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INTERIM REPORT TO THE NATURE CONSERVANCY COUNCIL
ON BRITISH RAIL LAND - BIOLOGICAL SURVEY
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# THE HISTORY OF THE RAILWAY FORMATIONS

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## PREFACE

1. As stated in the First Interim Report to the Nature Conservancy Council on British Rail land, the Institute of Terrestrial Ecology has made a desk study of the historical, geographical and management aspects of railway land. Each of the four Reports describing individual Regions of British Rail will include maps showing the relationship of the rail network to the topography, geology and soils of the area covered by the Region. There will be a map indicating the period when each length of railway was first constructed.

2. In Part I of the First Interim Report, there were sections describing:
   1. the Managerial Hierarchy and Organisation of British Rail and, in particular, those parts of British Rail most closely concerned with the management of vegetation on banks and cuttings.
   2. Railway Formations. Construction and Management of Banks and Cuttings, which was subdivided into:
      a. Construction
      b. Early management
      c. Contemporary management
   3. Wildlife on Railway Property, which indicated the stages in the development of official interest in the value of railway banks and cuttings for wildlife, and the response of British Rail to requests to take nature conservation into account when carrying out management work.

3. This present Report, on the History of the Railway Formations, should be read in conjunction with Part I of the First Interim Report, and it supercedes Section 2a, Construction. The present Report will look in turn at:
   1. the age and extent of the railway
   2. the construction of the railway
   3. the impact of the railway

4. It is anticipated that the Final Report will make reference to historical and geographical factors in any analysis of results from the biological surveys of all the Regions of British Rail. There may be reference to the history of specific lengths of line, where this appears to be relevant to an understanding of the vegetation at the present day. It must be stressed, however, that it is rare for precise and detailed information on the disturbance and management of the railway formations to have been recorded in the past.

## INTRODUCTION

In studying the ecological processes taking place in such obviously artificial habitats as the railways banks and cuttings, detailed references have to be made to the creation and management of those habitats. The age and management of each site are often not so easy to ascertain as may appear at first sight. Although railways were introduced and built over a comparatively short space of time, and were the ultimate responsibility of a relatively small number of agencies, almost every bank and cutting has been subject to modification arising out of frequently piecemeal improvement and management programmes. Each has experienced a complex history of use, management and perception which may have each affected the present-day status of the habitats for wildlife.

Information may be obtained in a variety of ways : this section will be based almost entirely on published studies and the manuscript evidence now preserved in the Public Record Office.

There are many books devoted to Britain's railways and, as Morgan (1973) has commented, 'one is tempted to feel that there is not a yard of track left in Britain whose history is not accessible from recently published sources'. The treatment is, however, very uneven, and Barman, as early as 1950, drew attention to the curious neglect of the buildings and men of the railways. George Stephenson was remembered, for example, primarily as a mechanical engineer who invented the Rocket : his role as a brilliant civil engineer had been almost overlooked. Writers have found so much information on the politics of promoting railways and the technology of railway engines, that they have tended to neglect the physical side of building and operating the routeways.

Gradually, a better balance of research has been achieved. Barman's own book stimulated greater interest in the architecture and significance of railway buildings, and Coleman (1968) has described in detail how the navvies lived and worked on the lines. The economic and social ramifications of the railways have been investigated in greater depth. In his book, the Age of the Railway, Perkin (1970) has protrayed the railway as the 'Great Connecter' of people and places, and thereby one of 'the chief factors (in) forming the social structure of today's industrially advanced nations'.

It was not until 1973 that a 'general account of the development of the structures of Britain's railways - of the bridges, tunnels and earthworks' - was published. Even in this book, Railways : civil engineering (Morgan, 1973), there is hardly any reference to one of the most striking features of most embankments and cuttings, namely the vegetation. Writers have either taken the vegetation for granted or have been deterred by the evidence which is, at best, meagre and varied in quality.

With the exception of the Great Central Railway of the 1890s (Rolt, 1971), the major lines were built before the advent of photography, and only line drawings are available of the construction and early appearance of the banks and cuttings. Some of the most famous drawings are those of J.C. Bourne (1846), who wrote that he had taken care 'to give in the first place a correct representation of each work of art, and in the second place to combine with this, as far as was practicable, the natural features of the landscape'. He continued that 'it is thus hoped that drawings sufficiently correct for the purposes of the engineer or the architect will please also the general lovers of the picturesque'. Unfortunately, his drawings are of little use to those interested in the plants growing on the sides of the railway at that time.

Few writers had detailed first-hand experience of the railways. The civil engineer, F.R. Conder (1868), described this book as 'almost exclusively original and personal', and F.S. Williams was an acknowledged lay authority, who 'was given every facility to obtain his information at first hand' (Williams, 1876). His books contain references to private correspondence with railway officials, meetings with chairmen, and the proceedings of shareholders' meetings. These writers were, however, the exceptions to the rule. Some detailed data may be gleaned from the guidebooks published for the railway traveller, and which described the more noteworthy features of the line and more distant views from the carriage window. In the case of the West Highland Railway, opened in 1895, the company itself published a guide. Called Mountain, moor and loch, the guide consisted of a 'wealth of delightful pen sketches and accurately observed descriptive material' (Thomas, 1972).

These limitations in the source material should be borne in mind when trying to reconstruct a comprehensive and extended history of the rail network. The pioneer and dramatic way in which the network evolved tended to militate against adequate records being made and retained for the benefit of the future historian.

## 1. the age and extent of the railway

In a recent study of the Settle-Carlisle railway, Jenkinson (1975) has stressed that the only way to understand the line as an element in the landscape is to study the circumstances in which it was conceived, built and operated. The same may be said of almost any railway line : economic, political and social factors all had a part to play in deciding when, where and how railways would be laid down and used.

There are precedents to every revolution, and the early planning and construction of the railways drew heavily on the experience of the canals and tramways. The continuity was illustrated by the use of the canal-term 'navvies' for the builders of the railways ; the raileay companies were just as dependent on 'the muscles of men and horses or the power of black powder to blast the rock in tunnels or cuttings'. Although some tramways were crudely built, many were skilfully adapted to the local topography, with gradients between 1 in 50 and 1 in 100, and embankments of 50 feet in height and 0.5 miles in length (Morgan, 1973).

The principal difference between the tram- and rail- ways was one of scale : the most revolutionary aspect was the concept of an inter-city and regional network. Railways were neither parochial nor components of a network of communications - they were the network. One of the greatest contributions made by men such as George Stephenson was their perception of railways as an entity, with their construction, motive power, commercial potential and internal management as essential and inter-related aspects of the overall enterprise.

The heroic period of railway building ended in 1852. Between 1830 and 1840, route mileage rose from 97 miles to 1,497 miles. Soon the first tentative steps became a 'more confident routine' in which 'literally everything was happening at once'. Between 1844 and 1848, parliament authorised 720 railway Bills, which would have resulted in the construction of over 12,000 miles of track if all the Bills had been implemented. Although there were many abortive promotions, over 7,500 miles were in use by 1852. These comprised the basis of the future system of trunk routes and more important branch lines. There followed a comparatively lean period in the 1850s, and then another great burst of activity which ended, equally dramatically, in the financial crisis of 1866 (Dyos & Aldcroft, 1969).

Contemporaries were impressed by the speed with which new concepts of mechanical and civil engineering had been introduced, but the depression of the 1860s also led to misgivings. According to Conder (1868), 'the civil engineer was under a cloud', largely because he had 'done too much. He has crowded the work of half a century into a few years ... He has covered the island with noble viaducts and lofty embankments, furrowed it with excavations, and pierced it with tunnels. He has ... bound England firmly together by an iron network'. The main difficulties arose from the fact that he had 'too often done this in anticipation of the wants of the day. He has provided, by a large present outlay, for a traffic that is undeveloped and, what is worse, has provided often in duplicate'.

The tendency to provide railways ahead of demand reflected the difficulties in securing a balance between short- and long- term demands. According to Bourne (1846), 'there is a peculiar feature in the oeconomy of railway making, in which it differs from the oeconomy of an ordinary manufacture; a railway must be as perfect as possible at the starting. It can seldom to any great extent be improved afterwards. A ribbon-weaver or lace-maker may at any time most convenient to himself purchase expensive but more economical machinery, and produce a better or a cheaper article; but a railway company cannot do this. If their line is not originally well selected, and one capable of being worked cheaply and safely, they can scarcely hope ever effectually to amend it. The advantages must be gained, and the outlay made, in the first instance or never'.

