The Clay Research Group

RESEARCH AREAS

Climate Change : Data Analysis : Electrical Resistivity Tomography
Time Domain Reflectometry : BioSciences : Ground Movement
Soil Testing Techniques : Telemetry : Numerical Modelling
Ground Remediation Techniques : Risk Analysis
Mapping : Software Analysis Tools
Electrokinesis Osmosis
Intelligent Systems

Climate Change • Data Analysis • Electrical Resistivity Tomography
Time Domain Reflectometry • BioSciences • Ground Movement
Soil Testing Techniques • Telemetry • Numerical Modelling
Ground Remediation Techniques • Risk Analysis
Mapping • Software Analysis Tools
Artificial Intelligence

Edition 141

February 2017

The Clay Research Group

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Future Editions

Over the next few months, the newsletter will cover the following topics:

- the relationship between the risk of subsidence and root zone overlap,
- plans for an independent review of the intervention technique,
- subsidence risk in the borough of Havering,
- building vulnerability,
- Aldenham levels, looking in particular at the Headmaster's house and Kennedy House.

In addition, there will be further insights into the various modules that drive the **A***i* application.

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Celebrity Trees

Last month it was Bill Oddie, and now, Daniel Craig and Rachel Weisz. The London Evening Standard report that a plane tree in the ownership of the famous couple (Daniel and Rachel) is thought to have caused damage to a neighbouring property in Camden.

Intervention Technique

The patent for the intervention technique (InterTeQ) is likely to be granted in the next month or so and plans are underway for an independent review of the technique at the site of the Aldenham willow.

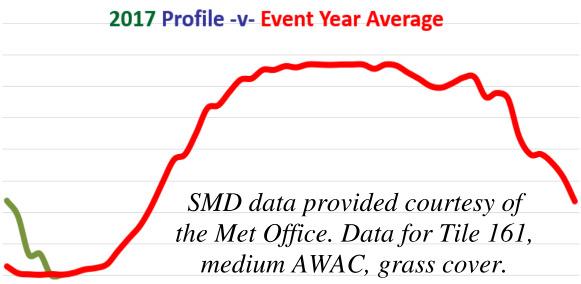
We have the benefit of 10 years levelling data against which pre- and post-treatment movement can be compared.

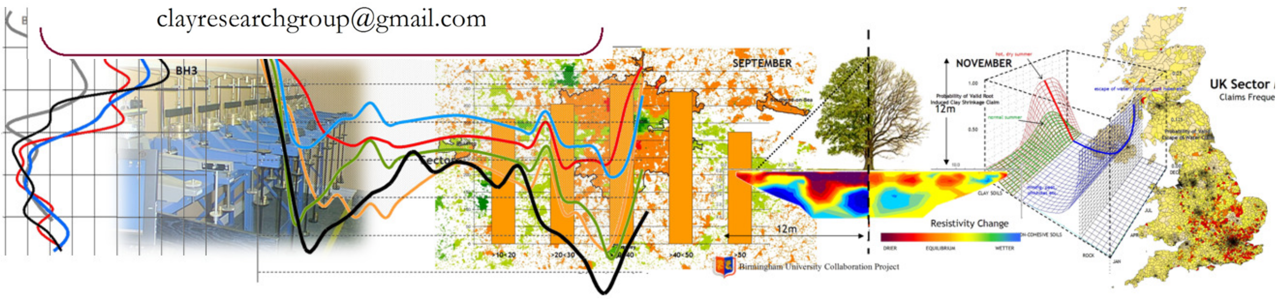
The technique has been used on over 100 claims although it is acknowledged that there is no data covering a surge year.

The objective is to utilise the persistent deficit at Aldenham as a proxy for such a year to accurately measure the benefits.

Soil Moisture Deficit

The soil is fully hydrated again, after late drying in 2016. See green line.





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Tree Planting Initiative

Keiron Hart has sent news that the Mayor of London, Sadiq Khan, has started his promised tree-planting programme with a £750,000 funding injection to plant nearly 42,000 trees across the capital.

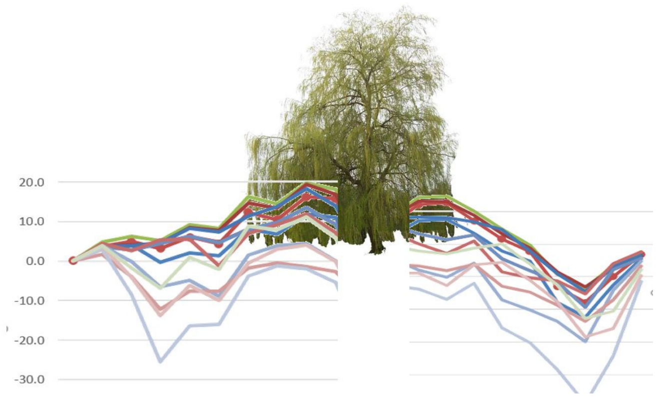
Mayor Khan explained, "Trees improve our environment and help clean up our toxic air, so despite inheriting no budget from my predecessor, I have worked fast to start a new planting programme and deliver the first batch of more than 40,000 saplings this winter. This is the first step in my plans for a major tree-planting programme across London in partnership with businesses and boroughs. I remain fully committed to ensuring that hundreds of thousands of new trees are planted over the next four years." Projects include:

- £50,000 to plant street trees in Sutton, mainly on public highways or in nearby areas of low canopy cover.
- £37,000 to plant at least one tree in every churchyard in the Diocese of London and the Diocese of Southwark.
- £30,000 to support small community charities in Hackney and Haringey, highlighting health benefits of tree planting.
- £13,000 to plant trees on seven residential estates across Hammersmith and Fulham in partnership with Groundwork.
- £13,000 to create three urban community orchards in parks across Redbridge, Ealing and Southwark.

Willow - Precise Levels

This month's edition examines the precise level data obtained at the site of the Aldenham willow and comparing the results from 2006 with 2007.

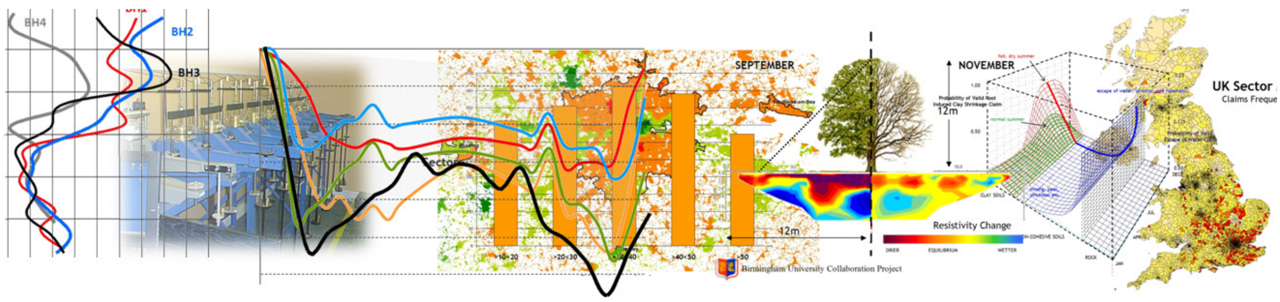
Whilst the subsidence that has been recorded has formed the subject of earlier articles, little mention has been made of the ground heave close to the willow - the 'upwards bulge' evident in the picture below where the ground has risen above the starting point in May 2006.



The answer lies in comparing the levels with the results of site investigations and soils analysis undertaken in May 2006.

The ground is rising close to the tree, whilst towards the root periphery it continues to subside. Why?

The study also assesses the month of maximum moisture uptake as inferred from precise level readings. By implication this throws light on understanding when to add water, supplementing previous articles looking at how much is needed to convert a potential event year into a normal year.



