1.0 Introduction

This report assesses the potential impact of the construction of Stonehenge Tunnel and associated works on the ground surface and water assets of Manor Farm.

Approximately 400 acres of Manor Farm is to be used for the construction of Stonehenge Tunnel.

The adverse impact of the workings can be sub-divided into three broad categories:-

- Adverse Impact on groundwater
- Adverse Impact on surface water
- Adverse Impact on soil and pasture

The public has not been given time to assess the vast number of reports dating back to 2001-2002. Land owners and those who live nearby should have been given paper copies of all reports. It is very slow and time consuming to examine reports, especially plans printed at A3, A2 or A1 size, on a computer. People should not have to print out copies and most do not have printers which can produce in colour at A3, A2 or A1 size. Knowledge is power and the public cannot hold government to account if they cannot or do not have time to examine all the documents. People have jobs and can only study reports in the free time. Politicians, civil servants and consultants spend their working time on the project; not their free time!

2.0 Topography

Manor Farm is located on the southern end of Salisbury Plain. The majority comprises gently undulating pasture varying in elevation from 100-115m aod. Towards the western boundary is the River Till which runs North /South and comprises a valley approximately 500m wide whose sides descend from approximately 100m aod to 70m aod.

3.0 Geology

The Geology Comprises Chalk of the Seaford Chalk Formation comprising white firm to moderately hard marly with many large nodular (up to 30cm across) flints. In The River Till valley Alluvium overlies Gravelly Head which overlies the Chalk. The Alluvium comprises clay, peat, silt, sand and gravel. The Gravelly Head comprise gravelly silty clay, locally chalky in ephemeral streams. There are also Head deposits on the floors of the dry valleys. The Chalk is highly permeable and due to the gently undulating surface rather than steeply inclined, rain percolates downwards, rather than runs off the surface, unless there the ground surface is frozen.

The topsoil and underlying Chalk cracks in dry summers, extending to depth of 1-1.2m and 3-5mm width at the ground surface.

4.0 Surface Water

Rain percolates through the Chalk and flows down to the water table. Consequently, the only surface water features are the River Till where the water table meets the ground surface. The River Till is fed by groundwater, not surface run off, except in exceptional circumstances. Winterbourne Stoke is subject to ground water flooding and occasionally surface water flooding. In the floods of autumn 2000, the River Till was approximately 1m above the bank – see Figure 1.

In the River Till, on the 16th January 1841, between Tilshead and Winterbourne Stoke there was catastrophic flood when three people were killed; over 30 homes destroyed and the flood waters reached a height of 7-8 ft above ground level. It would appear that sudden melting of snow, probably on frozen ground meant water ran off the surface rather than percolated downwards through the Chalk. There's no reason why sudden melting of snow on frozen ground could not occur again.

The headwaters of the River Till are typically at Shrewton in winter but in dry summers can be the Bell Inn, Winterbourne Stoke.

5.0 Groundwater

The groundwater reaches the ground surface in the River Till and causes groundwater flooding in Winterbourne Stoke. HE have used 2014 as the maximum groundwater elevation but this may not be the highest. Consequently, the maximum recorded in Winterbourne Stoke in 2014 by the River till was 75m aod and approximately 89 m aod a kilometre north of Greenland Farm. It should be noted that groundwater flooding will be under reported in Winterbourne Stoke as properties are on septic tanks not mains sewage; consequently flooding of sewers by groundwater is not reported to Wessex Water. Also, the flooding in the River Till in autumn 2000 was far worse than in 2014. The groundwater levels quoted are for dips and do not necessarily record the highest groundwater levels of the Autumn 2000 Floods which left a mark on a willow tree which was approximately 1m above the banks of the River Till.

Figure 1

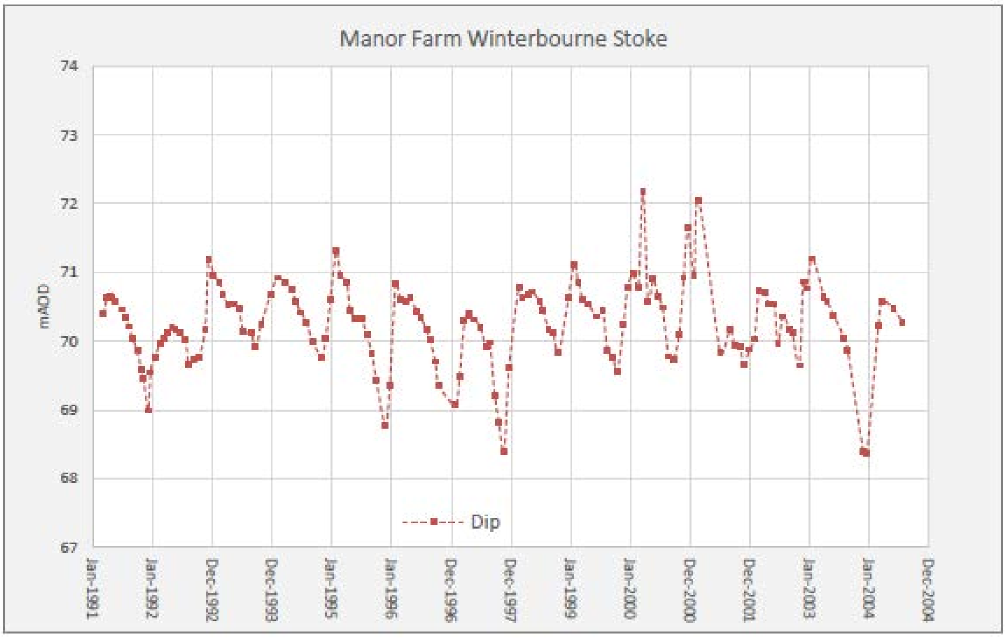


Figure 2
Groundwater Levels

There are no monitoring boreholes along the section from the River Till and Long Barrow Junction. The closest investigation borehole is 16174 –R3 which was dry when water levels were measured between September 2001 and May 2003 so the autumn floods of autumn 2000 were not measured.

