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

The Clay Research Group
www.theclayresearchgroup.org

March 2009

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Acceptance Month

Glenda's paper, entitled "Imaging and Monitoring Tree Induced Subsidence using Electrical Resistivity Tomography" has been accepted for publication in **Near Surface Geophysics** and should appear around June – coinciding with her final interviews for her PhD so our best wishes.

Allan Tew has been formally accepted for an external EngDoc (alongside some stiff competition) degree with the title *"The Repair of Subsidence Damage – Innovation in the UK"* and commences in March of this year.

Contact Us

splante@hotmail.co.uk

Annual Subsidence Conference

ASTON UNIVERSITY

18th June 2009

To make a booking please telephone…

Helen Mallinson 0121 204 3593
or
Claire Wallis 0121 204 3624

E-mail:-
cpd-seas@aston.ac.uk

If you would like to submit a paper for the conference, please E-mail an outline to m.sadegzadeh@aston.ac.uk

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SITE MEETING

We were pleased to welcome representatives from some of the London Boroughs and Jim Smith, chair of the JMP, to Aldenham, along with our old friend, Peter Osborne – see below.

From left to right, Dr. Allan Tew, Ian Brett-Pitt, Richard Rollit, Jim Smith, Peter Osborne, Jake Tibbetts (Islington), Andy Tipping (Barnett and outgoing Chair of LTOA), Kishan de Silva (consulting engineer) and Cyril Nazareth.

We walked over the research site and explained our proposals for testing the Intervention Technique, planned to commence early this year.

The tree officers pointed out that the Oak was already in a stressed state due to its age and the build-up of a persistent moisture deficit which accounts for the branch fall in May 2007. We estimate the crown suffered a 25% reduction.

They thought this might make comparisons with earlier years difficult. Hopefully the fact that we have two years data subsequent to this won't spoil the exercise.

It was agreed that continuing with this particular tree would be useful, and we have put together a proposal which is currently being presented to Aldenham and the funding parties.

Correction

In last months edition we referred to Jim Smith, the London Trees and Woodland Framework Manager, as the instigator of the Joint Mitigation Protocol. The honour should have gone to John Parvin of Zurich Insurance, and former Chair of The Subsidence Forum. Jim Smith is the current chair of the JMP. Our apologies.

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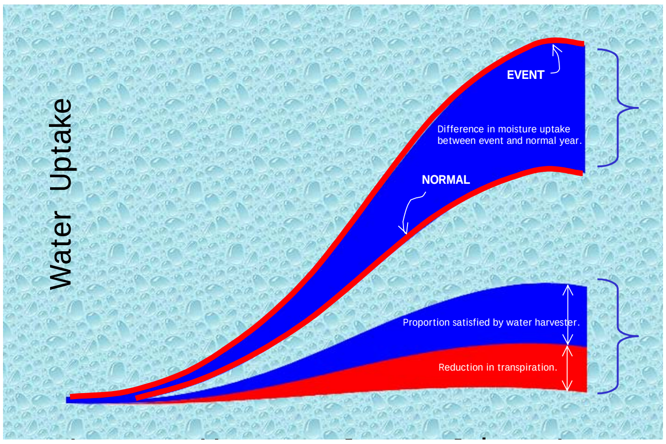
Water Uptake

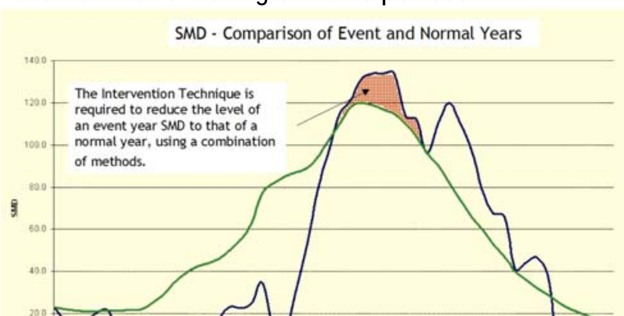
The Intervention Technique can't satisfy the entire needs of the tree in terms of water supply in event years. Instead, it attempts to replicate the condition that exists in normal years, 'knocking the top' off the water uptake curve. See below.