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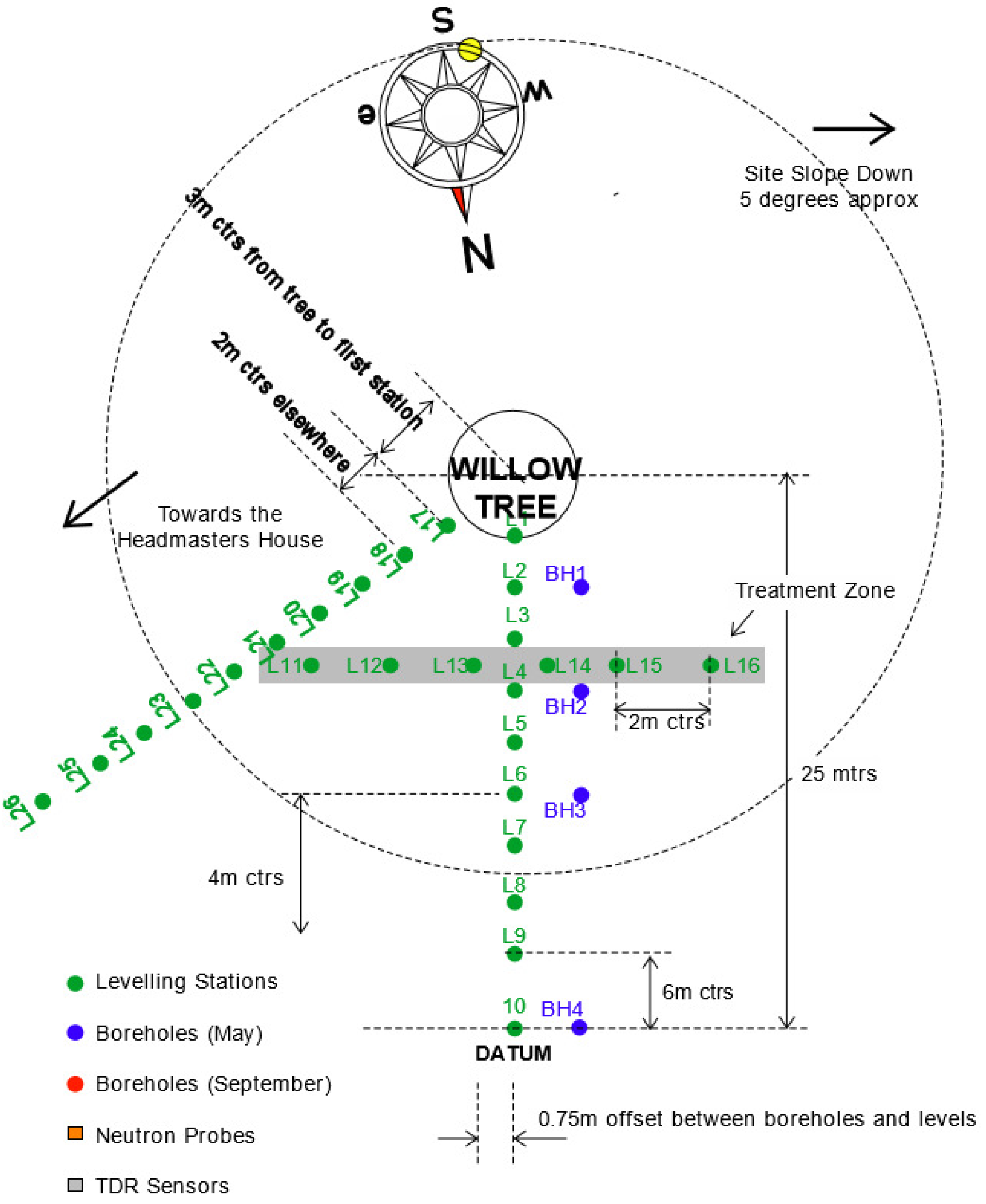
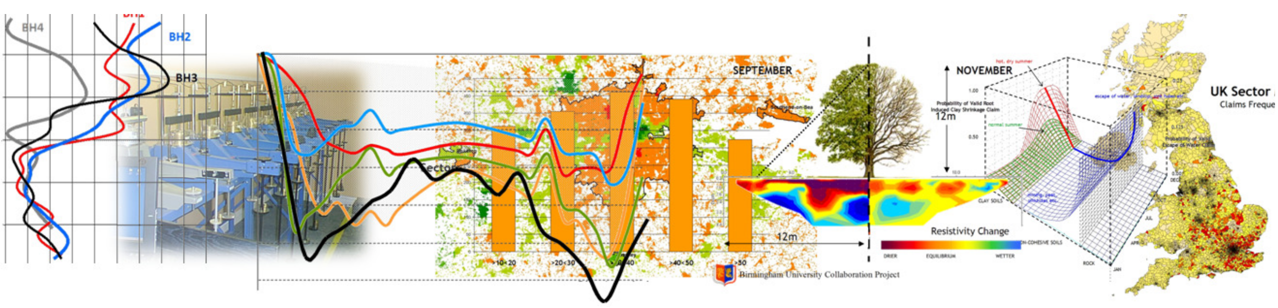
Aldenham Willow

Site plan showing layout of precise levels and boreholes.





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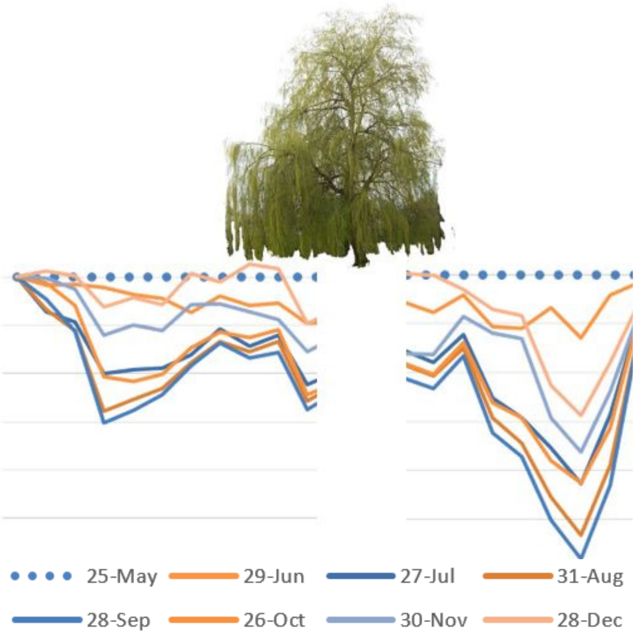
Aldenham Willow

Ground Movement over Time

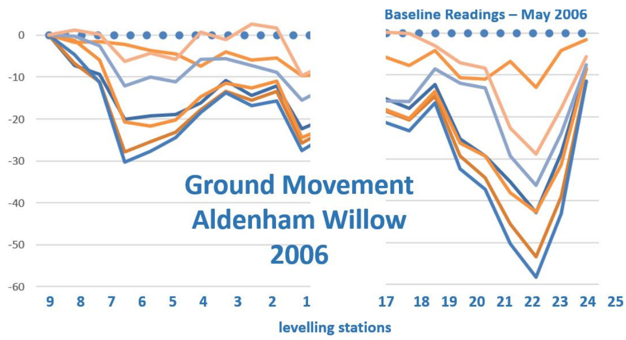
Precise levels were first taken in May 2006 and are represented by a bold, blue dotted line in the following images.

This datum did not represent the equilibrium moisture content of the ground. The willow is a mature specimen and site investigations and soils analysis undertaken at that time revealed there was a persistent moisture deficit when monitoring commenced. Something confirmed by the heave that took place the following year.



Each of the lines represent the profile by month for 2006, with the bottom blue line representing the subsidence (relative to the initial readings) that occurred in September. Winter recovery is recorded from October onwards.

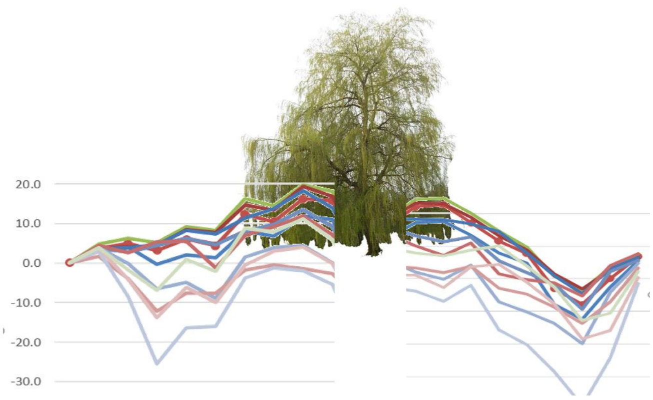
The location of levelling stations are identified along the 'x' axis, along with the amplitude of movement on the 'y' axis on graph below.



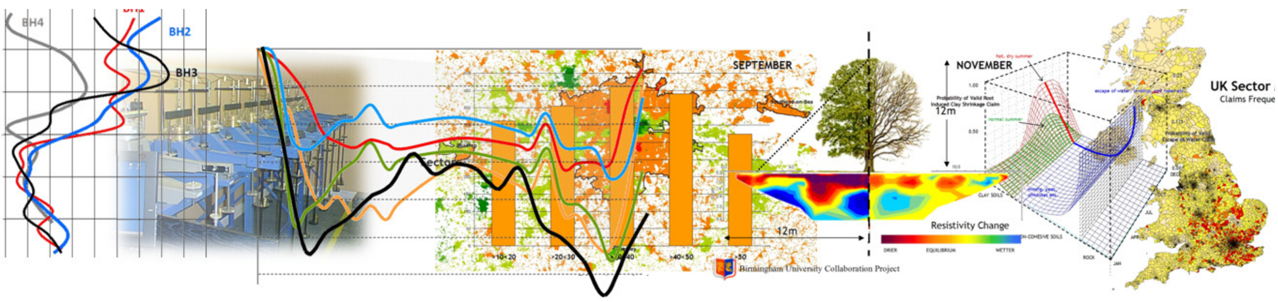
Readings were taken every month for the first two years, and then bi-monthly. Below are profiles for 2007.

