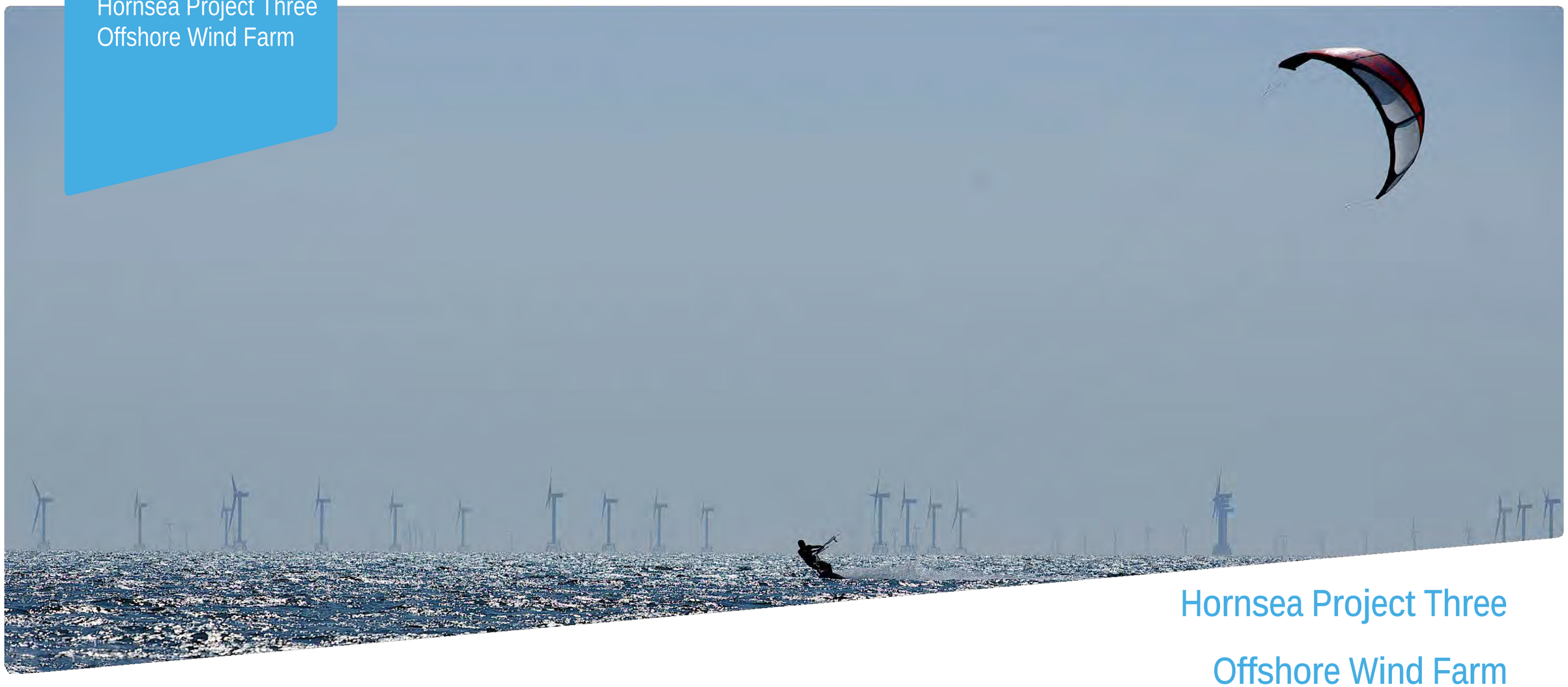
Hornsea Project Three
Offshore Wind Farm



Hornsea Project Three

Offshore Wind Farm

Preliminary Environmental Information Report:
Chapter 1 – Geology and Ground Conditions (Part 1)

Date: July 2017

Hornsea 3
Offshore Wind Farm

DONG energy

Environmental Impact Assessment

Preliminary Environmental Information Report

Volume 3

Chapter 1: Geology and Ground Conditions

Liability

This report has been prepared by RPS, with all reasonable skill, care and diligence within the terms of their contracts with DONG Energy Power (UK) Ltd.

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Front cover picture: Kite surfer near one of DONG Energy's UK offshore wind farms © DONG Energy Hornsea Project Three (UK) Ltd., 2016.

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Glossary

Term	Definition
Aquifer	A subsurface layer or layers of rock or other geological strata of sufficient porosity and permeability to allow either a significant flow of groundwater or the abstraction of significant quantities of groundwater.
Artificial ground	Artificial ground is a term used by the British Geological Survey (BGS) for those areas where the ground surface has been significantly modified by human activity. Whilst artificial ground is not part of the 'real geology' of bedrock and superficial deposits it does affect them and needs recording because the near surface ground conditions are so important to human activities and economic development. Artificial Ground includes: Made ground —such as embankments and spoil heaps on the natural ground surface. Worked ground — areas where the ground has been cut away such as quarries and road cuttings. Infilled ground — areas where the ground has been cut away then wholly or partially backfilled. Landscaped ground — areas where the surface has been reshaped. Disturbed ground — areas of ill-defined shallow or near surface mineral workings where it is impracticable to map made and worked ground separately.
Bedrock	Term used for the main mass of rocks forming the Earth and present everywhere, whether exposed at the surface in outcrops or concealed beneath superficial deposits or water. The bedrock has formed over vast lengths of geological time ranging from ancient and highly altered rocks of the Proterozoic, some 2500 million years ago or older, up to the relatively young Pliocene, 2.6 million years ago.
Chalk	The Chalk Group (often just called 'Chalk') is the lithostratigraphic unit (a certain number of rock strata) which contain the late Cretaceous limestone succession in southern and eastern England. The same or similar rock sequences occur across the wider northwest European chalk province. It is characterised by thick deposits of chalk, a soft porous white limestone, deposited in a marine environment.
Confined aquifer	Permeable rock units containing ground water that are confined above or beneath lower permeability rock or superficial deposits such as clay, which limit groundwater movement into and out of the confined aquifer.
Compressible Ground Hazard	Weak ground that compresses under load from overlying structures.
Designated Sites	The UK's approach to conservation employs a range of different types of site and extensive area designations for landscape and nature conservation purposes. Statutory designated sites or areas relevant to geological and geomorphological conservation administered by Natural England (an Executive Non-departmental Public Body responsible to the Secretary of State for Environment, Food and Rural Affairs) are: Special Areas of Conservation (SAC); National Parks; Areas of Outstanding Natural Beauty (AONBs); Sites of Special Scientific Interest (SSSI); and National Nature Reserves (NNR). Non-statutory designated sites administered by county or unitary local authorities comprise: Local Geological Sites (LWS) formerly included Regionally Important Geological Sites (RIGS); Local Nature Reserves; and Sites of Nature Conservation Importance.
Geology	The scientific study of the origin, history and structure of the earth.
Geomorphology	The scientific study of landforms and their evolution over different timescales.
Glaciagenic	Materials deposited as a result of glaciation or deglaciation.
Glaciofluvial	Glacial river deposits, or glaciofluvial deposits, consist of material that has been transported by rivers originating from glaciers.
Ground conditions	An assessment of the history and chemical and physical characteristics of the soil conditions at a site.
Groundwater	All water which is below the surface of the ground in the saturated zone and in direct contact with the ground or subsoil.
Groundwater Directive	Directive 2006/118/EC of the European Parliament and of the Council of 12 December 2006 on the protection of groundwater against pollution and deterioration.
Hydrogeology	The branch of geology dealing with water below the earth's surface and with the geological aspects of surface waters.
Natural ground subsidence	Lowering or collapse due to change in drainage patterns, groundwater abstraction largely associated with coal mining areas and karst landscapes. Can also occur in compressible soils such as peats.
Permeability	A measure of the ability of a porous material such as a soil or rock to transmit fluids (liquids or gases).
Principal aquifer	Layers of rock or drift deposits that have high inter-granular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifers.
Secondary A aquifer	Permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers.
Secondary B aquifer	Predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers.
Secondary undifferentiated aquifer	Has been assigned in cases where it has not been possible to attribute either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.
Shrink-Swell hazard	As a result of changes in moisture content in clay rich ground, shrinkage leading to differential settlement and swelling can lead to ground heave
Soil	Soil is a natural body consisting of layers (soil horizons) that are primarily composed of minerals which differ from their parent materials in their texture, structure, consistency, and colour, chemical, biological and other characteristics. Soil is the unconsolidated or loose covering of fine rock particles that covers the surface of the Earth and is the end product of the influence of the climate (temperature, precipitation), relief (slope), organisms (flora and fauna), parent materials (original minerals) and time.
Superficial deposits	The youngest geological deposits formed during the most recent period of geological time, the Quaternary, which extends back about 2.6 million years from the present. They rest on older deposits or rocks referred to as bedrock.
Till	A glacial deposit consisting chiefly of unstratified clay with embedded boulders.
Unconfined aquifer	Permeable groundwater aquifer rock unit that is in direct contact with the atmosphere through open pore spaces of the overlying soil or rock. The groundwater surface in an unconfined aquifer is called the water table.
Undifferentiated sediments	Rocks or sediments for which it is not possible to specify a finer age division.

Term	Definition
Unproductive aquifer	Drift or bedrock strata which are generally unable to support abstractions greater than 10 $m^3.d^{-1}$ and are unlikely to provide significant base flow. Formerly non- aquifers.
Water Framework Directive (WFD)	Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy.

Acronyms

Acronym	Description
BGS	British Geological Survey
CEA	Cumulative Effect Assessment
DECC	Department of Energy and Climate Change
MHWS	Mean High Water Springs
NPPF	National Planning Policy Framework
NPS	National Policy Statement
SPZ	Source Protection Zone
SSSI	Site of Special Scientific Interest
UXO	Unexploded Ordnance
WFD	Water Framework Directive

Units

Unit	Description
g	Gram (weight)
GW	Gigawatt (power)
km	Kilometre (distance)
kV	Kilovolt (electrical potential)
kg	Kilogram (weight)
kW	Kilowatt (power)
m	Metre (distance)
MW	Megawatt (power)
mg/l	Milligram per litre (concentration)

Unit	Description
Ma	Million years (time)
$w.m^{-1}$	Watts per linear metre (power consumed over distance)

1. Geology and Ground Conditions

1.1 Introduction

1.1.1.1 This chapter of the Preliminary Environmental Information Report (PEIR) presents the findings to date of the Environmental Impact Assessment (EIA) for the potential impacts of the Hornsea Project Three offshore wind farm (hereafter referred to as Hornsea Three) relevant to geology and ground conditions (namely the Hornsea Three landfall area, the onshore cable corridor search area, the onshore HVAC booster station, the onshore HVDC converter/HVAC substation and the connection with the Norwich Main National Grid substation), during its construction, operation and maintenance, and decommissioning. The onshore cable corridor search area comprises a 200 m wide corridor within which the refined onshore export cable corridor (80 m wide) will be located. The refined onshore cable corridor will be included in the application for Development Consent. The onshore HVAC booster station is an option which would only be considered for the HVAC transmission option (see volume 1, chapter 3: Project Description).

1.1.1.2 This chapter summarises information from technical reports and information, which are included at volume 6, Annex 1.1: Borehole Logs, Annex 1.2: Abstraction Licences and Annex 1.3: Discharge Consents and Permits.

1.2 Purpose of this chapter

1.2.1.1 The primary purpose of the Environmental Statement is to support the Development Consent Order (DCO) application for Hornsea Three under the Planning Act 2008 (the 2008 Act). This PEIR constitutes the Preliminary Environmental Information for Hornsea Three and sets out the findings of the EIA to date to support pre-application consultation activities required under the 2008 Act. The EIA will be finalised following completion of pre-application consultation and the Environmental Statement will accompany the application to the Secretary of State for Development Consent.

1.2.1.2 The PEIR will form the basis for Phase 2 Consultation which will commence on 27 July and conclude on 20 September 2017. At this point, comments received on the PEIR will be reviewed and incorporated (where appropriate) into the Environmental Statement, which will be submitted in support of the application for Development Consent scheduled for the second quarter of 2018.

1.2.1.3 In particular, this PEIR chapter:

- Presents the existing environmental baseline established from desk studies and consultation;
- Presents the potential environmental effects on Geology and Ground Conditions arising from Hornsea Three, based on the information gathered and the analysis and assessments undertaken to date;
- Identifies any assumptions and limitations encountered in compiling the environmental information; and
- Highlights any necessary monitoring and/or mitigation measures which could prevent, minimise, reduce or offset the possible environmental effects identified in the EIA process.

1.2.1.4 The effects considered in this chapter include those on geology, hydrogeology and groundwater that form part of the onshore physical environment. Effects on hydrology and surface water resources are considered in volume 3, chapter 2: Hydrology and Flood Risk.

1.3 Study area

1.3.1.1 The geology and ground conditions study area comprises the onshore elements of Hornsea Three (as described in 1.1.1.1) and the potential locations of the main construction compound plus a 1 km buffer. The potential locations of the main compounds are identified in volume 1, chapter 3: Project Description. Additional construction compounds will be required to facilitate the construction process and will be identified in the Environmental Statement.

1.3.1.2 The size of buffer was chosen primarily to allow for variance in final location and alignments and to identify any existing assets or infrastructure (including landfills) that might affect or be affected by Hornsea Three. The study area is shown on Figure 1.1 below. A wider or narrower buffer was used for some geological/ground conditions features as these distances represent the area where impacts are most likely to occur. These distances are identified below:

- Geology within 50 m:
  - Artificial ground;
  - Superficial deposits; and
  - Bedrock geology.
- Hydrogeology:
  - Principal aquifers within 1 km;
  - Secondary aquifers (either secondary A, secondary B or secondary undifferentiated) within 500 m;
  - Groundwater and potable water abstraction licenses within 1 km; and
  - Source Protection Zones (SPZs) within 1 km.
- Environmental permits, incidents and registers within 500 m;
- Landfill and other waste sites within 1 km;
- Mineral extraction sites and Mineral Safeguarding Areas within 1 km;
- Current land use within 500 m;
- Historical mapping within 500 m;
- Designated sites within 500 m;

- Natural hazards (natural ground subsidence, shrink-swell hazard, compressible ground hazard) on site or within 500 m; and
- Mining and associated risk of subsidence within 50 m of the onshore HVAC booster station and HVDC converter/HVAC substation site.

1.3.1.3 The scope of the PEIR assessment for geology and ground conditions has been discussed with the local planning authorities leading up to the PEIR submission and further feedback is welcomed at this stage.

1.4 Planning policy context

1.4.1.1 Planning policy on offshore renewable energy Nationally Significant Infrastructure Projects (NSIPs), specifically in relation to geology and ground conditions, is contained in the Overarching National Policy Statement (NPS) for Energy (EN-1) (DECC, 2011a), the NPS for Renewable Energy Infrastructure (EN-3) (DECC, 2011b) and the NPS for Electricity Networks Infrastructure (EN-5) (DECC, 2011c).

1.4.1.2 NPS EN- 1 and NPS EN-5 include guidance on what matters are to be considered in the assessment. These are summarised in Table 1.1 below. Other planning policy and guidance relevant to this chapter.

- National Planning Policy Framework (NPPF) (2012);
- Web based planning practice guidance is provided by the Department for Communities and Local Government (DCLG). Guidance on the Natural Environment (updated in January 2016), and Land Affected by Contamination (updated in March 2014); and
- Norfolk Geodiversity Action Plan (2011).

Table 1.1: Summary of NPS EN-1 and EN-5 provisions relevant to geology and ground conditions.

