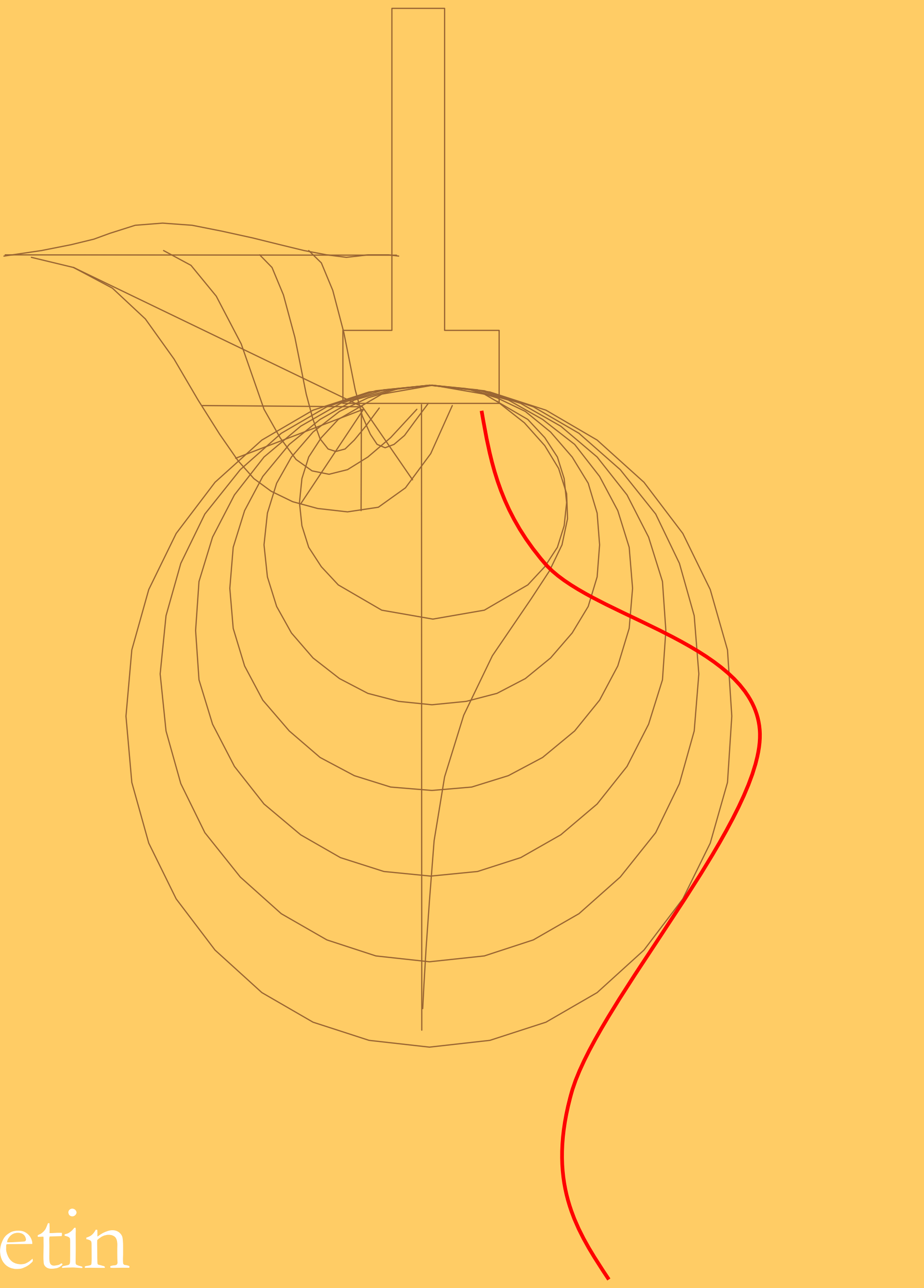
The Clay Research Group



Monthly Bulletin

The Clay Research Group

Aldenham SCHOOL

Supporting Research

CONTENTS

"DEAR DIARY …"

Articles in the Surveyor Journal and The Post this month relating to telemetry, and in the Horticultural press the month before looking at our work in the BioSciences.

Reassuring confirmation in the academic press of our suggestion that trees take up moisture early in summer which offers a possible explanation of how trees survive in the urban environment. With tarmac, paving and hard-standing everywhere, the ability to 'take a large drink' at the beginning of the year (following winter rainfall) and then survive on less throughout the summer is a great advantage.

The various threads of the work are coming together and delivering an insight into the way that climate and trees interact with soils in a way that we hadn't anticipated. The energy (climatic) to drive trees to take up moisture happens very early in the year usually. The tree responds vigorously initially, and then reduces the amount of moisture they take.