Positive recovery (i.e. rising above the start level in May) took place to the stations nearest the tree – continuing to rise until April of 2007 before subsiding again in July (or earlier – no readings were taken in June).

Maximum recovery over the term was recorded in November 2016 and amounted to 32.8mm.



Levels for Aldenham Willow – 2007



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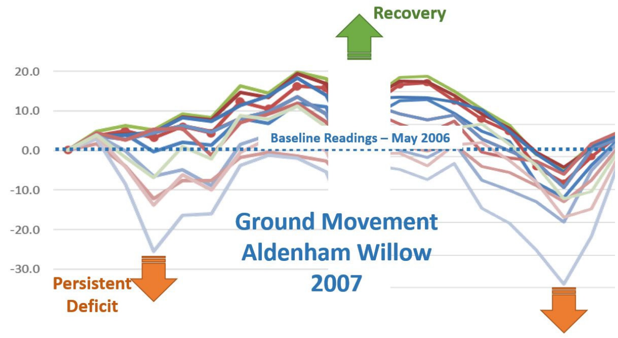
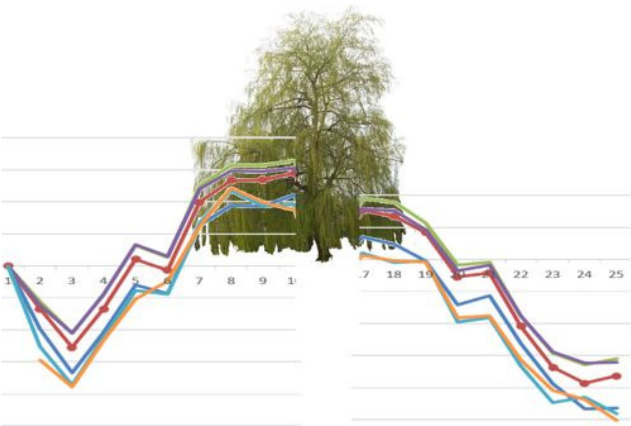
Ground Movement within Influence Zone of the Root System of the Aldenham Willow

Below, a more detailed profile of ground movement for 2007, in the vicinity of the Aldenham willow, showing the amplitude of recovery and subsidence through the year.



From the May 2006 baseline, maximum subsidence occurred at station 23, and amounted to 49mm.

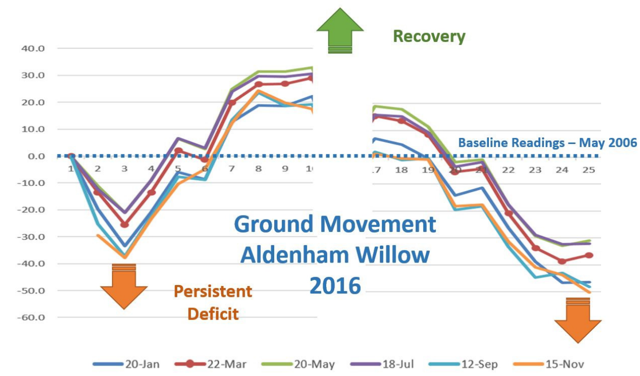
Bringing the record up to date, below the profile for 2016. Recovery nearest to the tree was just over 32.8mm, and maximum subsidence of around 50mm took place at Station 25.



Levels for Aldenham Willow – 2016

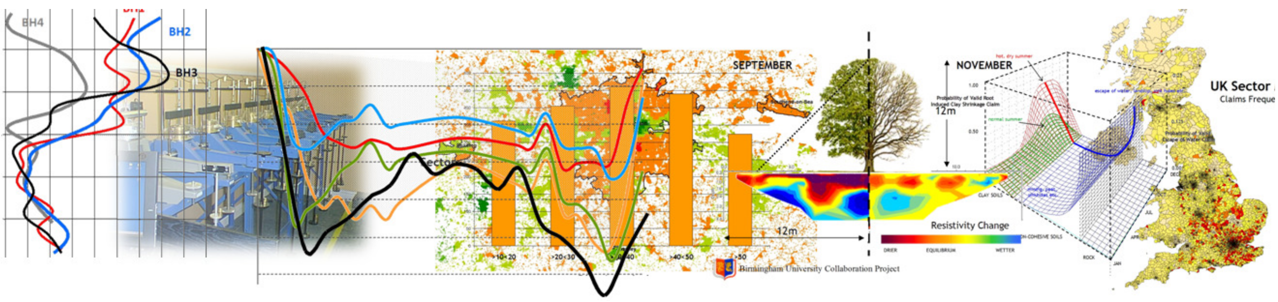
Below, bringing readings up-to-date with a summary chart showing areas of recovery and subsidence for the stations within the zone of root activity of the Aldenham willow, situated in the rear garden of the headmaster's house, opposite the main school.

The recovery and subsidence are relative to the initial readings taken in May 2006.



Ground Movement Profiles
Aldenham Willow – 2016

In 2006, maximum subsidence occurred in September and in 2007, October. Naturally there will be variability associated with weather, soil permeability and tree physiology. However, reference to the weather record might deliver some guidance on the drivers behind moisture abstraction by trees, and data from the Met Office is examined on the Pages 11 and 12.



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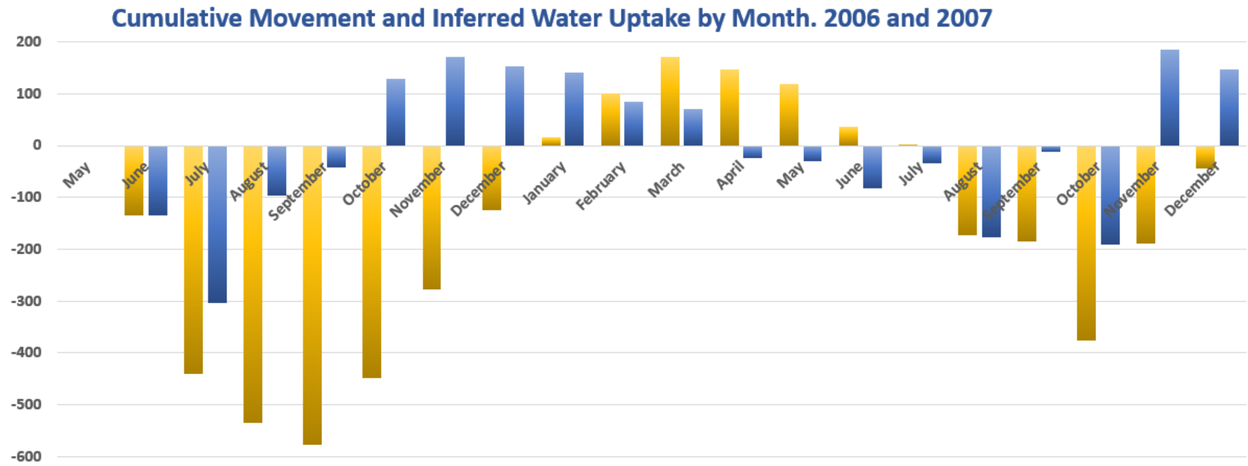
Cumulative Ground Movement and Inferred Moisture Uptake

The Aldenham Willow

Below, a chart plotting cumulative ground movement by month (yellow) and differences by month (blue) from May 2006 through to December 2007 – the two years for which we have monthly data. As seen on previous pages, in 2006 the cumulative movement peaks in September and in 2007, October.

The values have been obtained by adding differences across all stations. So, if Station 5 subsided by say 10mm and Station 7 by 12mm, the value would be the sum of the two = 22mm. The values below reflect the sum of movement across all 25 stations. In September 2006 for example, the cumulative movement when compared with May of the same year was nearly 600mm.