As a result, the railways were built on a generous and durable scale. 'Brunel's leaping Thames bridges and the cuttings and tunnels of the Stephensons have needed only routine servicing to keep them fit for an age when train speeds and axle-loadings both average more than twice that of the traffic they were designed to bear - and when total train weights have increased by an even greater ratio' (Morgan, 1969). It was not until the electrification of the London-Manchester and Liverpool lines in the 1960s that the ballast and drainage regime of the permanent way were completely renewed. As a biographer of the great railway contractor, Thomas Brassey, wrote, such durability was 'no mean tribute to work carried out in the first half of the nineteenth century' (Walker, 1969).

In spite of the scale and permanence of the railway network, there was no national railway master-plan. Dyos and Aldcroft (1969) have described how 'the railway system very quickly became a kind of parallelogram of forces in which its very shape was the product not only of the underlying commercial requirements of the economy but of the political tactics and deeper strategy of the protagonists themselves'. As each new line was built or proposed, so it affected the value of other lines and companies. By 1850, there were 214 railway companies, which had constantly to adapt themselves to 'their total environment, changing their lines, their financial basis, their internal organisation, and their commercial policy, to suit circumstances that could not be finally stabilized until the whole railway economy had evolved'.

In this highly volatile, ad hoc situation, decisions were often taken on a strictly company or local basis. One of the most difficult lines to construct, the Settle-Carlisle railway, was almost entirely the outcome of inter-company rivalry. The Midland Railway Company was desperate for a direct route to Scotland in order to prevent its Midland lines 'degenerating into a minor provincial railway'. Far from opposing the line because of the way in which it duplicated those built by the London and North Western and the Great Northern Railway Companies, parliament was once again so frightened of a monopoly developing that it allowed the duplication of routeways to Scotland (Jenkinson, 1975). In the case of the West Highland Railway, it was local interests that decided the route. The most obvious course would have been to build the line from Fort William down the coast through Onich, Ballachulish, and Appin to link up with the Callander-Oban line at Connel Ferry, but the people of Lochaber had sponsored the line and so Lochaber had to be included on the route. This meant circumventing Britain's highest mountain, Ben Nevis, and a routeway over Rannoch Moor, at a height of up to 1,350 feet above sea level. In a hundred miles, there was no branch line or a village of any size (Thomas, 1972).

According to Grinling (1905), the detailed laying out of a line was based on two principles, namely that 'traffic, like water, will find its own level - it will go by the shortest route', and secondly that 'an engineer can do anything, if he be only given money enough'. As the author of the standard history of the Great Northern Railway, Grinling was undoubtedly influenced by the experience of that company, and reference to one phase in the selection of the route between London and York may be instructive. When Joseph Locke was commissioned to select a route in 1844, he tried to balance three attributes : the easiest route from the engineering point of view, the most direct route, and access to as many flourishing centres as possible.[1]

The weight given to each factor varied along the route. Between London and Potters Bar, there was no choice but to adopt a route which involved a tunnel of a mile in length and large earthworks through London Clay. The route to Hatfield was 'easier', but primary consideration had again to be given to engineering constraints between Hatfield and Hitchin. Even on the course 'best adapted to the surface of the country', there would have to be viaducts, deep cuttings and short tunnels. There was a relatively direct and easy route from Hitchin to Huntingdon, from whence two possible routes were proposed, namely via Peterborough, Deeping, Bourne, Folkingham, Sleaford, Lincoln and Gainsthorpe, or by another passing through Stilton, Wansford, Stamford, Grantham, Newark and Tuxford. Locke pointed out that Peterborough, Lincoln and Gainsthorpe contained three-quarters of the population and potential goods traffic in the towns of the first alternative, and that the optimum route would incorporate these three towns on a line which otherwise followed the second alternative. He believed this could be achieved by linking Newark and Lincoln to the main line by short branch lines which could, in themselves, become part of an east-west network of routes.

Many historians have cited the railways as an outstanding example 'of the bold faith and imperturbable daring that fired the makers of the nineteenth century'. This is probably an exaggerated view : each company had profound doubts and misgivings. For example, the proposals made by Joseph Locke were only a few of the most important made during the long promotion of the Great Northern Railway, and the eventual route was markedly different from that which he suggested for some parts (Grinling, 1966; Nock, 1974). Contemporary writers were very conscious of the weaknesses in planning and operating the railways. For example, Bourne (1846) described how 'it is difficult to show any regular correspondence between the population of a district and the traffic upon its Railway, or to determine at all satisfactorily what extent of country may be regarded as supplying any particular station, the result is so materially modified by circumstances beyond the reach of general observation. The physical features of the country, or even the existence of good roads, are frequently very imperfect guides, being counterbalanced by some local circumstances leading the traffic in another direction'. Likewise, it was just as difficult to forecast the impact of railway lines on a particular industry or sector of country. Although railways were welcomed as a great benefit to agriculture, Sidney (1848) confessed that there was no way of measuring this. 'There are no records of our home trade, and no statistics of our agriculture on which it would be possible to found calculations'.

It should also be stressed that, even in times of boom, capital was not unlimited. Although a line of 126 miles was authorised in 1836 from London to Norwich and Yarmouth, so little capital was raised that, seven years later, the line had to be terminated at Colchester. It was only some years later that a new company completed the original objective (Dyos & Aldcroft, 1969). It is doubtful if even the most successful of the pioneer schemes would have been started if their eventual cost had been realised at the outset. The cost of the London-Birmingham line was £5.5 millions, compared with Robert Stephenson's estimate of £2.4 millions. The London-Bristol line cost £6.5 millions, twice Brunel's estimate (Rolt, 1968).

These estimates were further evidence of the inexperience of the railway industry. Contractors failed to allow for such contengencies as unexpectedly difficult rock strata, and the companies often provided inadequate and inaccurate descriptions of the work required. This in turn stemmed from the unprecedented scale and complexity of the civil engineering undertaken. The London-Birmingham line, at its peak, employed 20,000 men under 29 contracts. Such aspects as structural theory and soil mechanics were in an elementary stage; solutions had to be found by bitter experience. In this context, Joseph Locke was one of the most influential engineers of the nineteenth[1] century because of his ability to devise carefully detailed specifications and control his contractors' performance in a rigorous manner. By doing so, he set a record on the Grand Junction line by exceeding his original estimate of £17,000 by only £2,000 (Pannell, 1964; Rolt, 1970).

In spite of the assertions in the 1860s that the age of railway construction had ended, new lines were built and widening programmes continued into the twentieth century. Although 'remarkably undramatic in its general character', the aggregate effect was considerable (Dyos & Aldercroft, 1969). The projects provided 'the new engineers with an opportunity to improve on the work of the old by learning from their mistakes' (Simmons, 1968). In this context, the

Great Central Railway, completed in 1899, was probably the finest line ever built from the engineering point of view. It had a ruling gradient of 1 in 175, easy curves, and for the first time considerable use was made of powered equipment, including forty steam excavators (Morgan, 1973).

Although some lines were built in a spirit of pointless rivalry or unjustified optimism, many more were designed to satisfy genuine increases in the traffic of goods and people. By 1862, the Midland Railway Company found that over 2,400 goods trains, and a thousand passenger trains, had been delayed each year by congestion on the London-Hitchin line, which was shared with the Great Northern Railway Company (Acworth, 1900). Consequently, the company decided to build a new and independent line from Bedford, through Luton, to London (St. Pancras). After 1868, the Bedford-Hitchin line was reduced to the status of a branch line.

Many cut-offs or short-cuts were made on some of the earliest lines to be laid down. In the late 1880s, 13.5 miles of new tracks were built as part of a scheme to provide a more direct link between Liverpool and Manchester (Acworth, 1900). Perhaps the most famous examples occurred on the Great Western Railway - dubbed by some the Great Way Round. The construction of the Severn Tunnel provided a byepass to Gloucester on the south Wales route, and the opening of the Badminton line in 1903 brought south Wales a further 10 miles nearer to London (The Times, 1935; Nock, 1962).

Meanwhile, third and fourth tracks were added to existing lines, thereby transforming the appearance and character of many cuttings and embankments. The decision to quadruple the Great Western Railway as far as Didcot was probably the main reason for the eventual abolition of the broad gauge on that system in 1892. On the London and Northwestern system, it was decided to build a third line from Willesden to Tring as early as 1856 and, by the late 1880s, this had been joined by a fourth line as far as Bletchley. By 1900, there were four lines to Rugby, and later to Crewe (Acworth, 1900).

Both the scope for, and limitations of, track widening were clearly seen on the Great Northern Railway (W.T.P., 1898; Sekon, 1908; Grinling, 1966). Four of the five tunnels between Kings Cross and Potters Bar had been tripled by 1897. Deep cuttings had been widened, and even larger retaining walls had been installed to hold back the treacherous London Clay. The existing lines became essentially new lines. Contracts required that 'the slope of the cuttings are to be finished as the cutting advances, and are to be nearly and uniformly trimmed or dressed to the specified dimensions and inclinations, to be covered with soil and sown with seeds'.[2] As Grinling (1897) commented, the original contractors 'would probably fail altogether to recognise their own handiwork'.

