TREE PLANTING ON MAN-MADE SITES IN WALES

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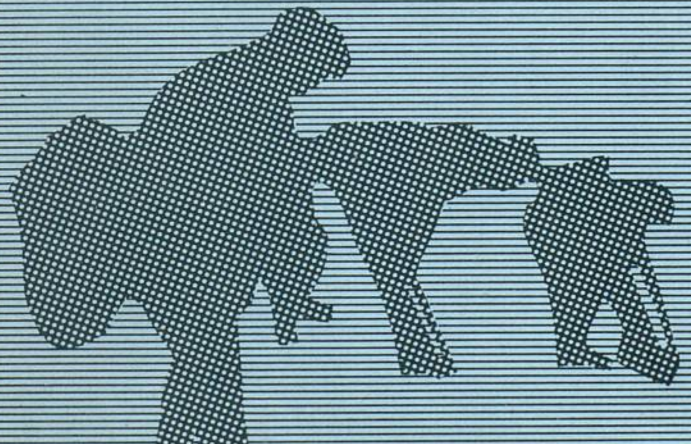

Forestry Commission 1979

OCCASIONAL PAPER 3

TREE PLANTING

ON MAN-MADE SITES IN WALES

by K.F. Broad
Forestry Commission

Introduction by J.W.L. Zehetmayr
Senior Officer for Wales, Forestry Commission

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FOREWORD

This paper is the record of thirty years work on planting in Wales, carried out by the Forestry Commission outwith its main remit for growing timber. Most of the reclamation of derelict land or tips and much of the planting has been financed by Government Agencies or Local Authorities and much of the resulting plantation has been or will be incorporated into the Commission's Forests.

The initiative for this paper came from a review for the Prince of Wales' Committee, the objective of which is to conserve and enhance the Welsh environment, both rural and urban.

A general summary prepared by J.W.L. Zehetmayr (Senior Officer for Wales, Forestry Commission) served as the basis for a detailed study by K.F. Broad (Research and Development Division, Forestry Commission, in 1974-75, which forms the main text.

It seems likely that the Forestry Commission will continue with such work for many years, particularly in South Wales, given the continued drive to clear dereliction and at the same time to step up opencast working.

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INTRODUCTION

by J.W.L. Zehetmayr
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The landscape of Wales is changing in many ways at the present time, a process that has gone on continually since the end of the ice age but which has been accelerated by man in the last two millenia. The most radical change for the worse has undoubtedly been due to the Industrial Revolution, which in Wales began over two hundred years ago, leaving a legacy of spoil heaps, old quarries and abandoned workings, pitheads and railyards. Possibly the urban spread of the present century has equalled this change in overall impact but most of the artifacts of this period are still in use, and the developments of recent decades have at least been ameliorated by planning conditions.

The restoration of worked-out sites was slow to start in Wales owing to the intractable nature of the terrain and the massive scale of the problem, but soon after the war the planned restoration of opencast coal sites was begun *(Opencast Coal Act 1951)*, followed by grants for restoration of sites for industrial use in certain areas *(Local Employment Act 1960)*. The Lower Swansea Valley Project, begun in 1961, marked a major step forward with comprehensive work on restoring the worst area of dereliction in Britain; this work will not be completed until the '80s (Hilton 1967).

After the tragedy of the Aberfan tip slide of 1966, the work was extended to restoration of sites as a general policy not necessarily linked with development. The Derelict Land Unit set up by the Welsh Office at that time, gave grants of 85-95 per cent to Local Authorities; in 1976 this work was taken over by the Welsh Development Agency whose Reclamation Division gives 100 per cent grants to Local or other authorities among which is included the Forestry Commission. A recent summary of the position has been made in a report on *Derelict Land in Wales* (Welsh Council 1976).

The Commission's first experience of derelict land was in planting old tips and spoil heaps, often small and grassed over, but sometimes bare, which lay within areas acquired for forestry. The earliest work on any scale, however, was in replanting areas of forest which had been opencast mined during or soon after the war; this work was extended in the late '50s to opencast areas adjacent to the forest. On these sites, where the soil structure and normal water regime have been destroyed, afforestation has advantages over agriculture because trees are less demanding and have deeper rooting systems than herbs or grasses.