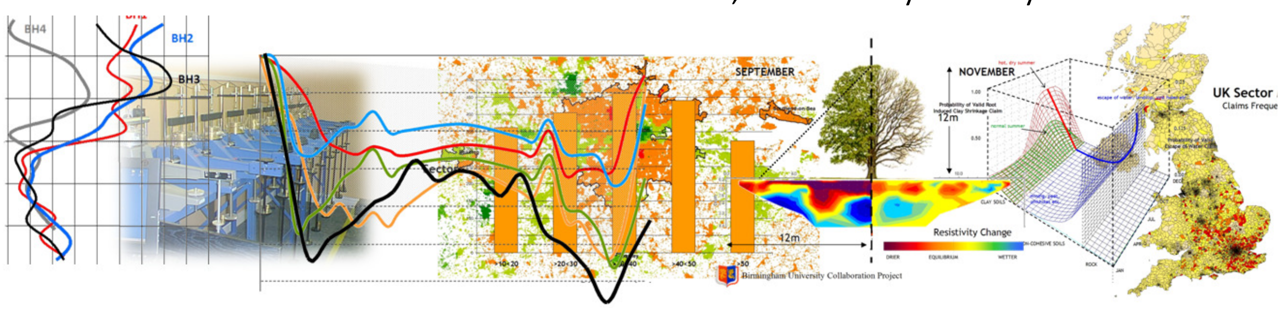
The blue bars record the difference between cumulative movement values. They register the movement that has taken place in the month. Precise level readings are generally taken towards the end of each month.

This measure has been used to infer moisture uptake by the willow. Negative values are water loss, and positive values, rehydration of the soil.

In 2006 the greatest ground movement using 'differences by month' (blue bars), took place in July. Cumulative ground movement across all stations exceeded 400mm in that month.

In 2007, most 'movement by month' took place in August and October – around 200mm each month – with little movement in the month of September.

Winter recovery between 2006 and 2007 peaks in March, although that recovery is incomplete. Total cumulative subsidence amounted to around 590mm, and recovery was only 170mm.



Cumulative Ground Movement and Inferred Moisture Uptake

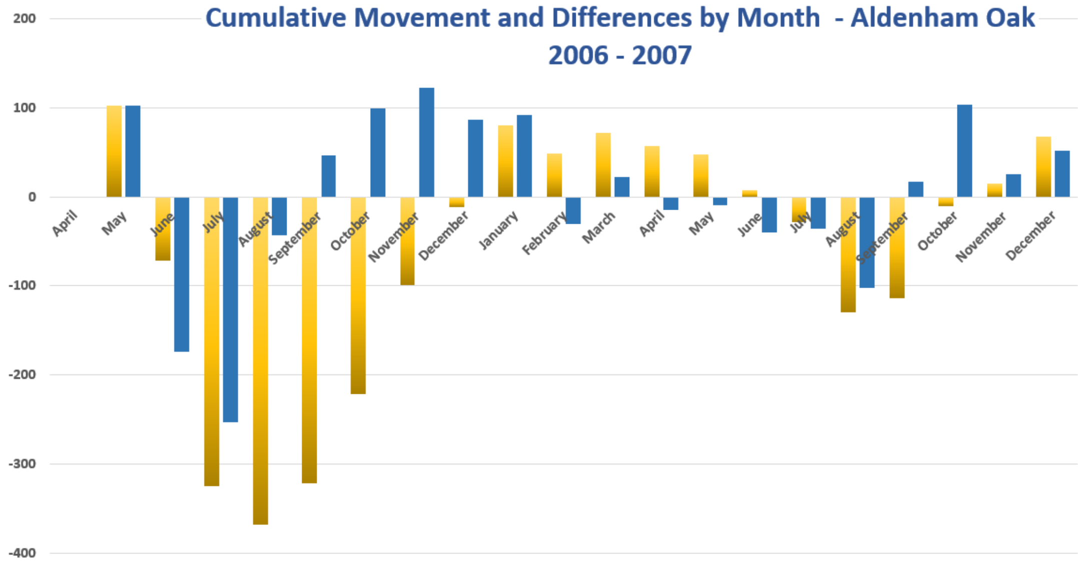
The Aldenham Oak

Below, a bar chart recording the difference between cumulative subsidence (yellow) and movement by month (blue) for the Aldenham oak. The cumulative subsidence by month sums movement from all stations. The same exercise as described on the previous page for the willow. The movement by month (blue) is used as a proxy to estimate water uptake. The ground is subsiding due to root induced water loss.

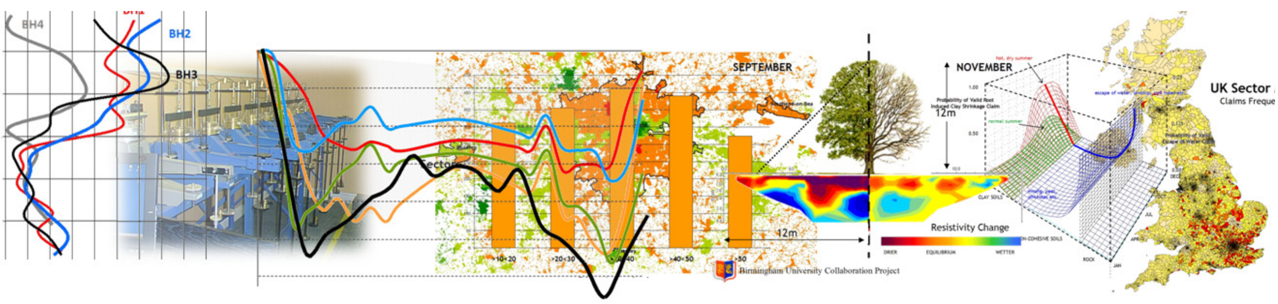
As was the case with the willow, maximum movement in 2006 took place in July. In 2007, maximum movement at the site of the oak took place in August, compared with October for the willow.

The geology in the vicinity of the oak is heterogenous as described in earlier editions, but the pattern of movement by summing the individual stations is similar to that recorded at the site of the willow.

In 2006, cumulative movement peaks in August (September for the willow). In 2007, the situation is different with less ground movement taking place, peaking in August (October for the willow), but of far less amplitude. In 2006, movement across the stations totalled around 380mm, and in 2007 = 120mm.



This compares with 590mm in 2006 and 380mm in 2007 at the site of the willow, reflecting the influence by species and geology.



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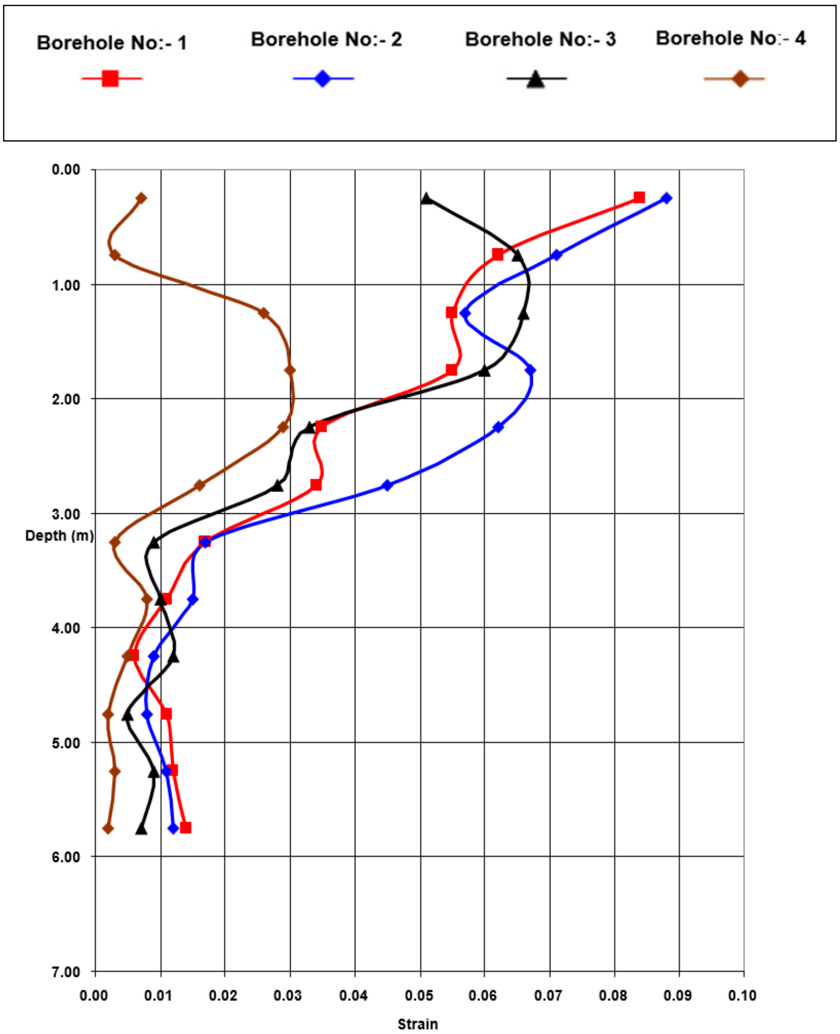
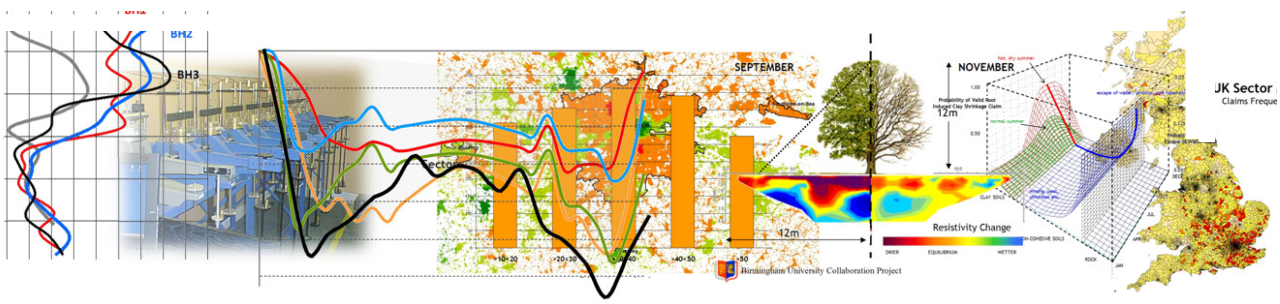
Strains Recorded from samples taken from Boreholes Sunk in May 2006 at the site of the Aldenham Willow



Disturbed and undisturbed soil samples retrieved from the investigations that were carried out in 2006, 2007 and 2008 were tested in a variety of ways – suctions, oedometers, penetrometers, and plasticity index comparisons with the moisture content.