6.0 Chalk and it's Relevance to Pasture

The high permeability of the chalk means rain rapidly percolates downwards. Also the Chalk supports low nutrient grassland. The ability of the Chalk to transmit rain water down from the surface, means animals can stay on the pasture for most of the year. However, when Chalk is close to it's Liquid Limit and it is crushed it can produce a slurry. It should be noted that Dew Ponds, used for holding water are constructed by wetting and crushing Chalk such that the material has the consistency of thick cream. Chalk grass land is free draining and low nutrient. If phosphatic rich Chalk sediment is washed into topsoil, then combined with compaction could make it less free draining and more nutrient rich.

7.0 Issues Impacting on Manor Farm

7.1 Water Supply From Boreholes.

Manor Farm comprises 5 boreholes, identified by letters A to E- see Figure 3.

BH A .Brick well, 25m deep, 1.6m in diameter. Abstraction licence 1.4 m^3 per hour, 14 m^3/d, 5973m^3/yr.

BH B. 13m deep, 1.6m in diameter. Abstraction licence 1.4 m^3 per hour, 11 m^3/d, 3982m^3/yr.

BH C. 31m deep, 77mm in diamtere. Abstraction licence 1.4 m^3 per hour, 14 m^3/d ,4977m^3/yr.

BH D.10m deep, 1.6m in diameter. Abstraction licence 1.4 m^3 per hour, 14 m^3 /d 4977m^3/yr

BH E. 5m deep, 1.6m in diameter. Abstraction licence 1 m^3 per hour, 5 m^3/d 818m^3/yr

7.2. Possible Contamination of Boreholes From Site Works/Construction

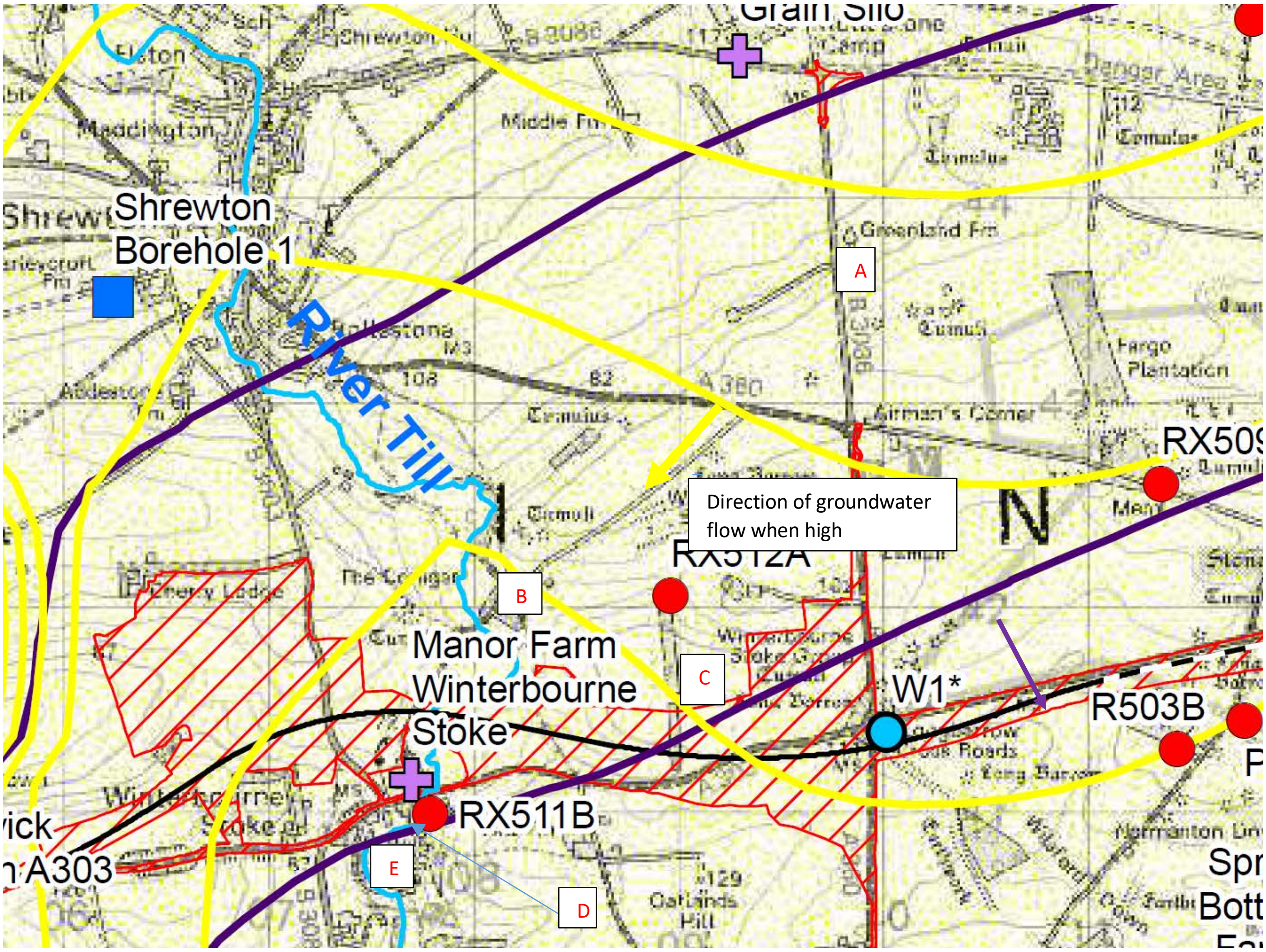
The movement of vehicles over the dry Chalk surface will create fines. There will be fines on stockpiles of excavated material. Rain will wash the fines into fissures in the ground surface of the Chalk and hence into the groundwater. Where the surface was impermeable, the water carrying the fines would run down slope and enter the fissures in the Chalk surface surrounding the worked areas . Stockpiles of topsoil could be sources of humic material which after rain fall events could be washed off their surface and into cracks in the Chalk surface.The contamination could comprise:-

