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Author Catherine Mowat
Floodplain Meadows Partnership Ambassador Programme

Analysis of vegetation and hydrology on two moors on the Somerset Levels and Moors – King's Sedgemoor and Tealham Moor

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Analysis of vegetation community and hydrology on two moors on the Somerset Levels and Moors – King's Sedgemoor and Tealham Moor

Executive summary

A study was undertaken on two fields on two different moors on the Somerset Levels and Moors between 2015 and 2017 in order to understand the relationship between hydrology and vegetation community on the sites. The work was undertaken on a field on King's Sedgemoor and on Tealham Moor between 2015 and 2017. Both sites comprised agriculturally unimproved swards on peat soils with similar water management regime - both were in Raised Water Level Areas, where the water levels are kept higher than the water levels in other nearby areas in spring. This study will provide an opportunity to compare results with published hydrological studies on other moors in the locality.

The vegetation community on the King's Sedgemoor field comprised MG14a *Carex nigra-Agrostis stolonifera-Senecio aquaticus* grassland, typical sub-community, with a drier mixed community on the raised ditch banks. The Ellenberg F value for the species in the field, ignoring the drier ditch bank community, was 7.3. The Tealham Moor field comprised MG8c *Cynosurus cristatus-Carex panacea-Caltha palustris* grassland, sub-community *Carex nigra – Ranunculus flammula* with an Ellenberg F value of 6.92. The Ellenberg data supported the fact that the King's Sedgemoor field was wetter.

The King's Sedgemoor field had 22.6 species/ sample, quite a high number for its community. However, it had high levels of reed sweet grass *Glyceria maxima*, a species which has increased in recent years on the site and which indicates water logging and/or high nutrient levels. Surface gutters were cut in December 2015 to address this, but it is too soon to assess their effect. The Ellenberg N value for the King's Sedgemoor field was 5.1, which is quite high for the community type. The Tealham field was in good condition, with 24.4 species/sample and no high levels of invasive species or indicators of waterlogging. Species richness in both fields were above the national mean for their communities (if it is possible to compare these, as quadrat sizes in national samples is not known).

Hydrological studies involved a transect with 6 dipwells from ditch edge to field centre, and showed water tables to be at or near to ground level (above or below) in the winter, dropping gradually during spring and summer to a maximum depth of 74cm on King's Sedgemoor and 39cm on Tealham Moor in 2016, but to maximum depths of 52 and 54.5cm respectively in 2017. These corresponded with published water table depth zones associated with MG13 and MG8 communities using dipwell data from 2016, but the 2017 dipwell data suggested the hydrology of both sites, not just the Tealham site, to be more supportive of MG8.

It is recommended that the study on King's Sedgemoor be continued in order to monitor vegetation changes following the gutter cutting in December 2015 and water table changes.

Agricultural productivity on the King's Sedgemoor site was found to be low, with a hay yield of 5.4t/ha followed by grazing at 0.5LU/ha for 6 weeks.

An attempt was made to assess the zone of influence of the ditch, but the only conclusion that could be drawn was that it was over 6m on King's Sedgemoor. An attempt was also made to assess the influence of gutters on water table height but none was discernible.

The work formed part of the Floodplain Meadows Partnership's Floodplain Ambassador training scheme, funded by the Esmée Fairbairn Foundation.

1 Introduction

The aim of the investigation was to study the zone of influence of the ditch into the field for each site in hydrological terms, and to describe the vegetation communities in relation to hydrology. Having the two sites provided a useful comparison.

This study was undertaken as part of the Ambassador training run by the Floodplain Meadows Partnership (FMP) http://www.floodplainmeadows.org.uk/ funded by the Esmée Fairburn Trust, aiming to equip professionals and committed volunteers through England and Wales with skills so that they could provide advice and management for floodplain meadows to other parties.

Two fields were chosen on the Somerset Levels and Moors (SL&Ms) – one on King's Sedgemoor (Figures 2, 3 and 4, and cover picture) and one on Tadham Moor (Figures 2, 3, 5 and 6), which lie in different river catchments (in the Parrett and in the Brue). The SL&Ms are floodplains, subject to sporadic flooding, mainly in the winter. The area has been subject to drainage over a number of centuries, with a resulting landscape of rectilinear fields separated by ditches. In summer, ditch levels are traditionally kept to a 'summer pen' level where they act as wet fences and provide drinking water for cattle, and in winter the ditch levels are lowered to a 'winter pen', when they can store and convey some of the rainwater. Figure 1 describes the water supply mechanisms for the soils on deep peat on the SL&Ms (from Wheeler B.C., Gowing D.J.G., Shaw S.C. et al, 2004).

Figure 1 A schematic representation of the hydrological context of MG8 grassland

(from Wheeler B.C., Gowing D.J.G., Shaw S.C. et al, 2004)

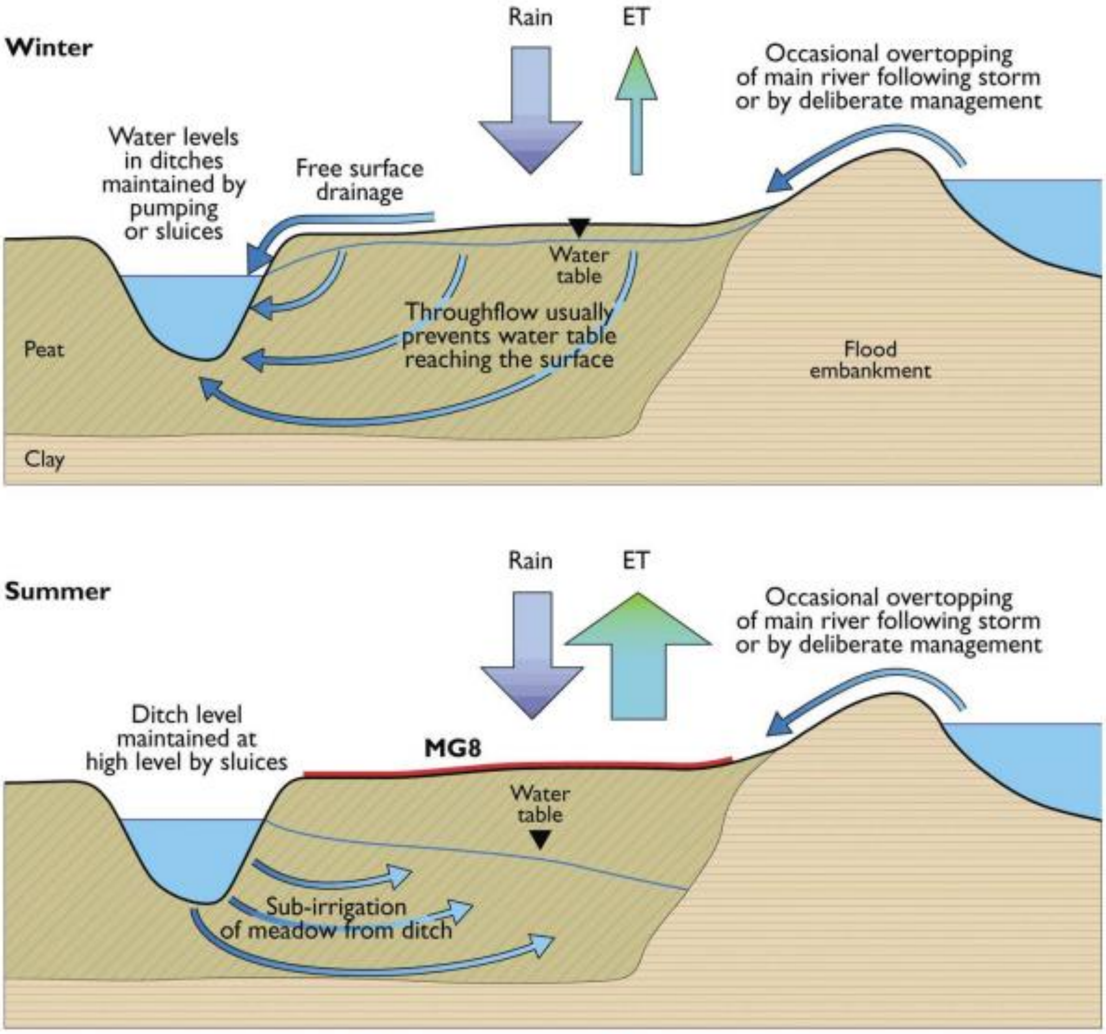


Figure 4.1 A Schematic Representation of the Hydrological Context of MG8 Grassland

Both sites comprised deep peat and the fields were agriculturally unimproved meadows, and both within Sites of Special Scientific Interest (SSSIs), and also forming part of the SL&Ms Special Protection Area (SPA) on account of their wintering bird populations. The King's Sedgemoor field was one of a suite of fields and other sites that make up the National Nature Reserve. It was owned by Natural England, but tenanted by a farmer. The Tealham Moor field was owned by the Somerset Wildlife Trust, and farmed by a farmer. Both fields were subject to environmental payments from the Higher Level Stewardship Scheme on account of the raised water levels.

Both study fields lay in Raised Water Level Areas (RWLAs), although this did not have a bearing on the results. RWLAs are areas where the pen is higher in winter and spring than on surrounding land in order to provide a splashed habitat (with low water levels, typically less than 15cm) for winter waders and then for breeding waders. By mid-June, the pen on the RWLA's has dropped to that of surrounding ditches.

While both study fields were in RWLAs, the part of the RWLA in which the Tealham field sat was only rain-fed, with no other water supply; ditches in winter could therefore be lower than field level, and so fields could be relatively dry. The King's Sedgemoor RWLA, however, was fed by a stream, and so winter water levels could be kept at field level, guaranteeing a wetter field.

Both sites had gutters – straight surface drains (Figures 4 and 6). These have two purposes. One is to provide wet 'features' for waders, when they hold water in winter and spring when ditch levels are sufficiently high to 'push' water into them, or they are blocked as so rainwater cannot drain out. When unblocked, they help to drain the field surface, an important role in summer when fields need to be dry for grazing, hay cutting and other field operations.