Although there were four tracks by 1900 between Woolmer Green and Huntingdon (except at Arlesey and Sandy) and for lengths as far north as Grantham, each relief line seemed to fill up almost before being opened and, worse still, there was little hope of removing the bottlenecks nearer London. The four tracks became two between Woolmer Green and Digswell and for a further two miles between Potters Bar and Wood Green. This was largely due to the presence of five tunnels, with an aggregate length of 3,300 yards, and a forty-arched, viaduct. Instead of adding a further two tracks to these lines, the company decided that it would be easier and cheaper to build a loop-line, which would have the added advantage of tapping new sources of traffic. Already a branch line had been built from Wood Green to Enfield, and an Act of 1898 authorised an extension of 19.5 miles through Hertford to rejoin the main line at Langley Junction. Work did not begin until 1906 and was not completed until 1920. In addition to the delays caused by war, heavy engineering works were required. The Pangsbourne Tunnel was the longest on the Great Northern Railway, and the presence of London Clay meant that the slopes of embankments and cuttings could be no greater than 3 to 1 (Hopwood, 1920; Hodge, 1976).

The first World War probably marked the peak in route mileage occupying an estimated 250,000 acres or 0.45 per cent of the land surface (Best & Coppock, 1962). By means of physical adaptations and, more especially, agreements and amalgamations between companies, a reasonably unified network of 23,400 miles had evolved. This was particularly striking in the London area, where a maze of inter-connecting lines was built, with virtually no dead-end branches. It is therefore relevant to ask whether it included representative samples of each major type of rock, soil and habitat in the British Isles. Did the property of the railway companies provide a microcosm of the natural environment of Britain? Any answer should bear in mind that no master-plan was ever conceived or implemented, and that there were considerable variations in the density of the network. In the densely populated, industrial parts of lowland England, no point was more than 2 miles from a railway, whereas in rougher country, with a sparse population, the rail net was much more open and some parts might be over 20 miles from a railway (O'Dell & Richards, 1971).

Since the early part of the century, the length of track has shrunk to about 11,300 miles, causing the network to become even more open in upland areas and even such areas as the industrial North-east and south Lancashire have experienced line closures. The original or present-day network may also be investigated to see whether there are considerable lengths of line, formed at the same date in a similar manner. Again, the documentary evidence suggests a considerable variation, reflecting the extended period over which lines were laid down and the incidence of subsequent widening and realignment programmes.

## 2. the construction of the railway

The building of the Liverpool-Manchester railway between 1821 and 1831 has been described as the beginning of the era of 'planned, mathematically exact routes', based on a levelled course, specially prepared track, and a motive force. The engineer, George Stephenson, had to build cuttings, embankments and tunnels in order to achieve a relatively straight and level line through extremely varied country for a distance of 31.5 miles. Out of the Olive Mount cutting alone, the navvies removed and carted over 1.5 million cubic yards of stone for a distance of up to two miles (Greenleaf & Tyers, 1948).

In his book Our iron roads, Williams (1883) described how the engineer traversed the intended route of the railway, with 'Ordnance Map in his hand, and the mountain barometer in his pocket, with which to take "flying levels"'. In determining the line of the London-Birmingham railway, Robert Stephenson is reputed to have walked the route over twenty times, whilst his assistants made trial borings and shafts. The line from Leeds to Ilkley was cited by Acworth (1900) as the 'perfect microcosm' of the kind of difficulties which could arise even on a short and comparatively unimportant line. He wrote:

> see how in one place the cutting is carried through the most obdurate of all obstacles, the boulder-clay; how, a little further on, the peat has been dug away to afford a solid foundation; how, in a third place, the embankment has been floated on brushwood ... (the visitor should also) notice the elaborate drainage, lest water should lodge anywhere to undermine the security of the permanent way; notice too the substantial stone bridges, in some instances not more than 200 yards apart, built for

> the convenience of a few sheep or an occasional farm cart, because even this is cheaper than the price that must otherwise be paid as compensation for severance

In order to achieve maximum speed, it was important to keep the gradients and curves to the minimum. Early engineers estimated, for example, that the amount of tractive force required to mount an incline of 1 in 200 was twice as great as that needed to take the same load at the same speed over a level course (Williams, 1883). As a result, engineers took advantage of the Thames' flood-plain and terraces in laying out the London-Windsor line, and of raised beaches in designing the routes from Glasgow to Troon and to Ardrossan and Saltcoats. On the Welsh coast, the railways to the north and south of Barmouth kept close to the base of the sea cliffs (Appleton, 1962).

In a few cases, it was possible to build an almost straight and level track. This was achieved for 30 miles north of York, and gradients were negligible over a length of 100 miles between Retford and York. Another outstandingly straight and level line ran for 50 miles between Redhill, Tonbridge and Ashford (Allen, no date). On most other lines, the character of the topography made this hard to achieve. Beaver (1936) has illustrated the relationship between topography and gradient profiles for several main lines, two of which are illustrated in figures 1 and 2. He stressed that there is a large vertical exaggeration in gradients and geological dips, and that the profiles are those of the track and not of the neighbouring land surface. The figures indicate a marked difference between the relatively even, gentle profile of the London-Rugby line and that to the London-Leicester line, which has a pronounced 'switchback' gradient.

These differences in profile reflected the alternative strategies available to the engineer (Ritchie, 1846, Rolt, 1970). The rise and fall in topography could be distributed as equally as possible over the entire length of the line, as on the London-(Rugby)Birmingham line, where the gradient never exceeds 1 in 330, except between Euston and Camden where stationary engines provided the motive power for several years. The alternative was to concentrate the changes in level in a few steep parts and make the remainder of the line as level as possible. The pioneer Liverpool-Manchester railway adopted this method : there are two steeply inclined planes of 1 in 90, compared with the rest of the line which is less than 1 in 849 (Williams, 1883). In order to keep gradients to the minimum, the lines built by Brunel and the Stephensons are distinctive for their