Summary of NPS EN-1 and NPS EN-5 provision	How and where considered in the PEIR
Geology	
Where the development is subject to EIA the applicant should ensure that the ES clearly sets out the effects on internationally, nationally and locally designated sites of ecological or geological conservation importance (paragraph 5.3.3 of NPS EN-1).	The PEIR assesses identifies internationally, nationally and locally designated sites of geological conservation importance which may be affected in paragraphs1.10.2.3 to 1.10.2.15.
The applicant should show how the project has taken advantage of opportunities to conserve and enhance biodiversity and geological conservation interests (paragraph 5.3.4 of NPS EN-1).	Due to the nature of the proposed development, there are no significant opportunities to conserve or enhance any geological conservation interests.
Ground Conditions	
For developments on previously developed land, applicants should ensure that they have considered the risk posed by land contamination (Paragraph 5.10.8 of NPS EN-1).	The PEIR considers the risk posed by land contamination in paragraphs 1.10.2.1 to 1.10.4.11.
Infrastructure development can have adverse effects resulting in groundwater or protected areas failing to meet environmental objectives established under the Water Framework Directive (WFD) 146 (Paragraph 5.15.1 of NPS EN-1).	Assessment of ground disturbance is undertaken specifically on secondary A and B aquifers and on the principal aquifer in paragraphs 1.10.2.1 to 1.10.4.11.
Where the project is likely to have effects on the water environment, the applicant should undertake an assessment of the existing status of, and the impacts of the proposed project on, water quality, water resources and physical characteristics of the water environment. In particular the ES should describe, any impacts of the proposed project on water bodies or protected areas under the Water Framework Directive and source protection zones (SPZs) around potable groundwater abstractions (paragraphs 5.15.2 and 5.15.3 of NPS EN-1).	The PEIR assesses the impacts on source protection zones and water bodies protected under the WFD in paragraphs 1.10.2.21 to 1.10.2.33.
NPS EN-5 Section 2.8: Landscape and Visual identifies the greater environmental consequences of undergrounding of power lines in comparison with overhead cabling where disturbance of ground may have an impact on soils and geology (paragraph 2.8.9 of EN-5).	Assessment of ground disturbance is undertaken specifically on secondary A and B aquifers and on the principal aquifer in paragraphs 1.10.2.21 to 1.10.2.41.
Applicants should safeguard any mineral resources on the proposed site as far as possible, taking into account the long-term potential of the land use after any future decommissioning has taken place (paragraph 5.10.9 of NPS EN-1).	A mineral assessment of any Mineral Safeguarded Areas would be undertaken along the onshore export cable corridor and onshore HVAC booster station (see Table 1.13). The onshore HVDC converter/HVAC substation does not fall within a Mineral Safeguarded Area.

1.4.1.3 NPS EN-1 and NPS EN5 also highlight a number of points relating to the determination of an application and in relation to mitigation. These are summarised in Table 1.2 below.

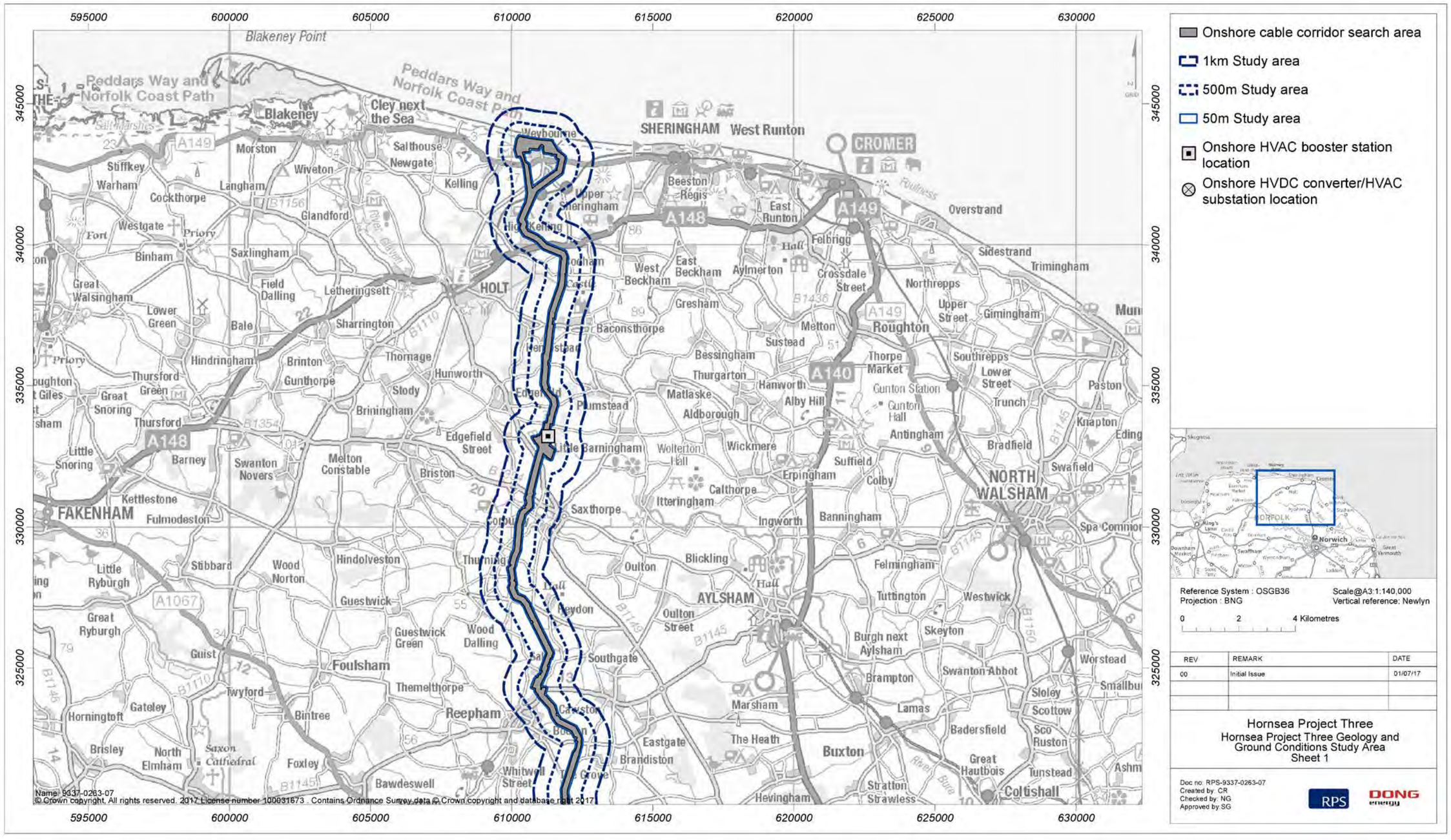

Figure 1.1: Hornsea Three geology and ground conditions study area:

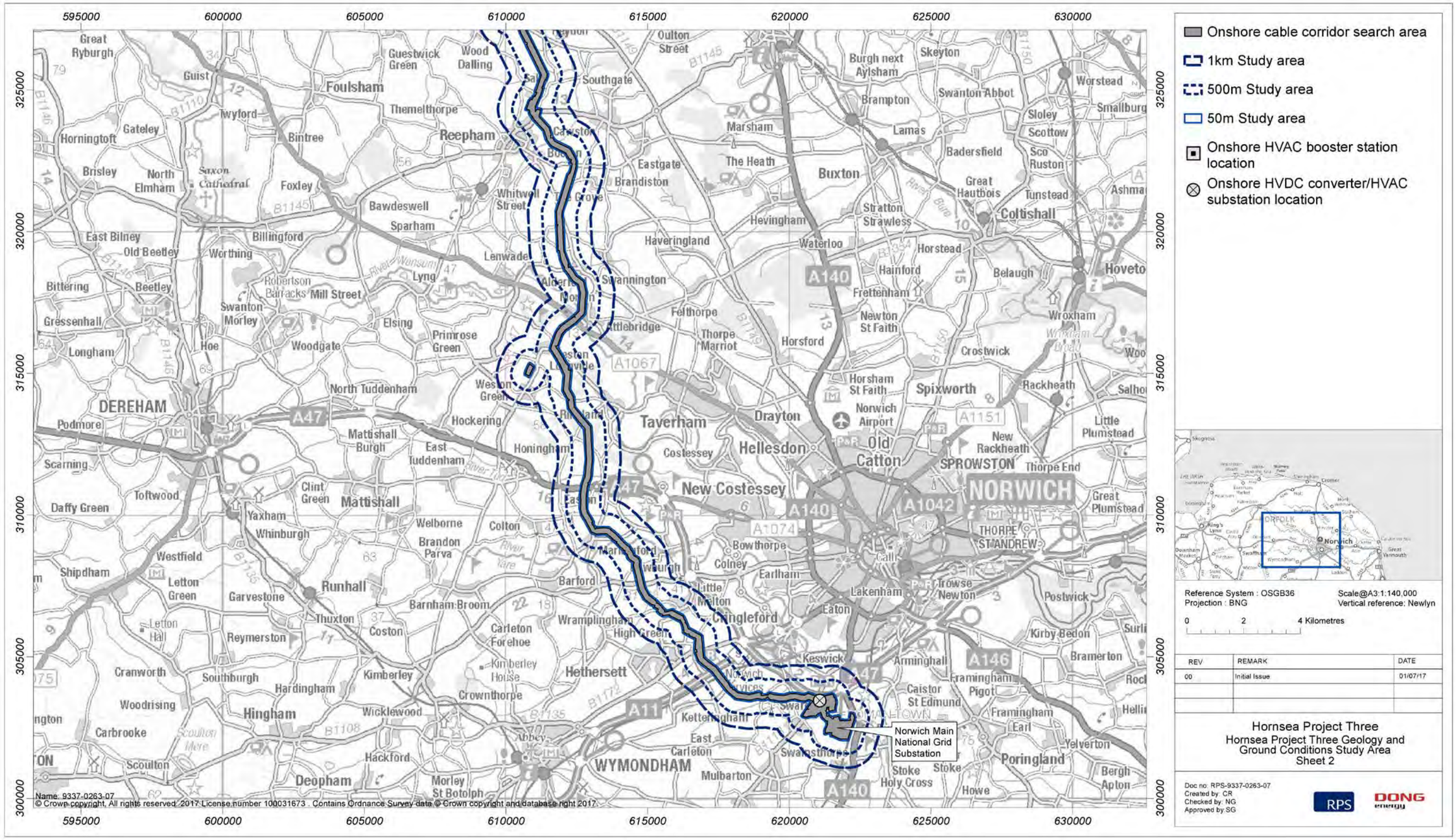

Figure 1.1: Honrsea Three geology and ground conditions study area.

Table 1.2: Summary of NPS EN-1 and NPS EN-5 policy on decision making relevant to geology and ground conditions.

Summary of NPS EN-1 and NPS EN-5 policy on decision making (and mitigation)	How and where considered in the PEIR
Geology	
Decision making should ensure that appropriate weight is attached to designated sites of international, national and local importance and to geological interests within the wider environment (paragraph 5.3.8 of NPS EN-1). Sites of Special Scientific Interest (SSSIs) including all National Nature Reserves should be given a high degree of protection (paragraph 5.3.10 of NPS-EN1).	Potential impacts on designated sites has been assessed and due weight afforded with appropriate mitigation measures recommended.
Development consent will not normally be granted where development within or outside an SSSI is likely to have an adverse effect on an SSSI, except where the benefits (including need) clearly outweigh the impacts on the features for which the SSSI is designated or the broader impacts on the national network of SSSIs. Decision makers should use requirements and/or planning obligations to mitigate the harmful aspects of the development and where possible to ensure the conservation and enhancement of the site's geological interest (paragraph 5.3.11 of NPS EN-1).	
Decision making should give due consideration to regional or local designations for sites of regional and local biodiversity and geological interest, which include Regionally Important Geological Sites, Local Nature Reserves and Local Geological Sites (paragraph 5.3.13 of NPS EN-1).	No county or local geological sites have been identified in the geology and ground conditions study area.
Ground Conditions	
The applicant should demonstrate that during construction they will seek to ensure that activities will be confined to the minimum areas required for the works (paragraph 5.3.18 of NPS EN-1).	The PEIR assesses an onshore cable corridor search area within which the refined onshore export cable corridor will be located. The final Environmental Statement will demonstrate that the Applicant has endeavoured to ensure construction activities are confined to the minimum areas required for work (see volume 1, chapter 3: Project Description and chapter 4: Site Selection and Consideration of Alternatives). Appropriate mitigation measures in relation to geology and ground conditions are set out in Table 1.13.
Where a proposed development has an impact upon a Mineral Safeguarding Area, the IPC should ensure that appropriate mitigation measures have been put in place to safeguard mineral resources (paragraph 5.10.22 of NPS EN-1).	Mineral Safeguarded Areas have been identified within the geology and ground conditions study area. A mineral assessment of any Mineral Safeguarded Area would be undertaken along the onshore export cable corridor and onshore HVAC booster station (see Table 1.13) in line with Norfolk County Council guidance. The onshore HVDC converter/HVAC substation does not fall within a Mineral Safeguarded Area (see Figure 1.3).
The environmental and archaeological consequences of undergrounding, for example undergrounding a 400kV line may mean disturbing a swathe of ground up to 40 metres across, which can disturb sensitive habitats, have an impact on soils and geology, and damage heritage assets, in many cases more than an overhead line would) (paragraphs 2.8.8-2.8.9 of NPS EN-5)	No recommended mitigation in relation to geology in NPS EN-5. The PEIR assesses the potential effects of cable undergrounding on geology and ground conditions.

1.4.1.4 The National Planning Policy Framework (NPPF) replaces previous PPSs. Section 11 of the NPPF is concerned with conserving and enhancing the natural environment and paragraph 121 states that planning policies and decisions should ensure that sites are suitable for any proposed new use and that account is taken of ground conditions and land stability including natural hazards, former activities and appropriate mitigation including remediation. After remediation, land must not be capable of being determined as contaminated land under Part IIA of the Environmental Protection Act 1990 and adequate site investigation information prepared by a competent person must be presented.

1.4.1.5 The NPPF also contains policies requiring Local Authorities to have regard to mineral safeguarding. Paragraph 143 of the NPPF states that local planning authorities should define mineral safeguarded areas and that local plans should "*set out policies to encourage the prior extraction of minerals, where practicable and environmentally feasible, if it is necessary for non-mineral development to take place*".

1.4.1.6 On 6 March 2014 the Department for Communities and Local Government (DCLG) launched the Planning Policy Guidance as a web-based resource. Land Affected by Contamination (updated March 2014) considers where contamination is most likely to occur and the role of planning in addressing contamination issues. Guidance on the Natural Environment (updated in January 2016) includes the need to protect geodiversity.

1.4.1.7 Mineral Safeguarding Areas/Mineral Consultation Areas are recognised in national policy and there is a requirement for Mineral Planning Authorities to define these areas as part of the mineral planning process. The adopted Norfolk Minerals and Waste Local Development Framework (Norfolk County Council, 2011) addresses these requirements, and forms part of the Development Plan for Norfolk. Norfolk County Council, in its capacity as the Mineral Planning Authority, has defined Mineral Safeguarding Areas to cover sand and gravel, carstone and silica sand. These areas are also defined as Mineral Consultation Areas for mineral resources.

1.4.1.8 National policy also requires Mineral and Waste Planning Authorities to safeguard existing mineral and waste sites and mineral site allocations. In Norfolk, this is defined within the Norfolk Minerals and Waste Local Development Framework, and a list of safeguarded sites is maintained. Safeguarded areas are surrounded by a consultation area. The baseline data contained references and mapping for the safeguarded mineral resources and sites. Minerals and Waste Core Strategy Policy CS16 'safeguarding' contains more information regarding mineral resource, and mineral and waste site safeguarding in Norfolk.

1.4.1.9 At a local level, the onshore cable corridor search area lies within the districts of North Norfolk, Broadland and South Norfolk. The onshore HVAC booster station is located within North Norfolk and the onshore HVDC converter/HVAC substation is located in South Norfolk. There are no saved policies regarding geological or ground conditions aspects in the Joint Core Strategy for these authorities and no Local Development Plan policies have yet been developed.

1.4.1.10 The Norfolk Geodiversity Action Plan (NGAP) (Norfolk Geodiversity Partnership, 2011) covers the county of Norfolk (i.e. the areas administered by Norfolk County Council, North Norfolk District Council, Broadlands District Council, and South Norfolk Council etc.). It aims to understand, audit, protect and enhance the Norfolk geodiversity resources whilst promoting geodiversity awareness, understanding, and embedding its importance within planning and policy.

1.4.1.11 The Norfolk Geodiversity Partnership is a forum for individuals and organisations interested in conserving and enhancing Norfolk's earth heritage whose vision is:

- That the contribution of geodiversity to the landscape, biodiversity, economy and culture of Norfolk will be valued and understood; and
- That the geodiversity of Norfolk will be protected and enhanced for the sustainable use and enjoyment of all living things.

1.5 Consultation

1.5.1.1 Table 1.3 below summarises the issues raised relevant to geology and ground conditions, which have been identified during consultation activities undertaken to date. Table 1.3 also indicates either how these issues have been addressed within this PEIR or how the Applicant has had regard to them.

Table 1.3: Summary of key consultation issues raised during consultation activities undertaken for Hornsea Three relevant to geology and ground conditions.