With the steadily increasing size of the Commission's estate within the coalfield and industrial area of South Wales, advice and assistance was requested by many other agencies and over the last 20 years a great variety of sites outside the forest have been planted for a variety of Government departments, local authorities and nationalised industries. Whether they are on derelict land, industrial areas or alongside motorways, almost all the sites have in common the disruption of the natural soil and rock formations, with in many cases the addition of industrial waste. The variation is from the massive disruption of natural materials as in opencast mining to the entirely artificial substratum of smelter waste or domestic refuse. This and loss of the soil, and disruption of natural drainage, often combined with high rainfall, means the sites are generally infertile and, in addition, the metallic waste may lead to toxicity.

The particular importance of the Commission's role in industrial South Wales is, in part, due to the virtual complete absence of private woodlands and thus of contractors in forest work; in part, to their knowledge of the problems of the area, notably of uncontrolled sheep grazing and fire; and to the substantial forest presence in the area - 25,000 hectares of plantation - which enabled the Commission to protect and manage the young plantations established for other owners as if they were part of the national forests.

The purpose of this booklet is to record for this wide range of sites the methods used, the successes and the failures of these plantings, the objectives of which have varied from timber production to pure landscape planting. It is intended for the guidance of those who may wish to plant on comparable sites and also to record the site factors, history, treatments and early growth while these are to a large extent ascertainable from such written records as exist; from the memories of the foresters involved; and by the survey of their condition during 1974-5.

COAL INDUSTRY SITES

The history of the Forestry Commission in South Wales since 1919 is inextricably bound up with that of the coal industry and, while the Conspectus of Site Types (Table 1) shows a wide variety of influences and edaphic factors, the greatest area and involvement is in coal industry sites.

The dissected plateau of the South Wales Valleys encompasses only a limited amount of moderately fertile low-lying land within a large area of upland; wet, exposed, and relatively infertile. As the coal workings and related industry, towns, railways and roads filled the valley bottoms and crept up their sides during the 19th Century so agriculture retreated to the higher land. Coal Companies to a large extent owned the land and tenanted farms existed on sufferance, liable to be undermined or tipped on almost at will.

Farming became entirely pastoral and in places the hill grazings virtually became ranches as fences, hedges and walls fell into decay. Such areas were thus eminently suitable for purchase by the State for afforestation, a move begun in 1919 after the timber shortage of World War I and the formation of the Forestry Commission.

Development in the first 15 years was slow owing to lack of knowledge of how to plant on such rigorous sites and to loss by fire, consequent on the large population near to whom the forests were being planted - a situation rare in Britain although not unique.

From 1936 there was a substantial increase in the rate of acquisition to provide work for the unemployed on planting and road building, and during the next decade the first plantings were made on small tips and mine sites as they were encountered. Since then there have been several stages of increasing involvement, thus the planting of major spoil tips *in situ* was undertaken as a deliberate facelift operation, sometimes sponsored by local authorities. The outstanding example is the 50 acre tip at Bargoed, Gwent, planted in 1960 - see Plate 1.

A much greater area is involved in the planting of worked out opencast coal sites from about 1958 onward as an alternative to restoration to agriculture. Afforestation is cheaper since replacement of top soil, while desirable, is not essential, and restoration to forest is in fact largely confined to the poorer sites where the top soil was thin and relatively infertile.

TABLE 1

Conspectus of Landscaping with Forest Trees on Man-Made Sites in Wales

Site type	*Extent of site type and planting*	*Examples* *OS Grid Ref No: area(ac) and earliest planting year*	*Notes* *FC = Forestry Commission* *NCB = National Coal Board*
COAL INDUSTRY SITES			
Coal tips *in situ*	2-300 acres in all; a few large sites but mainly small old tips. Planting approx. 1940-65. Mainly Corsican/Lodgepole pines, some Japanese larch.	Bargoed Tip; Gwent ST/155 955; 50 ac 1960. Cwm Parc, Rhondda, Mid Glam SS/955 960; 24 ac 1963.	Mainly within forests. Bargoed part financed by Local Authorities.
Coal tips spread	Over 200 acres potential. Areas where coal recovery is underway will probably come in.	Mynydd Ty Isaf Rhondda SS/922 978; 22 ac 1973. Dare Valley Country Park SO/975 027; 25 ac 1973.	Regrading financed by Welsh Office/Welsh Development Agency.
Opencast coal sites	c. 2500 acres in S. Wales planted with a potential of 2000 more, mainly in substantial sites, many still to be completed. Planted from 1950 onward. Mainly Lodgepole pine with some Corsican pine and Japanese larch.	Varteg Hill, Crynant, W.Glam. SN/785 075; 100 ac 1959. (early site, minimum restoration) Cefn South, Cefn Cribbwr, Mid Glam. SS/860 835; 70 ac 1968. (Restored to current specification - part re-opencast).	About 1200 acres is FC land and the remainder NCB, much of which will eventually be acquired by FC. Planting financed by NCB under restoration conditions.
INDUSTRIAL SITES			
Degraded by airborne mineral pollution.	c. 500-1000 acres in vicinity of smelters now closed. Readily planted with Lodgepole pine.	Foel Fynyddau (Copper Mountain), Cwmafan, W.Glam SS/783 936; 150 ac 1962. Kilvey Hill, Swansea SS/670 947; 160 ac 1970.	FC areas. Swansea City contributed to planting at Kilvey.