The intervening period is when we see the 'L/360' flexure taking place, setting the scene for September.

CRG Update

We have confirmation in the academic press supporting our findings that trees take up water earlier in the year than we may have previously thought. We arrived at our conclusions by deducting one months ground movement from the last. The article in *The Journal of Experimental Botany* puts the science to this. It was published in June 2007. The difficulty is the non-linear relationship that exists when we consider the water retention curve and the fact more suction is required to remove more moisture, but we appear to be on the right track.

This now leads us to another question. If ground movement takes place in the early months of summer, why do claims follow a few months later? Why is there an apparent time lag?

Ground movement sufficient to cause damage in clay soils takes place over months and we can only assume the period between early summer and damage appearing is the equivalent of the expiry of 'L/360' – the amount a building can flex prior to cracks appearing.

The structure is flexing and the cumulative movement manifests itself in late August and early September – although minor in relation to that which has gone before – it is the straw that breaks the camel's back. This has implications for the ground treatment project. It isn't always large changes in moisture and huge ground movement that causes damage, as we see in this edition.

We also have our missing link that explains why the SMD towards the end of May and beginning of June is so important in predicting whether it will be an event year or not. This is the period when most movement takes place. We knew there was a statistical link, but not the reason. Late May and early June are proving to be critical months. Richard Rollit updates us on Page 7.

In the last year we have defined when trees take up moisture (early summer), why (in response to small changes in soil moisture content), how (in cases of a persistent deficit) and the regulatory mechanisms in place that control this (ABA signalling). We have built qualitative methods of assessing moisture uptake by month and indirectly estimating the role of ABA taking into account climate change.

The CRG have also produced the first study of root activity sufficient to cause ground movement in the presence of a persistent moisture deficit. This hasn't been described before as far as we are aware.

Climate change – in addition to the excellent work by Southampton, we have a glimpse into the future at Aldenham, beneath both the Oak and Willow from the precise level data. There are persistent deficits beneath each, of the sort that will flow from climate change over the next 50 years.

The telemetry project is starting to deliver results. Electrolevels and moisture sensors are being deployed commercially and the numbers will probably double in the next 12 months as a result of the success of the DataREADER application. Case studies will be appearing regularly.

Ground treatment is the next challenge and the work described above was essential in providing direction. We know that small changes in moisture content at the end of summer can be critical. Most houses withstand the larger changes earlier in the year. The technique and method will follow.

Our understanding of the complex interaction between the soil moisture retention curve, micro-climate and ABA in the 'root to shoot signalling' mechanism continues to develop. Like many ecosystems, the mechanisms appear to be both complex and straightforward at the same time.

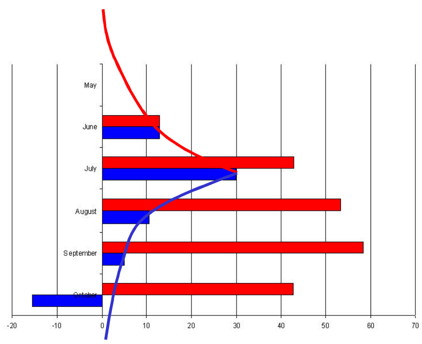
In this edition we publish the ERT images gathered by Glenda and bring the developing story of the CRG up to date.

The Clay Research Group

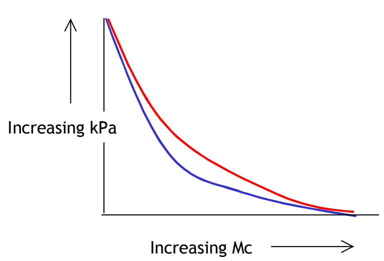
Moisture Retention Curves

Understanding how trees take up moisture allows us to build retention curves 'on the fly' for individual species on a specific (but still variable) soil type in different climatic conditions (global and micro-climate) taking account of the health of the tree – and it isn't rocket science.

The only drawback is, we need precise level data every month, and for every tree. A small price to pay if it means building a bespoke curve!



It takes account of hysteresis as we see below. This is the difference between wetting (blue) and drying (red).

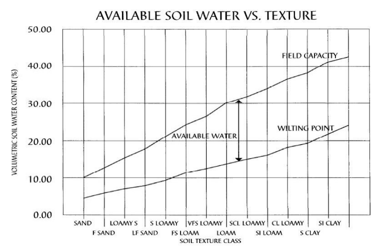


A water retention curve plots the relationship between the soil moisture content and matrix potential in the soil. At potentials close to zero (i.e. no negative porewater pressures), the soil is saturated.

