Office of the Deputy Prime Minister
Creating sustainable communities

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Mineral Planning Factsheet

Salt

*This factsheet provides an overview of **salt** supply in the UK. It is one of a series on economically important minerals that are extracted in Britain and is primarily intended to inform the land-use planning process.*

January 2006

Salt (sodium chloride, NaCl), occurs in nature in solid form as **rock salt** (halite), or in solution as **brine**. Rock salt occurs in beds, commonly associated with mudstone, ranging from a few centimetres up to several hundred metres in thickness. The purity of individual salt beds depends on the extent of mudstone interbedding. Salt-bearing strata do not crop out at the surface in the UK because of dissolution by groundwater. Natural brine is produced by the dissolution of salt-bearing strata by circulating groundwater. Brine is also produced by solution mining by injecting water into salt beds and pumping out the resulting salt solution. This may contain up to 26% NaCl when fully saturated.

Demand

Salt is used in solid form as rock salt and, more importantly, as brine. Of total salt production in the UK, approximately 30% is used as rock salt, principally for de-icing roads, although small tonnages are used as a fertiliser for sugar beet and as an additive to animal feeds. The remaining 70% is consumed as brine. Most (70%) brine production is used directly by the heavy inorganic chemicals industry as an essential basic feedstock. The remainder is evaporated using a vacuum process to produce white salt.

Brine wellhead.

As a chemical feedstock in the heavy inorganic chemical industry, salt-in-brine is used in the electrochemical process for the production of chlorine and caustic soda (sodium hydroxide Na0H), and in the Ammonia-Soda Process for the production of soda ash (sodium carbonate Na_2C0_3). A by-product of the electrolysis of brine is hydrogen, which is used as a fuel for power generation and as a process gas.

Chlorine is essential to the world's chemical industry. Up to 60% of all chemical manufacturing in Western Europe depends on the element. It is an essential intermediate in the production of plastics and polymers, such as PVC, nylon and polyurethane, and is used in sewage and industrial effluent treatment, water disinfection and in household and industrial bleaches. A wide range of other chlorine derivative products is also produced. Caustic soda is used in soap and detergents manufacture, in alumina production and papermaking, but has also a wide range of other uses. Soda ash is used mainly in the manufacture of glass and detergents; other uses include industrial chemicals, aerospace alloys, water purification and effluent neutralisation. Calcium chloride liquor is a by-product of the process, which amongst other uses, is used in the formulation of oil well drilling fluids.

White salt is sold as a chemical feedstock, for food processing and table use, for water softener regeneration, tanning and in the production of animal feeds.

Salt-bearing strata are ideally suited for the creation of storage cavities for gas and certain fluids. Completed brine extraction cavities are used for storage purposes, although cavities have also been specifically created for gas storage. The high flow capability of salt cavities is ideal for peak sharing and daily balancing needs. On Teesside completed brine cavities are used for the storage of products such as ethylene, ethane and naphtha, as well as natural gas and hydrogen. Salt cavities have been used for oil storage in the past. Completed brine cavities are, however, not ideally shaped or spaced

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apart for gas storage. Gas cavities should be more spherical or cylindrical with domed roofs and with a grid spacing related to their size (diameter). At the Warmingham Brinefield in Cheshire, smaller cavities have been specially designed for gas storage. The brine created is used for salt production, thus maximising the use of the salt resource. At the Holford Brinefield in Cheshire, abandoned brine cavities are used for ethylene storage, and one is currently used for natural gas. Permission has recently been granted for a new gas storage facility at the Holford Brinefield. The facility will consist of eight separate underground storage caverns, with a total capacity of 165 million cubic metres. At Atwick, near Hornsea in the East Riding of Yorkshire, cavities were specifically created for the storage of high pressure natural gas at depths of around 1800 m. Current UK gas storage capacity is, by international standards, small. The UK became a net importer of natural gas in 2004. As the UK becomes increasingly dependent on imported gas there will be a requirement to develop further storage facilities to cope with peak demands. If storage facilities are created distant from existing brine consumers, then any brine generated will need to be disposed of into the sea. Plans have been proposed for a new gas storage facility in the Preesall salt deposits below the Fleetwood Peninsula, Lancashire. The planned facility would consist of multiple underground caverns created by a washing process, in which pumping seawater into the salt deposits dissolves the salt. Potential also exists for developing gas storage caverns in offshore salt deposits.

