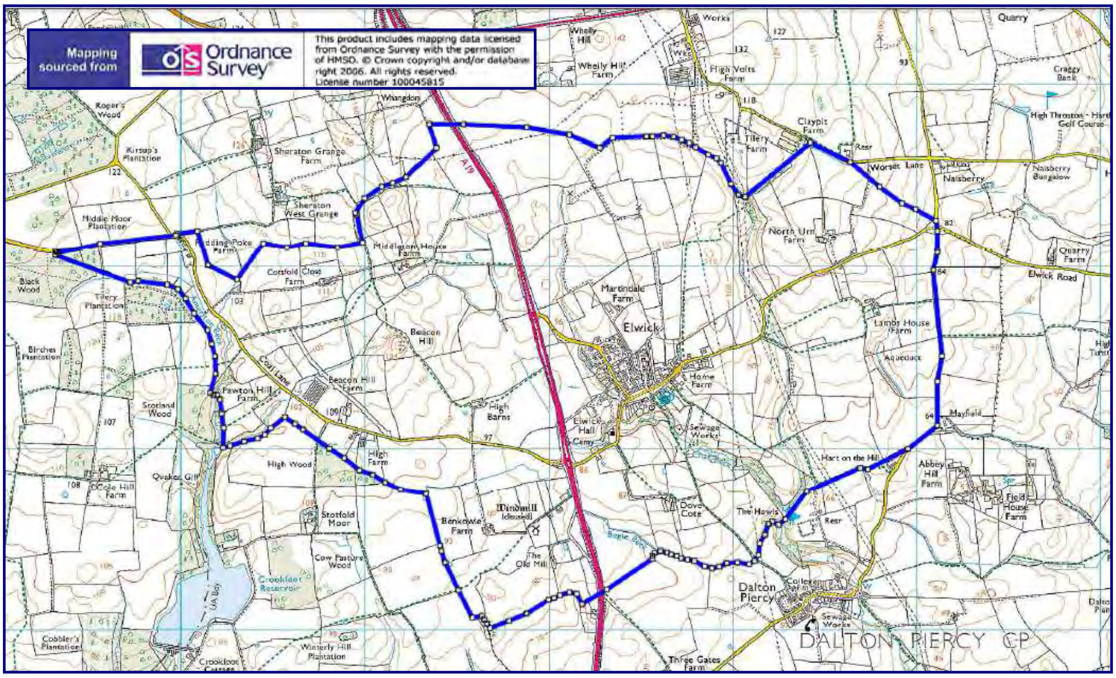
THE ELWICK ATLAS PROJECT



HYDROGEOLOGY AND SURFACE HYDROLOGY

REPORT

Heather C Tait

BACKGROUND

This hydrological report has been prepared as part of the Elwick Village Atlas Project. The subject of hydrology is extensive. It is the study of circulation, distribution and chemistry of water within the Earth. The aim of the report is to raise awareness of the local hydrological environment and with a view to improvements in aquatic habitat provide suggestions for community involvement.

Relevant hydrogeology and surface hydrology are considered to help the local community gain a fuller understanding of the hydrological links between bedrock geology, superficial geology, groundwater, surficial water, aquatic ecology, precipitation, water quality and water supply. Current and historic anthropogenic impact and the potential impact of climate change are considered and relevant legislation relating to the water environment in the UK is discussed.

As part of the hydrological study the local community was invited to join in workshops and field studies of the Char Beck and the Craddon Beck during which the local geology, groundwater, surface water hydrology, fluvial geomorphology and aquatic habitat were examined. Children studying Key stage 2 at St Peter's Primary School took part in a field trip to the Char Beck where a practical exercise to investigate the relationship between stream flow, channel morphology and fluvial erosion, transport and deposition was undertaken.

For those interested in further reading a range of documents has been attached to the report. A list of books and websites is also attached.

ACKNOWLEDGEMENTS

I would like to express thanks to those who contributed to the information contained in this report. In particular I would like to thank the Groundwater Team at Hartlepool Water and the Groundwater Team at the Environment Agency for providing specific technical information related to the locality. I would like to thank the Environment Agency and the British Geological Society (BGS) for their permission to use maps and information extracted from their Websites and for their permission to attach relevant PDF documents to the report for further reading. I would like to thank Dr Brian Young BGS (retired) and Mrs Lesley Dunlop of Northumbria University for their assistance with geological information, mapping and permissions, Dr Ken Bradshaw of Durham County Council for assistance with mapping and permissions, F.S Sturrock & Sons for access to certain stretches of the Char Beck, Mr Ian Bond Ecologist with Hartlepool Borough Council and Mr Robert Smith Countryside Warden Hartlepool Borough Council (Retired) for information regarding Water Voles and historical survey of Water Vole populations.

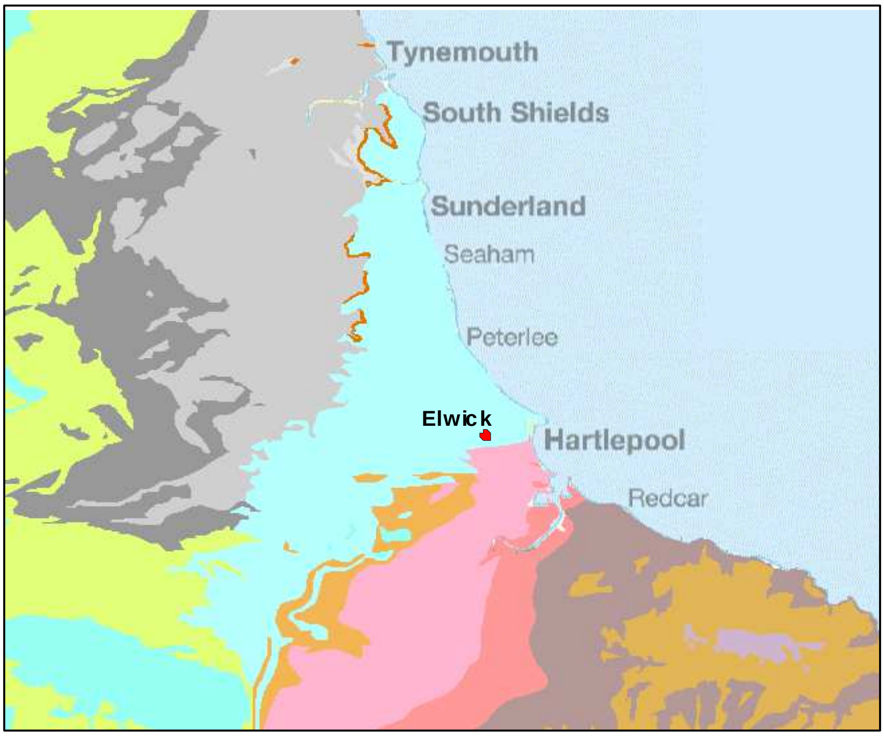
I would also like to express particular thanks to local resident Mr George Howe for helping me to get to know the village, for his assistance during extensive walk over surveys of the watercourses at Elwick, for the wealth of local knowledge imparted and for his kindness and enthusiasm for the project.

Heather C Tait

INTRODUCTION

The village of Elwick lies on elevated ground to the east of Hartlepool town. Land rises from south of the village towards the north and west. In the direction of Whelly Hill Farm height is around 120m above sea level (A.O.D.), beyond the A19 at Beacon Hill land rises to 134m A.O.D. The topography of Elwick and the surrounding area has been greatly influenced by the glacial and interglacial periods of the Quaternary. Substantial glacial diamitic drift, a mixture of poorly sorted clays, sands, gravels, cobbles and boulders was draped unconformably over the Permian Limestone landscape. Erosion of the drift has resulted in an open undulating landscape cut through by deep, steep sided narrow valleys known locally as Denes. The Denes lie to the south of Elwick and convey the waters of the Craddon Beck, the Char Beck and the Bogle Beck via the Dalton Beck to the River Greatham, a tributary of the River Tees. The lowest ground in the locality at 55m A.O.D. is to be found at the confluence of the Denes in the area known as the Howls.

Location of Elwick on the Magnesian Limestone Plateau



Legend: 1:65000 Bedrock Geology

- Ravenscar Group – Sandstone, Siltstone and Mudstone
- Lias Group – Mudstone, Siltstone, Limestone and Sandstone
- Triassic Rocks (Undifferentiated) – Mudstone Siltstone and Sandstone
- Triassic Rocks (Undifferentiated) – Sandstone and Conglomerate, Interbedded
- Zechstien Group – Dolomitised Limestone and Dolomite
- Permian Rocks (Undifferentiated) – Mudstone, Siltstone and Sandstone
- Permian Rocks (Undifferentiated) – Sandstone and Conglomerate, Interbedded
- Pennine Upper Coal Measures – Mudstone, Siltstone, Sandstone, Coal, Ironstone, Ferricrete
- Pennine Middle Coal Measures Formation (Undifferentiated)
- Pennine Lower Coal Measures Formation (Undifferentiated)

BEDROCK

Elwick lies on the south eastern corner of the Durham Province of the Magnesian Limestone Escarpment. The escarpment runs from South Shields in the north to Nottingham in the south (Bearcock & Smedley 2009). The rock was laid down during the Upper Permian period 299 to 251 million years ago and belongs to the Zechstein group of strata. In the UK these Permian rocks are a complex sequence of fluvial, desert, marine and evaporite deposits. They were laid down during cycles of transgression, regression and evaporation of the shallow, tropical Zechstein Sea when Britain was located close to the equator. Divided into the Upper the Middle and the Lower Magnesian Limestone the rock is classified as a whole for Hydrostratigraphical purposes as the Magnesian Limestone Aquifer. The Aquifer lies over the Marl Slate and the Yellow Sands which in turn lie unconformably over Carboniferous Coal Measures that were once extensively mined for coal to the north and west of Elwick.

Figure1. LITHOSTRATIGRAPHICAL SUBDIVISION OF THE PERMIAN AND TRIASSIC ROCKS OF DURHAM.