Figure 2 Location of the two study sites

Tealham Moor is the upper, King's Sedgemoor the lower of the two red spots

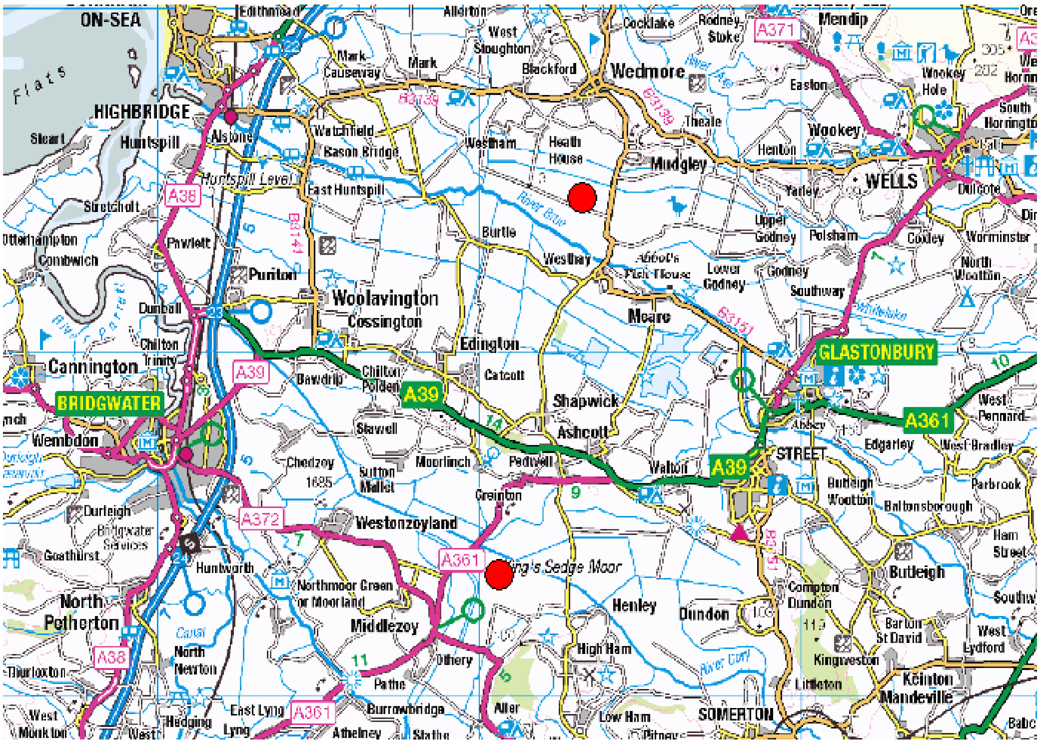
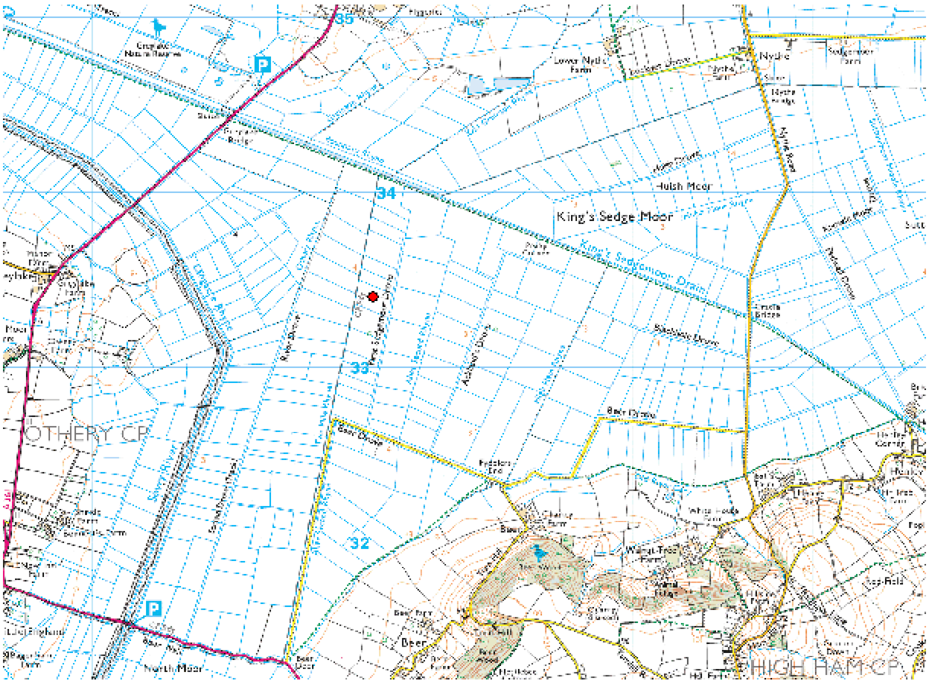
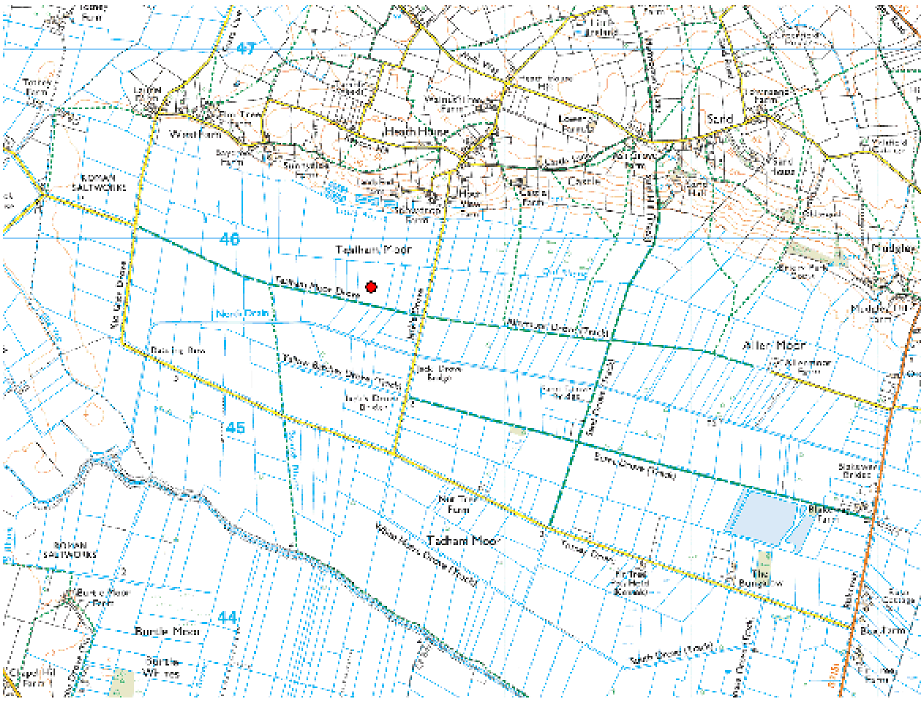


Figure 3 Location of the two study sites showing field boundaries

Above: King's Sedgemoor
Below: Tealham Moor
The locations are indicated by a red spot.





The peat on King's Sedgemoor dates to approximately 1100BC at the surface (Richard Brunning, county archaeologist *pers comm*.) – younger layers have presumably disappeared through oxidisation. The peat is relatively unaltered. The age of peat on the surface of Tealham Moor is not known. This moor was subject to drainage and drying in the 1980's, a period of dry summers, and as a result the top layers of peat have partially decomposed and has become humified (the natural layers of undecomposed vegetation are no longer present). It is not known whether King's Sedgemoor was subjected to the same degree of intensification in the 1980's.

The initial aim of the study had been to study just one site - King's Sedgemoor - where gutters had just been created, and to assess the area of influence of the gutters in irrigating the soil in the fields and potentially changes in vegetation in relation to the gutter. However, the gutters' installation was delayed and they were only put in in December 2016, half-way through the Ambassador training course. The Tealham Moor site was therefore chosen as a back-up, and dipwells put in in September 2015, although it was not considered as suitable as it had smaller gutters - foot drains 40cm wide and 25cm deep - which were possibly too small to provide meaningful results.

The second aim had been to assess the zone of influence of the ditch into the field.

It had been hoped to undertake a study of a site over 2 years in order to see whether the vegetation changed in this time. However, due to delays described above, the first NVC vegetation analysis was only undertaken (on Tealham Moor) in September 2015, too late in the year for clear results. This left only 2016 for satisfactory field work and analysis, although dipwell monitoring was continued in 2017 on both sites. Having two sites allowed a direct comparison between them, which helped to compensate for the lack of 2 years of complete data.

Both sites had an NVC survey undertaken some 10 to 15 years ago, and it was hoped that this study would provide an opportunity to assess changes in vegetation over time. Unfortunately only a map was found of the 2005 NVC survey of King's Sedgemoor and the NVC survey report for Tealham Moor has currently not been found.

1.1 Other studies

Hydrology of peat soils on the SL&Ms has been extensively studied, although not on King's Sedgemoor or Tealham itself. This has usefully been summarised in a report to the Internal Drainage Board following the floods of 2012-2014, and references of studies quoted below may be found in the report (Stratford C. and Acreman M., 2014).

A summary of some of the findings summarised in the Stratford and Acreman report and which are relevant to this report are provided below:

- Peats on SL&Ms are very variable. Peats on Southlake Moor have been calculated to be hydraulic conductivity of 1m/day (Armstrong and Rose, 1999), while those on Tadham have been calculated as 2m/day (Bradford 2004). However, on Catcott Heath hydraulic conductivity can vary from 0.5m/day to 5.5m/day. Water is likely to pass more slowly through well humified (decomposed) peat than through undecomposed peat, which can have voids in it (more porous).
- (Page 26) Acreman et al (2002) concluded that dipwells up to 8m from the ditch are influenced by the presence of a ditch; beyond this the water table response of fields is governed by rainfall and evaporation. However, on West Sedgemoor Gilman (1994) noted that a strip some 30m wide dried out more rapidly than the rest, while the centre of the field remained dry.
- Stratford and Acreman conclude that the most likely distance of influence of ditches for the SL&Ms is between 8m and 10m, with a potential minimum of 5m and maximum of 30m.
- On Tadham Moor (peat soils, Figure 8 in Stratford and Acreman, reproduced in appendix 7 below) the water table fell by a little over 50cm (July 1997) at 50m from the ditch, gradually increasing with distance from the ditch (Appendix

- On West Sedgemoor (peat soils, Figure 10 in Stratford and Acreman, from Gilman 1994, reproduced in Appendix 7 below), the water table appears to sink to a maximum of 0.7m below field level at a distance of around 30m from the ditch (July, 1987)

2 Methods

2.1 Transect

A transect was laid across part of each field; the length was 40m on King's Sedgemoor (the transect was 50m from the field end) and 82.1m on Tealham (78m from the field end). 6 dipwells were placed along the transect: Appendix 1 shows their locations in more detail. The spacings of the dipwells were irregular as it had been intended to assess both zone of influence of gutters and zone of influence of the ditch. Therefore 3 dipwells in each field were located close to gutters (on gutter edge and at 1m and 1.5m distance to either side on King's Sedgemoor, and within gutter and at 0.5 and 1m to each side on Tealham Moor). The dipwells assessing the ditch zone of influence were at 3m and 6m from the ditch, (or similar values), and a final dipwell represented the field centre.

Figure 4 King's Sedgemoor showing transect

Dipwells 3, 4, 5 and 6 are shown and the 2.5m wide gutter (taken December 2016). Scattered peat is visible from the digging of the gutter.

Figure 5 Tealham Moor showing transect

A tape measure indicates the line of the transect across the field (looking west from field centre towards ditch)

2.2 Levelling

The top of each dipwell was levelled using a level mounted on a tripod and a staff. Levels were measured from the nearest Internal Drainage Board benchmark to the top of each dipwell, and then back to the benchmark again to check readings; in both sites the readings at start and finish came to within 1cm of each other, and so height readings for the study may be taken as being to 1cm accuracy. Appendix 2 shows the levelling data, and these are also shown visually in Figures 7 and 8.

2.3 Water table assessment

The dipwells comprised 1m lengths of 40mm wide plastic piping into which 5mm holes were drilled to allow water movement once inserted into the ground. A plastic sleeve was stuck into one end into which a lid could be screwed; a small hole was drilled into each lid to allow pressures to equalise in and outside the dipwell. The dipwells were placed in the ground by removing a 5cm core of peat using a soil auger, the piping was put in a stocking sleeve (ladies' tights) to prevent soil from entering the dipwell column, and the dipwell was then inserted into the ground until the top was flush with the ground surface, and the lid screwed on.

The dipwells were visited at monthly intervals and readings taken. Ditch levels were also taken for the ditches around the study fields.

Figure 6 insertion of dipwell

The photograph below, on Tealham Moor, shows the dipwell with its screw-top lid and held in a nylon sleeve about to be inserted in a hole that has been made to receive it by use of a soil auger. The foot drain with water in it is behind the man.

2.4 Vegetation analysis

The vegetation in the fields was assigned to National Vegetation Classification (NVC) communities (Rodwell 1991, 1992) using quadrats. Initially a 1m^2 quadrat was laid close to each dipwell (to avoid any trampling of vegetation near the dipwell) (explanations of where the quadrats were placed are provided in Appendix 3).

The percentage cover for each species present in the quadrat was assessed by eye and recorded. The quadrat was then extended to 2m x 2m and any further species noted as present. In addition, each field was walked in order to assess the vegetation in the whole field; any boundaries between vegetation communities were mapped and quadrats laid randomly in those communities; this resulted in 3 additional quadrats (A, B, C) being placed in the King's Sedgemoor field (so as to have 5 quadrats representing the main community, as 5 quadrats makes NVC assessments more accurate). One new quadrat was placed in the Tealham field. The data for each quadrat was then put through MAVIS software (Modular Analysis of Vegetation Information System) (Centre for Ecology and Hydrology https://www.ceh.ac.uk/services/modular-analysis-vegetation-information-system-mavis) in order to note the NVC community. MAVIS calculates closeness of fit of the results for the 5 closest matching NVC community; a good match can be said to be obtained if the fit is 60% or above.

2.5 Ellenberg scoring

Ellenberg scores for species' tolerance to soil moisture (Ellenberg F values) were taken for each quadrat (using the original Ellenberg scores) (Ellenberg 1988) using MAVIS software. Where Ellenberg did not provide an original score, a 'final' score (adapted for climatic conditions of the British Isles) was used. Each species is assigned an F value, and when grouped together to provide a community score this provide an indication of the wetness tolerance of the plant community. An N score for fertility was also calculated.

2.6 Hydrotool

The vegetation community for each site was predicted using a digital analytical tool known as the Hydrotool (provided by the FMP). The water table depths for the site over a known period together are entered with soil type, and the tool calculates the number of wet and dry weeks for that year for the given soil type (the wet threshold for peat is taken as 35cm below the surface and the dry threshold as 45cm below the surface). The Hydrotool provides a diagram showing vegetation community as described by number of wet and dry weeks in a year. The number of such weeks calculated by the Hydrotool are used to 'read off' the tool where the vegetation for the site fits.

2.7 Soil assessment

The soil was assessed to 1.2m depth using a 1.2m soil corer. Each sample was laid on the ground as it was drawn out to display the soil as a column. The soil texture would have been assessed using a soil key (http://www.floodplainmeadows.org.uk/about-meadows/meadow-management/soils), together with structure. The soils in this study comprised peat, and instead were examined for undecomposed fragments in order to assess whether the top layer had become humified (had changed their structure and become chemically altered).This horizon was measured and a photograph was taken of the soil.

The soil pH and extractable phosphorus content (Olsen's P test) was calculated from soil samples made up from soil collected from 6 points on each field at 5cm depth; the two bulked samples (one from each moor) were air dried then sent to a laboratory for analysis.

