A Nuffield Farming Scholarships Trust

Report

Award sponsored by

The John Oldacre Foundation

Land drainage and its role in farming's future

Rob Burtonshaw

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NUFFIELD UK

A Nuffield (UK) Farming Scholarships Trust Report

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"Leading positive change in agriculture. Inspiring passion and potential in people".

Title

Land Drainage and its role in farming's future

Scholar

Rob Burtonshaw

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Objectives of Study Tour

- To access the drainage industry worldwide, and try to reconnect the UK industry to the rest of the world
- To investigate whether conservation drainage techniques pioneered in America can be transferred to the UK
- To access new machinery and to investigate whether different techniques can be transferred to the UK
- To raise the profile of drainage

Countries Visited

- The United States of America (Iowa, Illinois, Minnesota, Indiana, North Dakota, South Dakota, Kansas, Ohio, Michigan, Pennsylvania, New York, Missouri)
- Ontario, Canada
- The Netherlands

Findings

- Drainage undervalued in the United Kingdom, installation of new drainage at historic low
- Denitrifying bioreactors has potential to reduce nitrate levels in the UK's water courses
- Costs can be reduced by the use of trenchless drainage and other technologies such as GPS grade control
- Yield mapping is confirming the yield gains of an effective drainage scheme

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Disclaimer

The views expressed in this report are my own and not necessary those of the Nuffield Farming Scholarship Trust, of my Sponsor, The John Oldacre Foundation or any other sponsoring body.

1. Personal introduction

I'm the third generation of my family to work for, manage, and own, Farm Services Limited, land drainage contractors based in Lighthorne, Warwickshire. For seventy years the company has been putting pipe in the ground with the aim of removing excess water from the land. During this time the company has survived the variations in demand and has developed a strong client base of repeat business.

After the removal of grants, the company diversified into sportsfield drainage and increased its area of operation. The post-grants environment was very different. With demand low, the vast majority of drainage companies went out of business or moved into other areas. Thus when I joined the company in 2001, I found a small, quiet industry, with no formal qualifications or course available. All I learnt was from my grandfather and father, and it provided a strong foundation. However, I was aware that virtually every scrap of knowledge I had about drainage came from my one source, my family. I became keen to expand my knowledge and experience, yet struggled to find a way of doing so. Understandably rival contractors were reluctant to share the details of their businesses and the few consultants still active were helpful but concerned about conflict of interest. In addition it became clear that the industry had lost a great deal of expertise and that drainage technique, methods and design had stood still for over twenty years.

When I was introduced to the idea of a Nuffield Farming Scholarship, I immediately realised that this was a way of addressing my concerns. I had heard bits and pieces regarding the drainage industry around the world, but knew very little.

Me, Rob Burtonshaw

At one point the UK was a destination people visited to learn about drainage; now I wondered if I could learn from others. Searching the internet, and after a quick conversation with Mastenbroeks - Land Drainage machinery manufacturers - I realised that other countries, especially The United States of America, Canada and the Netherlands had robust, thriving industries. Despite concerns that drainage would not be viewed favourably by the selection panel, I decided to apply for a Scholarship

It took a little time to persuade my wife, Louisa, and my father, Paul, that the considerable commitment required to complete a Nuffield Farming Scholarship, not to mention the time away from home/work, would be worthwhile, but they understood my goal. Without their support I would not have been able to consider such an endeavour.

My subject matter, land drainage has, as far as I can tell, not been the subject of a Nuffield Farming Scholarship before. This perhaps says something about how far out of fashion drainage has become, and also about the quietness of the industry. This lack of a precedent has meant that I have had a double edged sword, an opportunity to do something unique, but I lack a well-trodden path full of contacts and numerous Nuffield links. However I was able to find some initial contacts thanks to the help of Fred Clarke of Mastenbroek, Peter Darbishire and, of course, the internet.

2. Land drainage machine installing pipe

2. Historical perspective

Drainage is almost as old as farming itself. Archaeological evidence of ditches and of other basic methods of moving water away from crops have been recorded in ruins in Mesopotamia dating back over seven thousand years. Ever since farmers have tried to control the amount of water their crops receive, from the Romans to Cromwell, each age has strived to improve yield by draining land.

However when, in 1835, Thomas Scragg invented a method of mass producing clay drainage tiles cheaply, the number of acres drained dramatically increased. Between 1850 and 1880 over £12 million was invested by farmers in new drainage schemes; the equivalent in today's money would be £12 billion. It must have been difficult in winter to travel from village to village without passing a group of men digging drainage trenches! The work, pre Joseph Cyril Bamford, would have been back breaking, time consuming, and would have been a major investment in the farming business. The benefits of land drainage were well known and the subject even managed to be mentioned in George Elliot's Middlemarch where Mr. Brooks shuns new 'scientific' farming techniques in favour of the proven, common sense of the 'draining tile'. This period has been called the first golden age of drainage - the second occurred immediately after the Secord World War.

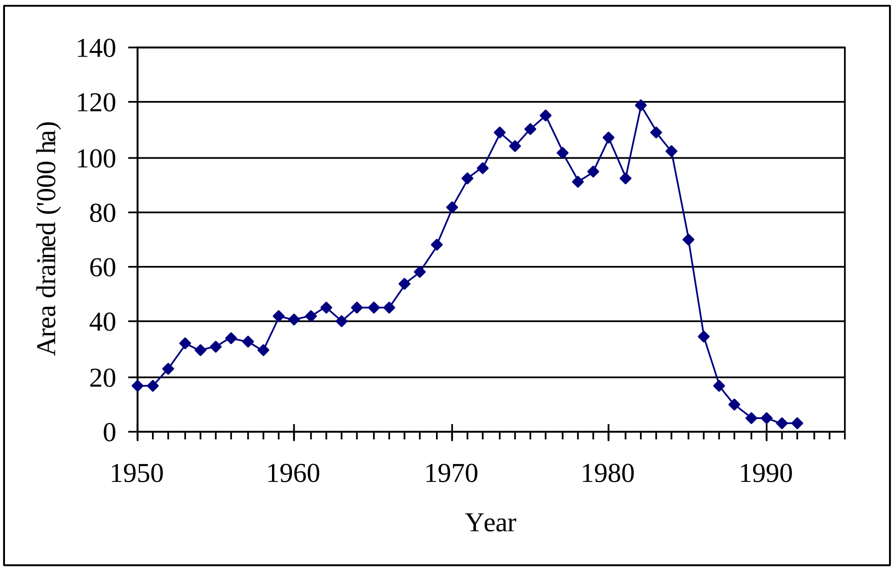
Having been forced into action by the attempt to starve the nation into submission in the Battle of the Atlantic, progressive post-war governments subsidised agriculture to increase production. Land drainage was seen as a critical part of this push for production, and grants were available as well as a network of advisers to offer design and guidance. Training courses were organised by the War Ag, and one of these course was how my grandfather first became involved in the industry. Coupled to this was the Field Drainage Experimental Unit, charged with investigating new ideas and providing data to inform decision making. Britain was, alongside the Netherlands, the world leader in drainage and the ideas and techniques developed spread around the world. However change was on the way.

Governmental thinking had changed by the early 1980s, and many subsidies across many industries were withdrawn. Drainage grants proved to be a very easy target. Over production had created 'food mountains' and media pressure for change increased. In addition food security was not the political issue it was before and the idea of importing cheaper food was attractive rather than forbidding. Unable to cut most European subsidies, the government completely removed drainage grants and cut funding for research to almost nothing. It was often said, contrary to the evidence, that all the land which required draining was already drained and that further improvements in yield would come from varieties and other methods. *(see Appendix 1 at end of report).*

Unsurprisingly farmers' behaviour was altered and the number of acres drained annually fell dramatically. The graph on the next page shows the number of hectares drained each year from 1950 to 1992. From a peak of 120,000ha in 1982 the figure had dropped to well below 10,000ha by the early nineties – please note that grant application forms were accepted for projects which were undertaken over the course of a couple of years, hence, the relatively high figures in the mid eighties.