Above we see the curve for the Aldenham Oak where we have both suctions and moistures. The relevance? It helps support our theories about moisture uptake early in the year. If the retention curve works, it is another piece of supporting evidence.

Available Moisture

This graph appeared in last months newsletter. It provides some indication of field capacity and wilting points for a variety of soils.



For the highly shrinkable London clays we estimate a volumetric Mc at field capacity (depending on PI) of around 50% at Aldenham, which corresponds with a moisture content at Wilting of around 25% looking at the table.

The wilting point is around 1,500kPa.

On to ABA

Which brings us – as ever – to ABA. It is clearly triggered by very small changes in soil suction and this was borne out by the study in last months newsletter where we saw the ground responding very early in the year to moisture change.

The drier the soil, the quicker the response.

If the tree takes a huge gulp in June or July (as seems to be the case) but the negative porewater pressures in the soil aren't at 'wilting point', then self-evidently something is shutting water uptake down. The tree doesn't die.

We have to conclude it is being regulated.

We suggest that 'something' is the water retention properties of the soil triggering the production of ABA.

This mechanism is finely tuned and almost certainly contains a great deal of genotypic variation which will include the capacity to pump water efficiently (as in the case of the Oak) and hormonal control to send out roots to acquire moisture from further afield.

Ground Movement

So, the question arises if ground movement takes place early in the year, why does it take two months for cracks to appear? Why do we see claims being notified in September?

To understand this we have to ask the opposite question. Do buildings flex and then crack in a very short period of time? Less than a month? Maybe a week?

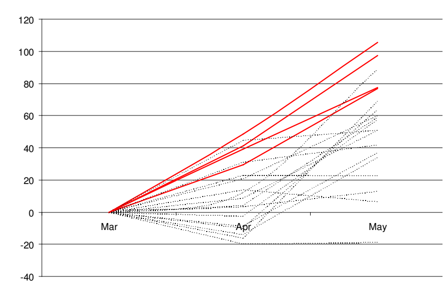
No, published work tells us buildings flex by 'around 'L/360' where L is the length of the wall. The actual figure isn't important here because it manifests itself in the form of staggered notifications, but we can take the period between late June and the middle of August as the period in which this flexure takes place.

All buildings on clay soils with trees nearby move seasonally. It takes a very small amount of change for cracks to appear. It is that finely balanced.

Predictive SMD

As the theory evolves we see how important the spring and early summer months are in establishing the relationship between climate and tree moisture uptake.

Statistically there is an apparently robust relationship between the SMD at the end of May and ensuing event years. Below we see how the gradient of the slope at that time has been used to predict surge.



The red lines indicate the slope of the line between April and May for 1990, 1995, 1996 and 2003. All busy years. Although the gradient is a factor, it is the values that deliver the energy quotient sufficient to enable the trees to move the ground.