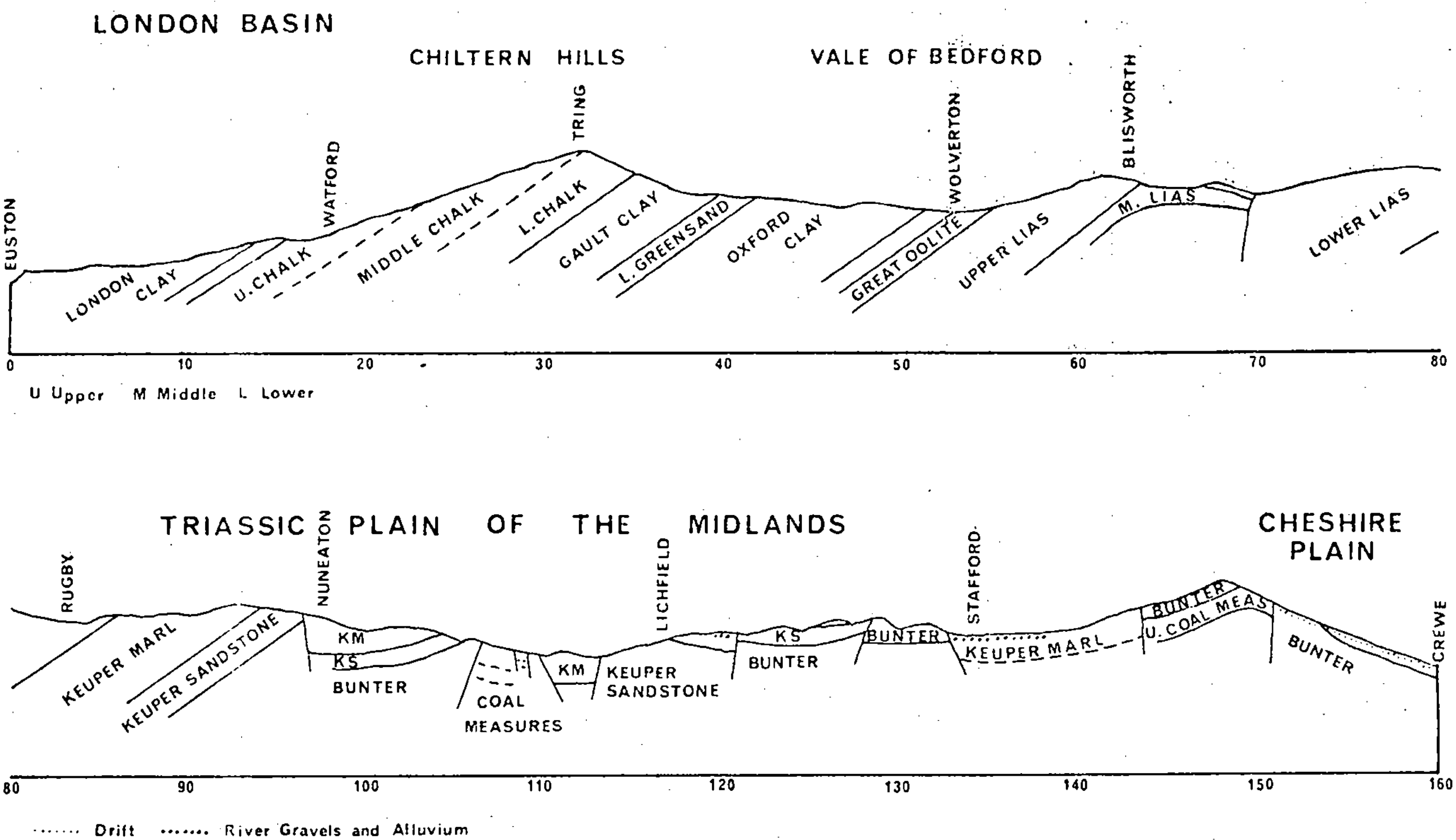



Fig 1. LMSR (Late LNWR) Euston to Crewe

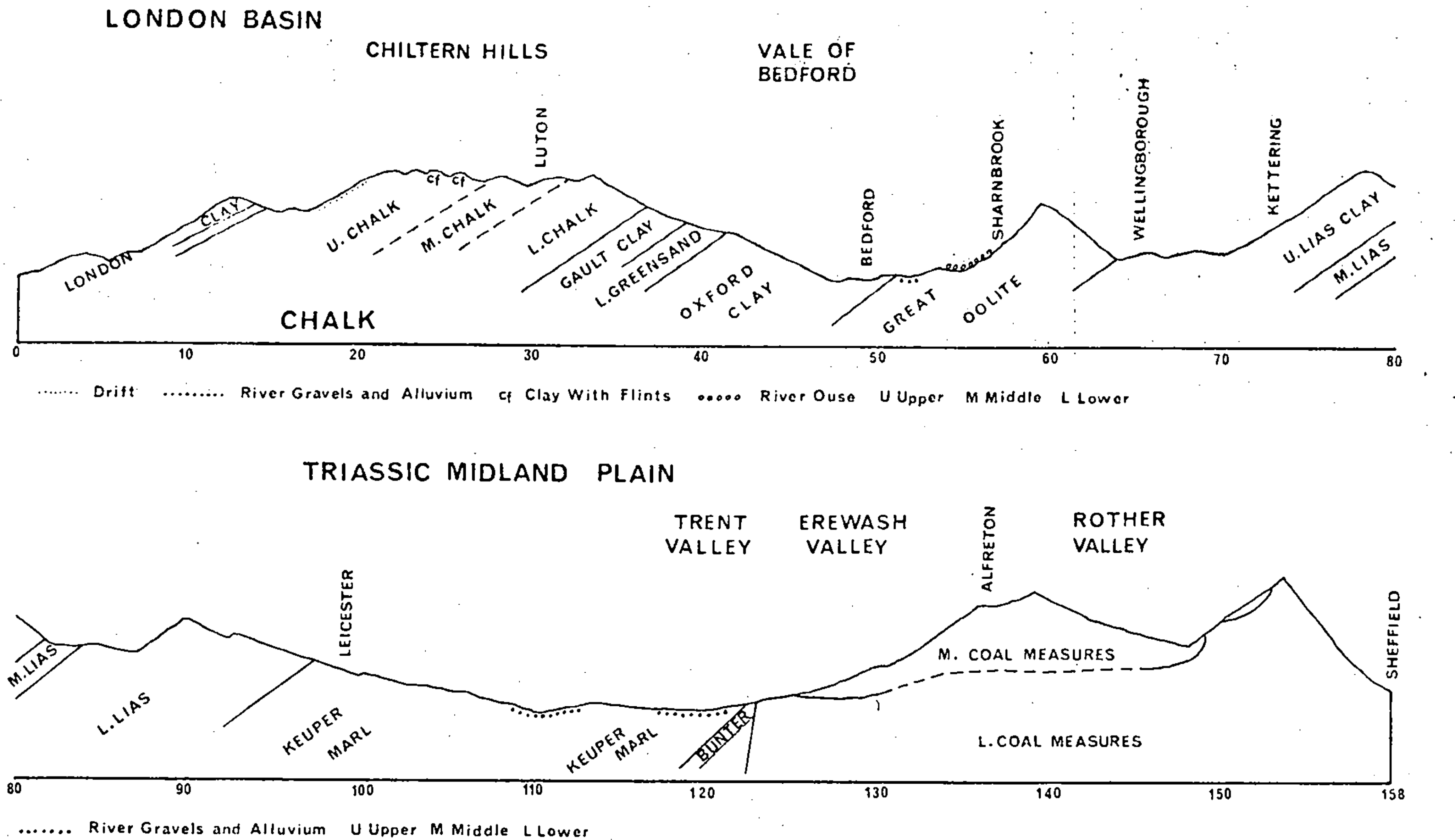



Fig 2. L M S R (Late M R) St Pancras to Sheffield

major earthworks. A cutting of two miles in length and up to 60 feet in depth was required to traverse the high ground between Twyford and Reading. The two great cuttings at Roade and Tring on the London-Birmingham line are perhaps the greatest railway engineering feats in Britain. At Roade, over 300,000 pounds of gunpowder were used to help remove over 1 million cubic yards of clay and flint-hard limestone (Greenleaf & Tyers, 1948).

Soon, improvements in locomotive power made it possible for engineers to contemplate steeper overall gradients. A seventeen-mile length of the London-Southampton line was built in the late 1830s at a gradient of 1 in 250. When the London-Portsmouth line was opened in 1859, gradients of up to 1 in 80 caused comparatively little comment (Coleman, 1968). Engineers were particularly keen to exploit the opportunities presented by stronger engines because of the way steeper gradients helped to reduce the size of the earthworks and need for tunnels. On the London-Southampton line, the steeper gradient made it possible to traverse the Hampshire Downs in a series of 'stupendous cuttings', rather than in tunnels. When the Bedford-Leicester line was being built, the Crimean War was being fought and 'men and money' were in short supply. Because only £1 millions were subscribed for a line of 63 miles, long tunnels were out of the question. The only way of negotiating the higher ground was by steeper gradients and cuttings of up to 60 feet in depth.

In some cases, these economies were soon regretted when goods trains became longer and heavier. The southward bound coal trains on the Bedford-Leicester line found the gradients of up to 1 in 20 on the Sharnbrook summit almost prohibitive and, in 1868, a new line had to be opened for goods traffic, called the Wymington deviation. By running at a lower level and through a tunnel for part of its course, the maximum gradient was only 1 in 165, and that in favour of loaded trains going to London (Williams, 1876). It was not until later in the century that the drawbacks of steeper gradients for passenger trains were appreciated. By then, the demands for greater speeds and more comfortable (therefore, heavier) rolling-stock had outstripped the great improvements in locomotive power (Rolt, 1970).

One of the fiercest battles between gradients and the directness of a line was fought over the Lancaster-Carlisle route, built by Joseph Locke. The choice was between a line over Shap Fell, involving four miles at a gradient of

1 in 75 and another which was 30 miles longer but followed a coastal route. Opponents of the Shap line stressed the steepness of the gradient, harsh winters and large-scale earthworks that would be needed, but Locke contended that even 'if ninety miles could be made with as little cost as sixty, no one could maintain that ninety miles would be kept in repair for the same as sixty; as little as could any one expect to travel over that increased distance without a proportionate loss both of money and time' (Devey, 1862). Locke's view prevailed, and the Shap route was built between 1844 and 1846 at an estimated saving of £100,000. Later commentators have suggested that neither route was suitable and that a compromise should have been found. In order to avoid the 'gruelling gradient facing north-bound trains', there were proposals from 1862 onwards for a deviation, with a ruling gradient of 1 in 135 and a mile-long tunnel. Parliamentary powers were obtained in 1898 and the 1930s, but the deviation was never built (Reed, 1969).

One way of reducing the time and cost of railway construction was to select a route whereby the amount of material excavated from cuttings corresponded with that required for the embankments. If a descending gradient could be achieved, with each cutting alternating with an embankment, it was comparatively easy to remove the excavated material in waggons and instal a drainage system in the cutting. A great deal of skill was required to obtain this ideal because the fragments of rock used in the embankments occupied a larger space than the rock in its original state in the cutting. Some material also had to be set aside at intervals, in the form of spoil-heaps, in order to repair any slips in the cuttings or subsidence on the embankments (Dempsey, 1855).