Supply

The UK is a large salt producer with an estimated total output of some 5.8 million tonnes in 2004, over 95% of which was produced in England. The remainder is rock salt mined in Northern Ireland. Of total UK output, about 70% was extracted as brine and the remainder mined as rock salt. Following the cessation of brine pumping on Teesside in 2002, salt is now only produced in two areas in England; Cheshire and the North York Moors National Park. The Cheshire Basin accounts for over 85% of the total. In the North York Moors National Park, rock salt is mined as an ancillary product at the Boulby Potash Mine (see Factsheet on **Potash**).

Brine extraction ceased in Lancashire in 1993, following the closure of the chlorine plant at Hillhouse in Fleetwood, and also in Staffordshire in 1970 and in Worcestershire in 1971 because of subsidence problems. Very minor quantities of sea salt are produced by the evaporation of seawater at Maldon in Essex.

Output of salt-in-brine, brine (white) salt, which is produced by the evaporation of brine, and rock salt, has not been disclosed for a number of years because of the limited number of producers. However, the BGS has produced estimates for the *United Kingdom Minerals Yearbook* (Figure 1). Apart from rock salt production, output has remained relatively static but with an overall declining trend. Salt-in-brine production may have been slightly underestimated in previous years.

Production of rock salt is largely a function of the severity of the weather (demand for de-icing salt increases during cold winters) and output is thus variable. Demand for white salt is fairly static, if not declining, at about 1 Mt/y.

Trade

The UK is essentially self-sufficient in salt. Historically exports have exceeded imports but trade is currently roughly in balance, although

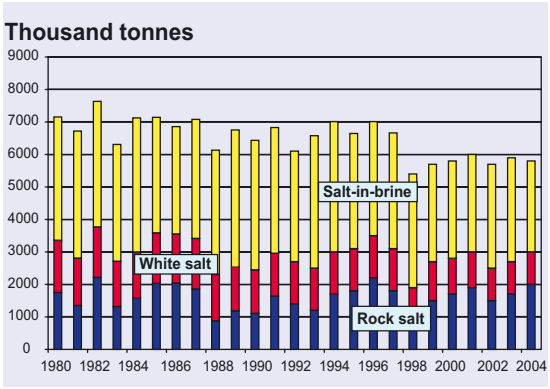

Figure 1 UK production of salt, 1980–2004.
Source: UK Minerals Yearbook, BGS.

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	Exports		Imports	
	Tonnes	£000	Tonnes	£000
1996	47 154	21 419	316 796	13 010
1997	284 571	18 639	242 368	11 796
1998	485 815	18 274	237 284	11 807
1999	276 402	22 125	261 434	11 573
2000	307 899	16 548	201 400(a)	na
2001	299 607	17 466	234 900(a)	na
2002	326 760	20 135	306 488	12 870
2003	537 497	23 202	217 009	10 928
2004	690 990	26 634	219 437	13 713

Table 1 Imports and exports of salt, 1996–2004. *Source: HM Revenue & Customs. (a) BGS estimate.*

exports have a higher value (Table 1). Exports include white salt and rock salt.

Consumption

Total UK consumption of salt has declined from about 7 million tonnes in 1980 to about 5.5 million tonnes in 2004.

Economic importance

The total value of salt production in all forms (rock salt, white salt and salt-in-brine) in the UK was £233 million in 2004 according to official statistics. Salt-in-brine is, however, a critical raw material for the heavy inorganic chemicals industry in north-west England. For example, the Runcorn site operated by INEOS Chlor is an integrated chemical plant largely producing chlorine and caustic soda. The turnover of INEOS Chlor is some £550 million, a major proportion of which is ultimately derived from brine production in Cheshire. About 1 450 people are employed at the Runcorn site, but the company estimate that 133 000 jobs are indirectly supported by the Runcorn site.

The company is currently undertaking a £390 million modernisation programme at its Runcorn site, mainly to replace existing mercury based cells for chlorine manufacture by state-of-the-art cellrooms, using environmentally-friendly membrane technology.

Brunner Mond, which is also critically dependent on brine as a basic feedstock for the manufacture of soda ash, employs 480 people in its UK operations, which have a turnover of £104 million.