2.8 Nutrient loading from floods

A small piece of artificial turf was pinned into each site in order to trap any sediment from floods, so that nutrient loading could be calculated. In fact only a very small flood occurred during the study and this yielded no sediment as it was so minor, and so this method did not yield results.

2.9 Productivity

Productivity of grassland was assessed by asking the farmer how many bales of hay were made on each field, and number and age of cattle grazing it.

3 Results

3.1 Transect

Appendix 1 shows the transect and dipwell locations at each site. Figures 7 and 8 show the water table at each dipwell location plotted against distance from the ditch, and Appendix 2 provides the tabulated data.

Figure 7 King's Sedgemoor dipwell data in relation to distance from ditch

Dipwell data are shown for January, April and July 2016. The height values are mAOD. Ditch levels for January and July are shown as a line; the ditch level for April is not known, but would have been slightly below that of January. The ditch edge is at the left hand side of the graph, with Dipwell 1 3.2m from the ditch and Dipwell 6 40m distant. Dipwell 4 is on the edge of a 2.5m side surface gutter, and Dipwells 3 and 5 to either side, at 1m and 2m distance from each edge of the gutter.

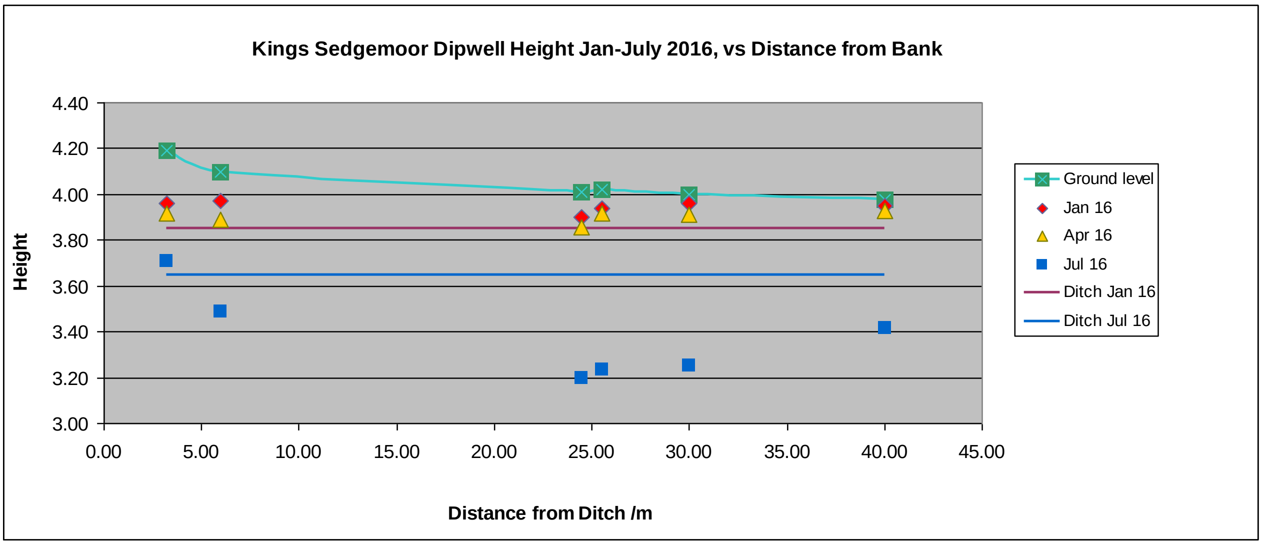


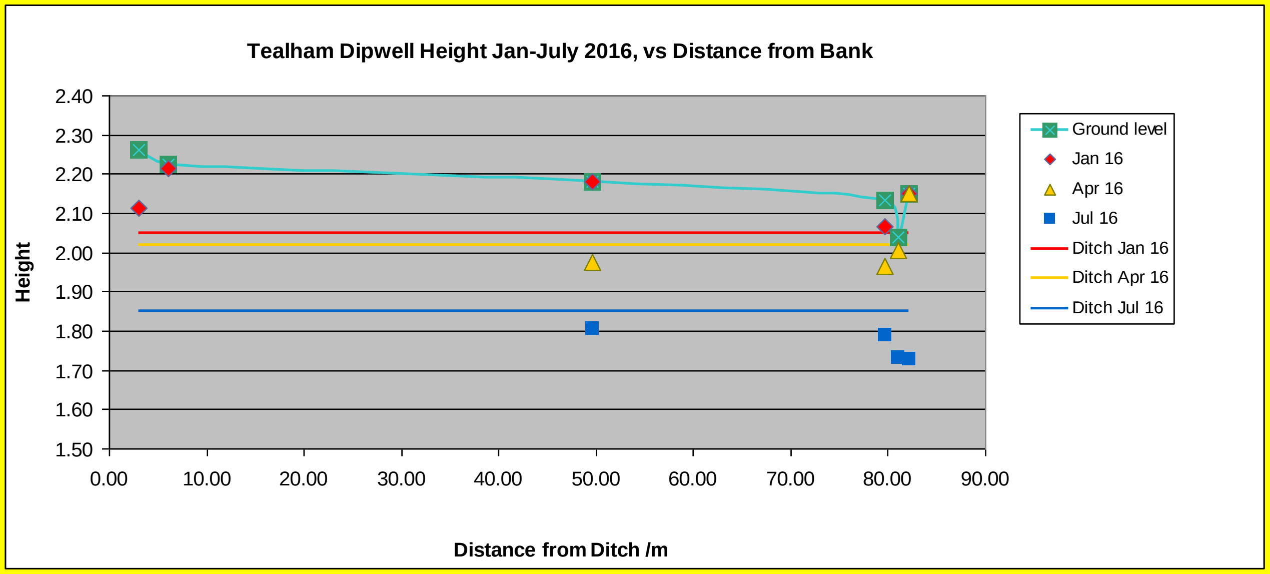
Figure 7 indicates that in winter the central part of the field was wet with light splashing (Dipwells 5 and 6 full to field level) and the water table was fairly even across the field; the water table on the bank was above that of the ditch. All dipwells recorded water levels above those of the surrounding ditch. In April the water table had fallen slightly. It might be postulated that the water table had barely fallen in the field centre, and fell slightly more nearer the ditch (especially Dipwell 2). In July the water table was markedly lower away from the ditch and fell to a maximum of 76.4cm below the surface in Dipwell 3, with Dipwells 4 and 5 close by being similar. The water table was higher at Dipwell 6.

This pattern of Dipwell 6 having a higher water table was consistent until late autumn (Appendix 2): in October Dipwell 6 had a lower water table than that of Dipwells 3 to 5 and by November it was some 35cm lower and had reached its maximum depth; in the meantime the other dipwells were showing a rising water table. Within a month of this situation, in December, the water table had come up to the surface once more through the whole field.

The dipwell data for 2017 was different, however. Although data for the year was incomplete at the time of writing of this report, it showed that the maximum depth reached by the end of August was only 52cm (in Dipwell 3); the 2017 spring and summer was somewhat drier than that of 2016. Dipwells 3-6 generally showed consistent water table depths in mid-summer.

Figure 8 Tealham Moor dipwell data in relation to distance from ditch

Dipwell data are shown for January, April and July 2016, data is taken from Appendix 2. The height values are mAOD. Ditch levels for each of the 3 months is shown as a line. The ditch edge is at the left hand side of the graph, with Dipwell 6 3m from the ditch, Dipwell 5 6m from ditch and Dipwell 49.6m from the ditch; Dipwell 1 some 82m distant. Dipwell 2 is in a surface foot drain, and Dipwells 1 and 3 to either side, at 1.5m and 1m distance from it.



In January 2016 there was light splashing on the field and all the dipwells showed a reading of about 0, i.e. they were full, apart from Dipwell 6 near the ditch where the water table was 15cm below the surface. The levels were above that of the surrounding ditch, as rain falling on the field was held in by the raised banks around the field. In April the water table was dropping. No data is available for the two dipwells near the ditch, but it had dropped in the other dipwells apart from Dipwell 6, in the field centre. In July the levels had dropped further, down to a 42cm in the field centre (Dipwell 1). Unfortunately, no more readings were taken that year to be able to compare directly with King's Sedgemoor dipwells (all measured in 2016), but the previous autumn readings suggest that the maximum that the water level dropped had been 39cm, in October 2015; there was a wet September that year, however, and so the results may be unusual in that the autumn water table may have been higher than usual.

Sporadic dipwell readings in 2017 indicate a maximum water table depth by the end of August of 54.5cm. This is lower than those of 2016, despite the fact that the summer was wetter, perhaps influenced by the fact that no hay cut was taken in 2017 (one was taken in July 2016), allowing the vegetation to draw up more moisture (some 30 cows plus followers were turned into the field in late August 2017).

3.2 Levelling

Figures 7 and 8 and Appendix 2 show the absolute height of the top of each dipwell at each site, together with ground level.

3.3 Water table assessment

Figures 7 and 8 show the water table height for 3 months at each site; data is shown in Appendix 2.

3.4 Vegetation analysis

Appendix 1 shows quadrat locations. Appendices 3 and 4 show the plant species recorded at each quadrat for King's Sedgemoor and for Tealham Moor respectively; the MAVIS outputs showing the NVC communities that were derived from the quadrats are also displayed.

King's Sedgemoor

Initially 5 quadrats were laid along the transect, numbered so as to correspond with the nearby dipwells - Q1, 2, 4, 5, 6 - there was no Q3 as dipwells 3 and 4 were only 1m apart and Q4 represented both. Following this the field was walked in order to assess community boundaries in the field. All round the field the slightly raised banks supported a drier more grassy community, which had been described by Quadrats 1 and 2. The remainder of the field (apart from the gateway) appeared be one community – described by Quadrats A and B (so as to make up 5 quadrats for MAVIS analysis); finally, Quadrat C was laid because it seemed to be in a more grassy area, although it turned out to be in a similar community.

A MAVIS analysis was carried out for the central part of the field - Quadrat 3, 4, 5, A, B This showed the community to be a good fit to MG14 Brown sedge – creeping bent – marsh ragwort (*Carex nigra - Agrostis stolonifera – Senecio aquaticus*), (Wallace H.and Prosser M., 2017) with slight tendencies towards MG14a typical sub-community (The MAVIS output for MG14 were relatively high, at 65.50, with 65.69 for MG14a). The community was dominated by *Agrostis stolonifera*, *Carex nigra* (both are MG14 community constants), together with brown sedge *Carex disticha* and reed sweet grass *Glyceria maxima*, the latter which is more typical of swamp communities. The other MG14 community constants were all present – creeping buttercup *Ranunculus repens*, cuckooflower *Cardamine pratense*, marsh ragwort *Senecio aquaticus*, rough meadow grass *Poa trivialis* and amphibious bistort *Persicaria (Polygonum) amphibia*. Three of the five MG14a typical sub-community species were present – common spikerush *Eleocharis palustris*, lesser spearwort *Ranunculus flammula* and jointed rush *Juncus articulatus*.

The community was more species-rich than many MG14 communities, with 22.6 species per quadrat, as against 14.8 for MG14 nationally (Wallace H. and Prosser M., 2017); however, it is not known what size are the quadrats (samples) in the national database, and whether a direct comparison can be made.

Quadrat C was a less good fit to any particular NVC community. MG14a was the closest fit, (MAVIS output 49.57), a poorer fit as it lacked *Carex nigra*. Instead, it was dominated by *Carex disticha*, a species which can occur in various wetter floodplain grassland communities, and it was a little more grassy, with more *Poa trivialis* and a little more timothy *Phleum pratense*. There were tendencies towards MG15 meadow foxtail – rough meadow grass – cuckooflower (*Alopecurus pratensis – Poa trivialis – Cardamine pratensis*) grassland through the presence of *Poa trivialis, Cardamine pratensis, Agrostis stolonifera* and *Ranunculus repens*. The differences were not sufficient to map this as a different community.

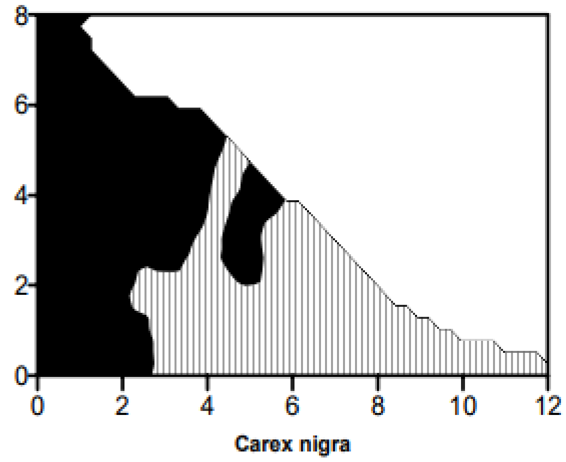
Quadrat 1 was on a raised bank, and again a relatively poor fit to any particular community. The closest fits were MG4c *Alopecurus pratensis – Sanguisorba officinalis*, *Holcus lanatus* sub-community (MAVIS output 52.67), MG10a *Holcus lanatus – Juncus effusus* rush pasture (50.97) and MG15b *Alopecurus pratensis – Poa trivialis – Cardamine pratensis* grassland (50.04). The bank was dominated by grasses: sweet vernal grass *Anthoxanthum odoratum*, crested dog's-tail *Cynosurus cristatus* Yorkshire fog *Holcus lanatus*, *Phleum pratense* and *Agrostis stolonifera*, all species which are characteristic of the above 3 communities. The first two of these species are characteristic of drier communities such as MG6 and were not found in the remainder of the field, apart from in Quadrat 2 which was also slightly raised and was a transition between the bank community and the remainder of the field. Certain other species characteristic of drier areas were also only found on the bank, such as common knapweed *Centaurea nigra* and meadow vetchling *Lathyrus pratensis*.

