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EFFECT OF MOLE SUBMERGENCE ON THE LIFE OF MOLE CHANNELS

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ABSTRACT

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It has been suggested that submergence of mole channels in field drainage systems will cause their premature collapse and lead to a failure of the system. Limited experience on Field Drainage Experimental Unit's sites has not supported this view.

An experiment was set up on a clay soil with a good moling potential, and where a previous moling had lasted up to 5 years. In a pumped drainage scheme submergence was examined to determine if it was a cause of mole channel failure. Isolated plots were subjected to short (usually less than 3 h) and long periods (up to 20 days) of submergence. The hydrological performance and the condition of the mole channels was monitored for 5 years.

Short periods of submergence did not appear to have a substantial effect on the mole drainage system and a 4—5-year life of the mole channels could be expected. Longer periods of submergence did not cause any immediate deterioration but the gradual collapse of the roof and side walls, which was the normal mode of failure, became more accentuated. This effect reduced the life of the mole channels to 3—4 years, although 3 years after moling the watertable control of the submerged plots was substantially better than similar adjacent undrained land.

INTRODUCTION

Just over half of all drainage schemes rely on deep soil disturbance in addition to the permanent pipe system (Armstrong, 1981). Mole drainage is used widely in heavy impermeable soils where high clay contents make stability of the formed mole drainage channel likely, (Nicholson, 1934; Trafford and Massey, 1975). In such impermeable soils failure of the mole drainage channel means the effective failure of the drainage system.

This paper examines the potential failure of a mole due to an inadequate channel outfall giving temporary submergence. There are three situations in which this might occur. Moles have either no or a restricted connection to the lateral drains, the connection is present but the lateral drains

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are unable to take the flow and are surcharged or the connection is present but the lateral drain outlet is submerged due to high ditch levels.

The need for an adequate outfall of newly drawn mole channels was noted by Nicholson (1942) who stated that no outlet for the mole channel could lead to a failure of the system. Current Ministry of Agriculture recommendations (MAFF, 1979) say that submergence of a mole channel system will cause collapse and lead to a failure of the system.

The prime cause of the deterioration of mole channels reported by Nicholson (1934) was the piecemeal collapse of the walls and roof upon wetting and drying cycles. By comparing the soil water release characteristics after slow and fast wetting of air dried and ground samples, Childs (1942), Rycroft and Alcock (1974) and Rycroft and Thorburn (1974) showed that mole channel life could be related to changes in pore size distribution as a result of the wetter treatments.

In replicated experiments they found that known good moling soils retained their pore structure during both slow and rapid wetting cycles whereas soils known to be unsuitable for moling, slaked and structure collapsed, particularly under a rapid wetting cycle. They felt that this simple test was likely to relate to the potential life of the mole channels because the expansive forces which arise when dry soil is wetted in the laboratory are the same forces which cause mole channels to shrink and collapse. It is thus likely that repeated submergence and subsequent draining of mole channels may affect the life of the channels by affecting the stability of the roof and walls.

Direct field evidence of mole failure due specifically to the lack of an adequate outfall is sparse. In modern day drainage where permanent pipe drainage systems are installed first, moles should have a satisfactory connection with the laterals. At a Field Drainage Experimental Unit (FDEU) site in Warwickshire moles were drawn in a Denchworth Series soil (clay content 65%) with initially a restricted connection to the pipe drainage system. The channels were drawn in saturated soil in February and were submerged for up to 7 days before satisfactory connections were made. When inspected 1 week and 3 months after installation, the channels showed little collapse but some sedimentation. At another site also on Denchworth Series soil, moles drawn in a wet autumn maintained 50% of their original cross-sectional area, 9 months after being drawn with no connection to the pipe drainage system.

Peak drainflow rates from this arable site were up to 4 times the standard daily design rate, (MAFF, 1982). This caused back-up conditions in the drain pipes nearly to the surface with submergence of the mole drains adjacent to the drain-pipe for up to 4 h. Subsequent examination of these channels has shown them to be no worse than channels which had not been submerged.

The problem of surcharge of drain pipes causing a back-up of water into mole channels can occur readily because most pipe-drainage schemes are designed for mean daily flow rates, not peak flow rates (Smith and Trafford, 1976; MAFF, 1982).