TABLE 1 continued...

Site types	*Extent of site type and planting*	*Examples OS Grid Ref No: area(ac) and earliest planting year*	*Notes FC = Forestry Commission NCB = National Coal Board*
INDUSTRIAL SITES ctd..			
Lower Swansea Valley Project including:- Spoil heaps with heavy metals and industrial waste-lands of many types.	c. 150 acres planted within the project area including a number of large and several small sites. A wide variety of species used.	SS/67 96; 1963.	Financed by the Project Team and later by Swansea City. FC as agent for larger plantings.
Industrial screens	Screening by plantation rather than individual or lines of trees.	Hirwaun Industrial Estate. SN/935 062; 14 ac 1960, giving a half mile screen.	Financed by Industry concerned. FC as agent.
		Llanwern Steelworks, Gwent. ST/360 873; 80 ac 1968, 3 mile screen.	
Fly Ash, ex Central Electricity Generating Board	Experimental plots with several species. Only alder and broom successful.	Connah's Quay, Clwyd.	CEGB Research Report 1/70.
Slate and quarry waste	c. 100 acres, partial planting combined with screening from untouched land, mainly pines and Japanese larch.	Dyfi Corris, Gwynedd. SN/750 080; 20 ac 1958.	Either on FC estate or planted for owner on a repayment basis.
M-WAY & TRUNK ROADS	Major planting over considerable lengths.	M4 Newport to Chepstow 1964. 18 miles: 78,000 trees, 24,000 shrubs.	Financed by Welsh Office: FC as agent for planting and management.
	Wide variety of species used as specified by Department of the Environment.	A449/A40 Newport to Monmouth 1969. 22 miles: 72,000 trees, 29,000 shrubs.	

The most recent development has been the planting of tips and their sites after regrading or removal. The possibility of major engineering work prior to planting only emerged after the Derelict Land Unit started work in 1966 and the scope for grant aid was widened to facelift operations rather than purely those for safety, industry or housing. With the backing of the Local Authorities, the Forestry Commission graded and planted a number of tips on forest land using its own engineering and forest staff. Since 1976 it has been possible for the Welsh Development Agency to grant aid the Commission directly to undertake such work, and more comprehensive schemes have been put in hand, linked not only to forest planting but to landscaping and recreational development.

There was close cooperation between the National Coal Board and the Forestry Commission from the beginning. At an early stage there was an agreement between the Chairmen, then respectively Lord Robens and Lord Radnor, that the NCB would make available to the Commission surplus poor grazing for planting, while the Commission would undertake planting on restored opencast on behalf of the NCB as part of the restoration required by the Act, and that subsequently the Commission would acquire the land where this fitted into the existing forest pattern. In contrast to the tips planted mainly for landscaping and amenity the opencast sites were regarded as primarily timber producing.

To facilitate the actual planting, a specification for restoration to forest was drawn up and has been gradually modified as the problems became apparent. The essentials may be briefly summarised in that it has been found relatively simple to establish trees provided three conditions are fulfilled:-

i) The site is protected from sheep and stock by fencing.

ii) The slopes must be stable after reshaping and grading - normally to a maximum gradient of 1 in 3.

iii) The surface compaction consequent on the use of heavy machinery for contour restoration and grading is relieved by ripping or ploughing to 0.5m depth; this ripping is across the contour so that runoff is never concentrated and erosion is minimised.