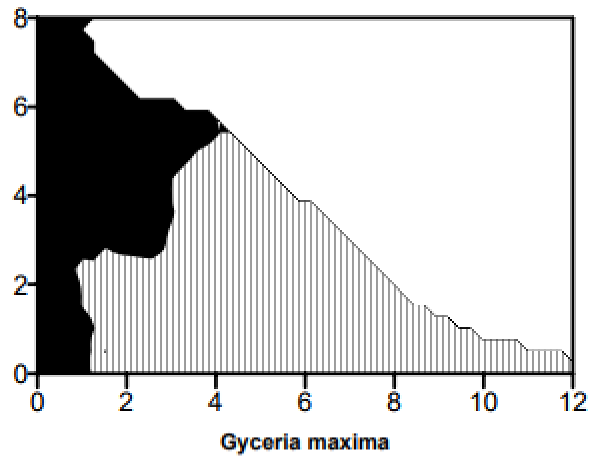
The King's Sedgemoor field had an NVC survey carried out by Hilary Wallace in 2005, for which currently only a map is available; this was found after the NVC survey had been carried out for the field. In 2005 the centre of the field was mapped as MG14 (then termed AgCx), with a small area of M22; Quadrats A, 6 and probably 3, 4 and 5 fell into the area mapped as MG14; B possibly lay in the area mapped as M22 *Juncus subnodulosus –Cirsium palustre* (blunt-flowered rush – marsh thistle) fen-meadow.

The question arises as to whether B was in fact M22 or MG14. Constant species for M22 are *Juncus subnodulosus*, meadowsweet *Filipendula ulmaria*, greater bird's-foot trefoil *Lotus pedunculatus*, tufted vetch *Vicia cracca* and fen bedstraw *Galium uliginosusm*. Of these, B only had very low levels of *Juncus subnodulosus* and *Filipendula ulmaria,* and indeed the only other M22 constant species that was noted in the field as a whole was *Vicia cracca*. It would therefore seem that M22 was not present (or had somehow been overlooked). It is difficult to separate floodplain M22 from MG8 on southern sites including nearby West Sedgemoor (Wallace H.and Prosser M., 2017), and it might be inferred that it is difficult to separate M22 from MG14 (which is in essence a species-poorer version of MG8). Wallace and Prosser add that other species indicative of M22 are *Lythrum salicaria* and *Mentha aquatica*, only the latter of which was present on King's Sedgemoor site.

Responses of individual species to soil hydrology was been presented by Gowing et al 2002, and three examples are given below.

Figure 9 The preferred water-regime zone of three species found on the Tealham Moor site. The dark region represents the range of water regimes in which the species occurs significantly ($P<0.05$) more often than by chance. The horizontal axis is Sum Exceedence Value in metre.weeks for soil drying, the vertical axis is Sum Exceedence Value in metre.weeks for waterlogging. From Gowing et al, 2002





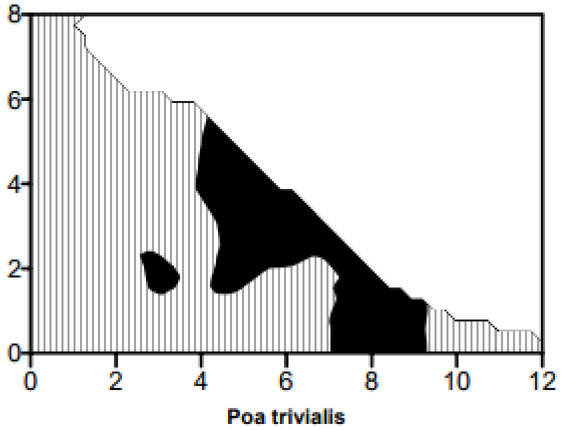


Figure 9 illustrates how two of the dominant species on the Tealham Moor site, *Carex nigra* and *Glyceria maxima*, tend to grow in sites which are waterlogged for much of the year, and only dry out for short periods, while rough meadow grass *Poa trivialis,* of which there was less on the site, tends to occur on drier sites and can tolerate fluctuating water levels.

Tealham Moor

The vegetation community on the Tealham moor field in July 2016 was the same throughout the field. It comprised a very close fit to MG8c *Cynosurus cristatus – Carex panacea – Caltha palustris* grassland, *Carex nigra – Ranunculus flammula* sub-community (MAVIS output 73.42), (although also a close fit to MG14b (MAVIS output 69.32) - there is an overlap between the two communities Wallace and Prosser 2017, Figure 4). The most dominant species were *Agrostis stolonifera, Carex disticha, C. panacea, C. nigra, Filipendula ulmaria, and* marsh pennywort *Hydrocotyle vulgaris*, with patches of *Juncus acutiflorus*. All the MG14 constant species were present, most at a high frequency. The site was quite species-rich, with an average 24.4 species/quadrat.

Figure 10 Tealham Moor July 2017

An NVC survey was also carried out on the same quadrats in October 2015, as a practice exercise. The results more mixed, with MG8c and MG15b *Alopecurus pratensis – Poa trivialis - Cardamine pratensis* close contenders (65.47 and 66.43 respectively), and MG14b also close (MAVIS 64.73). Autumn is not a favourable time to carry out NVC surveys as certain species, such as yellow rattle *Rhinanthus minor*, are no longer visible, and species occupy different proportions of the vegetation as they are at different stages of their development compared with early summer.

3.5 Ellenberg score

Appendix 5 shows calculations for the Ellenberg F value. The Ellenberg F value (using original values) on the King's Sedgemoor field, avoiding the drier bank area (i.e. discounting species only found in Quadrats 1 and 2), was 7.30. That of Tealham Moor (again discounting the quadrat nearer the drier bank) was 6.92. These results indicate that the community on King's Sedgemoor is tolerant of slightly wetter conditions than that of Tealham Moor.

The Ellenberg N for King's Sedgemoor was 5.1; that of Tealham Moor is not known.

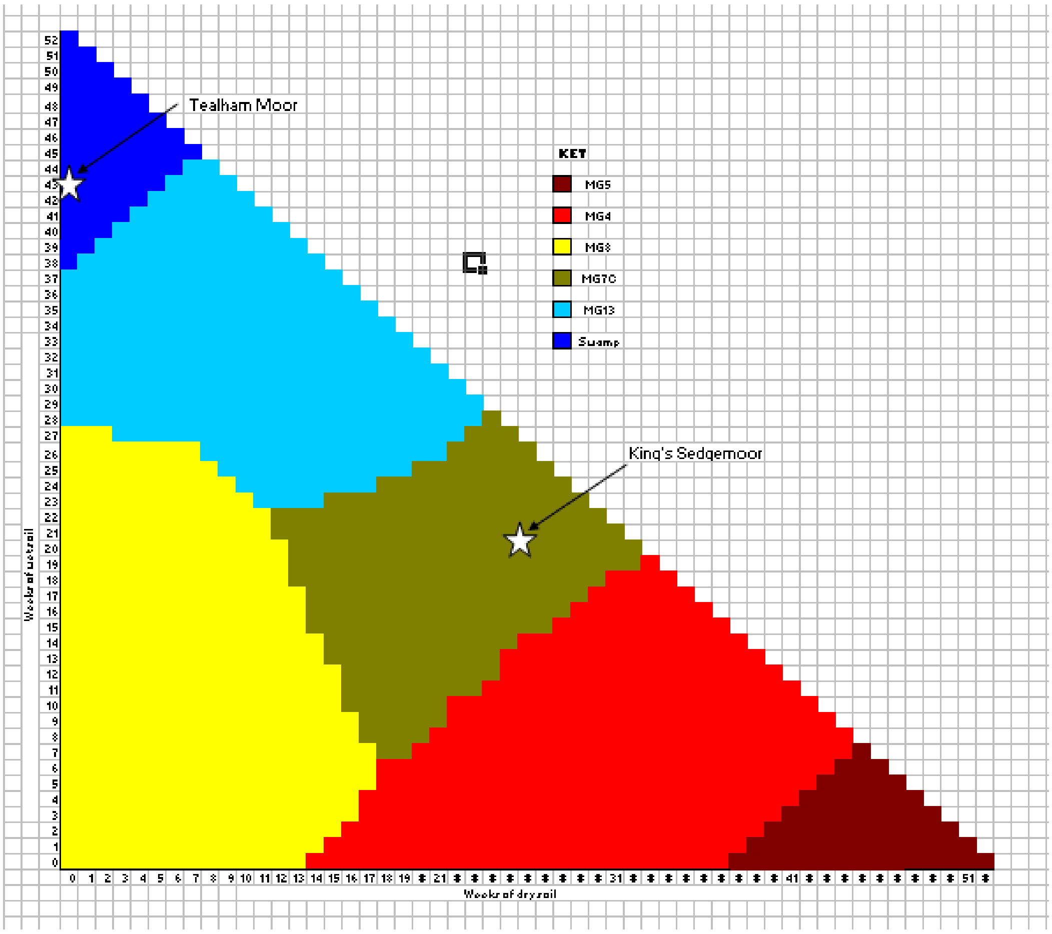
3.6 Hydrotool

Results from the Hydrotool are shown below; data is provided in Appendix 2.

Figure 11: Hydrotool diagram showing predicted NVC community taken from 1 year of dipwell readings

Readings are taken from near to the field centres, i.e. Dipwell 6 on King's Sedgemoor (January to December 2016) and Dipwell 1 on Tealham Moor (September 2015 to August 2016). The data may be found in Appendix 2. The field edges were not assessed.

It should be noted that the Hydrotool has been configured for the 'old' NVC communities pre-dating those published in 2017 (Wallace and Prosser 2017). MG14 is not shown, for example; MG7c has changed to MG15.



The 12 months of dipwell data on King's Sedgemoor suggested that there had been 26.1 dry weeks and 21.7 wet weeks in that year, resulting in a predicted MG7C community (Figure 11 above).

Unfortunately only 9 months of data were available from the Tealham Moor dipwells for 2016, with May, June and August missing; best guesses for these were used and so the data is not as reliable. These resulted in no dry weeks for the 12 month period and 39.1 wet weeks and the predicted community was a swamp. This is quite different to the community that actually is found there.

From the relatively few months during which the two sites were visited, Tealham did indeed seem to be wetter, with splashing present between November and April inclusive in the 12 month period, while King's Sedgemoor only had two months of splashing in the calendar year. Direct comparison is problematic, however, as there were only 3 months of overlap in the studies on the two sites, with the Tealham readings starting and ending before those of King's Sedgemoor. It is also possible that the raising of pens to the usual winter field level on King's Sedgemoor was delayed to allow the contractor to drill out the new gutters, which could account for December being dry, where normally it would have been wetted up, being part of a RWLA. The method of reading ditch levels were not discovered until November 2017, so it is not possible to assert this.

3.7 Soil assessment

Figure 12 Soil profile on King's Sedgemoor

The soil on King's Sedgemoor comprised entirely peat (Figure 12). A 1.2m core of pure peat soil; undecomposed plant fragments (Figure 13) began to appear at 35cm, and by 70cm depth the peat was unaltered (marked by the pale pencil in Figure 12).

Olsen's P was 17; pH was 4.99.

Two cores were taken on Tealham Moor (Figure 13). Again, the soil comprised entirely peat. In one the upper 35cm of peat had been humified and was amorphous, in the other the peat was humified to a depth of 70cm. Fragments of unaltered peat were very apparent below these depths. Olsen's P was 20.4; pH was 4.99.

For comparison, Olsen available P in soils supporting MG8, are normally between 2 and 12 mg per kilogram of dry soil (Wheeler B.C., Gowing D.J.G., Shaw S.C. et al, 2004).

Figure 13 Soil profile on Tealham Moor

Figure 14 Undecomposed plant fragments in the peat

3.8 Nutrient loading

Only one minor flood occurred during the two years of study. The artificial turf had been in place on King's Sedgemoor during this period, but no nutrients were deposited - the fibres were examined at their base. No flood occurred on Tealham Moor while it was being studied. It is believed that nutrient loading is low from river floods is low on the Tealham Moor site, as the River Brue sediment is dropped onto fields which lie nearer to the river.