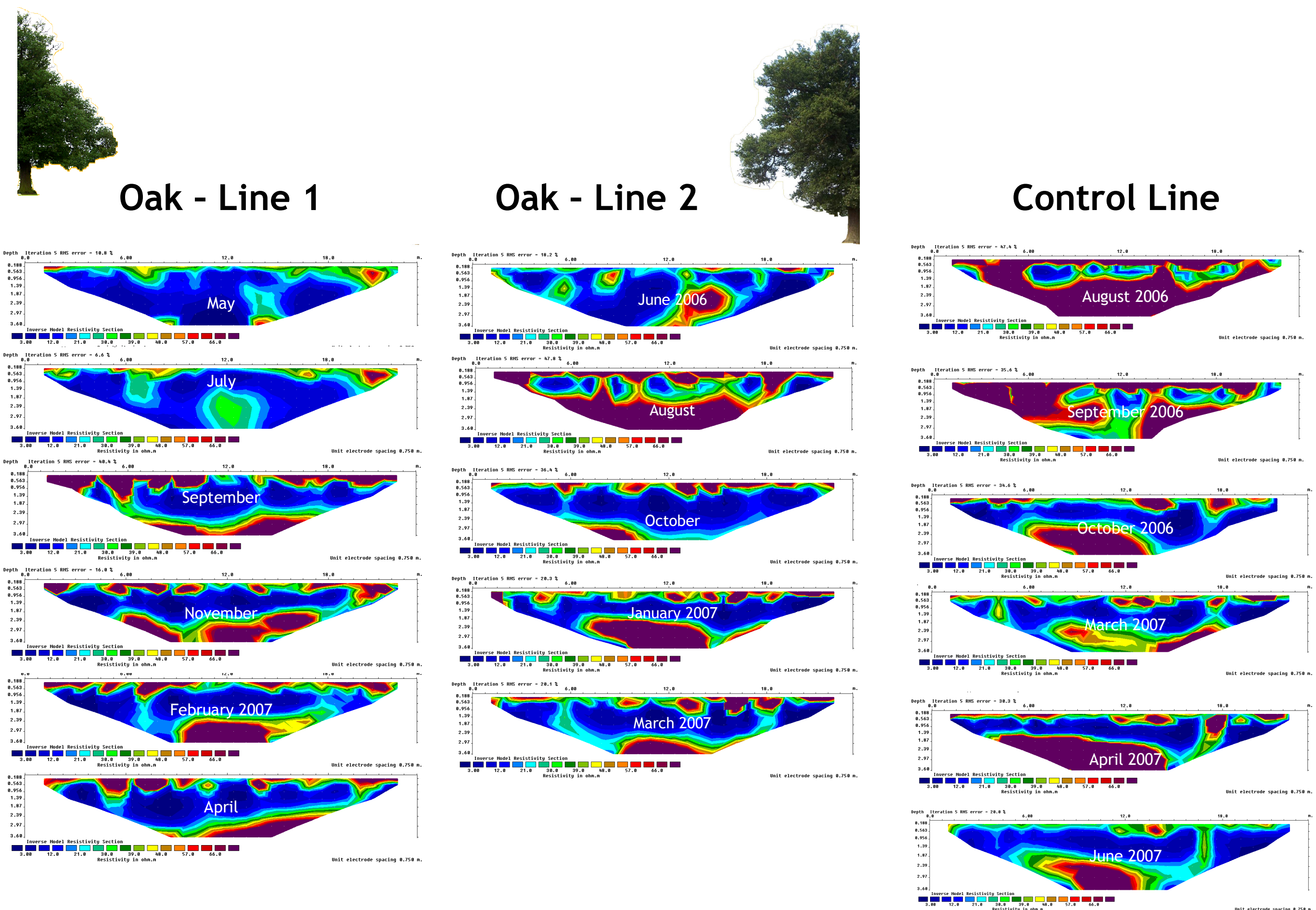
WHO IS PAYING?

InFront Innovation (IFI) are the main funding agency of the CRG. They have also contracted with Keele to provide support for the PhD work relating to the ERT element we see reproduced here. The project is half way through the second of a three year term and happily IFI are willing to share the output with the industry. IFI also meet the cost of the project leader and consultancy in the supervision of the work and production of the newsletter.

Addressology Ltd., contribute some of the output of their work where it might be of general technical interest and again, sharing is part of their philosophy. **Crawford** fund the cost of electrolevels and TDR sensors along with the significant contribution made by Richard Rollit. They also provide case studies – most of the published examples come from Crawford. They also fund the precise levels, undertaken by GeoServ. Paul Thompson of **Marishal Thompson** has purchased the original weather station and is paying for the upgrade.

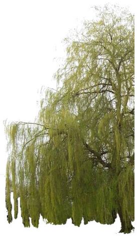
Aldenham School have provided the site, ongoing access and arranged for a meeting room with catering from time to time. Many consultants have contributed their time towards correcting our mistakes and providing positive guidance. **Southampton**, **Keele** and **Birmingham Universities** have all made significant contributions in terms of time and effort. **MatLab** undertake a variety of investigations and tests throughout the year, together with laboratory testing.

ERT Imagery – Aldenham Oak

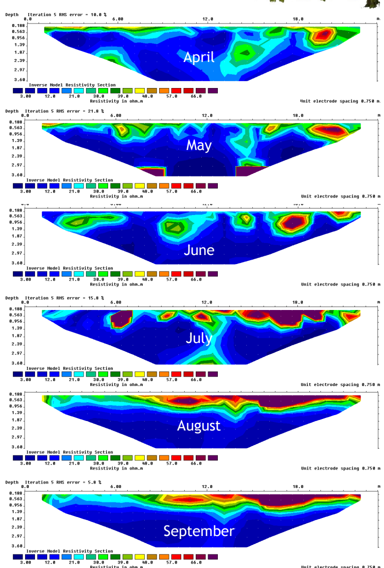


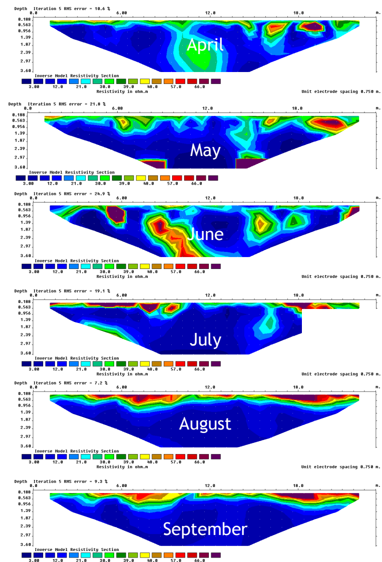
Extracts from the ERT images for Lines 1 and 2 of the Aldenham Oak showing the change by month from May 2006 through to the winter of 2007 where we have data. The control line – initially hoped to be remote from root activity but most probably in the heart of it – shows the significant change over seasons. We see the dark areas associated with desiccation in August changing to the more blue tones associated with rehydration in March before returning to a drier state.

