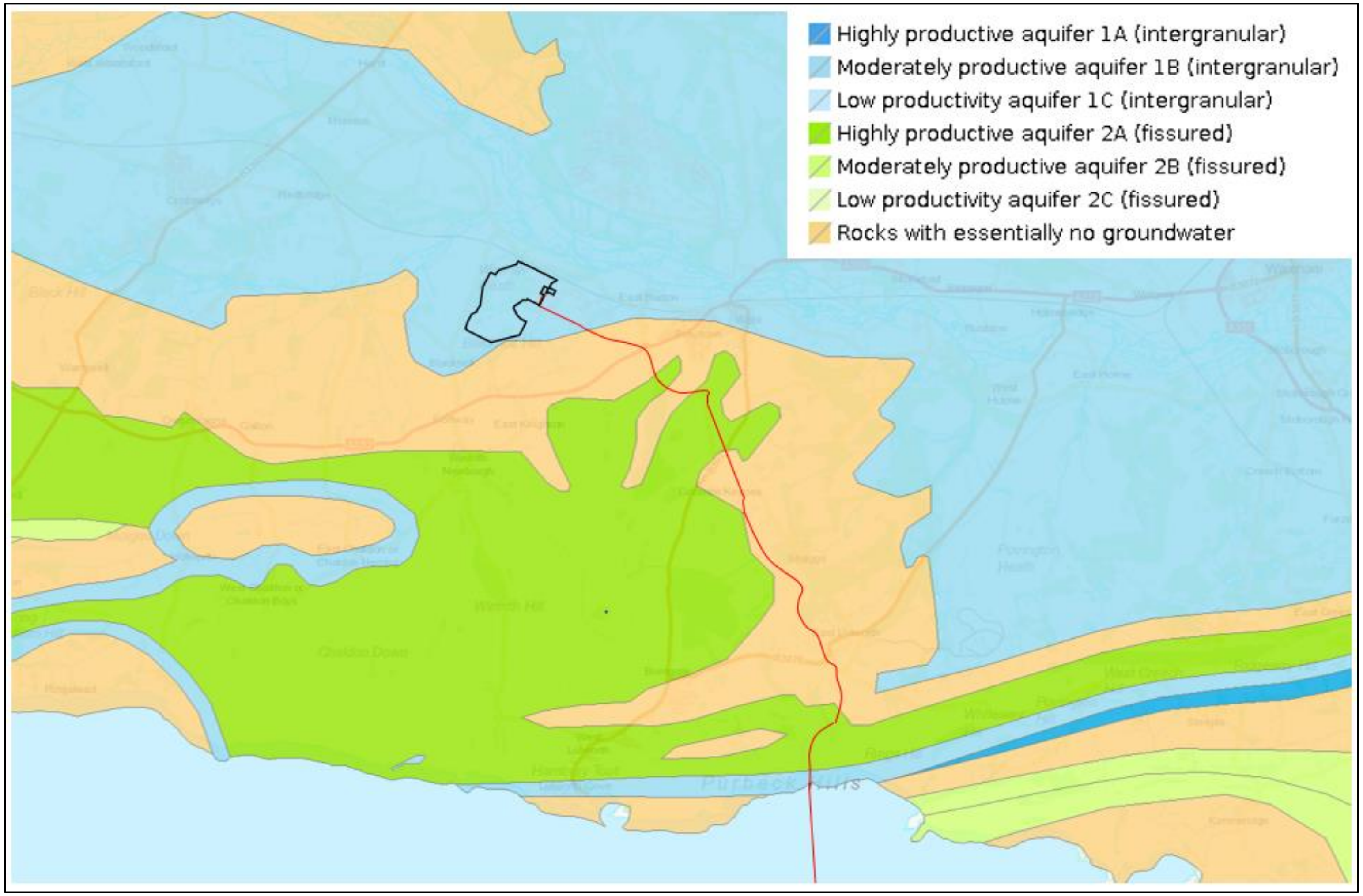


Figure 45: Hydrogeology in the region around the Winfrith site showing the productivity of the Hydrogeology (Ref 5) (1:625,000 scale).

5.4 Hydrogeochemistry

The chemistry of the site groundwater controls the speciation, solubility and hence the retardation of many contaminants in the aquifer. The chemistry of groundwater also controls its potability and, in turn, its value and likely exploitation as a resource for potential abstraction. The EA has performed catchment quality assessments of surface and river quality across UK (Ref. 78, 79), but no such quality assessment has been performed for groundwater (SD-14).

This section summarises information on the major element geochemistry of the site and region relevant to the pipeline and compares this to the UK groundwater baseline conditions. More detailed information on the geochemistry of the groundwater beneath the site, including pH and salinity, is provided in the hydrogeological interpretation (Ref. 5). Trace element and radiochemistry data are provided in (Ref. 45, 46). Some of the data presented in this section are related to individual boreholes. A map of groundwater monitoring borehole locations and names is given in Appendix C (Ref. 80).

5.4.1 Winfrith site

The chemistry of the groundwater beneath the site is strongly influenced by the ground cover and particularly the regions of acid heathland. Concentrations of major ions in the groundwater of selected boreholes are presented in Table 8. The overall salinity of groundwater is generally lowest under the heathland at the western edge of the site and higher beneath developed areas of the site (Ref. 5). The levels of major elements in the groundwater are within potable limits on all parts of the site.

Table 8: Concentrations of major ions in the groundwater of selected boreholes on or near the site (Ref. 5).

mg/l	Calcium	Magnesium	Sodium	Potassium	Chloride	Alkalinity as $CaCO_3$	Sulphate	Nitrate
OW17 - Heathland								
22/05/2002	4.3	0.7	7	<2	12	<10	10	12
01/10/2002	5.4	1	9	2	12	4	17	7.9
OW20 - Transitional								
22/05/2002	24	1	10	<2	18	30	20	6.2
01/10/2002	28	1	12	2	20	42	39	5.6
OW57 - Not heathland								
24/02/2003	66	3.7	9.5	2	15	140	33	0.8

Under the heathland that makes up a significant portion of the site, the groundwater typically has a pH less than 5.5. Beneath areas of high ground cover this pH raises to neutral (pH of

7) (Ref. 5). This is consistent with the presence of dissolvable minerals such as $CaCO_3$ in areas of development that are lacking in the soil of acid heathland.

Of importance to the integrity of the concrete structures is the concentration of sulphate in the groundwater. The sulphate concentrations measured around the Dragon and SGHWR reactor buildings fall into the least aggressive category defined by the Building Research Establishment (BRE) (Ref. 5).

The pH, salinity and chemistry of major elements in the groundwater of the site are discussed and analysed in further detail in the Hydrogeological Interpretation report (Ref. 5).

5.4.2 Palaeogene Sediments of the Wessex Basin

The Palaeogene sediments of the Wessex Basin have been well studied as part of the British Geological Survey (BGS) UK hydrogeological baseline report series (Ref. 81), which assessed the quality of water in 26 of the most important aquifers in the UK. The major and trace element concentrations in this aquifer are reported in the baseline report (Ref. 81) and data for key analytes and parameters are presented in Table 9. This data set includes the Poole and London Clay Formations and, although the study area is located to the east of the Winfrith site, near Bournemouth, the contiguous nature of these units suggests that similar hydrogeochemical conditions would be present nearer Winfrith.

5.4.3 Dorset Chalk Aquifer

The hydrogeochemistry of the chalk aquifer of Dorset has been studied as part of the BGS UK hydrogeological baseline series (Ref. 82). The Portsdown Chalk Formation is one of the units which comprises the White Chalk, which extends beneath Dorset. The BGS report covers the entirety of the Dorset region including the Winfrith site. The baseline major and trace element chemistry of the groundwater is reported in (Ref. 82) and is presented in Table 9.

It is important to note that beneath the Winfrith site the chalk aquifer is at depth and is hydraulically separated from the near surface groundwater in the Poole Formation by the London Clay. There are differences between the Chalk and the Poole Formation aquifers, which supports the assumption that the London Clay limits mixing between these two aquifers (SD-15). However, to the south of the site the Portsdown Chalk outcrops at the surface and is therefore relevant to the assessment of the pipeline.

5.4.4 UK Groundwater Baseline

Natural UK baseline groundwater concentrations have been calculated from data on the 26 principal aquifers, with major and trace element chemistry summarised in the BGS survey (Ref. 83). A comparison of the median values for selected parameters and analytes with the ranges for the regional groundwaters discussed is provided in Table 9.

The Winfrith site groundwater is more acidic than the Wessex Palaeogene, Dorset Chalk and the UK baseline, which are neutral. As noted above, this is likely to arise in part from the presence of podzol soils. Similarly, the higher concentrations of sodium, nitrate, and iron at the Winfrith site are likely to arise from surface activities.

Table 9: Ranges of values for selected parameters and analytes measured at the Winfrith site (Ref. 5), the Palaeogene sediments of the Wessex Basin (Ref. 82), the Dorset Chalk aquifer (Ref. 83) and the UK groundwater baseline values (Ref. 84).

Analyte/Parameter	Unit	Winfrith Site	Wessex Palaeogene	Dorset Chalk	UK baseline
pH	-	4 - 7	4.69 – 7.33	6.94 – 7.58	*7.2*
Electrical conductivity	$\mu S\ cm^{-1}$	<100 - 400	165 – 823	343 – 1177	*850*
Calcium	$mg\ L^{-1}$	4.3 – 66	5.2 – 128	50 – 125	*80.6*
Magnesium	$mg\ L^{-1}$	0.7 – 3.7	1.72 – 15.7	1.7 – 19.4	*6.43*
Sodium	$mg\ L^{-1}$	7 – 12	11.4 – 111	6 – 155	*15.9*
Potassium	$mg\ L^{-1}$	<2 - 2	0.9 – 15.5	0.9 – 7	*2.52*
Chlorine	$mg\ L^{-1}$	12 - 20	17.4 - 108	14 – 223	28
Sulphate (SO_4)	$mg\ L^{-1}$	10 – 39	2.7 – 91.8	2.5 – 43	*28.1*
Bicarbonate (HCO_3)	$mg\ L^{-1}$		5.2 – 315	107 – 324	236
NO_3 as N	$mg\ L^{-1}$	0.8 - 12	<0.2 – 34.8	0.05 – 12.00	*3.1*
NH_4 as N	$mg\ L^{-1}$		<0.03 – 0.323	<0.003 – 0.310	*0.019*
Iron	$mg\ L^{-1}$		0.007 – 11.3	<0.005 – 20	*0.015*

5.4.5 Nitrate Vulnerable Zones and Drinking Water Safeguard Zones

The Winfrith site lies within a nitrate vulnerable zone (NVZ), Figure 46 (Ref. 84). Its designation reflects its location within the catchment area for Poole Harbour, which suffers from eutrophication due to elevated input of dissolved available inorganic nitrogen. The NVZ designation requires farmers in the NVZ to reduce nitrate pollution and follow a number of rules and good practices. The pipeline passes through a NVZ for Groundwater on its route to the coast, reflecting the proximity, and connectivity, of the chalk aquifer to the surface to the south of the site.

The Winfrith site does not lie in any Drinking Water Safeguard Zones, reflecting the lack of connection between the Poole Formation and the chalk aquifer.

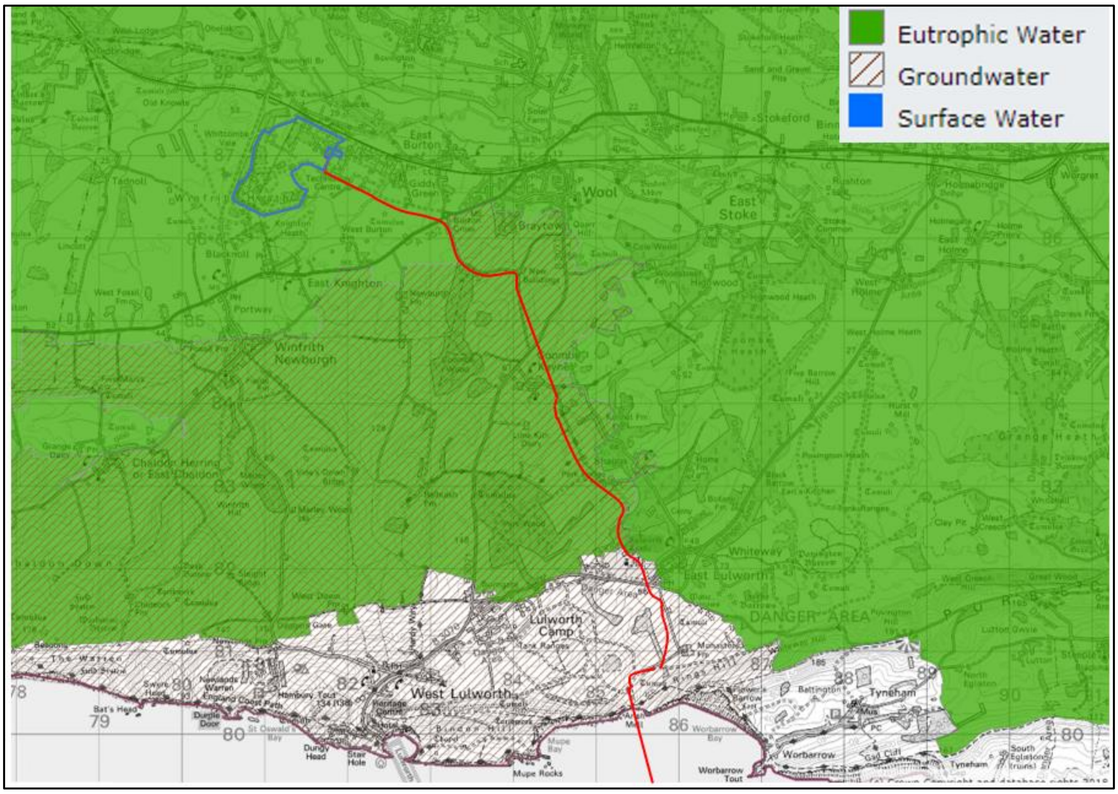


Figure 46: Nitrate Vulnerability Map indicating Winfrith's location within a Nitrate Vulnerability Zone (NVZ) protecting Poole Harbour from eutrophication (Ref. 23).