Certain of the early sites were restored to a lesser standard, eg by random tipping where loose material gives good growth, or without ripping where on compacted areas growth is poor. Unfortunately, the former gives quite unacceptable terrain both for landscaping and for subsequent skidding out of the timber, so that regrading, with the consequential compaction in turn necessitating ripping, is now universal.

It is worth noting that as the size of opencast sites and depth of working have increased, so it is the engineering rather than silvicultural problems covered in this paper that have been the subject of most difficulty and of much consultation. In the early years, the foresters concerned concentrated on the 90 per cent of restored or graded areas that could be planted by accepted forestry techniques, while the real problems arose in the unplantable areas of the high walls and of the drainage channels.

The elimination of the high walls is now the restoration policy of the NCB, though some will remain, while the rugged terrain and high rainfall of South Wales make the restoration of the drainage basins and the training of the streams a constant problem. Many of the features of opencast sites are present, although on a lesser scale, on the regraded tip sites. Thus drainage basins may be altered in extent and streams diverted. Also water courses in the restored ground have no solid base and may erode back, change course, flood and indeed behave as rivers must have done after the retreat of the ice exposed the glacial debris!

Many structures adequate for the coaling and restoration period are not acceptable as permanent forest artifacts, eg lagoons, dams, piped or culverted streams. The ideal is a restored land form compatible with local topography and a surface drainage system on an erosion resistant base with correct gradients and cross sections for the drainage basin involved. These are clearly Civil Engineering problems and must be left for resolution by the engineers of the NCB Opencast Executive.

OTHER SITE TYPES

While this major involvement with coal sites was developing in the '60s various other projects were afoot in South Wales, the most notable being the Lower Swansea Valley restoration plan sponsored by Swansea Borough Council, University College of South Wales, the Nuffield Foundation, the Welsh Office and the former Department of Scientific and Industrial Research.

Here the Commission planted on a repayment basis on a wide variety of industrial sites both semi-natural and restored and then went on to afforest Kilvey Hill, a notable landscape feature to the east of the city. The more sheltered landward side had been denuded of vegetation by fumes between 1770 and 1900, during the heavy metal smelting period of Swansea's history. The City Council leased the hill to the Commission and partly financed the planting to bring it into line with the Commission's commercial objectives. That such land could be planted had already been indicated by early growth on 'Copper Mountain' in Margam Forest behind Port Talbot, where a 900 ft chimney laid up the hill had belched out poisonous fumes in the last century.

Also in the '60s major forest screens were planted to soften the outline of an industrial estate at Hirwaun near Aberdare and of the Llanwern Steel Works near Newport, Gwent. Here sub-strata varied from concrete hut foundations to spoil heaps, with much compacted ground,as is inevitable in the vicinity of industry. In North Wales at this time slate and other quarry surrounds were planted to soften the raw quarry edges, though generally it was not practicable to plant the quarry itself.

The most recent enterprise, the 'Motorway' planting undertaken for the Welsh Office on 'M' and major trunk roads, has much in common with the other projects since topsoil is often lost in the process of construction of cuttings and embankments, while slag and other industrial waste may be used for infilling and severe compaction results from the passage of heavy machinery. In the last decade well over 50 miles have been planted to landscape the roads to Department of the Environment specifications; and it has been agreed that the Commission will continue to manage the trees and plantations after their establishment, when problems will inevitably emerge in that the trees are subservient to the main purpose of the roads and must not obscure sight lines, cast shade, or too much litter. It is to be hoped that here timber production can be a subsidiary, long term, goal in view of the large numbers of trees and considerable area involved.

With the widespread nature of these plantings outside the 'commercial' forest areas of the Commission, there arise questions quite apart from the technical matters which form the main part of this work. These are the extent to which considerations of conservation, landscaping, and timber production should determine the species composition and layout of the planting. Thus on trunk roads in open country it would appear that use of native species should predominate on grounds of both landscape and conservation. To some extent they can compensate for loss of hedgerows and, like railway embankments, the 'M' way borders are becoming a recognised habit, epitomised by the well-known kestrel population. Conversely, there seems little point in attempting to establish 'native woodlands' on radically altered opencast areas or the compacted motorway interchanges; timber producing pines may both grow best and look well, with, over the country as a whole, a long term addition to our resources.