Both contemporary writers and the contracts drawn up between companies and builders describe in detail the methods of making the banks and cuttings. Williams (1883) described how a 'gullet' was first made 'just large enough to receive a row of waggons that are to bear away the earth, and into the gullet the tramway is run. The wagons can now be brought close alongside the material to be moved, and several men being set to work at each, the soil is flung into them with ease and celerity. Meanwhile, as the stuff is removed the gullet is opened farther and farther into the hill'. The building of the embankment began as the first waggons from the cutting were unloaded, and the embankment gradually proceeded en masse, for its full height, across the low ground. As it 'moved' the contractor extended the waggon-way so that the waggons could continue to tip the 'stuff' over the advancing edge. Once construction was completed, the waggon-way was replaced, by ballast, blocks and rails of the permanent way, a term first used on the London-Birmingham line in 1838.

On most lengths of line, it proved impossible to achieve a complete balance between excavated material and the construction of embankments. The cutting might be too remote from any embankment; the cutting might have to be too deep to provide sufficient material for the embankment; the embankment might have to be excessively high to absorb all the 'stuff' available. Sometimes, the excavated material was not suitable for building embankments : on the London-Croydon line, the yellow plastic clay was sent to spoil, and only the blue arenacious clay was used (Brees, 1837). In the case of the Great Western Railway in north Wiltshire, the company 'could not stay to cart the earth from the cutting to the places where it was required for embankments : so where they excavated thousands of tons of clay they purchased land to cast it upon out of their way, and where they require an embankment they purchase a hill, and bodily remove it to fill up the hollow' (Williams, 1883).

Large quantities of material were often left over. On the Liverpool-Manchester line, some of the 800,000 cubic yards of clay and sand from the Kenyon cutting were used to form embankments to the east and west, the remainder was 'heaped up, like Pelion upon Ossa, towering over the adjacent land' (Booth, 1830). A prominent feature in the excavation of the Tring cutting on the London-Birmingham line was the famous series of forty horse-runs of up to 50 feet in height, which were used to lift the surplus material up to the spoil banks aligning the route (Williams, 1883). Sometimes, the spoil heaps marked the point where a contractor finished his length of line : the heap at Denbigh Hall marked the site of the temporary terminus of the London-Birmingham line during its construction (Freeling, 1838).

The creation of spoil-heaps and side-cuttings meant that a wider tract of countryside was directly affected by the making of the railway. On the Grand Junction railway, material for part of the Aston embankment was obtained by 'diverting the course of the river Tame into a new channel, cut by the side of the Railroad, and by sweeping out a large artificial pool on a contiguous piece of land purchased by the Directors'. At another point, the line passed 'through the core of Bunker's Hill, which rose about 36 feet above the level of the rails. One side of this mole was nearly cutaway to furnish the necessary materials for the succeeding embankment' (Roscoe, 1839). Completely new habitats were formed. On the line to New Holland in Lincolnshire, Sidney (1848) described how smooth tenacious blue marl was excavated from a depth of up to two feet from the neighbouring fields in order to construct the embankment of 20 feet in height. 'Wherever excavations had taken place, surface-water had accumulated in pools of such depth, and with such rapidity, as showed the difficulty of getting it off the land in so flat a district'.

A further by-product of railway construction were the sequestered plots, which Parker (1974) has defined as those comparatively small and inaccessible plots of land isolated, or surrounded, by two or more railway tracks. At the peak of the railways it is estimated there were over 1,750 of these plots, of which about a third were vacant and had no obvious use when surveyed in the early 1970s.

The width of country acquired for the formation of the railway reflected the policy and resources of the companies and the nature of the topography and rock. A width of 72 feet was taken by the London-Brighton line, 69 feet by the London and South-west railway, and 64 feet 6 inches by the Bristol-Exeter line (Ritchie, 1846). One of the objections to the 7-feet gauge, as opposed to the more normal 4 feet 8½ inches, was that it required extra land. In order to help reduce the width required, various expedients were employed. On the Grand Junction railway, a viaduct was built over the intensively cultivated, small gardens that would have been so expensive to acquire on the fringes of Birmingham (Roscoe, 1839). Likewise, steepsided cuttings were a way of economising on land and construction work. The walls of the cuttings through basaltic or whinstone rock on the Edinburgh, Glasgow and Grennock railways were almost perpendicular (Ritchie, 1846). At a later date, maintenance costs sometimes outweighed the initial savings. For many years, the Roade cutting on the London-Birminghan line had to be constantly patrolled 'to guard against mischief from falling portions of its rocky sides, which looked like masonry but in reality were very dangerous' (Neele, 1904).

According to Ritchie (1846), engineering had 'assumed a new feature from bygone times. To be a railway engineer not only requires an accurate eye to take up the general aspect of the country, but, at the same time, to have a clear conception of its geological character'. In the building of the Grand Junction railway, great difficulty was experienced, for example, in the Newton cutting of up to 80 feet in depth, which was 'of the most singular nature, having no regular stratum of any kind throughout its whole length' (Roscoe, 1839). Most commentators agreed that boulderclay was 'the most difficult material that railway contractors can have to deal with!'. At one moment, it could only be 'conquered by blasting, whilst at another, after a rain, it turns into a thick gluey clay'. Exceptional difficulties could also be encountered when lines cut across the grain of the country. The Brockenhurst-Christchurch line, for example, ran between the higher ground of the New Forest and the sea, and 'intercepted enormous stores of surface water on their way to the Solent'. Slips of up to a hundred yards in length frequently occurred in cuttings made through the Barton clay, after only a few hours of rain (McDermott, 1887).

One of the greatest obstacles to construction was bogs and fens. On an embankment south of Kirby Stephen on the Settle-Carlisle line, tipping proceeded for a year without making any progress. 'The tip rails during the whole period were unmoved, while the masses of slurry rolled over one another in mighty convolutions, persisting in going anywhere and everywhere except where they were wanted' (Williams, 1883). The Liverpool-Manchester railway crossed Chat Moss. Because of the depth of the bog, George Stephenson devised a system of dried peat and brushwood hurdles, which enabled an embankment of sufficient height and firmness to 'float' the permanent way across the moss (Booth, 1830; Carlson, 1969). The contractor responsible for building the Great Northern Railway across the fenland of Huntingdonshire described how he could 'stand upon it, and shake an acre of it together'. He engaged an experienced drainage engineer as his principal agent, and agreed to the purchase of a steam drainage engine and 100 acres of faggot wood. The latter were used to build a raft consisting of alternate layers of peat sods and faggots, on which soil was subsequently tipped. The effect 'was to displace the water, but to leave the solid parts behind. This was not to be done by suddenly adding on great weight, but by a gradual and slow increase of weight, so that the water has time to escape without carrying away with it the solid matter' (Helps, 1872; Grinling, 1966).

Considerable attention was given to drainage on every embankment and cutting. According to Wood (1838), the angle of slope depended 'in some degree, upon the depth of the excavation, or height of the embankment; in the former, when the material is sand, gravel, chalk or gravelly clay, a slope of one and a half horizontal, to one perpendicular, is quite sufficient; and in excavations, up to thirty or forty feet, this slope has been found to stand very well. In some descriptions of clay, such as the plastic clay of London, and clay of a similar nature, a slope of one and three-fourths, or two to one, is necessary'. In one notorious case on the South London line, west of Peckham, there was a danger for some years of several fine houses collapsing down the increasingly unstable sides of a cutting in the London Clay. Movement ceased only when heavy retaining walls were built (McDermott, 1887). In the Brent valley, a different kind of problem was encountered by the Great Western Railway when an embankment was built over 'a thick bed of diluvial marle, interstratified with thin seams of gravel'. The weight of the embankment led to a compression of the underlying material and an upheaval of the neighbouring ground. The company had to instal drains and extend 'the base of the embankment so as to load the uplifted marle' (Bourne, 1846).

As the President of the Institution of Civil Engineers commented in 1844, engineers were used to landslips in the first six to eight months of the life of a canal, but railway embankments and cuttings appeared never to be stable. Although water might be the primary cause of these slips, the more immediate cause was the passage of a train. When the lower beds of rock 'became converted to mud, and the adhesion of the particles was destroyed, the mass only required a slight impulsive force, such as the vibration consequent of the passage of an unusually fast or a heavy train, to set it all in motion and to cause a slip'. The proceedings of the Institution contained several series of articles on ways of reducing the chances of landslips. Great stress was always laid on improvements in drainage.