Date	Consultee and type of response	Issues raised	Response to issue raised and/or where considered in this chapter
24 September 2016	Norfolk County Council – consultation meeting	Identification of existing minerals extraction sites and safeguarded areas in the vicinity of the projects onshore scoping area.	Mineral Safeguarded Areas are identified in paragraphs 1.7.3.1 and 1.7.3.2. Where relevant planned mineral extractions have been considered in the cumulative impacts assessment section 1.12.
24 November 2016	Environment Agency – Scoping Response	The Environment Agency was pleased with the impacts being scoped into the Assessment. If an area of land contamination is identified within the cable corridor which may affect principal and secondary aquifers a Preliminary Risk Assessment will need to be undertaken.	A review of current and historical land use within the geology and ground conditions study area has been undertaken is described in paragraphs 1.7.5.27 to 1.7.5.34 and Table 1.13. Procedures to deal with contamination (including Preliminary Risk Assessments where appropriate) would be prepared before development commenced (see Table 1.13).
		The Environment Agency recommends that the cable corridor does not pass through areas designated as Source Protection Zone 1.	Source Protection Zones within the geology and ground conditions study area are described in paragraphs 1.7.5.19 to 1.7.5.22.
		HDD should be used where sensitive habitats cannot be avoided. Further information will be required detailing the sensitive locations where it is proposed to carry out HDD. However, ground investigation is required to inform the suitability of HDD and there may be locations where this technique would not work due to the geology. Appropriate pollution prevention measures will need to be in place to prevent the release of drilling fluid into the water environment and to prevent the release of silt downstream together with appropriate incident plans in case of any pollution incidents.	Site investigations will be undertaken (during detailed design) at each proposed HDD location to confirm suitability of geology (see Table 1.13). Measures for trenchless techniques under watercourses and pollution prevention measures are outlined in Table 1.13 .
28 November 2016	Norfolk County Council – Scoping Response	Additional data sources should be added to the list. • Safeguarded Mineral resource mapping, as defined within the Norfolk Minerals and Waste Local development Framework; and • Safeguarded Mineral and Waste sites, as defined within the adopted Norfolk Minerals and Waste Local development Framework.	These data sources were obtained from Norfolk County Council following the meeting in September 2016. Mineral safeguarded areas are described in paragraphs 1.7.3.1 and 1.7.3.2 and shown on Figure 1.3. Where relevant planned mineral extractions have been considered in the cumulative impacts assessment section 1.12 and Mineral Safeguarded Areas are considered in section 1.10.2.
		An additional paragraph is required to explain that Mineral Safeguarding Areas/Mineral Consultation Areas are recognised in national policy.	Text has been added in paragraphs 1.4.1.7 and 1.4.1.8.
		Table 10.2 of the Scoping Report should be amended to take into account the potential for impacts to safeguard mineral resources and safeguarded mineral and waste sites.	Assessment of the impacts to mineral safeguarded areas is discussed in paragraphs 1.10.2.16 to 1.10.2.19.
6 December 2016	PINS – Scoping Opinion	Careful consideration should be given to the potential for overlapping cable corridors with the Norfolk Vanguard offshore wind farm and any resultant cumulative impacts.	Cumulative impacts are discussed in section 1.12.
25 November 2016	Public Health England – Scoping Response	We would expect the promoter to provide details of any hazardous contamination present on site (including ground gas) as part of the site condition report. Emissions to and from the site should be considered in terms of previous history of the site and the potential of the site, once operational, to give rise to issues.	Potential contamination is identified in paragraphs 1.7.5.27 to 1.7.5.33. An approach to deal with potentially contaminated land is set out in Table 1.13 .

1.6 Methodology to inform the baseline

1.6.1.1 The baseline conditions were identified by a desktop review of:

- British Geological Survey (BGS) 1:50,000 geological mapping;
- BGS borehole records for locations in the vicinity obtained from the BGS website;
- GroundSure (2017a) Enviro Insight database reports on environmental information for the Hornsea Three landfall area, onshore cable corridor search area, onshore HVAC booster station and onshore HVDC converter/HVAC substation;
- GroundSure (2017b) Geo Insight database reports on environmental information for the Hornsea Three landfall area, onshore cable corridor search area, onshore HVAC booster station and onshore HVDC converter/HVAC substation; and
- Environment Agency information on groundwater vulnerability, SPZs and bedrock/superficial deposit aquifer status.

1.6.2 Desktop study

1.6.2.1 Information on geology and ground conditions within the geology and ground conditions study area, identified in Figure 1.1, was collected through a detailed desktop review of existing studies and datasets. These are summarised at Table 1.4 below.

Table 1.4: Summary of key desktop reports.

Title	Source	Year	Author
Hydrogeology	Hydrogeological Map of Northern East Anglia	1976	BGS (published by predecessor body the Institute of geological Sciences - IGS)
BGS 1:50,000 and 1:10,000 digital geological mapping	BGS via Groundsure GeoInsight Report	2016	BGS
Borehole records for locations in the vicinity	BGS Website http://mapapps2.bgs.ac.uk/geoindex/home.html	2016	BGS
SPZs/Aquifer Designations	Environment Agency via Groundsure EnviroInsight Report	2016	Environment Agency
Private Water Supplies	BGS Well data set and Local Authority Environmental Health data sets	2016	N/A
Natural Hazards data set	BGS via Groundsure GeoInsights Report	2016	BGS
Geological descriptions	BGS Website http://mapapps2.bgs.ac.uk/geoindex/home.html	2016	BGS
County Geodiversity Sites	Norfolk County Council (www.norfolk.gov.uk)	2017	Norfolk County Council
Waterbodies designated under WFD	http://environment.data.gov.uk/catchment-planning/	2017	Environment Agency
Designated geological sites.	www.magic.gov.uk.	2017	Department for Environment, Food & Rural Affairs (Defra)

1.6.3 Designated Sites

1.6.3.1 All designated sites within the geology and ground conditions study area that could be affected by the construction, operation and maintenance, and decommissioning of Hornsea Three for geology and ground conditions, were identified using the three step process described below:

- Step 1: All designated sites of international, national and local importance within the geology and ground conditions study area were identified using a number of sources. These included MAGIC and Norfolk County Council Website.
- Step 2: Information was compiled on the relevant geological features for each of these sites as follows; name, location and details of relevant features.
- Step 3: Using the above information and expert judgement, sites were included for further consideration if, for example:
  - A designated site directly overlaps with Hornsea Three; and
  - Sites and associated features were located within the potential Zone of Impact (ZoI) for impacts associated with Hornsea Three.

1.6.4 Site specific surveys

1.6.4.1 No site specific surveys have been undertaken for geology and ground conditions at the PEIR stage as the onshore export cable corridor has not been refined and the location of the proposed HDD crossings has not been finalised. Site specific surveys, such as intrusive investigations would be undertaken, if required, during the detailed design stage.

1.7 Baseline environment

1.7.1.1 This section reviews the geology and ground conditions within the geology and ground conditions study area (as described in paragraph 1.3.1.1). The onshore assessment commences landward of the MHWS and does not consider the intertidal zone (considered in volume 2, chapter 1: Marine Processes).

1.7.2 Designated sites

1.7.2.1 Designated geological sites within 500 m of the onshore elements of Hornsea Three and therefore, most likely to be potentially affected by activities associated with it are described in Table 1.5 and shown on Figure 1.2. The description of the geological features has been taken from the Natural England website www.natureonthemap.naturalengland.org.uk (Defra, 2017).

Table 1.5: Designated geological sites.

Site	Closest distance to onshore elements of Hornsea Three	Features
Weybourne Cliffs SSSI	0 km	Cliffs east of Weybourne afford the best Pleistocene sections showing the pre-Cromerian deposits of the Cromer Forest bed. The type locality for the Pastonian Weybourne Crag.
Weybourne Town Pit SSSI	0.25 km	The type locality for the Pleistocene 'Marly Drift', a chalk-rich glacial till of supposed Anglian age.
Kelling Heath SSSI	0 km	Kelling Heath SSSI provides perhaps the best example of glacial outwash plain in England It has steep slopes and is dissected by deep dry valleys and is a geomorphological site of national importance.

Description from Natural England website via www.natureonthemap.naturalengland.org.uk (Defra, 2017).

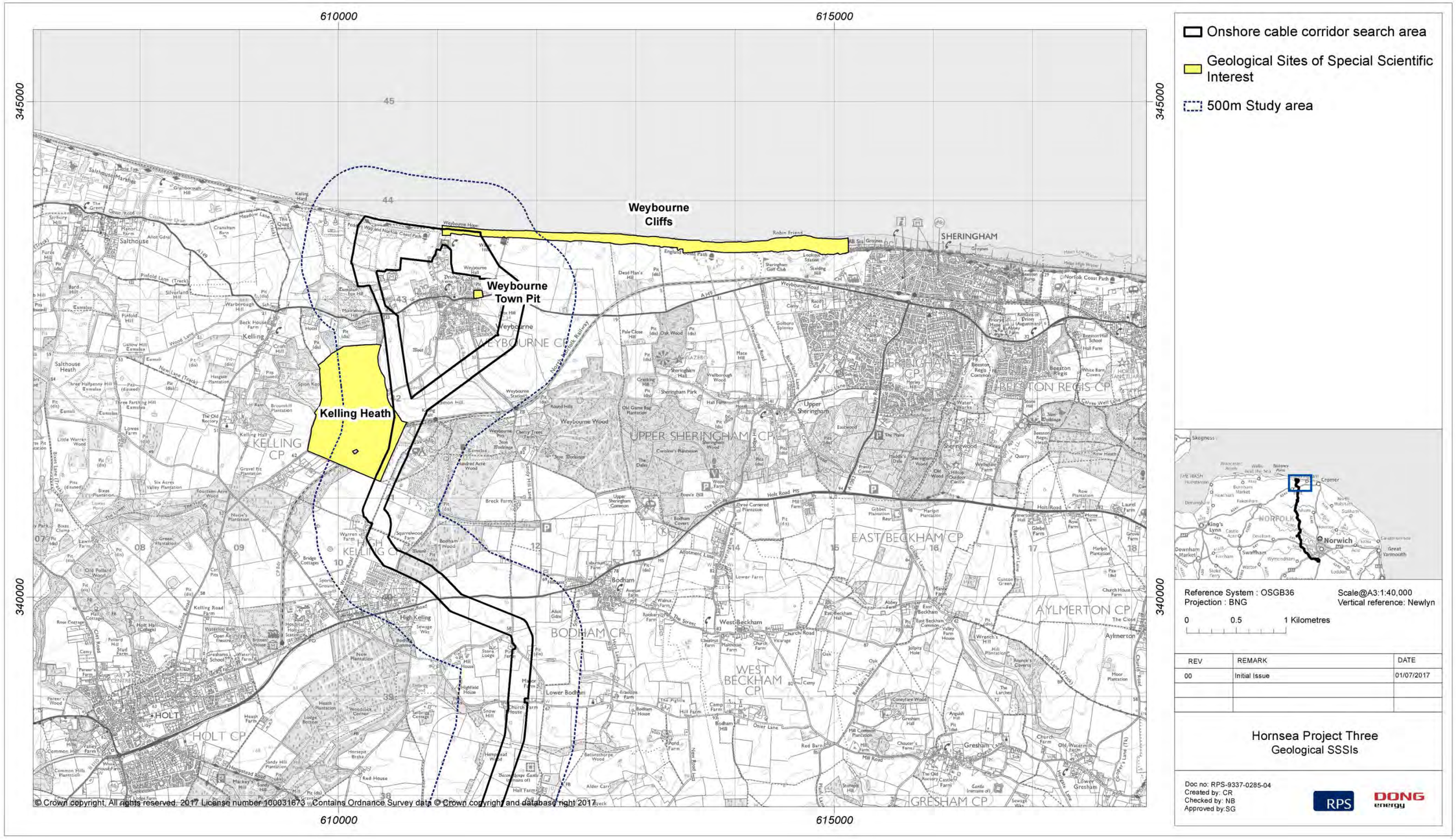

Figure 1.2: Designated geological sites.

1.7.3 Mineral Safeguarded Sites and Areas

1.7.3.1 Sand and gravel resources are abundant and located throughout large areas of Norfolk (Norfolk County Council, 2011). The closest sand and gravel quarry to the geology and ground conditions study area is at Mangreen, which is approximately 400 m to the east of the onshore cable corridor search area (see Figure 1.3). The quarry has been extended to the immediate south of the original quarry. Both the quarry and its extension are operational with restoration required before the end of 2023. Two site allocations for further southern extensions to Mangreen quarry have been put forward through the Minerals Site Specific Allocations Development Plan Document.

1.7.3.2 The Minerals and Waste Development Framework identifies several Mineral Safeguarded Areas (sand and gravel), which are located within the geology and ground conditions study area (in particular sections of the onshore cable corridor search area and the site of the onshore HVAC booster station). The onshore HVDC converter/HVAC substation is not located within a Mineral Safeguarded Area. Guidance from Norfolk County Council on the mineral safeguarding process for aggregates (Norfolk County Council, 2014) defines Mineral Safeguarded Areas as "*those areas where there isn't an underlying mineral resources which may be of economic interest, which should be protected from unnecessary sterilisation by non-mineral development*". The guidance also states that mineral deposits found in Norfolk are highly variable and the data used to define the Mineral Safeguarded Areas is general in nature. The guidance goes on to state that planning applications for non-mineral uses in Mineral Safeguarded Areas should consult the Mineral Planning Authority on the assessment of the mineral resources to identify the quality of any mineral and the depth of any overburden present.

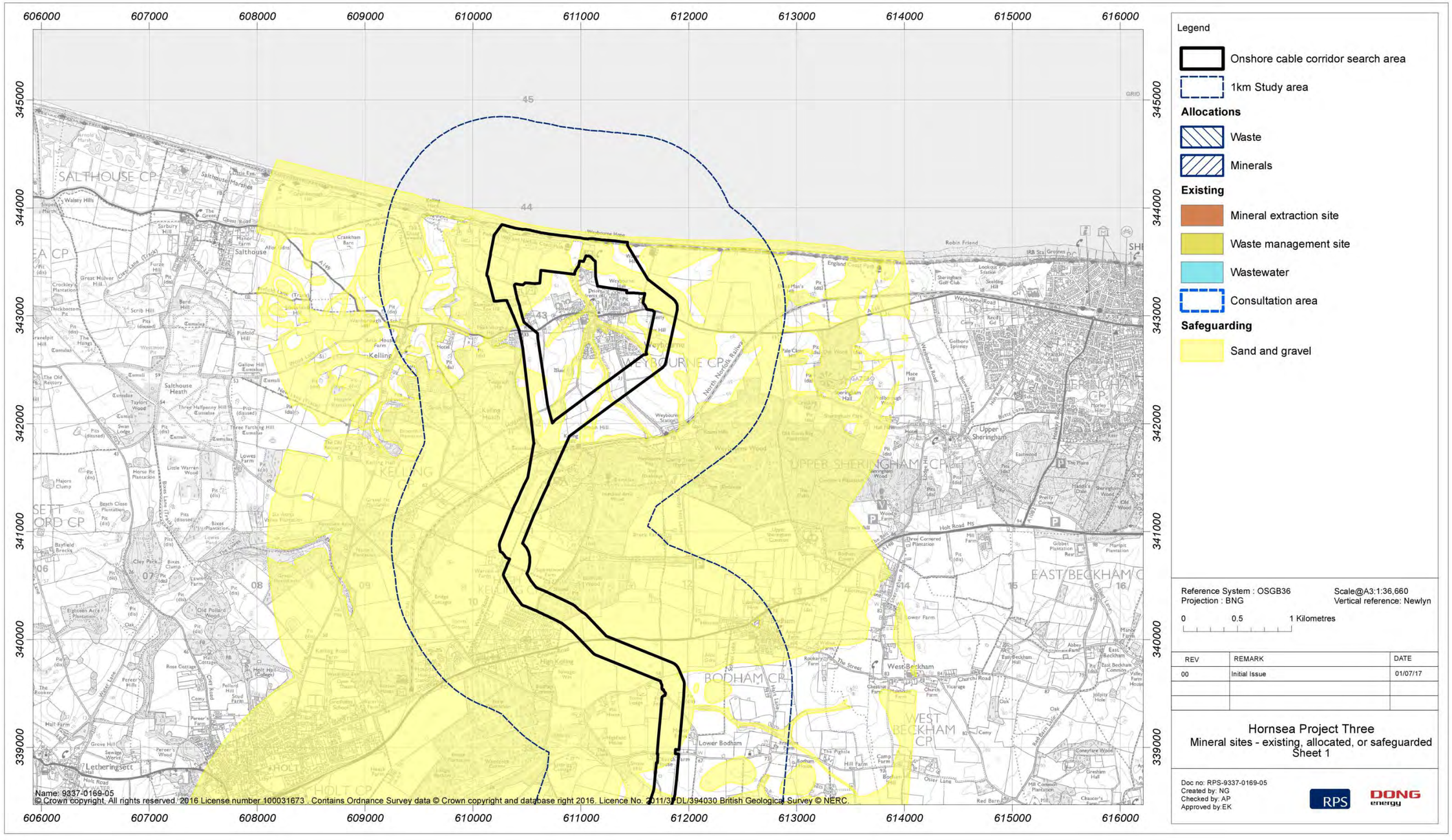

Figure 1.3: Mineral extraction sites and mineral safeguarding areas.