3.9 Productivity

On the King's Sedgemoor 42 round bales were cut on 20th July 2016; the farmer said always tends to get about the same number of bales. This equates to 5.4t/ha (field area of 2.6ha, assuming 3 round bales equate to 1 tonne). National levels of hay yield (Agro Business Consultants Ltd.) give low intensity hay production as 5.8t/ha (86% dry matter), 7.0t/ha medium intensity and 7.5t/ha for high intensity hay. Hay productivity on the Tealham Moor field is therefore slightly below the national average for extensive hay production.

17 Hereford store cattle and steers, aged 28 months grazed for 6 weeks from 29 September to 5 November 2016. The cattle were roaming a larger area of 8.65ha including the study field, making a stocking rate of 0.5LU/ha, which equates to very extensive grazing. The vegetation had been eaten evenly down to some 10cm by November, so this stocking rate was well matched to the sward.

No productivity data was obtained for the Tealham field. It was, however, hay cut in July 2016 and aftermath grazed – heavily stocked for a short period. It was also noted that the farmer had had to abandon some equipment in field for 2 months as the ground was too soft in early summer to fetch it. In 2017 the field was lightly grazed in May then stocked for an unknown time from late August by some 30 cows with young followers.

4 Discussion

The Tealham Moor field (NVC MG8c, Ellenberg F 6.92) was slightly drier than the King's Sedgemoor field. This could be because, while both sites were RWLA's, it is difficult to retain water on it in spring – and sometimes in winter - as there is no external water supply to maintain the ditch levels, and therefore fewer weeks of surface water. King's Sedgemoor, however, has a water feed, allowing it to be kept wetter for longer in the spring.

It is worth noting that both sites have Ellenberg F levels above 6.5. Sites with levels above F6.5 are approaching a condition where it may become unmanageable by farmers. Better drainage is likely to be needed for farming purposes (David Gowing *pers. comm*.).

From both 2016 and 2017 data, the water table on Tealham (Appendix 2) lies within the tolerable zone for MG8 (Wheeler B.C., Gowing D.J.G., Shaw S.C. et al, 2004, water table depth zones in Figure 4.2) (the water table was within the desirable zone for this community in 2016). The Ellenberg F value of 6.92 is low for MG8c (Figure 14), perhaps indicating that the site is perhaps moving towards a drier MG8a *Sanguisorba officinalis* or MG8b *Carex nigra - Ranunculus flammula* sub-communities (or is has changed from these communities towards MG8c?). The community on the field has been MG8 for at least some 20 years (Kiff Hancock, Somerset Wildlife Trust *pers comm*.).

Care should t be taken on the Tealham Moor site that the site does not move to a more species-poor MG14 community. Communities on West Sedgemoor on the SL&Ms have been shown to change in the following direction following 5 years of seasonal inundation, a sequence which is not readily reversible, even after 5-7 years (Wallace and Prosser 2017):

MG8b → MG8c → MG14 (AgCx)

Regarding King's Sedgemoor, the community (NVC MG14a, Ellenberg F 7.3) was wetter than the Tealham Moor field. (Figure 15 shows that MG14 has a slightly higher tolerance to soil moisture compared with MG8c). MG14 has elements drawn from MG8, MG13 and S22 *Glyceria fluitans* water margin published for MG14, the water table on King's Sedgemoor (Appendix 2) in 2016 did conform to the hydrological pattern for MG13 inundation grassland (Wheeler B.C., Gowing D.J.G., Shaw S.C. et al, 2004).

However, in 2017 the water levels in the King's Sedgemoor field were less deep, despite the wetter spring and summer, and were similar to those on Tealham, they were more typical of those that could be tolerated by an MG8 community. From the 2 years of data, it might therefore be surmised that the hydrology supports an MG14 community, as the data shows elements of MG13 and MG8.

The vegetation in the King's Sedgemoor field has changed little since 2005, when the field comprised MG15 in the central parts with MG7c (now reclassified as MG15) towards the edges, and a small area of M22b (no species data is available). *Juncus subnodulosus* has however spread and now occupies much of the field, albeit at relatively low levels, indicating an increased wetness.

In terms of condition of the sites for farming, there is concern that there has been increased wetness in the King's Sedgemoor RWLA which has led to the spread of swamp species in the field such as *Glyceria maxima*, which were not present to such an extent in 2005 (Stephen Parker *pers comm*.). The floods of 2012 – 2014 probably reinforced this spread. This grass occupied some 20% of the quadrats in the MG14 part of the field. *Glyceria maxima* can thrive where the water table drops to 1m in summer (Wheeler et al 2004), but requires more nutrients than MG14a (Figure 15 below).

The presence of *Glyceria maxima* may also reflect the relatively high fertility of the site, with an Ellenberg N value of 5.1; the 2012-2014 floods may have brought in nutrients.

The Ellenberg F value for King's Sedgemoor field is more typical of MG14b communities (Figure 15), rather than MG14a. MG14b tends to me more species-rich (Wallace and Prosser 2017), and if this F value indicates that it might be changing to MG14b then this change might be welcomed.

When the dipwells were inserted in December 2016, they did not fill with water even an hour later. This might indicate a particular quality of the peat on the moor.

The fact that King's Sedgemoor is a wetter site is in contradiction to the Hydrotool results; these are, however, unreliable as insufficient summer readings were taken on Tealham Moor, leading to 'best guesses, being input as data.

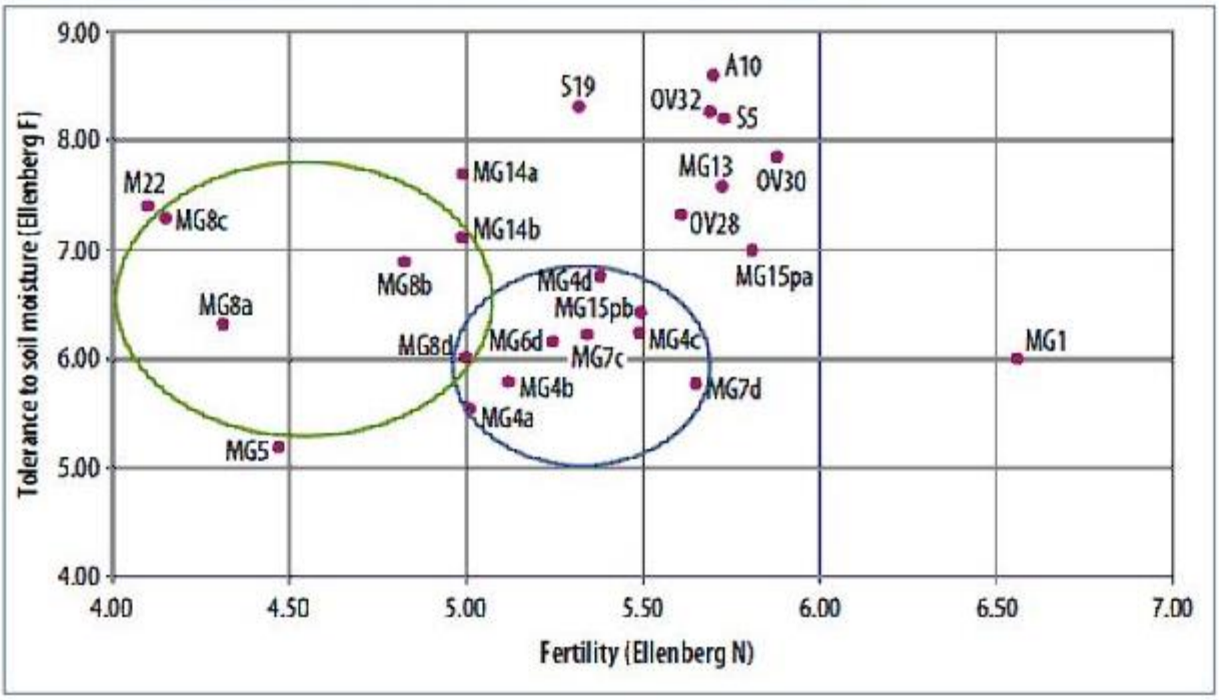
Gutters were put in to the King's Sedgemoor field in December 2016 as a joint project between Natural England and the RSPB in order to try and reduce the high levels of *Glyceria maxima*, and to allow the water to drain out more swiftly in late spring once ditch levels start to drop. It is too soon to assess the effect that this has had, but it is hoped to repeat the survey in 2018, at least in some capacity, to assess any changes. It the gutters do not bring about drops in *Glyceria maxima* levels, then double cuts might be tried to strip nutrients from the field, although this could be problematic given the breeding snipe in the field. The grass is palatable to stock and is clearly being eaten down to the same height as the other vegetation at the end of the season, and so grazing is helping to keep the grass under control. Grazing takes place in autumn after the main growing season, so its effect on control of the grass will be limited.

The invasion by swamp indicators illustrates the delicate balance between conservation of rare plant communities such as MG8 and MG14 and the desire to provide damp spring conditions for breeding waders such as snipe and curlew, which are enhanced when gutters are kept wetter for longer by keeping ditch levels at field level well into April, aiming to keep the water table in the field high. Inserting gutters is a delicate decision. A number of gutters were inserted in King's Sedgemoor RWLA in December 2016 yet the number of breeding snipe in spring 2017 was higher than it had been for several years, and so it would appear that the gutters had not had a detrimental effect on snipe numbers in the first year of this trial. On Tealham, snipe appear to focus on field edges by ditches as field centres are drier (personal observation by the author).

Fortunately, rush levels on both sites were low (Appendix 2) – high levels of rushes reduces the attractiveness of the fields to graziers, which in turn can lead to insufficient management, invasion by coarse species, and a negative spiral of ever-poorer field condition. Rush levels on the King's Sedgemoor field were less than 5% per quadrat for the 5 species combined, and levels were equally low on Tealham Moor apart from occasional patches of *Juncus acutiflorus*. Other species considered to be problems, such as *Senecio aquaticus*, were also few in number.

Figure 15 (from Rothero E., Lake S., Gowing D. 2016)

Figure 8.16 The distribution of communities on floodplain meadows in relation to Ellenberg's values for fertility and waterlogging. Increasing values refer to increasing fertility and increased waterlogging. The numbers are relative values not real measurements.



From Figure 15, it would be expected that the King's Sedgemoor site would have a higher Olsen phosphorus reading than that of the Tealham Moor site, as MG14a has a higher fertility than MG8c. However, this study shows the opposite, with 17 on King's Sedgemoor and 20.4 on Tealham Moor. Both sites have a higher Olsen P value than the average: MG8 is generally 2-12 (Wheeler et al 2004).

Both fields seem unimproved and possibly have never been artificially fertilised, lying as they do on low-lying and marginal land. Without nutrient loading results from floods, it is not clear where the nutrients come from. On King's Sedgemoor, they may naturally lie in the peat, possibly even from upwelling water from limestone hills to the north, as witnessed by the presence of *Juncus subnodulosus*, a species indicative of calcareous influence (even though pH is relatively acid, at pH 4.99). The Tealham Moor field lies 1km from the River Brue, which is known to drop sediment in floods (e.g. as witnessed from aerial photographs from major winter floods in 2014) – a little sediment may have reached the study site.

One aspect of the study had been to assess how water table changes with distance from ditch. The upper diagram in Appendix 7 shows how the summer water table on Tealham Moor, another peat moor on the SL&Ms, has a gradient, dropping with distance from the ditch; the lower diagram suggests that ditch influence extends 30m on West Sedgemoor, also a peat moor on the SL&Ms. Section 1.1 above summarises other studies on the influence of ditches on water tables on peat moors.

This study might suggest (Figure 7 above) that ditch influence on King’s Sedgemoor in 2016 extended at a gentle gradient to 25m, as beyond this the low summer water table levelled out. This may however be incorrect, as there were no dipwells between 6m and 25m; the summer water table may in fact have reached its low point closer to the ditch than 25m. The same may be said of the dipwell results on Tealham Moor (Figure 8). All that can be stated is that the ditch’s influence went beyond 6m, as the water table at 6m was still higher in spring and summer than that at 25m from the ditch. This is in keeping with other studies on the Somerset Levels and Moors discussed above. Unfortunately dipwell data for the Tealham Moor site is sketchy as dipwell data for April and July (Figure 8) are missing – it was not possible to locate the dipwells.

It is unfortunate that results are inconclusive and that the zone of influence of the ditch cannot be assessed; it would have been better to place dipwells more regularly with distance from the ditch at closer, perhaps 3m, intervals.

The other aspect of the study had been to assess the influence of gutters on water table. Indeed, the study had been designed around this, hence the irregular spacing of the dipwells in order to cluster dipwells around the ditch. If sphere of influence is known, optimum gutter spacing on fields could be worked out to maximise hydration of fields in spring, if desired for example for breeding wader habitat.