			DURHAM AREA FORMAL NAME	TRADITIONAL NAME		
TRIASSIC	Zechstein Sequence		Mercia Mudstone Group (Undivided)	Keuper Marl		
			Sherwood Sandstone Group (Undivided)	Bunter Sandstone		
PERMIAN	ZS7	Zechstein Group	Roxby Formation	Upper Anhydrite and Marl		
	ZS6		Rotten Marl Formation	Rotten Marl		
	ZS5		Boulby Halite Formation	Middle Halite		
			Billingham Anhydrite Formation	Billingham Main Anhydrite		
			Seaham Formation	Magnesian Limestone	Upper Magnesian Limestone	Seaham Formation
	ZS4		Seaham Residue and Fordon Evaporite Formation			Seaham Residue
	ZS3		Roker Formation			Hartlepool and Roker Dolomite
						Concretionary Limestone
	ZS2		Ford Formation		Middle Magnesian Limestone	
	ZS1		Raisby Formation		Lower Magnesian Limestone	
			Marl Slate Formation	Marl Slate		
			Yellow Sands Formation	Yellow Sands (Basal Permian Sands and Breccia)		

CARBONIFEROUS ROCKS (Stone *et. al*. 2010).

To the south of Elwick running through Dalton Piercy, the West Hartlepool Fault marks the southern boundary of the Magnesium Limestone Plateau. The strike of the fault is approximately east to west. Downthrow is to the south and in the Permian strata the downthrow varies along the length of the fault from around 90 - 180m (Smith *et.al.* 1967). The bedrock south of the fault consists of the Triassic Sherwood Sandstone.

The Zechstein Group consists of good aquifers interbedded with impermeable beds and in Durham the Magnesian Limestone Aquifer is important for public, domestic, agricultural and industrial water supply. There is significant spatial variability in the hydraulic and the hydrochemical properties of the aquifer. Primarily it is the features of secondary porosity such as joints, bedding planes and fractures that create hydraulic connectivity within limestone. As water passes through the rock it reacts with carbon dioxide to form a weak carbonic acid. This weakly acidic groundwater causes dissolution and enlargement of discontinuities to create sinkholes, voids and channels through which high rates of hydraulic conductivity may be found.

$H_2O + C0_2 \rightarrow H_2CO_3$ (carbonic acid)
$CaCO_3$ (limestone) + $C0_2 + H_2O \rightarrow Ca_{2+} + 2HCO_3-$ (in solution)

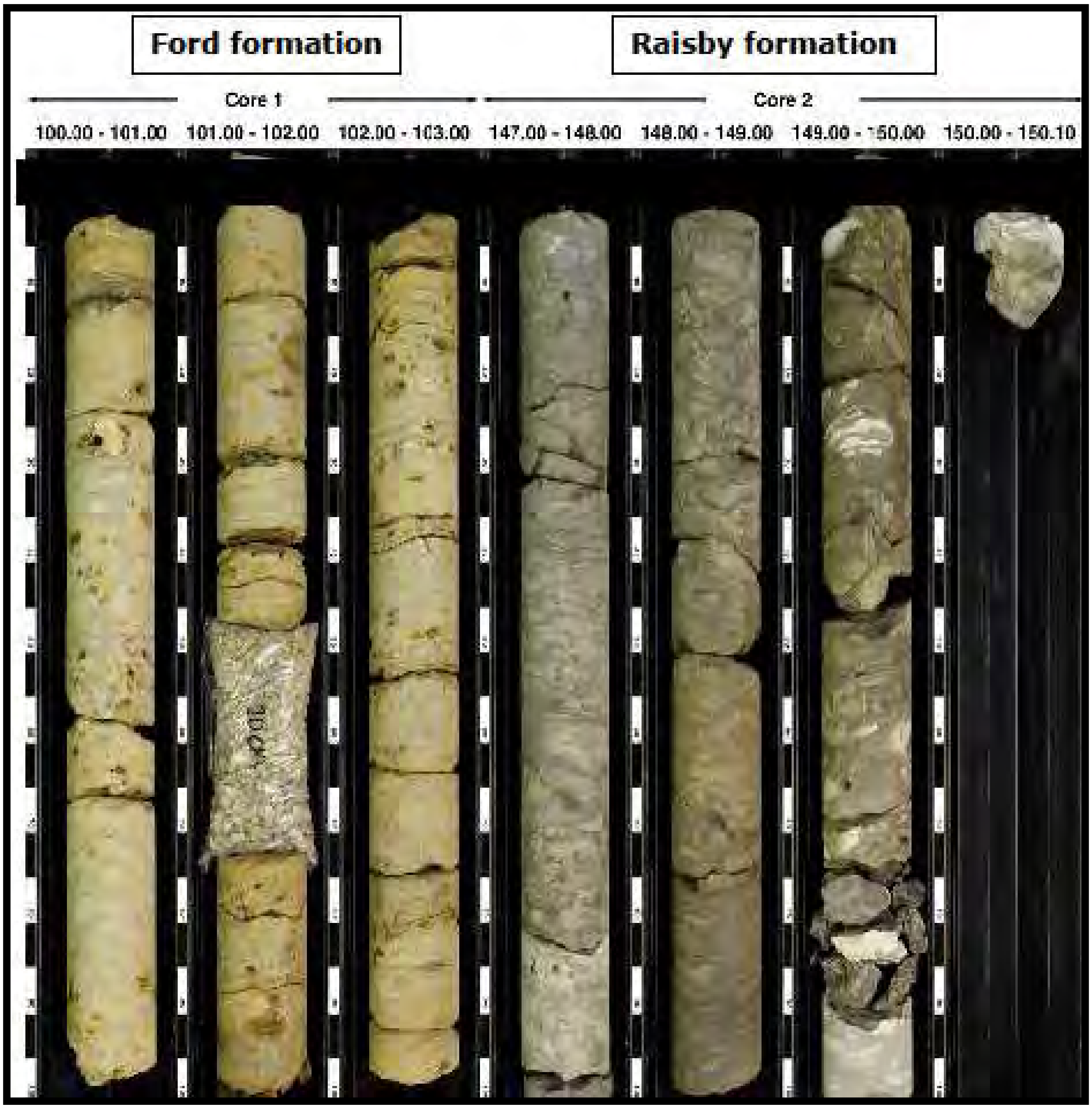
Groundwater flow in the matrix and small fissures of limestone is typically slow and laminar whilst flow in large conduits such as caves systems may be fast and turbulent. Dolomitic rock is less soluble than limestone and although it may be resistant to dissolution it displays localised solubility. Therefore, the extent of fracturing, the patterns of jointing and dolomitic content are particularly relevant for hydraulic conductivity in the Magnesian Limestone. Transmissivity is extremely variable and according to Allen et al. (1997) tends to be highest along major faults such as the West Hartlepool Fault.

The regional dip of the Magnesian Limestone is to the east and typically between 5 - 7 °. Locally in association with major faults and gentle folds dip may be greater than this. According to Younger (1995) (cited in Bearcock and Smedley 2009) north of the West Hartlepool Fault flow within the aquifer is down dip in a general west–east direction and it is most likely that there is submarine discharge from the aquifer to the North Sea. Although values for transmissivity can range from 6 to 4300 m^2 day^{-1} within the aquifer, in reality, transmissivity of 60–800 m^2 day^{-1} is generally noted (cited in Bearcock and Smedley 2009).

During glacial and interglacial periods in the region of Elwick the Triassic mudstones, sandstones and upper units of the Zechstein Group including the Upper Magnesian Limestone and the Hartlepool Anhydrite (an upper bed of the Middle Magnesian Limestone) were removed. Today, the bed rock below Elwick consists of the remaining Middle Magnesian Limestone and the Lower Magnesian Limestone formally referred to as the Ford Formation and the Raisby Formation.

The **Raisby Formation** is a shelf deposit that is typically uniform and evenly bedded. It was deposited on a gentle eastwards dipping shelf. This deposit consists of a dense, fine grained, yellow to cream coloured, mainly high-grade, slightly calcitic dolorstone ($CaMg(CO_3)_2$ with rare, grey, fine-grained limestone. Chaotic and often contorted rock structures may be found in the Formation due to 'slumping' of partly lithified sediment (Lawrence and Cooper 2009). Though the Formation seldom exceeds 50m in depth it demonstrates a great lateral variation in thickness due to the uneven nature of the weathered Carboniferous landscape over which deposition took place. For instance south of the West Hartlepool Fault at Dalton Piercy the Formation is 76m thick and 4 miles offshore north of Hartlepool it is 12m thick. In contrast, due to depositional environment, the surface of the Formation is topographically level (Allen *et al.* 1997).

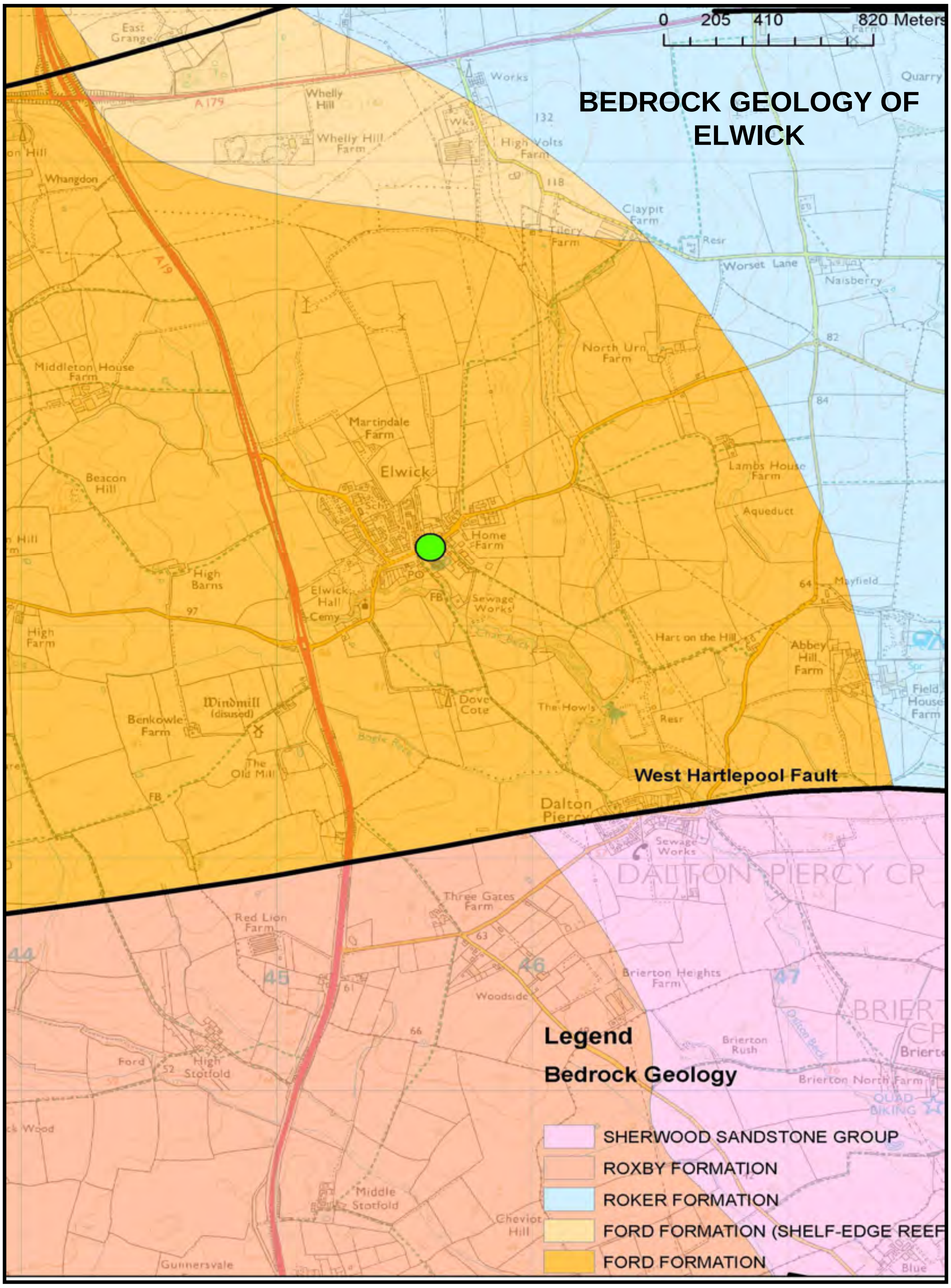
Ford Formation and Raisby Formation Lithology