Above, the results of the oedometer test in May 2006 revealed desiccation in all locations (see site layout plan on page 3), with highest readings closest to the tree (BH1), diminishing with distance towards the root periphery (BH4).



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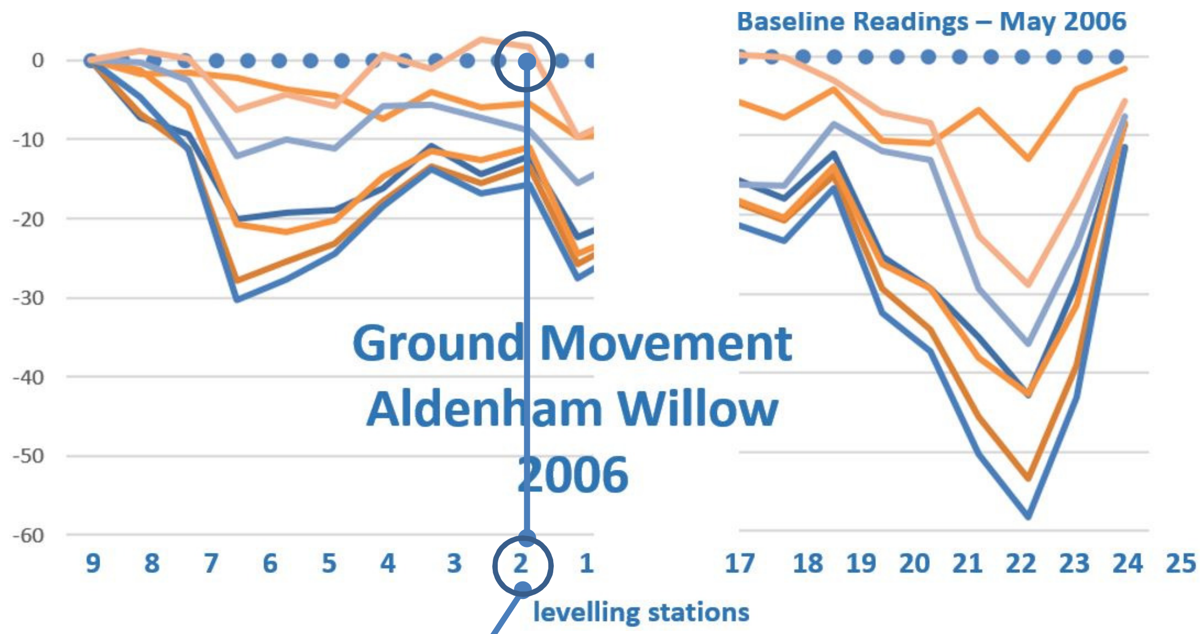
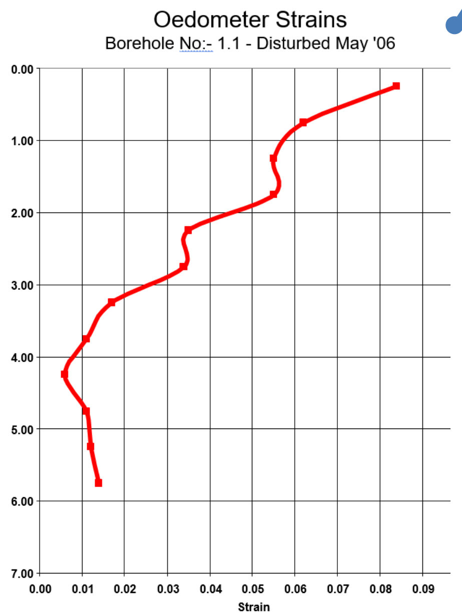
Levels and Site Investigations Combined

Below, the plot of ground movement profiles throughout 2006, commencing in May (blue dotted line). Although the May profile has been used as a datum, it records values from soil with a persistent moisture deficit – see below. This explains the profiles for 2007 and 2016, where the ground rises above this original and notional datum.



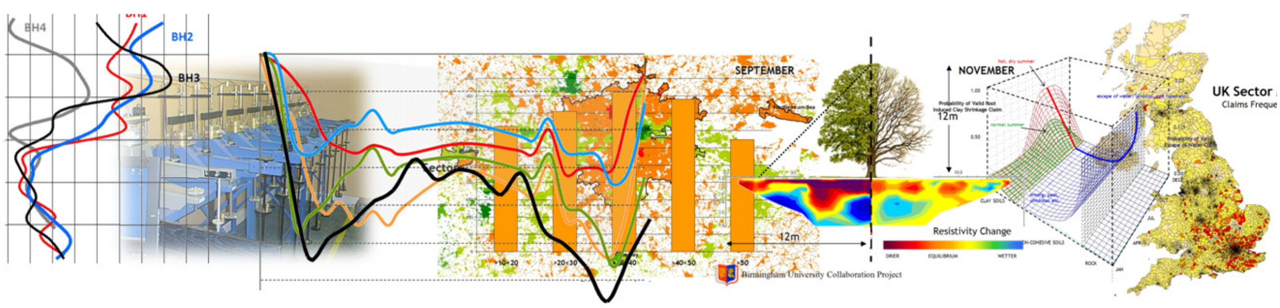


Left, the results of a site investigation undertaken in May, 2006. The borehole was sunk adjacent to level station 2, about 5mtrs from the willow.

Here, there is clear evidence of desiccation extending to a depth of around 3.5mtrs bGL.

See plan on Page 3. The results reveals excess suctions of around 1,200kPa.

This is unusual following the winter rainfall, confirming a persistent moisture deficit beneath the willow. Although the May profile is used as a datum, it is a dynamic baseline and accounts for subsequent readings where the ground contours rise above the starting point.



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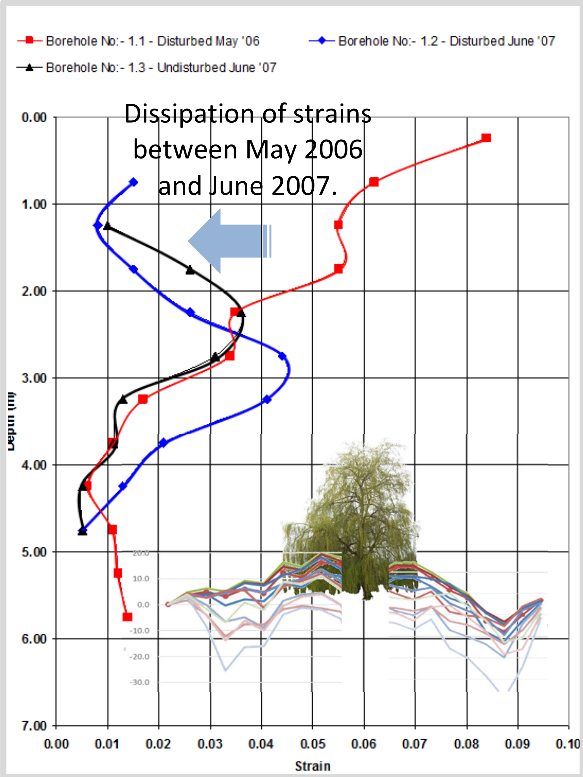
Heave of the Site