5.5 Water Use

Both groundwater and surface water in the area are exploited as a drinking water resource or for agricultural use. A number of large-sized surface water abstraction sites are located downstream of the site on the River Frome to the east of Wool (approximately 4-5 km east of the site) (Figure 47). Abstraction and use of groundwater in proximity to the site is discussed in more detail in the hydrogeological interpretation report (Ref. 5).

Groundwater is abstracted nearby for a variety of purposes including agriculture and public water supply. There are several groundwater abstraction stations within 5 km of the site, which are mostly small to medium sized (SD-16).The groundwater within the shallow aquifers beneath and downstream of the site has the potential to be used as a future resource; it is most likely, however, that any abstraction borehole would be sunk into the more productive confined aquifer in the Portsdown Chalk below the London Clay (Figure 44).

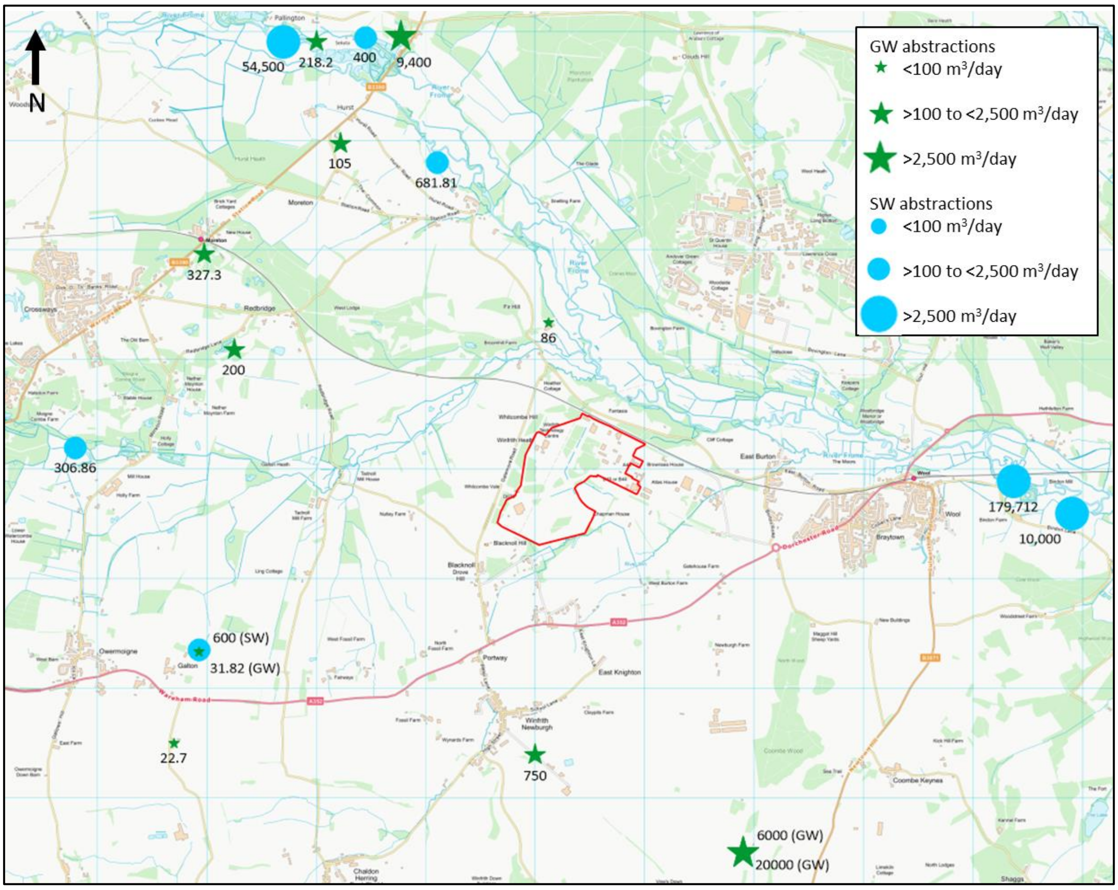


Figure 47: Location of groundwater and surface water abstraction sites as reported by the EA in 2020 (abstraction maps no longer publicly available).

Several groundwater source protection zones have been defined by the EA (Ref. 85). These zones protect important ground water sources from any activities that may cause pollution in the area. The Winfrith site is outside any groundwater protection zones. Parts of the route of the pipeline are within a Zone 1 area, between Lulworth Castle and the coast, and a Zone 2 area near Coombe Keynes (Figure 48). These zones are defined as:

- Inner zone (Zone 1): 50-day travel time from any point on water table to the source (minimum radius of 50 m).
- Outer zone (Zone 2): 400-day travel time from a point below the water table. Zone has minimum radius of 250 or 500 m around the source.

The zones that have been identified appear to be related to the surface occurrence of the Portsdown Chalk Formation (Figure 30).

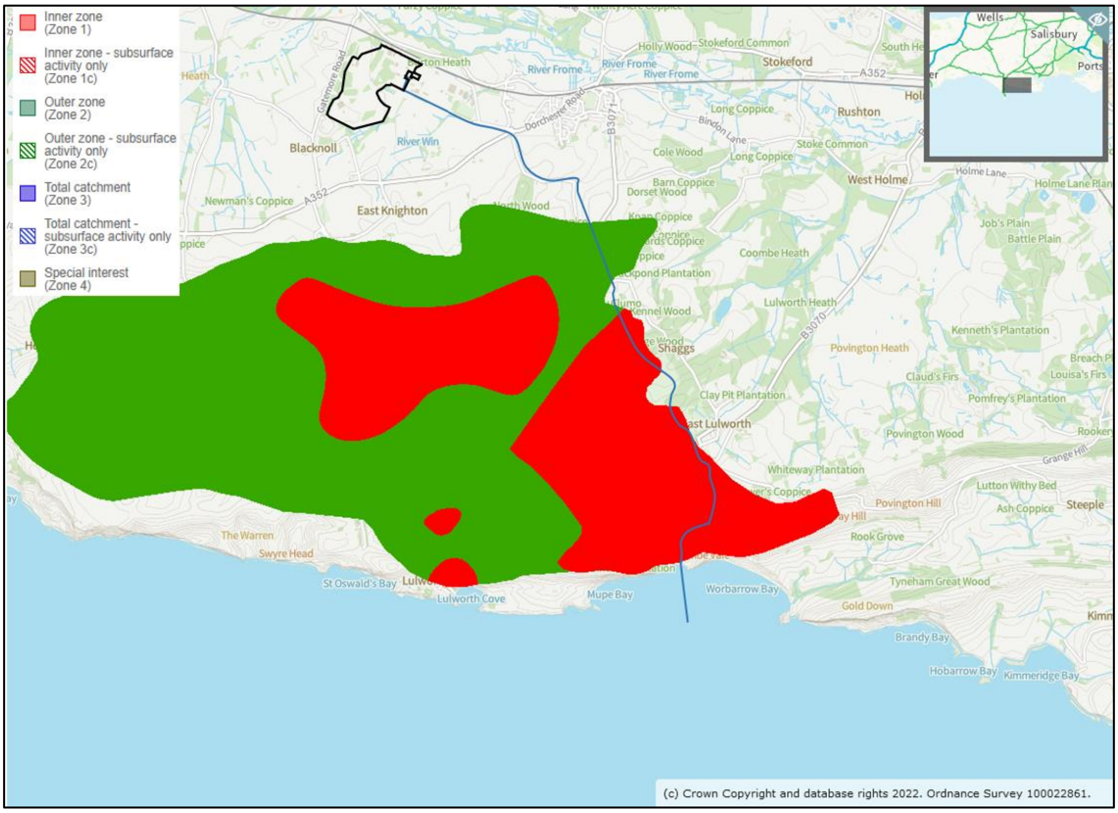


Figure 48: Groundwater protection zones[7] in the region of the Winfrith site (Ref. 23).

5.6 Flood Risk

Section 4.4 outlines the potential for natural disruptive events to affect the site. One of the most important potential disruptive events that could affect the site is flooding, and this section discusses flood risks from surface water and groundwater.

Surface water flood risk zones are defined by the EA to support government planning policy. Flood risk zones are based on the annual exceedance probability (AEP) - the likelihood of a fluvial or tidal flood of a given size or larger. An AEP of 0.1%, for example, means that the annual probability of river or sea flooding is approximately 1 in 1,000 (Ref. 74). The zones are defined as:

- Zone 1 (low probability) has a fluid and tidal flooding AEP < 0.1%.
- Zone 2 (medium probability) has a fluvial flooding AEP = 0.1-1.0%, or a tidal flooding AEP = 0.1-0.5%.
- Zone 3a (high probability) has a fluvial flooding AEP > 1.0%, or a tidal flooding AEP > 0.5%.
- Zone 3b (functional floodplain) has a fluvial or tidal flooding AEP > 5.0%.

The entirety of the Winfrith nuclear licensed site is currently in Flood Zone 1 with an AEP < 0.1% (Figure 49). There is a flood risk to the north of the site from the functional floodplain of the River Frome, and to the east and south of the site from the River Win. Some

[7] Inner zone – subsurface activity only (Zone 1c): Extends Zone 1 where aquifer is confined and may be impacted by deep drilling activities. Outer zone – subsurface activity only (Zone 2c): Extends Zone 1 where aquifer is confined and may be impacted by deep drilling activities. Total catchment (Zone 3): Defined as area around source within which all groundwater recharge is presumed to be discharged at source. Total catchment – subsurface activity only (Zone 3c): extends Zone 3 where aquifer is confined and may be impacted by deep drilling activities. Special interest (Zone 4): usually represents a surface water catchment which drains into the aquifer feeding into the groundwater supply.

areas between the Dorset Innovation Park and the River Win are defined as a medium probability flood risk zone (Zone 2).

Site operators have not recorded any historical flood events of note as having occurred on the site (Ref. 74). Flooding of the River Win near the A352 at East Knighton, and at East Burton and Winfrith Newburgh has been recorded periodically. Floods in December 2012, Spring 2016 and February 2024 led to some flooding of Winfrith Newburgh and the A352 (Ref. 86).

The current risk of tidal flooding on-site is low due to the average elevation (>25 m AOD) and the distance from the discharge point of the River Frome in Poole harbour (Ref. 74).

Groundwater modelling of the site has assessed the current risk of groundwater flooding and shows that during periods of average recharge this is limited to regions near the Frome ditch, the site of the old Zebra reactor and several other regions off-site (Ref. 87)[8]. Further modelling of the site at the planned end state has assessed the effect of changes to drainage and land use and is described in Section 6.1.

A number of perched aquifers exist across the site in the Poole Formation due to clay lenses within the sand formations (Figure 32 and Figure 44). Following heavy rainfall this may lead to some ponding of surface water and potential flood risk. Some soils associated with the ‘Shirrell Heath 1 Formation’ are slow draining and hence susceptible to some seasonal waterlogging.

[8] This groundwater modelling has largely been superseded by work reported in hydrogeological interpretation (Ref. 5), which uses a revised approach to defining recharge and is more appropriate for assessing groundwater responses to climate change. The conclusion in the Environment Agency flood map (Ref. 8987) relating to current flood risks are considered to remain valid.