Once funding was withdrawn ADAS/MAFF no longer recorded the amount of land which was being drained. However, I suspect that everyone in the industry would agree that the figure has remained somewhere close to the figures recorded in the early nineties.

The conclusion from this data is that we are draining less land than at any point since the Second World War and that a historically small amount of drainage has been carried out in the last thirty years. The nation's drainage infrastructure has aged considerably and, whilst drainage can last for many generations, nothing lasts forever. Many old schemes have stopped working or are functioning below the desired level and often the decline is gradual, therefore difficult to diagnose. Chris Scofield of ADAS suggested in 1987 that 50,000ha of land drainage was ceasing to work each year. I suspect that a good percentage of these failed schemes can be revived by maintenance; nonetheless it is still very likely that the percentage of drained land in the UK is falling.



Graph showing the number of has. of agricultural land drained in the period 1950 to 1992 with grant-aid. ADAS ESO111.

3. World perspective

The decline in land drainage in the United Kingdom has been in stark contrast to the rest of the world. The soil type and topography of the Netherlands dictates that Dutch farmers re-drain land relatively frequently and therefore the drainage industry is maintained at a constant level, with many more acres drained each year than in Britain. In North America the demand for drainage is proving difficult for contractors to meet.

In Ontario, Canada, the drainage industry is estimated to be worth in excess of $50 million; south western Ontario is approximately the size of England but the number of contractors is many times that of England, and still contractors have waiting lists. On average 100 million feet (304,800 metres) of drainage pipe is installed in Ontario each year. The demand for drainage is perhaps even stronger in The United States of America. Despite the recent drought, the corn belt is experiencing a massive growth in the demand for drainage with contractors reporting waiting lists of over two years and frustrated farmers purchasing their own equipment to avoid having to wait for a contractor to become available.

In North America the demand for drainage is proving difficult for contractors to meet.

Contrary to popular thought, the percentage of land already drained in North America is almost comparable to that of the UK. In Southern Ontario the percentage of farm land which has been drained is approximately forty five per cent. This figure includes areas of light soils without a drainage requirement, whilst in Lambton, Essex and Kent Countries the percentage of land drainage is around eighty percent. *(see Appendix on last page of report)*

3. Trenchless land drainage machine

4. My travels

Following the advice of the then Nuffield Director, I focused my travels on relatively few countries, and spent a considerable time in each.

My first destination was **the Netherlands,** followed by **Southern Ontario**, then the **United States**. I also took the opportunity to visit as many people in the UK as possible.

During my travels I have tried to squeeze in as much as possible. This has included meeting over fifty contractors, eight machinery manufacturers, nine universities, numerous academics, consultants, half a dozen pipe manufacturers and representatives of local government. On some occasions I was only able to spend a couple of hours with a person/company, on others I was able to spend a couple of days with them. I also made the effort to speak to as many farmers as possible, who - as the end users of drainage - have a unique and perhaps the most important perspective on the industry.

Countries visited

The Netherlands	July 2012
Canada – Southern Ontario	August 2012
USA - (Iowa, Illinois, Minnesota, Indiana, North Dakota, South Dakota, Kansas, Ohio, Michigan, Pennsylvania, New York, Missouri)	September/October 2012

4. Herman Van Der Geest and his Mastenbreok 15/15 drainage machine, The Netherlands.

5. How the rest of the world drains land

Drainage techniques differ around the world depending upon soil type. My Nuffield Farming Scholarship opened up a whole new world in methods of drainage and equipment I had not seen before. Like most British contractors we tend to have our own way of working, with minor modifications depending on soil type. I found a similar approach and attitude elsewhere in the world, although that technique varied greatly.

In the light, sandy soils of **the Netherlands** it is necessary to use filter wrapped pipe – normally a woven geo-textile or fabric held in place with nylon thread. Despite this barrier, pipes still 'silt up' and it is necessary to jet-wash the drains every couple of years. Often in the Netherlands drainage is installed to control the water table, rather than ground water as is normally the case in the UK. This, as well as the free draining soils, means that the use of permeable (stone) backfill is not required. Due to the requirement to jet-wash, the use of a main drain with junctions is not practicable and each drain normally has its own outlet. This makes the drains easier to find and monitor, and as drainage is normally installed parallel to the field boundary, as laid (sometimes called "as built") completion plans are not required. In fact contractors in the Netherlands spend little or no time on design. The absence of any fall means fields can be drained in any direction and, as standard practice is to drain parallel to a field boundary, lateral location is predetermined.

This absence of permeable fill, the lack of design, and pointlessness of completion plans, are some advantages of the Dutch style of drainage. However on their flat fields the scheme is very dependent upon the laser controlled levels, and there is no room for error. Often the high water table causes problems as well.

I visited Herman Van Der Geest, who is the chairman of the Dutch Land Drainage Contractors Society; he operates in a reasonably small area around the town of Hillegom. It is an area renowned for tulip production and the soil type is extremely light, with a very high water table. The photograph on the previous page shows Herman's Mastenbreok 15/15 installing drainage and it is possible to get some idea of the sandy-ness of the soil.

See previous page for a photograph of Herman Van Der Geest and his Mastenbreok 15/15 drainage machine, in The Netherlands.

The other difficulty, often encountered by Herman on this job, was the high water table. The water level in the nearby lake and in the ditches around the field was approximately 400mm from ground level. If the drains were laid at a level to allow them to flow into the water course, they would be too shallow to be safe from cultivation and would not be deep enough to lower the water table to the optimum level for crop production.

The answer Herman and other Dutch contractors have developed is an enclosed scheme, where the drains flow to a chamber and the water is pumped out into the water course. Unfortunately this adds to the cost of the drainage scheme and requires the continued expense of running a pump. Unlike most schemes I saw being installed in the Netherlands, this design required a main/collector drain with junctions to lateral drains.

5. Pumping chamber in construction for enclosed drainage scheme, The Netherlands

6. Dutch V-plough drainage machine installing pipe, the Netherlands

7. Dutch V-plough drainage machine installing pipe – Mastenbreok owned and operated by Jimmick Drainage, The Netherlands

8. RWF Bron 450 trenchless drainage plough owned and operated by Ellingson Companies, USA

As contractors in **the Netherlands** have no requirement to use permeable fill nearly all trenchless drainage is installed using a v-plough rather than the straight leg plough we operate. The advantage of a v-plough, shown in photograph on the previous page, is that the disturbance is greatly reduced and installation is faster than by open trench. V ploughs are effective in the light, stone-free soils of the Netherlands, but not suited to clay soils or where stones might be present. Drain depths tend to match those in the UK as to drain diameters, but lateral spacings are tighter, drains often being only ten metres apart.

Soil type in **North America** is different both to the Netherlands and the UK. The dark soils of the Mid-West tend not to lose their permeability with depth, unlike the soils which I'm accustomed to draining, where the topsoil, approximately 300mm deep, displays reasonably good permeability, but the subsoil tends to be clay and impermeable - again this negates the requirement for permeable fill. The vast majority of drains in North America are installed by trenchless method using machinery like the RWF Bron in the photograph on previous page.

Most drainage schemes in the United States and Canada are far larger than what would be normally considered in Britain. One hundred-acre schemes with one outlet are common, and this requires both machinery and materials on a larger scale. Installing large diameter pipe can be done using a wheel trencher as seen in photograph nine. I have not seen this type of machine working before. In the UK the desire for narrow trenches and flexibility in trench width - in order to reduce the amount of permeable used - means that such machines are not employed. In North America if the diameter of the pipe is too large to be installed by trenchless method, then a wheel trencher is used. Wheels are more efficient than the chain trenchers seen in the UK when excavating wide trenches.