The 'y' axis represents the cumulative moisture uptake in the early part of the year – the most significant period as we see on the following page.

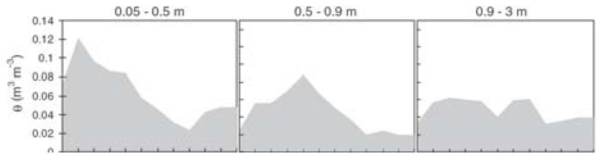
Water harvesting would contribute towards the deficit – the amount is indicated diagrammatically by the blue area at the bottom of the image. The red portion shows the benefit from a reduction in transpiration by raising the pH within the tree and PRD.

These figures are qualitative only and the proportions are estimates based on relative ground movement for differing climatic periods.



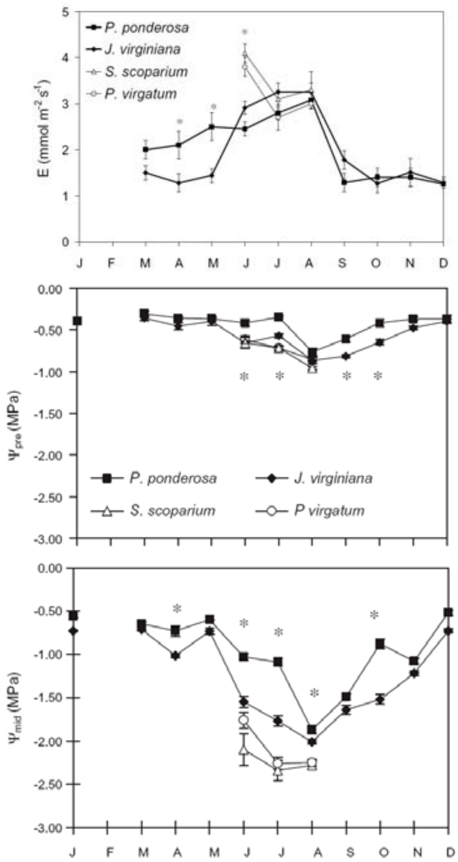
To model water uptake by the Aldenham Oak we have used the SMD Neutron Probe data – Page 4. What was the uptake of the Oak to lower the ground level by 'x' amount in a soil with known PI?

The following has been taken from *"Seasonal Changes in Depth from Water Uptake for Encroaching Trees and Two Dominant C4 Grasses"*, Eggemeyer et al, Tree Physiology, Dec 2008, exploring moisture changes in two trees (pine and cedar) and two varieties of grass.



Above is water uptake by month, from 3 depths below ground, for the trees, **bearing in mind they are pine and conifer.** Water from shallow depth is abstracted early in the year, and diminishes towards late summer. Water at depths of between 0.9 and 3mtrs bGL show a fairly regular uptake.

Below is a record of transpiration rates throughout the year for the trees and grasses. At the bottom of the page are water potential differences between pre-dawn and mid-day.



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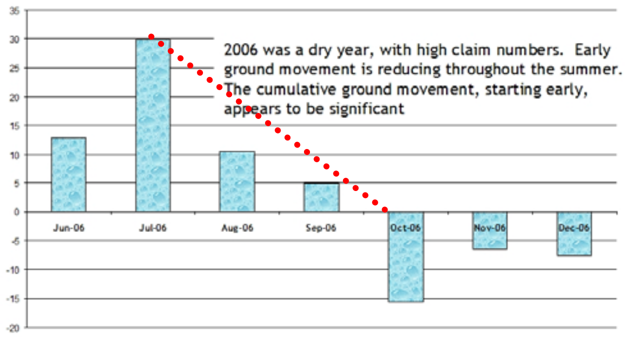
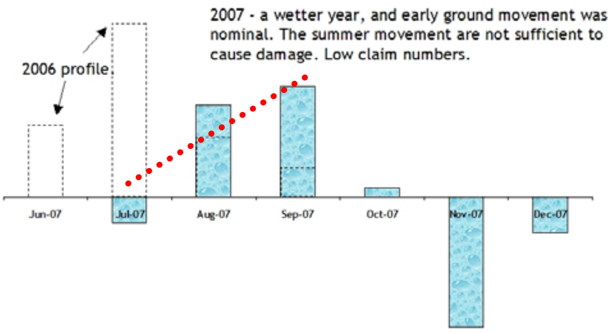
Wet Year, Dry Year