Structure of the industry

Two companies produce rock salt in England; Salt Union Ltd, which operates the Winsford Mine at Winsford in Cheshire, and Cleveland Potash Ltd, which produces rock salt as a by-product of potash mining at the Boulby Mine in the North York Moors National Park. Salt Union is a wholly owned subsidiary of Compass Minerals International of the USA. In Northern Ireland, the Irish Salt Mining and Exploration Co. Ltd has operated the Kilroot rock salt Mine since 1965.

Three companies, all based in Cheshire, produce brine. INEOS Chlor Ltd, a privately-owned group, is by far the largest. The company acquired the ICI Chlor-Chemicals business in 2001 and operates the Holford Brinefield at Lostock Gralam in Cheshire and formerly extracted brine at Saltholme on Teesside. This operation ceased in June 2002 with the closure of the Wilton chlorine plant, thus removing the need for brine. The company produces some 3.2 Mt/y of contained salt-in-brine. Brine from the Holford field is supplied to the company's own plant at Runcorn for the electrolytic manufacture of chlorine and caustic soda. Permitted chlorine production is some 737 000 tonnes and 831 000 tonnes of caustic soda, although output is less. In addition, brine is also supplied to Brunner Mond (UK) Ltd at Lostock and Winnington for the manufacture of soda ash (sodium carbonate) of which the company is the UK's sole manufacturer and Europe's second largest producer. INEOS Chlor also supplies brine to the Salt Union's Western Point plant at Runcorn for the manufacture of white salt. INEOS announced in late 2005 its intention to purchase the Salt Union's vacuum salt business.

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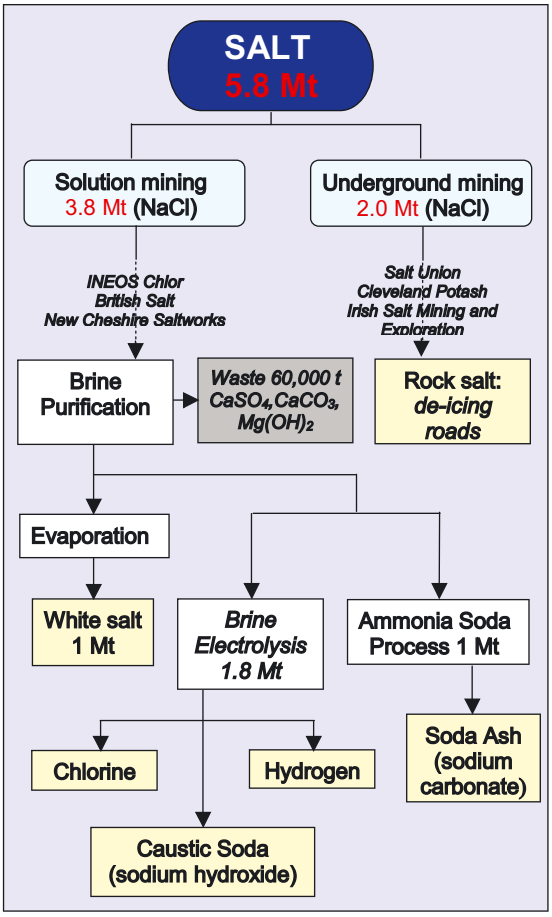

Figure 2 Salt supply chain, 2004.