The greater size of schemes in America, especially in the **Red River Valley, North Dakota** – perhaps the area of the world with the greatest demand for drainage – is very obvious when visiting. Photograph ten *(two pages further on*) shows lateral drains which have just been installed by Ellingson Companies. The laterals are over half a mile long. They start with 6" diameter pipe which then decreases to 5", then to 4". By way of comparison, the longest laterals we install would be just over 300 metres, and would have a diameter of 60mm (2") or 80mm (3"). Installing such a large scheme does create problems; even on a minimal grade the depth of the outlet is often too deep for a gravity outlet. If the end of the lateral drain is at standard depth, as with the Netherlands, often a pumped outlet is required, as shown in photograph eleven

Regulation relating solely to drainage is found only in Canada. The Ontario Ministry of Agriculture, Food and Rural Affairs, regulates drainage machines, drainage companies and operators of drainage machines in the province. Only a licensed contractor, with approved machinery, operated by a licensed driver, can install drainage in Ontario. The design of the regulation is to ensure that installation is carried out to a sufficient standard. I found little complaint from contractors who welcomed laws to prevent sub standard workmanship and unskilled persons, despite the extra level of relatively light bureaucracy.

For optimum performance different soils require different techniques. Most of the time local knowledge is the most important factor governing design. However this does mean we should not question traditional practice. My travels clearly demonstrate that there are many different ways to drain, and assessing soil type, condition and use must be part of the design process. Since my travels I have adopted a more open approach to design, dictated by the soil I see under my feet rather than what has been done before.

9. Port Industries Hydramaxx wheel trencher, with RJB and Kevin Shrimp in front, USA.

10. Half mile laterals in the Red River Valley, ND, USA

11. Pumped drainage outlet in the Red River Valley, ND, USA

6. GPS grade control

Since its widespread adoption in the 1980s, laser grade control has been the predominant method of guaranteeing that drains are laid to the correct level. Gravity is a well understood concept; it is also unforgiving. For drainage to work, all drains must be laid accurately. If set up correctly, a laser has proven to be very reliable. Any system hoping to surpass it must prove to be at least as accurate as laser control.

The laser level works by sending a level beam from a tripod to be picked up by a receiver attached to the digging boom of a drainage machine. This provides a fixed reference from which the depth of the digging boom can be adjusted independently of the ground level. A grade can be programmed into the sender if levels are taken at the start and end of a drain.

Most farmers are very familiar with GPS (Global Positioning Systems), and the majority of new tractors are sold complete with systems. Relatively cheap hand held devices can yield accurate positioning with around 25mm on the horizontal. Until recently equipment which can match such accuracy vertically has been very expensive - as a rule of thumb a 25mm margin of error horizontally is doubled vertically. Such margins of error are far too great when a drain might be laid on a minimum grade. In the past the cost of a GPS system with the accuracy required for drainage has been prohibitive but, as with most new technology, the price of such equipment has fallen and is now within reach of drainage contractors. All but one of the contractors I met during my travels through America and Canada operated with GPS. This is perhaps a misleading statistic as I tried to meet only the most progressive and forward thinking contractors, but what is not in doubt in that the majority of contractors in North America are using GPS, and nearly all of the leading contractors do so.

GPS control offers a number of advantages over the traditional laser methods. Firstly, once the GPS is set up (including the RKT base station) as long as the drainage machine does not move further than two miles from the base station, there is no need to adjust or reposition - unlike the laser which often requires moving. On an undulating field this can save a considerable amount of time.

> the majority of contractors in North America are using GPS

Secondly the GPS control box is able to calculate grade adjustment every metre; with a laser this process is done by hand. Not only does this save time, but it also allows many more adjustments to be made. Each calculation requires the operator to take some levels and often adjust the grade setting on the laser, which takes time and normally the operator will make as few adjustments as possible; meaning that whilst the drain is laid on the correct grade it is often slightly deeper than absolutely necessary. Being deeper than necessary increases costs, mainly as it requires more permeable fill to be used.

When using GPS grade control the grade calculations are done instantly and adjusted when required to maintain not just a *correct* grade, but the *optimum* grade. Although the saving is slight over each metre the calculation becomes considerable when taken over a year's worth of production.

RTK base station

Two companies dominate the software GPS grade control market in North America: **Trimble** and **AGPS**. Trimble has been a leader in GPS technology and holds a dominant position in the grade control market, through its Farm Works software. Trimble has a network of dealers in both North America and Europe and also produces GPS hardware. Most contractors I met in North America operated a Trimble grade control system, most had very positive comments and praised the ease of use, declaring it to be intuitive.

AGPS is small company whose heart and soul is built around Mike Cook, a drainage contractor based in Westphalia, Michigan. Mike was the first drainage contractor to use GPS on a regular basis and developed his own software designed on his thoughts and experiences. AGPS grew out of this early attempt and, over the years, the system has been refined and improved; it is very much a system designed by contractors for contractors. APGS do not manufacture any hardware and their software needs to be installed onto devices built by others. They are also a relatively small company who do not have any operations in Europe. A healthy competition between AGPS and Trimble has developed with Trimble adopting some of the AGPS innovations and AGPS doing likewise with Trimble's usability.

A couple of contractors in the UK have already adopted GPS grade control, mainly in the east of the country where traditionally the drainage industry has been at its strongest and the ground is often flat requiring additional care when installing. As often happens when new technologies are offered as a replacement to a long standing method, uptake has been slow. I also heard doubts about GPS grade control raised by Dutch contractors. In fact, only one contractor I met was operating a GPS grade control system; all the other were still using laser control. Most of the negative comments were concerned with the cost of the system and the difficulties in learning a new method; one or two voices were concerned about the accuracy.

As mentioned previously accuracy is of critical importance, and contractors are right to be apprehensive. However manufacturers insist that GPS grade control is as precise as laser and have tested the system extensively. In addition the GPS devices openly display the number of satellites they are able to utilise plus a predicted accuracy. But perhaps the most reassuring argument is the miles and miles of drain installed under GPS grade control by North American contractors.

Whilst widespread adoption may still lie in the future, I have no doubt that GPS grade control will take over from laser. The advantages in terms of reduced permeable fill use and ease of operation are considerable. I hardly heard a dissenting voice in North America and many heaped heavy praise on GPS grade control, one contractor even declaring that the change from laser had increased efficiency by twenty percent. Potentially the advantages to British contractors could be far greater, the only barrier remains the high cost. GPS grade control is approximately ten times as expensive as a laser controlled system, and it is very noticeable that areas of high adoption relate very closely to areas of high demand for drainage.

12 Trimble GPS display, on surveying vehicle, USA

13 GPS grade control cab station, USA

7. Trenchless Drainage

There are two dominant methods of installing drainage pipe:

- open trench which uses a chain trencher, and
- trenchless where the pipe is ploughed into the ground.

The photo on the next page show a chain trencher and there is a photo of a trenchless machine on page 5.

Most pipe installed in the UK is via the use of chain trenchers - in fact Farm Services Limited is one of the few companies in Britain who still operate a drainage plough. The reasons for the predominance of open trench drainage are, I believe, mainly due to the increased flexibility offered by chain trenchers. With a chain trencher it is possible to install sports field drainage and pre-construction pipeline drainage; neither task suits a drainage plough very well. As the industry in Britain has moved away from the type of contract which suits a large trenchless machine (large agricultural fields) it has been logical not to invest a significant sum – a shade under £300,000 - in a machine with limited flexibility. In North America, where agricultural drainage dominates the market, the vast majority of drains are installed with a drainage plough.

The increased flexibility of a chain trencher is an obvious advantage, and often the smaller size and lighter weight of these machines is very useful. However the speed of installation is far faster when using a trenchless machine. Production is often twice as great with a drainage plough as opposed to a chain trencher. This increase in production allows the price per metre to be reduced.

> Production is often twice as great with a drainage plough as opposed to a chain trencher

As mentioned before, I feel strongly that everything that can be done to reduce price should be adopted. It is true that existing drains, and for that matter, existing utilities, are easier to spot if trenched through rather than ploughed through. If existing drains are present and known to be working well, then there are compelling reasons to use a chain trencher. Alternatively if an existing scheme is elderly or performing poorly trenchless drainage is a more cost effective method.

Despite an extensive search I can find no data whatsoever to suggest that one method of installation performs better than another. Certainly some farmers both in Europe and America will a have a preference for one method or the other. This inclination tends to be formed by a reluctance to risk a different method when the other worked before. Both methods should, if possible, be installed under good dry conditions which reduces the damage done to the soils.