There is no doubt that on some of the industrial sites described, plantings were too much of a forest type with close spacing in pure crops. With small areas, in varied ownerships, subsequent tending and thinning is likely to be neglected with risk of windthrow. Here wider and more irregular planting would have been preferable, but there are also risks. Leaving areas bare to grass over within the plantation fences would inevitably attract sheep, a major cause of damage to plantations in industrial South Wales. On the poorest sites at high elevation, on compacted ground difficult to alleviate, or on areas where timber recovery is unlikely there is a case for planting to produce scrub, using willows, birch and alder to give a more varied wildlife habitat than the rough grassland that is so often the end point of reclamation work.

Finally, a word on the social implications of planting. There are examples in industrial areas where there is nothing to show today for considerable sums spent on tree planting, due to neglect after the first year or so, to vandalism and, most important, to browsing by stock, mainly sheep and ponies.

The Commission's work has rarely extended into the separate realm of tree planting in towns but often the plantings described, along with many normal forest areas, back on to the linear settlements of the valleys. In general, the planting on man-made sites have suffered less than other forest areas, probably because the lack of ground vegetation both slows fires and does not offer the same attraction to sheep.

Often it is suggested that 'instant trees' are the solution and it is worth making the point here that all the Commission's experience supports the use on these difficult sites of forest type trees - up to 50 cm - with planting areas, even though small, fenced as a whole. The alternative, so often attempted, of using larger standard or semi-mature trees with individual guards, generally gives much less satisfactory results, and is also very expensive.

As plantings extend further into urban areas, as do some of the areas planted by the Commission but not within its estate, the need for special protective measures arises. The outstanding success story in Wales is in the Lower Swansea Valley where the voluntary effort of youth groups has been led by a succession of young 'conservators' and for 15 years have successfully wardened an urban forest that is probably unique in Britain.

At a time when there is considerable public concern about the loss of tree cover, the work reported in this paper shows an approach to the problem that has been largely successful and could, with certain changes of emphasis, help considerably in restoration or, where necessary, in the creation of new landscapes.

Chapter 1

METHODS OF SURVEY

Assessments were made of the growth rates of the most commonly planted species, together with observations on site conditions and treatments. On occasion some less frequently used species proved worthy of inclusion.

Throughout the survey, General Yield Class has been used as the measure of crop performance (Hamilton and Christie, 1971). General Yield Class is obtained by measuring top height and age and referring to the top height/age curves for that species. Top height is defined as the mean height of the 100 trees of largest diameter (at breast height) per hectare. In practice, in any even-aged stand at least five trees are measured. The age of the stand is defined as the number of growing seasons since planting. Yield Class is the maximum value of the quotient total production/age, in m^3 per hectare per year.

In this survey, Yield Class (YC) is used to compare the growth rate of different species on similar sites, with the object of determining the most successful species from a timber production point of view. Yield Classes are by convention defined at intervals of two cubic metres but for greater precision it was decided to recognise intervals of one cubic metre (thus the difference between YC9 and 13 is 'two Yield Classes').

It is appreciated that maximum timber production is not necessarily a primary object of management and indeed it may be a consideration of little or no consequence. Nevertheless, Yield Class is a useful guide to the future choice of species when used in conjunction with subjective appraisals of health and vigour.

In the larger blocks of trees, such as those of opencast workings, 1/100th hectare sample plots were selected for Yield Class assessment. A series of points, to give the desired number of sample trees, was located at random through the stand. The tree of largest breast height diameter within a radius of 5.6m from each point was found and these trees were used to estimate top height. Each species and each age category was separately assessed.

Where groups of trees were small and irregular, such as frequently occurred on roadside planting schemes, an individual group of trees, regardless of size, was treated as a potential sample unit from which the five trees of largest diameter could be chosen. In mixtures, five of each species were selected. **It must be stressed that many of the crops inspected during this survey were considered to be rather young for a forecast of Yield Class.**

The crop assessment data were noted on record cards together with details of crop health, survival rate, planting distance and silvicultural treatments. Altitude, aspect, topex (a measure of exposure based on angles measured to the horizon), slope, soil type, vegetation and method of ground preparation were similarly recorded.

A number of opencast sites were selected for a more detailed study involving the assessment of soil pH (degree of acidity or alkalinity) and the determination of nitrogen, phosphorous and potassium levels in samples of the needles. Records were scanty for ground not acquired by the Forestry Commission. Where failures had been replaced with the same species, possibly over several seasons, the accurate determination of crop age and the survival rate of the original crop was difficult. In the absence of written evidence age was estimated from whorl counts and survival rates were subjectively classed as high, moderate or low.