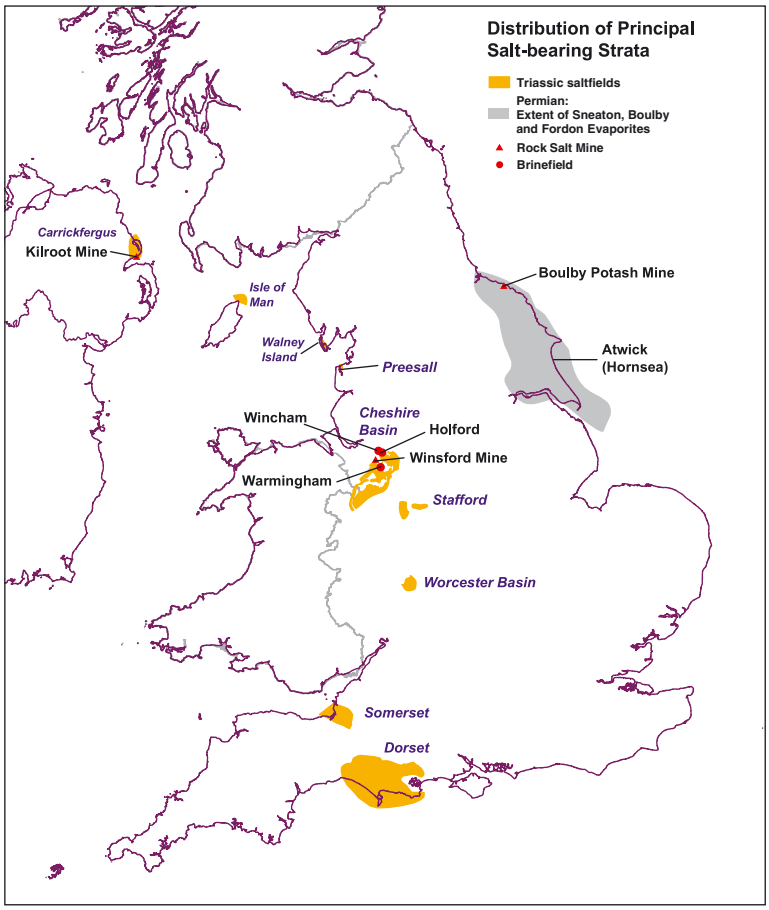

Figure 3 Distribution of salt-bearing strata and principle producing sites.

Brine is also produced by British Salt, a subsidiary of US Salt Holdings, at the Warmingham Brinefield in Cheshire for use in the manufacture of white salt at its Middlewich plant. The New Cheshire Saltworks Ltd is a very small producer of white salt at Wincham, near Northwich.

The salt supply chain is summarised in Figure 2.

Resources

The UK has huge resources of salt, which mainly occur in England, with only limited resources in Northern Ireland. Salt-bearing strata of Permian and Triassic age underlie extensive areas (Figure 3). Resources of Triassic age are economically the most important and account for some 90% of total production, most of which is derived from the Cheshire Basin. The deposits in Northern Ireland are of Triassic age. Permian deposits are only worked at the Boulby Mine.

Triassic

The most important salt resources in England occur within the Triassic Mercia Mudstone Group, which has a widespread outcrop. However, salt-bearing strata generally only occur where the Mercia Mudstone thickens in major depositional basins. The most important of these, and the source of some 90% of total salt output, is the Cheshire Basin, which also extends into north Shropshire.

There are two salt-bearing formations in the Cheshire Basin, a lower Northwich Halite Formation and an upper Wilkesley Halite

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Formation. Production is entirely confined to the former. The maximum known thickness of the formation is some 280 m and the salt occurs in beds that are virtually pure halite and in others where there are varying amounts of mudstone and siltstone. It has been estimated that some 25% of the formation consists of mudstone. The Wilkesley Halite Formation is even thicker and has a known thickness of some 405 m. The upper half of the Wilkesley Halite Formation is somewhat purer than the Northwich Halite.

Triassic saltfields have also been worked in the past at Preesall in Lancashire, in Worcestershire, Staffordshire, on Walney Island in Cumbria and in Somerset. Extensive areas of salt-bearing strata also underlie Dorset. It is highly unlikely that any of these deposits will become of commercial interest as a source of salt in the foreseeable future. However, where thick (>100 m), relatively pure beds of salt occur they may be of interest for creating cavities for storage purposes.

In Northern Ireland salt resources within the Carnduff Halite in the Triassic Mercia Mudstone Group underlie the area between Carrickfergus and Larne (in south Co. Antrim), and has been worked for over 100 years. The Kilroot Mine operated by the Irish Salt Mining and Exploration Company Ltd has been working this resource since 1965. 15 km to the north of Kilroot a drillhole intersected 400 m of Triassic halite in three seam groups as well as 113 m of halite in the older, deeper Permian Upper Marls. Significant salt resources have not been identified in any other part of Northern Ireland to date.

Permian

Salt-bearing strata of Permian age extends at depth from Teesside beneath much of east Yorkshire and into north Lincolnshire. Deposits occur at several horizons, the most extensive being the Boulby Halite, which is also the only UK Permian salt of current economic importance. It was exploited by brine pumping on Teesside until 2002 and is mined at the Boulby Potash Mine. Thick salt deposits also occur lower in the Permian sequence within the Fordon Evaporites. At Hornsea in east Yorkshire these deposits have been used to create cavities some 100 m high and 100 m wide at depths of between 1710 m and 1840 m for use in natural gas storage. A stratigraphically higher salt horizon, the Sneaton Halite, occurs above the Boulby Halite but is less extensive.