Left:
14. Chain trencher.

Below :
15. Trenchless land drainage machine

8. Recycled aggregates

Permeable fill is expensive and the source of many headaches on site. I look on enviously as my American and Dutch colleagues install drains without using any permeable backfill. Unfortunately in most British soils its use is unavoidable. At around a metre's depth, most soil types in the UK do not possess a great degree of permeability. Water tends not to move through these soils at sufficient speed. Many times we have excavated old drains, installed without permeable, which are installed correctly but which are dry as the water rarely reaches them. A gravel or stone band, placed above the drain, guides water from the more permeable top soils into the drain. Experiments carried out by the FDEU concluded the same point.

If it is necessary to use a permeable fill, then the most cost effective, appropriate material should be used, and if a recycled product is available I see no reason why it should not be used. Crushed concrete, brick and pre-used quarried stone, if washed and passed by a magnet and found to be hardwearing, are suitable for drainage.

A good proportion of the cost of aggregates is transport, which is exactly the same for a recycled product; the saving can be made in the price of the product and the lack of taxation. This saving, at the present time, is approximately twenty percent, not huge but a saving none the less.

15. Sample of recycled permeable fill

9. Investigation into yield improvements

There are many advantages of drainage, as anyone who has had to rescue a combine axle deep in mud will testify. However the primary motive for farmers throughout history has been to grow more crop in the same space. Historical tales suggest the effects of drainage were considered almost miraculous. American Joe Johnson, who was later labelled the Father of American Drainage, placed his ability to produce up to six times as many bushels per acre as his neighbours down to 'DCD'- Dung, Credit and Drainage.

Unsurprisingly history data regarding yield improvement has been lost – that is, if any experiments took place at all. It is likely that very little rigorous research was undertaken and that individual farmers simply installed drainage in one field to see its effect before undertaking further works. Uptake and dissemination occurred by speaking to their neighbours and best practice spread. By modern times the advantages of drainage were considered obvious and monies spent on such research would have been pointless. The decision of the War Ag to introduce grants seems to have been taken without consideration of any scientific studies - rather the pressure came from below with individual inspectors seeing the difference drainage could make.

Frustratingly, despite a great deal of drainage research, modern yield data is equally difficult to find. From the early 1950s up until the late 1980s MAFF (Minstry of Agriculture, Fisheries and Food) funded the Field Drainage Experimental Unit (FDEU). The idea was to promote best practice and advance the industry by conducting field trails into new techniques. With a network of drainage advisors to feed this information to farmers, the system oversaw the development of new materials and their introduction into the market place. Perhaps the biggest change was the change from clay tiles to rolls of plastic pipe, which greatly improved productivity and eventually enhanced workmanship. The FDEU were also key in the development of trenchless drainage, the use of permeable fill and wrapped pipe, plus helped introduce lasers to control grade.

This work was conducted in an atmosphere in which drainage did not have to be sold or marketed to farmers. With grants available covering at least fifty percent of the cost, demand was high and the decision to drain was a relatively easy one for most comer-cially minded farmers. Research focused solely on improving techniques and materials, investigations into yield were regarded as pointless.

I have, however been able to find one four year field trial which took place on denworth soils in Draycote carried out by FDEU. The four year trial showed that a comprehensive drainage scheme improves yield by 22.5%. I have been able to speak to a number of people involved with this and similar trials. They often questioned the results of the experiments, as in order for the research to be considered as fair, planting and any applications were applied to the whole plot at the same time. Whilst this might seem to guarantee fairness, it does not replicate normal farm practices. For example, well drained soil warms and dries more quickly in the spring allowing the crop to be planted earlier; this lengthens the growing season and increases yield. It is likely that the Draycote results do not reflect the true benefit of drainage.

When travelling though the United States I was able to visit a number of universities conducting drainage research and which had active field trials. Later in my report I will cover their research; however none of this research is interested in yield. The universities consider field trials with the aim of establishing yield improvements to be a commercial matter for the industry to pay for. Of course the drainage industry in relatively small and it is certainly fragmented into small companies without the means to pay for large and lengthy field trials.

Field trials into land drainage are difficult and expensive. Drainage has different effects on different soil types and it is also dependent not just upon the volume of rainfall, but its timing and frequency. It is also affected by average temperature, cloud cover and cultivation techniques. In order to gain robust data which can be used with confidence it is necessary to repeat the experiment numerous times, over many years. This research needs long term funding which is very difficult to get, plus compliant farmers who, understandably, are not willing to sign up to an experiment which will last for many years.

Many contractors I spoke to in America had little interest in spending money to improve the yield benefit from drainage. Demand for drainage is booming in the Mid-West and many contractors have more work than they can handle and have no need to promote or sell the benefits of drainage. When I asked why demand was so buoyant, everyone, without exception, mentioned yield mapping. Contractors reported that once the yield improvements were visible in black and white farmers invested in drainage. Yield monitoring and mapping are far more common in the States and the adoption of monitoring seems to be closely followed by an increase in drainage.

Only in Ontario was I able to find any modern harvest data regarding the effect of drainage. The Crop Insurance Commission of Ontario is a three way partnership between farmers, the provisional government and the federal government, designed to provide security to growers. It is not necessary to discuss the mechanism of the programme but, in brief, a benchmark yield was established for each farm and each crop. If this yield is not reached then payments are triggered.

When I asked why demand was so buoyant, everyone, without exception, mentioned yield mapping.

During the 1970s the Ontario Ministry of Agriculture and Food desired to understand the effect of drainage on Ontario's farm land. Having gained the personal views of farmers who had installed drainage, they decided to try to create some data. In 1979 the Crop Insurance Commission agreed to the presence of a question on the application form regarding drainage. This question asked farmers to state if their farm was drained, practically drained or undrained. After 1999 the forms were no longer completed by an independent insurance adjuster, but by the land owner. This decision created some doubt to the data and the question was removed. Despite this the crop insurance data provides twenty years of statistics on drainage which is perhaps unmatched anywhere in the world.

On the next page is a table showing the analysis of the data. It should be noted that data is only available for crops which qualified for the insurance scheme. The table shows average values for the entire province, which includes some northern areas of marginal land which explains the low average yield.

As the table shows, over a twenty year period, the yield of each of Ontario's major crops increased greatly if grown on drained land. Corn (maize) grown on drained land showed a 29% increase over under-drained land, whilst soya showed a 26% increase. Most impressively, Ontario's third most popular crop, winter wheat, demonstrated a 38% increase.

Soil, climate and topography are completely different in Canada and comparisons have to be tempered. However these statistics support the historic opinions and the data from the Draycote field trials. It may be difficult to assert the exact yield benefit but I believe that drainage increases yield by a factor which is very difficult to match by other methods.

The need to maintain and increase yields in the face of a growing world population and continued pressure on the amount of land available for agriculture is vital. **I believe that there is a moral imperative to use the land we take from nature as efficiently as possible and to do that it is necessary to increase our investment in drainage.**

Crop	Years	# of Records	Yield Tiled bu/ac or lbs/ac	Yield No Tiled bu/ac or lbs/ac	Total Acres Tiled	Total Acres No Tile	**% Increase in Yield**	% Acres Tiled
Corn	20	209,098	115	89	11,189,949	7,420,135	**29**	60
Soybeans	20	177,853	39	31	10,865,953	5,527,814	**26**	66
Wheat Winter	20	136,510	62	45	3,710,608	1,840,279	**38**	67
Grain, Spring	20	130,566	2,663	1,934	2,337,036	2,441,330	**38**	49
Beans, White	20	29,615	1,554	1,284	97,326	336,683	**21**	22
Canola	10	5,170	1,598	1,420	147,591	177,458	**13**	45
Beans, Col	20	5,164	1,438	1,302	234,637	82,786	**10**	74
Wheat, Spr	10	4,552	44	33	125,644	91,417	**33**	58
Sunflower	10	337	1,409	1,264	6,837	3,561	**11**	66

Yield increase with land drainage

10. Promotion of drainage

Ever since the removal of subsidies the drainage industry has shrunk and looked to diversify. It is perhaps not surprising that in such an environment contractors have not spent time or money promoting drainage. This ever decreasing circle of a lack of demand, thus discouraging promotion, has resulted in a historical low in investment in drainage.