Again, the results are inconclusive. In order to help to assess gutter sphere of influence, daily monitoring would have been necessary when water rises from ditches into gutters, and when water recedes from the field surface and is only held in gutters. The gutter sphere of influence is likely to be limited to about a month i.e. to the time when they have lost water and the surrounding land is still wet, or when they hold water and the surrounding land is still dry. This would require much more intensive monitoring, with more dipwells to avoid the apparently random readings in dipwells close to gutters in Figures 7 and 8, and closer spacing, perhaps 50cm intervals.

The spacing of old gutters on fields on the Somerset Levels and Moors is variable, being approximately some 4-6m apart. It is not known how the distances were chosen; it would be interesting to find out. However, those farmers that dug the gutters are long passed away.

The influence of gutters on alluvial soil at East Cottingwith was noted during a Natural England NVC survey by the author in 2016. There, the gutters (introduced in 2006), had an influence of 5-10m to either side. Given the different soil types there, it would be unwise to drawn direct comparison however.

Productivity of the Tealham Moor site, at 5.4t/ha, was low compared with national values for low productivity grassland, but not as low as some extensively managed floodplain grasslands. This was combined with very low aftermath stocking rates of 0.5LU/ha.

5 Conclusions and Recommendations

The King's Sedgemoor field (NVC14a, Ellenberg F 7.3) was relatively species-rich with 22.6 species/quadrat (excluding ditch banks) compared with a national average for MG14a communities of 14.8 species /sample (although it is not known what size quadrats these samples were). It had a wide range of sedges and grasses. The field did, however, have high levels of *Glyceria maxima*, indicating that it had 'swampy' elements in the given conditions, which could reduce species richness over time, and reduce the attractiveness of the field for farming. A 2005 survey indicates that the site comprised the same grassland community, then termed AgCx, although currently no species data for the field for this survey has been found to help assess how species may have changed, or whether for example the *Glyceria maxima* has indeed increased. *Juncus subnodulosus* may also have increased.

The Tealham field (NVC 8c, Ellenberg F 6.92) was slightly more species-rich than the King's Sedgemoor Field, with an average of 24.4 species/quadrat, which is higher than the national average of 19.3 species/sample (although it is not known what size quadrats these samples were). This field has been well managed, and does not have a predominance of any particular species which might suggest that it is at risk of changing. An NVC survey was carried out on the site some years ago but it has not been possible to locate this for the time-being. It has therefore not been possible to assess change over time.

It is intended to carry out a repeat of the quadrat surveys in 2018 in order to assess if there have been any changes over this time, together with more dipwell readings in 2017 and 2018.

Management recommendations

Raised water levels appear to have caused the spread of *Glyceria maxima* into the King's Sedgemoor field, and possibly the increase of *Juncus subnodulosus*. However, species richness in the field remains quite high, with 22.6 species/quadrat (away from the field edges), and the broad community has not changed since 2005.

Three 2.5m wide gutters were cut into the King's Sedgemoor field in 2016 and these should help to reduce the less desirable species, from a farming point of view, such as *Glyceria maxima*. This will be monitored. The hay cutting date of early to mid July is probably optimal as it potentially allows 2 broods of snipe chicks to fledge before cutting, while still cutting hay before plants become too rank to be useable. If breeding waders had not been a consideration, hay would ideally be cut in late June/early July to help strip nutrients from the site. Grazing levels of 0.5LU/ha for 6 weeks appear good, as the sward was 10cm at the end of the grazing season.

A condition assessment was carried out on King's Sedgemoor SSSI by Natural England in May 2016, led by the author. Once analysed, the results should be used to assess the effect of the raised spring waters on vegetation on the RWLA as a whole. This may feed into a wider discussion on RWLA's on the Somerset Levels and Moors.

Management on Tealham Moor appears optimal as levels of 'problem' species were low. The site is intensively grazed for a short period, which helps to reduce levels of rush and other potentially invasive plants as cattle are forced to eat these, therefore helping to maintain the plant diversity. Gutters are also present and actively maintained to help remove water in summer floods. Species richness is quite high for the community, at 24.4species/sample.

Recommendations regarding monitoring

1. The reports from the historic NVC surveys on King's Sedgemoor and Tealham Moor should be obtained, to help analyse how the communities have changed since that time. The historic quadrat data from these reports would be particularly useful as this would allow a more detailed comparison than simply using maps.
2. The new gutter on King's Sedgemoor are beneficial – *Glyceria maxima* indicates that the site is starting to tend towards a swamp, and *Juncus subnodulosus* has also spread; this will keep this change in check. Unfortunately, the study has not shown gutter influence. This could be assessed once the gutters have been in place for 2-3 years by analysing vegetation in a transect out from each gutter in order to see whether wet-tolerant species such as *Glyceria* change in abundance with distance from the gutter. At the same time, breeding snipe records should be kept to assess whether the gutters are having any detrimental effect on breeding numbers.
3. The study was unfortunately limited to 1 year per site, with a few additional dipwell readings. It is intended to extend this for a further 2 years, when the dipwells will probably no longer be useable. It is intended to continue dipwell readings through 2017 and dipwell and quadrat readings in 2018 in order to assess any vegetation changes. Visits will focus on the summer and autumn period, as it can be assumed that in the winter period the water table will be at or near the ground surface. Beyond this, the dipwell will probably no longer be useable, as plant roots will have penetrated the holes, and stock will have trodden them in.
4. In order to help to assess gutter sphere of influence, daily monitoring would have been necessary when water rises from ditches into gutters, and when water recedes from the field surface and is only held in gutters.
5. Monthly rainfall records from a local weather station would have helped to take rainfall into account when analysing dipwell readings, and consistent ditch level reading on the same day as dipwell readings
6. Readings taken on similar dates when working on more than one site to allow better comparison
7. Gaps in dipwell readings, particularly in summer, mean that analysis is incomplete. Additional dipwell readings will be taken on both moors in 2017, in particular in summer and autumn.
8. Problems with insufficient dipwell readings were associated with delegating the task of taking readings to another organisation, who were unable to carry it out, and a broken metal detector. While metal pegs were put in the ground near the dipwells on Tealham, the metal detector that had been loaned broke. A new one has been sourced, which will aid summer dipwell readings. The taking of readings will no longer be delgated!
9. More soil cores would have produce more consistent results regarding the depth of humified peat.
10. To really assess zone of influence of ditch, dipwells should have been placed at more regular intervals from the ditch up to some 30m distance. A 40m transect was usable; the 81m long transect was too long as it made it more difficult to find the dipwells.
11. The use of metal plates would have helped to prevent dipwells from being trodden in by cattle, which would have made recording more straightforward.

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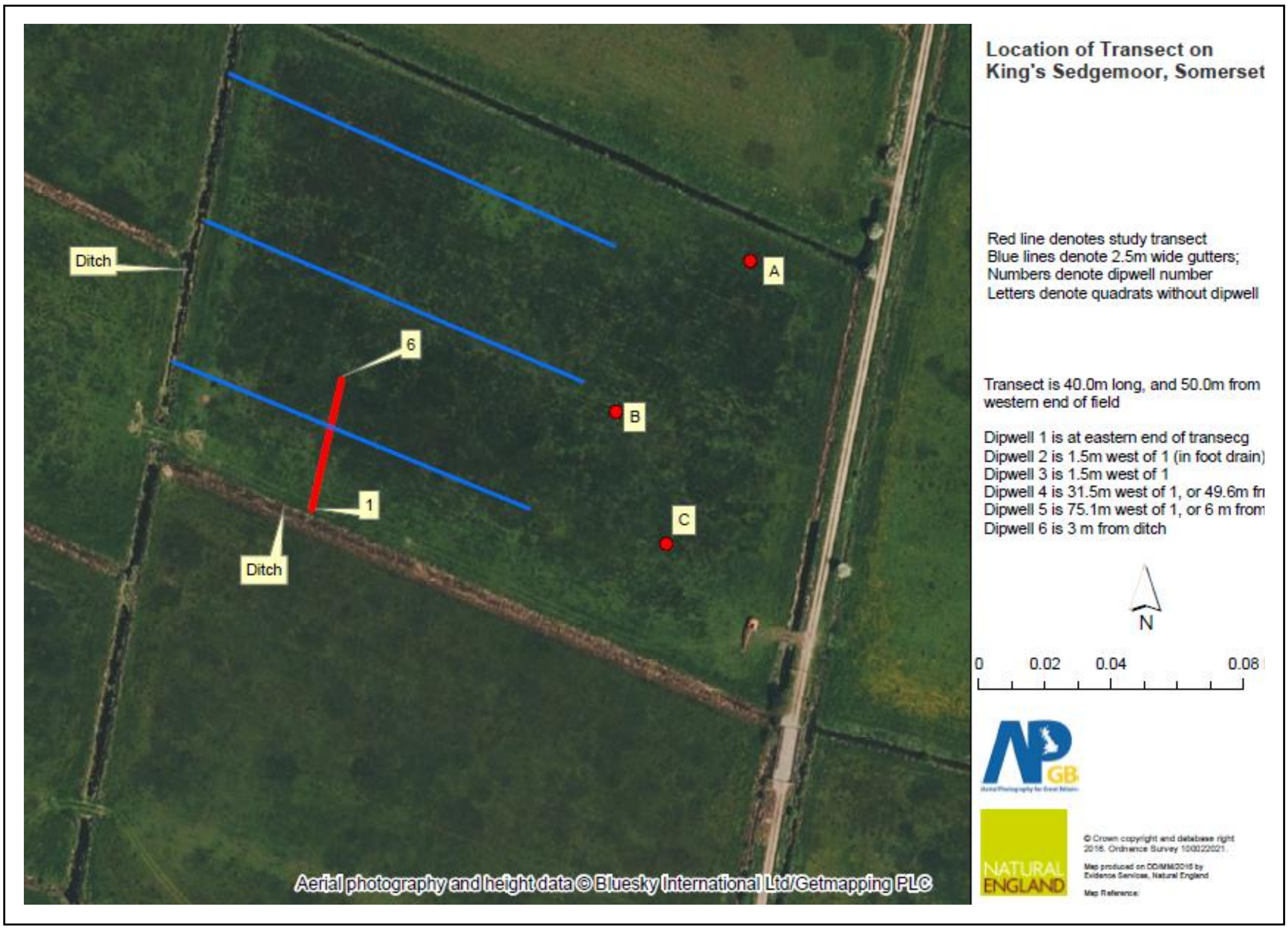
Appendices

Appendix 1 - Location of quadrats and transect on the two sites

King's Sedgemoor

The dipwells are located along the red transect line; the soil sample was taken 10m south east of Dipwell 6

The dipwell data below is incorrect. The following are the correct dipwell distances from southern ditch: Dipwell 1 3.2m, Dipwell 2 6m, Dipwell 3 24.5m, Dipwell 4 25.5m, Dipwell 5 30m, Dipwell 6 40m.



Tealham Moor

The dipwells are located along the red transect line; the soil sample was taken 10m south east of Dipwell 3.

Length of transect should read 82.1m, so that dipwell 3 is 79.9m from ditch edge, and 1.5m west of dipwell 2 (not dipwell 1 as stated below).

Appendix 2 - Dipwell data for the two sites

King's Sedgemoor Dipwell data: water depth (cm) in relation to top of dipwell

Raw dipwell water level data in cm (black); levelled top of actual dipwell in m (in red) i.e. black data is water level cm below top of dipwell until July 2017– from July 2017, readings are cm below surface)

0 = dipwell full of water

10 = water table 10cm below top of dipwell

-4 = water level 4cm above top of dipwell

i.e. splashing present

Dipwells put in on 29/12/15

	Dipwell reading (Jan 2017)						
Date	near ditch			edge of gutter		field centre	
	1	**2**	**3**	**4**	**5**	**6**	**Comments**
Height - top of well mAOD	4.19	4.05	3.96	3.96	3.96	3.95	
Height of well below surface mAOD	0.02	0.045	0.05	0.055	0.04	0.03	
Surface of ground mAOD	4.21	4.10	4.01	4.02	4.00	3.98	
29/12/16 dipwells installed							No readings taken because dipwells not recharged within 1 hour of being put in. Gutter holding water
17/01/2016	23.1	7.8	6.2	2.3	0	0	Light splashing on moor
27/02/2016	27.9	14.7	10.7	5.5	1.5	0	Light splashing on moor
03/04/2016	27.3	16.3	10.1	4.5	4.7	2.1	
27/04/2016	38.8	30.5	22.6	15	19.2	17	1cm of water in gutter - it is draining - the gutter to west is full
						35	No readings taken - 35 is half-way between April and June (used in Hydrotool)
14/06/2016	48	49	52.2	47.1	49.9	50	
24/07/2016	48.3	56	76.4	72.6	70.5	53.1	Water level in ditch hasn't dropped recently
02/09/2016	56.2	x	75.3	75	75	68.5	Unable to undo lid of dipwell 2 - dipwell dropped 3cm.
26/09/2016	42.3	42.1	68	64.6	69	74.6	Dipwell 3 has now dropped 2-3cm, so water level should be 71. Ditch 1-2" higher than it was in summer
16/10/2016	24	34	66	60	70	71.5	
13/11/2016	24.2	19	42.2	42.7	45	74	Cattle in field. Gutter empty, no splashing on moor
18/12/2016	14.2	6	0	-4	-3.5	-4.6	Shallow splashing between Nov and Dec visit. Gutter full
15/01/2017	13.2	3.2	-4.2	-5	-5.2	-4.5	3 to 6 are underwater
10/02/2017	13.8	2	-2.5	-1	-2.6	-4.5	Gutters nearly full
12/03/2017	15.5	8	-2.4	-3.5	-4.5	-5.5	
23/04/2017	39	33	27	25	24	26	All gutters dry; no rain for a month
14/05/2017	41	34	33	33	31	31	All gutters dry
							May and June no rainfall
29/07/17	x	37	44	40.8	42.5	43	Dipwell 1 bent and unusable; intermittent rain in July
31/08/2017	x	43	52	44.5	49.5	49	Intermittent sun and light rain and sun in August

Distances from ditch: Dipwell 1 3.2m, Dipwell 2 6m, Dipwell 3 24.5m, Dipwell 4 25.5m, Dipwell 5 30m, Dipwell 6 40m.