Revisiting the precise level data to see what could be determined by comparing a dry year with a wet year, and using the ‘by month’ differences in ground movement produced the following graphs.

Below we have plotted the data from the site of the Willow in 2006 (top) and 2007 (bottom), and we see that in a dry, high claims year, “ground movement by month” commences early, diminishing towards the time of maximum notifications, which seems counter-intuitive.



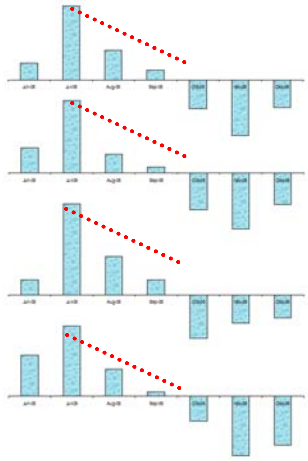


In contrast, in a wetter, ‘low claims’ year we see a different pattern, with ground movement rising in the summer. See above.

The amplitudes differ but the over-riding consideration appears to be the early start, reinforcing the role of the Soil Moisture Deficit (SMD) values in predicting the late summer claims.

If this is so, the movement in August and September in a dry, event year, however small, is ‘the straw that breaks the camels back’, and not the cause. That appears to lie in the earlier movement.

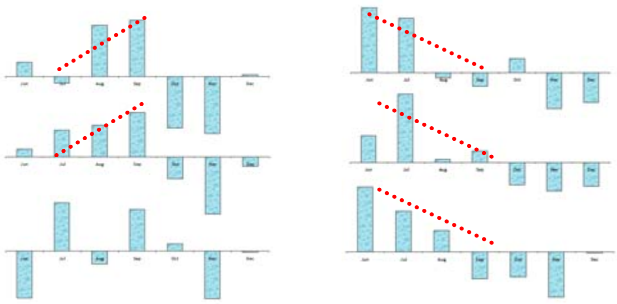
We then plotted the pattern across several individual stations for the Willow – see below. All revealed a similar pattern.



Comparison ‘By Month’ Ground Movement Profiles from Various Stations across the Willow Footprint Showing the Consistent Pattern in a Dry Year - 2006.

How would the profile develop with a different tree, and variable soil conditions? Are the findings unique to the Willow?

Apparently not. Looking at similar readings across several stations around the Oak tree on a mixed soil type (clay and abundant gravel lenses) reveals similar profiles.



Oak - Wet Year   Oak - Dry Year

Above, left we see ‘difference by month’ ground movements increasing towards the summer in a quiet year, but diminishing in a busy claims year.

It would appear that the ground movement measure is a good predictor. This simplifies to the reading in June/July. We don’t have to wait until September. As with the SMD readings, the scene appears to be set early in summer, shortly after the tree comes into leaf.

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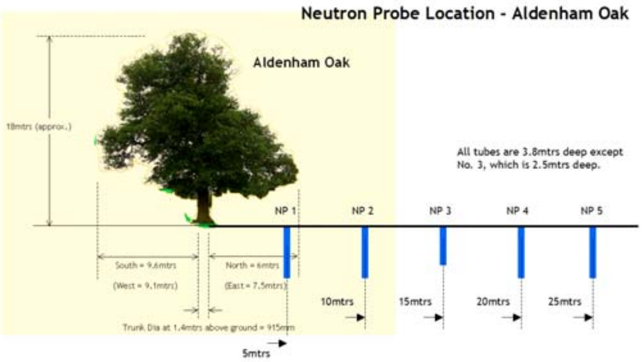
Neutron Probe Data Supplied by Southampton University