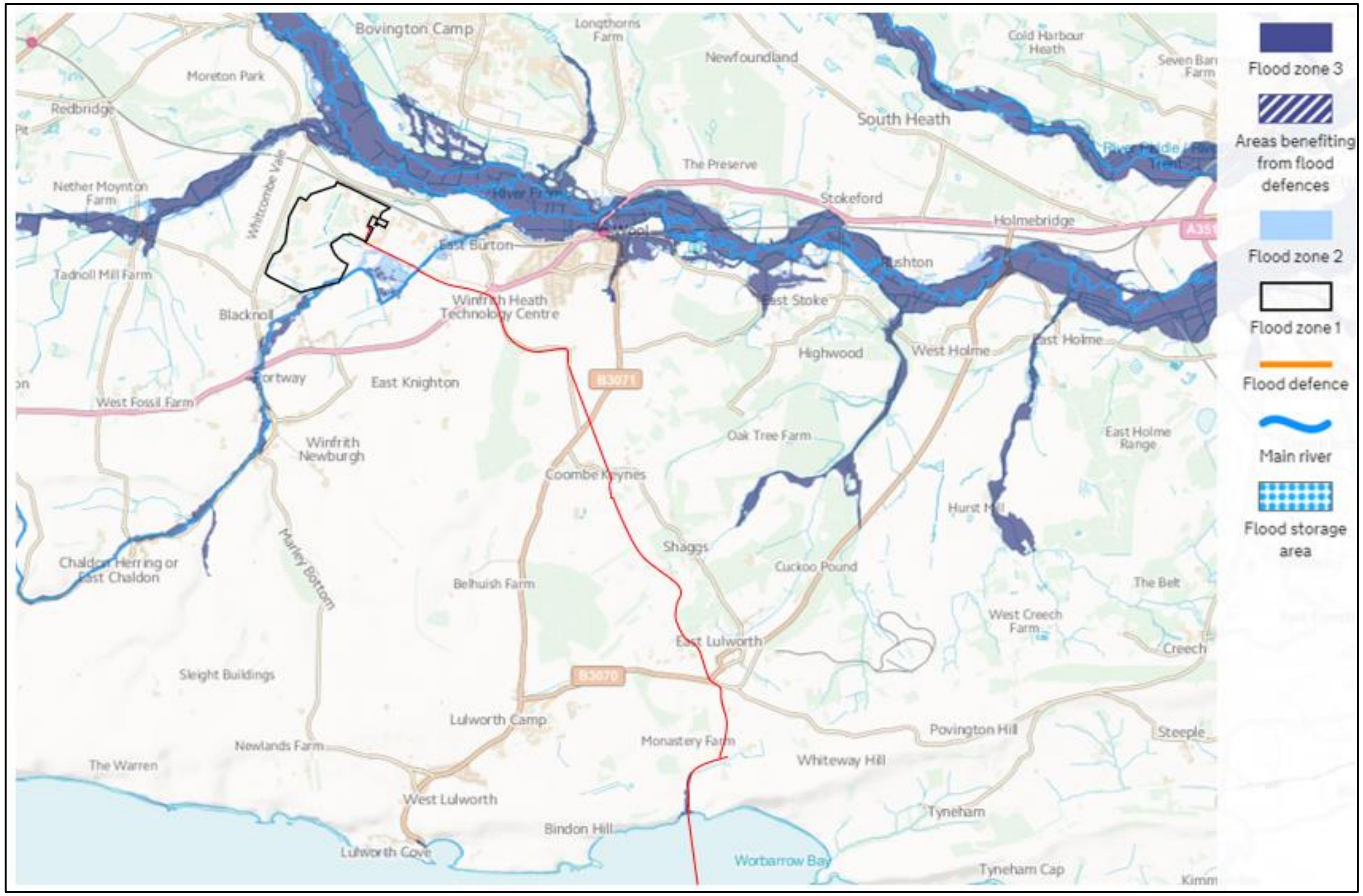


Figure 49: Map showing the flood risk of the Winfrith region (Ref. 88).

6 Future Evolution of the Site

This section discusses how the characteristics of the site are expected to evolve from the current conditions.

6.1 Hydrology of the Site at the End State

The Winfrith end state includes returning the site to a heathland landscape, removing all buildings, hard standing areas and non-native trees, with public access to the site.

Passive water management will continue to route water from most of the site towards Flume 1, and then into the Frome Ditch (Ref. 98). To achieve a more natural hydrograph across the site, decommissioning of the existing surface water drainage system needs to be undertaken (Ref. 96).

The construction of a valley mire and decommissioning of surface water drainage system will aid the development of a more natural hydrograph. The RMP has developed this whilst focussing on preventing an increase in flood risk to neighbouring areas (Ref. 98).

Through decommissioning and removal of site infrastructure and drains, along with the removal of hard landscaping, a reduction in surface runoff will occur. This will therefore slow the rate at which surface water flows off-site, and therefore increase groundwater recharge.

As a consequence of the changes to the surface environment, there are likely to be changes to patterns and extent of recharge and hence to the potential for flooding. Groundwater modelling of these effects (Ref. 98) makes the assumptions that drains are to be decommissioned or removed so that preferential flow path development is prevented.

- Hardstanding (roads, pavements) are to be removed to enable heathland vegetation development. This will result in greater groundwater recharge;
- Structures are to be removed to 1m bgl, with the exception of Dragon where the structure will be demolished to ground level; or suitably covered, to enable habitat development; and
- Non-native trees on the site are to be removed which may allow increased groundwater recharge.

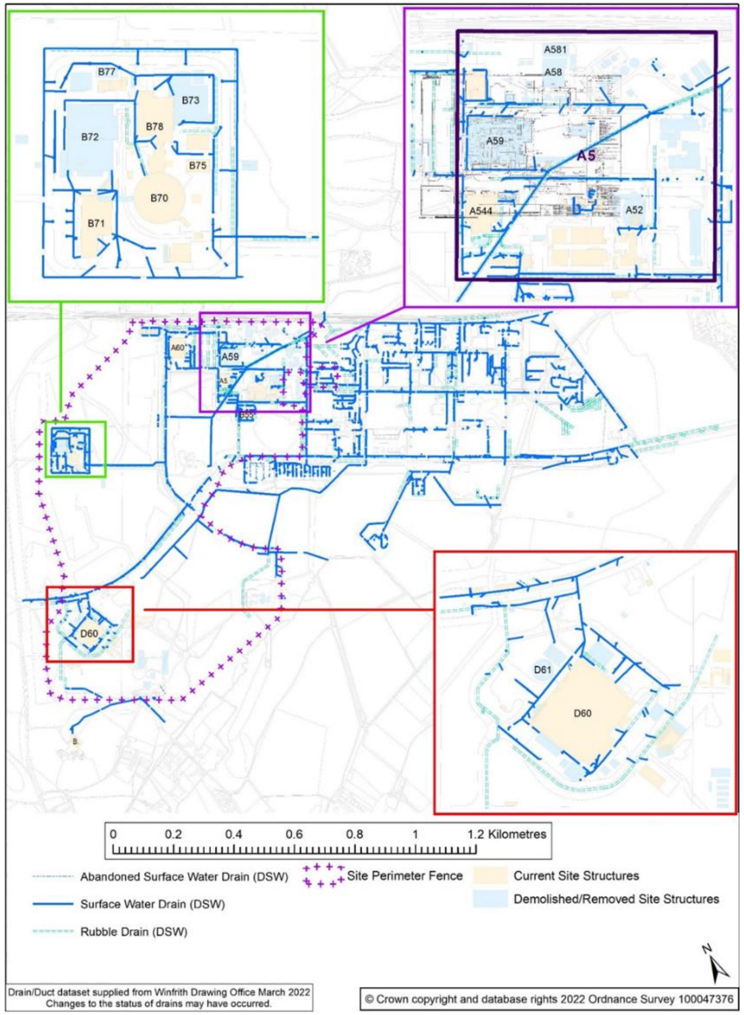


Figure 50: Winfrith drainage system (Ref. 5).

The modelling of groundwater conditions at the end state (Ref. 5) used a set of recharge data for the Frome and Piddle catchments supplied by BGS for the period 1990-2014 (corresponding to the calibration period of the underlying hydrogeological model). The results for a simulated observation well at the SGHWR are shown in Figure 51 and show that the average groundwater elevation would rise by approximately 0.4 m through implementation of the End State. The corresponding change at the Dragon reactor is a rise of about 0.3 m. Although the average elevation rises, however, the range of groundwater elevations at these locations does not change.

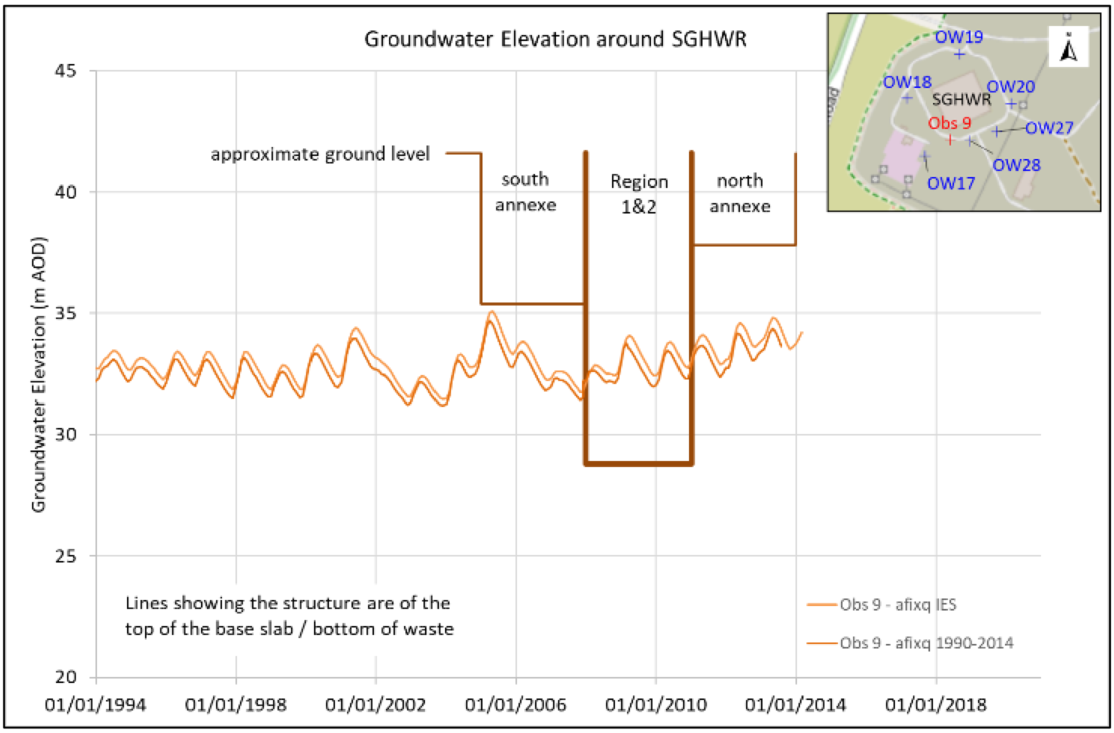


Figure 51: Modelled hydrographs at the IEP of the SGHWR (Ref. 5).

The groundwater elevation contours for the month in which modelled groundwater levels are highest and locations where groundwater is modelled to emerge at the surface are shown in Figure 52. With the seasonal rise in groundwater levels, groundwater discharge occurs to more of the River Win and further upstream in the River Frome. During periods of elevated groundwater, surface discharges occur in the north-east area of the site and to the west of the Monterey roundabout (Ref. 5). The maximum expected increase in groundwater levels in these areas is about 2 m (Ref. 5).

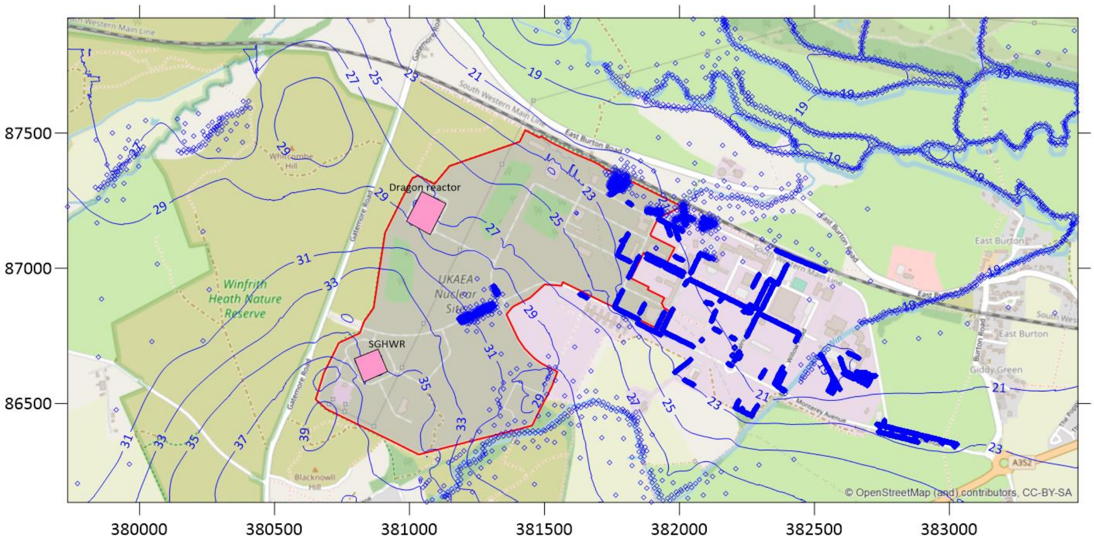


Figure 52: Groundwater elevation contours (m AOD) and locations of groundwater emergence (blue diamonds) at the IEP assuming the highest modelled groundwater levels (Ref. 5).

The groundwater modelling indicates that the planned end state design will cause a small increase in the area of groundwater emergence surrounding Monterrey Roundabout and the ALES facility. This is at rare and extreme groundwater level conditions. There is predicted to be little change to groundwater flooding risk during typical winters except in a few additional areas of the former drainage network.