As an alternative forecast of growth - important from the landscaping angle - estimates have been made in appropriate places in the text and tables of the expected top height of crops at 25 and 50 years. It should be noted that the tallest crops are not necessarily those of highest timber yield; Japanese larch (a light-demanding tree), 25 years old and YC10 has a top height of 14 m, while Sitka spruce (a shade bearer) at the same age and yield class would have a top height of only 9 m.

Table 2 presents, against a range of Yield Classes, the forecast approximate top heights at 25 and 50 years of those species commonly planted on man-made sites.

TABLE 2

Forecast Top Heights at 25 Years (and 50 Years) in Metres

Yield Class	*Scots pine*	*Corsican pine*	*Lodgepole pine*	*Japanese larch*	*Sitka spruce*	*Beech*	*Sycamore Ash Birch*
4	4(11)	5(11)	6(12)	8(14)	4(11)	5(12)	11(16)
6	6(14)	7(13)	8(15)	11(17)	6(14)	9(17)	13(18)
8	8(16)	8(16)	10(18)	13(20)	7(16)	12(21)	15(20)
10	10(18)	10(18)	12(21)	14(22)	9(18)	14(24)	16(22)
12	12(20)	11(20)	13(24)	16(24)	10(21)	-	17(24)
14	13(22)	12(22)	15(26)	17(27)	11(23)	-	-

Chapter 2

OPENCAST COAL SITES

Origins and Characteristics

The mining of coal by the opencast method developed during the war years (1939-45) and soon became established as a profitable alternative under suitable conditions to orthodox deep mining.

Those opencast coal sites planted by the Forestry Commission after workings are on the outcrops which fringe the South Wales Coalfield. The majority exploit the seams of the Lower Coal Series, the shales of which are relatively soft and easily eroded.

The depth at which opencasting becomes uneconomic is determined by the ratio of overburden to coal. The current norm is 25-30 cu. yds of overburden to one ton of coal, and the practical limit is reached at the present time at a maximum depth of around 500 ft. Mining to these depths involves the disturbance of vast quantities of overburden shales and sandstones, quite apart from sub- and topsoils.

The earliest sites were accepted for afforestation in the unaltered 'hill and dale' condition and were planted with the minimum of ground preparation. The overburden, dumped in irregular heaps by excavators, draglines and lorries created a micro-topography which provided ample shelter, good drainage and a loose substrate which was easily planted and which permitted satisfactory root development. The main drawback was the difficulty in establishing tree crops on the steeper, unstable slopes and the problems inherent in the future working of timber on such uneven ground.

More stringent specifications for restoration have been introduced over the years in order to create stable, low gradient surfaces that are easier for forest operations and which fit more readily into the general landscape. If a site is to be restored for agriculture the topsoil is replaced; but forestry normally has to make do with the other overburden materials and topsoil is rarely used.

The most widespread material on the restored surfaces is shale which generally disintegrates rapidly under the influence of sun, rain, frost, wind and the action of roots of colonising plants. Often within a few years a heavy clay loam is formed in which the fine-textured materials are largely impervious to rain so that waterlogging and ponding of depressions may take place during wet periods. Due, however, to the material being derived from many different depths, variations in structure, fertility and moisture-retention occur which, if combined with further variations in topography and compaction, can result in an extremely heterogeneous surface. With the passage of time, different rates of weathering and 'soil' formation lead to even more diverse conditions. Sometimes superficial differences are easily discernible, colour changes and textural variations marking the transition from shales to sandstones, subsoils or topsoils; at other times no obvious differences exist, yet ground vegetation or tree growth vary greatly.

Vegetation

The rate of natural colonisation is apt to be slow and restored sites may be devoid of vegetation for many years, especially in those areas of pure shale, but if top- and subsoils happen to be on the surface colonisation is usually more rapid. In the absence of competition, some lichen species *(Cladonia, Peltigera* and *Parmelia* spp.) will readily grow on pure shale and mosses are not uncommon. The most frequently encountered grasses are *Deschampsia flexuosa, Holcus lanatus, Festuca* spp. and *Agrostis* spp., the distribution of which is generally sparse, and indeed often negligible on steeper slopes. More level areas and hollows will occasionally foster a relatively dense growth of vegetation. Broom, gorse, rushes, thistle, bracken, bramble, heather, bilberry, ragwort, plantain, coltsfoot, yarrow, clover, creeping buttercup, willowherb and hawkweed are common, and the more usual woody plants are birch, alder, willow and rowan.