The yield advantages of drainage are great, and to ignore a proven technology is madness. Farmers understand the advantages of drainage but are often ignorant of the details, presuming that the payback time is longer and only investing when they see no other alternative. The removal of subsidies has created a legacy where some farmers believe that drainage is so expensive that it can only be afforded with government assistance.

I believe that the British drainage industry has done agriculture a disservice by not explaining the benefits and by diversifying into other areas rather than fighting to promote drainage. It is extremely unlikely that subsidies will return to drainage and farmers have to plan and schedule drainage into their investment programme. However without publicity and promotion of drainage by contractors this is unlikely to happen. **I encourage contractors to promote drainage, to write articles for publication and to talk to farmers' groups**. I also hope that new technology can help.

The data available from yield mapping can be used to explain the yield benefits, and whilst one contractor acting alone would be unable to collect enough samples to make the data worthwhile, the industry as a whole can.

I argued this point to the Land Drainage Contractors Association during the organisation's AGM. We agreed to collect and pool information regarding the yield increases seen by our clients, and then to publicise this information. When travelling in North America, time and time again yield mapping was credited for increasing demand for drainage.

When travelling in North America, time and time again yield mapping was credited for increasing demand for drainage.

For many years the Land Drainage Contractors Association and the Farmers Weekly held a drainage demonstration each year. At its peak the demonstration was a very large event with a dozen contractors draining a large field over a day or two, supported by a special pullout in the Farmers Weekly. Whilst it may not be feasible to arrange an event of such size, I believe it would be beneficial to all to revive this event. It was been over thirty years since drainage was installed on a large scale, and a generation of farmers has never seen drainage being installed.

11. The future: conservation drainage

Preserving the natural world and having an understanding of the consequences of our actions dominates much of mainstream thought, and a great deal of media attention. Many aspects of farming are subject to environmental regulation and I can only foresee this increasing in years to come. If we are going to pass on what we have received we must curb our most damaging actions and promote solutions. The land drainage industry being relatively small has not been subject to rigorous legislation, and indeed whilst I'm very keen to argue that draining land can have many environmental benefits, the effect of drainage on the environment is complex and has negative as well as positive effects.

> Whilst drainage outlets are a conduit rather than a cause, research has shown that during the winter months high nitrate levels have been found to exist in water exiting drainage outlets.

The effect of agricultural activities on water quality is well known and control systems are in place. For example here in the UK we have many Nitrate Vulnerable Zones subject to legislation which aims to limit the pollution of water. High levels of nitrates and phosphorous cause issues, not just to the fauna and flora living in and around the water courses, but also to drinking water and to life around our coast. Nitrates are water soluble, and the role of land drainage is to remove excess water from the land. If nitrates are present then they too will be removed. Whilst drainage outlets are a conduit rather than a cause, research has shown that during the winter months high nitrate levels have been found to exist in water exiting drainage outlets. This problem is particularly acute in the USA and a number of universities have spent a considerable amount of time finding solutions to the problem.

The Mississippi River system is the largest in North America and one of the largest in the world. The basin drains approximately 1,250,000 square miles which is the fourth largest drainage basin in the world and covers most of the Mid-West and the corn belt of America. This is some of the most fertile land in North American and as such, is intensively farmed. Whilst agriculture is not the only source of pollution, farming activities have helped to cause leaching, and run-off of nitrogen in particular, which has resulted in localised problems in drinking water quality and a major hypoxic zone in the Gulf of Mexico.

Certain farming practices such as autumn fertiliser applications are being targeted and farmers are being encouraged to apply fertilisers in spring and to install buffer strips and waterways to reduce run-off. The role of land drainage is also being considered. However, farmers in the corn belt have seen the difference drainage makes to their yield and would strongly oppose any restriction on drainage or reduction in drainage efficiency.

12. What is Hypoxia?

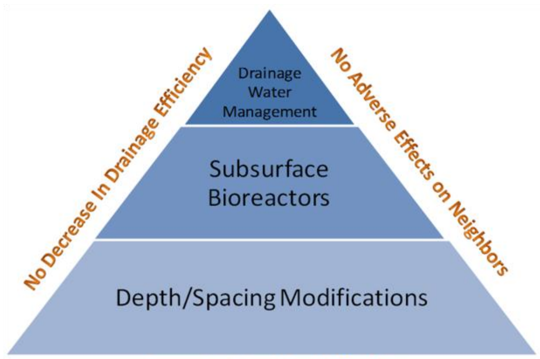
Hypoxic zones are aquatic areas of excess nitrate pollution. They can be caused by natural events such as wind changes and costal upwelling. However the majority of hypoxic zones are produced by human activities such as sewage pollution, industry and agricultural runoff. Increased amounts of nitrogen and phosphorus trigger an increase in the numbers of certain types of phytoplankton, whose population density is normally limited by the nutrient level. This is called eutrophication and results in algal blooms which can be visible from the air. Once the algae bloom, they die and decompose, a process which uses oxygen thus depriving this element from other forms of life. The lack of oxygen causes 'dead zones' where fish and other marine life are scarce or non-existent, damaging the ecosystem.

Hypoxic zones can be found throughout the world, especially in Europe and North America. They occur in costal, shallow water and impact on coastal communities and the fish industries as well as the natural world. It is possible for hypoxic zones to go into retreat, and this is known to have happened in the Black Sea, when high prices following the fall of the Soviet Union caused a reduction in the use of agricultural fertilisers.

Arguably the most widely studied Hypoxic Zone is in the Gulf of Mexico. The size of the Zone has been measured since 1985 and over the last five years this has revealed a five year average size of around 5,500 square miles, with a peak in 2002 of approximately 8,500 square miles. A desire to, at the very least, control the size of the zone has resulted in a number of studies and developments, a minor part of this being focused on land drainage.

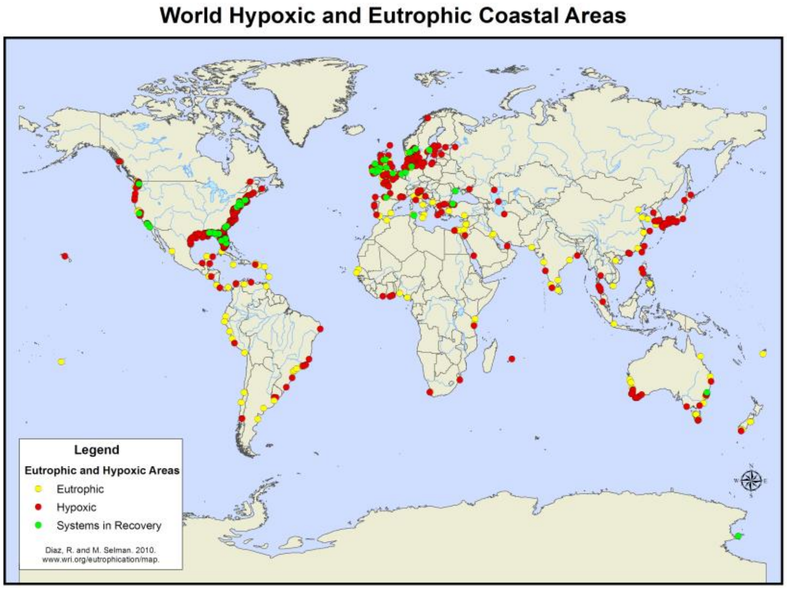
Some of this research is, I'm sure, of value to the UK.

A number of Mid-West universities have been working on possible solutions and have field trials in operation. Their efforts have been labelled 'Conservation Drainage' and a great deal of collaboration has taken place in order to agree a framework which will satisfy all parties. The triangle below is a way of demonstrating some of the techniques involved with conservation drainage and the goals of the movement.