Photograph supplied by Hartlepool Water 2013

Lying over the Raisby Formation is the **Ford Formation.** It consists of a sequence of rocks deposited in thee distinct environments associated with a warm, shallow sea barrier reef. Lithology varies depending on the particular environmental setting during deposition. There are back reef and shallow lagoon deposits in the east, highly fossiliferous reef deposits and to the west a series of fore reef and off reef deposits. Consequently the Formation consists of a wide range of carbonate rock types including dolostone, dolomitised limestone and calcitic dolomite. Predominantly white to buff in colour the rock facies consist of soft oolitic grains, concretionary grains and highly fossiliferous reef deposits. Thickness is variable. Typically it is thicker than the Raisby Formation (Kortas and Younger 2013). At Dalton Piercy below the West Hartlepool Fault thickness is approximately 90m and in the region of Elwick thickness is around 40m. Locally the Ford Formation may be resistant to erosion and forms topographic highs such as Beacon Hill to the west of Elwick (Smith *et.al* 1967).

South of St Mary's Church at the Elwick Borehole the combined thickness of the Ford and the Raisby Formations was found to be 132m. Some intergranular storage does occur in both the Raisby and the Ford Formation where reef limestone and dolostone predominate (Stone *et. al*. 2010). Recent coring of an observation borehole has shown distinctly different porosity and permeability between the Formations (Hartlepool Water 2013).



British Geological Survey. NERC. GeoIndex. 2013

GROUNDWATER

An aquifer is a layer of consolidated or unconsolidated material that has the capacity to store and transmit significant quantities of water. Water bearing capability is determined by porosity and permeability. Porosity determines the amount of water that can be held in a rock and depends upon the number of pore spaces in the fabric of the rock or soil. Permeability is the capacity for transmitting a fluid. Porosity and permeability depends on the extent of the pore system and the size and shape of the connections between the pore spaces.

Within an aquifer water flows from zones of high pressure to zones of low pressure and typically there is a vertical and horizontal component to flow. Aquifers are classed as confined and unconfined. A confined aquifer is saturated and overlain by a confining layer that prevents vertical recharge from the surface. In a confined aquifer the surface of the water is referred to as the peizometric surface rather than the water table. A confining layer or aquitard may contain water but does not transmit water in significant quantities. In an unconfined aquifer the surface of a water table does not necessarily mimic surface topography as it is influenced by the geological structure of the aquifer and the degree of abstraction. The depth of a water table varies with climatic variation and so the surface of the water table lies within a zone that is subject to intermittent saturation.

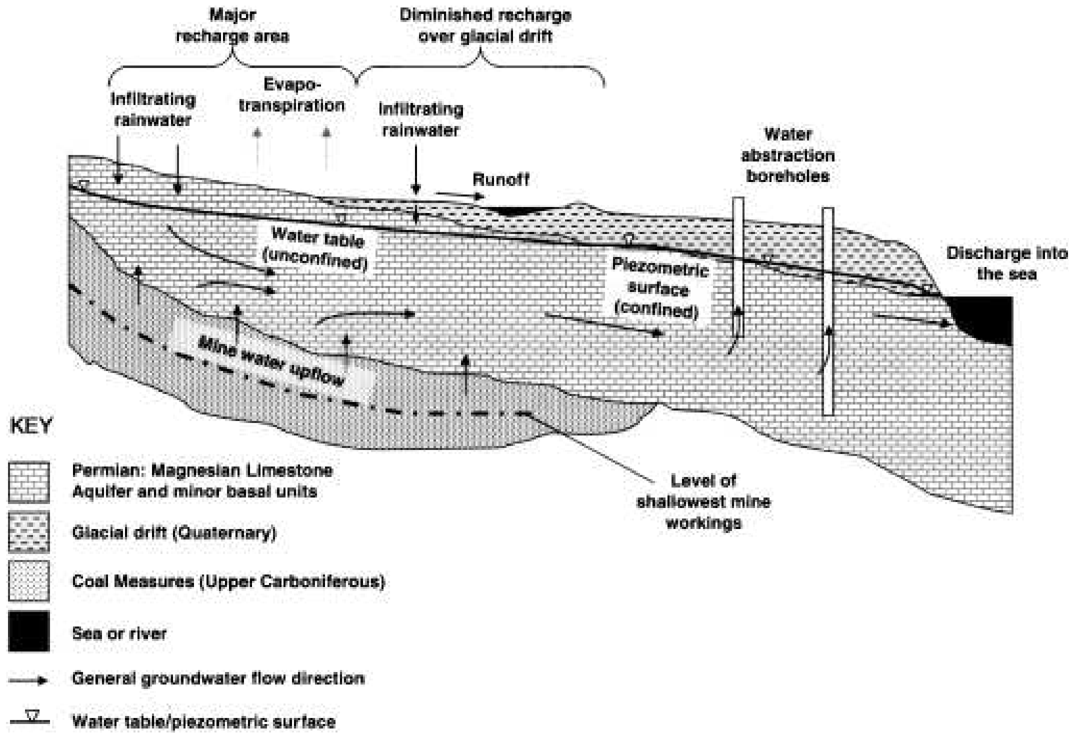
The composition and depth of glacial drift deposits result in variable rates of recharge to the Magnesian Limestone. It is thought that transmissivity is such that where drift exceeds 10m in thickness, vertical recharge generally does not occur (Environment Agency 2013). To the west and north of Elwick it is known that vertical recharge does occur to the Magnesian Limestone and on a regional scale the aquifer is classed as unconfined. It is also known that the drift increases in depth from west to east across the county and borehole data shows that directly east and west of Elwick the overburden reaches depths of 50m and 65m (Hartlepool Water 2013). However, it is still appropriate to class the aquifer as unconfined as the water table lies below the upper surface of the Magnesian Limestone i.e. there is not a confining layer above the water table.

During mining of the Coal Measures dewatering meant that the water table lay far below the Permian strata, deep within the Carboniferous strata. Closure of the coal mines and cessation of dewatering in the 1970's has resulted in regional water level rebound.
To date, according to Hartlepool Water (2013) there has been 180m recovery within the Coal Measures and a recovery of 10 -15m within the Magnesian Limestone.

GROUNDWATER QUALITY

The chemistry of a groundwater varies due to complex geological, geochemical, hydrogeological and climatic factors. Dissolution of dolomitic limestone means that groundwater contains high levels of positively charged calcium (Ca^{2+}) and magnesium (Mg^{2+}) cations and negatively charged bicarbonate (HCO^{3-}) anions. The cations give the groundwater the characteristic hardness and the anions the characteristic alkalinity. In some areas of Durham groundwater is known to have high concentrations of sulphate ($SO4^{2-}$), Sodium (Na^{+}) and chloride (Cl^{-}) ions (Bearcock & Smedley 2009). Elevated salinity (Na^{+}& Cl^{-}) may occur through saline intrusion in coastal areas and the rising of connate water due to abstraction. It may also arise due to anthropogenic pollution and natural geochemical variation such as presence of evaporite deposits. Historically the quality of groundwater in the region of Hartlepool was known to be affected by saline intrusion. However, since the 1970's management of abstraction has resulted in a dramatic reduction in the concentration of chloride ions and therefore a dramatic improvement in groundwater quality (Environment Agency 2013).

Residence time of groundwater in an aquifer may be years to decades and it is the flow of young water that is most vulnerable to pollution (Shand 2007). Groundwater quality within the Magnesian Limestone aquifer is generally considered to be good (Stone *et al*. 2010). However, the degree of hydraulic conductivity means that the aquifer is highly vulnerable to anthropogenic pollution. High levels of sulphate associated with coal mining and the cessation of dewatering are migrating in a plume of pollution down dip towards the east coast. Currently, the plume appears to be approaching Hartlepool and is the subject of considerable investigation (Kortas & Younger 2013).



The key features of the conceptual model for groundwater flow through the Magnesian Limestone aquifer including mine water up flow from the underlying flooded mine workings (Neymeyer *et al*. 2007 cited in Brassington and Younger 2009).

Nitrates may last 100's to 1000's years in an aquifer and although not widespread, presence of nitrates in areas of recharge in the north and west of County Durham indicates the degree of vulnerability to agricultural land use (Shand *et.al.* 2007 & Environment Agency 2013).

THE GROUNDWATER DIRECTIVE

(From the Environment Agency Website - What's in Your Backyard?)