The changes to groundwater levels are predicted to be generally small as groundwater levels and flows are a response to recharge across the catchment, such that the scale of change on site is very small in comparison to the catchment. This is furthered by the Poole Formation aquifer (sand and clays) having a high storage capacity, so the rebound of increasing groundwater levels is only thought to be slight (Ref. 5). The rebounding is likely to occur through the decommissioned drains not removing water as quickly resulting in increased recharge.

The removal of drains and excavation of the mire are not modelled to change groundwater flowlines and groundwater discharge locations; however, the increases in groundwater levels may give rise to groundwater emergence at the surface in locations it does not at present (Ref. 4).

Given the relatively small scale, magnitude, and extent of groundwater changes identified, it is considered unlikely that these would result in adverse environmental effects over and above any that would occur due to the remediation of the site. The uncertainties associated with the changes in flood risk are discussed in SD-19.

6.2 Possible impacts due to Climate Change

The climate of the Winfrith site will continue to change following the IEP, whether due to natural variations or due to human-induced climate change. In the short-term climate changes will be heavily influenced by greenhouse gas emissions and the resulting changes to the Earth's climate and processes, with several different climate scenarios possible.

6.2.1 Next Century

As the basis for considering the potential effects of greenhouse gas emissions, the United Nation's Intergovernmental Panel on Climate Change (IPCC) has established a series of climate change scenarios called representative concentration pathways (RCPs).

The RCPs specify the quantities of greenhouse gasses that will result in a given change by 2100 in the total radiative forcing (the difference between the incoming and outgoing energy at the top of the atmosphere) compared to pre-industrial levels (Ref. 89). Four radiative forcing values have been considered (2.6, 4.5, 6.0 and 8.5 W m^{-2}), which correspond respectively to scenarios RCP2.6, RCP4.5, RCP6.0 and RCP8.5 (Ref. 90):

- RCP2.6 can be considered an optimistic scenario which implies an immediate rapid decrease in emissions reaching global net zero in the 2080s.
- RCP4.5 and RCP6.0 correspond to different intermediate emissions trajectories representing an overall increase in emissions until mid-century before decreasing (with RCP6.0 representing a larger increase in emissions and a smaller decrease).
- RCP8.5 corresponds to a high emissions scenario, with emissions increasing rapidly over the next century.

These four scenarios are adopted in the UKCP18 climate projections. In order to derive probabilistic projections of the future climate, an ensemble of climate models are adopted for each scenario RCP scenario. Time series data for climate projections based on these models are available from the UKCP18 web interface on a 25 km grid (Ref. 91). In order to derive data for the Winfrith site, the data for the grid square 387500, 87500 is adopted.

Figure 53 shows the projected maximum summer air temperature for the period 1960-2100 for Winfrith in the median ensemble model for each climate change scenario. The models uniformly predict maximum summer temperatures escalating throughout the next century. In the most optimistic scenario, RCP2.6, summer maximum temperatures are projected to reach 35.1°C by 2100, up from 34.1°C in 2020. The more realistic RCP4.5 and RCP6.0 reach respective highs of 36.9°C and 37.8°C, and the most pessimistic RCP8.5 scenario projects maximum temperatures of 39.8°C.

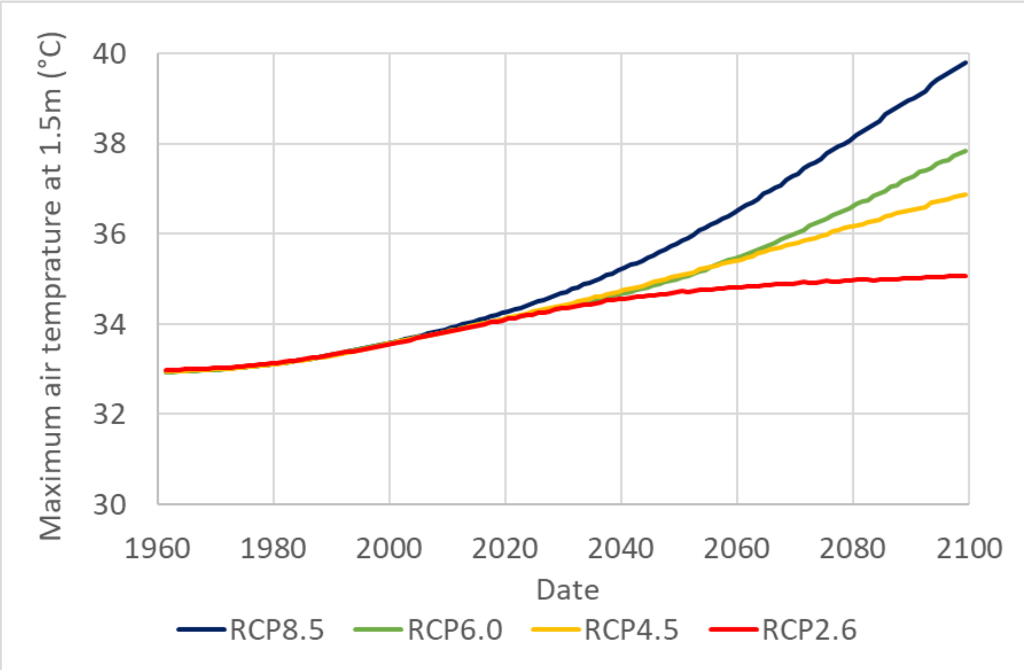


Figure 53: Median extreme summer air temperature UKCP18 projections for each emissions scenario for the grid square 387500, 87500 (Ref. 92).

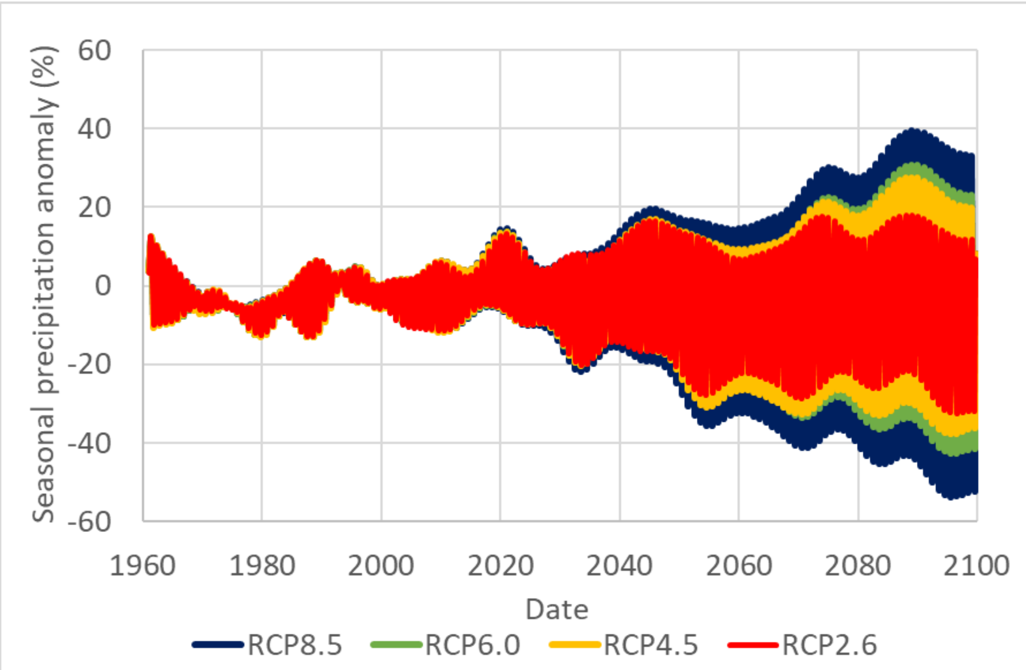


Figure 54: Median seasonal precipitation anomaly for UKCP18 projections for the grid square 387500, 87500 (Ref. 91). The period 1981-2000 is adopted as the baseline.

The percent differences in the seasonal precipitation over the period 1960-2100 compared to a baseline of 1981-2000 for the different climate change scenarios are shown in Figure 54. The lower edge of the anomaly area over the next century corresponds to summer precipitation, which is projected to be lower than the baseline in all scenarios. Conversely, the upper edge of the area corresponds to winter precipitation, which is projected to be higher than baseline. The overall trend of wetter winters and drier summers is consistent to all scenarios, with the magnitude of the difference from the baseline escalating in the higher radiative forcing scenarios.

Quantitative estimates of the effects of climate change over the next century on groundwater elevations and flow summarised in the hydrogeological interpretation (Ref. 5) have used two groundwater recharge scenarios – a cautious, central estimate (CCE) and a reasonable worst case (RWC). The underlying climate change scenarios on which these were based correspond to a medium emissions scenario in UKCP09 rather than to the high emissions scenario (RCP8.5 of UKCP18) (Ref. 59). The impact of both UKCP09 and UKCP18 has been assessed for Winfrith and concluded there was little difference and therefore the site is confident in using UKCP09. A comparison of groundwater responses to the different emissions scenario for a site close to Winfrith (Ref. 93) concluded that the future modelled groundwater elevation at the Winfrith site would be little different if recharge calculated using the high emissions scenario were used (Ref. 5). These climate scenarios are inherently uncertain, and this is noted in SD-17.

The CCE recharge scenario was selected based on the best fit of the recharge model to historical data. The RWC scenario has higher rates of recharge than any other scenario and these rates continue to increase throughout the simulated period (Ref. 5). Simulated hydrographs for an observation well close to the SGHWR in the 2080s for these two scenarios are shown in Figure 55. The highest groundwater level in the modelled results at SGHWR is 1.6 m above the base of the south annexe and is 1.4 m above the base of Dragon reactor. Groundwater levels under these conditions would be above the base level of the south annexe for 12% of the time (Ref. 5). The corresponding calculations for the Dragon reactor show groundwater levels above the base of the reactor for 9% of the time but always below the mortuary holes.

Groundwater elevation contours for the month in which modelled groundwater levels are highest (May 2093) and locations where groundwater is modelled to emerge at the surface are shown in Figure 56. The same locations for groundwater emergence are found for the RWC scenario. Groundwater is modelled to emerge to the west of the roundabout on Monterey Avenue downgradient of SGHWR. Downgradient of the Dragon reactor, groundwater is modelled to emerge in low lying land close to, and in, the River Frome.

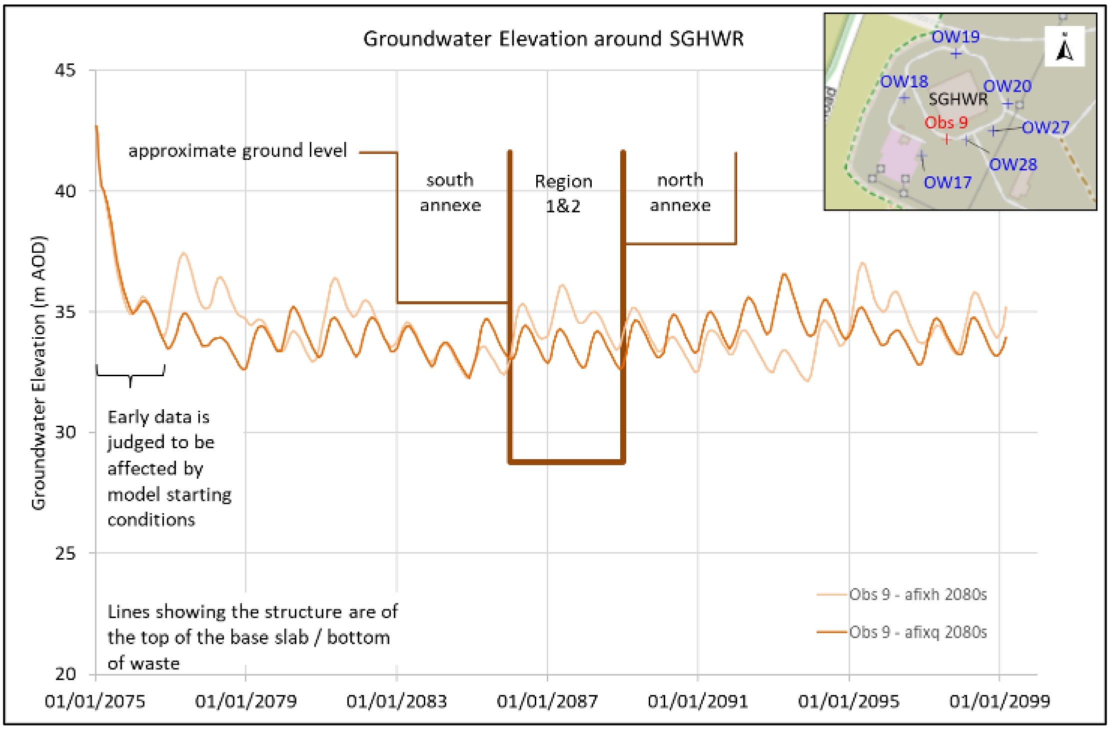


Figure 55: Modelled hydrographs for the 2080s at the SGHWR for two recharge scenarios – CCE (afixq) and RWC (afixh) (Ref. 5).