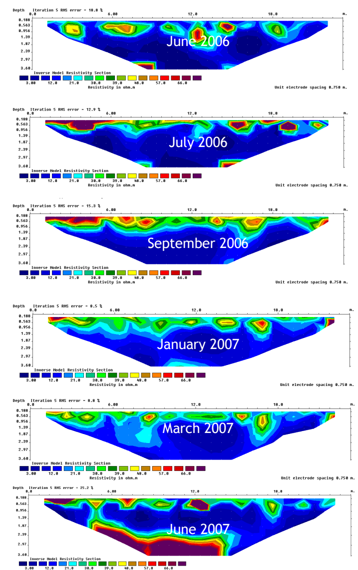
ERT - Willow



Line 1 **Line 2** **Control Line**





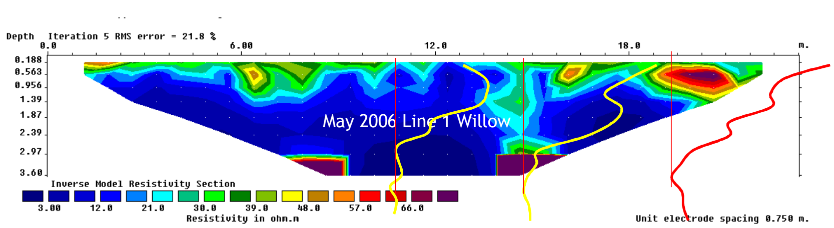


The data from April through to September 2006 for Lines 1 & 2 are shown above. The tree is to the right in both instances.

Line 1 picks up the shallow desiccation beneath the tree canopy but it doesn't capture the full depth of the persistent deficiency as described by the site investigations.

The shallow zone extends in the summer as we would expect and is more likely to be related to evaporation and superficial root activity.

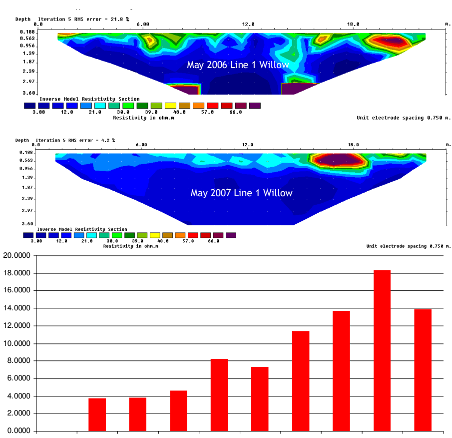
Line 2 fluctuates around the mid-point in June which assume is an anomaly but otherwise picks up the superficial desiccation which increases towards the root periphery, corresponding with the level readings.



Above we compare the strains from testing undertaken in May 2006 which indicates that desiccation extends to a depth of around 4mtrs close to the tree, reducing slightly in BH3, sunk close to Station 6 of the level survey.

Below we plot ground movement (red bar graph) aligned with data from the ERT array, taking a snapshot comparing May 2006 and May 2007.

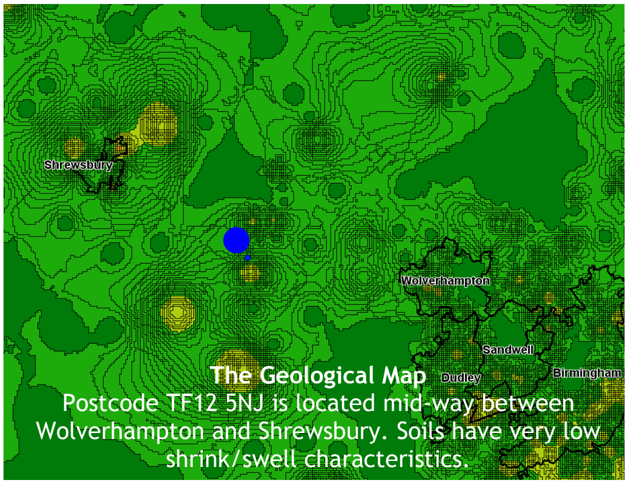
There was significant recovery in May 2007, as we see to the right of the graph.