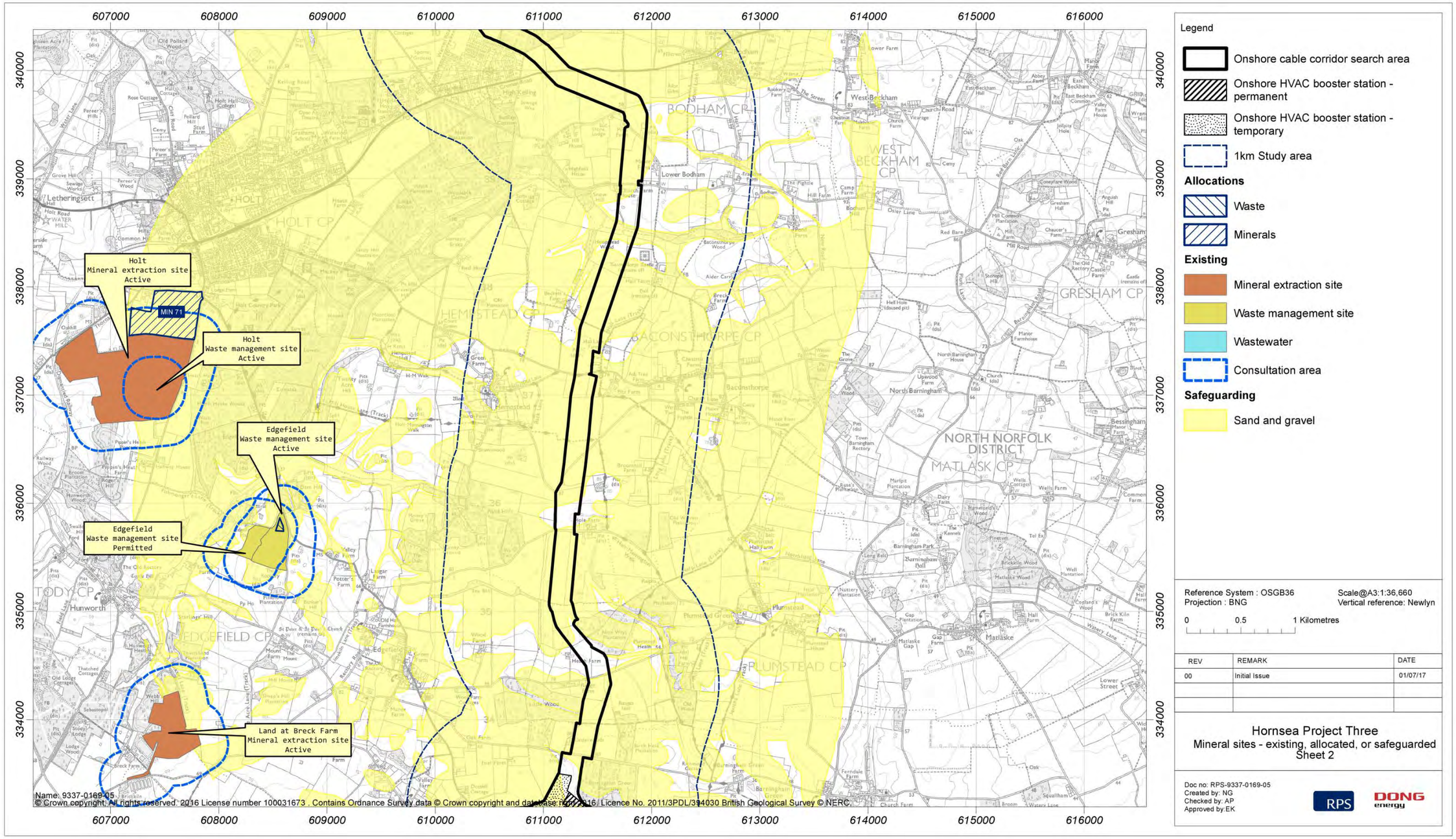

Figure 1.3: Mineral extraction sites and mineral safeguarding areas.

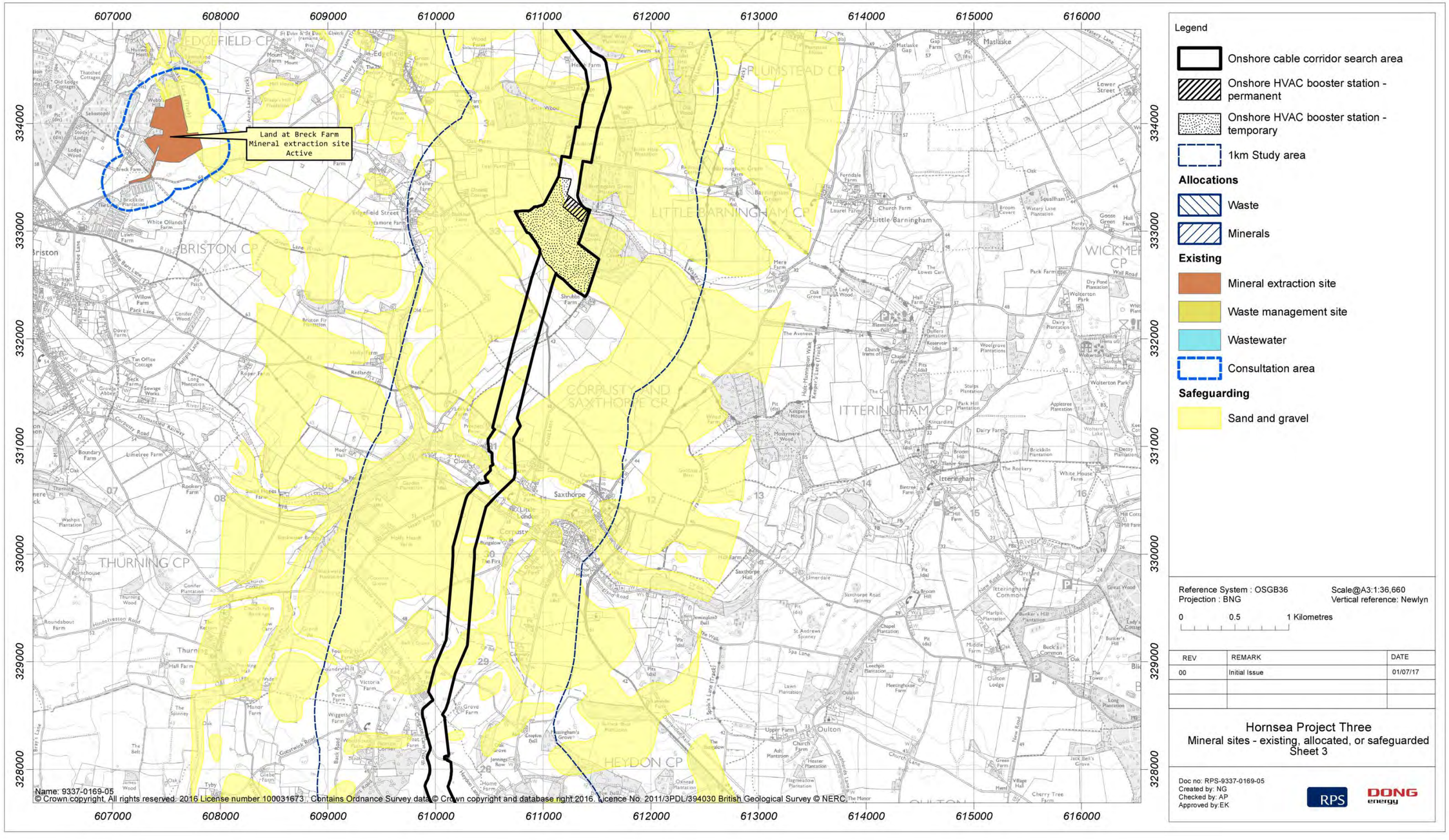

Figure 1.3: Mineral extraction sites and mineral safeguarding areas.

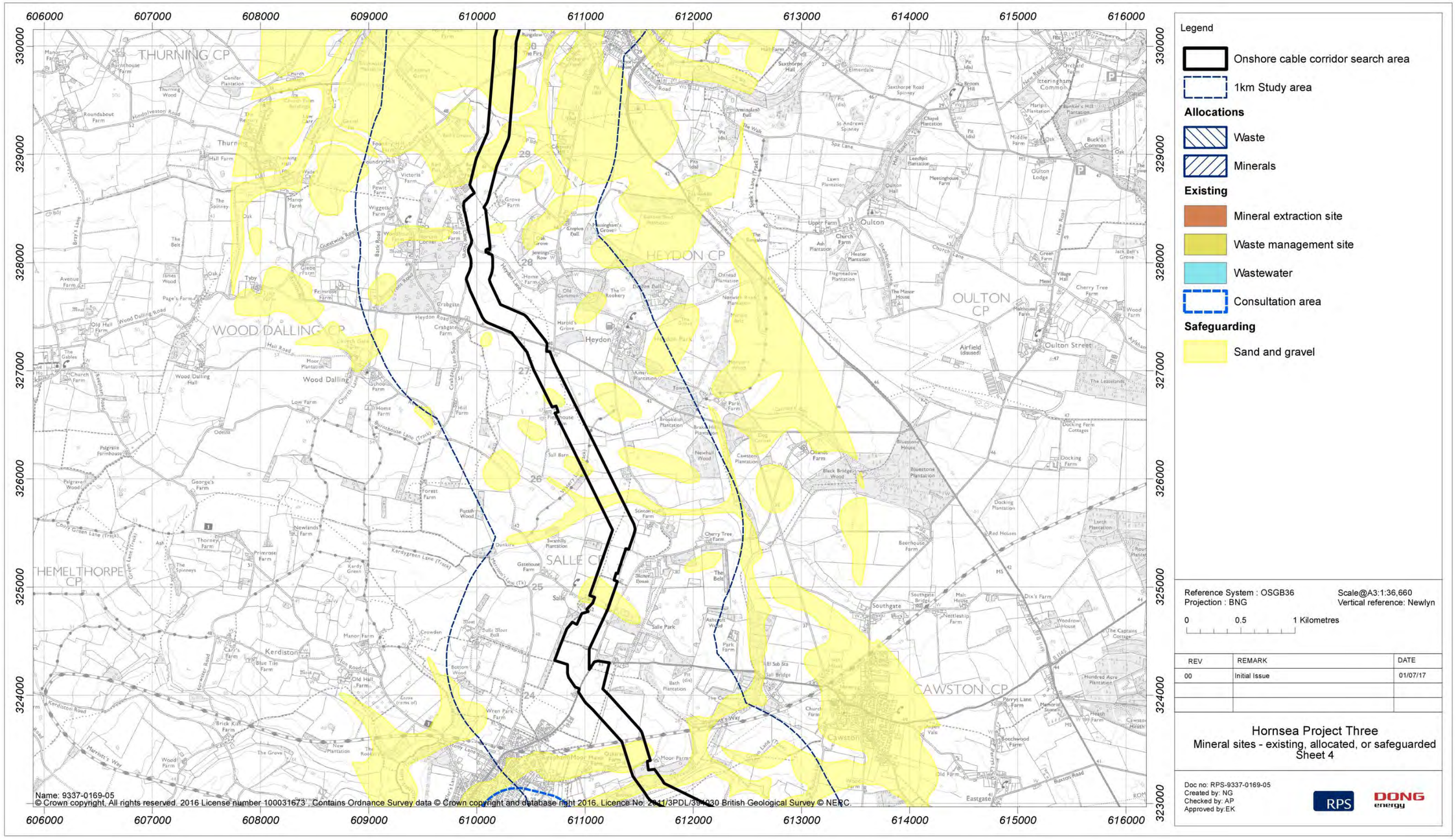

Figure 1.3: Mineral extraction sites and mineral safeguarding areas.

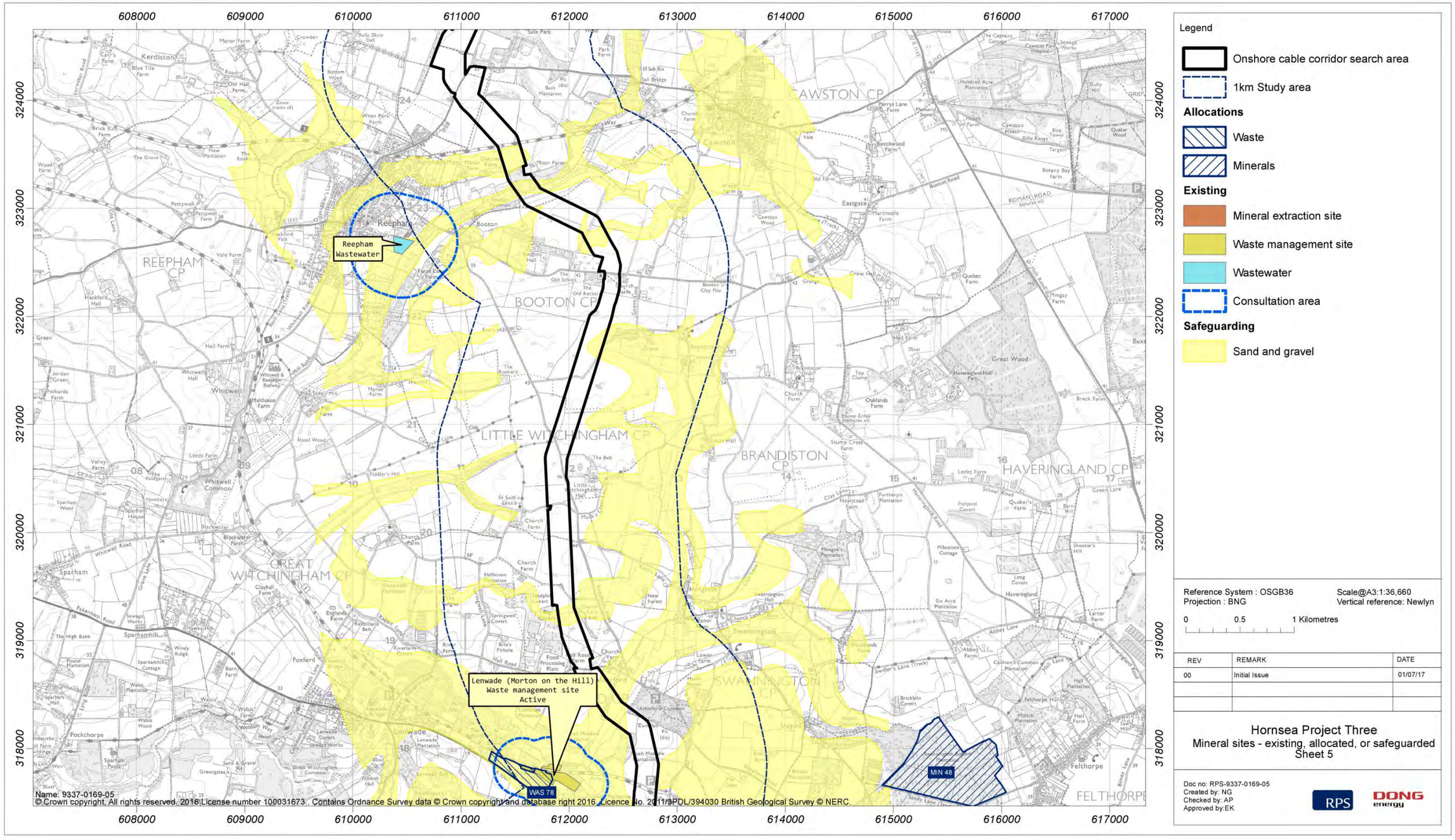

Figure 1.3: Mineral extraction sites and mineral safeguarding areas.

