



## Arboricultural Case Study

The relative water use levels of a London Plane compared to a False Acacia (Frisia) and a climbing plant (Wisteria)

Published 01 September 2007

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### Synopsis

This case concerns damage to a property in north London founded on modest footings and within an area of highly shrinkable clay soil. The property had suffered differential movement as the clay soil had water removed affecting the soils ability to support the house foundations. Essentially it was agreed between the arboricultural experts that the property had suffered movement caused by vegetation. However, the identity of the vegetation responsible was not agreed. The arboricultural expert appointed by the Council, believed that the homeowners' Frisia tree was the principal, if not sole, cause of damage to the property.

It was our contention that the Council's London Plane tree was a material cause of damage to the property. The home owners' Frisia would have contributed to soil drying beneath the property and in the absence of the London Plane may have caused some lesser damage in its own right. In our opinion the Wisteria was not a material cause or a significant contributory factor.

The Areas of Disagreement to be addressed by the arborists were as follows:

- The potential for Wisteria to have caused damage to the property.
- The nature of the growth of the homeowners' Frisia.
- The relative water use levels of the Council's Plane tree compared to the homeowners' Frisia.
- The relative extent of rooting of the Council's Plane compared to the homeowners' Frisia.
- The relative contribution to damage of the Council's Plane compared to the homeowners' Frisia.

### The past pruning of the Councils Plane tree

It was accepted that the Council Departmental records indicated that routine maintenance was carried out to the Plane trees in:

- March 1993
- April 1996
- March 1999
- October 2001
- October 2004

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**The nature of pruning works carried out**

It was agreed between the arboricultural experts that the Plane tree was subject to regular pollarding. There is no guidance within BS 3998 relating to pollarding other than at paragraph 13.7 which states:

*“Pollarding, which in some circumstances has been a traditional form of management, should not be used on trees that have not previously been pollarded, as the large wounds created initiate serious decay in mature and maturing trees”*

Whilst it is likely that London Plane was maintained as a pollard, the Council’s Street Tree Management Policy suggests that pollarding lapsed during the late 1960s and 1970s. Where such lapses occur, re-pollarding may expose trees to the same large wounds and serious decay referred to in paragraph 13.7 of BS 3998, above.

**The impact of the pruning works**

The most significant recent research relating to the affect of pruning on tree water use and subsidence is presented in “Controlling Water Use of Trees to Alleviate Subsidence Risk” (Hortlink Project 212, Final Report May 2004).

Experiment 5 of this research project (often referred to as ‘Hortlink Project 212’) related directly to assessing the impact of crown pruning on London Plane trees. The London Plane trees were originally 20m tall. Eight of the London Planes were reduced in height by 30% in 2000. This reduced canopy volume by 72%. Four of the previously reduced Planes, three previously unpruned Planes and three previously thinned Planes were then more severely pruned in 2003, i.e. they were reduced in height by 60%. This equated to a 90% reduction in crown volume (akin to pollarding). Thus in 2003, immediately after pruning the resultant Planes were in the region of 8m tall. This equates roughly with the size of Plane in this claim.

In terms of the impact of this pruning on conservation of soil moisture, the 30% crown reduction (72% volume reduction) resulted in only 10-40mm soil moisture conservation in the year of pruning i.e. 6% to 25%, and the effects reduced in subsequent years. The more severe 60% reduction (90% volume reduction) conserved 50mm of soil moisture in the year of pruning, i.e. 31.25%, with lesser effects inevitable in subsequent years.

We also assessed the unpublished level monitoring results of the Building Research Establishment at Queens Park, London. This level monitoring was cross-referenced to a pollarding regime applied to adjacent London Plane trees. It is apparent from the results that despite biennial pollarding, the magnitude of level movements actually increased. Clearly, in that instance, pollarding failed to provide an effective means of controlling tree water use or related building movements.

With the benefit of the Hortlink Project 212 it seemed unlikely therefore that a three yearly regime of 30% reduction (or pollarding) was ever likely to sufficiently restrict root growth of London Plane to prevent it causing subsidence.