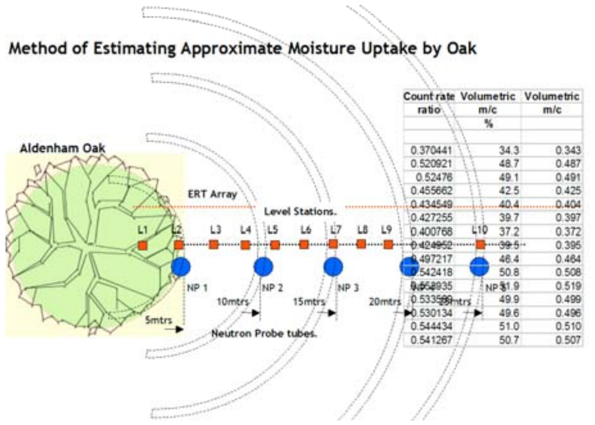
Calculating Water Uptake

We were wondering just how much water the Aldenham Oak drinks in the course of a year and have referred to the Neutron Probe data supplied by Southampton University to try and find out.



Briefly, five tubes were sunk into the ground, and volumetric moisture contents obtained over a two year period as part of the Climate Modelling research program being undertaken by Dr Derek Clark and Dr Joel Smethurst.

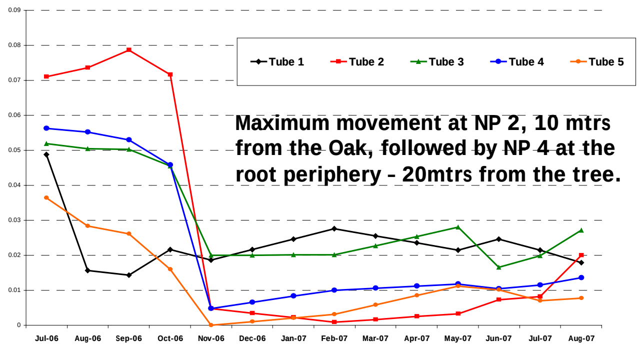
The tubes were sunk at 5mtr centres to a depth of 3.8mtrs bGL, apart from Tube NP 3, which met struck gravel and terminated at 2.5mtrs.



Count rate ratio	Volumetric m/c %	Volumetric m/c
0.370441	34.3	0.343
0.520921	48.7	0.487
0.52476	49.1	0.491
0.455662	42.5	0.425
0.434549	40.4	0.404
0.427255	39.7	0.397
0.400768	37.2	0.372
0.424952	39.5	0.395
0.497217	46.4	0.464
0.542418	50.8	0.508
0.552935	51.9	0.519
0.533580	49.9	0.499
0.530134	49.6	0.496
0.544434	51.0	0.510
0.541267	50.7	0.507

Taking each station in turn, we see the maximum change between the summer and the winter of 2006 took place at NP2, 10mtrs away from the Oak trunk.

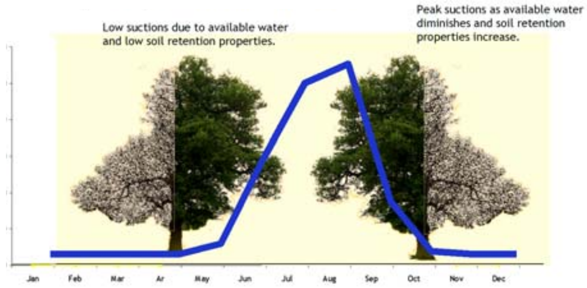
Little change took place closer to the tree at NP 1 where we see a persistent deficit, and further away, at NP5 at the root periphery. The intermediate stations, NP 3 (the shallow tube) and 4, saw intermediate change.



Tim Freeman kindly provided a method of estimating water uptake based on volumetric measure. By multiplying the soil/root volume by the change in volumetric moisture we can estimate the water uptake. Our average 7.3% moisture deficit in π x 25^2 x 1.2m average volume of soil = 0.073 x 2,355m^3 = 172 m^3 – 172,000 ltrs in a year.