The situation of high ditch water levels and submergence of the outfall will occur if the ditch maintenance is inadequate or for pumped drainage systems if flow exceeds the pump capacity or a pump failure occurs.

To find out whether inadequate outfall levels can damage mole drainage systems a field experiment was carried out between 1975 and 1980 to find the effect of submergencc on the life of mole drainage channels. The site chosen was near Noke (SP 549130) in the Otmoor Basin, 10 km north-east of Oxford. A previous moling of the site had been found to last 4—5 years. Three isolated plots were established, two of which had a mole-pipe drainage system and the third plot was undrained.

SITE DETAILS AND EXPERIMENTAL PROCEDURE

Site layout

Fig. 1 shows the layout of the plots. Plot 1 is undrained whereas Plots 2 and 3 have tile drains at 0.9 m depth and a main collector drain at 1.0 m depth. Mole drains were drawn in autumn 1975 prior to the experiment and in 1977 at 1.7 m spacing and 0.5 m depth. In both cases good channels

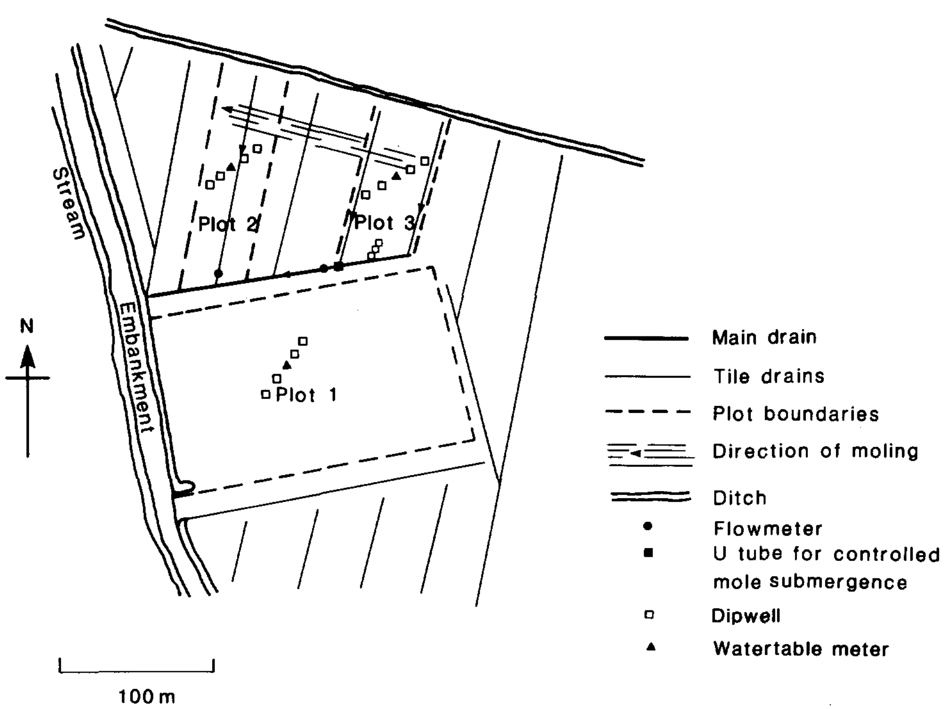

Fig. 1. Site plan.

and fissuring were found. In 1977 conditions were particularly suitable for moling, the average moisture content by weight was 30%, just above the plastic limit for this soil type (Spoor and Godwin, 1979). As the site was virtually flat, a pumped drainage scheme had been installed using receiver ditches leading to a central lagoon. Until an automatic system was available, the pumps were controlled manually.

The undrained plot was bounded by open ditches. Isolation of the drained plots was achieved by placing a clay plug in each individual mole run along the defined plot boundary.

To limit the disturbance to the private farming and additionally to monitor if free outfall conditions occurred for the main collector, the two drained plots were not identical in layout. Plot 2 was located with a central lateral whereas Plot 3 was bounded by two laterals. An advantage of this layout was the occurrence of a wide 'buffer' discard between the two drained plots.

A continuous record of drainflow was collected from Plots 2 and 3 using the FDEU vane-in-orifice flowmeter (Rycroft, 1972a). This was located on the central pipe drain on Plot 2 and the main collector drain on Plot 3.