1. Sediment containing calcium carbonate
2. Petroleum hydrocarbons from vehicles
3. Topsoil containing humic materials
4. Bacteria- E.Coli, Enterococci and Clostridia perfringens
5. Cryptosporidium
6. Grains of cement/lime/bentonite which have not fully reacted with water.

During high groundwater levels the flow is towards the River Till see Figure 3.

The movement of heavy vehicles on Chalk, especially with with a Grade of Dm or Dc when wet is likely to produce a slurry on the surface which when dries could produce a low permability crust. Consequently, the infiltration of water would be changed from being spread over a wide area to intense flows at the down slope boundaries of low permeability crusts. This could reduce recharge to the Chalk supplying BH C and hence it's yield. Rapid surface run off would carry sediment which on entering cracks, could migrate down to the water table and hence cause pollution from sediment, bacteria and petroleum hydrocarbons from vehicles. Consequently BH C could suffer from contamination due to site works and there is a slight chance Borehole B could be affected likewise. When the groundwater level is low, it flows in a south South East direction and so there is reduced chance of BHs C and B being contaminated. BH A is unlikely to be contaminated.

Boreholes D and E are could be adversely affected from the construction of the bridge due to piling below the groundwater; the most likely contamination would be sediment and bacteria. The earthwork operations to construct the road/bridge embankments during wet weather could cause contamination of boreholes E and D, most likely sediment, petroleum hydrocarbons from vehicles and bacteria.



Contours- Yellow High groundwater levels, flow towards River Till.Purple – Low Groundwater Levels

Figure 3 From appendix 11.4 Figure 3.8 Regional Model Groundwater Contours

Letters A to E are Manor Farm boreholes.

There appears to be confusion over the size and location of drainage infiltration areas (DFAs) in the Non Technical Summary February 2018 and Appendix 11.3 Road Drainage Strategy. The NTS has a DFA in the middle of Tunnel Arising 1,which is unlikely, as it would be impermeable when dry but could induce slope failure while still soft or firm.

The DFAs are proposed to take run-off from the road. The water could contain the following:-

1. Sodium chloride from de-icing salts.
2. Sediment containing petroleum hydrocarbons.
3. Copper and zinc
4. The producs of decaying bodies of deer, badgers, foxes, pheasant , etc,etc– road kill. The contaminants could be – ammonia, nitrate, phosphate,iron(blood), dissolved organic carbon, E.Coli, Entercocci, Clostridia and possibly Tubercolis from dead badgers.

The DFAs will treat some contaminants but wil not remove sodium chloride and nitrate. The Remi 8 brochure does not state whether it remove bacteria, especially pathogens. As the area is within a Nitrate Vulnerable Zone any increase in phosphate combined with nitrate, iron and dissolved organic carbon could produce an increase in growth of bacteria in groundwater and algae in surface water. It should be noted that the 50m distance between sources of contamination and water supply boreholes was based upon groundwater flowing through sand at 1m /day. E.coli dies after about 20 days in groundwater so 50 days was considered as safety margin (50 days = 50m). However, in fractured rocks such as Chalk groundwater can flow 10s of metres per day, even 1000s of metres per day. Consequently, what is important is travel time. Is the travel time from drainage infiltration areas to BHs D and E greater or less than 50 days ?

7.4 Cost of Providing Alternative Water Supplies to Existing Boreholes

The worst case is a sudden loss of water either due to contamination or reduction in yield from the borehole. The quickest short term solution is to tanker in water. It may then be necessary to sink a new borehole or go onto a mains supply.

7.4.1 Tankering

The cost of tankering the water for the 20729 cubic metres (Annual Abstraction) at approximately £800 per 30 m^3(standard contract) is £552,773.

7.4.2 New Borehole

Even if a license was granted, there are few good water well drillers; consequently it can take months to obtain one. The whole process, drilling and obtaining a new abstraction licence could take 6-12 months. A licence is given for a specific location so drilling a borehole at another one, even though the abstraction does not increase, will need a new one. New boreholes could cost £10k to £35K each. Replacing a 5m deep well with another one would be cheap but to have to sink a 30-50m deep borehole with an internal diameter of up 140mm could cost £35K. In this part of Salisbury Plain, the yield from the Chalk varies enormously, being high in the valleys and much lower in the higher ground in between. If a new borehole has to be sunk, an area of high yielding Chalk has to be located and then the location must be close to adequate electricity supplies which may require 3 phase. The borehole must also be away from pollution from manure heaps, slurry lagoons or run off from yards. The EA may not grant previous allowed abstraction rates or may imposes summer restrictions. During delay/reduction in quantity some or all animals have to be slaughtered.