Groundwater Directive (2006/118/EC) requires that groundwater achieves `Good' status with respect to quality and quantity to provide a range of benefits essential to healthy living. In the UK, the Environment Agency is charged with the task of implementing the legislation to `prevent or limit' deterioration of groundwater through mitigation and remediation. Significant increase in the concentration of pollutants and indicators of pollution must be identified and a starting point for reversal of the trend defined. The Environment Agency is responsible for establishing a `Programme of Measures' to monitor and progressively reduce pollution to prevent or limit deterioration of groundwater. If any quantitative or qualitative test for a particular aquifer indicates a poor status then the overall classification of that aquifer will be `Poor'.

Aquifer designation reflects the importance of the groundwater as a resource for drinking water supply and the role it plays in supporting wetland ecosystems and surface water flow. There two different types of aquifer designation:

1. Superficial (Drift) - permeable unconsolidated (loose) deposits such as sands & gravels.
2. Bedrock - solid permeable formations such as sandstone, chalk and limestone.

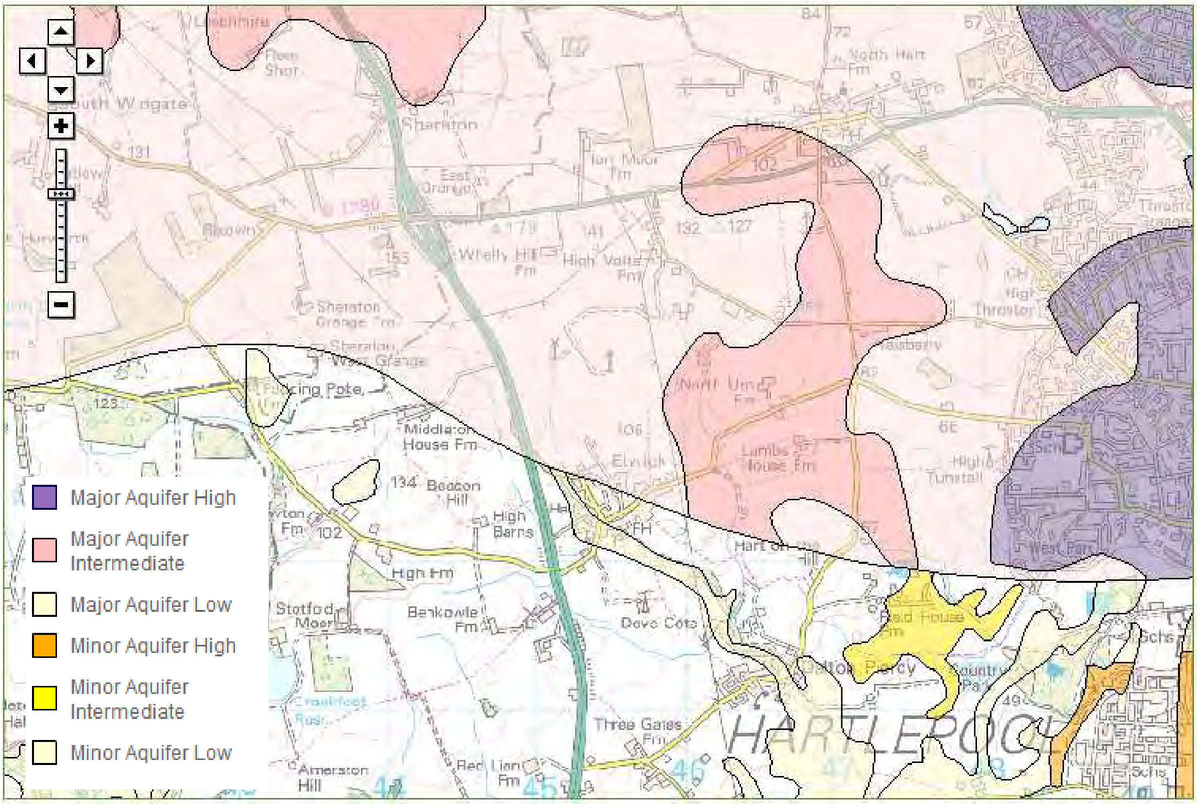
The Magnesian Limestone Aquifer is defined as a Principle Bedrock Aquifer. Under the Groundwater Directive chemical quality is considered to be `Poor' and deteriorating and this is due to the historic problem of saline intrusion. Currently, some abstractions near the coast at Hartlepool still demonstrate concentrations of chloride that are greater than the Drinking Water Standard of 250 mg/l. Unfortunately this salinity also means a classification of `Poor' for quantitative quality. The classifications of `Poor' are considered to be due to direct and indirect abstraction of groundwater (Environment Agency February 2013). Fortunately nitrate pollution has not been identified in this area of the aquifer.

The Groundwater Directive requires abstraction to be managed in a manner that safeguards both the water body concerned and any downstream water bodies that may be affected by a reduction in abstraction related flow.

Abstraction licensing for the countryside around Hartlepool is governed by the Tees Catchment Abstraction Management Strategy. Current abstraction is monitored and if it is thought that there may be impact on a surface water feature or a reduction of baseflow to a watercourse a `Hands Off Level' condition may be applied below which abstraction must be reduced or stopped (Environment Agency February 2013). Impact of new abstractions is assessed and subject to stringent limitations. They must be sustainable and must not alter surface water bodies or lead to a deterioration in water quality by causing either expansion of the existing mine water sulphate plume or further dissolution of minerals from the Coal Measures. (Environment Agency February 2013).

GROUNDWATER VULNERABILITY ZONES: ELWICK. Scale 1:40000

(Environment Agency WIMBY 2013)



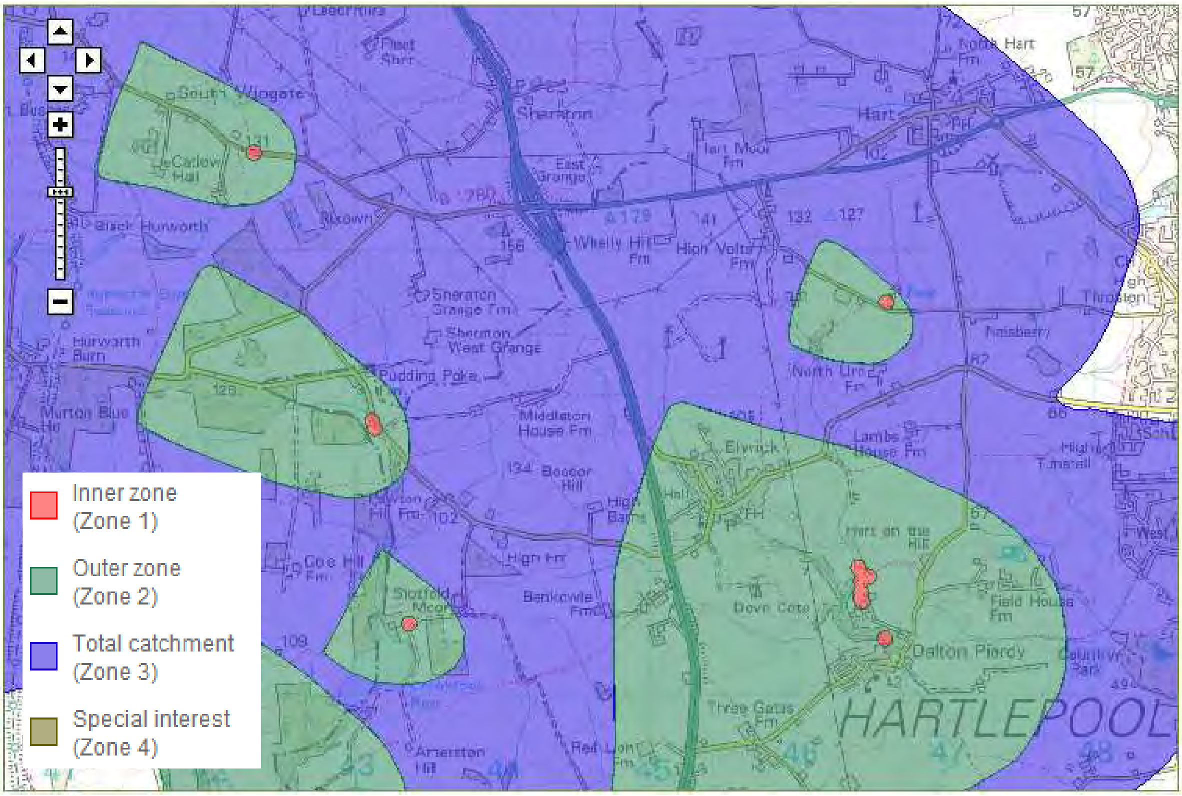
To protect drinking water supplies the importance of an aquifer and the potential risk from pollution are considered. The Environment Agency produces groundwater vulnerability maps to establish Source Protection Zones (SPZs). Just to the east of Elwick the Magnesian Limestone is considered to have an intermediate level of risk while further east around Hartlepool the aquifer is considered to be at high risk.

To protect drinking water supplies from wells, boreholes and springs SPZs are defined and used to establish appropriate pollution measures and monitoring of potential polluters. A groundwater catchment area is divided into three main protection zones. Size and shape of a zone depends on the physical properties of the ground, groundwater behaviour, methods of abstraction and environmental factors.

The inner zone has a minimum radius of 50m and ground water within this zone is defined as having a 50 day travel time to the source from any point below the water table. Depending on the size of an abstraction the outer zone has a minimum radius of 250m or 500m around a source. This zone is defined as having a 400 day travel time from a point below the water table. For aquifers that are subject to extensive abstraction the source catchment zones can be very large and may include the whole recharge area relevant to a particular source. For a confined aquifer, the source catchment may be a considerable distance from the point of abstraction.

GROUNDWATER SOURCE PROTECTION ZONES: ELWICK. Scale 1:40000

(Environment Agency WIMBY 2013)



The village of Elwick lies within the outer protection zone associated with the array of abstraction boreholes located to the south east near Dalton Piercy.