The watertable in each of the three plots was monitored by a row of four slotted sleeved dipwells, described by Talman (1978) together with an FDEU continous recording watertable meter (Fig. 1). On the undrained plot all measurements were made away from ditches to overcome any boundary effects. On the drained plots, dipwells were installed at mid-mole spacing. In addition a line of three dipwells was installed at 5 m intervals on Plot 3 adjacent to and upslope of the collector drain. A continuous record was also collected of rainfall.

The site was managed according to normal farm practices for the area, the drained plots being under continuous winter cereals, the undrained area in a cereal/grass rotation.

Soil properties

The clay content (average 55%) of the unnamed Otmoor alluvial gley was in the range normally considered suitable for moling (see Table I and II). Aggregate stability for the alluvial gley and four other local soil types was assessed using the Haines test (Childs, 1940) for an arbitrary maximum tension of 20 cm. The index was based on the ratio of the amount of water drained out of the sample, to tension applied, for both fast wetting (immediate) and slow wetting (after 24 h) curves.

The water release and stability index for typical stable, unstable and the test soils is given in Fig. 2. The results were compared to those found by Rycroft and Thorburn (1974) and Rycroft and Alcock (1974) and showed that although the Otmoor soil was not ideal, the stability was as good as

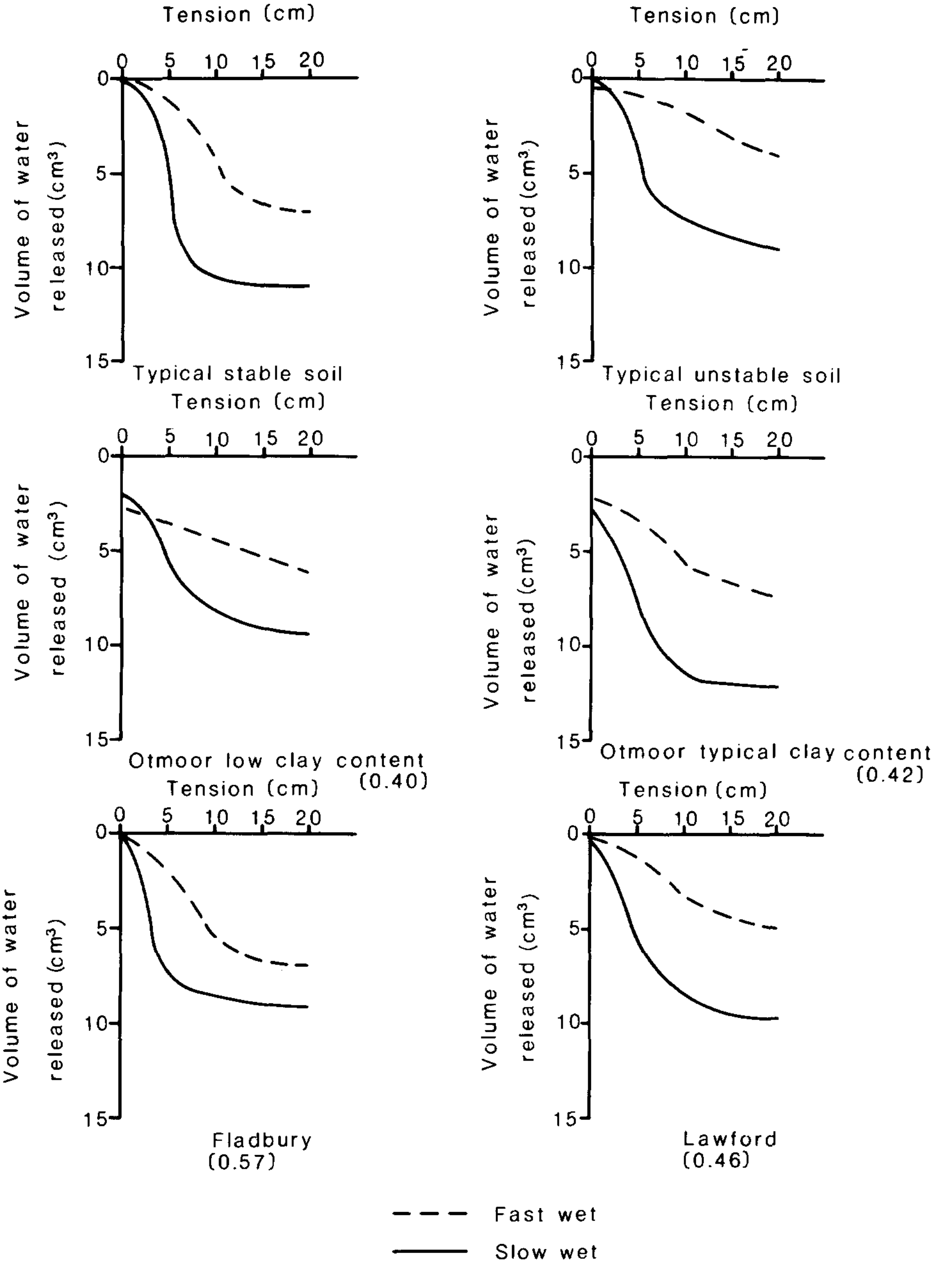

Fig. 2. Soil aggregate stability as derived from the relation between tension and water release at fast and slow wetting of the soil samples (sample volume 25 cm^3). The stability index is given in brackets.

TABLE I

Typical soil profile to moling depth

Horizon depth	Description
0— 8 cm	Very dark grey, humose stoneless non-calcareous clay, some mottles, fine angular to sub-angular blocky structure
8—45 cm	Dark grey, stoneless non-calcareous clay, mottled, coarse angular blocky structure, becoming prismatic at depth
45—70 cm	Grey, stoneless calcareous clay, mottled, medium prismatic or angular blocky structure, secondary $CaCO_3$ concretions and occasional shell fragments