7.4.3 Mains Water

Mains- supply from Wessex Water may not be available in quantity and pressure needed due to the following:-.

The MOD Base at Larkhill is to receive 4000 soldiers and their families.
The National Trust is planning an increase in visitors.
There are hundreds of houses planned for the area.
The Tunnel is likely to need a water supply.
Other farms may have to go onto the mains

Consequently, there may not be capacity in the mains should farms require it. To lay 1km of mains along a road can cost £100K. Wessex Water are responsible for bringing water to the property boundary and the distribution within is the responsibility of the owner. Consequently, additional works such as booster pumps, reservoirs, pipes and electricity cables may need to be installed. Water demand use is not constant over 24 hours but tends to have peaks in the morning and afternoon and it is critical to ascertain that any mains can supply peak demand. The cost of buying water from Wessex Water is £2.2 per cubic metre which for 20729 cubic metres is £45,603.8/year

7.5 Problems From Tunnel Arisings(TA)

The proposal to to place Tunnel Arisings at locations 1, 2, 3, 4, 5, and 9 which are on or next to Manor Farm. See Figure 4. The Chalk arisings will comprise two types:-

Arisings from the Tunnel Boring Machine which have beeen excavated from below the water table, mixed with bentonite will be in the form of a slurry which then has to be treated to enable it to be handled and used. The slurry will have the water content reduced by processing and probably lime or cement added to increase strength. The thickness of the tunnel arisings placed upon the ground in the location mentioned will be up to 2m but the strength of the material is not stated. For the TAs t to be able to withstand traffic it will need to achieve a shear strength of at least 50k Pa. A 2m thick layer of TAs will exert a force of about 40k Pa on the ground. There is the risk that the TAs will have such a low shear strength when initially placed they will flow downward into cracks in the surface of the Chalk before it fully strengthens, especially if there is rain- see Figures 5 and 6 .

Also if the TAs are on a slope, they could fail and move downhill, especially after rain and/or the ground is saturated due to high water table or a rain shower. TAs from previous jobs have been processed by reducing the water content, mixed with cement or lime and placed in a quarry. On this job the TAs are being placed on a slope with the potential of their strength being reduced from surface or groundwater and there is the possibility of vehicles moving over them. The top 1.5m of the TAs could have shear stengths exceeding 50K Pa but the bottom few centimetres could be a soft slurry and one would not know from a visual inspection of the surface crust.

Particles of very slowly reacting particles of   lime or cement or bentonite from the Tunnel Boring Machine slurry shield could be washed down into fissures which eventually set, causing reduction in permeability or even clogging submersible pumps. Particles can start to clog apertures when they are greater than 1/6 of the width. Consequently a combination of Chalk particles less than 0.1mm in diameter and slowly reacting particles lime, cement or bentonite could easily clog fissures of less than 0.5mm or even 1.0mm. Chalk can adhere to the surfaces of pump impellors and if there are particles of slowly reacting lime, cement or bentonite the problems could be worse, possible leading to failure.

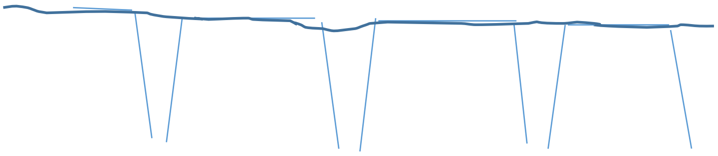


Figure 5. Chalk TAs placed initially   on fissured Chalk

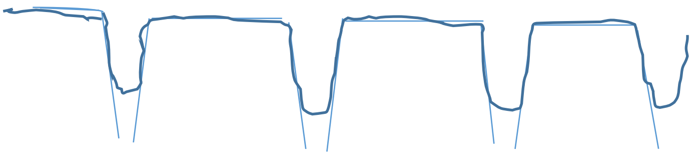


Figure 6. Chalk slurry having flowed into fissures and sealed them

When the Chalk TAs fully strengthens it will produce an impermable cap which rain will run off and so producing areas of intense flow down slopes. The ability of fluids to transport sediment is proportional to the cube of the velocity once movement is initiated, so rapid run off would cross the surface of TAs, transporting sediment into the surface of the Chalk and down into fissures and so enter the groundwater. If just sediment, then rain could cause increases in turbidity and bacteria in water. Animals droppings on the surface of the tunnel arisings could be washed into the ground water and pathogens such as E.Coli, Enterococci, Clostridia Perfringens and Cyptosporidia could be problems. The TAs change the nature of the recharge of the Chalk aquifer, from a fairly even distribution to potentially areas of intense recharge which increases contamination and the risk of groundwater flooding. The stability of the TAs need   to be assessed; could they fail and flow downslope and block the River Till and increase the risk of flooding ?

The Chalk excavated from the cuttings will vary in it's mechnical properties and the amount of rain during the works will be important on how it behaves. What is not explained is how the Chalk can be placed at the areas chosen and compacted such that it does not collapse, produces a smooth enough surface for farm vehicles but achieves the same permeability as the existing Chalk. Compacting Chalk to construct an embankment so that it achieves sufficient stability for a high speed trains is possible but it is impermeable.

There is the issue of phosphatic Chalk from the TAs entering the groundwater and surface water. As the area is within a NVZ any increase in phosphate , especially if there is dissolved organic carbon from topsoil could produce an increase in algal growth in surface water and bacteria in groundwater. There is an increased risk of algal blooms in the River Till. Radon gas is associated with the phosphatic Chalk and this element vapourise, however, no assessment has been made of daughter elements as lead.