Methods of Establishment

In the early post-war period sites handed over for planting in the 'hill and dale' condition received little in the way of ground preparation. Visual evidence on the survey suggested that except on small areas where topsoil has been restored, wood growth had not been vigorous; even on older sites colonisation was still usually sparse and the dissected topography discouraged any attempt at ploughing. Plant spacing was sometimes closer than usual - 4 ft x 4 ft was adopted in places in order to achieve a quick cover. Phosphatic fertilisers were used on some sites at time of planting, but whether or not this was a general practice is not known. Losses were often higher than on conventional soils and trees often died on the steep unstable slopes.

The introduction of specifications requiring the slopes to relate to the surrounding topography produced new difficulties. One of the main problems is exposure. Coastal South Wales is known to be a region of high wind speeds and frequent gales (Mayhead, Broad and Marsh 1974) and the increase in exposure consequent on the grading of the 'hill and dale' to more gentle slopes slows down tree growth, leads to poor tree form and limits the number of species able to flourish. The lower stems are often abraded by the stones and in extreme cases may be severed at ground level.

Another widespread problem on re-contoured sites is ground compaction. On 'hill and dale' sites heavy machinery used to replace the overburden compacted only the roadways, terraces and other working surfaces, but on the re-contoured areas their scouring-off and filling-in activities involved the crossing and recrossing of the whole terrain creating widespread compaction often many feet deep. To alleviate this compaction the ground must be ploughed or 'ripped' before planting and the trend is to very deep ploughing to maximise ground disturbance. The direction of ploughing is important. Contour ploughing has proved unsatisfactory - furrows tend to waterlog and overflow in wet periods leading to gulley erosion. Ploughing up and down the slope gives far better regulation of water movement. Other points of technique are that phosphatic fertiliser was generally applied around the base of each plant, while the planting position whether in the furrow, on top of the mound or at a midway point varied from forest to forest. Weeding has been necessary only on the most fertile materials - on pure shales it is never required.

Choice of Species

One of the earliest 'hill and dale' sites to be planted by the Forestry Commission - Aberpergwm, in the Vale of Neath - was used for a trial of 17 species in 1954. Unfortunately this site was lost to further opencasting to greater depth, but a report in 1959 gave important indications of the species most likely to flourish on sites such as these.

The species used, the percentage deaths at the end of the first season and the total heights at the end of six growing seasons are after White (1959) and are summarised in Table 3.

TABLE 3

OPENCAST SITES - CHOICE OF SPECIES

ABERPERGWM SPECIES TRIAL
RHEOLA FOREST SM 86 07

Species	*Deaths at end of 1st season (per cent)*	*Estimated top height after six growing seasons (metres)*		*Remarks*
		Good sites (Mostly slopes)	*Poor sites (Mostly flats)*	
Scots pine	25	1.1	0.8	Mainly on flats
Corsican pine	42	1.4	1.0	High initial mortality
Lodgepole pine	18	1.4	0.6	Producing cones
Japanese larch	6	2.0	0.9	Great variation in height
Norway spruce	3	-	0.5	-
Sitka spruce	8	1.2	0.5	-
Noble fir	29	0.5	-	-
Western hemlock	-	-	-	Vigour satisfactory
Red cedar	64	1.7	0.6	Few numbers
Lawson cypress	29	1.8	0.4	Few numbers
Red oak	25	0.8	0.4	-
Sycamore	-	-	-	Dying back
Birch	16	2.4	0.9	-
Black locust	28	Up to 6.0	Up to 0.9	Very successful but planted in well sheltered positions
Grey alder	13	Up to 6.0		
Alder	-	Up to 6.0	Up to 3.0	
Rowan	-	-	-	Dying back

The area was mined again after this assessment

Part of the Aberpergwm area was treated with potassic superphosphate at 2 ozs per plant but there could have been little noticeable difference between this area and untreated parts, for the report states that there appeared to be little need to apply artificial fertilisers or manure on such sites. Broom and lupin were used as soil improvers as their use seemed worthwhile.