TABLE II

Comparison of particle size distribution (by gravimetric analysis) of Otmoor soil at moling depth with other moling soils

Soil description	Location	Sand (60—>600μm)	Texture Silt (2—60μm)	Clay (<2μm)	Organic matter
Un-named alluvial gley	Otmoor	3.8	40	55*	0.7
Fladbury, alluvial gley soil	Goosey Wick	17.3	34	48	2.8
Evesham/Rowsham	Fyfield	9.3	30	61	0.8
Denchworth	Faringdon	7.0	38	56	—
Lawford	Northfield	44.7	23	32	—

*Mean of 7 samples. Lowest clay content 43%.

the Lawford, a soil normally moled and in which a mole channel life of 5 years can be expected.

A laboratory analysis of shrinkage properties and shear strength at moling depth was carried out by Spoor and Godwin (1979) on the Otmoor unnamed alluvial gley, another local alluvial gley (Fladbury Series) and an Evesham Series. They found that the properties of the Otmoor alluvial gley resembled more those of the Evesham (a good moling soil) than the Fladbury Series which exhibited much greater shrinkage properties and released larger quantities of water between increments of tension.

Experimental procedure

The effectiveness of the mole drainage treatments for the two drained plots was assessed by drainflow and watertable measurements. The pump system was not always reliable and a continuous autographic water-level recorder installed on the pumping lagoon showed that submergence of outfalls occurred on 16 occasions during the 5-year experiment. This 'natural' submergence was usually very short, lasting less than 3 h but one electrical failure towards the end of the experiment resulted in a submergence period of 20 h.

Controlled mole submergence of Plot 3 was achieved by blocking the plot outlet drain adjacent to and upslope of the flowmeter (Fig. 1). A U-bend installed in an access box on the main pipe drain was raised from the horizontal, unrestricted flow position, to the vertical position (Fig. 3). Flooding of the plot was then effected using natural rainfall events. Effective submergence was confirmed on Plot 3 by watertable data.

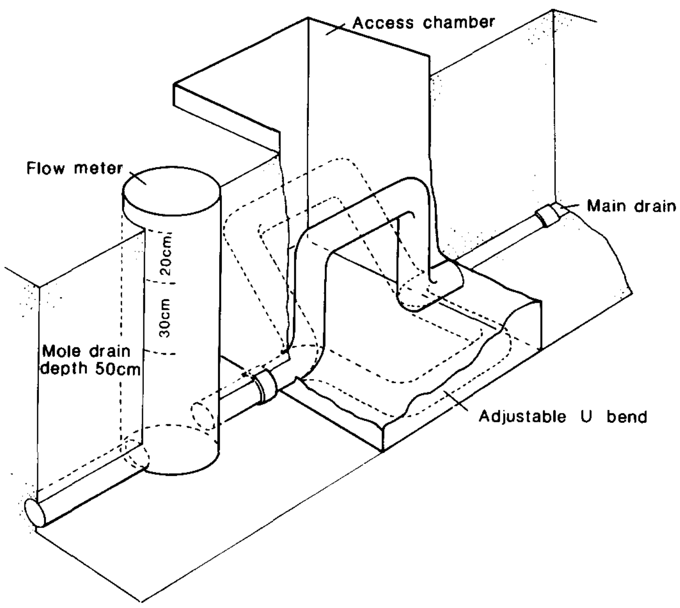

Fig. 3. U-bend installed on main pipe drain upslope of flowmeter to effect control submergence of Plot 3.