THE ELWICK WATER SUPPLY

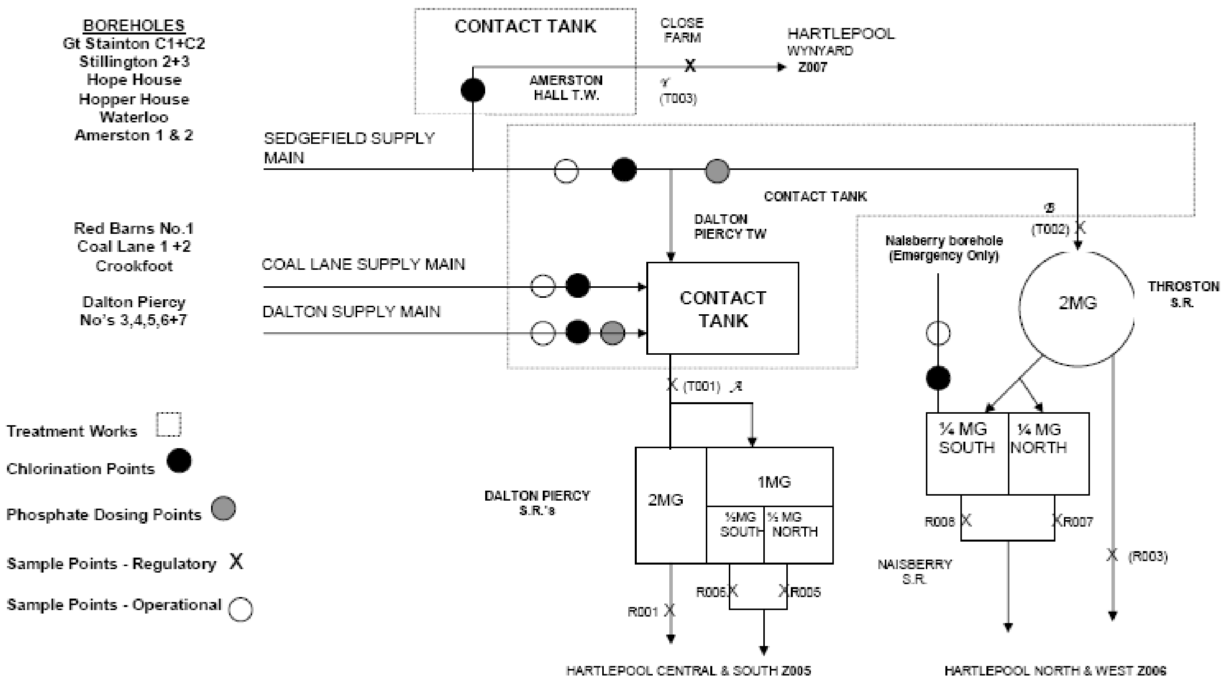
Until 1948 when mains water arrived Elwick was supplied by a pump located on the village green. By 1950 water was piped to every house and a sewage system had been developed (Hartlepool B.C. 2010)

Today, Hartlepool Water, a member of the Anglian Water Group, supplies water to around 90000 people in the borough of Hartlepool. The supply is entirely reliant upon groundwater from the Permian Magnesian Limestone Aquifer.

In the European Union, the Drinking Water Directive (DWD) 98/83/EC sets quality standards for drinking water to protect the health of the consumers. In the UK the DWD is implemented through the Water Supply (Water Quality) Regulations 2000. Water sampling regimes and quality standards for approximately 60 substances are defined. Under the legislation routine audit of suppliers such as Hartlepool Water is required and this is carried out by the Drinking Water Inspectorate.

Drinking water for Elwick is abstracted from six boreholes sunk deep into the Magnesian Limestone south of the West Hartlepool Fault. Borehole depths vary between 71m and 189m below ground level and tap the Raisby Formation and the Ford Formation. Water is piped from the wells to the treatment plant at Throston where it is disinfected and sampled before distribution. An estimated 23,000 people are supplied in the Throston Supply Zone that includes the West and Northern parts of Hartlepool town and the rural areas and villages of Dalton Piercy, Elwick and Hart. A typical sample analysis is attached at Annex 1.

Hartlepool Water Supply System Blending, Treatment and Sampling Arrangements



Hartlepool Water 2013

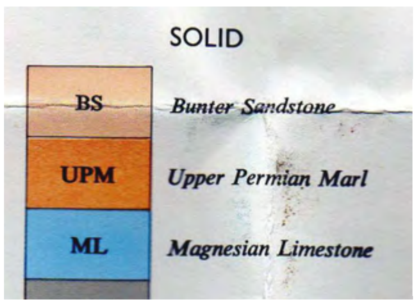
SUPERFICIAL DEPOSITS

In the vicinity of Hartlepool, controlling recharge and influencing water chemistry, superficial Pleistocene and Holocene glacial and interglacial drift deposits effectively form a confining bed over the Magnesian Limestone Aquifer. These deposits are poorly sorted and display extreme spatial variation in lithology, depth, extent and hydrological properties. The main units around Hartlepool are the Lower Boulder Clay, the Middle Sands, the Upper Boulder Clay and the Easington - Elwick Moraine. Porosity and permeability of the drift varies considerably. Impermeable stiff to very stiff boulder clays are interbedded with beds and lenses of permeable sands and gravels. Impermeable layers form aquitards whilst permeable layers form minor aquifers that may be locally significant.

Deposition of the Lower Boulder Clay was associated with a major ice-sheet and shows evidence of recurrent movement of ice. Sub-aerial outwash from retreating ice cut channels into the Lower Boulder Clay and deposited the sands, gravels and clays of the Middle Sands. The Upper Boulder Clay was again associated with an ice sheet event and displays variation from ice related deposition to glacio- lacustrine and glacio-fluvial related deposition. Comprehensive details of Quaternary drift deposits may be found in the Geological Survey Memoir for The Country between Durham and West Hartlepool compiled by Smith *et.al*. 1967.

British Geological Survey 1:10000 Solid & Drift Geology of Elwick

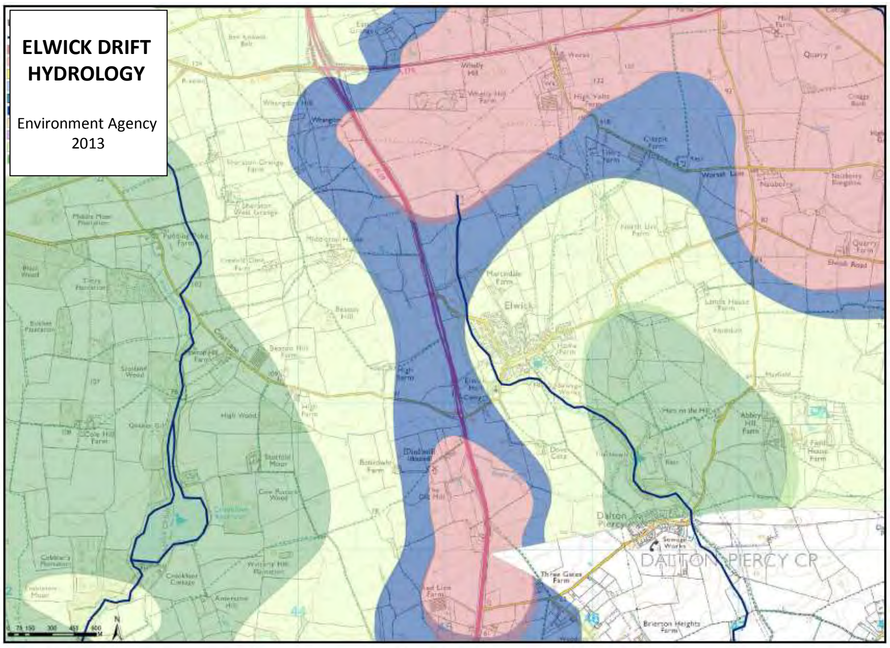
Recent and Pleistocene



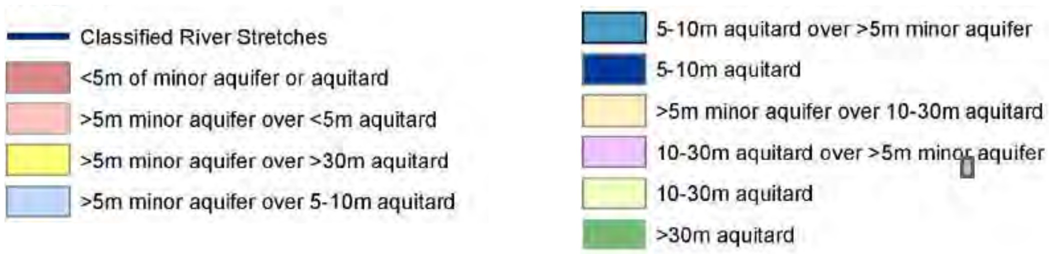
Permo-Triassic

In some areas such as Beacon Hill remnants of the Easington - Elwick Moraine are to be found lying over Upper Boulder Clay. Occasionally on top of these Moraine deposits there may also be a gravelly deposit. Between Hart and Elwick the Moraine deposit is mainly clay. South of Elwick the main constituent is gravel and this deposit forms the mounds that may be seen at Dove Cott Farm. 100m east of Elwick Church the Moraine deposit consists mainly of poorly sorted sands and gravels with streaks and lenses of reddish brown stony clay. In the Denes of the Char Beck, the Craddon Beck and the Bogle Beck, undifferentiated Boulder Clay can be seen interbedded with glacial sands and gravels. Glacio-fluvial terrace deposits that may contain organic matter and glacial lake deposits may be found close to the channels of both the Craddon Beck and the Char Beck.