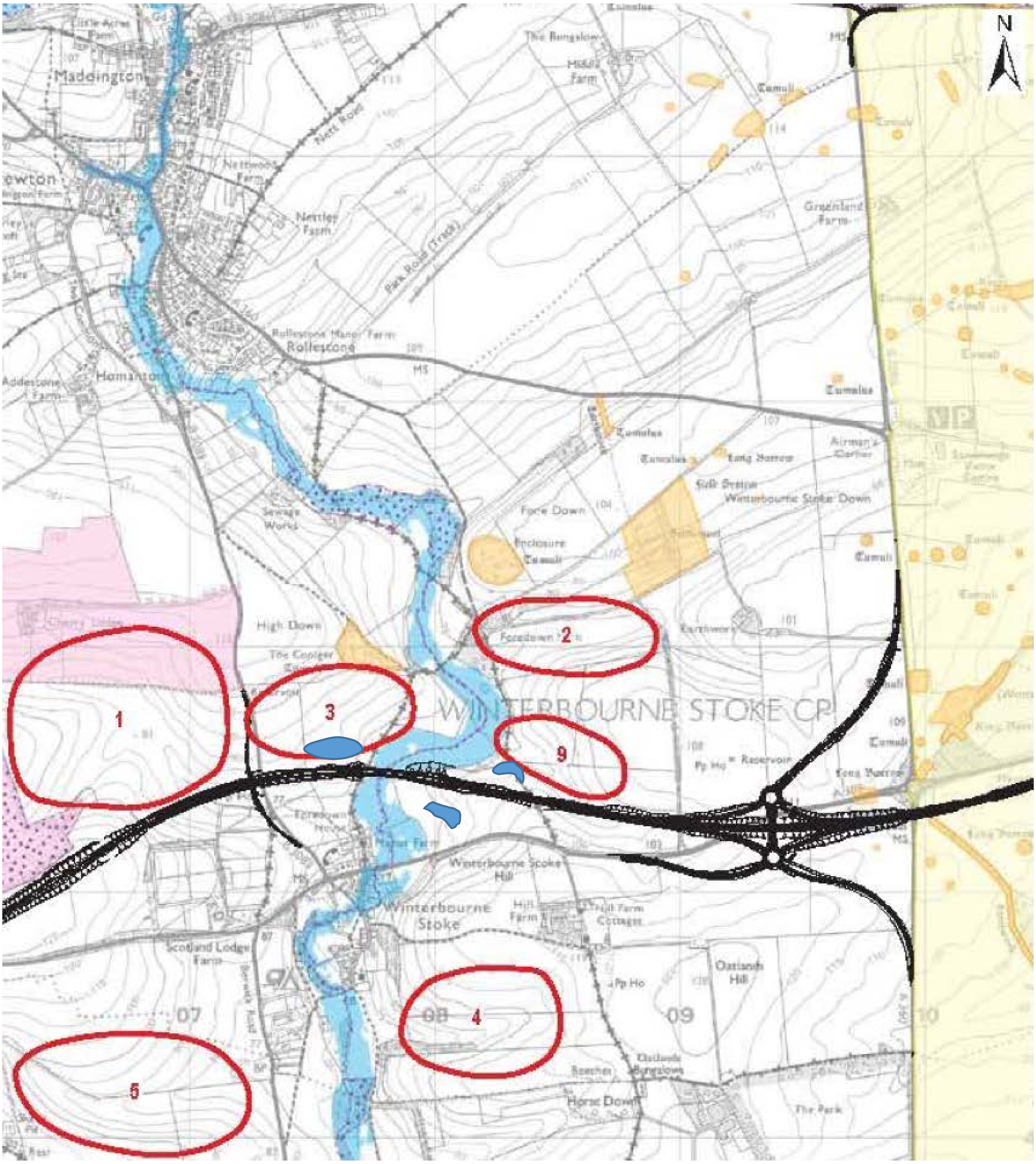


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Figure 7

Key

Tunnel Aisings

Drainage Infiltration Areas

7.6 Potential Problems From Drainage Infiltration Areas

Water from the road will be discharged to the ground within the valley of the River Till via DFAs which means the recharge of the aquifer will increase. As there is already groundwater flooding at Winterbourne Stoke, this will only worsen.

It needs to be assessed as whether the location of the DFAs could reduce the stability of the tunnel arisings(particularly No 3) especially if during heavy rain localised rising of groundwater occurred: .

Construction of Road Bridge

- The construction of the foundations of the road bridge beneath the water table, being impermeable and placed in permeable Chalk in the River Till will cause groundwater mounding, reduce the storage capacity of the hyporheic zone and ability to transmit groundwater southwards, so increasing the risk of flooding.
- Have the piers of the bridge been deigned to cope with a 1841 flood event? What would happen if uprooted trees were jammed against the piers in a 1841 flood event and the water rose behind them ?
- The construction of the embankments for the road reduce the volume available for storage above the water table in the valley of the River Till. The embankments are also likely to increase surface run off from rain.
- There needs to be an assessment of the combined groundwater and surface water risks from an Autumn 2000 and a January 1841 flood events from the construction of the following:-
    - o Drainage Infiltration Areas
    - o Tunnel Arisings
    - o Possible slope failure of the tunnel arisings and flow towards the River Till
    - o Construction of the road bridge
    - o Construction of Embankments
- What appears to be the result of the proposed design is to increase the total amount of water and the rate of flow entering the valley of River Till upstream of Winterbourne Stoke yet reducing the width and volume of the valley. Consequently there is an increase in risk from flooding.