Reserves

A figure for total permitted reserves of salt is not available. At the Holford and Warmingham brinefields in Cheshire there are sufficient reserves with planning permission until at least 2042, when the current consents expire. However, new cavities have to be created to sustain brine production. At Holford no new cavities have been created since 1982 and there is now a requirement for a phased development, particularly as they take several years to produce saturated brine. Future developments are likely to be linked with the development of cavities for natural gas storage. The sinking of new boreholes and the associated infrastructure requires planning agreement.

Proved reserves of rock salt at the Winsford Mine are sufficient for 70 years, although the current planning consent expires in 2011. Rock salt reserves at the Boulby Mine are dependent on potash reserves.

In the Kilroot area of Northern Ireland approximately 10 years of reserves remain, at the current rate of production.

Relationship to environmental designations

The Boulby Potash Mine is located in the North York Moors National Park. Elsewhere operations are not associated with any major environmental designations.

Extraction and processing

Salt-bearing strata do not crop out at the surface, because of dissolution by groundwater, and are absent to depths of about 70 m. The boundary at which solution is taking place is called the 'wet rock-head', and the overlying collapsed strata may lead to possible subsi-

dence at the surface. Where salt-bearing strata are too deep to be affected by groundwater circulation, the normal contact between the salt and overlying rock is known as the 'dry rock-head.'

Natural brine springs have been exploited at least since Roman times. Brine was boiled in open pans to produce salt. In 1670 rock salt was discovered at depth in Cheshire and this led to considerable commercial exploitation both by mining and drilling to the wet rock-head to pump natural or 'wild' brine. Shallow mines subsequently became flooded and pumping of the resultant brine caused the solution of roof pillars leading to catastrophic subsidence and damage at the surface. Natural brine pumping also led to unpredictable subsidence some kilometres from the point of extraction. Damage caused by this method of extraction led to the cessation of salt extraction in Worcestershire and Staffordshire. Remedial work to infill and stabilise the flooded salt mines beneath Northwich has started.

In Northern Ireland the legacy of uncontrolled brining operations has had a significant effect on the Carrickfergus area. To date there have been three large collapses, with a fourth predicted in the short to medium term.

Both underground mining and solution mining are used to extract salt. Rock salt mining is undertaken at three locations in the UK, at the Winsford Mine in Cheshire, the Boulby Mine in the North York Moors National Park and the Kilroot Mine in Northern Ireland.

Salt mining at the Winsford Mine began in 1844, but the mine was closed between 1892 and 1928. Since 1928 it has been the major source of rock salt in the UK. Mine capacity is about 2.25 Mt/y, but averages about 0.9 Mt/y. Extraction is by room and pillar mining and is currently from the Bottom Bed of the Northwich Halite Formation, at a depth of about 140 m. The salt is extracted from galleries 8 m high and 20 m wide. Pillars are 20 m x 20 m giving an extraction rate of 75%. Formerly drill and blast methods were used for salt extraction. A continuous mining machine was, however, introduced in 2002, which is used to extract the top lift of 4.5 m, with either bench blasting or the continuous miner being used for the bottom 3.5 m. The rock salt is crushed to either -6 mm or -10 mm underground and treated with an anti-caking agent to keep it free flowing. Rock salt mining produces no waste.

The mine is dry and stable; room and pillar mining does not create any surface subsidence. However, in 1968 the intersection of a borehole caused serious flooding. Protection barriers of 75 m are now left around boreholes. The salt contains about 92% NaCl and the presence of some mudstone provides a protective coating to outside stockpiles and prevents dissolution.

At the Kilroot Mine in Northern Ireland the salt beds vary in thickness from 9 to 27 m and occur at five separate levels (all of which have been worked). Access is via a decline and mining is by the room-and-pillar method, output is up to 0.5 Mt/y. At the Boulby Mine, rock salt is a by-product of potash mining (see factsheet on **Potash**).