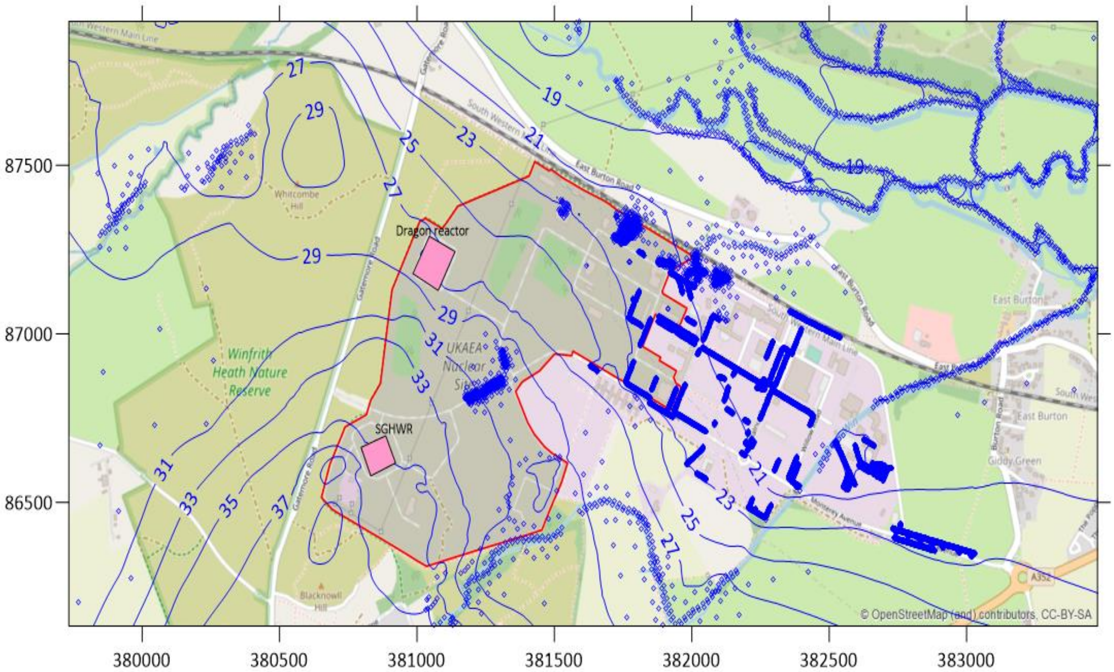


Figure 56: Groundwater elevation contours (m AOD) and locations of groundwater emergence (blue diamonds) for the highest modelled groundwater levels of the CCE simulation (May 2093).

These changes may lead to an increased chance of seasonal flooding, as soils dry out and potentially hinder infiltration during summer, leading to increased surface ponding with winter rainfall. This may also lead to an increased flood risk from the River Frome and River Win as there will be increased winter rainfall diverted from groundwater to the rivers. At the same time, drier and hotter summers and the associated increased incidence of drought might result in cracking in the engineered caps and enhanced surface erosion. The modelled changes in groundwater levels are based on assumed changes in recharge from changing patterns of rainfall and do not necessarily take account of changes in soil conditions or other factors that may also affect recharge (Ref. 5).

6.2.2 Long-term Climate Change

A classification scheme of climate states for use in describing the potential effects of climate change is given in Table 10. Most of the UK, including Winfrith, would currently be classified as temperate.

Table 10: Classification scheme used to describe climate states. Adapted from (Ref. 101, 102).

Climate states	Monthly Temperatures	Climates	Modern-day analogues
Tropical	>17°C all months	Tropical, monsoonal rain	Rainforest
Sub-tropical	>9°C in 8-12 months	Sub-tropical rain and seasonal rain	Mediterranean-type climates
Temperate	>9°C in 4-7 months	Temperate oceanic[9]	Present-day UK climate
Sub-arctic	>9°C in 1-3 months	Sub-arctic oceanic[9]	Boreal/Periglacial forest tundra
Polar	>9°C no months	Tundra, ice	Permafrost/Full glacial
Dry	Evaporation > precipitation (no temperature range)	Steppe, desert	Desert

For the most credible emissions scenarios, maximum global surface air temperature anomaly due to anthropogenic climate change will be reached at approximately 500-1,000 years after present (Ref. 94). A global average air temperature increase of up to 11°C is possible, although the local increase in the UK is anticipated to be lower than the average due to damping caused by the Atlantic. Assuming the cessation of anthropogenic carbon emissions, the impact on global air temperatures is expected to reduce gradually over a period of several tens of thousands of years after the peak.

Without a significant change in latitude, tropical conditions are unlikely to occur in the UK under any potential climate change scenario. Variations between sub-arctic, temperate and sub-tropical conditions are expected in the Dorset region over the period up to the onset of the next glaciation (100,000 – 150,000 years) (Ref 93, 94).

Sub-tropical conditions may be possible due to natural variability (Ref. 93, 94). This may lead to greater productivity of biota and vegetation, and changes to the soil type in the region. Rainfall may also increase in sub-tropical conditions. The combination of these impacts may lead to enhanced erosion.

[9] Temperate and sub-arctic continental climates are included in these climate states but are not relevant for a location on the oceanic margin.

Sea-level rise associated with a warming climate is expected in the future following the IEP. The Winfrith site is generally >25 m AOD and so is unlikely to be affected by sea level rise. It may be affected by changes in river patterns, as the rivers re-equilibrate following a change in source position.

Over longer time-scales, the global climate is expected to cool and continental-scale ice-sheets become established. At the Last Glacial Maximum, ice-sheets did not reach as far as Dorset (Ref. 95) and future ice-sheets are expected to have a similar pattern. Conditions in the region of the site may therefore become sub-arctic with periglacial conditions. This could lead to reduced groundwater percolation and recharge, and increased overland flow and surface runoff, with increased stream density (Ref. 93). Under more extreme patterns of glaciation, permafrost conditions could prevail and, depending on proximity to the ice front, erosion may occur due to periodic melting and re-advance events. Sea-levels would fall during the development of continental-scale ice-sheets.

7 Summary

This report presents a description of the current site and the expected state at the IEP.

The proposed end state for the site includes on-site disposals of the sub-surface SGHWR and Dragon reactor structures, with voids being filled by demolition arisings. The disposals will be capped and landscaped.

Across the rest of the site, ongoing decommissioning will ensure that buildings and structures will be removed to 1m bgl (with the exception of Dragon) to provide a landform suitable for the next planned land use of Heathland with Public access. Where structures or slabs are retained at 1m bgl, soils from the excavation of the mire feature will be emplaced to support a sufficient medium for the establishment of heathland vegetation.

Drains will be decommissioned and blocked before being left in-situ if demonstrated to be OoS and clean from chemical contamination. If found to be radiologically contaminated, these will either be removed or cleaned to ensure they meet OoS criteria. If any contaminated soil exists surrounding contaminated drains, then this will undergo suitable remediation.

After the IEP, there will be no further physical works ongoing at the site. The SGHWR and Dragon disposals may be subject to natural and external anthropogenic events and processes that may affect any radioactivity remaining, however, management by NRS through a Stewardship Plan will continue until the SRS when the permit is surrendered. The potential consequences of these may vary over different timescales, particularly when the influences of climate change are considered.

The site is not currently vulnerable to fluvial or coastal erosion and that general rates of surface erosion would be low. The potential for higher localised erosion rates through trampling or other processes will need to be considered in the design of any covering materials used above any radioactive features.

The seismic risk in the region is low and that any earthquakes that did occur would be low magnitude.

There will be some changes in the rate and patterns of groundwater and surface water flow. The maximum expected increase in groundwater levels in this scenario, without any increase in precipitation, is about 2 m in along parts of the drainage network, in the north of the site, and a few areas along the River Win and there may be some localised flooding in parts of the site as a result. Rises in groundwater levels in the west of the site, around SGHWR and the Dragon reactor, are expected to be <0.5 m.

Climate will change with increases in greenhouse gas emissions. The south-west of England is expected to get hotter throughout the year, with drier summers and wetter winters. There will be consequent changes in recharge and associated changes in groundwater levels with the bases of both the south annexe of SGHWR and the Dragon reactor being below groundwater for a small percentage of the time.

8 References

1 Magnox Ltd, *Winfrith Timeline: From the early years to the present day*, 2015.

2 SEPA, Environment Agency and Natural Resources Wales, *Management of radioactive waste from decommissioning of nuclear sites: Guidance on Requirements for Release of Nuclear Sites from Radioactive Substances Regulation*, Version 1.0, July 2018.

3 *Winfrith Site: End State Radiological Inventory – SGHWR and Dragon Reactor Complex,* ES(19)P281, Version 2, December 2024.

4 *Winfrith End State Project: Non-radiological Inventory,* ES(22)P367, Issue 4, May 2024.

5 *Winfrith Site: Interpretation of Present and Future Hydrogeological Conditions*, ES(21)P331, Issue 1, December 2024.

6 *Conceptual Site Model to Underpin a HRA of the SGHWR and Dragon Reactor (and Mortuary Tubes) End States*. ES(21)P332, Issue 1, December 2024.

7 *Hydrogeological Risk Assessment of the SGHWR and Dragon Reactor (and Mortuary Tubes) End States*. ES(22)P361, Issue 1, December 2024.

8 *Methodology for Managing Magnox Sites' GRR Uncertainties (and Guidance on the use of the Associated Database)*, NRS, Document DD/REP/0030/19, Issue 2, Sep 2020.

9 *Nuclear Site Licence Granted to Tradebe Inutec for Dorset Facility*, https://www.inutec.co.uk//news/article/nuclear-site-licence-granted-tradebe-inutec-dorset-facility, retrieved 15 August 2022.

10 British Geological Survey, *Geoindex Onshore*, Retrieved 18/03/2018 http://mapapps2.bgs.ac.uk/geoindex/home.html..

11 *Decommissioning of Winfrith Sea Pipeline, Appraisal of Decommissioning Options: Final Report*, Ref. 36562 r00313, June 2015.

12 *Six bowl barrows on Blacknoll Hill*, List Entry No. 1015334, Retrieved 16/03/2018. https://historicengland.org.uk/listing/the-list/list-entry/1015334.

13 British Geological Survey, *Geoindex Onshore*, Layers added "Ordinance Survey Terrain 50 DTM", Retrieved 18/03/2018 http://mapapps2.bgs.ac.uk/geoindex/home.html..

14 *Digital surface model LIDAR survey 19th January 2016*, Drawing No. GIS-16-05-009, Issue 2, September 2022.

15 *Digital terrain model LIDAR survey 19th January 2016*, Drawing No. GIS-16-05-010, Issue 2, September 2022.

16 *From nuclear to nature: Dismantling an atomic site*, BBC, 13 December 2017. http://www.bbc.co.uk/news/uk-england-dorset-38075798. Retrieved 15/03/2018.

17 *Dorset Innovation Park: Implementation Document*, April 2021.

18 *Inutec Ltd (T/A Tradebe-Inutec) B44 Winfrith Site Permit Number EPR/PP3890SE/T006*, February 2019.

19 *Relicensing Magnox Limited's Winfrith Licenced Nuclear Site on granting a new Nuclear Site Licence to Inutec Ltd*, Report ONR-SDFW-PAR-16-014, Revision 0, January 2019.

20 The Crown Estate (2018), *Frequently Asked Questions*, https://www.thecrownestate.co.uk/our-business/faqs/. Retrieved 16/03/2018.

21 *Magnox Winfrith Permit number EPR/PB3898DC/T003*, February 2019.

22 *Winfrith NDA Designated and Dedesignated Areas*, Drawing No. GIS-20-05-007, Issue 2, October 2024.

23 Natural England (2022), *MagicMap* http://www.natureonthemap.naturalengland.org.uk/MagicMap.aspx. Retrieved 16/09/2022.

24 *Winfrith Wetland Investigation and Assessment*, ES(24)P400 Version 4, Jun-2024.

25 *Winfrith Site displaying National Vegetation Classification (NVC) data*, Drawing No. GIS-21-10-016, Issue 3, October 2024.

26 Natural England/Environment Agency (2010), *Rehabilitating the River Frome SSSI*, Technical Report 9V7431/R//Exet, 2010.

27 *Strategic Environmental Assessment: Site Specific Baseline RSRL Winfrith*, Nuclear Decommissioning Authority, May 2013.

28 Jurassic Coast website, *What is the Jurassic Coast?* https://jurassiccoast.org/about/what-is-the-jurassic-coast/. Retrieved 20/04/2018.

29 Dorset County Council (2000), *Nomination of the Dorset and East Devon Coast for inclusion in the World Heritage List*, Document sent to UNESCO.

30 *Winfrith Site Groundwater Dependent Terrestrial Ecosystems*, Drawing No. GIS-18-05-027, Issue 5, November 2024.

31 *Online Mapper Tool,* https://mapapps2.bgs.ac.uk/ukso/home.html. Retrieved 05/10/2022, but exported data layer from 2015.

32 *Radiological Habits Survey: Winfrith, 2019,* Centre for Environment, Fisheries & Aquaculture Science (CEFAS), Lowestoft, Environment Report RL 09/20, July 2020.