In the dry summer of 2006, we estimate the Oak consumed around 1,000 ltrs of water a day **in excess of the field capacity** (i.e. if it rained all day, the moisture uptake from SMD values self-evidently can't be estimated economically). This loss would fluctuate by day and by month, peaking at around 2,000 ltrs a day in August.

The uptake in 2007 – a much wetter year - would have been more but the ground movement less.



The problem proved to be complex and we take comfort from the Giles Biddle's, "Tree Root Damage to Buildings" when he says *"It becomes a meaningless exercise to try to calculate the amounts of water which might be lost from a tree. Water loss will always be heavily dependent on water availability"*.

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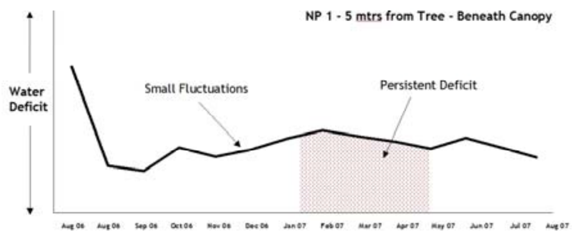
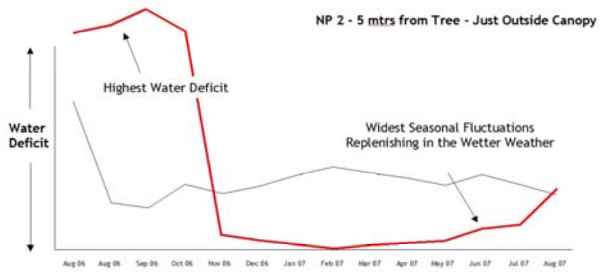
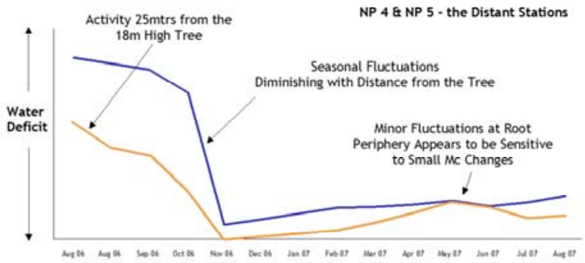
Neutron Probe Data Supplied by Southampton University

Station by Station

Below we plot each station in turn to show their maximum deficits. NP1 closest to the tree and beneath the canopy has a persistent deficit as we might expect. The tree is over 100 years old.



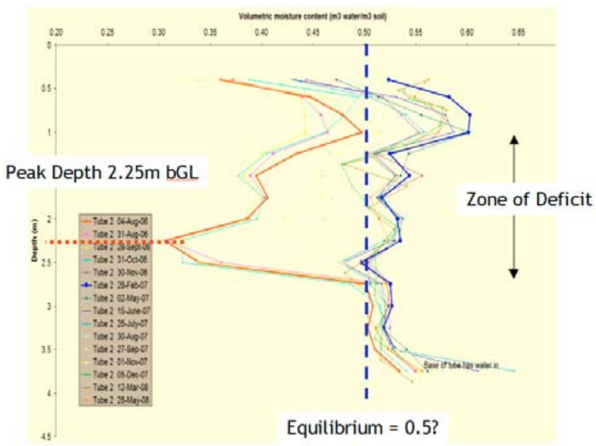




Station NP 2 undergoes the widest moisture change and this is located just outside the canopy. The plot provided by Southampton recording change is shown at the head of the next column. We can see the difficulty in calculating the moisture uptake with the fluctuations even at one location.

The change diminishes with distance away from the tree as we see at Stations NP 4 and NP 5.

NP 2 - Change Between Aug 2006 and Feb 2007



Above are the general characteristics of the profiles. This is the plot of NP 2 (just outside the canopy and nearest to the 'drip line') which shows the widest seasonal fluctuations with the soil rehydrating completely, recovering in one season.

The 'equilibrium' volumetric moisture content is estimated to be around 0.5 (50%) and the depth of the deficit extends down to nearly 2.75mtrs bGL.