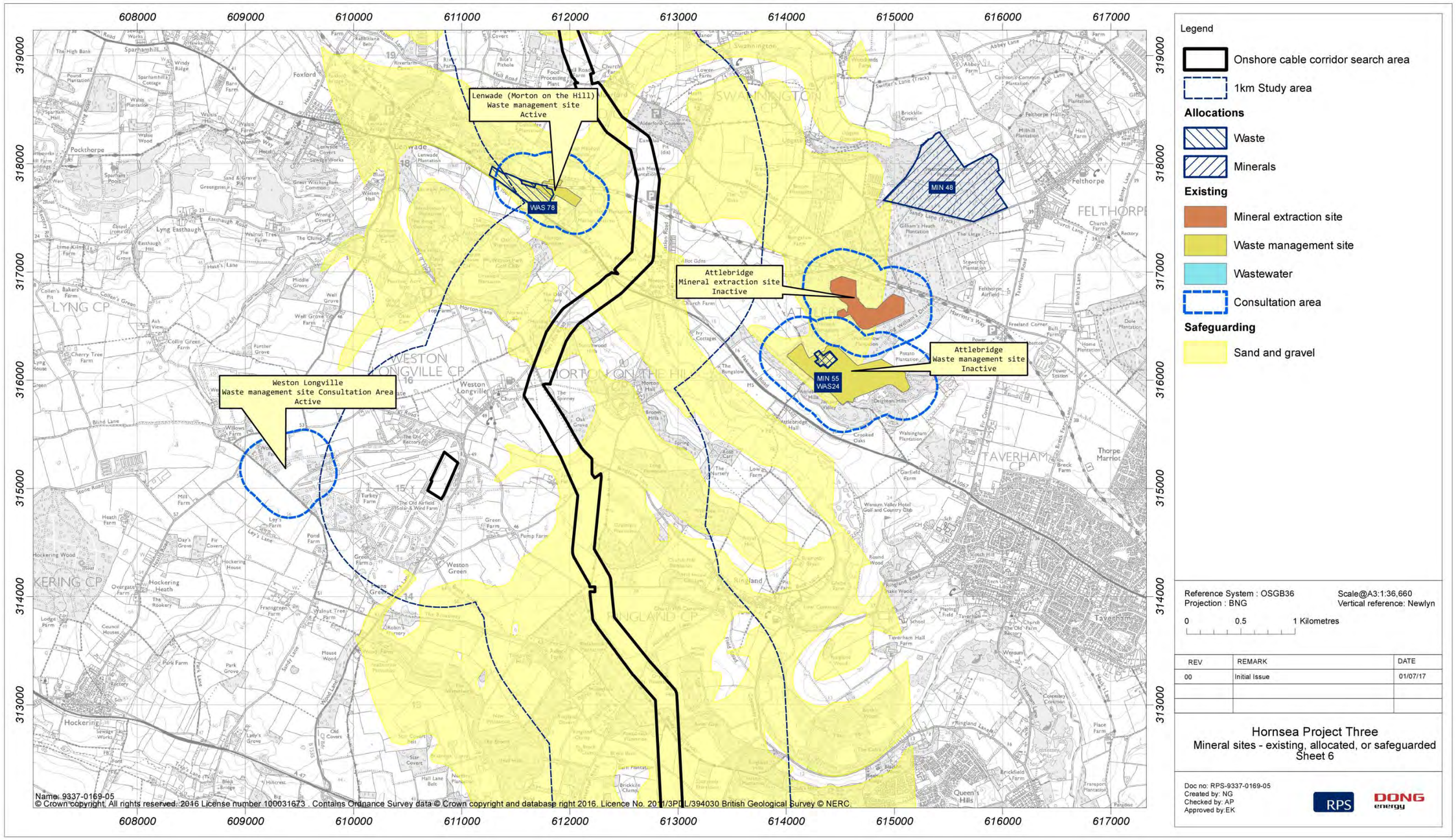

Figure 1.3: Mineral extraction sites and mineral safeguarding areas.

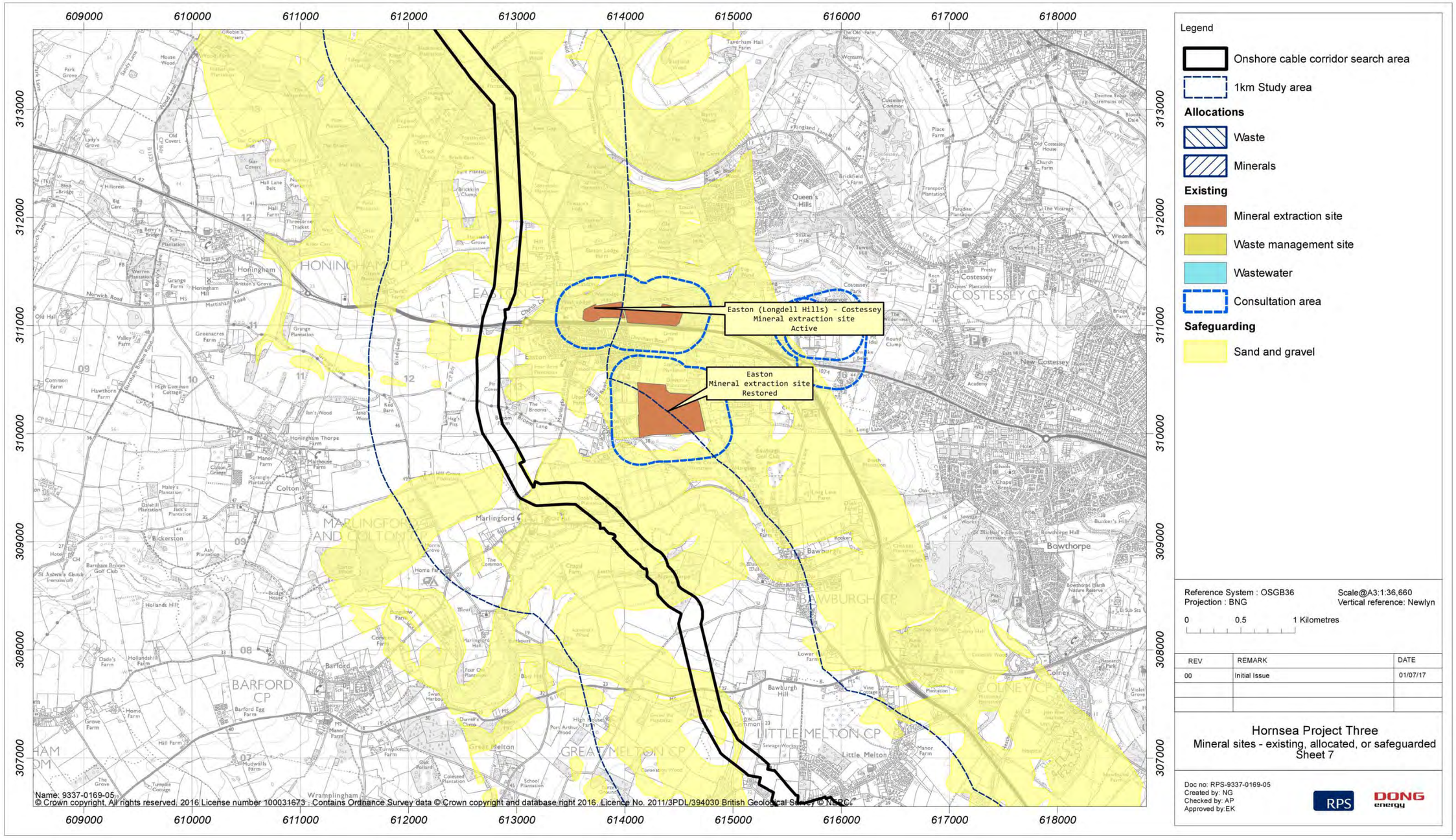

Figure 1.3: Mineral extraction sites and mineral safeguarding areas.

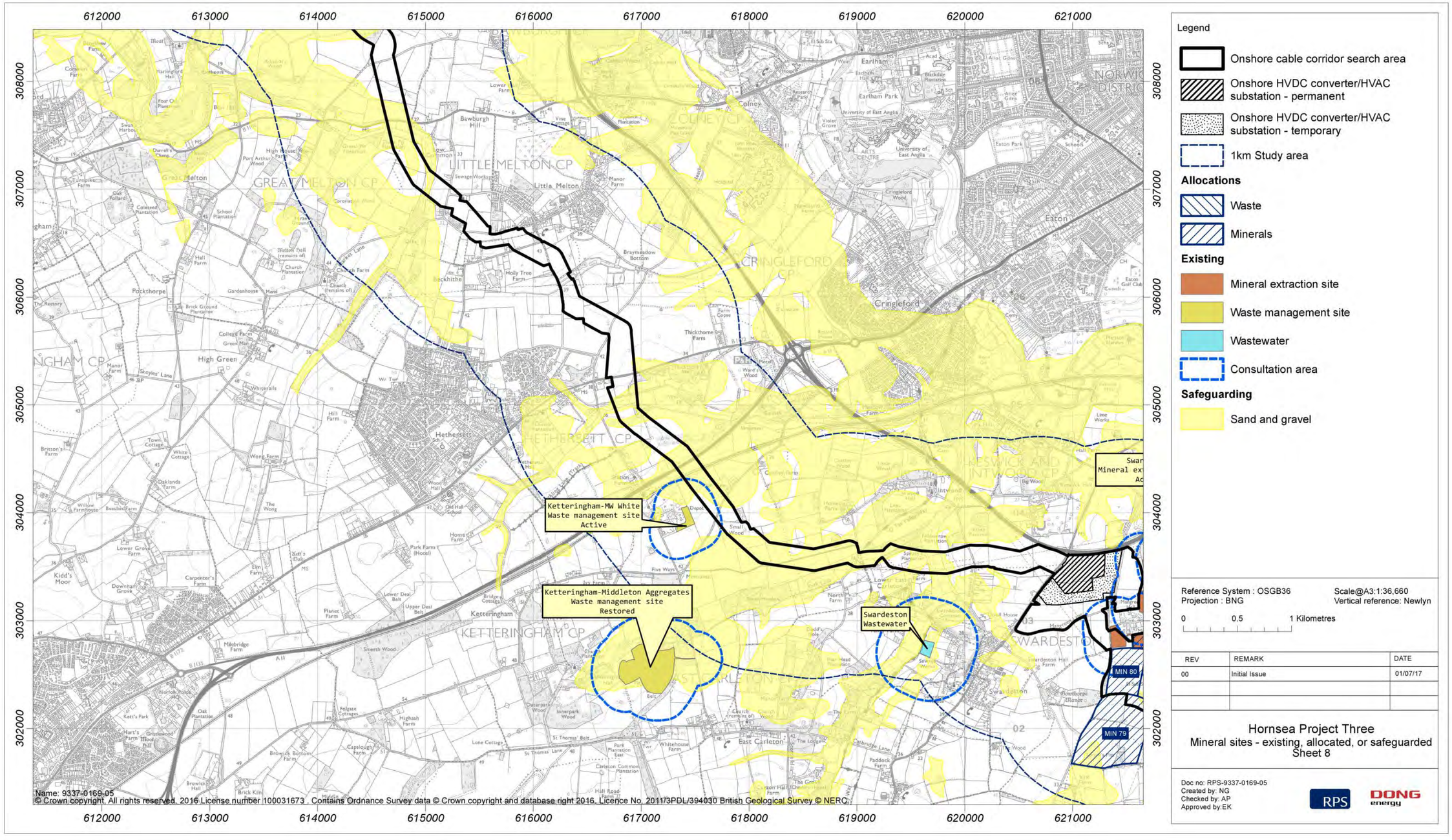

Figure 1.3: Mineral extraction sites and mineral safeguarding areas.

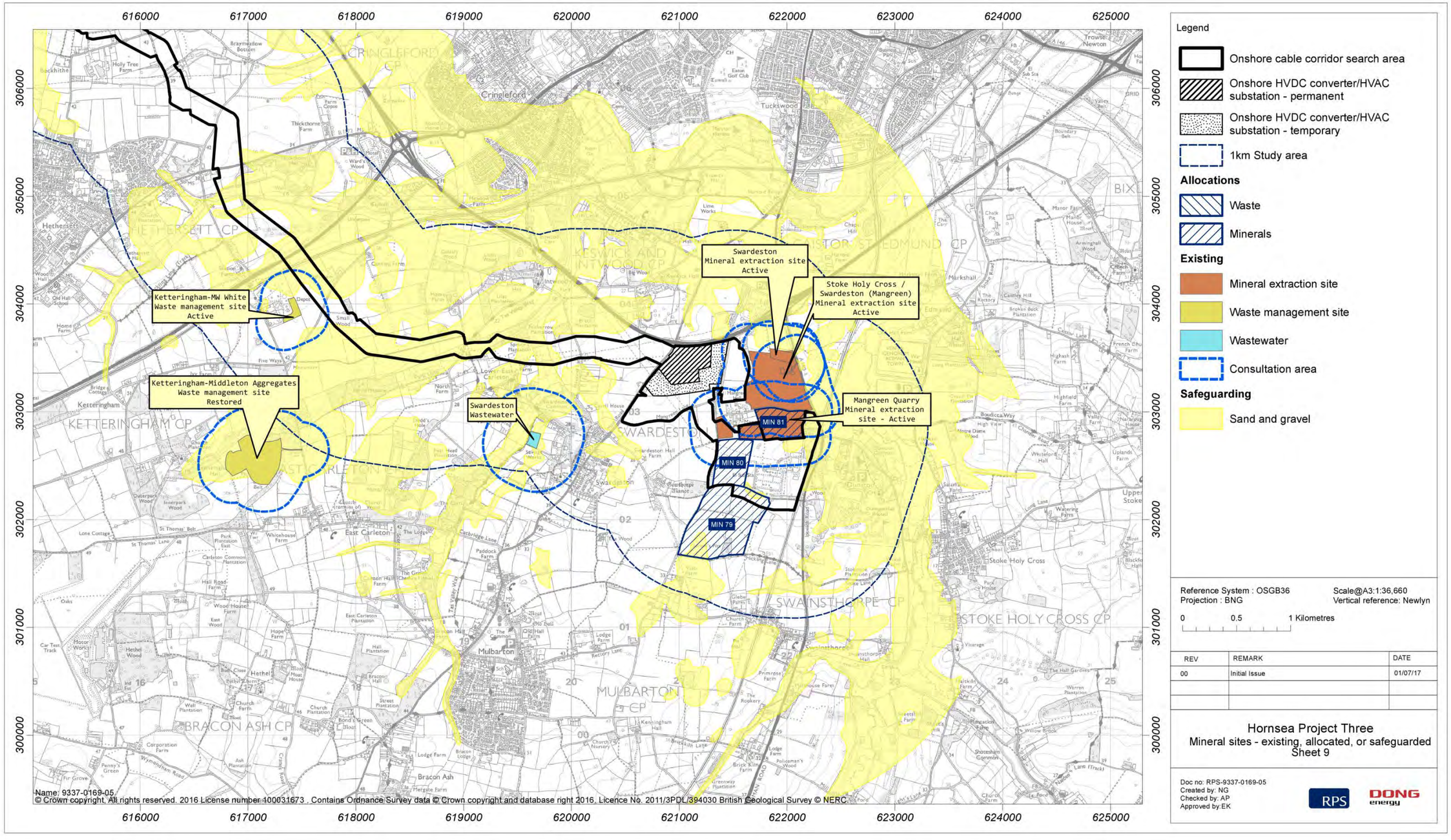

Figure 1.3: Mineral extraction sites and mineral safeguarding areas.

1.7.4 Geology: superficial deposits and bedrock

1.7.4.1 The superficial deposits and bedrock within the geology and ground conditions study area have been identified using the Groundsure Geo Insight report (Groundsure, 2017b), BGS geology maps and borehole logs.

Bedrock

1.7.4.2 The bedrock underlying the northern and central part of geology and ground conditions study area is split between the Lewes Nodular Chalk of the White Chalk Subgroup (in the west) and the Wroxham Crag Formation (in the east). The rest of the geology and ground conditions study area is underlain by Lewes Nodular Chalk of the White Chalk Subgroup.

1.7.4.3 The White Chalk Subgroup is described by the BGS as "*Chalk with flints. With discrete marl seams, nodular chalk, sponge-rich and flint seams throughout*" (British Geological Society, n.d.). There are a number of localised chalk exposures on the valley sides in the following locations: Aldeford, Aldeford Common, Scotchwood Hills (southwest of Attlebridge) and Algarsthorpe Farm (southeast of Marlingford).

1.7.4.4 The BGS describe the Wroxham Crag Formation as comprising "*a sheet of interbedded gravels, sands, silts and clays. The gravels are dominated by flint (up to c.80%) and by quartz and quartzite (up to c.60%), with far-travelled minor lithogies including Carboniferous chert, Rhaxella chert, Greensand chert, Spilsby Sandstone and felsic volcanic rocks from North Wales. The deposits are interpreted as estuarine and near-shore marine*" (British Geological Society, n.d.).

Superficial deposits

1.7.4.5 The majority of the geology and ground conditions study area is underlain by superficial deposits predominantly made up of different glacial deposits. In the northern part of the geology and ground conditions study area, the valley floors are dominated by Alluvium and Head. Peat is also present near Beach Lane at the Hornsea Three landfall area. The higher ground is underlain by Head deposits, Britons Lane Sand and Gravel Member and Weybourne Town Till. From Bodham to Corpusty the deposits are more varied but are still dominated by glacial deposits. These deposits include: Briton Lane Sand and Gravel Member, Head deposits, Weybourne Town Till, Sheringham Cliff Formation, Glacio-fluvial deposits, Alluvium and Till.

1.7.4.6 Moving south, the superficial deposits are similar to the above but with areas of River Terrace Deposits in the valley floors. Other mapped strata include Brickearth, the Lowestoft Formation and the Leet Hills Sand and Gravels Formation. The Leet Hills deposits are limited in their extent to the area of the existing substation at Dunston and its immediate surrounds.