One period of 20 days submergence of Plot 3 was effected for the first moling and this was extended to individual periods of controlled submergence of 10, 15 and 20 days each for the second moling in 1977. These periods represented the worst likely period of submergence and would be associated with a major pump failure.

Mole channel size was monitored throughout the period of the experiment by measuring the cross-sectional area of casts taken of the mole channel, as described by Talman (1976). The number of casts per sampling time varied but usually involved at least three samples of each treatment. The average cross-sectional area of each 0.8 m section was recorded. As

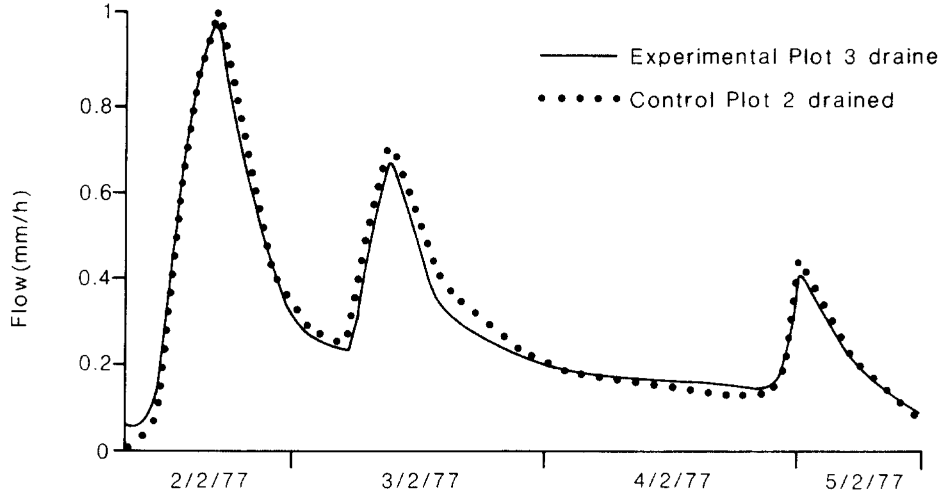

Fig. 4. Comparative hydrograph data, February 1977.

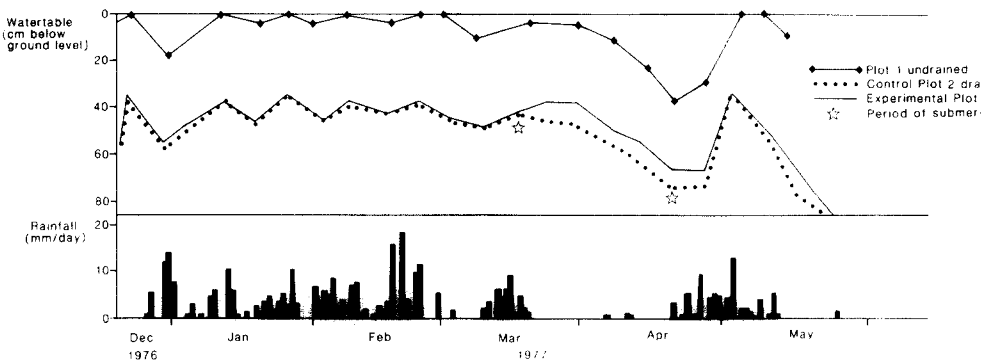

Fig. 5. Comparative watertable levels, December 1976—May 1977.

the sampling technique was destructive, variability due to different sampling positions could occur, but the effect was limited by the replication. Casts were taken in April and September of each year on a routine basis and immediately before and after periods of controlled submergence. Mole cast sampling was confined to the lower half of the plot where watertable data confirmed that submergence of the channels had occurred. The dug out mole section was repaired in each case by a short length of perforated 50 mm diameter plastic pipe.