The conversation drainage triangle – R. Cooke, Illinois State University

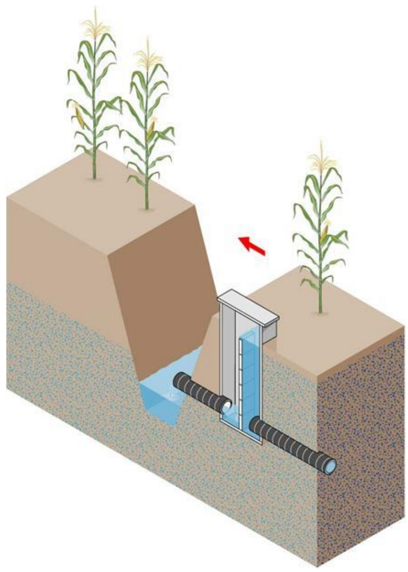
Inside the triangle are the various methods devised to mitigate the flow of nitrates. On the outside are the parameters which these methods must meet: that the measures must be convenient and cost effective, have no adverse effects on neighbours and, from my perspective the most important, that the measure will have no decrease in drainage efficiency. By complying with these parameters each mitigation method is practical and likely to be accepted by both farmers and the drainage industry, vital if these methods are going to be adopted on a large scale. I believe that the philosophy represented by this triangle is an excellent example of practical research being



undertaken to improve society without hindering farming.

Many of the mitigation methods devised in the Mid-West, will have only limited application in the UK. Understandably the American universities focus on the conditions, crops and topography of America, and whilst many aspects of agriculture are similar on both sides of the Atlantic, others are not. For example, the major crops grown in the Mid-West are soya and maize (corn). Each of these grows only during the summer and the ground is left fallow over winter. This is different to Britain where our predominant crop is winter wheat and other small grains. In addition, large parts of the Mid-West are extremely flat with many extremely large fields of over a hundred acres on slopes of less than one in a thousand. This flat terrain and fallow winters are perfect for the mitigation method on the top of the triangle: Drainage Water Management.

By installing a control device near the outlet of a drainage scheme the water level inside the drainage system can be regulated. During the winter when no crop is present and there is no requirement to be on the land, the water can be prevented from leaving the drainage system; the drains are switched off. A week or two before access to the land is required in the spring, the control devices are removed and the drainage works at full bore. By reducing the volume of water exiting the drainage scheme, the volume of nitrate is also reduced. This method does not remove or treat the nitrate- rather it simply reduces the amount entering the water course.



Drainage Water Management –
R. Cooke, Illinois State University

When in Iowa I was able to visit a company called Agri-drain based in Adair; they have developed control boxes such as the one in the picture below. They have also been developing subsurface inline gates which will allow water to be held in the drain on gradients greater than is possible using control structures alone. The devices are light weight and simple to install.

16. Drainage Water Management Control Structure – Agri-drain

There are certain locations in the UK, and some crops, those with a high value and a high water requirement, which might be suitable for Drainage Water Management (the control structure will also allow sub-irrigation during the summer). However the topography, soil type and the cropping choices of most of the country will mean that Drainage Water Management cannot be widely adopted in the UK.

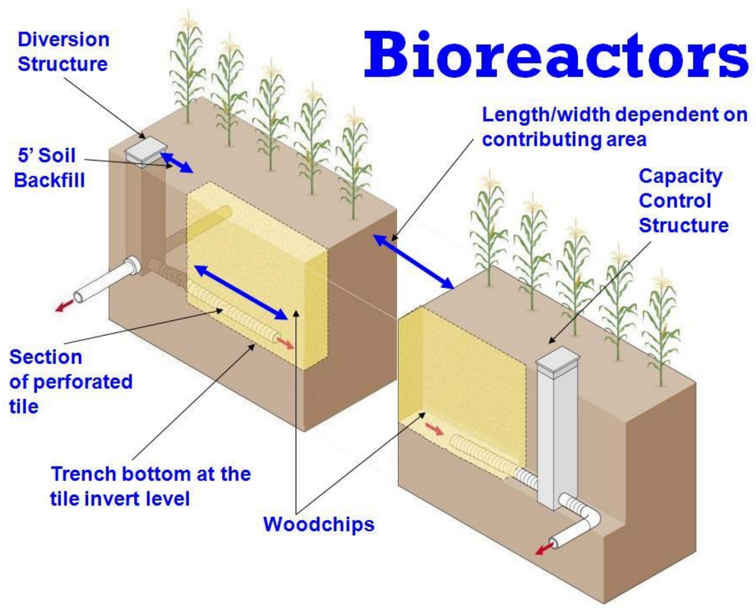
It is also the case that the spacing and depth modification being promoted in America, the method at the bottom of the triangle, will be of little use in this country. Research in America indicates that shallower drains closer together reduce the amount of nitrates leaving outlets when compared to deeper and wider drain spacings. In America there has been considerable support for deep drains spaced farther apart. Proponents of conservation drainage are encouraging farmers and contractors to install drains around a metre deep, and at twenty metre intervals. Such a specification is already standard practice in Europe.

The remaining mitigation method from the triangle, Subsurface Denitrifying Bioreactor, is far more suited to the agricultural practices of the UK and I believe could be a significant tool to reduce nitrate levels in our water courses.

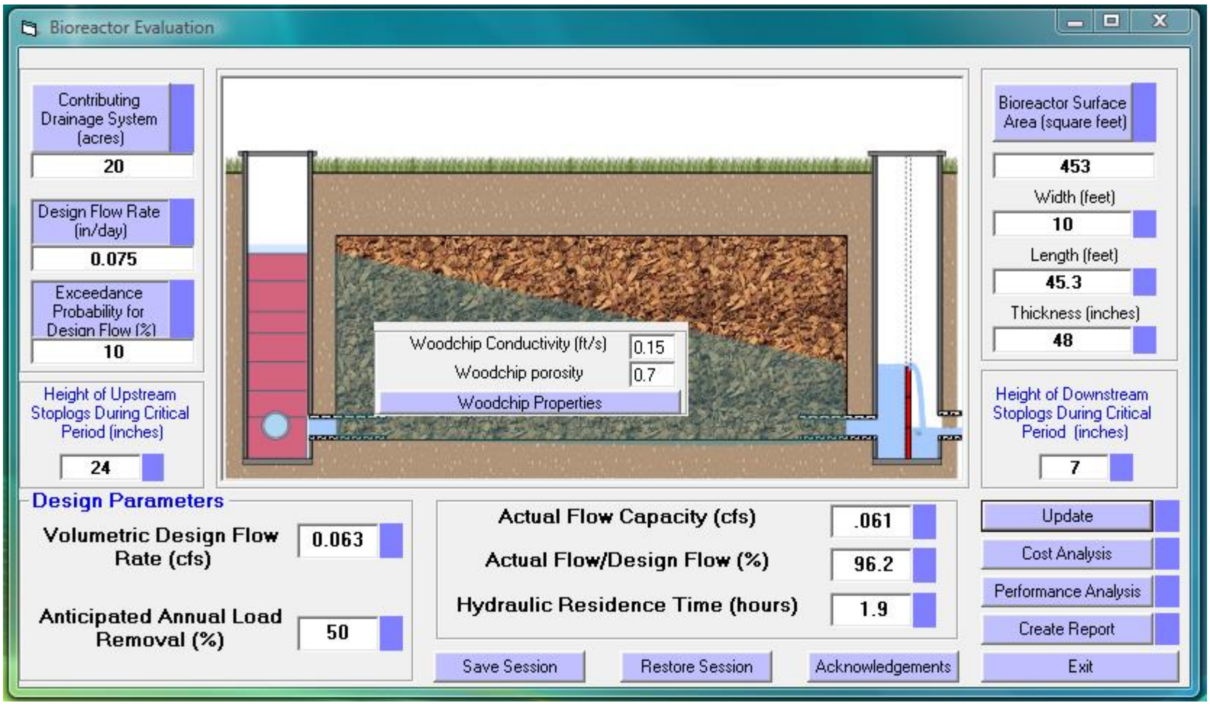
Bioreactors provide a habitat for micro-organisms and bacteria which feed upon the nitrates in order to live. They are installed near to the outlet of a drainage system and are buried, so that no land is lost to production. Drainage water containing nitrates enters the reactor, the micro-organisms and bacteria feed on the nitrates and remove or break it down, and the water leaving the system has nitrate levels far lower than when it entered.