1.7.4.7 The onshore HVAC booster station is underlain by Glacio-Fluvial deposits with a small area of Till at the site's northern tip. The onshore HVDC converter/HVAC substation is underlain by the Lowestoft Formation.

1.7.4.8 BGS (n.d.) provide the following descriptions for each of the superficial deposits encountered within the geology and ground conditions study area:

- Peat may be an organic-rich clay; humic deposits - accumulation of wet, dark brown, partially decomposed vegetation.
- Alluvium: Normally soft to firm consolidated, compressible silty clay, but can contain layers of silt, sand, peat and basal gravel. A stronger, desiccated surface zone may be present.
- River Terrace Gravels comprise sand and gravel, locally with lenses of silt, clay or peat.
- Head deposits are located in valley bases/sides and are described by the BGS as "*Polymict deposit: comprises gravel, sand and clay depending on upslope source and distance from source. Poorly sorted and poorly stratified deposits formed mostly by solifluction and/or hillwash and soil creep. Essentially comprises sand and gravel, locally with lenses of silt, clay or peat and organic material*" (BGS, n.d.).
- Brickearth varies from silt to clay, and is usually yellow-brown.
- The Briton's Land Sand and Gravel Member consists of horizontal, massive and low angle planar cross-bedded gravels and cobble gravels with thin seams of horizontal and rippled sand. The lithology has a distinctive high flint content (c.85-89%) of which the majority is of non-chatter marked variety (c.78-85%). The gravels also contain a wide range of far-travelled crystalline erratics including rocks of British and Scandinavian provenance.
- Till – Diamicton. The Weybourne Town Till Member consists of a highly calcareous silt and chalk-rich matrix supported diamicton. It is generally massive in structure, but locally, (such as at the unit's stratotype locality), the diamicton is highly stratified, consisting of highly attenuated and deformed inclusions of pre-existing till (Bacton Green Till Member).
- Sheringham Cliffs Formation is described by the BGS as "*consisting of a thick glacigenic sequence that contains several distinctive features such as the Mundesley Sand Member, which consists of stratified fine-grained sands; this is overlain by the laminated silts and clays of the Ivy Farm Laminated Silt Member. Overlying these waterlain sediments are the Runton Till and Bacton Green Till members; these are matrix-supported diamictons, which in turn, are overlain by thin units of clay (Trimingham Clay Member) and sand (Trimingham Sand Member). These deposits are truncated by the chalky Weybourne Town Till Member, a highly consolidated matrix-supported diamicton, and finally by the Runton Cliffs Sand and Gravel Member which forms the highest stratigraphical unit within the Formation*" (BGS, n.d.).
- Lowestoft Formation (also Happisburgh Glaciagenic) forms an extensive sheet of chalky till, together with outwash sands and gravels, silts and clays. The till is characterised by its chalk and flint content. The carbonate content of the till matrix is about 30%, and tills within the underlying Happisburgh Formation have less than 20%.
- Leet Hill Sand and Gravel Formations are "stratified and channelled proximal glaciofluvial outwash deposits. Lithologically, the gravels are rich in flint and quartzose clasts, and contain gravel sourced from different geological strata in northern areas" (BGS, n.d.).

1.7.4.9 BGS geological logs have been obtained for the geology and ground conditions study area. The location of the boreholes and a summary of the borehole logs and are included in volume 6, annex 1.1: Borehole Logs.

1.7.5 Hydrogeology and groundwater

1.7.5.1 The hydrogeology and groundwater conditions within the geology and ground conditions study area have been identified using the Groundsure Geo Insight and Enviro Insight reports (Groundsure, 2017b), hydrogeological maps, BGS geology maps and aquifer maps.

Bedrock

1.7.5.2 In North Norfolk, the Chalk aquifer is dominated by groundwater flow via fissures and bedding planes which tend to be more prevalent in the top 30 to 60 m of the chalk leading to a high flow potential at these depths. Depth to groundwater and ground water flow direction is heavily influenced by the overlying topography. Seasonal fluctuations in groundwater levels are likely to occur based on the low storage capacity of the chalk with such variation being more prevalent towards the higher topographic areas. Inter-seasonal variation in groundwater levels are also likely to occur based on the preceding weather conditions (i.e. higher groundwater levels following wetter than typical periods and vice versa). The chalk is a well utilised groundwater source as detailed below in the description of licensed abstraction boreholes and SPZs.

1.7.5.3 Chalk is generally located at approximately 10 m Above Ordnance Datum along the geology and ground conditions study area,indicating a significant depth of drift along much of the route with zones of thicker drift deposits along former glacial channels. The presence of overlying superficial deposits, including lower permeability clays means that the chalk will locally be a confined aquifer.

1.7.5.4 The Wroxham Crag Formation is less well utilised for supply due to its unconsolidated nature (i.e. loose material making construction and use of abstraction wells more problematic than the underlying chalk).

1.7.5.5 Groundwater flow in the upper part of the geology and ground conditions study area is towards the north. Groundwater levels are high at Hempstead due to a divide between groundwater catchments. To the north of the divide groundwater flow will be to the north, whereas to the south of the divide groundwater flow will be in a southerly direction.

1.7.5.6 Towards the centre of the geology and ground conditions study area, groundwater flow direction is determined by the river valleys which form the dominant topographic features. A groundwater divide is located at Heydon (E 610642 N 327003); to the north of this divide flow is generally to the north. South of the divide, groundwater flow is to the south and southeast.

1.7.5.7 The direction of groundwater flow in the southern end of the geology and ground conditions study area, and the onshore HVDC converter/HVAC substation, also follows the dominant topographic features of the river valleys with corresponding groundwater flows to the east.

1.7.5.8 The chalk is designated as a principal aquifer, which is defined by the BGS as *"layers of rock or drift deposits that have high intergranular and/or fracture permeability - meaning they usually provide a high level of water storage. They may support water supply and/or river base flow on a strategic scale. In most cases, principal aquifers are aquifers previously designated as major aquifer"* (BGS, n.d.).

1.7.5.9 Chalk is highly transmissive but can store relatively little groundwater as the majority of flow and storage is attributable to fractures. These characteristics mean that it is susceptible to drought with rapid flow and discharge occurring after it recharges in winter (i.e. most recharges passes rapidly through the aquifer system).

Superficial deposits

1.7.5.10 The hydrogeology of the superficial deposits will be dominated by localised perched groundwater generally present in the more permeable strata such as sand and gravels or more localised permeable lenses with more clay dominated strata such as Till. Groundwater flow within the superficial deposits will be more linked to local topography with potential for seepages when more permeable layers overlie less permeable layers.

1.7.5.11 All the superficial deposits underlying the geology and ground conditions study area, with the exception of localised peat and Brickearth, are all classified as either secondary A aquifer or secondary Undifferentiated. The peat is considered to be unproductive strata defined as having negligible significance for water supply or river base flow. Brickearth deposits are classified as secondary B aquifers.

1.7.5.12 Secondary A aquifer is defined by the Environment Agency (n.d.) as "*permeable layers capable of supporting water supplies at a local rather than strategic scale, and in some cases forming an important source of base flow to rivers. These are generally aquifers formerly classified as minor aquifers*".

1.7.5.13 Secondary Undifferentiated - has been assigned in cases where it has not been possible to attribute either category A or B to a rock type. In most cases, this means that the layer in question has previously been designated as both minor and non-aquifer in different locations due to the variable characteristics of the rock type.

1.7.5.14 The Environment Agency (n.d.) define secondary B aquifers as "*predominantly lower permeability layers which may store and yield limited amounts of groundwater due to localised features such as fissures, thin permeable horizons and weathering. These are generally the water-bearing parts of the former non-aquifers*".

Water Framework Directive

1.7.5.15 In relation to groundwater the Water Framework Directive (WFD) is designed to:

- Promote the sustainable use of water;
- Reduce pollution of water, especially by 'priority' and 'priority hazardous' substances; and
- Ensure progressive reduction of groundwater pollution.

1.7.5.16 The geology and ground conditions study area is located within the Anglian River Basin District. Each river basin district has to prepare a river basin management plan which provides a framework for protecting and enhancing the benefits provided by the water environment based on the following information:

- Baseline classification of water bodies;
- Statutory objectives for protected areas – areas of land and water bodies that have specific use that require special protection, e.g. waters used for drinking water or those supporting important ecological habitats and species. The legally binding objectives protect those uses from potentially harmful activities and new developments;
- Statutory objectives for water bodies – these are legally binding objectives. The default objective is "good" status, however less stringent objectives have been set in some cases where natural conditions or technical feasibility make improvement impractical. The default deadline for achieving objectives is 2021, however in some cases extended deadlines of 2027 have been set; and
- Summary programme of measures to achieve statutory objectives.

1.7.5.17 River basin management plans are updated every six years and the current plan for the Anglian River Basin District was prepared in 2016.

1.7.5.18 The groundwater bodies within the geology and ground conditions study area are the North Norfolk Chalk Unit (reference GB40501, G400100) and the Broadland Rivers Chalk and Crag Unit (GB40501, G400300). The status of these groundwater bodies is set out Table 1.6 and Table 1.7.

Table 1.6: WFD data for North Norfolk Chalk Unit.

Criteria	Classification
Waterbody ID	GB40501, G400100
Current quantitative quality	Good
Groundwater dependent terrestrial ecosystems (quantitative impacts)	Good
Impact on surface waters	Good
Saline or other intrusions	Good
Resource balance	Good
Current chemical quality	Poor
Upward chemical trend	Yes
2015 predicted quantitative quality	Good

.

Table 1.7: WFD data for Broadland Rivers Chalk and Crag Unit.

Criteria	Classification
Waterbody ID	GB40501, G400300
Current quantitative quality	Poor
Groundwater dependent terrestrial ecosystems (quantitative impacts)	Poor
Impact on surface waters	Good
Saline or other intrusions	Good
Resource balance	Good
Current chemical quality	Poor
Upward chemical trend	Yes
2015 predicted quantitative quality	Good by 2021
2015 predicted chemical quality	Good by 2027

Source Protection Zones

1.7.5.19 Table 1.8 outlines the different types of groundwater SPZs. The Environment Agency defines SPZs for groundwater sources such as wells, boreholes and springs used for public drinking water supply. The SPZs show the sensitivity to contamination from any activities that might cause pollution in the area and are based on the travel time through the aquifer to the abstraction point. The closer the activity is to the abstraction source, the shorter the travel time and hence greater the source sensitivity. SPZ mapping comprises three main zones (inner, outer and total catchment) and a fourth zone of special interest, which may be occasionally applied to a groundwater source but is not present in this locality.

1.7.5.20 The groundwater vulnerability within an SPZ1 is considered by the Environment Agency to be very high.

1.7.5.21 The SPZ mapping shown in Figure 1.4 shows the location of SPZs within the geology and ground conditions study area. The SPZs relate to existing major public water supply abstractions from the principal aquifer.

Table 1.8: Groundwater Source Protection Zone.

Zone	Definition
SPZ1	Inner protection zone defined as the 50 day travel time from any point below the water table to the source. This zone has a minimum radius of 50 m.
SPZ2	Outer protection zone defined by a 400 day travel time from a point below the water table. The previous methodology gave an option to define SPZ2 as the minimum recharge area required to support 25 per cent of the protected yield. This option is no longer available in defining new SPZs and instead this zone has a minimum radius of 250 m or 500 m around the source, depending on the size of the abstraction.
SPZ3	Source catchment protection zone defined as the area around a source within which all groundwater recharge is presumed to be discharged at the source. In confined aquifers, the source catchment may be displaced some distance from the source. For heavily exploited aquifers, the final Zone Definition.
Zone of Special Interest	For some groundwater sources an additional Zone of Special Interest may be defined. These zones highlight areas where known local conditions mean that potentially polluting activities could impact on a groundwater source even though the area is outside the normal catchment of that source.

1.7.5.22 There are eight SPZs within the geology and ground conditions study area, six of which are located within the onshore cable corridor search area. Details of the zones are as follows:

- Bernard Matthews Source – SPZ2 and SPZ3 just north of Alderford;
- Costessey Source – SPZ3;
- Norfolk Agricultural College Source –SPZ1;
- Colney Source – SPZ3;
- Mactintosh and Sons Source – SPZ3; and
- Dunston Common Source – SPZ2

Groundwater abstractions

1.7.5.23 Records held by Groundsure (2017a) and the Local Authorities identify 48 licensed and private groundwater abstractions located within the geology and ground conditions study area. Three abstractions are located within or adjacent to the onshore cable corridor search area and are used for general farming/domestic or spray irrigation purposes. The source of these abstractions and the majority of the abstractions within the onshore cable corridor search area is the underlying chalk bedrock. In a few cases, the abstractions are sourced from the superficial glacial sands/gravel deposits.

1.7.5.24 The groundwater abstractions within 1 km of the onshore cable corridor search area are identified in volume 6, annex 1.2: Abstraction Licences.

Discharge consents and permits

1.7.5.25 Records held by Groundsure (2017a) identify 14 consented discharges to land which are located within the geology and ground conditions study area. The discharges are regulated using discharge consents and environmental permits issued by the Environment Agency. The majority of discharge consents within 1 km of the onshore cable corridor search area relate to final/treated effluent from domestic properties which are discharged into land or into watercourses.

1.7.5.26 Consented discharges within 1 km of the onshore cable corridor search area are identified in annex 1.3: Environment Agency Discharge Consents and Permits.

Current land use

1.7.5.27 Land within the onshore cable corridor search area is predominantly used for agriculture and open land and also crosses roads, ditches/drains and larger watercourses.

1.7.5.28 A former military camp was located within the onshore cable corridor search area close to the Hornsea Three landfall area. An internet search has identified this site as the former Muckleburgh camp which was in use during the First World War and a Second World War as an anti-aircraft artillery station (Britains Finest, n.d.).

1.7.5.29 A number of filled ponds, substations and former storage tanks (particularly fuel storage tanks) located within the geology and ground conditions study area may have potentially caused localised ground contamination, which may need to be addressed as part of site investigations during the detailed design stage.

1.7.5.30 Reference to Groundsure (2017a) data identifies that there are no petrol stations or garages within the geolgy and ground conditions study area. Three garages were identified within 500 m of the onshore cable corridor search area, the closest of which was 135 m.

1.7.5.31 According to the Groundsure (2017a) records, there are no sites recorded as contaminated land under Part 11A of the Environmental Protection Act 1990 within the geology and ground conditions.

Figure 1.4: Source Protection Zones.

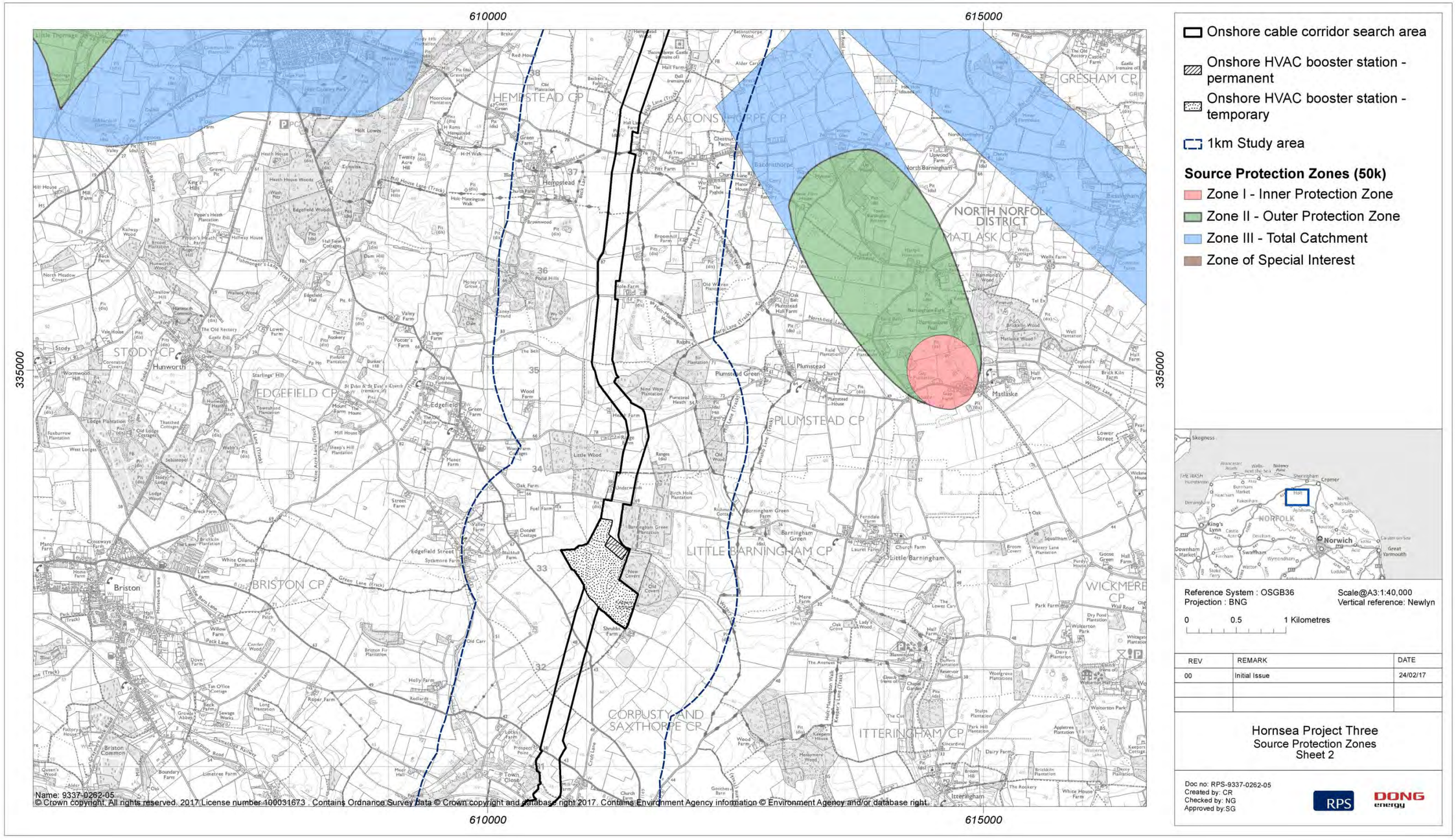

Figure 1.4: Source Protection Zones.