RESULTS

Despite the different plot layouts, drainflow from both plots in February 1977 (Fig. 4.) was similar and showed the typical peaky response to a rainfall event from moles in a clay site characterised by Rycroft (1972b) and Trafford and Massey (1975). The watertable levels recorded on Plots 2 and 3 (Fig. 5) at mid-mole spacing were typical of an efficient drainage system on a heavy clay soil and showed no obvious detrimental effect of the short periods of natural submergence that affected both plots from December 1976. Over the winter period 1977, the comparative depth to the watertable was 50 cm for the drained plots and 8 cm for the undrained plot. The consistent high watertable of the adjacent undrained area showed the effectiveness of the two drainage treatments. The undrained plot was taken out of cereals after two crop failures due to waterlogging.

The outfall of Plot 3 was sealed in mid-March 1977 for 35 days by raising the U-tube. The depth to the watertable at mid-mole spacing, both in dipwells 50 m from and immediately adjacent to the main pipe drain on Plot 3, was above mole depth and at least 10 cm less than Plot 2 for a period of 20 days. Rainfall resulted in drainflow on Plot 2 only. A mid-plot mole channel examined in late March showed standing water filling three quarters of the channel, a condition that was not observed with a free outfall. Natural seepage had increased the depth to the watertable to below mole depth on both drained plots by mid April when the U-tube was lowered.

Following the 20-day recorded submergence there was heavy rainfall in early May. Although the earlier submergence of Plot 3 moles had created different plot antecedent soil moisture conditions, uniformity of runoff was quickly established (Fig. 6). The marked superiority in watertable control of the two drained plots over the undrained plot shown in Fig. 5 clearly indicated that the mole channels had not collapsed immediately following submergence. It was noted however that there was more sedimentation in some moles that had been submerged for 20 days.

Mole channel deterioration, as determined by the cross-sectional area, with time and including the effects of submergence is given in Fig. 7. Variability within samples was similar for both pre- and post-submergence periods with the exception of one channel which was found to be largely full of sediment. No regression line has been drawn since the mole channel cross-sectional area is influenced by the seasonal shrinkage and expansion of the clay as well as the time from initial moling.

Although the existing moling had not completely collapsed (Fig. 7) there was a noticeable deterioration on both drained plots by autumn 1977 and the site was re-moled. After remoling more variability in the

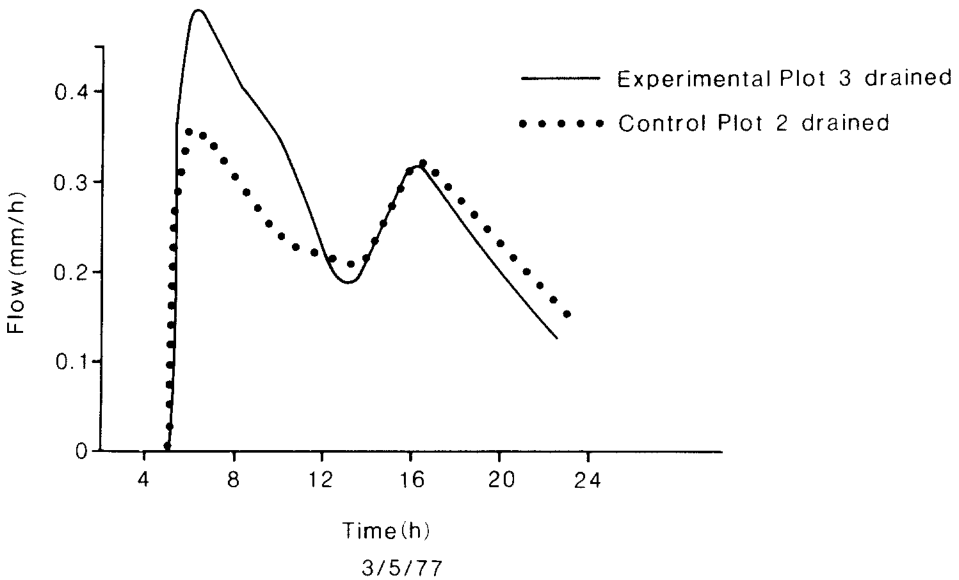

Fig. 6. Comparative post-submergence hydrograph data, May 1977.

watertable was noted, Plot 2 values generally being 5—10 cm lower than Plot 3. However drainflow hydrographs for Plots 2 and 3 in early February 1978 indicated the same uniform runoff pattern as for the first moling.