One way of reducing the erosion of the earthworks and improving stability was to cover the slopes with vegetation (Day, 1848). Experience on the Great Western Railway between Bristol and Bath indicated that even chalk slopes would benefit. Although they were not prone to the kind of landslips which occurred on slopes of gravel, sand and clay, the chalk slopes were subject 'to continual crumblings and the falling down of small fragments, unless protected by grass from 'the destructive force of atmospheric agents, and chiefly of frost' (Nixon, 1842). Several writers commented on the rapidity with which plants colonised the slopes. In one of the first accounts of a railway journey, an actress described how the walls of Olive Mount cutting on the Liverpool-Manchester railway were 'already clothed with moss and ferns and grasses' (Davies, 1975). In the Whittmore cutting of the Grand

Junction railway, Roscoe (1839) noted how 'the railway winds for the distance of two miles through a magnificent defile girt with walls of solid stone, and enclosed between slopes of new and freshly-green herbage'. Where construction works were permanently or temporarily abandoned, plant life soon reestablished itself. In the ten years following the financial crises of 1866, Nature 'covered the embankments with verdure', and shrubs and vegetation closed the entrances of an almost complete tunnel on the abandoned Croydon-Groombridge line (McDermott, 1887).

Engineers could not, however, rely on Nature, and positive steps had to be taken to secure a vegetation cover. In a paper published by the Institution of Civil Engineers, a French engineer recommended that the surface of loamy soils should be 'sown or planted with couch grass, clover, lucerne or French grass; occasionally with shrubs, acacia, willow, birch, maple, &c., the deep roots of which spread, compressing and consolidating the ground (Caudard, 1874-5). In many cases, meadows and pastures on the route of a railway were cut up into turves of six inches in thickness, and lifted. As soon as possible, they were relaid on the slopes of the new cuttings or embankments as a 'preservative' (Williams, 1883). The importance of these precautions is implied in the following extract from a contract for the building of the London-Birmingham line (Brees, 1837). This stated:

> as the embankments advance and become consolidated, their sides shall be carefully trimmed into places, or faces having the proper slope specified on the section, and the face of the slopes are then to be neatly covered with turfs of grass, no less than 8 inches in thickness, laid with the green sward outwards. The turf must be taken from the ground to be occupied by the base of the embankment, and where the land is arable, the soil must be carefully removed from the base of the embankment, and afterwards uniformly distributed over the slope not less than 6 inches in thickness. The slopes, which are to be thus covered with soil or vegetable mould, are to be sown with rye grass and clover seed, mixed in equal quantities, and not less than 3 lbs of the mixed seed per acre is to be sown and equally distributed on them as soon as the season will admit of its being properly done. When amongst the material which is brought to and shot over the end of the embankments, there shall be large lumps, they must, if more than 6 inches in diameter, be broken to pieces.

In order to minimise the length of time the turf was left in the stack, the contractor was ordered not to 'remove the turf or soil from the ground for a greater distance than one statute chain in advance of the face of the excavations or embankments, and that which has been cut must be removed back to a point where the slope is ready for receiving it, and laid down ... with as little delay as possible'.

There is every indication that the contractors were expected to adhere to these requirements : a letter from the joint secretary of the company in 1834, following an inspection of Contract Number I, stated that 'the embankments are turfed as fast as they are formed to protect them from the action of the weather and I trust that the work of the first Contract will soon rival in system those of the other two - which leave nothing for us to wish for'.[3] When a contract was being drawn up for the construction of a railway near the river Dee in Cheshire, similar stipulations were made, namely:

> to remove and carefully put aside sufficient top soil from the site of the cuttings and embankments to soil the slopes when trimmed, and also the whole of the formation at the site of excavation, to a thickness of at least six inches, measured at right angles to the line of the slope; and where it may be in grassland, the turf is to be carefully cut into sods for the same purpose[4]

To facilitate the development and maintenance of the slopes, the contract specified that:

> in all cuttings a row of sods, not less than 1 feet 6 inches wide and 6 inches thick, is to be laid where directed by the Engineer at the foot of slopes to support the soiling or sodding above; and the cost of this is to be included in the price for soiling and sowing the slopes. The faces of the slopes are to be sodded or covered with a layer of soil 6 inches thick, with the turfs or soil previously removed for that purpose from the site of the embankments or cuttings ... the slopes and formation at the site of excavation when soiled are, at the proper season, to be sown with rye grass and white clover seeds, in the proportion of one-and-a-half pound of clover seeds and three bushels of rye grass seeds per acre, and the sowing repeated in case of failure until a good turf is established

In addition to grass, there were suggestions that trees and crops might be planted on the slopes. On the London-Birmingham line, Freeling (1838) described how trees had been planted where the line entered Coventry and over the Fletchampstead embankment. He wrote, 'the slopes are prettily planted, and, if the trees thrive, they will give a most picturesque appearance to this portion of railway'. In his book, Our iron roads, Williams (1883) also drew attention to the way in which those trees ' which do not penetrate with a straight tap root' could help to 'bind together the surface soil, which they permeate and interlace'. He also referred to proposals as to how 'the sloping sides of a railway embankment, well sunned and sheltered, might be used for purposes of cultivation'. A correspondent to the London and North Western Railway Company in 1842 commended the planting of 'every description of fruit trees usually grown in England'. Their roots would 'become mixed and entwined in one mass of great unity and strength', helping to absorb the rain and dampness of the soil, so that 'the water which is now injurious would become beneficial'.[5]

In the event, little consideration was given to these proposals by companies struggling to turn their railways into successful and profitable operations. Once built, the prime task was to maintain the line and its earthworks in good order. As early as 1834-35, plans were drawn up for contracting out the 'maintenance of the way' on the Liverpool-Manchester line. The plans were not implemented until 1842, when it was soon discovered that it was cheaper for the company to employ its own staff for the work (Donaghy, 1972). A contract made for the London-Birmingham railway in 1839 indicates the priorities as seen by that company. For £300 per mile, the contractor was each year to maintain the permanent way, prevent or repair any slips and subsidence, maintain and replace any fences and hedges, and ensure good drainage in all parts. 'All the slopes in the possession of the Company (were) to be mowed at least twice in the year, the produce to be the property of the Contractor'.[6]

In 1943, the Permanent Way Institution published a textbook, British railway track design, construction and maintenance (Hammett, 1943), which made reference to the control of vegetation growth. In addition to being unsightly, weeds on the permanent way encouraged the ballast to become clogged with dirt and thereby reduce the free drainage of the ballast. Traditionally, the lengthmen had hoed the weeds in early summer, 'going right through the length and uprooting or chopping off all weeds in the track, and cesses', but the work was both expensive and laborious. Increasing use was made of chemicals : a special train was fitted with nozzles to spray the track with chemicals usually a mixture of Sodium Chlorate and Calcium Chloride, diluted with water. Not only was this a quicker method of control, but spraying had the advantage of killing all the weeds, whereas hoeing had been less effective.

The textbook stressed that advantage should be taken of any dry spell in February and early March for burning off dead grass and weeds on the banks. Only small areas should be burned at one time in order to prevent the fire getting out of control. After the 'torching', any loose debris or big stones should be removed in order to prevent their damaging the scythes later in the year. Mowing was usually carried out in June or July, according to the locality, before the grass began to seed. In confined spaces, a reaping hook was used instead of a scythe. The textbook noted that on some railways, a 'swath' was cut at the top and bottom of the slope, and the standing grass between the swathes was then burned.

## 3. the impact of the railway

Contemporary writers tended to dwell on the economic and social impact of the railways, describing how they would revolutionise the movement of goods and people, whether between home and work, or for holidays further afield (Freeling, 1838; Acworth, 1900). Booth (1830) wrote that 'perhaps the most striking result' was 'the sudden and marvellous change which has been affected in our ideas of time and space. Notions which we have received from our ancestors, and verified by our own experience, are overthrown in a day and a new standard erected, by which to form our ideas for the future. Speed - despatch - distance - are still relative terms, but their meaning has been totally changed within a few months : what was quick is now slow; what was distant is now near'.

Railways also made a physical impact. Like hills and valleys, fields and settlements, they became accepted parts of the landscape and, whereas most parts of the human landscape soon became worn out, pulled down or otherwise destroyed or changed beyond recognition, the bulk of the earthworks associated with the railways survive (Sherlock, 1922; Appleton, 1962). According to Barman (1950), the railways were the first to bring the visual experience of the industrial revolution to many parts of Britain and, even when the engines are withdrawn and permanent way taken up, the banks and cuttings usually remain.