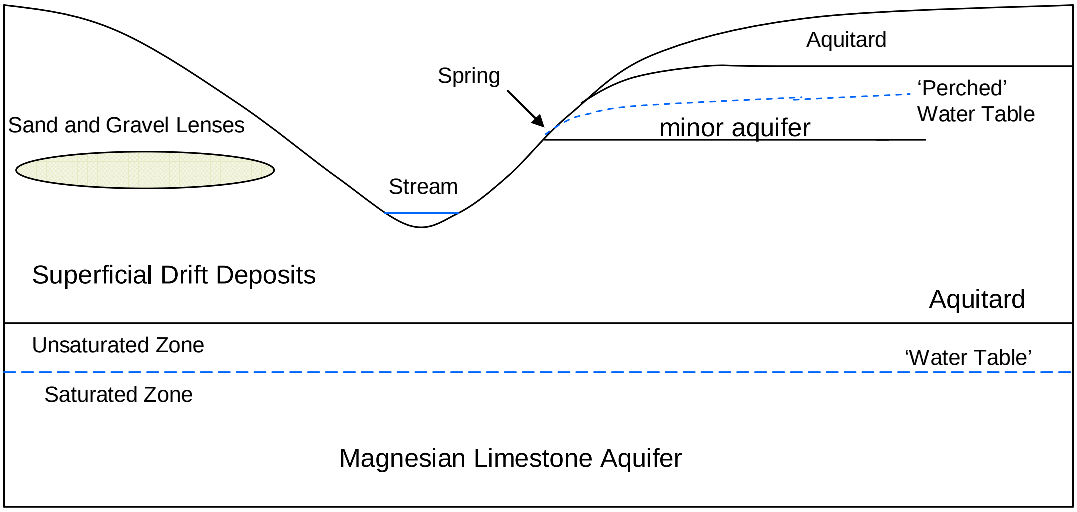
At Elwick the superficial deposits form an impermeable layer of aquitard over the Ford Formation. This impedes vertical recharge to the Limestone. The drift is thinnest in Elwick Gill and at the Howls where depths of around 20m may be found. As previously mentioned directly east and west the drift is between 50m and 65m in depth (Hartlepool Water 2013) and 896m south of St Mary's Church a depth of 34m was identified during construction of the Elwick Borehole. The depth of the drift deposits means that the Char Beck, the Bogle Beck and the Craddon Beck are disconnected from the Magnesian Limestone Aquifer and the water table that lies below the surface of the Aquifer. Therefore, there is no groundwater contribution to base flow in the streams from the Magnesian Limestone Aquifer. Baseflow relies entirely on locally created surface water flow. The surface flow that maintains flow to the becks at Elwick consists of precipitation minus evaporation and transpiration.



Estimation of Location and depth of different units within the Drift at Elwick



Permeable zones containing sands and gravels in the drift form isolated zones of saturation and perched water tables develop. Water levels within these minor aquifers fluctuate, respond rapidly to precipitation and are vulnerable to anthropogenic pollution (Stone *et al*. 2010).



SCHEMATIC DIAGRAM OF THE `UNCONFINED' MAGNESIAN LIMESTONE AQUIFER AND MINOR AQUIFERS OF THE SUPERFICIAL DEPOSITS.

SURFACE HYDROLOGY

Fluvial geomorphology is the study of dynamic processes that occur particularly in river channels and on floodplains that lead to production, movement and storage of sediment within a landscape. These processes define the nature of a river catchment and their study is the key to understanding changes that occur in the long-term development of a river and floodplain (Newson 2010).

The most significant parameters that determine flow pattern within a catchment are topography, the physical properties and depth of superficial deposits, the hydrological properties of bedrock, precipitation and land use. At Elwick surface flow is derived from drainage of minor sand and gravel aquifers within the drift, overland flow and subsurface interflow.

Overland flow occurs once the rate of precipitation exceeds the rate of infiltration into the ground. Overland flow travels towards the stream channels as runoff via rills and gullies. Subsurface interflow mainly occurs in the soil and the weathered drift. According to Stone *et al*. (2010) the Boulder Clay of the drift is generally weathered to 3m to 4m in depth.

Zones of lateral subsurface flow can be highly localized. There may be preferential flow paths such as manmade field drains or natural flow paths such as those that drain the highly conductive sands and gravel layers of the minor aquifers perched within the Boulder Clay.

The morphology of a watercourse is the result of a complex combination of factors that control erosion, transportation and deposition.   Most material that is transported along a watercourse originates from the sides and bed of the stream and from overland flow. During high flow large amounts of clay, silt and fine sand may travel in suspension whilst heavier grains of coarse sand, gravels, cobbles and boulders are transported as bed load moving by saltation, rolling and sliding. During high flow as fine particles are transported downstream larger particles of gravel, cobbles and boulders are left behind.   The geometry of a stream channel is shaped by the highest flows where as the character of the stream and aquatic habitat is mostly dependant on lower levels of flow.

Boulders		>200mm
Cobbles		60 – 200mm
Gravel		2 – 60mm)
Sand	Coarse	0.6 – 2mm
	Medium	0.2 – 0.6mm
	Fine	0.06 – 0.2mm
Silt		0.002 – 0.06mm
Clay		< 0.002mm

British Soil Classification System for Engineering Purposes BS5930:1999 v1.09.2010

The Catchment area of the Dalton Beck that includes the Char Beck, the Bogle Beck and the Craddon Beck displays a dendritic drainage pattern typical of Glacial Till. The shape of the catchment basin, the slope, length, permeability of the soil, soil moisture content, vegetation and land use effect stream flow in the becks.

Although at certain times of the year high energy stream flow is a feature of the Char Beck and the Bogle Beck in particular, the streams of Elwick display features of a lower stream gradient than is to be found in the hills to the west.   Floodplains are typically narrow and are frequently re-worked by high magnitude floods. The Char Beck, for example, meanders across a floodplain.

Char Beck south of the village playing field

When compared with steeper upland streams, down cutting is reduced and the degree of lateral cutting is increased. At points of impact the channel is frequently connected to the valley sides, and during high flow conditions this leads to high rates of bank erosion and widening of the Dene.

Char Beck downstream of Elwick

Some features more typical of upland streams may be found, such as, re-working of the flood plain through a process known as avulsion. This occurs during meander evolution or when a channel becomes choked with sediment or woody debris, the channel is diverted and a new channel is cut into the floodplain.

In the Char Beck valley these channels lie above the elevation of the current river bed and are clear evidence of vertical instability. These phases of instability may result in deposition of finer sediment in the abandoned meander loops.

Char Beck downstream of Elwick

During periods of high flow smaller particles of clay and silt are kept in suspension more easily than sand. When such fine particles are available a large amount may be transported and it is possible for clay and silt particles to be carried along the whole length of a watercourse from point of origin to the sea without temporary deposition. Whilst sand and gravel originating from the same location may experience many cycles of deposition, re-working and transportation before reaching the sea. During periods of flood in high energy systems where clay, sand, gravel and boulders are common the proportion of bed load to suspended load may be 50:50.

Where there is a mixture of sediment size the channel bed may become armoured with larger grains lying above and protecting finer grains below. During floods this armouring may be removed and the finer grains below mobilised.

The water courses in the Denes at Elwick are highly dynamic with diverse channel geomorphology. Sediment movement is often unpredictable and much of the channel sedimentology is coarse. Gravel banks are common and pools, riffles, rapids and glides produce a range of flow conditions from calm laminar flow to turbulent flow. This provides a diverse range of aquatic habitat for biota.

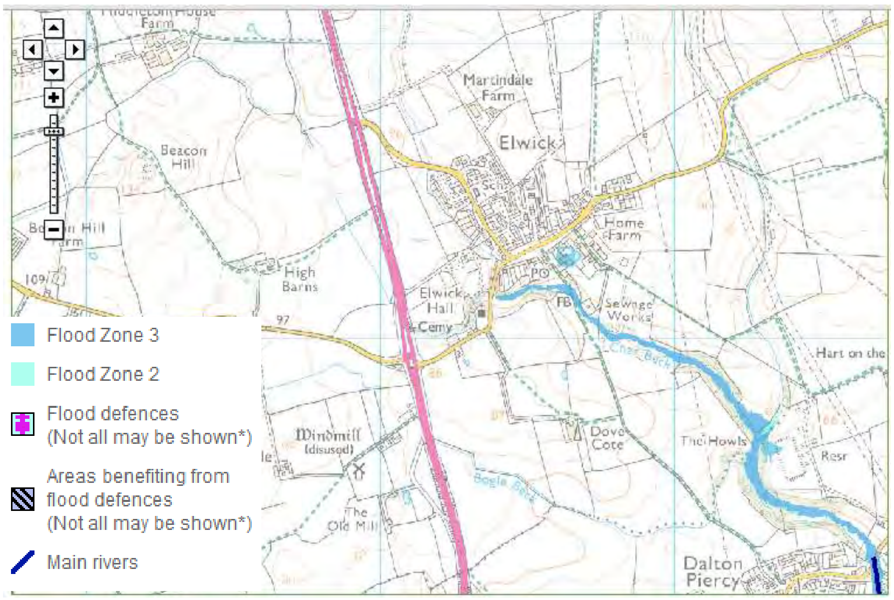
As water velocity increases and sediment moves during extreme flood events, communities are destabilized. Blanketing of habitat may occur and stream beds and bank sides may be scoured. This scouring regulates plant growth decreasing shading, organic matter and refuges and increasing water temperature. There are both positive and negative effects of flooding for aquatic life, spawning grounds may be cleansed and populations dispersed, where habitat is damaged and communities are washed out it may take some time for a site to recover.

The Char Beck towards the Howls

FLOODING

In recent years there have been several occasions when exceptionally high flow in the Char Beck has resulted in flooding of the road south of the village and there has been growing speculation as to the cause of these flood events.

NORTHUMBRIA RIVER BASIN MANAGEMENT PLAN
FLOOD RISK MAP FOR ELWICK. Scale 1:20000
(Environment Agency WIMBY 2013)



The Char Beck has a 1 per cent (1 in 100) or greater chance of a flood happening each year.

Evidence suggests that patterns of precipitation in the UK are changing.   According to Natural England (2013) by 2080 climate change on the Durham Magnesian Limestone Plateau is predicted to result in warmer drier summers with an increase in temperature of 1.5–4.5°C and decrease in precipitation of 18–45%. Winters will be warmer and wetter, temperature will increase by 1–3°C and precipitation will increase by 10–28%. It is also thought that extreme weather events will increase in frequency and heavy rainfall and storms may result in damage and loss of some habitats and species.

There is also evidence to suggest that there are changes to the intensity and duration of rainfall events that may increase the potential of flooding. Studies of flood events that occurred on the 23rd September 2012 and 24th November 2012 at nearby Tunstall have shown that although these storms did not produce particularly intense rainfall the total volumes that fell were considerable. During the September event approximately one month's rainfall fell over a two day period (JBA Consulting Sept. 2013). It is reasonable to consider that changing patterns of precipitation may be at the root of exceptional high flow events seen on the Char Beck and it is likely that increasing rainfall will increase the degree of response in the minor aquifers located in drift deposits.

There should also be consideration of soil type. In a soil matrix water is held under tension in a capillary fringe above the water table. In a heavy clay soil such as occurs at Elwick this capillary fringe may extend to 30 – 40cm above the water table. During a storm event it may only take a few millimetres of vertical recharge to bring this capillary fringe to saturation. The result is a very rapid response to rainfall and an increase in surface flow.