**The growth rate of the homeowners’ Frisia tree.**

It was confirmed that the Frisia was planted sometime in the early 1990s, at which time the tree was 7 feet (2.1m) tall.

In 1998, the estimated height of the tree was 7m.

Using these assumptions, we have calculated the range of average yearly height growth of the Frisia as follows:

Year planted	Annual shoot growth (m)
1990	0.54
1991	0.61
1992	0.70
1993	0.82
1994	0.98
1995	1.23

Therefore it is likely the Frisia was growing in height at somewhere between 0.5m and 1.2m per year.

This is a relatively fast rate of shoot extension for broadleaved trees, albeit that most trees tend to grow in height more quickly in their early years. However, in terms of overall growth it should be appreciated that because a small young tree such as this has a limited number of growing points, overall biomass production will be relatively low.

It was agreed within the Joint Statement of Arboricultural Experts that the Plane was pollarded in April 1996 and October 2004.

It was also agreed by the arboricultural experts that the pollard points on Plane were at about 7m height. From the height of the tree at any time it is therefore possible to estimate mean annual shoot growth. Using the height data from the inspecting engineers visit in 1998 and our own survey in 2006, this would suggest the following shoot growth:

Year	Height	Shoot length (derived from agreed 7m height to pollard points)	No. of growing seasons since last pollarded	Rate of growth
1998	12m	5m	3	1.67m
2006	10.5m	3.5m	2	1.75m

Therefore it is likely the Plane was growing in height at around 1.7m per year.

This was a very fast rate of shoot extension and is a typical response to crown reduction / pollarding. For instance, in Hortlink Project 212 (*op cit.*, p62), it is reported that:

*“Crown reduction substantially invigorated tree growth by increasing terminal shoot extension in the first season after pruning....Shoot lengths of the crown reduced trees were increased five fold compared to non-pruned trees. In the second year after pruning this effect continued, but to a lesser extent...”*

It should also be noted that in contrast to the young Frisia, the London Plane also had numerous growing points and consequently had a much greater overall biomass production.

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We therefore concluded that whilst the shoot growth of the Frisia may be considered fast or vigorous, it was likely significantly less than that of the Plane. Furthermore, in terms of overall biomass production, the growth of Frisia would have been a small fraction of that of Plane.

**The relative water use levels of the Councils' Plane compared to the homeowners Frisia (and Wisteria).**

In seeking to quantify the difference in water use levels between the Plane, Frisia and Wisteria we considered their differences in terms of size and species. We also made reference to direct water use measurements undertaken in the Hortlink Project 212.

**Species Differences**

Biddle presents a useful discussion on species differences in "Tree Root Damage to Buildings" (1998, Vol. 1, pp135-152).

Essentially Biddle concludes that, *inter alia*: variation within species is as, if not more, significant than variation between species; and the rank order of trees in terms of their propensity to cause subsidence damage (rather than water use per se) may change according to the criteria used.

For instance, NHBC classification of water demand ranks False Acacia and Plane as 'Moderate Water Demand'. This classification was developed by Biddle who refines this rank order in "Tree Root Damage to Buildings" (*op. cit.*, p147) into 6 bands. Within this refined categorisation, Plane is ranked in the group with third highest water demand, and False Acacia is ranked in the fourth highest group. (False Acacia is the parent species of the cultivar Frisia).

Given that Frisia is a slower growing and golden-leaved form of False Acacia, it seemed reasonable to expect Frisia to have a lower "water demand" than False Acacia.