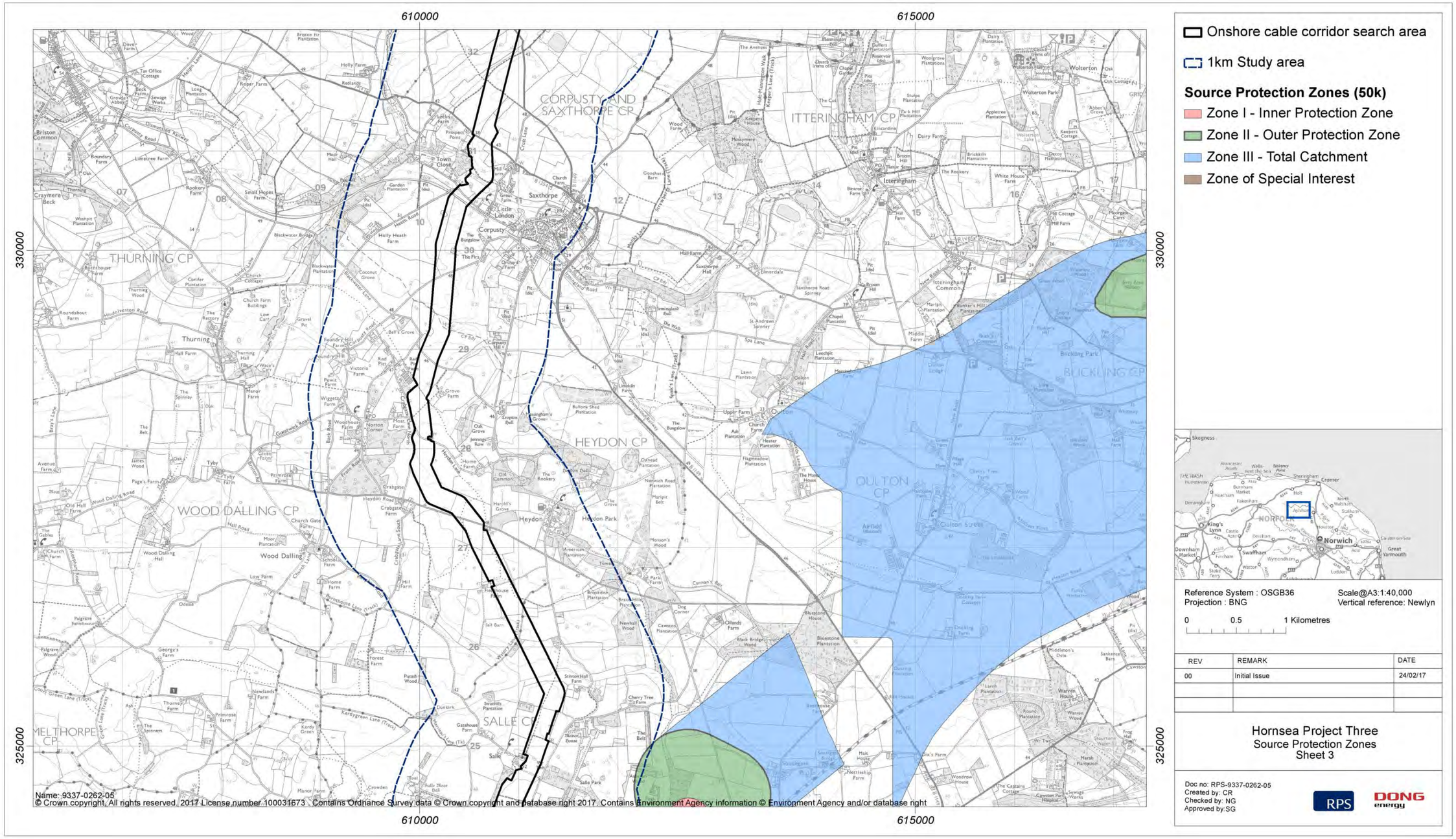

Figure 1.4: Source Protection Zones.

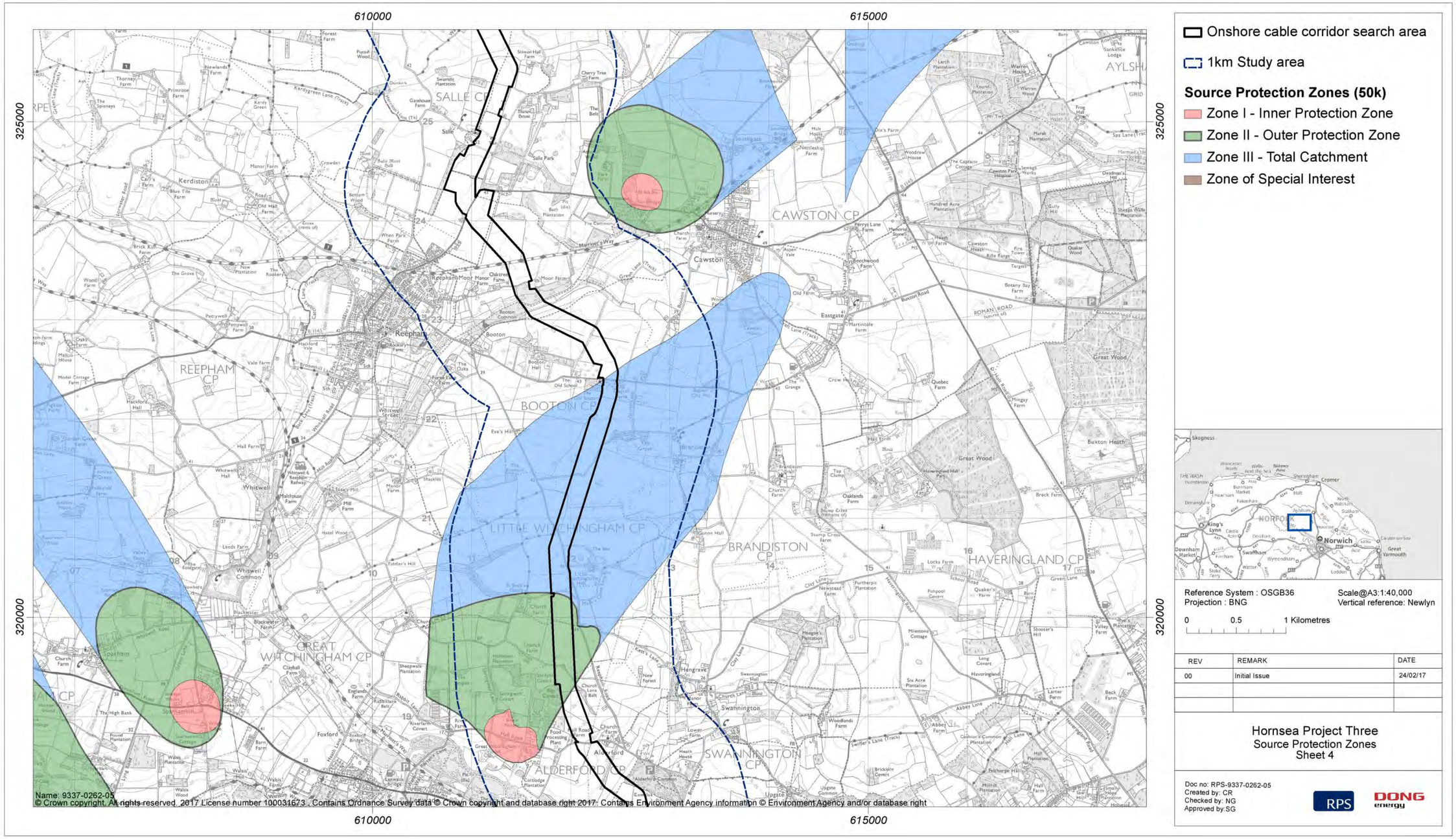

Figure 1.4: Source Protection Zones.

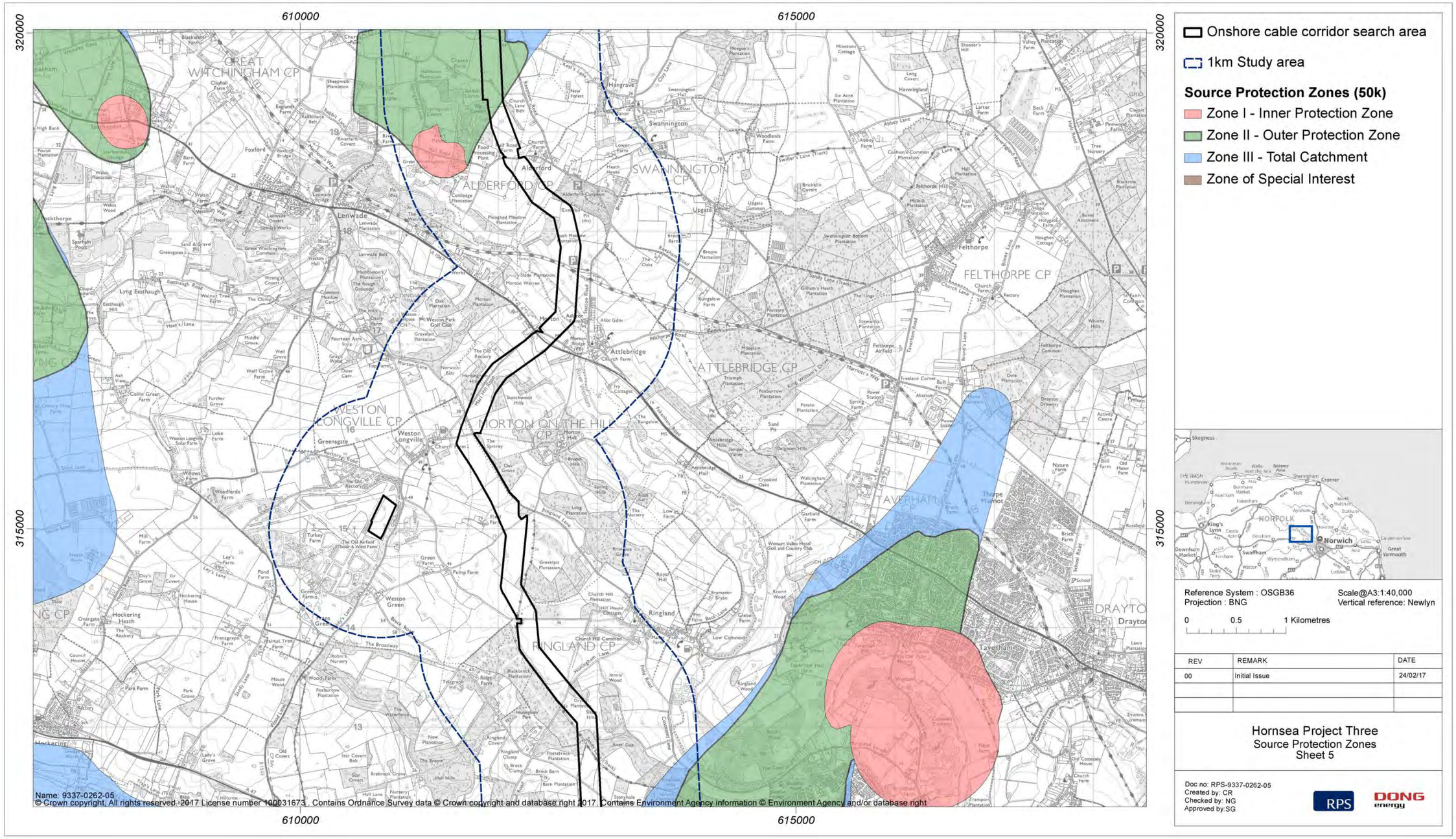

Figure 1.4: Source Protection Zones.

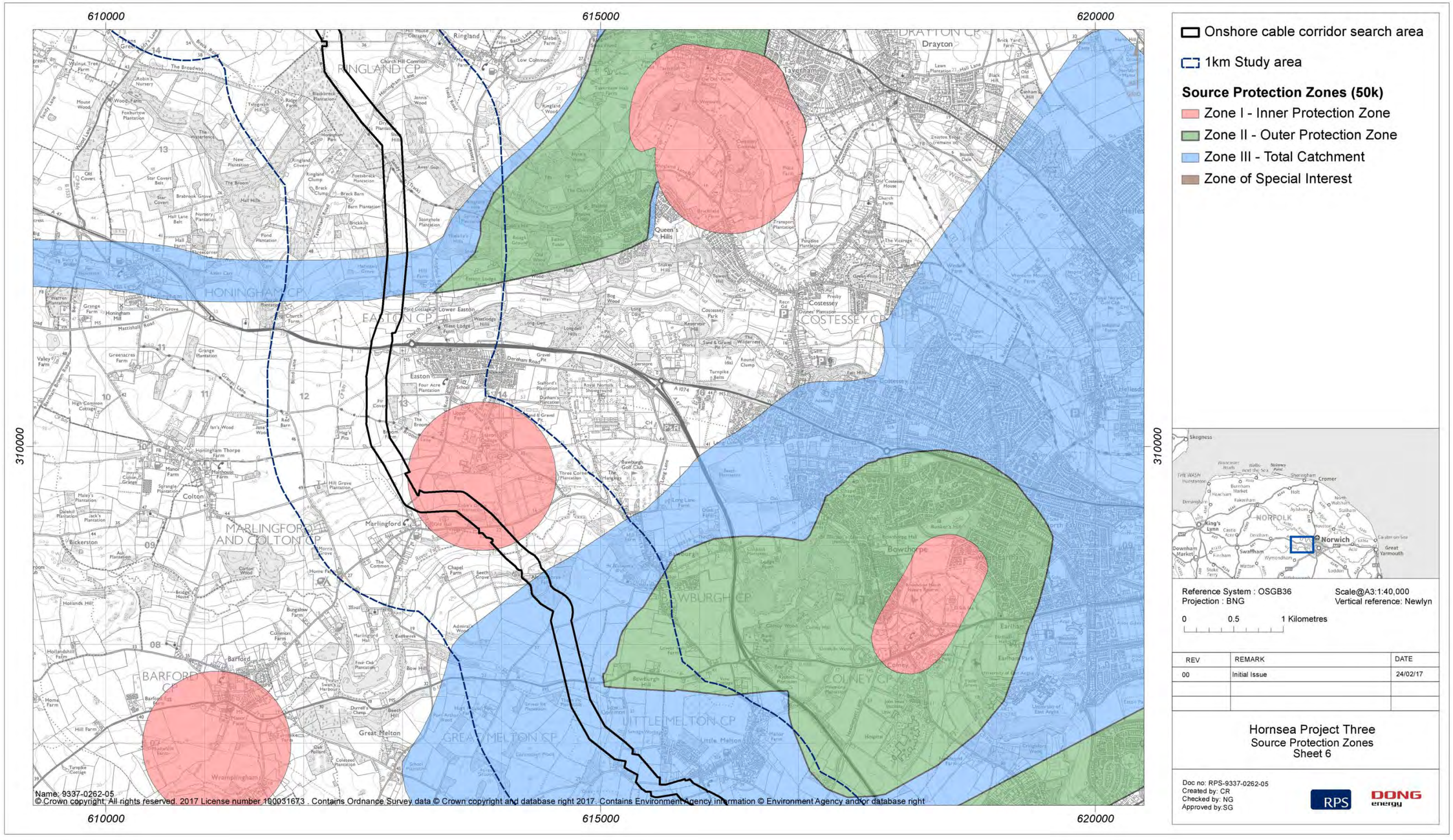

Figure 1.4: Source Protection Zones.