Currently, Hartlepool Borough Council is investigating the system of culverts that drain the village. It is possible that these drains are no longer capable of conveying surface runoff and the Borough Council will report on their findings in the near future. Recent flood events in the UK have served to highlight the importance of Sustainable Urban Drainage Systems and environmental assessment methods such as the Building Research Establishment Environmental Assessment Method (BREEAM) when considering building programmes.

On the Char Beck the effects of the flooding in September 2013 are evident. The capacity of a new culvert was exceeded, a river crossing was severely damaged and undermined and the river banks alongside underwent a considerable degree of erosion.

Dolomite used in construction of the crossing was transported a considerable distance, demonstrating the enormous power of the flood. Fine and medium sized dolomite gravel was found as far down steam as the Howls. In theory during high flow conditions, if the velocity of flow doubles then the current will be strong enough to move particles 64 times larger than could be moved during normal flow conditions and if the velocity increase to three times original flow then theoretically a grain 729 times original grain size could be transported. In reality in-stream attenuation substantially reduces these theoretical statistics. However, they demonstrate the dramatic capacity for extensive erosion and transportation during flood conditions.

Typically in environments that experience high energy stream flow where a channel is engineered the steam channel is prone to instability. As reduced power consumption in overcoming energy loss leaves a greater proportion of stream power available for eroding the bed and banks.

In the UK 43% of river length has experienced some form of channel engineering. It is now realised that anthropogenic influence increases the sensitivity of a river system and that understanding long-term geomorphological processes is important for sustainable catchment management, flood conveyance and sustainability of biodiversity (Newson 2010).

A section of the Craddon Beck at one time piped underground is now cutting a new channel through pastureland

LAND USE AND WATER QUALITY

Salinity, pH, temperature, odour, colour, oxygen content, chemical signature, sediment content, turbidity, light penetration and aquatic ecology are factors considered when assessing surface water quality. In areas of a river catchment where there are pressures of population, agricultural and industrial activity the potential for water pollution is increased.

Anthropogenic influence on the top meter of the soil is considered to be environmentally significant. Land use changes features such as surface roughness, vegetative interception of precipitation, evaporation and transpiration and the volume of runoff and chemical signature of surface water is altered.

Water courses are at risk from increased sedimentation due to poaching of river banks and runoff from cultivated areas and due to spillage, seepage and direct contamination there is risk of chemical, faecal, bacterial and nutrient pollution.

Boulder Clay of the drift is prone to livestock poaching particularly during the wetter months of the year

Under the Water Framework Directive (2000/60/EC) (WFD) the Environment Agency is required to develop integrated management of surface waters and consistent standards must be met:

- To achieve at least good status for all water bodies by 2015. Where this is not possible, subject to criteria set out in the Directive, the aim is to achieve good status by 2021 or 2027
- To prevent deterioration in the status of aquatic ecosystems, to protect them and improve the ecological condition of waters
- To meet the requirements of Protected Areas identified under WFD
- To promote sustainable use of water as a natural resource
- To conserve habitats and species that are directly dependant upon water
- To progressively reduce or phase out the release of individual pollutants and groups of pollutants that present significant threat to the aquatic environments
- To progressively reduce pollution of groundwater and prevent or limit the entry of pollutants
- For flood and drought mitigation

(Environment Agency Website)

The Directive requires that for each river basin a River Basin Management Plan based upon a detailed analysis of pressures on water bodies and an assessment of their impacts is published, reviewed and updated every six years. The plan sets out the environmental objectives for the water bodies within the River Basin District and how they will be achieved. Elwick lies in the Northumbria River Basin Catchment.

Between May 2006 and September 2008 the Environment Agency carried out River Habitat Surveys at more than 4,800 sites in England Wales and the Isle of Man. The results demonstrated that river ecosystems are under pressure and that in order to comply with the requirements of the WFD long-term action to restore the loss and continuing fragmentation of habitats is needed to improve river basin habitats.

Study of macro invertebrate populations are one of the many ways in which the quality of a watercourse is assessed. These populations are used to assess ecological quality. To date, macro invertebrate surveys are not undertaken for the becks at Elwick and surveys further downstream are used to indicate the status of the catchment. Due to low seasonal flow and the lack of `Good' status of aquatic habitat for macro invertebrates, the ecological quality of the Dalton Beck has been identified as `Bad'. As the main tributary to the Dalton Beck the Char Beck has been also identified as having `Bad' status. This status is predicted to remain `Bad' in 2015. Currently, individual assessment of chemical quality of the Dalton Beck, the Char Beck, the Craddon Beck and the Bogle is not required during assessment of the Greatham Tees Tributary.

The surface waters of Elwick are classed as `At Risk' from pollution by sedimentation associated with agricultural land use. It is also considered that there is probably a risk from diffuse agricultural pollution and in terms of agricultural land use the steams at Elwick are classed as `Priority Waters'. This classification places a responsibility upon those concerned with agricultural land management to abide by good management practices for watercourse protection. Comprehensive information regarding the Northumbria River Basin Management Plan and the requirements of the WFD may be found on the Defra and

Environment Agency Websites. To find out more about the environment where you live visit the Environment Agency Website - What's In Your Backyard? The site provides comprehensive information and interactive maps are available.

http://www.environment-agency.gov.uk/homeandleisure/37793.aspx

Looking towards the future, it is certain that the water environment in the UK will be different from that we know today.

COMMUNITY INVOLVEMENT

Water Voles and River Survey

Once common in the UK, Water Voles are known to have disappeared from 90% of sites in England. This decline in population has occurred mainly over the last twenty years and represents one of the fastest and most severe declines of a mammal species in the UK. At one time Water Voles were prevalent on the Craddon Beck and on the Char Beck from the Howls up into Elwick Gill.

Historically, surveys demonstrated that populations on these watercourses varied greatly on an annual basis, possibly due to the presence of mink (Smith 2013). Surveys undertaken by Emma Glister in 2006 and Mark Slaughter in 2009 confirmed the presence of Water Voles on both the Char Beck and the Craddon Beck. Since then no survey work had been undertaken and it is thought that today there may be no voles living on either beck.

Mr Ian Bond Ecologist with Hartlepool Borough Council has made suggestion that if in fact Water Voles are not present on the becks, there may be the opportunity for a programme of reintroduction to certain areas. The community may like to consider undertaking Water Vole surveys for both the Craddon Beck and the Char Beck under the guidance of Mr Bond. Survey could be undertaken in conjunction with the National Mammal Atlas Project which is being run by the Mammal Society to provide a new baseline of information on mammal distribution in the UK. The best time to carry out a Water Voles survey is during the breeding season when they are most active, between May and the end of August. Survey would not only demonstrate the presence or absence of Water Voles but would also provide comprehensive mapping of the hydromorphology and vegetative cover of the Craddon Beck and the Char Beck. Survey may indicate whether some environmental enhancement may be beneficial should reintroduction of Water Voles be considered.

Invasive Species

(Centre for Ecology and Hydrology 2004 & River Habitat Survey Website)

Invasive species of plant are becoming an increasing problem along waterways in the UK. Giant Hogweed, Himalayan Balsam and Japanese Knotweed have all been identified in the catchment of the River Tees.

Giant Hogweed

Japanese Knotweed

Himalayan Balsam

Introduced into the UK in 1839 Himalayan Balsam (Impatiens Glandulifera) a relative of the busy Lizzie quickly spread beyond the confines of gardens. Today, Himalayan Balsam may be found growing along banks of the Char Beck. Tolerating low light levels, growth is dense and rapid and heights of 2 meters may be reached. Clusters of pink flowers are produced between June and October and each plant has the potential to produce 800 seeds that may be ejected up to 7 meters from the plant and remain viable for up to two years. Gradually, as Himalayan Balsam colonises an area native vegetation is smothered out, river banks become devoid of vegetation during autumn and winter leaving them susceptible to erosion. This may have implications for the hydromorphology of a stream and risk to the aquatic habitat for fauna and flora from blanketing by silt.

The community may like to consider a control programme to eliminate this vigorous alien species from the Char Beck. Effective control may be gained by pulling or digging out the shallow rooting plants before they flower and set seed. A two year control programme should see eradication of Himalayan Balsam. Advice for control may be gained from:

Mr John Musham
Invasive Species Initiative Coordinator of the River Tees Trust:
River Tees Trust
01748 518066
johnmusham@teesriverstrust.org
http://www.teesriverstrust.org

John Muir Award

"The John Muir Award is an environmental award that encourages people of all backgrounds to connect, enjoy and care for wild places. The Award is open to all who demonstrate a commitment to wild places and can be completed on your own or as part of a group. It can compliment and celebrate what you already do or be used as a structure for new projects" (www.jmt.org).

Delivery of the John Muir Award is perhaps something that the community of Elwick may like to consider in relation to the watercourses of the parish. There is scope for the Award to be run in conjunction with perhaps a programme to control Himalayan Balsam, to conduct macro invertebrate or vole surveys or to undertake supervised clearance of overgrowth to reduce shading and improve stretches of aquatic habitat for a particular species such as Water Vole, Newt, Stickleback, Mayfly *etc*.