Case Study – Claim in TF12 5NJ

How we use the geology map, Triage and DataREADER applications

Step 1. Locate the property on the geological map to establish the shrink swell characteristics and assess the likely risk. In this case we see the risk is low with values less than 10%.



The Geological Map
Postcode TF12 5NJ is located mid-way between Wolverhampton and Shrewsbury. Soils have very low shrink/swell characteristics.

Step 2. Understand the claims history using the Triage application. Here we see high claims frequency and a likely cause of escape of water – a leaking drain. This is the assessment made before visiting the site.


TRIAGE

Home | New Claim | Reports | Contribute | Information | Applications | Logout

Claim Details - CRG Newsletter — Search For Claim: [ ] Find

Address:	Sample DataREADER	Claims Frequency:	High
	Telford	Probability Valid Claim':	Medium
	Shrewsbury	Soils Risk:	Medium
Postcode:*	TF12 5NJ	Possible Diagnosis:	Escape of Water

Step 3. If monitoring is required, use telemetry. See the output below. Two stations are fairly static and one is moving significantly.

Station 1. The red graph is increasing linearly, showing no sign of seasonal (i.e. cyclical) movement. Variance = 0.146 > 0.1, suggesting the movement is structurally significant. Fitted to right hand wall of porch. Cracks between porch and house wall in this locality.

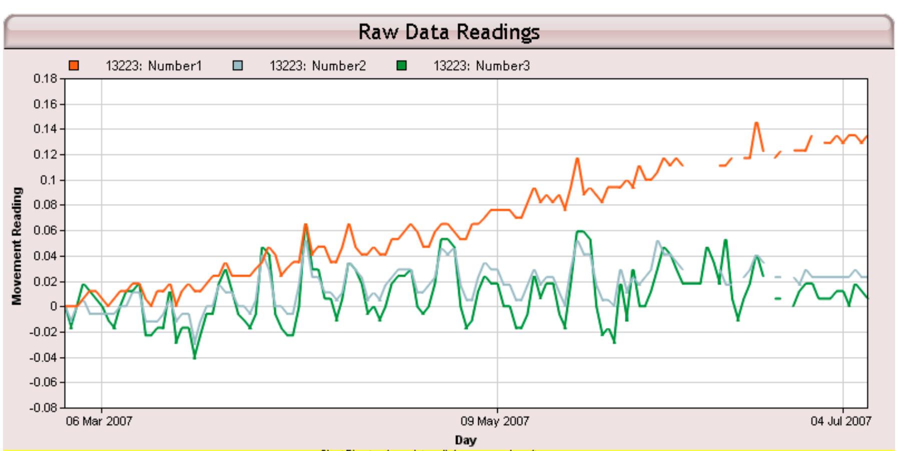
Station 2. Variance = 0.082 < 0.1 and not indicative of structural movement. Fitted to left-hand wall of porch. No damage on this side.

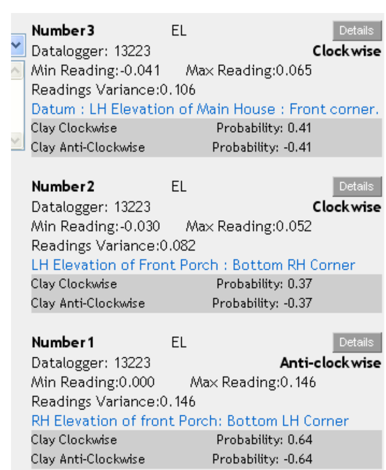
Station 3 is the Datum and we see no significant movement. Variance is 0.106 > 0.1 however a visual scan shows this is due to an irregular signal, and doesn't reflect a trend. It can be discounted. Stations 2 & 3 follow a similar patterns.

Conclusions

Stations 1 and 2 are fitted either side of a damaged porch and the absence of movement at Station 2 suggests that the cause must be very localised – situated near to the right hand wall of the porch. A leaking drain maybe, or some soft ground.

Investigations revealed a leaking drain, which was repaired.