Bioreactors are excavated to the same level as the pipe invert, lined with a geo-textile and filled with wood chip. The size of the excavation and the amount of wood chip depends upon the area the drainage scheme covers and the quantity of water expected to flow into the bioreactor. Control chambers are installed both before and after the reactor in order to regulate the flow of water entering the woodchip and the time the water spends in the chamber. At present the life span of a bioreactor is unknown. A number have been in the ground for approximately eight years, and it is predicted that they will last for at least fifteen to twenty years.

Bioreactors have been the subject of field trials in America for almost ten years, and during this time researches have been able to prove that they reduce nitrate levels. They have also been able to fine tune the design: by conducting a series of experiments, the required size and flow rate have been



Subsurface bioreactor - R. Cooke, Illinois State University



Subsurface Bioreactor evaluation guide

calculated to give optimum performance. Work on bioreactors has been pioneered by Professor Richard Cooke of Illinois State University who has nine reactors in the ground and is monitoring their performance.

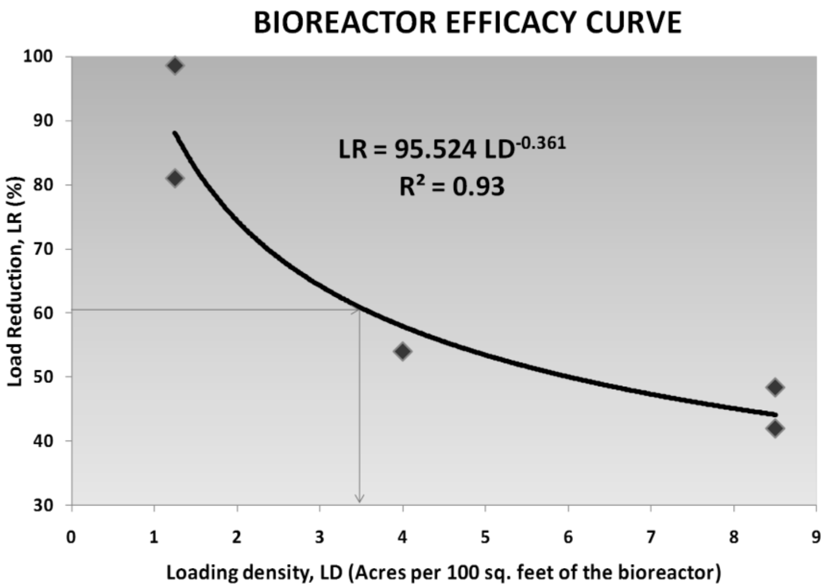
Richard has developed an understanding of the processes involved when water with higher than desired levels of nitrogen flows into the bioreactor. This understanding has allowed him to devise a bioreactor evaluation guide which is available online. The guide (see above) specifies the size of reactor required depending upon the area drained and the flow of water.

Table 1. Load reduction efficiencies of bioreactor sites for 2007-09

Site	Contributing Area (Acres)	Loading Density (Acres/100 sq.feet of bioreactor area)	Load Reduction % 2007-08	Load Reduction % 2008-09
Decatur West	5	1.25	81	98
Decatur East	16	4	54	--
Deland East	34	8.5	42	48

The results from Richard's field trails show very promising results. The table above shows published findings from some of Richard's field trials. *(continued in column on right)*

From this and other research it was been possible to produce an efficacy curve to show the expected reduction in nitrate load to loading density in differing sized bioreactors



The cost involved with the installation and maintenance of a denitrify bioreactor is relatively small. Woodchip can often be sourced on the farm, and the size of excavations required for the small scale reactors (when compared to North America) is modest. I doubt if installation would take more than one day and could be done with a wheeled 180^{o} excavator. Once in place the reactor should not need any maintenance, although it would probably be advisable to monitor the water quality when the reactor nears the end of its life, to detect when it ceases to work.

Bioreactors can be retrospectively fitted to existing drainage systems and, if buried, do not take any land out of production. They are designed not to reduce the effectiveness of the drainage and are based upon a simple well known principle.

Denitrifying bioreactors offer a positive solution to a problem. When modern farm practice produces an undesired side effect, the response is to prohibit the process. This is very effective in preventing the problems but the reason for doing the activity in the first case - to increase yields - is lost too.

Bioreactors offer a relatively inexpensive solution to a problem, which would not restrict farming practice.

17. Professor Richard Cook

18. Self standing on an open bioreactor

13. Conclusions

- Drainage is proven to increase yields and has a track record stretching back thousands of years. If forward momentum in farming is to continue and yields to increase again, established technologies as well as new breakthroughs should be utilised. I believe that drainage must play a vital part in farming's future

- Whilst it is likely that local knowledge will still provide the clearest clues upon how a field should be drained, contractors must be aware of soil type, the final use for the field and the client's wishes. Good design minimises costs and with so many different ways of draining, time spent on design is not wasted.

- It is the job of drainage contractors to promote drainage. The benefits of drainage are clear and proven; it is not up to farmers to seek out this information. For many years the drainage industry has been deadly quiet. Contractors must take control of the industry and promote drainage

- No one in our society can ignore the environment. Rather than viewing it as a hindrance, conservation drainage should been seen as an opportunity.

- The cost of drainage is the single largest factor preventing farmers from installing more. If at all possible costs must be reduced and passed on.

14. Recommendations

- **Promotion:** contractors should publish articles, place adverts and talk to farmers' groups. I also recommend that demonstrations are held, allowing farmers with little experience of drainage to understand the process.

- Trenchless drainage may not be a panacea but it is faster and therefore cheaper than open trench, and as previously mentioned, reducing the cost of drainage is key if more drains are to be installed. We should if possible install by trenchless method.

- It is a case of when, not if, GPS grade control becomes the predominant method for laying drains to a grade. The advantages are clear and it has already become dominant in North America. Whilst we in Europe are late to the party it does mean that many of the early problems have already been resolved.

- Denitrifying bioreactors offer a proactive, relatively cost effective solution to the problem of high nitrate levels, caused from water flowing out of drains into water courses. I believe that they can be a useful tool here in the UK. Investigation should be undertaken to see whether we are able to repeat the results obtained in America in the UK.

- The rate of drainage installation is at an historic low. The vast majority of the drains which British agriculture relies on are at least thirty years old, many are far older than that. Drains are a valuable asset and should be treated as such. They should be carefully maintained and outlets checked regularly. Drains can last for generations, but eventually they will need to be replaced. If yields are to be preserved, let alone increased, farmers must give consideration to a long term replacement programme.

15. Since my travels

My Nuffield travels coincided with some of the most unusual, challenging, and profitable weather in living memory. When leaving to attend the Contemporary Scholars Conference in January 2012 our drainage teams were installing pipe in dust clouds with the winter being one of the driest on record. This caused a downturn in orders and the rain which persisted all summer caused difficult conditions to install drainage.

That same rain, which caused England to have wettest summer since 1847, also saw a spike in enquires and demand for our services. This volatile pattern would appear to be the new normality and the business will have to be strong enough to cope with the extreme peaks and troughs.

Some considerable changes have occurred as I put my thoughts and Nuffield experiences into practice. Of course I would like to see the pace of change occur faster still. Farm Services Limited has featured in more industry publications in the last year than in all the other years of its existence added together. In addition, I have already spoken to more than a dozen farming groups to promote drainage. This is an ongoing effort which needs to be maintained.