33 *Agricultural Land Classification Map South West Region (ALCOO6)* http://publications.naturalengland.org.uk/publication/144017?category=5954148537204736. Retrieved 08/02/2018.

34 *Radiological Habits Survey: Winfrith, 2003,* CEFAS Environment Report RL02/04, 2004.

35 *Strategy Effective from April 2016,* Nuclear Decommissioning Authority, 2016.

36 *Strategy Effective from March 2021,* Nuclear Decommissioning Authority, 2021.

37 *Demolition and Land Reinstatement of Blacknoll Reservoir - Project Execution Plan*, Magnox Ref. MINF/PEP/003 Issue 1, 2024.

38 *Dragon Reactor Decommissioning: Dragon Interim Stage Letter of Compliance Submission.* Babcock International and Research Sites Restoration Ltd, RSRL Reference DRA/12/ILOC/01, Issue Two, 17 December 2012.

39 *Site Decommissioning & Remediation: Site Interim and End States. Optimising the End State of the Dragon Facility*, NRS, ES(17)P170, Issue 3, August 2017.

40 *Winfrith Decommissioning: EIA Scoping Report*, Reference 001-UA007723-UE31R-01-DRAFT, February 2016.

41 *Land Quality Register*, Document ES/19/SS/02, Issue 2.0, April 2019 (Excel spreadsheet supplied as a pdf extract in September 2022).

42 *Decommissioning of Active Handling and Decontamination Building A59*, Research Sites Restoration Ltd, 2008.

43 *Assessment of the former A59 area at the Winfrith site for compliance with the health and safety executive nuclear division criterion for release from nuclear regulatory control*, WOMAD Report No. WDB13648, Issue 1, March 2011.

44 *Winfrith End State Report: Area A59 Radioactive Inventory*, GSL 1624-14c and NRS ES(21)P337, Issue 1, December 2024.

45 *Soil and Groundwater Radiological and Chemical Background Values for the Winfrith Site*, ES/24/P392 Issue 1.0, October 2024.

46 *Winfrith Radiological and Non-radiological Heathland Soil Background Values Assessment* Document Reference: 73550/TR/182, Issue 3, April 2022.

47 *UK Soil and Herbage Pollutant Survey Report No.7: Environmental concentrations of heavy metals in UK soil and herbage*, Science Project No. SC000027, June 2007.

48 *The Environmental Permitting (England and Wales) Regulations 2016*, 2016 No. 1154, December 2016 (as amended).

49 *Mineral Resource Information for Development Plans: Phase One Dorset, Bournemouth and Poole,* BGS, Technical Report WF/01/01, 2001.

50 *ALES Sea Pipeline Bedrock Geology.* Drawing No. GIS-15-07-056, Issue 2, September 2022.

51 *ALES Sea Pipeline Marine Geology.* Drawing No. GIS-15-02-019, April 2015.

52 *Winfrith End State Project: Radiological Assessment for the Site End State,* ES(13)P025, March 2013.

53 *Bournemouth, Christchurch, Poole and Dorset Minerals Sites Plan 2019,* https://www.dorsetcouncil.gov.uk/planning-buildings-land/planning-policy/minerals-and-waste-planning-policy/minerals-planning-policy/mineral-sites-plan. Retrieved 21/09/2022.

54 BGS/Communities and Local Government (2011), *Ball Clay: Mineral Planning Factsheet*, 2011.

55 *Onshore Oil and Gas Activity Interactive Map*, https://www.arcgis.com/apps/webappviewer/index.html?id=29c31fa4b00248418e545d222e57ddaa. Retrieved 16/09/2022.

56 *UKCS Production Dashboard*: https://www.nstauthority.co.uk/data-centre/nsta-open-data/production/. Retrieved 13/9/2022.

57 South Devon and Dorset Coastal Authorities Group (2011), *South Devon and Dorset Shoreline Management Plan Review – Summary,* https://southwest.coastalmonitoring.org/wp-content/uploads/SDADCAG_SMP2/SDAD_SMP2_Final_Leaflet.pdf, Retrieved 22/09/2022.

58 *Principles for Flood and Coastal Erosion Risk Management Joint Advice Note*, Revision 2, July 2022.

59 *Use of UK Climate Projections 2018 (UKCP18),* Revision 2, July 2022.

60 *UKCP18 Science Overview Report*, Version 2.0, March 2019.

61 Soil Erosion by Water (2015), *European Soil Data Centre (ESDAC),* https://esdac.jrc.ec.europa.eu/content/soil-erosion-water-rusle2015. Retrieved 22/09/2022.

62 *Reviewing the Plan for Purbeck's future. Heathlands Background Paper*, 2015.

63 *Combating Urban pressures on European Heathlands in Dorset*, Proceedings of the Final Project Seminar, 2005.

64 *A literature review of urban effects on lowland heaths and their wildlife*, Report No. 623, 2005.

65 *Heathland: A burning issue*, https://www.independent.co.uk/environment/heathland-a-burning-issue-2025020.html. Retrieved 12/04/2018.

66 *'Thomas Hardy' Wool Bridge collapses into River Frome,* https://www.bbc.co.uk/news/uk-england-dorset-42702459. Retrieved 13/03/2018.

67 *The Jurassic shales of the Wessex area: geology and shale oil and shale gas resource estimation*, BGS/Oil & Gas Authority, London, UK, 2016.

68 *Eurocode 8 seismic hazard zoning maps for the UK*, British Geological Survey Technical Report, CR/07/125, 2007.

69 *An M_w based earthquake catalogue for central, northern and northwestern Europe using a hierarchy of magnitude conversions*. Journal of Seismology, Vol. 7, 507-531.

70 *Winfrith Site End State Project: Water Management & Ecological Appraisal*, 5001-UA006471-UP31R-R01, November 2013.

71 *Data: Variables from HadUK-Grid over UK for monthly, seasonal or annual data,* Centre for Environmental Data Analysis, https://ukclimateprojections-ui.metoffice.gov.uk/products (Registration required). Retrieved 02/09/2022.

72 *National River Flow Archive*. http://nrfa.ceh.ac.uk/data/station/info/44001, retrieved 20/09/2022.

73 *Hydrology Data Explorer: River Win Station 445930*, https://environment.data.gov.uk/hydrology/station/584639e2-90cb-493d-8edc-b66eda95d788

74 *Winfrith Interim End State Option: Flood Risk Assessment, Arcadis Report*, Version 3, 17 October 2017.

75 *Winfrith surface water & rubble drains showing the outfalls to the River Win*. Drawing No. GIS-18-06-033, Issue 2, September 2022.

76 *Surface water discharge points Winfrith and Dorset Green area*. Drawing No. GIS-18-06-030, Issue 3, September 2022.

77 *Risk assessment of tritium, nickel and zinc in groundwater at Winfrith*, SA/ENV-0573, April 2004.

78 *Frome Dorset (Lower) d/s Louds Mill Dorchester Water Body,* https://environment.data.gov.uk/catchment-planning/WaterBody/GB108044009692, retrieved 21/09/2022.

79 *Frome Dorset Trib (River Win) Water Body,* https://environment.data.gov.uk/catchment-planning/WaterBody/GB108044009650, , retrieved 21/09/2022.

80 *Winfrith site groundwater boreholes (available for use)*. Drawing No. GIS-18-09-058, Issue 3, September 2022.

81 *Baseline Report Series 15: The Palaeogene of the Wessex Basin*, British Geological Survey Commissioned Report No. CR/04/254N, 2004.

82 *Baseline Report Series 4: The Chalk of Dorset,* British Geological Survey Commissioned Report No. CR/02/268N, 2002.

83 *The natural (baseline) groundwater in England and Wales,* British Geological Survey Commissioned Report No. RR/07/06, 2007.

84 *DATASHEET: Nitrate vulnerable zone (NVZ) designation 2017 – Eutrophic Waters (Estuaries and Coastal Waters)*. NVZ Name: Poole Harbour NVZ ID: ET1.

85 *Manual for the production of groundwater source protection zones*. Environment Agency 2019.

86 Bournemouth Daily Echo Online (2018), *Storms bring disruption across Dorset 10/3/16*, http://www.bournemouthecho.co.uk/dorsetweather/14334123.PICTURES__Storm_brings_disruption_across_Dorset/ Retrieved 19/02/2018.

87 *Winfrith Interim End State Option: Groundwater Modelling Report*, Arcadis, Version 1, January 2017.

88 *Flood Map for Planning*: https://flood-map-for-planning.service.gov.uk/, retrieved 19/02/2018.

89 *UKCP18 Guidance: Representative Concentration Pathways*, 2018.

90 *The representative concentration pathways: an overview*, Climatic Change 109, 5-31, 2011.

91 UKCP18 (2022), *Product: Plume of time series anomalies for probabilistic projections (25km) over UK, 1961-2100*, https://ukclimateprojections-ui.metoffice.gov.uk/products/LS1_Plume_01, retrieved 01/07/2022.

92 UKCP18 (2022), *Product: Plume of time series anomalies for probabilistic projections of climate extremes (25km) over UK, 1961-2100*, https://ukclimateprojections-ui.metoffice.gov.uk/products/LS1_Plume_02, retrieved 01/07/2022.

93 *Winfrith End State: Comparison of projected groundwater levels underpinned by UKCP18 with those underpinned by UKCP09,* WSP Golder Technical Memorandum, September 2022.

94 *Development of a Common Framework for Addressing Climate and Environmental Change in Post-closure Radiological Assessment of Solid Radioactive Waste Disposal*, IAEA-TECDOC-1904, 2020.

95 *Site Restoration: Winfrith End State Stewardship Plan,* ES(23)P386, Issue 1, November 2024.

96 *Winfrith End State: Winfrith Drains Strategy.* ES(18)P239, Issue 2, February 2019.

97 *Winfrith End State Project: Winfrith End Point Specification and Definition.* ES(16)P117, Issue 3, December 2023.

98 *Winfrith Site: Restoration Management Plan.* ES(24)P399, Issue 1, November 2024.

99 *National seismic hazard maps for the UK: 2020 update.* BGS Technical Report. OR/20/053, 2020.

100 *Winfrith background soil samples location.* Drawing No. GIS-22-01-001, September 2024, Issue 2.

101 *ALES Sea Pipeline Superficial Deposits.* Drawing No. GIS-15-07-054, November 2024, Issue 3.

102 *Geology under the Winfrith Site.* Drawing No. GIS-14-03-009, November 2024, Issue 5.

103 *Stage B Addendum – Defining the end state for the Winfrith Sea Discharge Pipeline through the MoD Lulworth and Bovington firing range,* ES(24)P412, July 2024, Issue 1.

104 *A survey of radioactive caesium in British soils: A comparison of accumulations pre and post Chernobyl*, AEA-EE-0046, August 1990.

Appendix A Uncertainties, Assumptions and Gaps

A1 The table below summarises the information gaps and uncertainties identified in the development of this site characteristics report for inclusion in the central Winfrith Disposal Permit Uncertainty Management Plan Register (Ref. 9).

UMP Reference #	**Feature, Event or Process subject to Uncertainty**	**Description of Uncertainty**	**Treatment of Uncertainty / Statement of Assumption**	**Originator's Rating of Potential Significance/ Impact** (H/M/L)	**Originator's Recommended Action**
WIN-SD-001	IEP state	The assumed state of the site at the IEP is based on maps in the Restoration Management Plan.	The IEP state is assumed to be as indicated in the Restoration Management Plan.	Low	Tolerate
WIN-SD-002	Contaminant data (Section 4.1.2)	Data on contamination from soils on the Winfrith site are from various monitoring campaign undertaken between 2002 and 2019.	There have been no significant activities on site that would increase contamination levels, consistent with operational monitoring carried out in compliance with the current Permit. Therefore, levels are unlikely to have significantly changed since measurements were made between 2002 and 2019.	Low	Tolerate

UMP Reference #	Feature, Event or Process subject to Uncertainty	Description of Uncertainty	Treatment of Uncertainty / Statement of Assumption	Originator's Rating of Potential Significance/ Impact (H/M/L)	Originator's Recommended Action
WIN-SD-003	Pb-210, Ra-226 and Th-232 elevated levels (Section 4.1.3)	The average levels of Pb-210 are 5 times greater than the EPR23 OoS levels, Ra-226 levels are three times higher than EPR23 levels, while Th-232 is only slightly above the EPR23 levels. The reason for this elevation is unclear.	Pb-210 has a relatively short half-life of 22 years and so should reduce to negligible levels within a few centuries. Th-232 and Ra-226 have longer half-lives.	Low	Action
WIN-SD-004	Thickness of geological layers/cross-section through Winfrith site (Section 4.2.2)	The thicknesses of geological layers are assumed to be relatively constant. Data from publicly accessible boreholes does not include depth to bottom of Poole Formation and so spatial variation in thickness cannot be determined.	Thicknesses of superficial deposits from boreholes available on the BGS “Geoindex” online app (Ref. 101) are generally constant across the site, apart from some thinning associated with changes in topography/presence of rivers. It is assumed that thicknesses of the layers are also constant across the site.	Low	Tolerate
WIN-SD-005	Grain size of Poole Formation/London Clay (Table 5)	Physical properties (grain sizes) of the Poole Formation, London Clay and River Frome terrace deposits are given in a BGS technical report (Ref. 53). The data for the Poole Formation and London Clay sands are assumed to be representative of the Winfrith site.	The data is assumed to be average properties and representative of the formations on the site.	Low	Tolerate