King's Sedgemoor: Water depths converted to mAOD (from above table) and corrected where dipwells have dropped

Data from January 2017 not included

	Dipwell						Pen (ditch level)
	1	2	3	4	5	6	
Surface of ground AOD	4.19	4.10	4.01	4.02	4.00	3.98	
Distance from bank (m)	3.2	6.0	24.5	25.5	30.0	40.0	
Date	**Water Level (m)**						
17/01/2016	3.96	3.97	3.90	3.94	3.96	3.95	3.85
27/02/2016	3.91	3.90	3.85	3.91	3.95	3.95	3.85
03/04/2016	3.92	3.89	3.86	3.92	3.91	3.93	
27/04/2016	3.80	3.75	3.73	3.81	3.77	3.78	
14/06/2016	3.71	3.56	3.44	3.49	3.46	3.45	
24/07/2016	3.71	3.49	3.20	3.23	3.26	3.42	3.65
02/09/2016	3.63		3.21	3.21	3.21	3.27	
26/09/2016	3.77	3.63	3.28	3.31	3.27	3.20	
16/10/2016	3.95	3.71	3.30	3.36	3.26	3.24	3.65
13/11/2016	3.95	3.86	3.54	3.53	3.51	3.21	3.97
18/12/2016	4.05	3.99	3.96	4.00	4.00	4.00	3.99
15/01/2017	4.06	4.02	4.00	4.01	4.01	4.00	3.99

Distances from ditch: Dipwell 6 3m, Dipwell 5 6m, Dipwell 4 49.6m, Dipwell 3 79.6m, Dipwell 2 80.6m, Dipwell 1 81.1m

Tealham Moor dipwell data: Water depth (cm) in relation to top of dipwell

0 = full of water
10 = 10cm below top of dipwell

	East	Dipwell				West	Comment
		Foot drain				Ditch bank	
Date	**1**	**2**	**3**	**4**	**5**	**6**	
Height top of dipwell mAOD	2.15	2.041	1.957 gutter base	2.181	2.224	2.262	
			2.133 top of dipwell				
17/9/15	18	0 (full)	11.3	17.4	17.2	32	Dipwell put in, gutter full, wet September weather
11/10/2015	19.7	8.6	18.1	23.5	31.1	39	Drier October, ground soft
19/11/2015	3.5	under water	2.5	6.5	14.2	x lid stuck	Dipwell 3 has dropped approx. 7cm
08/12/2015	0	under water	0	4.8	9.3	21.8	
31/01/2016	0	under water	0	0	1	15	Shallow surface splash across field (2-5cm
27/02/2016	0	under water	0	2	0.5	17.3	Shallow surface splash across field (2cm/ very squelchy). Ditches at 2.04mAOD
March	**0**	x	x	x	x	x	
08/04/2016	0	3.5	10	20.7	x	x	Read by Somerset Wildlife Trust
May	**30**	x	x	x	x	x	Reading guessed
June	**40**	x	x	x	x	x	Reading guessed
03/07/2016	42	30.8	27.5	37.5	x	x	Unable to find 5 & 6; reading for 3 is in relation to ground surface as 3 had dropped
August	**40**						Reading guessed
2017							
29/07/2017	48.5	x	50.6	x	x	x	Remaining dipwells not found despite metal detecting for metal pins
25/08/2017	54.5	x	x	x	x	x	Cattle and bull present – just one reading taken

Values in blue (dipwell 1) are best guesses for missing data – this data was used in the Hydrotool analysis

Tealham Water depths converted to mAOD (from above table)

	Dipwell						Pen (ditch level)
	1	2	3	4	5	6	
Height AOD (m)	2.15	2.04	2.13	2.18	2.22	2.26	
Distance from bank (m)	82.1	81.1	79.6	49.6	6.0	3.0	
Date	**Water Level (m)**						
17/09/2015	1.97	2.04	2.02	2.01	2.05	1.94	1.85
11/10/2015	1.95	1.96	1.95	1.95	1.91	1.87	1.85
19/11/2015	2.12			2.12	2.08		1.85
08/12/2015	2.15		2.07	2.13	2.13	2.04	1.85
31/01/2016	2.15		2.07	2.18	2.21	2.11	2.05
27/02/2016	2.15		2.13	2.16	2.22	2.09	2.06
08/04/2016	2.15	2.01	1.97	1.97			2.02
03/07/2016	1.73	1.73	1.79	1.81			1.85

Data for 2017 not entered above

Appendix 3 - King's Sedgemoor Quadrat results and MAVIS outputs

The quadrats were 3m from the dipwells. The centre of the nearest side of each quadrat lay at a bearing of 16^{o} from the dipwells on Tealham Moor and 10 ^{o} from the dipwells on King's Sedgemoor

Quadrat	**1**	**2**	**4**	**5**	**6**	**A**	**B**	**C**
Veg height cm	**30**	**55**	**65**	**60**	**70**	**65**	**65**	**x**
Grid Ref ST	**40500 33351**	**40501 33354**	**4050 4 3337 5**	**4050 6 3337 7**	**4050 8 3338 7**	**4062 0 3342 4**	**4057 9 3337 5**	**40594 33332**
Agrostis stolonifera	20	10	30	40	15	20	20	30
Alopecurus pratensis						1		
Anthoxanthum odoratum	40	10						
Bromus sp		1						
Cynosurus cristatus	5	10						
Deschampsia caespitosa						101	101	
Festuca arundinacea			2	101	101	101		
Festuca pratensis					1	40		1
Glyceria fluitans		1						1
Glyceria sp	1							
Glyceria maxima			30	25	30		20	10
Holcus lanatus	30	4				5		
Lolium perenne		15	1	1	2	5		3
Phalaris arundinacea			2		1			
Phleum pratense	8		2	101			1	3
Poa trivialis	10	12	5	3	5	5	1	10
Cardamine pratensis		1	2	1	1	1	1	1
Carex disticha		5	20	4		30	10	60
Carex hirta		1			1			
Carex nigra		20	30	1	1	40	40	
Carex panicea			1	2	2	1		
Carex riparia						1		
Carex vesicaria	101	3	1					
Centaurea nigra	1	3						
Cerastium fontanum	1							
Cirsium sp seedling			1					
Eleocharis palustris					4			
Filipendula ulmaria		8					1	
Galium palustre	101		1	5	3	3	2	1
Geranium dissectum	101							
Juncus acutiflorus					1	1		
Juncus articulatus		1			2	1		
Juncus conglomeratus						1		1
Juncus effusus		3		1	1			
Juncus inflexus		1						
Juncus subnodulosus						2	3	
Lathyrus pratense	101							
Lysimachia nummularia			1	2	10	5	15	15

Quadrat	**1**	**2**	**4**	**5**	**6**	**A**	**B**	**C**
Veg height cm	**30**	**55**	**65**	**60**	**70**	**65**	**65**	**x**
Grid Ref ST	**40500 33351**	**40501 33354**	**40504 33375**	**40506 33377**	**40508 33387**	**40620 33424**	**40579 33375**	**40594 33332**
Mentha aquatica					102	101		
Myosotis laxa			3	1	6			101
Oenanthe croccata					102			
Plantago lanceolata	1	2				1		
Persicaria amphibia	1		1	1	1		1	
Potentilla anserina			5	1	20			
Ranunculus acris	1	1			101			
Ranunculus flammula				1	1			
Ranunculus repens	2	2	3	10	2	2	1	4
Rhinanthus minor	1	2						1
Rumex acetosa		1						
Rumex crispus					101			
Senecio aquaticus			1	3	10	3		1
Stellaria graminea	1	2						
Taraxacum agg		1	2		2	1		101
Trifolium pratense	1			1	1	1		1
Trifolium repens					1			101
Triglochin palustre				8		1		
Vicia cracca	101				102			
Total no. of species	**21**	**25**	**21**	**21**	**31**	**26**	**14**	**19**
Comments	On raised bank by ditch	Near raised bank, an intermediate community						More grassy
Dipwells 3 and 4 were 1m apart; a quadrat was placed between the 2, and Quadrat 4 describes the vegetation at both quadrats. Therefore there is no quadrat for Dipwell 3								
101 = not present in 1x1m quadrat but present in extended 2x2m quadrat								
102 = present in same community in vicinity of quadrat								

Quadrat 1 was analysed separately as it were on slightly raised ground (in order to process using MAVIS, a ‘fix’ was used to turn cover values into constancy values when only one quadrat is used); Quadrats 3 to B were analysed as a group as they were similar; Quadrat C was analysed on its own as it initially appeared to be a different community (using the same ‘fix’ as above).

King's Sedgemoor: Vegetation Constancy values for Quadrats 4 to B

Quadrat	4	5	6	A	B	Constancy Value
Agrostis stolonifera	30	40	15	20	20	**5**
Poa trivialis	5	3	5	5	1	**5**
Cardamine pratensis	2	1	1	1	1	**5**
Carex nigra	30	1	1	40	40	**5**
Galium palustre	1	5	3	3	2	**5**
Lysimachia nummularia	1	2	10	5	15	**5**
Ranunculus repens	3	10	2	2	1	**5**
Festuca arundinacea	2	101	101	101		**4**
Glyceria maxima	30	25	30		20	**4**
Lolium perenne	1	1	2	5		**4**
Carex disticha	20	4		30	10	**4**
Carex panicea	1	2	2	1		**4**
Persicaria amphibia	1	1	1		1	**4**
Senecio aquaticus	1	3	10	3		**4**
Phleum pratense	2	101			1	**3**
Myosotis laxa	3	1	6			**3**
Potentilla anserina	5	1	20			**3**
Taraxacum agg	2		2	1		**3**
Trifolium pratense		1	1	1		**3**
Deschampsia caespitosa				101	101	**2**
Festuca pratensis			1	40		**2**
Phalaris arundinacea	2		1			**2**
Juncus acutiflorus			1	1		**2**
Juncus articulatus			2	1		**2**
Juncus effusus		1	1			**2**
Juncus subnodulosus				2	3	**2**
Mentha aquatica			102	101		**2**
Ranunculus flammula		1	1			**2**
Triglochin palustre		8		1		**2**
Alopecurus pratensis				1		**1**
Holcus lanatus				5		**1**
Carex hirta			1			**1**
Carex riparia				1		**1**
Carex vesicaria	1					**1**
Cirsium sp seedling	1					**1**
Eleocharis palustris			4			**1**
Filipendula ulmaria					1	**1**
Juncus conglomeratus				1		**1**
Oenanthe croccata			102			**1**
Plantago lanceolata				1		**1**
Ranunculus acris			101			**1**
Rumex crispus			101			**1**
Trifolium repens			1			**1**
Vicia cracca			102			**1**
Total number of species	**21**	**21**	**31**	**26**	**14**	
Average number of species						**22.6**

King's Sedgemoor MAVIS outputs

MAVIS outputs for Quadrats 4, 5, 6, A, B	**MAVIS outputs for Quadrat 1 (raised bank)**	**MAVIS output for Quadrat C**
NVC: MG14a 65.69 NVC: MG14 65.50 NVC: MG14b 64.14 NVC: MG16 58.20 NVC: MG15a 55.23 NVC: MG8c 53.98 NVC: MG15 53.75 NVC: MG8v2 53.73 NVC: MG13v2 53.24 NVC: MG8b 52.94	NVC: MG4c 52.67 NVC: MG10a 50.97 NVC: MG15b 50.04 NVC: MG15 50.00 NVC: MG15a 45.17 NVC: MG10 44.72 NVC: MG9 44.10 NVC: MG6d 44.09 NVC: MG9a 43.28 NVC: MG8v2 43.27	NVC: MG14a 49.57 NVC: MG14b 49.29 NVC: MG14 48.13 NVC: MG15a 48.07 NVC: MG13v2 47.99 NVC: MG15b 47.59 NVC: MG15 46.21 NVC: MG6d 42.66 NVC: MG4d 41.88 NVC: MG16 41.41

Appendix 4 - Tealham Quadrat results and MAVIS outputs

Each dipwell had a corresponding quadrat apart from dipwell 2, which was so close to dipwell 3 that the two were combined as 'Quadrat 3', and dipwell 6, which was on a raised bank by the ditch; the bank was not surveyed. Quadrat A was not on the transect line. Quadrats surveyed in July 2016 prior to hay cutting.