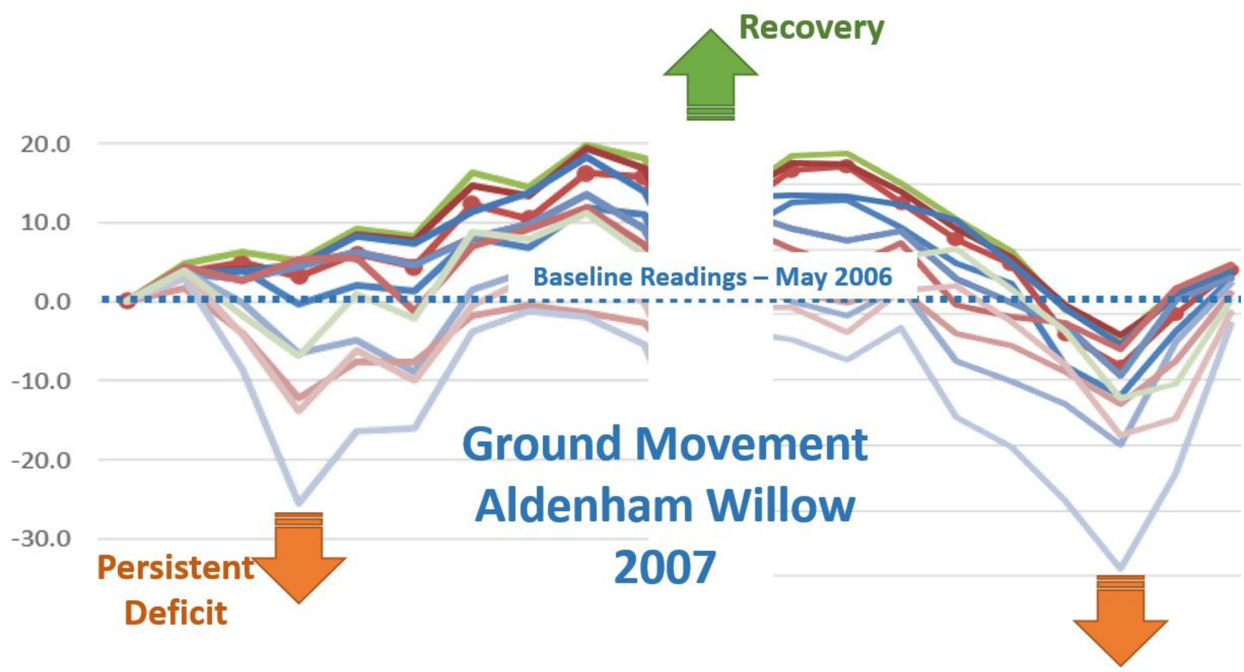
By June 2007, some ground recovery had taken place down to around 2mtrs bGL, with the oedometer strains (right) dissipating at shallow depth, consistent with rehydration of the soil by rainfall.

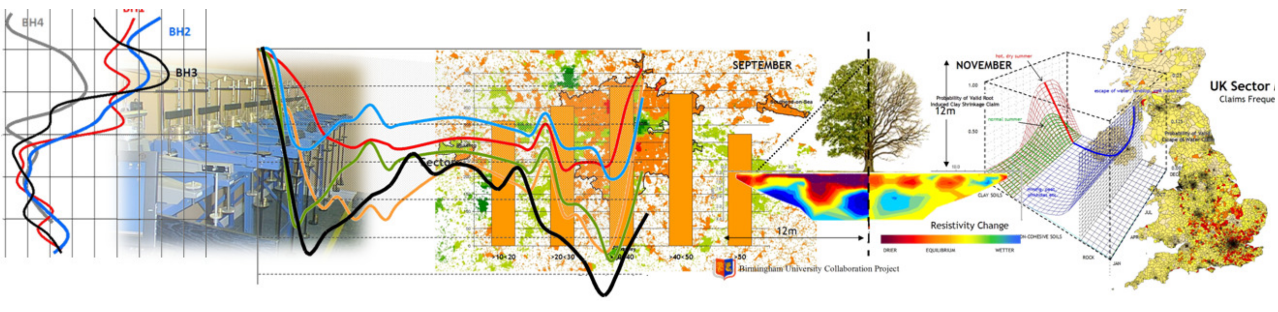
Water percolates slowly through the upper, desiccated, soils and takes time to replenish the deeper layers.

This dissipation of suctions causes the ground to rise (i.e. heave) above the May 2006 level, as we see below.

The recovery profile reveals a reduction in desiccation (but possibly not expiration) resulting in heave of the stations nearer the tree and an increase in desiccation towards the periphery of the root zone.

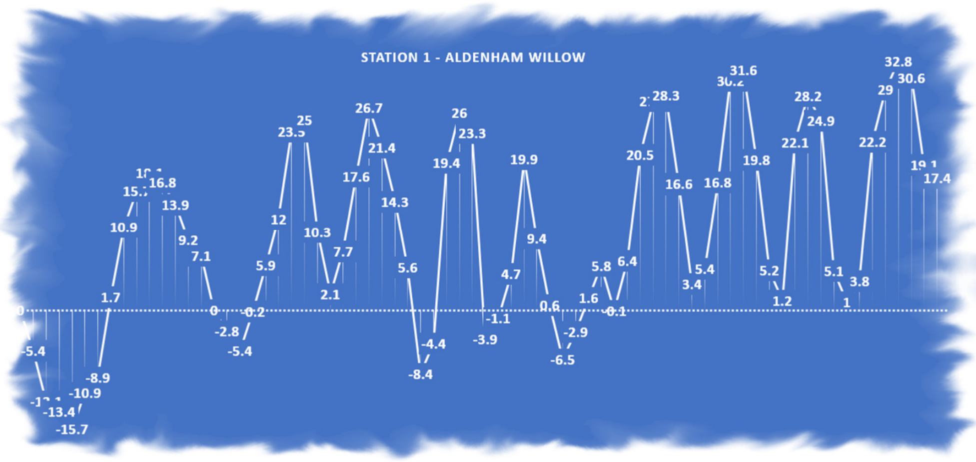




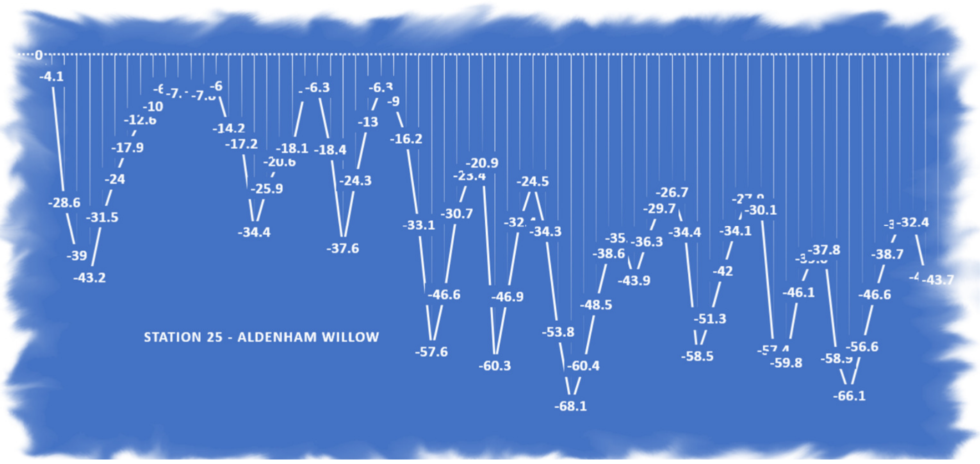


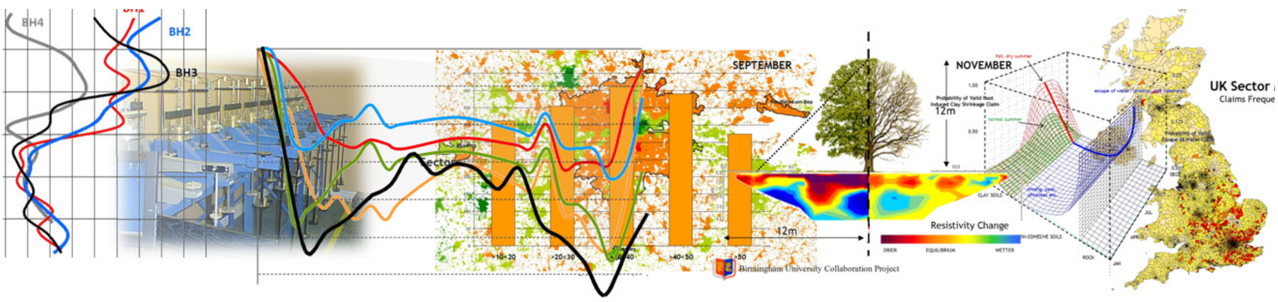
Stations 1 & 25 – Aldenham Willow

Movement recorded at Stations 1 (top) and 25 (below) of the Aldenham willow over the last 10 years. Both show a pronounced periodic signature. Station 1, which is 3mtrs from the tree, shows recovery of 32.8mm from the start position. In contrast, Station 25, furthest away from the tree, records a maximum subsidence of 68mm.