Before the railways were in operation, many feared that they would 'spread desolation along their path' (Drake, 1838). Lord Harborough refused to allow the Syston-Peterborough line to be built through his park. The company had to build a sharp curve instead, which became increasingly dangerous as train speeds rose in the 1880s. It was not until a more compliant owner succeeded to the park in 1892 that realignment was possible, and the old curve at Saxby was abandoned (Simmons, 1955). John Clare was representative of those who protested at the impact of the railway, writing in his diary of how an early surveying party led by George Stephenson in the Soke of Peterborough planned to 'despoil a boggy place that is famous for orchises' (Steane, 1974). A contemporary botanist bemoaned the destruction of 'the wild Botanic garden' of Battersea Fields in Surrey by a proposed railway to Nine Elms. He called upon fellow-botanists to cooperate in recording and mapping the area so that 'at a future period when railroads, and such like public undertakings, have demolished our richest locality in the immediate neighbourhood of the metropolis, we shall have at least a plan to show our descendents that a place existed which abounded in so profuse a supply of plants at a stone's throw from London' (Cooper, 1839). Alas, his plan does not survive.

Except as an excuse for impeding the progress of the railways and as a means of extracting more compensation, there was relatively little opposition on amenity grounds. Indeed, some writers actually welcomed the railways, both for making the countryside more accessible and for adding greater interest to those rural scenes. Thomas Potter described how trains could be seen from the top of Long Cliff in Charnwood Forest 'almost uninterruptedly' from Sileby to Derby, forming 'a pleasing object darting across the grand panorama' (Robbins, 1962). The impact varied according to the nature of the countryside. In the case of the West Highland Railway, 'never was there a railway that less disfigured the country through which it passed. Like a mere scratch on the mountain slopes, it glides from valley to valley, unobtrusive as a sheep path' (Thomas, 1972).

One reason for the general acceptance of the railway was the fact that contemporaries had already experienced large-scale changes of an arbitrary kind. In addition to the construction of turnpike roads and canals, parliamentary enclosure had led 'to minor landmarks being destroyed wholesale, little woods and coppices being uprooted, and small fields thrown together into large ones, which left the land in the counties most affected looking as though it had been newly shaved'. Although the changes were initially 'raw and brutish', they were soon concealed by vegetation and hedgerow-timber. Thus, George Eliot wrote, 'Our Midland plains have never lost their familiar impression and conservative spirit for me; yet, at every other mile, since I first looked on them, some sign of world-wide change, some new direction of human labour, has wrought itself into what one may call the speech of the landscape' (Robbins, 1962). The construction of the railway merely added one more incident, and one more feature of interest, to that landscape.

In his reference to the Darlington-Middlesbrough line in 1835, Sir George Head (1838) drew a distinction between the banks of a canal where navigators and loiterers created a nuisance, and the railways where travellers were like 'a flock of pigeons or swallows that confine their flight to the regions of the air, and leave neither track nor trace behind. Silence and stillness reign within its precincts, and harmonize with the grandeur of the spectacle'. Lloyd (1951), a century later, emphasised this same point by reference to rollingstock on the railway. The train moving over Shap Fell helped to emphasise the wild beauty of the region. It was only when the train stopped, and especially when it shunted and needed marshalling yards and other paraphanalia, that the railway ruined the landscape.

It is difficult to assess the impact of the building of the railways on archaeological remains and natural history because of the limited interest and knowledge of those subjects at that time. Although a priory at Lewes, and castles at Northampton and Berwick on Tweed, were destroyed, Maiden Castle, outside Dorchester, was saved by a diversion of the line. At the instigation of the Leicestershire Archaeological Society, the Great Central Railway was obliged by its authorising Act to preserve the remains of a Roman pavement in the new station at Leicester (Simmons, 1955). Robbins (1962) has claimed that 'on balance, archaeology has gained far more from railway excavation than it has lost'. The construction of the Bedford-Cambridge line, for example, led to the discovery of many vases and other relics of the Roman site of Salance at Sandy (McDermott, 1887). It is clear, however, that only a small proportion of the artefacts found by the navvies was ever preserved or recorded. The Annual Report of the Institution of Civil Engineers (Anon, 1855) urged contractors to impress on their men the need to preserve and surrender the relics, so that they could be forwarded to the Society of Antiquaries and incorporated in national collections. Whenever railway cuttings revealed parts of a Romano-British or Anglo-Saxon cemetary, archaeologists should be informed and given the opportunity to complete the excavations.

In the words of McDermott (1887), 'railway contractors are, indeed, valuable assistants to the antiquarian, whilst the geologist is equally indebted to them for sections of the stratification of the country'. When the Blisworth cutting was being made on the London-Birmingham line, geologists came from all parts of the kingdom to search for fossils thrown up from the layers of oolitic limestone and clay (Barman, 1950). On the Great Western Railway, Bourne (1846) noted how elephants' teeth were found in the flint gravel of the Moreton cutting and large ammonites in the blue clay of the Bourton cutting. McDermott (1887) asserted that, to the seeing eye, a railway journey could be more instructive than volumes of geological books, but, unfortunately, many of the exposures were only temporary. On the Enfield line, Miss Cresswell (1912) described how the bright cobalt blue of the London Clays soon turned to orange on exposure to the air. At first, the Edgehill Tunnel on the Liverpool-Manchester railway was gas-lit, and passengers could study 'the different colours and peculiar appearance' of the rocks, which ranged from 'the softest sandstone to the most compact free-stone'. By 1830, however, it was decided to whitewash the sides and roof in order to 'give better effect to the illumination'. As Booth (1830) commented, 'the geologist will be disappointed, in traversing this subterranean vault, to find the natural varieties converted by lime-water into one uniform and artificial appearance; but the principle of utility is paramount in a commercial undertaking'.

The railways made it easier for naturalists to penetrate the countryside. An illustrated guide to the scenery of the Whitby-Pickering railway described how many rare plants, including the Osmunda regalis, grew within striking-distance of the stations. A species list was included in the guide (Belcher, 1836). Plants could be spotted from trains for as long as speeds permitted. Two years after the Liverpool to Bolton line was opened, Christy (1833) recorded how he saw 'a patch of the white-flowered variety of Trefolium pratense, and on Chat Moss abundance of Osmunda regalis'.

Some naturalists were particularly interested in the way in which plants, characteristic of disturbed sites, invaded the earthworks of the railways for a few years. In his Botany of the Eastern Borders, Johnston (1853) described how the field poppy Papaver rhoeas, cornflower Centaurea cyanus, and toadflax Linaria vulgaris invaded the Berwick-Cockburnspath and Tweedsmouth-Kelso lines. The sides of the 'cut were, in many places, literally clothed with scarlet; and this was especially the case where the line had been cut through these gravel knolls' left by the glaciers. Johnston was particularly impressed by the way the London rocket Sisymbrium irio (Atlas of British Flora : S irio recorded before 1930; S. orientale after 1930), previously confined to the Ness-gate in Berwick upon Tweed, suddenly appeared in abundance on the station embankment, when completed in 1847. Two years later, only a few specimens remained and, in 1851, not one could be found.

The Flora of Halifax, compiled between 1895 and 1904, stressed the way in which a railway bank 'not only furnishes an interesting object lesson in the succession of plants that occupy it for some years after it has been made, but also offers a permanent home of a peculiar character, exactly adapted to the

Table 1. Species recorded on the railway embankment at Wyke, Halifax, in 1900. Those which also occurred at Hipperholme are distinguished by an asterisk.

1. Abundant or dominant species

* Hieracium boreale (probably H. perpropinquum)
* Lotus corniculatus
* Plantago lanceolata
* Poa pratensis
* Festuca longifolia (probably F. ovina)

Deschampsia flexuosa
Trisetum flavescens

2. Fairly common, or frequent

Solidago virgaurea
* Teucrium scorodonia

Galium saxatila
Scilla festalis

* Dactylis glomerata
* Trifolium pratensa

Trifolium medium
Trifolium repens

3. Patches

* Leucanthemum vulgare
* Hypochoeris radicata

Lathyrus pratensis

4. Rare

* Cerastium fontanum sp triviale
* Anthriscus sylvestris
* Ranunculus acris
* Rumex acetosa
* Holcus lanatus
* Centaurea nigra

5. Under the boundary wall

* Salix caprea

Stachys sylvatica
Ephilobium angustifolium

* Ephilobium montanum

Moehringia trinervia

requirements of those that eventually win the day' (Crump & Crossland, 1904). It will shelter plants which are rare elsewhere, and allow others perhaps to spread in a way that would be impossible on other types of land. The Flora noted that the vegetation on the older embankments had reached a stage of equilibrium and had become similar to that of the surrounding countryside. The main differences arose from the fact that old, undisturbed pastures were distinctive for their variety and number of species whereas the older embankments 'exhibited the supremacy of a few'. The grasses were mainly Deschampsia flexuosa and Holcus mollis; the hawkweed Hieracium boreale (probably H. perpropinquum) was particularly abundant; willow, broom, brambles, wood-sage and Heracleum were conspicuous.