Number3 EL Details
Datalogger: 13223 **Clockwise**
Min Reading:-0.041 Max Reading:0.065
Readings Variance:0.106
Datum : LH Elevation of Main House : Front corner.
Clay Clockwise Probability: 0.41
Clay Anti-Clockwise Probability: -0.41

Number2 EL Details
Datalogger: 13223 **Clockwise**
Min Reading:-0.030 Max Reading:0.052
Readings Variance:0.082
LH Elevation of Front Porch : Bottom RH Corner
Clay Clockwise Probability: 0.37
Clay Anti-Clockwise Probability: -0.37

Number1 EL Details
Datalogger: 13223 **Anti-clockwise**
Min Reading:0.000 Max Reading:0.146
Readings Variance:0.146
RH Elevation of front Porch: Bottom LH Corner
Clay Clockwise Probability: 0.64
Clay Anti-Clockwise Probability: -0.64

EXTRACT - *Journal of Experimental Botany*

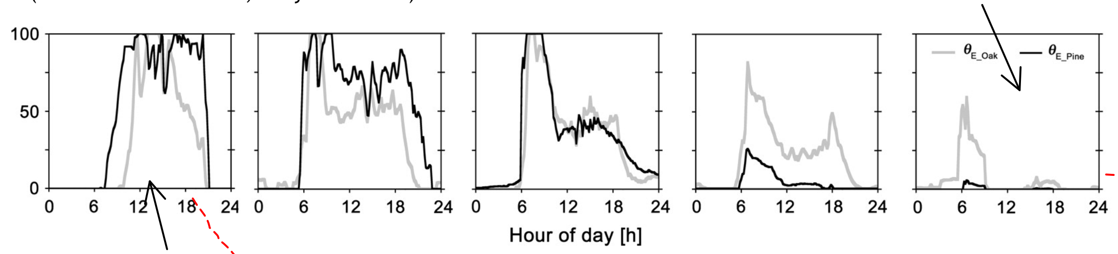
The following article is particularly relevant to our work and compares stomatal response to drought stress in Scots Pine and Oak. We better understand how stomatal regulation works without causing distress to the tree. Fine control, driven by prevailing climatic conditions is the key and in the top image (below) we see how the stoma open for longer on a cloudy day in a wet period, almost closing completely on a dry day, in a dry period. Although climate is undoubtedly an important factor in this mechanism we can only assume it triggers hormonal control.

The lower pictures show how the Oak tree maximises opening of the stomata in relation to water potential on a wet day, opening early and generating a huge water potential very quickly, but taking an altogether steadier approach in dry weather. The authors also confirm our own findings when they report there is "reduced physiological activity from mid-July onwards". Something we have described in our 'water abstraction by month' graphs. See below for their comments.

Stomatal Aperture

(Dark Line - Scots Pine, Grey Line - Oak)

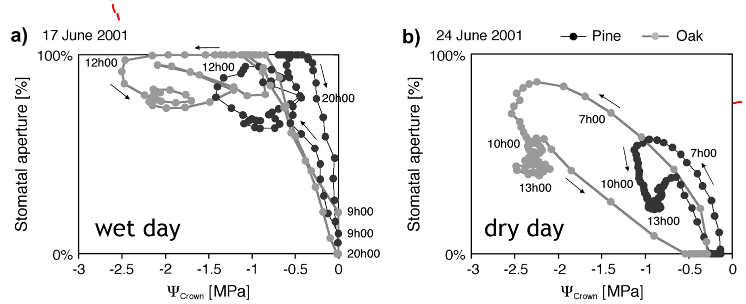
10 July 2003 - sunny day in an extremely dry period



13th July - cloudy day in a relatively wet period.

Stomatal Activity

Opening and Closing -v- Water Potential – Hysteresis Curves



To the left the stoma open very quickly and reach high water potentials when there is available water. In contrast, note the very slow opening and reduced water potentials when there is not.

This paper describes the relationship between stomatal opening and closing with water potential for two species of tree – Pubescent Oak and Scots Pine – with a view to modelling their response to drought stress. The data corresponds with our findings for the Oak at Aldenham in terms of water uptake and confirms that stomatal regulation need not cause damage to a healthy tree.

Stomatal Regulation by Microclimate and Tree Water Relations: Interpreting Ecophysiological Field Data with a Hydraulic Plant Model

Roman Zweifel[1,4,*], Kathy Steppe[2] and Frank J. Sterck[3]

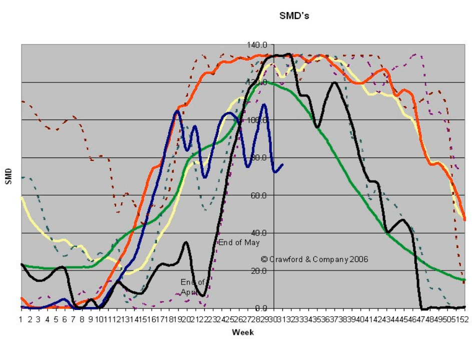
*"During the extreme drought in 2003 (Beniston, 2004), Pubescent **oak** and Scots pine (like other **tree** species in this area) dramatically reduced their physiological activity from mid-July onwards (Zweifel et al., 2006). The leaves of **oak** either turned white from one day to the next or they showed early leaf senescence like that usually observed in autumn." - Journal of Experimental Botany*

SMD Plays a Part

Now we can link in to SMD. Richard Rollit confirms "statistically there is a strong correlation between SMD values for tile reference 161, medium available water capacity (AWAC) with grass cover and claim numbers.