UMP Reference #	Feature, Event or Process subject to Uncertainty	Description of Uncertainty	Treatment of Uncertainty / Statement of Assumption	Originator's Rating of Potential Significance/ Impact (H/M/L)	Originator's Recommended Action
WIN-SD-006	Transport properties (Section 4.2.3)	Analogue radionuclide transport properties for the Poole Formation and River Terrace Deposits are reported in scoping calculations (Ref. 53). Transport properties for other relevant geosphere units (London Clay and Chalk) have not been reported in characterisation reports for the site. Only hydraulic conductivities, elemental sorption distribution coefficients and effective porosities are given.	The London Clay is assumed to be an aquitard, based on evidence from the BGS (Ref. 61) and so transport properties are not required, while the Chalk will be of less significance as a transport pathway compared to the Poole Formation. For the Poole Formation and River Terrace deposits the use of analogue data is justified where these are used in transport calculations, as the uncertainties associated with the modelling allow for use of such data.	Low	Tolerate
WIN-SD-007	Silica sands (Section 4.3.1)	Location of silica sand extraction quarries is unclear.	Assumed to be extracted in the same quarries as sand and gravel (by-product).	Low	Tolerate
WIN-SD-008	Regions of prospective mineral extraction (Section 4.3.1)	References to Dorset Council minerals extraction plans show areas of potential extraction (Figure 34). Whether these areas are the actual extension areas is unclear.	The prospective areas agree with areas of current extraction (see SD-011). At the time the uncertainty was raised in 2018 the extraction plan was in draft but has now been adopted (Ref. 53). Nevertheless, the actual location of future extractions remains uncertain.	Low	Tolerate

UMP Reference #	Feature, Event or Process subject to Uncertainty	Description of Uncertainty	Treatment of Uncertainty / Statement of Assumption	Originator's Rating of Potential Significance/ Impact (H/M/L)	Originator's Recommended Action
WIN-SD-009	Ball Clay (Section 4.3.2)	Location of Ball Clay extraction areas unclear.	The BGS minerals report notes that Trigon Hill is an area of Ball Clay extraction.	Low	Tolerate
WIN-SD-010	Coastal erosion (Section 4.4.1)	Rates of coastal erosion at Worbarrow Bay are unknown. There is evidence of a landslide further along the coast near the MoD firing line, but date of the landslide is unknown.	Rough timing of Worbarrow Bay landslide is known. The pipeline is located in a valley at Arish Mell, so any impacts are likely to be limited.	Low	Tolerate
WIN-SD-011	Soil erosion rate (Section 4.4.1)	Surface erosion rate and specific soil vulnerability is unknown.	Specific erosion rates are not included in this report, but heathland is a region that is vulnerable to erosion, particularly with enhanced public access.	Low	Tolerate
WIN-SD-012	Fluvial erosion (Section 4.4.1)	Erosion rates by the River Frome are unknown. There is evidence of erosion, with collapse of the Wool bridge reported and meander erosion observed.	The River Frome is sufficiently far from the site and the pipeline that erosion is unlikely to be important.	Low	Tolerate
WIN-SD-013	Control of groundwater flow (Section 5.3)	Groundwater flow is controlled structurally in the Poole Formation and topographically in the Portsdown Chalk Formation.	Topography and structures in the region appear to mirror one another, especially at the site, with a dip toward the north-east.	Low	Tolerate

UMP Reference #	Feature, Event or Process subject to Uncertainty	Description of Uncertainty	Treatment of Uncertainty / Statement of Assumption	Originator's Rating of Potential Significance/ Impact (H/M/L)	Originator's Recommended Action
WIN-SD-014	Groundwater quality (Section 5.4)	The EA plan for groundwater quality improvement has not been issued.	Environmental quality of the groundwater on site is based upon the findings of Section 5.4, with the hydrogeological interpretation (Ref. 5) giving an up-to-date review of the site groundwater chemistry.	Low	Tolerate
WIN-SD-015	Isolation of Poole and Chalk aquifers (Section 5.4)	The groundwater in the Poole Formation and Chalk aquifers are assumed to be isolated from one another by the London Clay.	Comparisons between the Paleogene baseline and Chalk baseline assumes that the two aquifers are isolated.	Low	Tolerate
WIN-SD-016	Groundwater abstraction sites (Section 5.5)	Ownership of regional abstraction wells is unclear. The locations and lists of owners are available. However, the owners are not linked to specific locations.	Minor and medium-sized abstraction wells appear to be owned mostly by small-holdings (e.g. farms, private enterprises), while large abstraction sites are assumed to be owned by Wessex Water Services Ltd.	Low	Tolerate
WIN-SD-017	Future climate (Section 6.2.1)	The different emissions scenarios show a wide range in the uncertainties of future rainfall and temperature over the next century. This will lead to unexpected changes in flood risk and water management on the site following the IEP.	Climate change models show broadly similar trends. The rainfall flood risk has been assessed qualitatively to deal with broad variations.	Low	Tolerate

UMP Reference #	Feature, Event or Process subject to Uncertainty	Description of Uncertainty	Treatment of Uncertainty / Statement of Assumption	Originator's Rating of Potential Significance/ Impact (H/M/L)	Originator's Recommended Action
WIN-SD-018	Future flood risk (Section 6.1)	There will be an associated uncertainty with these models, dependent upon the input conditions.	There are uncertainties associated with the changes in conditions and what may occur on site. Hence the models show a reasonable approximation of what is expected to occur, given the uncertainties.	Low	Tolerate
WIN-SD-019	Climate data for the site (Section 5.1)	Climate data has been taken from the "UKCP09 Met Office gridded land surface climate observations - monthly climate variables at 5 km resolution" for grid reference E382500 N087500. Data has been interpolated from Met Office Integrated Data Archive System (Ref. 71).	Rainfall data taken from UKCP09 is in good agreement with published rainfall data for Winfrith. The UKCP09 dataset is used for Met Office climate projections, and so is considered to be of good quality.	Low	Tolerate
WIN-SD-020	Changes in soil properties due to climate change	Climate change, with drier summers and wetter winters may lead to changes in soil conditions that affect recharge in addition to changes in rainfall patterns.	The uncertainties associated with greenhouse gas emissions and consequent changes in climate are large in comparison with those associated with changes in soil properties.	Low	Tolerate

Appendix B Land quality summary

B1 Table B.1 lists areas that have been identified with potential land quality issues, along with an assessment of the nature and potential pathways of the hazard to any receptors (Ref. 41). The risks associated with these hazards are included for the short-term and the long-term, based on the likelihood of occurrence. Those hazards with a risk of medium or above are discussed in Section 3.3. A map of locations is included as Figure B.1.

Table B.1: List of land quality on the Winfrith Site, extracted from (Ref. 41) identifying all potential or identified areas of potential concern.

Hazard Identification				Hazard Assessment		Risk	
APC Reference	**End-State Zone**	**APC Title**	**Potential Contaminants**	**Receptors**	**Potential Pathways**	**Short Term**	**Long Term**
APC1-A	Zone 10	Active Drains - SGHWR to ALES	Radionuclides	Groundwater	Infiltration from leaking drains via the unsaturated zone	Low	Low
APC 1-A	Zone 10	Active Drains - SGHWR to ALES	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Low	Low
APC1-B	Zone 3	Active Drains - SGHWR to EAST	Radionuclides	Groundwater	Infiltration from leaking drains via the unsaturated zone	Low	Low
APC 1-B	Zone 3	Active Drains - SGHWR to EAST	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Low	Low
APC 1-C	Zone 9	Active Drains - B70 to B76	Radionuclides	Groundwater	Infiltration from leaking drains via the unsaturated zone	Low	Low
APC 1-C	Zone 9	Active Drains - B70 to B76	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Low	Low
APC 1-D	Zones 5 and 6 N	Active Drains - A58 / A59 to ALES	Radionuclides	Groundwater	Infiltration from leaking drains via the unsaturated zone	Low	Low

Hazard Identification				Hazard Assessment		Risk	
APC Reference	**End-State Zone**	**APC Title**	**Potential Contaminants**	**Receptors**	**Potential Pathways**	**Short Term**	**Long Term**
APC 1-D	Zones 5 and 6 N	Active Drains - A58 / A59 to ALES	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Low	Low
APC 1-E	Zone 8	Active Drains - Innutec to ALES	Radionuclides	Groundwater	Infiltration from leaking drains via the unsaturated zone	Low	Low
APC 1-E	Zone 8	Active Drains - Innutec to ALES	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Low	Low
APC 1-F	Zone 6 South	Active Drains - A544 & B55 to ALES	Radionuclides	Groundwater	Infiltration from leaking drains via the unsaturated zone	Trivial	Trivial
APC2	Zone 5	Historical Solvent Disposal	Chlorinated Hydrocarbons	Groundwater	Infiltration from historical surface disposal via unsaturated zone	High	Medium
APC2	Zone 5	Historical Solvent Disposal	Chlorinated Hydrocarbons	Surface water	Surface water recharge from groundwater	Medium	Low
APC3	Zone 5 / Zone 6 North	Historical Electroplating Activities	Heavy metals (Zn / Ni)	Groundwater	Metals leached from contaminated ground	High	Medium

Hazard Identification				Hazard Assessment		Risk	
APC Reference	**End-State Zone**	**APC Title**	**Potential Contaminants**	**Receptors**	**Potential Pathways**	**Short Term**	**Long Term**
APC3	Zone 5 / Zone 6 North	Historical Electroplating Activities	Heavy metals (Zn / Ni)	Surface water	Surface water recharge from groundwater	Medium	Medium
APC4-A	Site Wide	Active Foul Drains	Radionuclides	On-site workers	Direct irradiation from near-surface contamination	Low	Low
APC4-A	Site Wide	Active Foul Drains	Radionuclides	Groundwater	Infiltration from leaking drains via the unsaturated zone	Low	Low
APC4-B	Zone 5	Active Foul Drains / A57 Tanks	Radionuclides	On-site workers	Direct irradiation from near-surface contamination	Low	Low
APC4-B	Zone 5	Active Foul Drains / A57 Tanks	Radionuclides	Groundwater	Infiltration from leaking drains via the unsaturated zone	Low	Low
APC5	Site Wide	Non-active Process Drains	Strong Acid / alkali solutions plus metals	Groundwater	Infiltration from leaking drains via the unsaturated zone	Very Low	Very Low
APC6	Zone 6 South	A53 / A54 (ALES) complex	Radionuclides	Groundwater	Infiltration from leaking tanks / drains via the unsaturated zone	Low	Low
APC6	Zone 6 South	A53 / A54 (ALES) complex	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Low	Trivial

Hazard Identification				Hazard Assessment		Risk	
APC Reference	**End-State Zone**	**APC Title**	**Potential Contaminants**	**Receptors**	**Potential Pathways**	**Short Term**	**Long Term**
APC7	Land Zone A6	A60 Underground Petrol Tanks	Hydrocarbons	Groundwater	Infiltration from leaking tank via the unsaturated zone	Very Low	Very Low
APC8	Zone 5	A641 (Storage Compound) & A584	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Very Low	Very Low
APC9	B45 Area	B431 - Redundant Diesel Refilling Station	Hydrocarbons	Surface water	Surface water run-off into drains discharging via Flume 1 into River Frome	Low	Very Low
APC10	Zone 8	Gardeners Compound (B51 & B53)	Horticultural chemicals	Surface water	Surface water run-off into drains discharging via Flume 1 into River Frome	Low	Low
APC10	Zone 8	Gardeners Compound (B51 & B53)	Horticultural chemicals	On-site workers	Inhalation and ingestion from surface contamination	Low	Low
APC11	Zone 1	B6 Fire Test Facility	Hydrocarbons	Groundwater	Downward migration through the unsaturated zone until groundwater is encountered.	Low	Low
APC11	Zone 1	B6 Fire Test Facility	Hydrocarbons	On-site workers	Inhalation and ingestion from surface contamination	Very low	Very Low

Hazard Identification				Hazard Assessment		Risk	
APC Reference	**End-State Zone**	**APC Title**	**Potential Contaminants**	**Receptors**	**Potential Pathways**	**Short Term**	**Long Term**
APC12	Zone 9	B751 Testing Pit	Hydrocarbons and Radionuclides	Groundwater	Downward migration through the unsaturated zone until groundwater is encountered.	Trivial	Trivial
APC13	Zone 9	B76 Delay Tanks	Radionuclides	Groundwater	Infiltration from leaking tank via the unsaturated zone	Very Low	Trivial
APC13	Zone 9	B76 Delay Tanks	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Very Low	Trivial
APC14	Zone 9	Matthew Hall Hut	Radionuclides (Pu / Am)	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Low	Very Low
APC15	Zone 2	Zebra Complex	Radionuclides	Groundwater	Infiltration from surface contamination via the unsaturated zone	Very Low	Very low
APC16	Zone 3	D69 and Drawpit H (SGHWR - EAST)	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Low	Trivial
APC16	Zone 3	D69 and Drawpit H (SGHWR - EAST)	Radionuclides	Groundwater	Downward migration of contamination through the unsaturated zone until groundwater is encountered.	Medium	Low