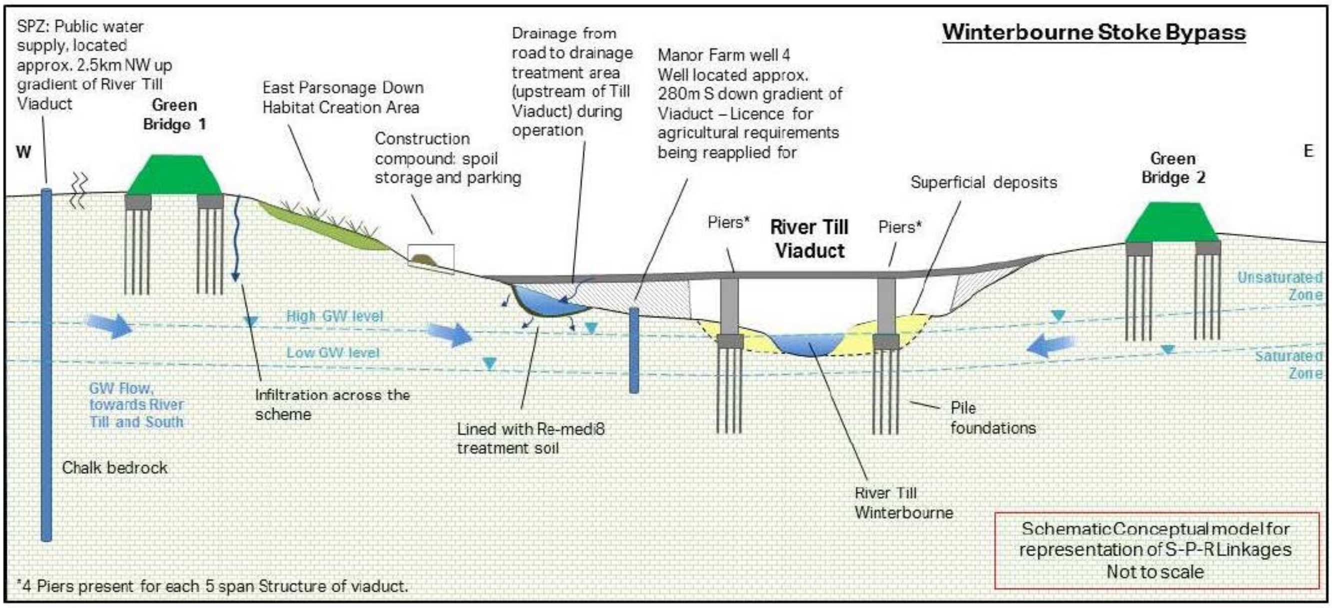

Figure 8

7.7 Impact of Machinery on Chalk Surface

It is possible to remove the topsoil and stockpile but this runs the risk of sediment being washed off the surface by rain and entering the fissures of the Chalk so causing contamination.

Chalk quarries stop operations when it becomes too wet because the surface is reduced to a slurry. In the area, in winter, the only vehicles trafficing the Chalk are cars weighing 2 T at most along trackways yet their weight is sufficient to produce a slurry of the Chalk when wet . When dry, the crushed Chalk sets hard and produces an impermeable layer. As has been previously stated, Dew Ponds are created from Chalk which has been wetted and reduced to a slurry which when dries produces a layer which can remain water tight for hundreds of years. It is likely that trafficking causing dissolution of Calcium Carbonate when wet which when dry, precipitates and cements the Chalk slurry. Tractors which can weigh up to 17 tons only undertake work when on the pastures during the drier spring to autumn months.

During the construction works large areas of land are to be used. Though topsoil can be removed and stockpiled. The action of vehicle movements on Chalk, especially when wet needs to be assessed. At the ground surface the Chalk is invariably Grade Dc comprising medium gravel weak to medium density with a matrix of uncompact comminuted Chalk. In Engineering in Chalk p120-122([1]), it states that undrained shear strength of the crushed Chalk is reduced with water content and approaches zero at the liquid limit, which will be usually less than 35%. Once the shear strength is less than 50kPa plant may be unable to traffic the area when the moisture contents of the fines exceeds Liquid limit minus 5 % for Chalks with a clay content of 10-15 %. Where the clay contents of the Chalk exceeds 15%, the point at which crushed white Chalk approaches zero shear strength could be the liquid limit minus 20%. Where the fines content of the crushed Chalk passes 10-20% there is a deterioration on in earthworks trafficability. Appendix10.1, Preliminary Ground Investigation Report pages 105 to 110 discusses the extent and properties of structureless Chalk and Figures 6-35 and 6-36 PSD curves shows the fines content of Chalk graded at Dm and Dc see Figures 9 and 10.Most of the samples of Dm and Dc Chalk have fines contents greater than 10 %, so they will susceptible to becoming slurries when their moisture content approaches their Liquid Limit.

The lower the dry density of the Chalk, the weaker it is. Dm chalk varies from 1.5 to 1.6 Mg/m3 and Dc from 1.5 to 1.9 Mg/m3 which are within the upper end of weak classification for Chalk. The only Liquid Limit is 42% for Dm which is high due to high clay content. From the information obtained earthmoving vehicles weighing up to 117T will reduce Chalk to slurry when it has moisture content above 18%.