Controlled submergence of the Plot 3 moles by again raising the U-tube was carried out in February 1978. Effective submergence shown again by the depth to the watertable was maintained for periods of 10, 15 and 20 days, respectively. After submergence, comparative plot data showed that runoff responses of Plots 2 and 3 was broadly similar (Fig. 8). Dipwell data from moles 3 years old showed good agreement between Plots 2 and 3 (Fig. 9) and again the considerable superiority over the undrained Plot 1. Watertable control over the winter 1979/80 was typical of a good mole drainage system on both drained plots despite both short and long periods of submergence.

Mole channel deterioration determined from the cross-sectional area is given in Fig. 7. In 1980 the average cross-sectional area of the mole channels drawn in 1977 and subject to only limited natural submergence (Plot 2) was 30 cm^2 compared to 70—75 cm^2 when new. On this basis a useful life of 4—5 years could be anticipated. A progressive and more marked deterioration, with greater variability, of the experimental Plot 3 mole channels was noted, failure being primarily due to fragments falling from the roof and walls. Roof fragmentation became more noticeable in both plots after the summer 1978 and the effect was severe on the experimental plot by late 1979. The comparative cross-section for channels subject to both short periods of natural submergence and long periods of controlled submergence was 14 cm^2 in 1980.

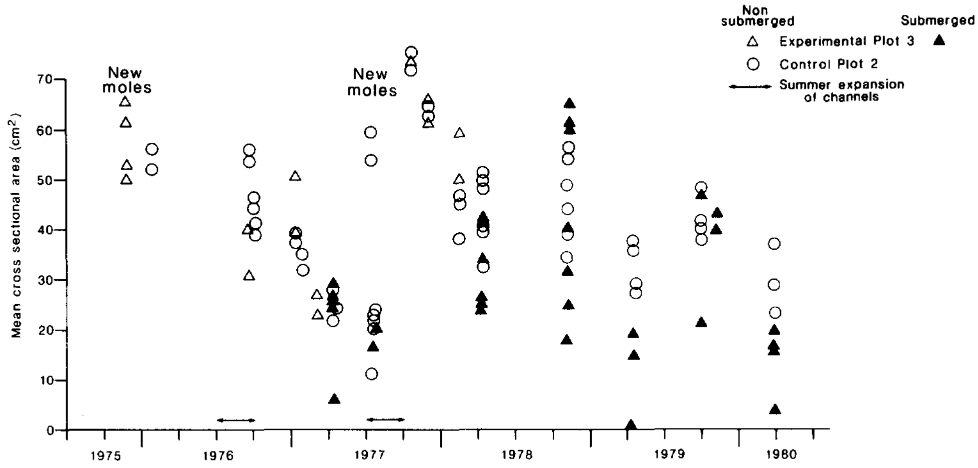

Fig. 7. Mole channel deterioration 1975—1980. For each sampling period the mean cross-sectional area of at least three mole channel sections is given.

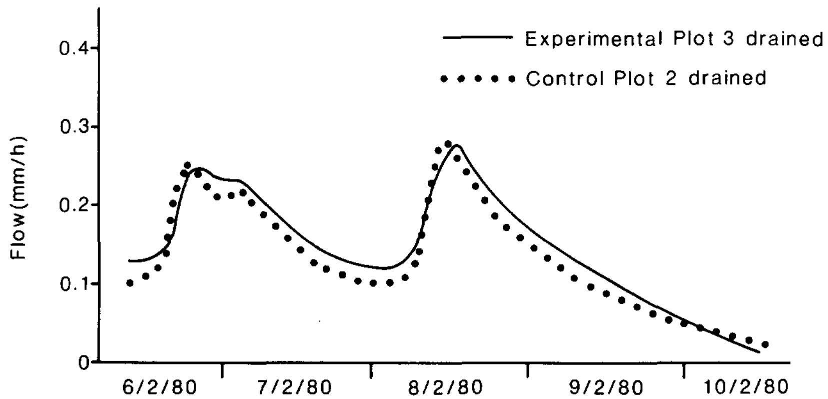

Fig. 8. Comparative post-submergence hydrograph data, February 1980.