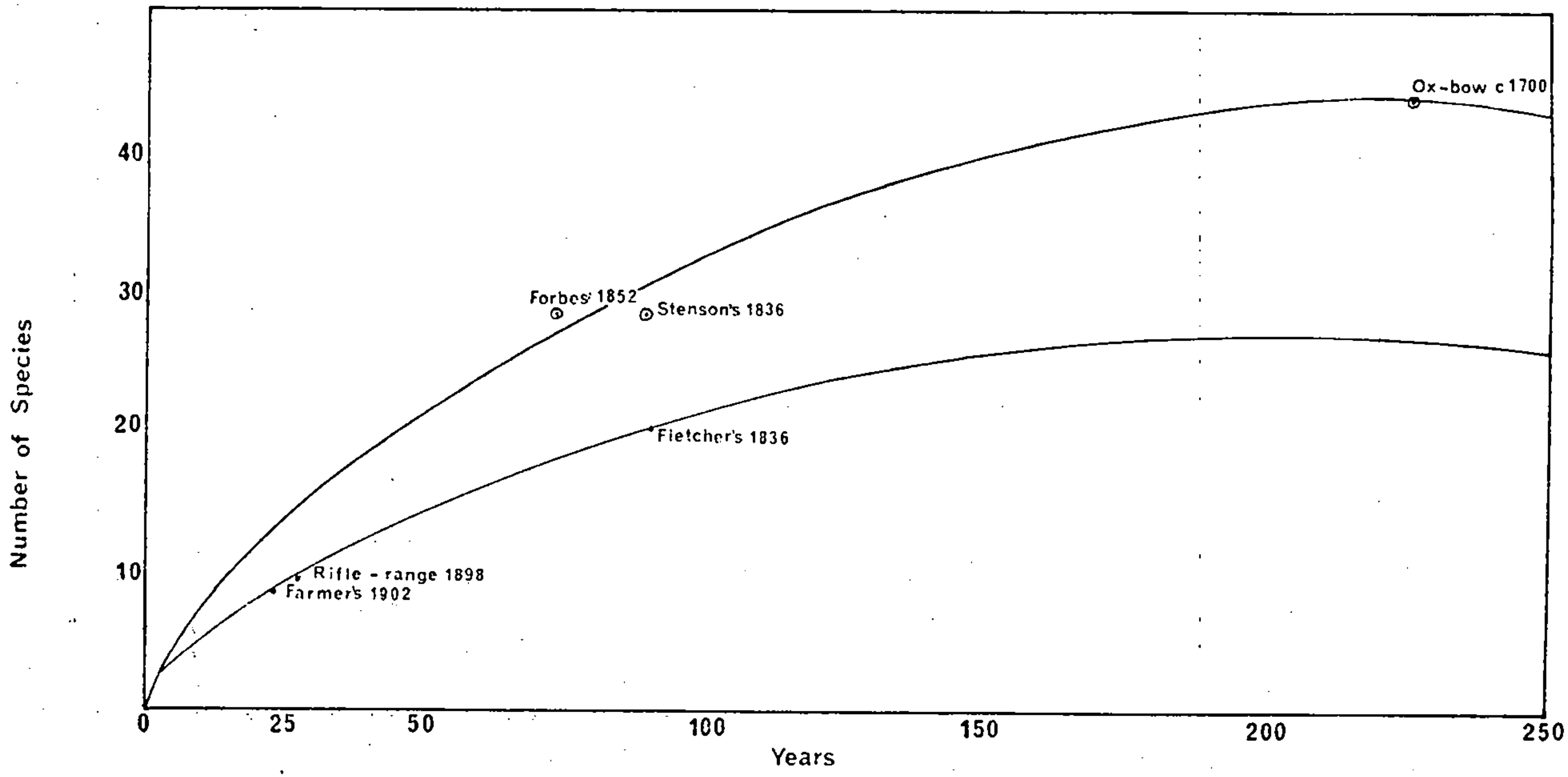
The Flora illustrated the earlier stages of plant succession on embankments by comparing an example adjoining Wyke station (made 'a number of years' previously) with 'a level stretch of newly made embankment mostly formed within the last year or two for sidings at Hipperholme station'. W.H. Crump and C.E. Moss recorded 30 species at Wyke (table 1); the prominence of 'the typical railway-bank hawkweed' and abundance of four grass species indicated that the evolution of the flora had 'clearly reached an advanced stage'. The presence of bluebells and a few other species reflected the fact that a woodland was nearby. The larger and newer embankment at Hipperholme contained 70 species, which could be divided into four groups.

In the first group, the most abundant were Linaria vulgaris and Tripleurospermum maritimum ssp inodorum. Hieracium vulgatum and Leucanthemum vulgare were most conspicuous on the slopes and older ground. Leontodon autumnalis, Tussilago and Polygonum persicaria were prominent. At least five of the species would be unable to maintain their dominant position after one or two years. In the second group, the following were present in fair quantity and well distributed : eight common grasses, three clovers, two chickweeds, groundsel, Rumex acetosella, Plantago lanceolata, Epilobium montanum, charlock, Atriplex, Ranunculus repens and Cirsium arvense. In the third group of 'plants not generally distributed', there were patches or clumps of Convolvulus arvensis, Spergula arvensis, Rumex acetosa, Millfoil, Tansy, Timothy grass, Holcus lanatus and H. mollis, Aira caryophyllea, Rumex obtusifolius and R. acetosa, with Heracleum, Plantago major, Capsella, Ranunculus acris, Teucrium scorodonia (on the older ground only), Hieracium boreale (see above), Polygonum lapathifolium and Cirsium vulgare. The fourth group consisted of plants which occurred only singly or in very small numbers. These included a young willow (S. caprea), figwort, dandelion, groundsel, sowthistle, Centaurea nigra, Hypochaeris radicata, Achillea ptarnica, Polygonum convolvulus, Melilotus altissima, Lotus corniculatus, Silene vulgaris, Vaccaria pyramidata, Stachys sylvatica, Rumex crispus, Alopecurus myosuroides, Catapodium rigidum and Equisetum arvense. The authors of the Flora concluded that 'the number of species, the character of the dominant ones, the subordinate position of the grasses, though over a dozen were present, all illustrate the immaturity of the flora of this railway bank'. Although there were only a few seedlings of willow and a small specimen of furze, brambles and bracken were present at the foot of the slope.

Stimulated by the lectures of J.C. Willis on 'Age and area', Godwin (1923) studied the extremely varied pond floras of seven pits in the Trent Valley of Nottinghamshire. Willis had postulated that plant distribution was an extremely slow process and one greatly retarded by even small barriers. Godwin found that an ox-bow lake, formed about 1700, contained 44 species, whereas there were between 20 and 30 species in three borrow-pits created during the construction of the railways in the mid-nineteenth century. Two ponds formed at the turn of the present century had only 10 species. The relationship between their age and species numbers is shown in figure 3 : those ponds where dispersal was facilitated by the presence of streams occur on the steeper curve.

In assessing the potential for colonisation, account has to be taken of the changing environs of the railway banks and cuttings, as described by numerous writers. After the extension of the railway to Harrow in 1878, McDermott (1887) described how 'a large number of villas sprung up where formerly the cattle grazed, and hamlets have increased to fair-sized towns, whilst Harrow has become practically a suburb of London'. Soon after the railway across Chat Moss was built, increasingly extensive areas were drained. 'Green lines of young plantations marked the boundaries between successful cultivation and primitive desolation' (Roscoe, 1839). By 1867, the entire area was under cultivation and 'all appearance of a moss or morass had disappeared' (Neele, 1904).

Fig 3.



Number of Species
40
30
20
10
0
25
50
100
150
200
250
Years
Ox-bow c 1700
Forbes' 1852
Stenson's 1836
Fletcher's 1836
Rifle - range 1898
Farmer's 1902

## Manuscript references

1 Public Record Office (PRO), RAIL 236, 266

2 PRO, RAIL 236, 525. Agreement as to widening between Hatfield and Digswell.

3 PRO, RAIL 384, 277

4 PRO, RAIL 535, 3

5 PRO, RAIL 1008, 97

6 PRO, RAIL 384, 185

## Figures

1. The profile of the London-Crewe line.
2. The profile of the London-Sheffield line.
3. The relationship between the age and species numbers of seven ponds in the Trent Valley.

## Table

1. Species recorded on the railway embankment at Wyke, Halifax, in 1900.

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