There are four Challenges are at the heart of the John Muir Award. To achieve an Award each participant must:

- Discover a wild place
- Explore its wildness
- Conserve - take personal responsibility
- Share experiences

There are 3 levels of Award that encourage progressive involvement in time, activity and ownership:

- Discovery Award (introductory level) minimum 4 days (or equivalent)
- Explorer Award (intermediate level) minimum 8 days (or equivalent)
- Conserver Award (advanced level) minimum 20 days (or equivalent) over a 6 month period

For a negligible cost a member of the community may train to assess the John Muir Award Scheme through attendance at two day residential course. These courses are run at several different venues during the year. A ten minute film introducing the award and further information may be found at http://www.jmt.org/jmaward-about-the-award.asp

IMPORTANT NOTE FOR COMMUNITY INVOLVEMENT

Please ensure that expert advice is sort before undertaking survey and project work that may affect the aquatic environment. Technical information and assistance in establishing aims, objectives and protocols for aquatic environmental projects may be gained from:

Mr Ian Bond CEnv MCIEEM
Ecologist
Hartlepool Borough Council
Civic Centre
Victoria Road
Hartlepool
TS24 8AY
01429 523431
ian.bond@hartlepool.gov.uk
http://www.hartlepool.gov.uk/

Mr Ben Lamb
Trust Manager
The Tees Rivers Trust
Sedbury Stables
Gilling West
North Yorkshire
DL10 5LQ
01748 518066
benlamb@teesriverstrust.org

Mr David Johnson
Living Waterways Officer
Tees Wildlife Trust
Margrove Heritage Centre
Boosbeck
Saltburn
Redcar and Cleveland
TS12 3BZ
01287 636382
info@teeswildlife.org

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GLOSSARY OF TERMS

Anhydrite -	Evaporate deposit: anhydrous calcium sulphate, $CaSO_4$.
Anthropogenic-	Human activity
Base flow -	Proportion of flow not associated with direct runoff, below baseflow there is a detrimental impact to aquatic ecology.
Boulder Clay -	Deposit of clay containing stones and boulders associated with glaciers and ice sheets
Carboniferous Period -	3.62.5 to 290 Million years ago
Connate Water -	Water trapped in rock pore spaces during deposition
Concretionary -	Hard sedimentary rock formed by mineral precipitation within the spaces between grains, they are often ovoid or spherical
Diamitic -	Sedimentary deposit in which particle size varies from clay to boulder
Discontinuities -	An interruption in normal rock structure such as bedding planes, joints and fractures
Dolomite -	Carbonate mineral that contains magnesium $CaMg(CO_3)_2$
Dolomitic -	Contains Dolomite
Dolostone -	Rock made of Dolomite
Drift Deposits -	Unconsolidated superficial sediment
Evaporite Deposits -	A rock formed by mineral precipitation of concentrated brine
Facies -	A distinct rock unit
Fluvial -	Relating to a river
Glacio-fluvial deposits -	Sorted, stratified material deposited by water flowing from glaciers and icesheets
Glacial Outwash -	Sediment deposited by glacial melt water
Glacial Till -	Unsorted material deposited by a glacier
Glides -	Gentle or slow moving shallow reach of water
Holocene Period -	10 000 years ago to the present day

Hydrogeology -	Study of subsurface groundwater
Hydrology -	Study of water circulation, distribution and chemistry
Hydrostratigraphic -	Geological units related by hydrological parameters that are distinct from surrounding bodies of rock
Invasive Species -	A species not natural to a the habitat, invasion is often ecologically threatening
Lacustrine -	Related to a lake
Laminar flow -	Water molecules flow smoothly in parallel layers
Macro Invertebrates -	Organisms without back bones that are visible to the naked eye
Magnesian Limestone -	Limestone with a small amount of Dolomite
Moraine Deposits -	Depositional landform generated by ice
Oolitic -	<2mm in size and in limestone are small grains or fragments coated by concentric rings of carbonate
Permian Period -	290 – 245 million years ago
Pleistocene Period -	2.5 million years ago until 10 000 years ago
Potable -	Water that is safe to drink
Quaternary -	1.64 million years ago until present
Rapids -	Swift turbulent flow where velocity is greater than surrounding water, typically located where the surface is obstructed
Regression -	Recession of the sea from a shallow sea or a terrestrial area
Riffle -	Short, shallow reach of water where current is fast, flow turbulent and bed load frequently breaks the surface during normal flow
Rill -	Shallow, narrow erosion channel in topsoil. Rills may evolve to become gullies and streams
Saline Intrusion -	May occur in coastal regions of aquifers due to groundwater abstraction
Superficial Deposits -	Unconsolidated superficial sediment
Terrace Deposits -	Almost flat landform with a steep edge

Topography - Shape and elevation of a surface

Transgression - Incursion of the sea into a shallow sea or onto a terrestrial area

Transmissivity - The rate of water movement in a particular medium

Transpiration - Water lost from a plant via the process of evaporation

Triassic Period - 245 – 208 million years ago

Turbulent flow - Water molecule movement is irregular and chaotic

Unconformably - Not following underlying rock sequence in age or structure

Annex 1.

SAMPLE RESULTS FOR THE PUBLIC WATER SUPPLY AND SUPPLY POINT SUPPLYING HARTLEPOOL NORTH AND WEST 2012

Hartlepool Water Public Water Supply Zone
Zone Code: Z006 Population: 24445

Parameter Name	Prescribed Concentration or Value (pcv)	Units	No. of samples taken	Samples contravening pcv Number	%	Concentration or Value (all samples) Minimum	Mean	Maximum
MICROBIOLOGICAL PARAMETERS								
Total Coliform Bacteria	0	No. /100ml	60	0	0	0	0	0
Colony Counts 2 days @ 37°C	No abnormal change	No. /1ml	24	0	0	0	2	46
Colony Counts 3 days @ 22°C	No abnormal change	No. /1ml	24	0	0	0	3	46
E. Coli	0	No. /100ml	60	0	0	0	0	0
Enterococci	0	No. /100ml	8	0	0	0	0	0
CHEMICAL PARAMETERS								
Aluminium	200	μg/l Al	8	0	0	<6.6	<7.0	<7.3
Ammonium	0.5	mg/l NH_4	12	0	0	<0.007	<0.013	0.03
Antimony	5	μg/l Sb	8	0	0	<0.28	<0.28	<0.28
Arsenic	10	μg/l As	8	0	0	0.26	0.41	0.52
Benzo(a)pyrene	0.01	μg/l	8	0	0	<0.00053	<0.00053	<0.00053
Cadmium	5	μg/l Cd	8	0	0	<0.0081	<0.009	0.017
Chromium	50	μg/l Cr	8	0	0	<0.2	<0.29	0.95
Colour	20	mg/l Pt/Co	12	0	0	<1	<1	<1
Conductivity	2500	μS/cm @ 20°C	12	0	0	800	833	860
Copper	2	mg/l Cu	8	0	0	0.0066	0.018	0.037
Iron	200	μg/l Fe	8	0	0	1.3	3.2	6.2
Lead	25	μg/l Pb	8	0	0	0.032	0.29	0.95
Manganese	50	μg/l Mn	8	0	0	0.5	1.7	4.2
Nickel	20	μg/l Ni	8	0	0	<0.034	<0.38	1.5
Nitrate	50	mg/l NO_3	8	0	0	4.8	5.7	6.8
Nitrite	0.5	mg/l NO_2	8	0	0	<0.0011	<0.0013	<0.0014
Nitrite/Nitrate formula	1		8	0	0	<0.096	<0.12	<0.14
Odour	Acceptable to consumers	Dilution No.	12	0	0	0	0	0
PAH sum of 4	0.1	μg/l	8	0	0	0	0	0
pH (Hydrogen ion)	6.5 - 9.5	pH value	12	0	0	7.3	7.5	7.8
Selenium	10	μg/l Se	8	0	0	<0.31	<0.44	0.76
Sodium	200	mg/l Na	8	0	0	40	42	46
Taste	Acceptable to consumers	Dilution No.	12	0	0	0	0	0
Trihalomethanes total	100	μg/l	8	0	0	6.1	8.3	11.1
Turbidity	4	NTU	12	0	0	<0.08	<0.10	0.18

CUSTOMER INFORMATION

Parameter Name	Prescribed Concentration or Value (pcv)	Units	No. of samples taken	Number	%	Minimum	Mean	Maximum
Chlorine residual (free)	No standard	mg/l	60	0	0	0.22	0.36	0.5
Phosphorous	No standard	μg/l P	83	0	0	340	635	780
Alkalinity	No standard	mg/l HCO_3		Typical value			380	
Calcium	No standard	mg/l Ca		Typical value			105	
Magnesium	No standard	mg/l Mg		Typical value			45	
Potassium	No standard	mg/l K		Typical value			2.7	
Hardness (total)	**No standard**	**mg/l Ca CO_3**		Typical value			**450**	
Hardness - Clarke Degree	**No standard**	°C		Typical value			**28**	
Hardness - French Degree	**No standard**	°F		Typical value			**40**	
Hardness - German Degree	**No standard**	°D		Typical value			**22**	

THROSTON SUPPLY POINT

Parameter Name	Prescribed Concentration or Value (pcv)	Units	No. of samples	Samples contravening Number	%	Concentration or Value (all samples) Minimum	Mean	Maximum
MICROBIOLOGICAL PARAMETERS								
Clostridia Perfringens	0	No. /100ml	8	0	0	0	0	0
CHEMICAL PARAMETERS								
Chloride	250	mg/l Na	8	0	0	31	43	52
Clopyralid	0.1	μg/l	8	0	0	<0.0066	<0.015	<0.016
Benzene	1	μg/l	8	0	0	<0.013	<0.016	<0.03
Boron	1	mg/l B	8	0	0	0.059	0.088	0.12
Bromate	10	μg/l BrO_3	8	0	0	<0.3	<0.55	<0.97
Cyanide total	50	μg/l CN	8	0	0	<0.3	<0.59	2
1,2 Dichloroethane	3	μg/l	8	0	0	<0.036	<0.047	<0.06
Diflufenican	0.1	μg/l	8	0	0	<0.0089	<0.0089	<0.0089
Fenpropimorph	0.1	μg/l	8	0	0	<0.0044	<0.0052	<0.0056
Fluoride	1.5	mg/l F	8	0	0	0.76	0.94	1.1
Heptachlor	0.03	μg/l	8	0	0	<0.0016	<0.0016	<0.0016
Heptachlor Epoxide	0.03	μg/l	8	0	0	0	0	0
Mercury	1	μg/l Hg	8	0	0	<0.013	<0.034	<0.037
Metaldehyde	0.1	μg/l	8	0	0	<0.0056	<0.0083	0.025
Metazachlor	0.1	μg/l	8	0	0	<0.0084	<0.0084	<0.0084
Pendimethalin	0.1	μg/l	8	0	0	<0.0054	<0.0054	<0.0054
Sulphate	250	mg/l SO_4	8	0	0	110	121	140
Tetrachloromethane	3	μg/l	8	0	0	<0.025	<0.038	<0.074
Tetra/Trichloroethene	10	μg/l	8	0	0	0	0	0
Total organic carbon (TOC)	No abnormal change	μg/l	8	0	0	0.54	0.79	0.98
Total Pesticide	0.1	μg/l	8	0	0	0	0.005	0.025

FURTHER READING: Websites and Books

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The Coal Authority - Publications and Information:
http://coal.decc.gov.uk/en/coal/cms/publications/publications.aspx

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