DISCUSSION

Field observations before the experiment was established indicated that, under normal management conditions and an adequate pumping system, the life of good mole channels in the Otmoor alluvial gley soil could be up to 5 years. In the undrained state, high water levels restricted the land use.

During the 5-year experiment 16 short periods of natural mole submergence affected both drained plots. This normally lasted less than 3 h and occurred due to high ditch levels caused by problems arising from the pump system.

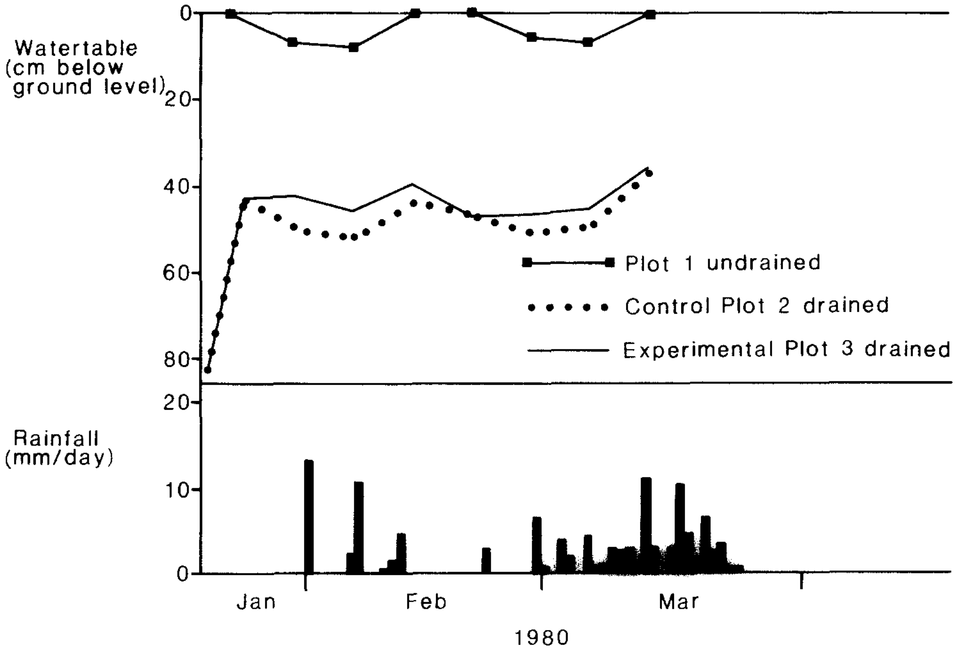

Fig. 9. Watertable levels, post-submergence, January—March 1980.

Deterioration in mole channel cross-sectional area was caused primarily by the gradual collapse of the roof and walls of the channel. This was found in all channels on the experimental site and is the type of failure reported by Nicholson (1942) to occur widely as a result of the rapid wetting and drying cycles of the soil. However this form of collapse became more marked and led to a more rapid deterioration of the mole channels that had been submerged for long periods. More variability in mole channel size was found in the submerged Plot 3 moles and roof/wall collapse had in some cases reduced the channel life to less than 3 years. A localised increase in sedimentation was also observed.

Since a comparison of the Otmoor soil with other soil types has indicated it was potentially a good moling soil with an expected life of 4—5 years, the submergence of the mole channels for long periods was shown to be detrimental. However, 3 years after moling the watertable control on both Plots 2 and 3 was typical of any mole drainage system which was 3 years old (Trafford and Massey, 1975). The average depth to the watertable at mid mole spacing was 40 cm over the winter period on both Plots 2 and 3 compared with near to the surface for the undrained Plot 1.

CONCLUSION

Comparison of the properties of the Otmoor alluvial gley soil with other moling soils indicated that it had a good moling potential and a mole channel life of the order of 4—5 years might be expected. The normal mode of failure was from fragments of the roof and walls falling into the channel.

Short periods of mole submergence, normally less than 3 h, did not substantially reduce the life of the mole channels. Longer periods of submergence (up to 20 days) reduced the life of the channel from typically 5 years to 3 or 4 years by accentuation of the piecemeal collapse of the roof and walls.

The drainage status of an area which had undergone submergence of the mole channels was found to be substantially better than similar undrained land, even in the third winter.

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