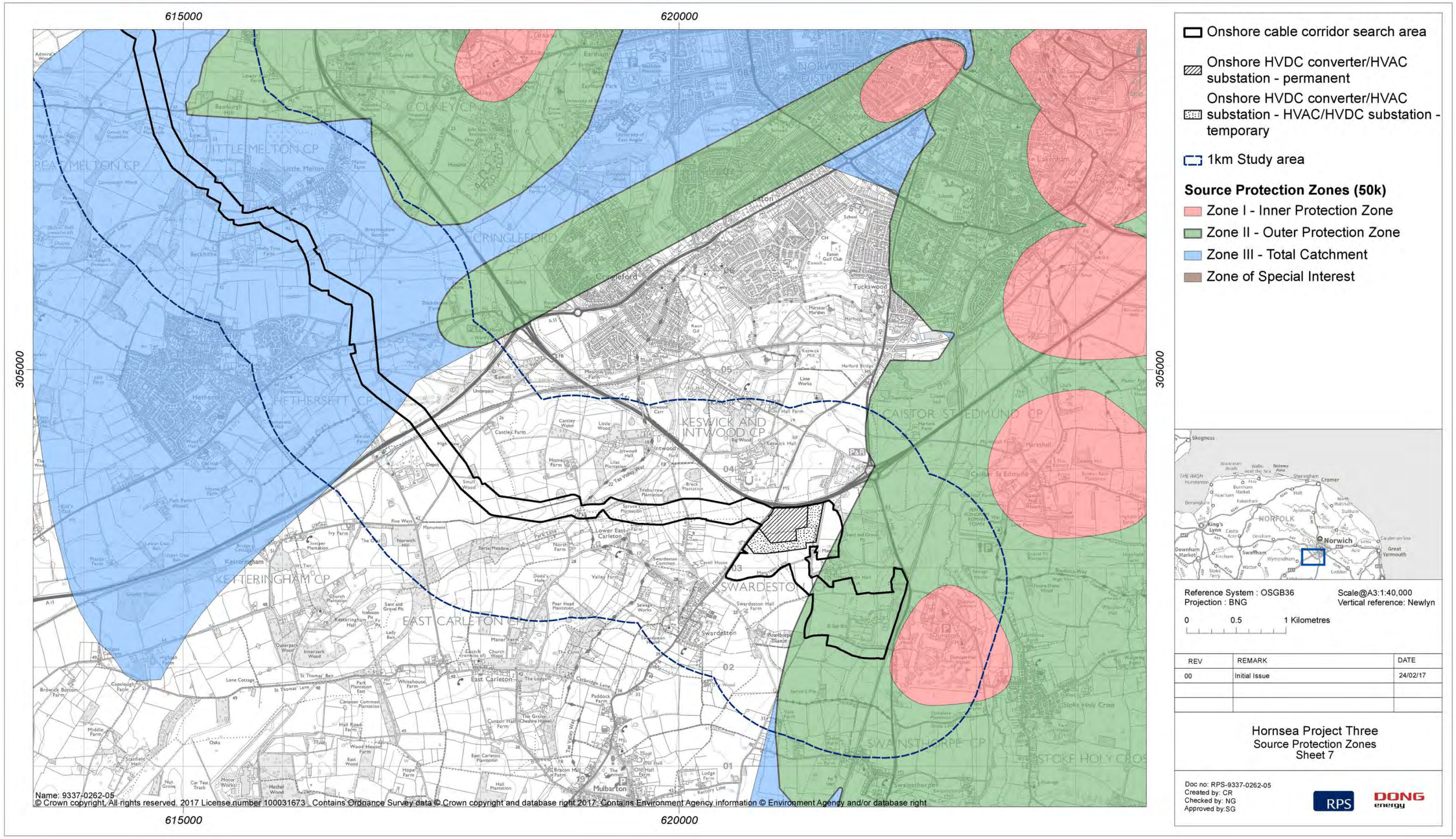

Figure 1.4: Source Protection Zones.

Landfill and other waste sites

1.7.5.32 Existing and allocated waste management facilties within the geology and ground conditions study area are shown on Figure 1.3. The figure shows two facilities within the geology and ground conditions study area, which are based at Lenwade (Morton on the Hill) and at Ketteringham.

1.7.5.33 In addition to these sites, Groundsure identified the following three historic landfill sites within the geology and ground conditions study area :

- Off Mangreen Lane, Swardeston. NGR 621600, 304000 (Environmental Permitting Regulations Waste);
- Central Depot, Heathersett, Norwich. NGR 617300, 303600 (Industrial, Commercial, Environmental Permitting Regulations Waste), and
- Keswick Lime Pit, The Lime Works, Keswick. NGR 621200, 304800 (Inert Environmental Permitting Regulations Waste).

Natural hazards and mining

1.7.5.34 The geology and ground conditions study area is not in an area affected by coal mining. There is no evidence of mining or the associated risk of subsidence within 50 m of the onshore HVAC booster station and HVDC converter/HVAC substation.

1.7.6 Future baseline scenario

1.7.6.1 The future baseline in relation to geology and ground conditions is unlikely to differ significantly from that which has been described above. It is assumed that in the absence of Hornsea Three, the majority of the geology and ground conditions study area would remain as farmland and that there would be no significant change in geology, hydrogeology and ground conditions without any significant change in land use.

1.7.7 Data limitations

1.7.7.1 BGS geological mapping terminology classifications are inconsistent, due to different publication dates of the mapping. This also affects the aquifer classifications as these are based on the underlying geological mapping. Whilst potentially adding a degree of confusion it does not affect the certainty/predictability of assessment as the sensitively is not fundamentally changed.

1.7.7.2 The data set of private water abstraction data (i.e. not licensed abstractions held by the Environment Agency) set out in the PEIR may not be complete as responses had not been received from all of the local authorities at the time of writing. However, some of the private water supply data is contained within the BGS well record data which is included in the assessment. Should a number of previously unidentified wells be found to be located within the geology and ground conditions study area, then the sensitivity of the underlying aquifer may increase. This would affect the certainty/predictability of the assessment. However, this limitation would be addressed within the Environmental Statement.

1.8 Key parameters for assessment

1.8.1 *Maximum design scenario*

1.8.1.1 The maximum design scenarios identified in Table 1.9 have been selected as those having the potential to result in the greatest effect on an identified receptor or receptor group. These scenarios have been selected from the details provided in the project description (volume 1, chapter 3: Project Description). Effects of greater adverse significance are not predicted to arise should any other development scenario, based on details within the project Design Envelope to that assessed here be taken forward in the final design scheme.

Table 1.9: Maximum design scenario considered for the assessment of potential impacts on geology and ground conditions.

Potential impact	Maximum design scenario	Justification
Construction phase		
Impacts of construction may affect designated geological sites.	<u>Hornsea Three landfall</u> Open cut techniques installing up to eight cables with a corridor up to 20 m either side of each cable. The width of the corridor at landfall would be up to 20 m either side of each cable. Up to eight transition joint bays of total up to 2,000 m^2 (250 m^2 x 8). <u>Onshore export cable corridor</u> Temporary onshore cable corridor is 80 m wide and 55 km long (including 60 m wide permanent corridor (wider where obstacles occur)). Up to six cable trenches (each containing one circuit) each trench is 5 m wide and 2 m deep. Depth of stabilised backfill up to 1.5 m. Up to 330 junction bays and link boxes. Closest separation distance between junction bay and link box: - 750 m. Up to 74,250 m^2 area required for junction bays (based on 330 junction bays (each junction bay is 9 m x 25 m)). Up to 2,970 m^2 area required for link boxes (based on 330 link boxes (each link box: is 3 m x 3 m)). Up to two temporary haul roads 5 m wide (7 m wide at passing places).	Open cut construction methods for the Hornsea Three landfall and the onshore export cable corridor represents the maximum design scenario for designated geological sites as these methods would directly damage the geological resource and change the natural processes of erosion. Open cut methods may also indirectly damage the designated sites by diverting perched groundwater flows which may lead to erosion. The HVAC transmission option represents the maximum design scenario due to the greater number of cable trenches required and therefore, the greatest area of disturbance.
Impacts of construction may result in the loss of mineral resources within Mineral Safeguarded Areas	<u>Hornsea Three landfall</u> Open cut techniques installing up to eight cables with a corridor up to 20 m either side of each cable. The width of the corridor at landfall would be up to 20 m either side of each cable. Up to eight transition joint bays of total up to 2,000 m^2 (250 m^2 x 8). <u>Onshore export cable corridor</u> Temporary onshore cable corridor is 80 m wide and 55 km long (including 60 m wide permanent corridor (wider where obstacles occur)). Up to six cable trenches (each containing one circuit) each trench is 5 m wide and 2 m deep. Depth of stabilised backfill up to 1.5 m. Up to 330 junction bays and link boxes. Closest separation distance between junction bay and link box: - 750 m. Up to 74,250 m^2 area required for junction bays (based on 330 junction bays (each junction bay is 9 m x 25 m)). Up to 2,970 m^2 area required for link boxes (based on 330 link boxes (each link box: is 3 m x 3 m)). Up to two temporary haul roads 5 m wide (7 m wide at passing places). Up to 50 HDD crossings. A compound would be located at both ends of the HDD crossing each with a footprint of up to 4,900 m^2 (70 m x 70 m) with permeable surfacing. <u>Onshore HVAC booster station</u> Permanent area of site is 25,000 m^2 plus a temporary works area up to 25,000 m^2. Building scenario with the largest footprint - single building with area of 4,500 m^2 (150 m length and 30 m width) and height up to 12.5 m.	The maximum design scenario for potential loss of mineral resources would be the HVAC transmission option due to the greater number of cable trenches required and the potential need to construct the onshore HVAC booster station as this may result in greater areas of sand and gravel being sterilised. The onshore HVDC converter/HVAC substation is not located within a Mineral Safeguarded Area. HDD methods represent the maximum design scenario for the potential loss of mineral resources at crossing locations due to the greatest footprint required.

Potential impact	Maximum design scenario	Justification
Impacts of construction may cause disturbance or contamination of secondary aquifers. The WFD status of the groundwater might also be affected.	<u>Hornsea Three landfall</u> Open cut techniques installing up to eight cables with a corridor up to 20 m either side of each cable. The width of the corridor at landfall would be up to 20 m either side of each cable. Up to eight transition joint bays of total up to 2,000 m^2 (250 m^2 x 8). <u>Onshore export cable corridor</u> Temporary onshore cable corridor is 80 m wide and 55 km long (including 60 m wide permanent corridor (wider where obstacles occur)). Up to six cable trenches (each containing one circuit) each trench is 5 m wide and 2 m deep. Depth of stabilised backfill up to 1.5 m. Up to 330 junction bays and link boxes. Closest separation distance between junction bay and link box: - 750 m. Up to 74,250 m^2 required for junction bays (based on 330 junction bays (each junction bay is 9 m x 25 m)). Up to 2,970 m^2 area required for link boxes (based on 330 link boxes (each link box: is 3 m x 3 m)). Up to two temporary haul roads 5 m wide (7 m wide at passing places). Up to 50 HDD crossings across surface watercourses. A HDD compound would be located at both ends of the HDD crossing each with a footprint of up to 4,900 m^2 (70 m x 70 m) with permeable surfacing. <u>Onshore HVDC converter/HVAC substation</u> Permanent area of site is 128,000 m^2 (including an area which may be used for landscaping) plus a temporary works area of 100,000 m^2. The transmission option with the greatest number of buildings and largest footprint is the HVDC converter station – up to five buildings. The main building (single building scenario) for the HVDC converter station will have a footprint of 11,250 m^2 (75 m x 150 m). Dimensions for the multiple building scenarios would be reduced proportionately but the overall footprint would be the same. <u>Onshore HVAC booster station</u> Permanent area of site is 25,000 m^2 plus a temporary works area up to 25,000 m^2. Building scenario with the largest footprint - single building with area of 4,500 m^2 (150 m length and 30 m width) and height up to 12.5 m.	The maximum design scenario for disturbance of secondary A and B aquifers would be the HVAC transmission option due to the greater number of cable trenches required and the potential need to construct the onshore HVAC booster station as this would result in the largest area of disturbance of the secondary aquifers. The onshore HVDC converter station represents the maximum design scenario as this has the greatest number of buildings and largest footprint and therefore, the largest disturbance from the construction of foundations. In terms of contamination to secondary aquifers, both crossing options may create pathways for contaminants, however HDD methods represent the maximum design scenario as they go deeper below the ground, increasing the likelihood of hydraulically connecting with groundwater in secondary aquifers.
Impacts of open cut trench construction may affect the groundwater quality of the principal aquifer including at the SPZs. The WFD status of the groundwater might also be affected.		The 2 m depth of the onshore export cable trench represents the maximum design scenario for affecting groundwater quality of principal aquifers by open cut trench construction as in some locations of the onshore export cable corridor superficial deposits may be locally thin and there is the potential for the cable trenches to intersect the principal aquifer and therefore, create a pathway. The HVAC transmission option requires a greater number of cable trenches, link boxes and junction bays and therefore the greater footprint increases the possibility of intersecting the principal aquifer.
Impacts of trenchless conduit construction and piling works (potentially required for the construction of the onshore HVAC booster station or onshore HVDC converter/HVAC substation) may affect the groundwater quality of the principal aquifer, including conduit construction within any SPZs. The WFD status of the groundwater might also be affected.		HDD methods represent the maximum design scenario for affecting groundwater quality of the principal aquifer as these methods go deep below the ground (bypassing lower permeability superficial deposits) and may create a pathway for contaminants to the groundwater resource within the principal aquifer with minimal potential for attenuation. The onshore HVDC converter station represents the maximum design scenario as this has the greatest number of buildings and largest footprint and therefore, the largest disturbance from the construction of foundations.
Impacts of construction may affect the quantity and quality of surface waters fed by groundwater. The groundwater WFD status might also be affected.		The HVAC transmission option represents the maximum design scenario for affecting the quantity and quality of surface waters fed by groundwater as it requires the greatest number cable trenches and the potential need for the onshore HVAC booster station resulting in the greatest area of disturbance and a higher likelihood that temporary localised dewatering of the trenches may be required. Dewatering of secondary aquifers may impact on the quantity of surface waters where there is a hydraulic connection. In terms of crossing locations, HDD represents the maximum design scenario as they go deeper below the ground, increasing the likelihood of creating a pathway.
Operation and maintenance phase		
Impacts of operations and maintenance may affect the water quality of secondary aquifers and any associated surface waters together with the principal aquifer. The WFD status might also be affected.	Routine maintenance of the onshore HVDC converter/HVAC substation and HVAC booster station. Permanent onshore cable corridor area is 3,300,000 m^2 (60 m wide and 55 km long).	The maximum design scenario for water quality of secondary aquifers (any associated aquifers) and the principal aquifers during operation is that chemicals and oils would be used in the routine maintenance of the onshore HVDC converter/HVAC substation. An onshore HVAC booster station would also potentially be required for the HVAC transmission (in addition to a HVAC substation) which would also require maintenance and therefore, represents the maximum design scenario
Impacts of operation may affect groundwater quality from thermal effects of underground power cables. The WFD status of the groundwater might also be affected.	<u>Onshore cable corridor search area</u> 1.5 m depth of thermally stabilised material to surround the cables and back fill the trench.	The HVAC transmission option represents the maximum design scenario in terms of thermal pollution effects on principal aquifers from operation of cables. The WFD status of the groundwater might be affected by any degradation in groundwater quality.

Potential impact	Maximum design scenario	Justification
Decommissioning phase		
Impacts of decommissioning may cause disturbance or contamination of secondary aquifers (and any associated surface waters) and principal aquifer and may affect the WFD status.	Removal of the following (above and below ground): Onshore HVAC booster station Permanent area of site is 25,000 m^2. Onshore HVDC converter/HVAC substation Permanent area of site is 128,000 m^2 (including an area which may be used for landscaping). Onshore cable corridor search area The cutting of underground cables and sealing of ducts. Structures of jointing pits and link boxes removed (where feasible).	The maximum design scenario for disturbance or contamination during decommissioning is the removal of the onshore HVDC converter/HVAC substation and onshore HVAC booster station as this presents the greatest disturbance and potential risk of contaminants being released. The removal of the jointing pits and link boxes during decommissioning represents the maximum design scenario as this would result in disturbance of land along the onshore export cable route.