Almost all solution mining is now by controlled brine pumping. The method was introduced by ICI in the 1920s and involves the creation of stable cavities in suitable salt strata by the introduction of water under carefully controlled conditions, thus preventing subsidence. The process recovers up to about 25% of the total salt reserve. Brine is extracted from cavities up to 145 m in diameter and up to 200 m in height. The size and shape of the cavities are designed to maintain the stability of the overlying strata and so avoid surface subsidence. Each cavity is developed through a single borehole with a triple tube system. Water is pumped into the cavity and brine is continuously displaced through the centre tube. Once the cavity has enlarged sufficiently, usually after a couple of years, this process produces saturated brine, containing 26% NaCl. The position of the water injection tube and the depth of a compressed air blanket, which is used to prevent upward development, control the area of salt dissolution. By changing the position of these during development, the final size and shape of the cavity can be controlled. Cavities are developed from the base upwards and during development their size and shape is monitored by

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sonar techniques. Insoluble mudstone falls to the bottom of the cavity. The brine wells are laid out on a regular grid with new wells being drilled some 200 m apart. Completed solution cavities are left full of saturated brine, although some are used for both waste disposal and storage purposes. Controlled brine pumping takes place at the Holford and Warmingham brinefields from the Northwich Halite Formation, at depths of over 250 m. At Holford up to 50 cavities are currently being used for brine extraction.

Only very minor quantities of natural brine are now produced at Wincham, near Northwich.

The brine produced by solution mining requires purification before it can be used either as a chemical feedstock or in the production of white salt. The purification process involves precipitating calcium sulphate, calcium carbonate and magnesium hydroxide, and these insoluble wastes are disposed of into worked out salt cavities. The waste is subject to the landfill tax at the lower rate of £2/t applying to inactive or inert waste. Disposal of waste in this way is believed to be the best environmental option. Total production of these wastes is estimated to be of the order of 60 000 t/y.

By-products

There are no currently useable by-products in the strict sense, although the use of the wastes from brine purification have been looked at periodically and warrant further study. However, salt extraction both by conventional and solution mining creates large, stable voids that are themselves important economic assets both for storage purposes and waste disposal. The Winsford Mine, with some 26 million m^3 of space, has a constant temperature and humidity and is dry and gas-free. Part of the mine is currently being used for secure document storage. A proposal to use part of the mine for the permanent storage of hazardous wastes was granted planning permission in December 2003 and waste disposal commenced in 2005. Strict criteria will be used for the type of material stored, which will be dry waste that is non-flammable, non-biodegradable and non-radioactive.

Alternatives/recycling

The chemical uses of salt are directly related to its composition and it is unlikely that any other source of sodium and chlorine ions could be used as an alternative in the UK. Other materials (e.g. urea) have been used for de-icing roads in special circumstances, such as on bridges to avoid corrosion, but on cost grounds, rock salt is unlikely to be replaced for road treatment.

Salt is valued for its chemical properties and is thus consumed in use. Some recycling of the products derived from salt takes place. For example, soda ash is an essential component in the manufacture of soda-lime-silica glass, the most common glass composition. Recycling glass thus also recycles soda (Na_2O) in addition to silica and lime.

Transport issues

Brine from both the Holford and Warmingham brinefields is supplied to downstream processing operations entirely by pipeline. Rock salt is delivered by road from the Winsford Mine, although a small proportion (5%) will be subsequently transferred to rail for movement to Scotland. At the Boulby Potash Mine rock salt is removed from the site by rail for onward transfer by lorry and ship from Tees Dock. Rock salt from the Kilroot Mine in Northern Ireland is exported by sea, including to the USA.

Planning issues

Modern methods of underground solution and rock salt mining do not cause subsidence and raise only modest planning issues at surface. Pumping of natural brine is unlikely to be permitted in future, although some old permissions are still in operation and there is still a legacy of subsidence from historic working by this method.

It is likely that in the future, the major planning issue will not be the extraction of salt itself, but the subsequent use of the void created for waste disposal and for storage purposes. Of particular interest is the scale of the impact of these additional operations at surface.

Underground gas storage requires considerable surface infrastructure including pipelines, water pumping stations and gas compressors all of which have an environmental impact. The 'need' argument will centre around the national requirement for storage of fuel gas/liquid hydrocarbons or safe disposal of hazardous waste, rather than the demand for brine or rock salt. The principle issues likely to be considered in any planning inquiry include the need for the development, the sustainable use of mineral resources, the impact on the environment of the area, particularly the freshwater and marine ecology, the suitability of the geology to accommodate the proposed underground caverns, safety and security, ground stability, visual and landscape impacts and the effects on tourism and economic development.

Authorship and acknowledgements

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