The ground evaporation deficit can be seen at the point of contraflexure, extending down to between 750 and 900mm bGL. The presence of a 'point of contraflexure' at this depth in nearly all of the readings suggests we can distinguish between root induced desiccation evaporation.

On Page 7 we have plotted all of the stations and superimposed very approximate stress isochrones to plot the influence zone of the tree, revealing the depth of desiccation. The zone diminishes with distance from the tree and follows a fairly regular pattern, peaking just beyond the canopy.

Bearing in mind we are dealing specifically with the Oak, the distance of root activity extends well beyond the tree height, reaching a distance in excess of 25mtrs. The tree is 18mtrs tall.

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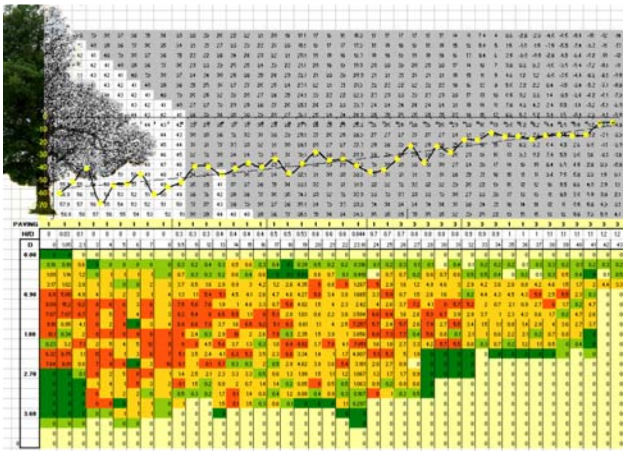
Estimating Ground Movement

The SMD values per station should follow ground movement profiles and using a water shrinkage factor (wsf) of 4, looking at NP 2 (the station with most change), the difference in SMD between September 2006 and Feb 2007 is around 200mm, suggesting ground movement of 50mm or so.

NP 2 is situated between Level Stations 4 & 5, where 40mm of movement has been recorded using precise levels.

Using volumetric moistures the anticipated ground movement over 2mtrs would be 2,000 x 0.073 (Page 4) = 140mm, and then applying the same wsf = 140mm / 4 = 35mm.

There is a reasonable agreement between the various approaches at NP 2 given that we are dealing with trees, soils and climate.



Above, the Disorder Model delivers an estimate of ground movement of around 40mm, taking into account species, climate and soil type.

Neutron Probe Data and Trees

"Tree Root Damage to Buildings", 1998, by Giles Biddle (Willowmead Publishing) contains far more detail on moisture change. The two volume technical reference explores soils (investigations and testing), climate (including the use of SMD), root induced moisture change and is highly recommended. Contact Giles for copies on biddle@willowmead.co.uk

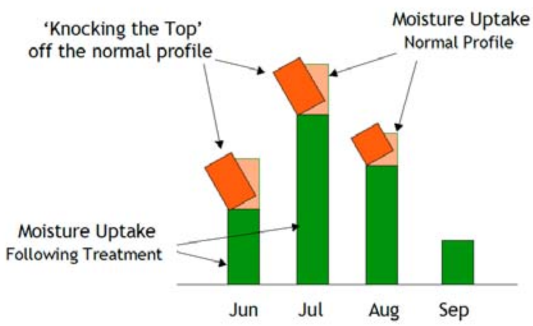
The Relevance?

This work sets the background to understanding how the Intervention Technique can best be employed.

Without some understanding of the depth of desiccation, the location and duration, designing a solution would be difficult.

Our objective in recognising that the tree takes up most water early on in the year is to interfere with the opening and closing regime of the stoma. They would normally be fully open in the wetter period but by raising the xylem pH, we hope to control this mechanism early in the year.

Stage 2 is 'knocking the top off' the moisture abstraction curve in dry event years – see Page 1.



Increasing the water retention properties of the soil, but allowing moisture release at times of peak demand satisfy the roots over time, and avoids quick drain-down.