I also spoke at the Land Drainage Contractors Association AGM, where I was invited to join the council and drew considerable support for the collection of yield data. Yield monitoring technologies are growing here in the UK, although still nowhere near as common as in America. I have been keen to collect yield mapping data showing the harvest before and after the installation of land drainage. Whilst one contractor will always struggle to have enough data for the results to be useful and scientifically rigorous, a number of contractors joining together could have access to a great deal of data and within a couple of years have enough data for robust, if generalised, conclusions to be drawn. This is the first time contractors, (who are, of course, competitors) have worked together in the industry to promote agricultural drainage. I hope that from the harvest of 2013 we will be able to collect data and present this to farmers and the industry in general.

This is the first time contractors, (who are, of course, competitors) have worked together in the industry to promote agricultural drainage

So far, this year has been a busy one for our trenchless drainage plough, and I hope that we will continue with our new marketing effort. Slowly a network of suppliers of recycled aggregates is developing and products suitable for drainage are being produced in more and more locations. The adoption of GPS grade control is on our 'wish list' - I'm hopeful that we can make the investment sooner rather than later.

I have been in discussions with the Severn River Trust to install a denitrifying bioreactor in the UK. Interest has developed into planning and I hope to install the first bioreactor in the UK this winter. The site of a bioreactor is as yet unknown and a few issues remain, however with the support of the Severn River Trust I believe that we are on course.

I have thoroughly enjoyed my Nuffield adventure and I'm convinced that the experience has transformed my professional life. Nuffield has given me something which is unique. No other contractor in Europe - perhaps the world - has the breadth of experience I can now call upon. I hope to put it to good use.

Nuffield had also given me a goal to aim for. Ohio State University oversees the International Drainage Hall of Fame, and surely entry is the aspiration of my career!

See picture below.

Rob Burtonshaw

Farm Services Ltd
Chesterton Estate Yard
Banbury Road
Lighthorne
Warwickshire CV35 OAF

rob@farmservicesltd.co.uk
tel : 01926 651540
mob: 07813 064615

19. The Drainage Hall of Fame, USA

16. Thanks

I must most especially thank both **my wife and my father** for their support, both in manning my responsibilities in the business and for putting up with my long absences from home.

Others I particularly want to thank include:

Contractors
Netherlands
Jimmick Drainage - George Jimmink
Gebr Van Geest - Herman Van Der Geest
Heershap Drainage BV - Jan Heerscap
Barth Drainage B.V
Combi Drain BV - Jackie Jagt / Willem Noordhoek

Canada
Roth Drainage - Gerald Neeb
Mark Cook Drainage Ltd - Mark Cook
Martin Agri Drainage Ltd
McCutcheon Farm Drainage – Ken McCutcheon
K.M.M. Drainage
Gillier Drainage Inc

USA
Soil and Water MGMT Systems, Inc - Mike Cook
Louis McFarland
Elingson Companies - Derrik (spike) Ellingsion / Roger Ellingson
ADI - Dan Peebles
Leichty & Son
Hall Drainage
Hodgman drainage
Seevers Farm Drainage
David Kennedy

Machinery Manufacturers
Netherlands
Interdrain - Nico van Deursen / Robert Derksen
Steenbergan HollandDrain - William Smeekes / Stephan Reedijk

USA
AGPS - Riley Skeen / Nate Cook
Schlatters Inc - Joey Schlatter
Northland Trenching Equipment Inc. - Corey Nied
Port Industries – Kevin Shrimp

Canada
RWF Bron - Mark Ordorico / Jason Bleach / Ron Hall / Robert Hall
Wolfe Heavy Equipment - Keith Gilies / Peter Dymond

Universities
Wageningen University and Research Centre - Henk Ritzemen
RJ Oostergbann (Rolland) (retired)
Ohio State University - Norman Fausey / Larry Brown
Iowa State University - Mathew Helmers
Purdue University - Jane Frankenberger / Eileen J Kladivko / Laura Bowling
Illinois State University – Richard Cooke / Kent Mitchell

Pipe/supplies manufactory
USA
Agri Drain - Lisa Newby
Hancor - Bob Rabey
Timewell - Aaron Kassing
Prinsco - Kent Rodelius
ADS - Kevin Rapp
Springfield Plastics - Stephen Baker

Canada
ADS Canada - Nathaniel Johnston
Ideal Pipe - Ron Mc Farlane

Government
Ontario Ministry of Agriculture, Food and Rural Affairs - Sid Van Der Veen / Andy Kester / Tim Brook

Others
Crosby De Witt
Peter Dearbishire
Trimble - John Downey

UK
Dick Godwin
Gordon Spoor
Hugh Hamner
Kirk Hill
Jenny Lambert
Mastenbroeks – Fred Clarke / Chris Petit
TGMS
Bruce Broakway
Robin Hodgkinson
Colin Dennis
John Rands
Robert Cooper

17. Executive summary

Land drains, buried a metre below the ground, working twenty four hours a day, three hundred and sixty five days a year, are perhaps the hardest working but least thought about farm equipment in Britain. Perhaps it is understandable that drains are often forgotten. Once the field has been cultivated nearly all signs of the investment disappear and, as drainage tends to prevent problems before they occur, it will always be easy to overlook.

What should not be ignored are the benefits well drained ground can give to those who work the land. For thousands of years people have drained land to increase yield and to make farming easier. Almost everything in farming starts with the soil and good drainage is the foundation of good soil. It is, quite simply, impossible to farm profitably on sodden fields.

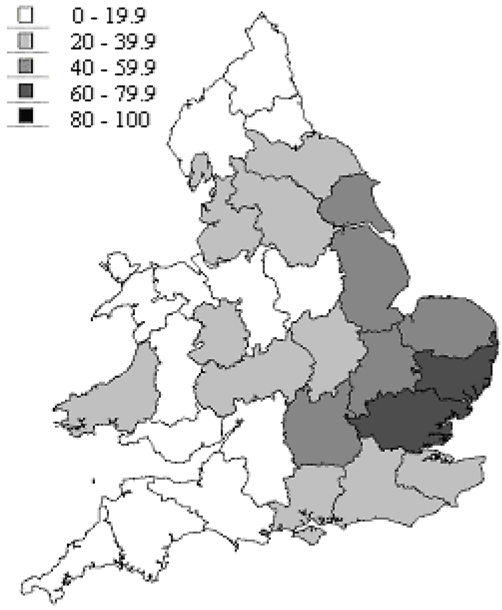
Land drainage is a capital expense and as such represents a considerable investment for a farmer. Traditionally drainage has been installed during periods of growth in the agricultural industry and when governments have provided grants. This has resulted in gluts and droughts in the amount of pipe installed, which presents a problem for farmers. The most recent glut ended in the early 1980s, meaning that the vast majority of drains in Britain are at least thirty years old. Drains, correctly installed, can last for many years. However this is dependent upon maintenance and ground conditions. The performance of many drains installed during the nineteen eighties will have begun to deteriorate. Over the course of my Nuffield studies it has become very apparent that the state of land drainage in the UK is declining and that if yields are to be maintained let alone improved further investment in drainage is a must.

The future of land drainage must address the major obstacle preventing farmers from investing in drainage: the price. Whilst the cost of drainage has seen modest price rises recently, making it more affordable than at any point in living memory, the majority of farmers still stated price as the major reason why they did not invest in drainage. My experiences in America and Canada have convinced me that the cost of drainage can be reduced by the use of GPS grade control and installation by trenchless methods.

Overlooked by virtually all drainage contractors is the promotion of their services. Contractors have taken a back seat and opted for diversification instead of promoting drainage and investing in marketing and sales.

Modern drainage, installed in the right place is an environment positive, improving yields by using a renewable source: gravity. I believe that if we are to use land there is a moral argument to use it to the best of our ability in a sustainable manner. Conservation drainage allows drainage schemes to be ‘proactive’ and offers a solution to some water quality issues. Experiences in the Mid-West of America have shown considerable benefits with the use of denitrifying bioreactors. This is an available, proactive, solution to excess nitrogen in water courses.

18. Appendix



Percentage of the agricultural land area in each old MAFF Division, requiring drainage, that is drained by surviving pipe drains installed in the period 1950 to 1992 with grant-aid. ADAS ESO111

20. Peter Darbishire beside Nuffield sign in Ontario, Canada