It is noted that "water demand" is defined by Biddle as the ability of a tree to dry a clay subsoil rather than the amount of water used. The distinction is relevant because it is not necessarily the total amount of water used that is relevant but also the pattern and intensity of soil drying. An example of this is the comparison between beech and oak. Research into the relative water use of beech and oak at the water catchment level indicate little difference between the species, yet Oak is considered to have a higher 'water demand' than beech. This is most likely because of differences in rooting characteristics. Beech (*Fagus sylvatica*) is intolerant of heavy clay soils and its roots tend to be restricted to relatively shallow depths where conditions for growth are more favourable. In contrast, oak (*Quercus robur*) is native on clay soils in which it can extend its roots to significant depth, giving it a competitive advantage on clay soils. It is the deeper rooting of oak in clay soils which results in oak roots being more prevalent beneath the foundations of buildings and hence causing more subsidence damage.

Alternatively, a rank order based on the ratio of species abundance to number of reported claims involving that species, produces a ranking in which False Acacia appears more likely to cause damage than London Plane – see Biddle (*op cit.*, Figure 9.7, p144), however, as stated by the Building Research Establishment in Digest 298 (1999, p2), "*ranking acacia near the top seems anomalous*".

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There is little available information relating to the species characteristics of Wisteria in relation to its water use. In general terms, Biddle notes "*Climbers such as ivy, Virginia Creeper or Wisteria, can often cover a very extensive area off a single stem with the potential to cause intense soil drying in that location*" ("*Tree Root Damage to Buildings*", 1998, Vol. 1, p150).

Our own opinion, is that species alone is likely to make a relatively small difference in relation to the water use of the Plane, Frisia or Wisteria. Rather, differences in their water use are likely to be better explained by differences in their size.

## Size Differences

Since water loss from a tree is largely via its leaves, total leaf surface area does provide some indication of the potential total water use: for instance, see "*Tree Roots and Buildings*" (Cutler & Richardson, 2<sup>nd</sup> Edition, 1989, which states "*Total crown volume (hence leaf area) is generally more important than absolute height in relation to water demand*"). We would stress however, that trees have mechanisms to control and reduce water loss and as such there is unlikely to be a direct linear relationship between total leaf surface area and tree water use.

Nonetheless, we have sought to estimate the leaf surface area of the Plane, Frisia and Wisteria as follows.

Leaf area index (LAI) is a measure of total leaf surface area / ground surface area, as defined by the drip-line or crown spread of the tree ("drip-line area"). Using LAI figures and crown spread data it is therefore possible to approximate total leaf surface area.

Hortlink Project 212 (figure 3.11, p83) provides LAI figures for the heavily pruned London Plane trees in that experiment. It is clear from this publication that LAI increases markedly in response to heavy pruning.

In summer 1998, when the damage occurred, the London Plane would have been in its third season of growth following pollarding in 1996. The LAI for Planes in their third season after heavy pruning in the Hortlink Project 212 was approximately 7.

At the time of our survey in August 2006, the Plane had a crown diameter of about 7.5m. However, that was at the end of the second growing season after pruning in October 2004. It is highly likely therefore that the crown spread would have been larger in 1998.

We calculated average shoot growth of Plane to be in the region 1.7m per year. However, shoot extension is likely to decline in the third growing season following pruning. It seems reasonable to assume the crown diameter of Plane would have been 2m to 3m wider in 1998 than 2006 that is 9.5m to 10.5m crown spread.

Using a LAI of 7 and crown spreads of 9.5m to 10.5m suggests the total leaf surface area for the Plane was approximately **496m<sup>2</sup> to 606m<sup>2</sup>**.

In considering the Frisia, we have used a GIS package (Manifold, 6.5, Enterprise Edition) to estimate the extent of the crown. The software has then automatically calculated the "drip-line area" as 17.7m<sup>2</sup>.

We have been unable to obtain LAI figures for Frisia. However, we note from the abstract of "*Leaf Area and Biomass in Mixed and Pure Plantations of Sycamore and Black Locust in the Georgia Piedmont*" reports LAI figures for *Robinia pseudoacacia* (False Acacia), of which Frisia is a cultivar, of around 4.3 to 4.9.

Using a drip-line area of 17.7m<sup>2</sup> and LAI of 4.3 to 4.9, suggests Frisia had had a leaf surface area of approximately **76m<sup>2</sup> to 87m<sup>2</sup>**.