Hazard Identification				Hazard Assessment		Risk	
APC Reference	**End-State Zone**	**APC Title**	**Potential Contaminants**	**Receptors**	**Potential Pathways**	**Short Term**	**Long Term**
APC17	Off-site	Frome Ditch	Radionuclides	General Public	Direct irradiation, inhalation and ingestion from surface contamination	Very Low	Low
APC17	Off-site	Frome Ditch	Radionuclides	Surface water	Surface water run-off of particulate contamination	Very Low	Very Low
APC18	Zone 7 & 10	Redundant SGHWR to ALES active pipeline	Radionuclides	Groundwater	Downward migration through the unsaturated zone until groundwater is encountered.	Low	Low
APC19	Zone 3	D630 Rubble Stockpiles	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Very Low	Low
APC19	Zone 3	D630 Rubble Stockpiles	Asbestos	On-site workers	Inhalation from surface contamination	Very Low	Low
APC20	Zone 6 North	A59: Pit 3 and A591 / HVA area	Radionuclides	Groundwater	Leaching from Residual Material	Medium	Low
APC20	Zone 6 North	A59: Pit 3 and A591 / HVA area	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Very Low	Very Low
APC21	Zone 6 North	A59.1 Redundant active drains	Radionuclides	Groundwater	Leaching from Residual Material	Low	Low

Hazard Identification				Hazard Assessment		Risk	
APC Reference	**End-State Zone**	**APC Title**	**Potential Contaminants**	**Receptors**	**Potential Pathways**	**Short Term**	**Long Term**
APC22	Zone 6 South	P&S Storage Compound	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Very Low	Very Low
APC23	Zone 5	A6 Railway Siding Soakaway	Radionuclides	Groundwater	Downward migration of contamination through the unsaturated zone	Very Low	Very Low
APC24	Off-site	Win Ditch	Radionuclides	General Public	Direct irradiation, inhalation and ingestion from surface contamination	Low	Low
APC 24	Off-site	Win Ditch	Radionuclides	Surface water	Surface water run-off of particulate contamination	Very Low	Very Low
APC 25	Zone 6 South	A52 Footprint	Radionuclides (Alpha)	Groundwater	Downward migration of contamination through the unsaturated zone	Low	Low
APC 26	Zone 3	A57 'Pea-Shingle' Mound	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Low	Trivial
APC 27	Zone 7	Q-Site dummy lights	Hydrocarbons	Groundwater	Downward migration of contamination through the unsaturated zone	Trivial	Trivial

Hazard Identification				Hazard Assessment		Risk	
APC Reference	**End-State Zone**	**APC Title**	**Potential Contaminants**	**Receptors**	**Potential Pathways**	**Short Term**	**Long Term**
APC 28	Zone 9	B73 Fuel Store Facility / Mortuary Tubes	Radionuclides	Groundwater	Downward migration of contamination through the unsaturated zone	Low	Low
APC 28	Zone 9	B73 Fuel Store Facility / Mortuary Tubes	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Medium	Low
APC 29	Zone 6 North	A56 Diverter Valve 3	Radionuclides	Groundwater	Downward migration of contamination through the unsaturated zone	Medium	Low
APC 29	Zone 6 North	A56 Diverter Valve 3	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Low	Very Low
APC 30	Zone 10	Drawpit A (SGHWR to EAST pipeline)	Radionuclides	Groundwater	Downward migration of contamination through the unsaturated zone	Low	Very Low
APC 30	Zone 10	Drawpit A (SGHWR to EAST pipeline)	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Very Low	Very Low
APC 31	Zone 9	B70 (Dragon) Flask storage layby	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Very Low	Very Low

Hazard Identification				Hazard Assessment		Risk	
APC Reference	**End-State Zone**	**APC Title**	**Potential Contaminants**	**Receptors**	**Potential Pathways**	**Short Term**	**Long Term**
APC 32	Zone 9	B70 (Dragon) Construction Complex	Asbestos / Hydrocarbons	On-site workers	Inhalation from surface contamination	Very Low	Very Low
APC 33	Zones 10 and 7	Deposition from SGHWR stack emissions	Radionuclides	Groundwater	Downward migration of contamination through the unsaturated zone	Very Low	Very Low
APC 33	Zones 10 and 7	Deposition from SGHWR stack emissions	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Very Low	Very Low
APC 34	Off-site A7	A7 Diesel Contamintion	Hydrocarbons	Groundwater	Downward migration of contamination through the unsaturated zone	Very Low	Very Low
APC 35	Zone 5	Soil contamination north of A57 Settling Tanks	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	Very Low	Very Low
APC 36	Zone 4	Break Pressure Tanks	Radionuclides	On-site workers	Direct irradiation, inhalation and ingestion from surface contamination	NA	NA
APC 37	Zone 10	D6317 Portacabins Diesel Generator Spill	Hydrocarbons	Groundwater	Downward migration of contamination through the unsaturated zone	NA	NA

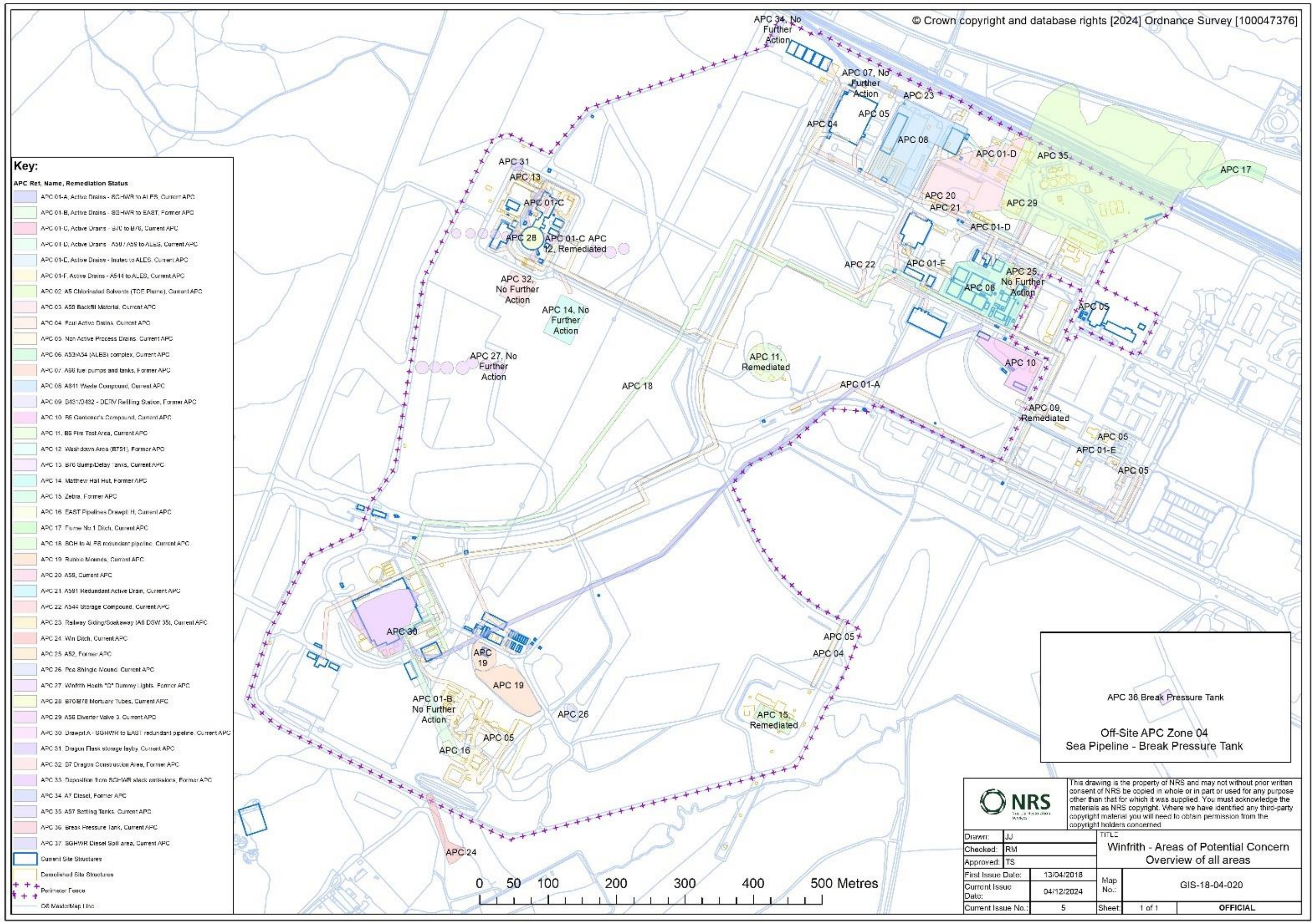


Figure B.1: Locations of land quality investigation areas on the Winfrith site (Ref. 41).

Appendix C Groundwater Borehole Locations

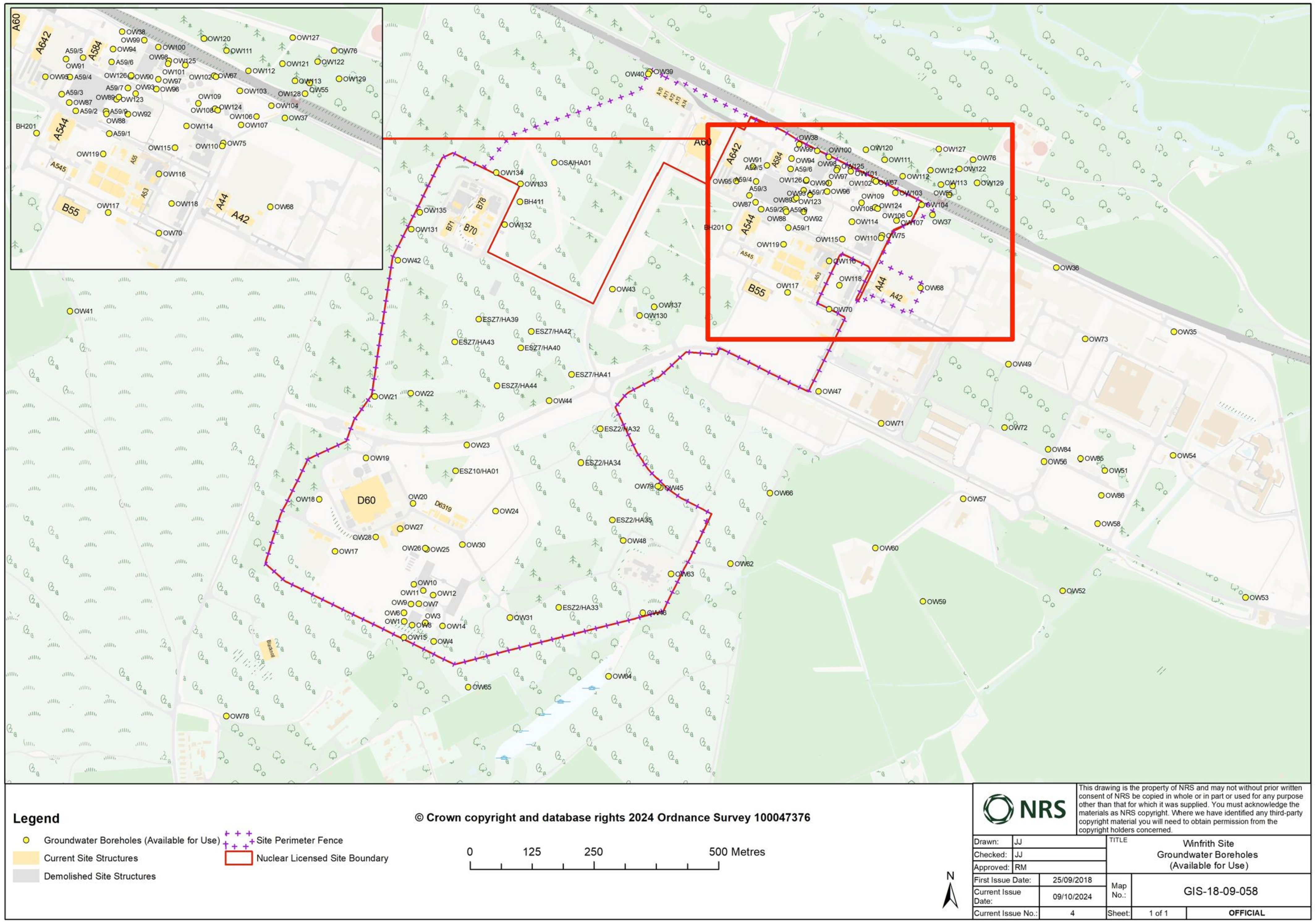


Figure C.1: Map denoting the locations and names of current groundwater boreholes at the Winfrith site (Ref. 103).