If the SMD rises rapidly in the early months – and the end of May is critical – we can see how the combination with the tree-water uptake has an influence on claim notifications.

A high SMD early in the year initiates the response of the tree.



Richard Rollit has provided this guide showing SMD profiles for a variety of years. We see the pattern is set early in the year, often peaking around the end of June, beginning of July. Event years extend over longer periods as we see from the red line.

The ingredients of the SMD (hours of sunshine, temperature, wind speed, rainfall and humidity etc) are causal factors, driving the tree to respond by taking up water earlier. This isn't an 'either or' haphazard choice. The greater the SMD, the greater the water uptake by the tree – or so it appears."

The exception to the 'May is the indicator' rule was 2006 which started much later as we see from the black line in the graph above. The steep gradient and peak values delivered the energy needed to trigger a late rise in claim numbers which soon tailed off. There will be exceptions to any rule that seeks to resolve the interaction of natural elements and whilst 2006 might illustrate this it is another 'signature' that we can add to our predictive library.

SMD is essential part of any model and Crawford use a week-by-week feed from the Meteorological Office - Richard is co-ordinating this aspect of the research.

Ground Treatment

Ground treatment that takes account of this cycle – how the trees link into the climate and how they react to the soil drying – is going to involve medication of the tree. Trying to change the water potential of the soil without reducing the water uptake of the tree isn't going to deliver a practical solution. We have to concentrate on the tree.

Direct soil treatment has many drawbacks as we have seen from our own work in the laboratory over the last 12 months. Sometimes the treatment has caused more ground subsidence than the tree. And then we have the ground contamination problems associated with PEG, salination etc.

Electrokinesis offers a possible solution – flocculation of the soil and movement of the water away from roots would be beneficial – but we don't see this as a practical application for routine domestic subsidence claims.

Instead we will attempt to 'water in' taking advantage of the twin benefits this offers.

Rehydration to restore the building to its original condition as quickly as possible, accompanied by buffering the xylem pH using the same medium to switch the tree off.

The rehydration treatment has to be targeted close to the house, in the region of the damaged foundation. The introduction of the buffer can be anywhere within the root zone.

The work on PRD (see last edition) suggests partial wetting is in fact advantageous – ABA is being produced in response to the roots in dry soil and then uploaded via the xylem using water taken from the rehydrating zone.

In summary, our proposals are simple.

They take account of the needs of the building and the tree, seek to medicate the tree naturally whilst allowing it to be retained – in the short term at least.

If successful we will deliver a prompt solution for many cases, at a significantly reduced cost and within a sensible timeframe allowing negotiations between the tree owner and the insurers to be concluded amicably.

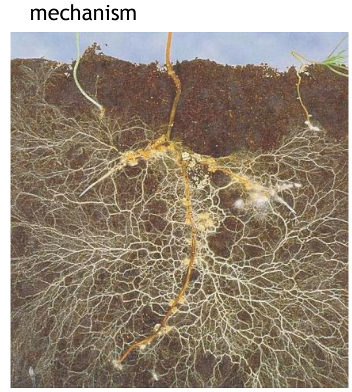
Mycorrhizal Symbiosis

Mycorrhizal symbiosis has been shown to modify host hormonal relations so it's relevance in terms of stomatal control and moisture uptake is central to our theme.

They are a commonly occurring fungi associated with roots, taking nutrient from the tree, and in return, sourcing nutrients from the ground.

Robert M. Auge summarises their role as follows:-

1. assist leaves to maintain a more normal water balance (closer to responses of unstressed controls), and fix more carbon, during drought stress
2. improve transpiration at similar, low soil water potential
3. appeared to be linked to changes in leaf osmotic potentials.
4. scavenge water of low activity more effectively or influenced so-called non-hydraulic root-to-shoot communication differently
5. rose plants having divided root systems - one half nonmycorrhizal, one half mycorrhizal - displayed different stomatal conductances upon partial drying, depending on whether mycorrhizal or nonmycorrhizal roots were dried
6. Phosphorus nutrition was probably not involved in the mycorrhizal mechanism



The Mycorrhizal benefit includes sourcing nutrients from 1m away from the root tip – including moisture uptake as a transport medium.