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At the time of our survey in 2006, we recorded that the crown of the Wisteria was approximately 2.9m tall and 1m wide. The crown area is substantially smaller than would be defined by a rectangle of these dimensions, i.e. 2.9m<sup>2</sup>. We estimate that the area of wall covered by the Wisteria, is about 1.75m<sup>2</sup>. However, as shown by the engineers' photograph, the Wisteria was larger in 1998, say double, i.e. 3.5m<sup>2</sup>.

We are unaware of any LAI figures for Wisteria. However, it appears to us inevitable that its LAI would be less than that of the Frisia. This is because with the Frisia, we are considering the combined surface area of all leaves from crown base (at say 2m) to crown tip (7m). In contrast, the depth of the crown of the Wisteria is in the region of, say, 500mm. For the purposes of comparison, we estimate the LAI of the Wisteria to be in the region of 1 to 2. (It is noted that this LAI is considered in terms of the wall area covered not ground surface area). On this basis, we estimate the leaf surface area of the Wisteria to be in the region of **3.5m<sup>2</sup> to 7m<sup>2</sup>**.

In summary, our estimates for leaf surface area of the Plane, Frisia and Wisteria in 1998 are as follows:

<b>Tree / Shrub</b>	<b>Leaf Surface Area</b>
London Plane	496m <sup>2</sup> to 606m <sup>2</sup>
Frisia	76m <sup>2</sup> to 87m <sup>2</sup>
Wisteria	3.5m <sup>2</sup> to 7m <sup>2</sup>

Thus on the basis of total leaf area comparisons, London Plane is an order of magnitude larger than Frisia, which in turn is an order of magnitude larger than the Wisteria.

#### **Water use measurements**

Hortlink Project 212 also undertook direct measurement of tree water use over several years. The species included in the experiments were London Plane and Cherry trees.

We reiterate that the London Plane trees were originally 20m high. Eight of the London Planes were reduced in height by 30% in 2000. This reduced canopy volume by 72%. Four of the previously reduced Planes, three previously unpruned Planes and three previously thinned Planes were then more severely pruned in 2003, i.e. they were reduced in height by 60%. This equated to a 90% crown reduction. Thus in 2003, immediately after pruning the resultant Planes were in the region of 8m tall. This equates roughly with the size of Plane in this claim.

Daily water use for the reduced Plane trees in 2003 following the severe crown reduction was around 260 litres per day. The research clearly demonstrates that water use is likely to have increased significantly in years 2 and 3 after pruning. For instance following the 30% height reduction in 2000, water use had recovered to around 300 to 500 litres per day in 2001 and 500 to 600 litres per day in 2002. We also note that water use levels of the unpruned, 20m tall London Plane trees in 2003 was also around 260 litres per day. That is reduced from previous years (e.g. in excess of 700 litres per day in 2002) and is likely due to a lack of available water during the hot dry conditions experienced in 2003.

In seeking to quantify the water use of the Frisia it is unfortunate that Hortlink Project 212 did not include either Frisia or False Acacia in any of the experiments. However, Hortlink Project 212 did include measurements on Cherry trees. These Cherry trees were 8m in height with total leaf surface areas in the region of 40m<sup>2</sup> to 60m<sup>2</sup>. That is broadly similar in height and leaf area to Frisia.

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Like False Acacia, Cherry is also classified as being of ‘Moderate Water Demand’ (NHBC Standards, Chapter 4.2, ‘Building Near Trees’, p20). Cherry (*Prunus*) is also classified in the same grouping as False Acacia by Biddle (*op cit.*, p147).

As such, it seems reasonable to use the water use of the cherries in the Hortlink Project 212 as a guide to the likely level of water use of Frisia. The water use of the unpruned cherries in the Hortlink Project 212 was in the region of 12 to 70 litres per day.

In summary, it appears that the best available estimates for the approximate water use levels of the Plane and Frisia are as follows:

Tree / Shrub	Water Use
Plane	260 to 600 litres per day
Frisia	12 to 70 litres per day

Once again these are order of magnitude differences and accord with the size differences discussed at 5.3.10 to 5.3.24 above.