Which brings us back to the graph on Page 2 entitled "Water Uptake" and reinforces the fact that we don't have to achieve any degree of accuracy. It is a broad brush solution - hopefully.

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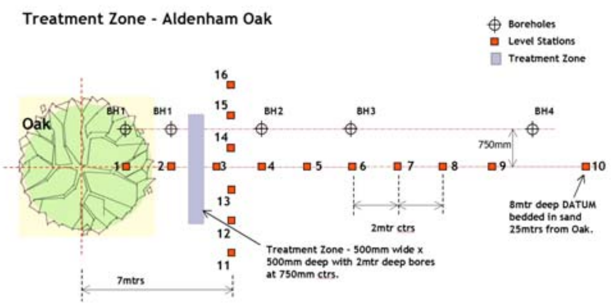
Treatment Zone

To test the efficacy of the Intervention Technique we are arranging for an installation at Aldenham, about 5mtrs away from the Oak and between the tree and levelling stations 11 – 16 (see below).

These stations were set up to emulate the front house wall of a typical property and the arrangements would put the zone to the front of the garden of a commonly encountered street-tree situation.



Comparing ground movement with readings over the last few years we hope to be able to determine whether the treatment has delivered a material benefit. The objective is to reduce movement to a level where the tensile resistance of an average building can cope, without cracks appearing – around 15 - 20mm.

We can also compare levels either side of the tree to see if there is a statistically significant difference from previous years.

Our installation is self-contained with anti-flood valves, a water harvesting chamber and access to top-up the minerals if required. We aim to achieve a partial root drying (PRD) zone 'in reverse' by wetting one side of the root zone.

The naturally occurring minerals will form part of the treatment. The objective is to increase the xylem pH to enhance and reinforce the effectiveness of ABA – the self-medication element of the treatment – and the PRD (a) increases ABA production whilst (b) delivering it to the leaves effectively.

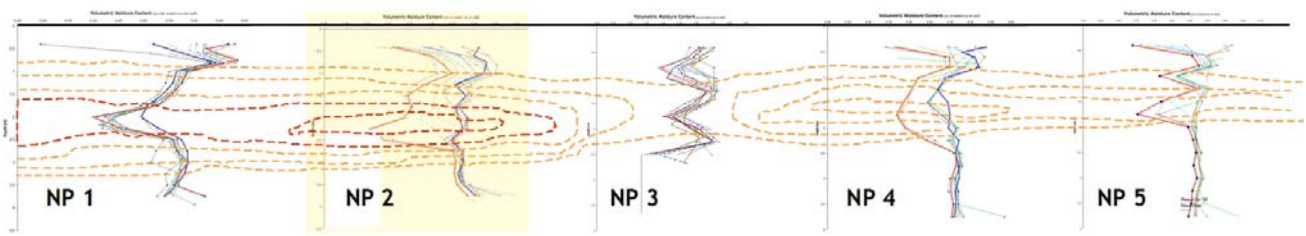
The water harvester fulfils the PRD requirement and 'knocks the top off' some of the water demand early in the growing cycle.

Testing this with high-risk species will be demanding and care will be needed to take account of the persistent deficit. We may see upward movement associated with the initial rehydration process.

The study will provide some insight into how the root system of a mature tree responds.

Neutron Probe Data

The tree is 5mtrs to the left of NP 1, and the stations are 5mtrs apart. The shallow zone of evaporation can be seen extending down to around 750 - 900mm below ground level, fluctuating seasonally. Root activity is having a seasonal influence (apart from at NP 1, where there is a persistent deficit) peaking at around 2mtrs. Moisture deficit stress isochrones have been superimposed.



Persistent Deficit over 3 Years, extending from 0.75mtrs to 2.5mtrs bGL, peaking at 2mtrs bGL with widely fluctuating change at ground level associated with rainfall and drying.

Seasonal Deficit in the summer months, extending from 1 - 2.75mtrs bGL, peaking at 2.25mtrs.

Variable geology produces irregular pattern of wetting and drying. BH terminated at shallower depth due to gravels.