Both are ratcheting but in opposite directions. The clay soil near to the tree (station 1) is gradually hydrating and even the lowest points are now above the start position if only by 1mm in the summer and 32.8mm in the winter. In contrast, soil at the root periphery (station 25) is drying year on year and we see the development of a persistent deficit. This unusual situation reveals the dynamic approach of roots, seeking water from new locations when the original supply has become unavailable due (in this instance) to the development of high suctions.





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Heave over time compared with May 2006 estimate

Heave beneath the willow is associated with a persistent deficit that existed at the time monitoring commenced in May 2006.

With peak suctions of 1,200kPa at BH1 at that time and little recovery over the winter months, roots would have experienced difficulty extracting moisture.

Roots in this zone are still extracting water as there is a clear periodic signature, but they are not taking as much as the peripheral roots.

Lateral extension of the roots provided access to saturated soils initially, but as soil tests undertaken at that time revealed, even in May 2006 suction values at the root periphery were evident, although not as high (400kPa compared with 1,200kPa) and not extending over such a depth (2mtrs, not 3mtrs).

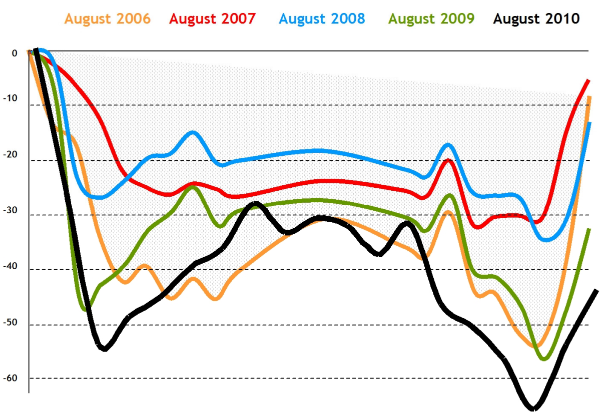
As the results on the previous page reveal, moisture uptake closer to the tree reduced in subsequent years with consequent heave of the ground.

Samples retrieved in May 2006 gave estimates of heave of around 80mm. This estimate was derived from disturbed samples using the oedometer.

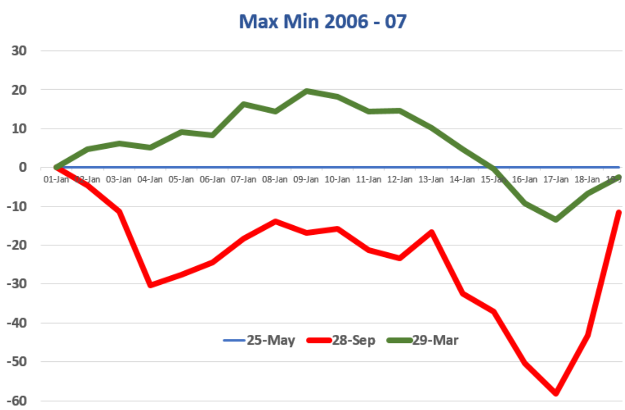
Subsequent research undertaken by Clive Bennet at MatLab Limited led him to adjust the estimate of swell from disturbed samples by discounting the initial 0.01 strain which was due to relaxation of the sample and then halving the total estimate. The updated value is around 40mm.

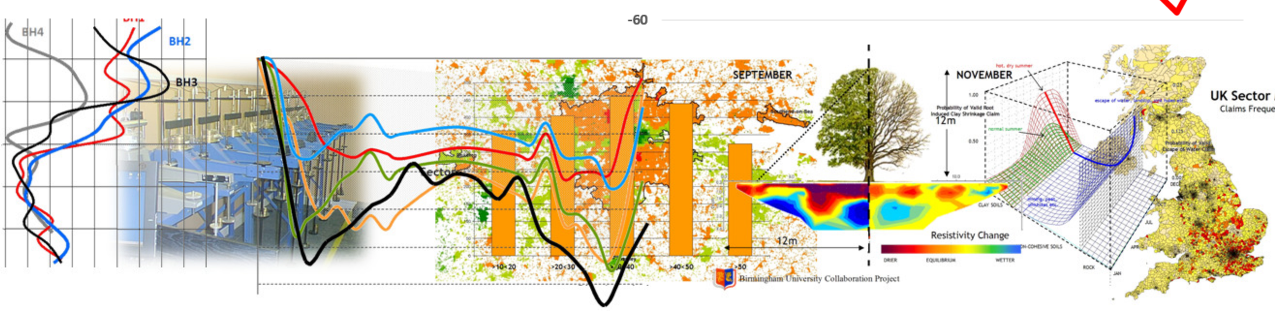
Bringing the study up-to-date, in the winter of 2015 measured recovery was around 30mm, suggesting the initial estimated heave may be close to having expired.

Hopefully the wetter weather experienced over the last 10 years have eased root stress in areas of the ground with high suctions.



A selection of profiles of ground movement for the month of August for the years indicated reveal a fairly regular pattern across the root zone with variation in amplitude. Later studies will try to correlate these differences with weather patterns – rain, hours of sunshine, wind and temperature.





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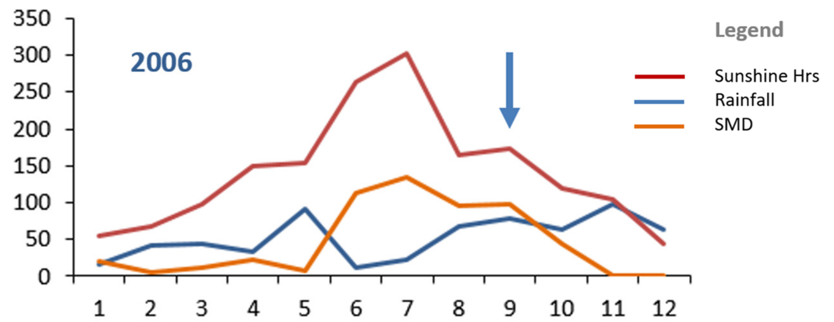
Driver Behind Month of Peak Ground Movement

The ‘driver’ behind the month in which peak subsidence occurs may simply be the absence of rainfall to rehydrate the soil as can be seen in September 2007. 78mm of rain fell in 2006, and only 17.4mm in the same month in 2007.



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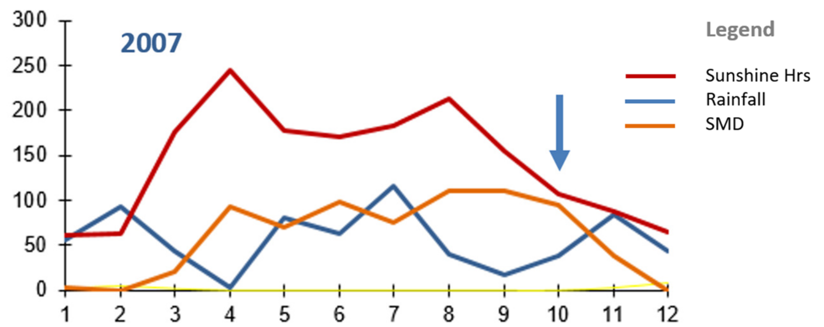
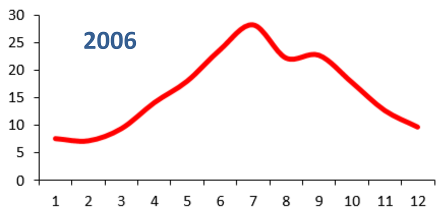
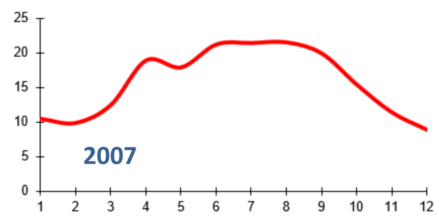


The soil moisture deficit (SMD) is also higher (i.e. the soil is drier) in October 2007 as would be expected with lower rainfall. In September 2006, the SMD was 97mm, and in 2007, 110.9mm.