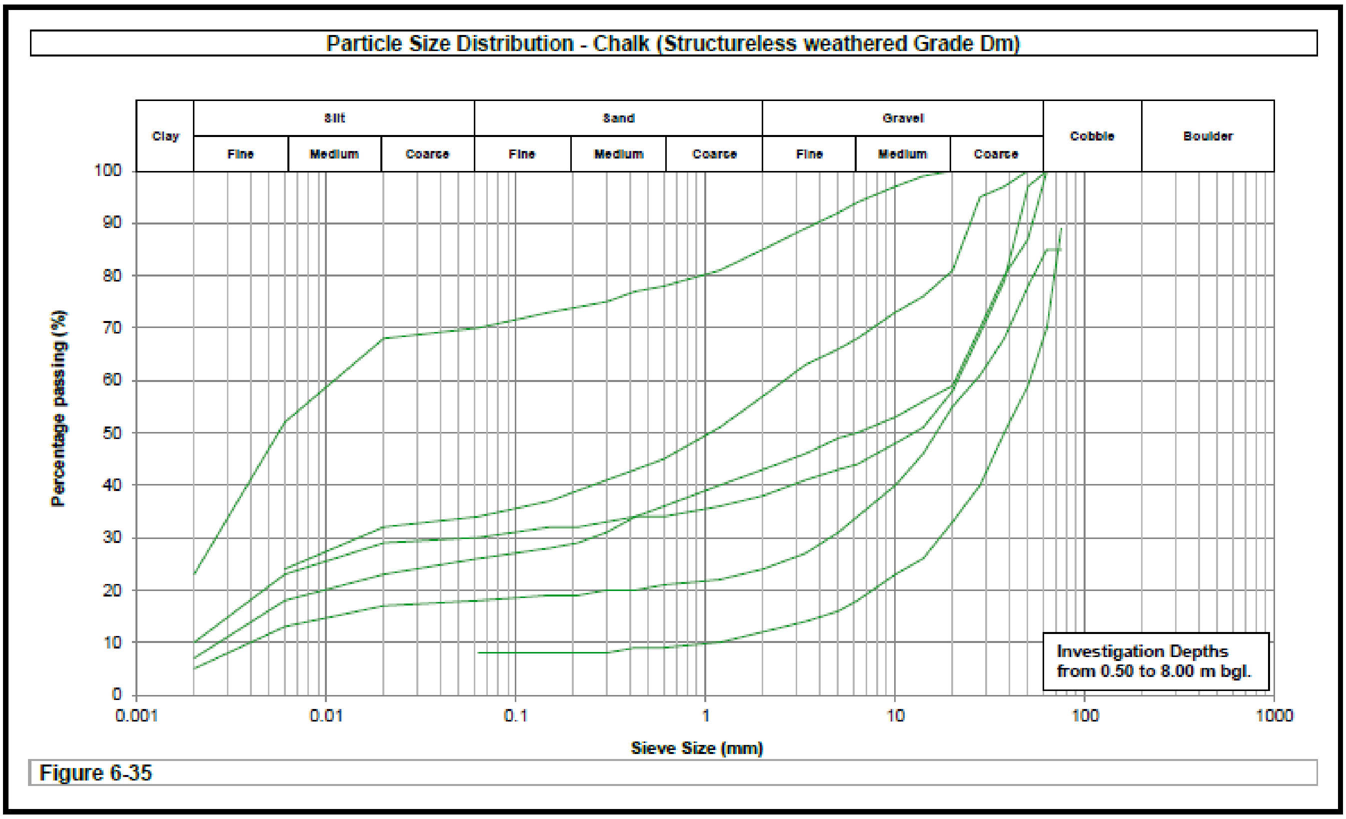

Figure 9

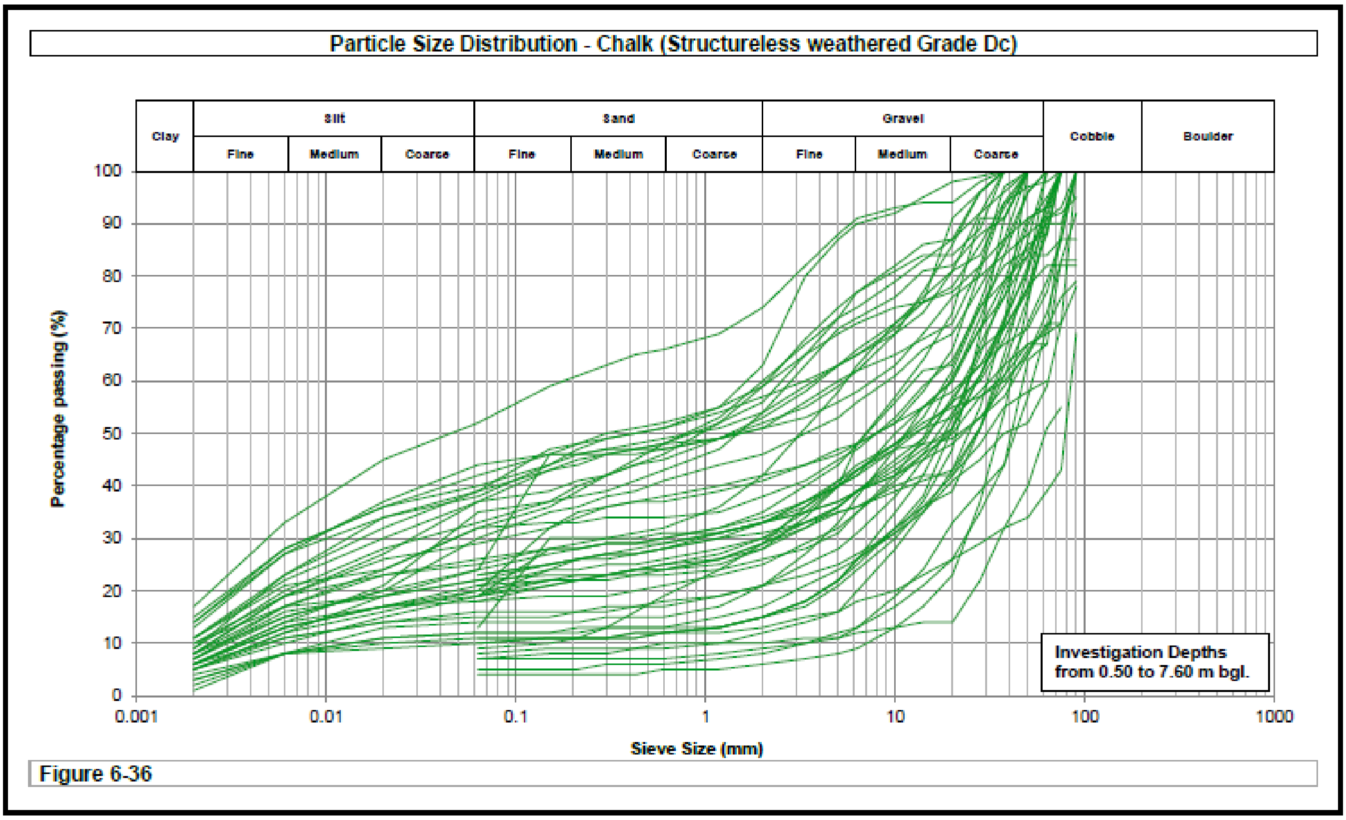

Figure 10.

What has not been considered is the weight of some earth moving plant. Figure 11 shows a lorry which when fully laden is 117T and figure 12 shows a 75 T lorry when fully laden.

Figure 11

Figure 12

What is being ignored is how the surface of a construction can be reduced to slurry when conditions are wet. - see figures 13-15. The Chalk will be reduced to slurry which when it dries will be as impermeable as the lining of a Dew Pond resulting in free draining Chalk land pasture being changed to an impermeable layer. Replacing topsoil onto an impermeable crust of Chalk will not recreate the permeable Chalk pasture!

Photographs of Construction Sites

Figure 13

Figure 14

Figure 15

7.8 Suggestions for Testing

1. Infiltration tests to assess infiltration of water into the Chalk prior to site works.

2. Assess impact of vehicles on Chalk when wet. Earth moving vehicles as shown in figures 13- 15 can weigh 75-112 Tons , whereas the a tractor has maximum weight of about 17 T and will only move across a field in the drier parts of the year. When

vehicles have weights of up to 117 T, compaction of Chalk could occur to a depth of 1m or more. Highways England need to assess the workings of a Chalk quarry during wet months in order to understand what could occur.

3. Once a test has replicated the movement of vehicles which will occur during construction during wet months across the Chalk ground surface, infiltration tests should be undertaken. It is likely that construction traffic will reduce the permeability of the Chalk. Consequently even when topsoil is replaced it will no longer be free draining pasture but one prone to water logging. Either haul roads will have to be constructed to prevent the Chalk being reduced to a slurry in wet months the project must be re-designed.

8.0 Summary

1. Manor Farm has five boreholes, A to E. Bhs C, D and E are likely to be adversely affected by construction either reduced yield and/or from contamination. BH A will be unaffected and BH B may be slightly affected by contamination.

2. In the event of loss of water from boreholes the options are.