Seasonal Deficit in the summer months, extending from 0.75 to 2.5mtrs bGL, peaking at 1.75mtrs.

Seasonal and reduced Deficit in the summer months, extending from 0.75 to 2mtrs bGL, peaking at 1.75mtrs. This tube is 25mtrs from the 18m tall Oak.

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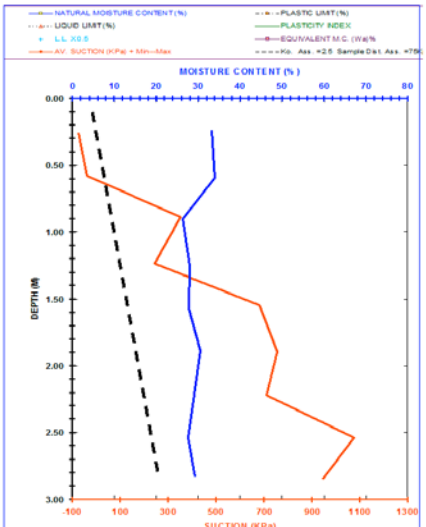
The Joint Mitigation Protocol

Following our meeting at Aldenham, we better understand the objectives of the JMP. Their efforts in getting people to meet and discuss the issues we face is a huge step in the right direction, as is the proposal of a sensible timeline.

Questions remain around both the level and nature of evidence that is proposed and to illustrate this, we reproduce some actual results below and ask the question, “do they provide evidence of desiccation?”



Opinions and interpretations expressed in the chart above are outside the scope of UKAS accreditation.

Although there are high suctions, further investigations revealed there was no evidence of root induced desiccation. The high suctions were a product of either the soil mineralogy, or a problem with the Whatman’s 42 filter paper – this has been explored in previous editions and is a well-recognised issue in our industry.

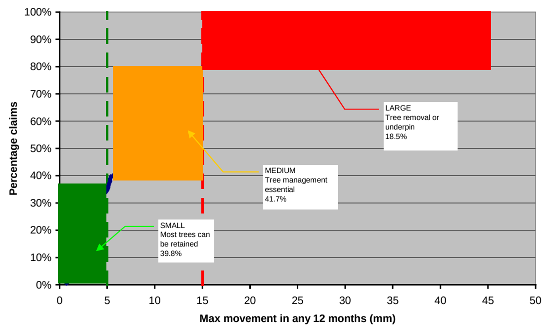
Our concern with the nature of the evidence listed is that we will have opposing parties putting whatever interpretation suits their case. The very problem we are seeking to avoid is being adopted as a resolution.

Another often-encountered problem is seeing cracks in October, and carrying out soil tests in November, only to find the suction bulge has dissipated.

An Alternative

If the JMP is to succeed we wonder if a level of evidence could be agreed to avoid confusion and extended debate.

Tim Freeman delivered a paper at Aston *(available as a download from web site at www.geo-serv.com)* in 2007 entitled “An Objective Framework for Dealing with Third Party trees” in which he proposes categories of movement, obtained using precise levels, leading to clearly defined outcomes.



He proposes a simple set of rules whereby if movement of ‘x’mm has taken place, then ‘y’ happens. In extreme cases that might lead to underpinning or tree removal, but in other instances, the tree would be retained and the property repaired.

Tim has produced the above graph following an assessment of claims handled in 2003 – an event year. The outcome would be far less onerous in wetter years.

It might be sensible for the JMP/Subsidence Forum to canvas the leading industry experts (perhaps Tim Freeman, Giles Biddle, Richard Driscoll and Mike Crilly) to see if a set of rules could be agreed, setting out what happens when a defined level of movement has been recorded. Perhaps they could also advise on the minimum number of readings needed to provide a suitable level of evidence. The tree value could be factored in with advice from arboriculturalists.

Without this in place then we have to ask, “what happens next?” One engineer might say 5mm of movement is sufficient to ask for tree removal whilst another might be happier with 30mm. Without agreed guidelines, by experts in our profession, we risk limiting the value of the Protocol.

We understand the Subsidence Forum is the area for constructive debate and hopefully they will include this in their review.