Quadrat	**1**	**A**	**3**	**4**	**5**	
Vegetation height (cm)	**25**	**35**	**x**	**50**	**30**	
Grid Ref ST	**41295 45790**	**41253 45730**	**41293 45751**	**41265 45755**	**41225 45763**	**Constancy value**
Agrostis stolonifera	5	1	10	10	1	**5**
Anthoxanthum odoratum	10	40	4	10	20	**5**
Cynosurus cristatus	2	1	1	101	5	**5**
Cardamine pratensis	1	1	1	1	1	**5**
Carex disticha	40	20	10	8	20	**5**
Carex panicea	15	15	2	101	20	**5**
Filipendula ulmaria	4	1	7	10	1	**5**
Hydrocotyle vulgaris	3	20	1	1	1	**5**
Plantago lanceolata	1	101	1	1	2	**5**
Ranunculus flammula	1	1	1	101	1	**5**
Holcus lanatus	10		4	5	5	**4**
Phleum pratense	2	3		1	1	**4**
Poa trivialis	1		1	1	1	**4**
Juncus acutiflorus	1		1	35	101	**4**
Trifolium pratense	2			1	1	**4**
Alopecurus pratensis seedlings	1		1	1		**3**
Carex nigra	5	1	20			**3**
Juncus effusus	1		2		1	**3**
Ranunculus acris	3			1	1	**3**
Rumex acetosa	1			1	1	**3**
Festuca pratensis	3	1				**2**
Festolium x			40	5		**2**
Festuca rubra	4			1		**2**
Glyceria fluitans	1		1			**2**
Cerastium fontanum				1	1	**2**
Juncus articulatus	1	101			1	**2**
Leontodon autumnalis		1	1			**2**
Oenanthe fistulosa		2		12		**2**
Persicaria amphibia	2		1			**2**
Prunella vulgaris	1				1	**2**
Ranunculus repens	1				1	**2**
Trifolium repens	1				1	**2**
Calliergonella cuspidata	1				3	**2**
Lolium perenne seedling			1			**1**
Phalaris arundinacea	1					**1**
Centaurea nigra	4					**1**
Cirsium dissectum					20	**1**
Equisetum palustre					1	**1**
Galium palustre		1				**1**
Lotus pedunculatus			1			**1**
Mentha aquatica		1				**1**
Rhinanthus minor					1	**1**
Senecio aquaticus				1		**1**
Stellaria graminea				1		**1**

Quadrat	1	A	3	4	5	
Vegetation height (cm)	**25**	**35**	**x**	**50**	**30**	
Grid Ref ST	**41295 45790**	**41253 45730**	**41293 45751**	**41265 45755**	**41225 45763**	**Constancy value**
Taraxacum agg				101		**1**
Total number of species (excluding mosses)	**31**	**18**	**22**	**24**	**27**	
Average number of species						**24.4**
			Includes part of the foot drain		c.8m from ditch - dipwell 5 not found	

Tealham Moor MAVIS outputs

Festuca pratensis x Lolium perenne not included in analysis as not recognised by MAVIS

MAVIS output July 2016	MAVIS output October 2015
NVC: MG8c 73.42 NVC: MG8v2 73.09 NVC: MG14b 69.32 NVC: MG14 66.73 NVC: MG8a 65.03 NVC: MG6d 65.03 NVC: MG8b 64.67 NVC: MG15b 63.27 NVC: MG4c 62.22 NVC: MG4v2 62.17	NVC: MG15b 66.43 NVC: MG8v2 66.24 NVC: MG8c 65.47 NVC: MG14b 64.73 NVC: MG6d 64.00 NVC: MG4c 62.96 NVC: MG8a 62.25 NVC: MG15 60.74 NVC: MG14 60.37 NVC: MG8b 60.16

Appendix 5 - Ellenberg F calculations

Figures in black are original F values as presented by Ellenberg. Where these are not available, 'final' values have been used, shown in red. Species only found in the quadrats closest to the banks, which are drier than the rest of the field, have not been included (ie Quadrats 1 and 2 on King's Sedgemoor and Quadrat 5 on Tealham Moor)

King's Sedgemoor	F		Tealham	F
Agrostis stolonifera	7		Agrostis stolonifera	7
Alopecurus pratensis	6		Alopecurus pratensis	6
Cardamine pratensis	6		Anthoxanthum odoratum	6
Carex disticha	9		Cardamine pratensis	7
Carex hirta	6		Carex disticha	9
Carex nigra	8		Carex nigra	8
Carex panicea	8		Carex pallescens	6
Carex riparia	9		Carex panicea	8
Carex vesicaria	9		Centaurea nigra	5
Cynosurus cristatus	5		Cerastium fontanum	5
Deschampsia cespitosa	7		Cynosurus cristatus	5
Eleocharis palustris	10		Deschampsia cespitosa	5
Festuca arundinacea	7		Festuca arundinacea	7
Festuca pratensis	6		Festuca rubra	6
Filipendula ulmaria	8		Festulolium [spp]	7
Galium palustre	9		Filipendula ulmaria	8
Geranium dissectum	5		Galium palustre	9
Glyceria fluitans	9		Glyceria fluitans	6
Glyceria maxima	10		Glyceria maxima	9
Holcus lanatus	6		Holcus lanatus	10
Juncus acutiflorus	8		Hydrocotyle vulgaris	9
Juncus articulatus	9		Iris pseudacorus	9
Juncus conglomeratus	7		Juncus acutiflorus	8
Juncus effusus	7		Juncus articulatus	9
Juncus inflexus	7		Juncus effusus	7
Lathyrus pratensis	6		Leontodon autumnalis	5
Lolium perenne	5		Lolium perenne	6
Lysimachia nummularia	6		Lotus pedunculatus	8
Mentha aquatica	9		Mentha aquatica	9
Myosotis laxa	9		Myosotis laxa	9
Oenanthe crocata	8		Oenanthe fistulosa	9
Persicaria amphibia	11		Persicaria amphibia	11
Phalaris arundinacea	8		Phalaris arundinacea	5
Phleum pratense	5		Phleum pratense	8
Plantago lanceolata	5		Plantago lanceolata	5
Poa trivialis	7		Poa trivialis	5
Potentilla anserina	6		Potentilla anserina	6
Ranunculus acris	6		Prunella vulgaris	5
Ranunculus flammula	9		Ranunculus acris	6
Ranunculus repens	7		Ranunculus flammula	9
Rhinanthus minor	5		Ranunculus repens	7
Rumex crispus	7		Rhinanthus minor	5
Senecio aquaticus	8		Rumex acetosa	5
Taraxacum officinale agg.	5		senecio aquaticus	8
Triglochin palustre	9		Stellaria graminea	5
Vicia cracca	7		Taraxacum officinale agg.	5
			Trifolium pratense	5
Average	**7.30**		**Average**	**6.92**

Appendix 6 - Quadrat photographs

King's Sedgemoor Quadrat photographs


Quadrat 1


Quadrat 2


Quadrat 4


Quadrat 5


Quadrat 6


Quadrat A


Quadrat B


Quadrat C

Tealham Vegetation Quadrat photographs


Quadrat 1


Quadrat 3


Quadrat 4


Quadrat 5

Quadrat A

Appendix 7 - Two Figures from Stratford C. and Acreman M. 2014

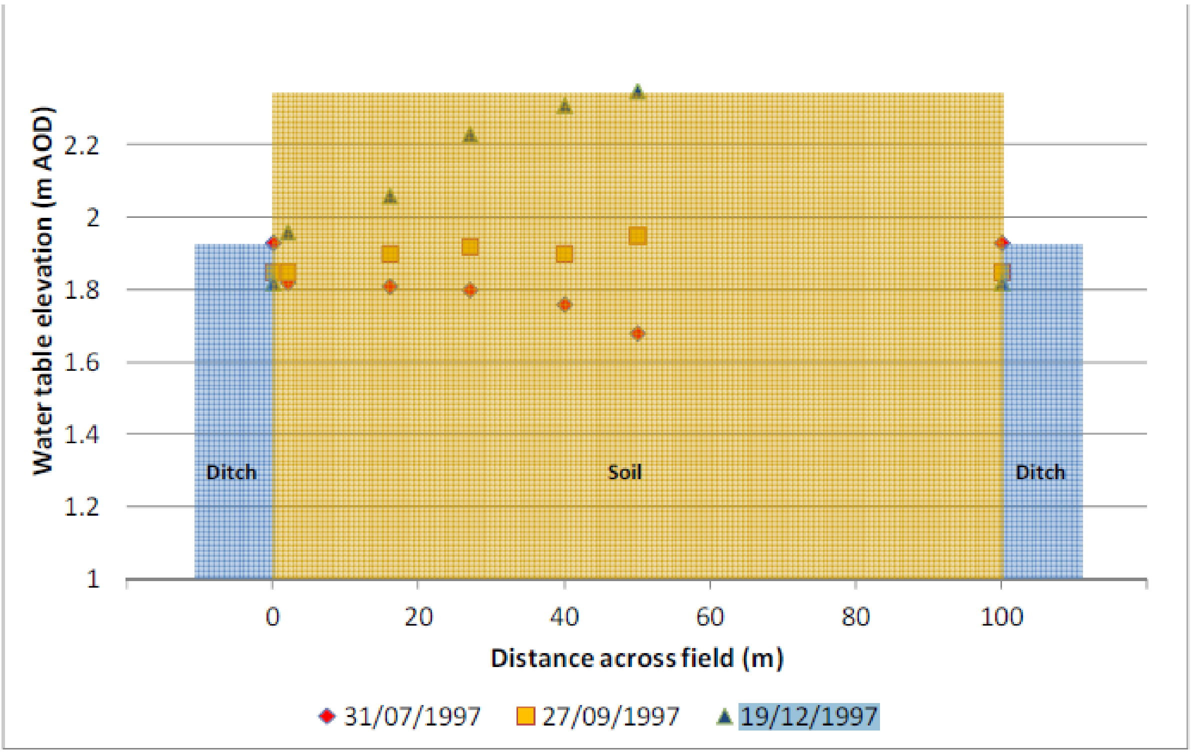


Figure 8. Cross section from ditch, through the soil body, to ditch showing the elevation of the water table at Tadham Moor. The figure shows a cross-section through a field, with ditches on either side at 0 m and 100 m across the field. The x axis is the horizontal distance across the field and the y axis is the elevation measured against a local datum. For reference the soil surface is at approximately 2.3 m. Measurements of the water table in the soil were made at the following distances across the field; 1 m, 16 m, 25 m, 40 m and 50 m. Three time periods are shown and the changing shape of the water table can be clearly seen.

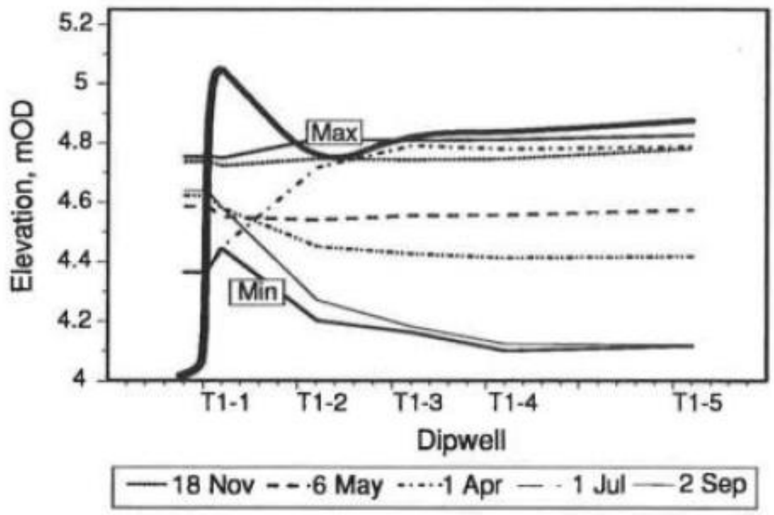


Figure 10. The rhynes of West Sedgemoor, with their lateral drains, form a reticular pattern which divides the Moor into rectangular fields. Results from transect T1, consisting of dipwells at 2, 12, 22, 32 and 52 m from a principal rhyne, the New Cut, show that the groundwater levels in the field are independent of the rhyne water level, except in a strip about 30 m wide. The data shown in the figure are for the summer of 1987. *From Gilman, 1994.*