We are unaware of any similar data relating to Wisteria. However, in our opinion, the water use of the Wisteria is likely to be an order of magnitude lower than the Frisia, i.e. less than **10** litres per day.

**The relevance of water use levels**

In a heavy clay soil such as that present on this site, there is limited lateral movement of moisture. That is, the primary input of water is from rainfall moving vertically downward through the soil profile. As such, plants using significantly larger volumes of moisture must exploit larger volumes of soil and / or dry the soil more intensely.

Given the order of magnitude differences in tree water use noted in this instance, Plane clearly had the potential to dry a larger volume of soil, and therefore cause greater soil movements over a wider area, than the Frisia and likewise Wisteria.

**The relative extent of rooting of the defendant’s London Plane compared to the claimants’ Frisia and Wisteria.**

In considering the relative rooting of the Plane, Frisia and Wisteria, it should be recognized that root growth is opportunistic and highly influenced by environmental conditions (see paragraph 7 of ‘Tree Root Systems’, Arboricultural Advisory and Information Service Research and Information Note 130/95/ARB, Dobson, 1995) In ‘Tree Roots and Buildings’ (*op cit.*), Cutler & Richardson present summary data relating to distance at which roots of various tree species implicated in subsidence damage to buildings have been encountered). This data should be treated with caution due to the relatively small sample size and sampling limitations (see Biddle, *op. cit.*, p142).

Within the Cutler publication, at pages 46-47, Planes are described as moderately deep-rooted on clay soils. The maximum tree-to-damage distance recorded for Planes in the sample was 15m; 90% of cases occurred within 10m and 75% of cases occurred within 7.5m. These results were obtained from a sample size of 327.

However, in relation to these distances relating to Planes Cutler & Richardson state:

*“Planes are pre-dominantly used as street trees. The distances at which a high proportion of reported damage occur are short...probably reflecting the average combined pavement/front garden measurements”.*

In relation to False Acacia, the same publication makes no comment regarding rooting depth in clay soils (see pages 36-37). The maximum tree-to-damage distance recorded for Planes in the sample was 12.4m; 90% of cases occurred within 10.5m

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and 75% of cases occurred within 8.5m. These results were obtained from a sample size of 20.

Various other references, for instance the USDA Plant Fact Sheet relating to False Acacia (aka Black Locust) describes the tree as having “a shallow, aggressive root system”.

In relation to Wisteria, Cutler & Richardson (*op cit.*, pp66-67) provide no data relating to maximum tree-to-damage distances and in fact report only one identification of Wisteria causing subsidence.

By reference to the Cutler & Richardson data it therefore appears that the root spread of Planes and False Acacia are broadly similar. However, it is noted that the distances relating to Planes may be under-estimated whereas, the root spread relating to False Acacia may be an over-estimate in relation to its smaller growing cultivar Frisia. Further, in this particular instance, the Frisia is a significantly smaller tree than the Plane.

As an alternative to the Cutler & Richardson data, we have also made reference to NHBC Practice Note 4.2, Building Near Trees. It is noted that this publication was not intended to provide a model for predicting or estimating the extent of root growth. Rather, it is essentially a cost/benefit analysis of how deep to extend foundations for new buildings in proximity to trees. Nonetheless, as a cost/benefit model for this purpose it must implicitly seek to assess risk of subsidence from an identified tree and to this end seeks to categorise in terms of their water demand and define their zones of influence.

NHBC defines the zones (i.e. lateral extent) of influence for trees by water demand category as follows:

<b>Water demand</b>	<b>Zone of influence</b>
High	1.25 x mature height
Moderate	0.75 x mature height
Low	0.5 x mature height

Taken from Table 2, page 3 of NHBC Practice Note 4.2

In relation to mature height, page 4 advises that: (1) where the actual tree height is less than half of the mature height, the actual height should be used as opposed to the mature tree height; (2) where trees have undergone heavy crown reduction or pollarding the mature height should be used.