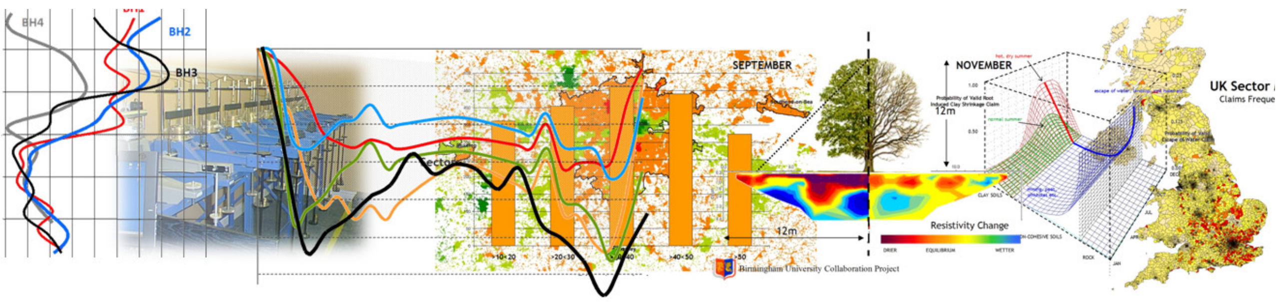




Left, the maximum temperature by month plotted for the two years.

2006 was a few degrees warmer throughout the months of August, September, October and November.

In summary, the main driver dictating when the peak subsidence occurs as a result of root induced clay shrinkage would appear to be rainfall, rather than hours of sunshine or temperature.



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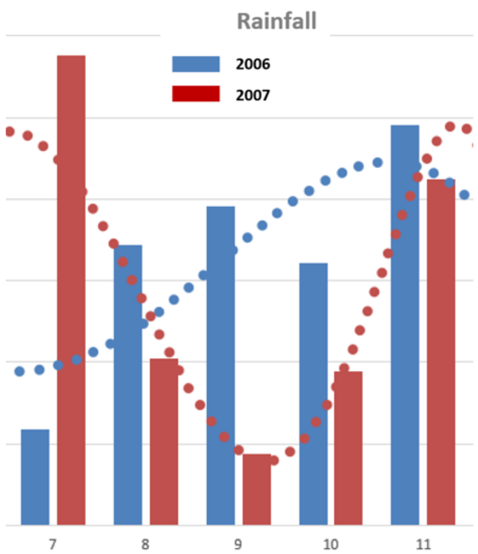
2006 -v- 2007 Rainfall Link to Ground Subsidence

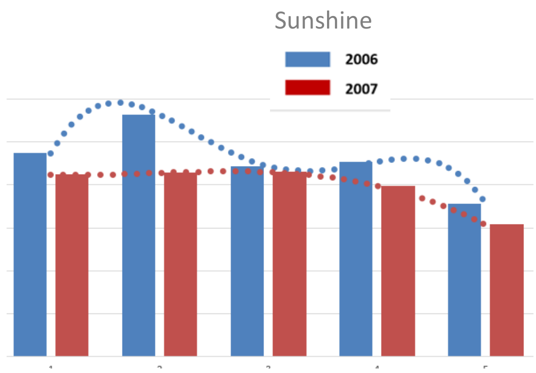
Rainfall by month for the years noted from July through to November (7 – 11 on the 'x' axis). The bar graph reveals that 2007 (red) was much wetter than 2006 (blue) in July, but afterwards, 2007 was drier in August through to November, inclusive.



The lines from the 6th order polynomial cross around August, with 2006 (blue) getting wetter and 2007 (red) drying.

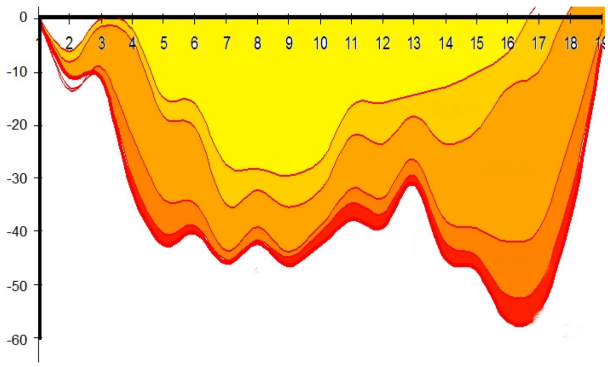
It would appear from the weather data that (a) rainfall is the primary driver and (b) absence of rainfall is the cause of delayed recovery in 2007.

Top, right, hours of sunshine for the months June through to October for the two study years. 2006 was nearly 7 degrees warmer than 2007 in July, and two or three degrees warmer in August, September and October.

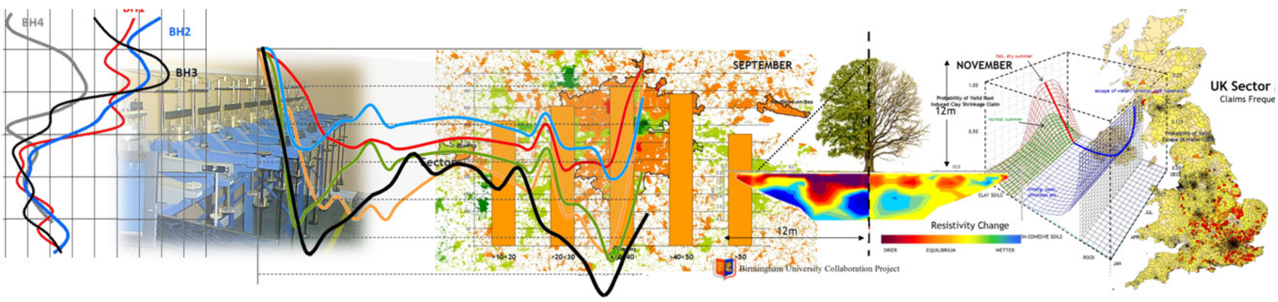


That being the case, we might have expected the period of subsidence to have been longer in 2006, confirming that rainfall is the key driver, rather than temperature.

By comparing weather data with cumulative movement across the root zone by month (sketch below) we hope to improve our understanding of the interaction between weather and root activity.



The issue around predicting event years is less clear. Tracking the SMD early in the year (late May and early June) 'sets the scene', but as has been seen over recent years, intermittent rainfall can interfere with longer term projections.

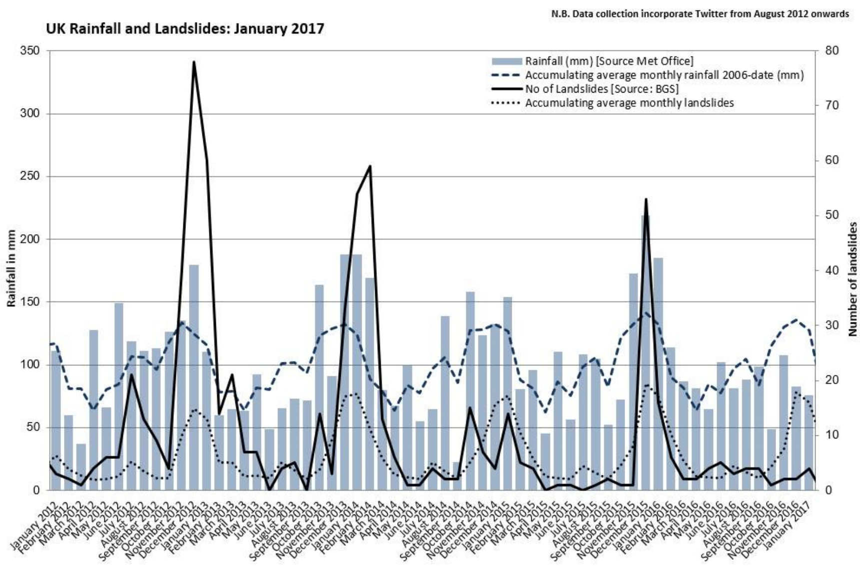


The Clay Research Group

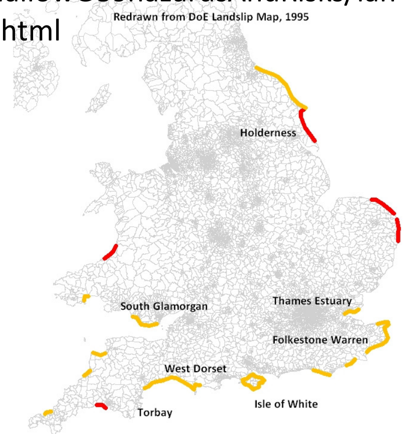
Landslip in Devon

Reports in the press of another landslip on the coastline of Devon. One of the occupiers living at Cliff Road, Sidmouth, Devon lost his garden shed. He said when he bought his house in 1997 the rate of erosion was around 10cm a year. Now that has gone up to around a metre a year.

Below, a chart produced by the BGS combining the incidence of landslip and rainfall, revealing a clear correlation between the two.



Above, graph produced by the BGS plotting the incidence of Landslides with rainfall.
http://www.bgs.ac.uk/research/engineeringGeology/shallowGeohazardsAndRisks/landslides/landslidesAndRainfall.html



Right, a map of coastal landslip around the UK produced by the Department of the Environment.

Rainfall reduces the friction between soil particles whilst increasing the weight of the soil mass. Combined with coastal erosion, further loss is likely associated with erosion at the base of the cliff.