    1. Tanker in water but this cost £800 per 30 cubic metres and would a short term option. 6 months of tankering the daily abstraction rate of 61 m^3 /d would cost £292,800.

    2. Construct new boreholes but obtaining the services of a good water well driller and obtaining a new abstraction licence from the EA would take 6- 12 months and cost upwards of £35K.

    3. Obtain a mains supply from Wessex Water. 1km of water mains could cost £100K. The cost of buying water from Wessex Water is £2.2 per cubic metre which for 20729 cubic metres is £45,603.8/year. It could take a year to obtain a new mains supply.

3. Heavy earth moving plant, weighing up to 117T would reduce the Chalk ground surface to a slurry when wet, which when it dries and hardened would create an impermeable crust. How could the ground be returned to free draining Chalk pasture?

4. Large areas being trafficked by earth moving plant and construction of areas of TAs will produce rapid run off of rain leading to mobilisation of contaminants such as sediment, bacteria- possibly pathogenic, cryptosporidium and petroleum hydrocarbons which via fissures in the Chalk ground surface, could enter the groundwater

5. Construction of the foundations of the bridge, embankments, sites of Tunnel Arisings (TAs) and Drainage Infiltration Areas within the valley of the River Till could increase the risks of groundwater and surface water flooding by increasing the volume and rate of water being discharged into it and reducing the volume of storage and cross sectional area of the valley to transmit southwards. HE have not assessed the risk of flooding based upon the January 1841 and autumn 2000 flood events. Consequently, there is an increase in the risk of groundwater and surface water flooding in the valley of the River Till at Winterbourne Stoke.

6. In light of the problems raised the best options are:-

    1. Road bypass around Salisbury.

    2. Tunnel above water table as suggested in 2000.

    3. Present tunnel but redesign road over the valley of the River Till, assess damage to Chalk pasture by plant traffic; impact of Chalk arising's on rain infiltration, run off, geotechnical stability and adverse impact of scheme on water supplies.