On this basis the zone of influence of the Frisia would be its actual height (7m) multiplied by 0.75, i.e. 5.25m. In comparison, that of the Plane would be its nominal mature height (26m – see Table 12, p18) multiplied by 0.75, i.e. 19.5m.

It may be argued that the use of the nominal mature height data is inappropriate, for instance see Biddle (*op. cit.*, p277). However in terms of overall water use I note that in Hortlink Project 212, in September 2003, the Planes severely pruned (60% height reduction) in April 2003, used broadly similar amounts of water to the unpruned, 20m tall, Plane trees, i.e. around 260 litres per day. The maximum mean reduction in water use between reduced and unpruned Plane trees in the experiment was in the region of 25% (Figure 3.13, July 2002 data, p85).

Applying this same reduction to the zone of influence of Plane calculated above gives 14.6m.

We stress that these zones of influence of 5.25m for Frisia and 19.6m or 14.6m for the Plane should not be considered actual or estimated rooting distances for these

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trees. Rather, the purpose of the exercise is to provide some relative comparison between the Plane and the Frisia and their ability to extend their roots into and dry the surrounding soils.

In relation to the Wisteria, NHBC stipulates (at page 5) a no shrub planting zone of 3m for minimum depth (1m) deep foundations in high volume potential soils.

The above analysis therefore provides generalised rooting distances for the Plane, Frisia and Wisteria as follows:

	Cutler & Richardson			NHBC
	max	90%	75%	
London Plane	15m	10m	7.5m	14.6m to 19.6m
Frisia	12.4 m	10.5m	8.5m	5.25m
Wisteria	n/a	n/a	n/a	3m

It therefore appears that on the basis of the literature reviewed, it is reasonable to expect Planes to have deeper and more widespread rooting than Frisia. This is entirely as we would expect given the relative sizes of the trees in this instance and indeed their normal mature heights, i.e. Plane is a larger growing tree than Frisia. This is also in accordance with our experience that London Planes are capable of causing subsidence damage to properties at greater distances than False Acacia or Frisia.

The wider spreading and deeper rooting of London Plane in conjunction with a level of water use an order of magnitude greater than Frisia, will inevitably result in London Plane causing ground movements of greater amplitude and over a wider area than Frisia.

## Conclusions

The Councils' Plane tree was a mature specimen maintained on a triennial pruning cycle having been pollarded in March 1993, April 1996, March 1999, October 2001 and October 2004.

The homeowners' Frisia was a small young tree planted in the early 1990s that was subjected to only minor pruning.

The shoot extension growth of the Plane was in the order of 1.7m per year. That of the Frisia was in the order of 1.2m per year or less. Both would be considered fast rates of shoot growth. However, in terms of overall biomass production the growth of the Plane would have been many times greater than that of the Frisia.

The water use of the Plane tree would have been an order of magnitude greater than that of the Frisia and two orders of magnitude greater than the Wisteria.

The roots of the Plane tree would likely have extended many metres farther and to greater depth than that of the Frisia: as would be required to support its greater water use. The rooting of the Wisteria was likely to have been shallow and localised.

The Plane tree was a material, and the dominant cause, of damage to the property.

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The Frisia is likely to have contributed to soil drying beneath the bay structure and could possibly have caused damage to the bay structure, in its own right, i.e. in the absence of the Plane tree, but to a lesser extent.

The Wisteria would have had a small contributory role and would have been unlikely to cause damage in its own right.

Wisteria Vine



Robinia "Frisia"  
(Golden False Acacia)



London Plane



OCA UK Limited  
4 The Courtyards  
Phoenix Square  
Wyncolls Road  
Colchester Business Park  
Colchester  
Essex CO4 9PE

Tel: 01206 751626  
Fax: 01206 855751

E: [info@landscapeplanning.co.uk](mailto:info@landscapeplanning.co.uk)

[www.oca-arb.co.uk](http://www.oca-arb.co.uk)

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