Tree growth was always much poorer on level areas than it was on slopes.

The change from 'hill and dale' finishes to smooth slopes meant that the lessons of the earlier plantings and trials could no longer be applied. Many of the species that displayed good rates of growth in the well sheltered 'dales' stood little chance of success in the more exposed conditions. Lodgepole, Scots and Corsican pine have emerged as the most important species while larches, although in some places planted on pure shale, are generally used on the better sites where top- and subsoils lie at the surface and also boundaries where the shale surfaces intermix with the natural *in situ* soils. Spruces are seldom planted nowadays and broadleaved species are rare.

Results of Survey

Overall growth. There are 18 opencast sites in South Wales planted by the Forestry Commission, with a total area of about 820 ha (2020 acres) of which 16 were inspected during this survey. Table 4 sets out average Yield Classes of the main species used at each site. Many of the values are estimates of the 'average' site Yield Class because growth was so variable. A view of the Tirpentwys opencast site is shown in Plate 2 and of the Treforgan site in Plate 3.

TABLE 4

OPENCAST SITES - RESULTS OF SURVEY

				Estimated Average Yield Class			
Opencast site	*Grid reference*	*Forest responsible for planting and management*	*Range of approx. ages in 1975*	*Scots pine*	*Lodgepole pine*	*Corsican pine*	*Japanese & Hybrid larch*
Cefn South	SS860 835	Margam	6/7	6	8	7	6
Waun y Gilfach	SS850 885	Margam	11	6	6	10	
Tir Ergyd	SO010 050	St Gwynno	7		8		
Rhigos Complex	SN878 049	Rheola	9/11	6	5	10	3
Tirpentwys	SO240 020	Ebbw	11/7		8		
Treforgan	SN790 060	Crynant	16/14		8	10	
Gurnos	SN765 099	Crynant	10	7	6		6
Pengosto	SN715 137	Crynant	5		6		4
Abercrave	SN810 110	Crynant	8		6	8	6
Waunllwyd	SN865 125	Crynant	9/8		4		
Coedcaemawr	SN745 080	Crynant	13		6		6
Gorse Farm	SN550 110	Pembrey	5		6		
Pantyfelin	SN540 130	Pembrey	3			8	4
Pont Henry	SN476 097	Pembrey	10	6	6		7
Trimsaran	SN460 050	Pembrey	10		6		8
Cwmamman	SN666 128	Coed Abertawe	8		6		6
Average Yield Class				6	6	9	5

Note: The current, complex ownership of sites is not indicated, but the majority are still in NCB ownership or lease with the FC managing the plantations.

Relative growth. To estimate what the growth rate might have been had the site never been disturbed, the growth rate of trees on adjacent unworked areas was measured wherever possible. It was found that growth rates on the opencast ground were at least 2 Yield Classes (and sometimes as much as 7) below that on soils *in situ*. This implies only two-thirds or one half of the expected volume growth and, moreover, this difference is accentuated because the more valuable spruce generally planted on the natural soils has to give way to the less valuable pine on opencast sites. Table 5 sets out some of the measured differences.

TABLE 5

COMPARISON OF TREE GROWTH ON DISTURBED AND UNDISTURBED SUBSTRATES

	Species and Yield Classes			
Opencast site	*Crops on shale*		*Adjacent crops on undisturbed soils*	
Waun y Gilfach	Corsican pine	10	Sitka spruce	14
	Scots pine	6		
	Lodgepole pine	6		
Treforgan	Lodgepole pine	8	Sitka spruce	12
Rhigos	Lodgepole pine	5	Sitka spruce	14
			Lodgepole pine	14
Tirpentwys	Lodgepole pine	8	Lodgepole pine	14 *
Gurnos	Lodgepole pine	6	Sitka spruce	18
Waunllwyd	Lodgepole pine	4	Sitka spruce	16
Coedcaemawr	Lodgepole pine	6	Sitka spruce	16
Gorse Farm	Lodgepole pine	6	Sitka spruce	16
Trimsaran	Lodgepole pine	6	Sitka spruce	16
Mean		6		15

* On agriculturally restored soils

Variability of growth. The variability of height growth that can occur in even-aged crops, often within narrow spatial limits, has already been noted. It was most marked in Lodgepole pine crops - other species tended to be more uniform. A typical example was seen at Rhigos complex (Empire section) where, in a 10 year old Lodgepole pine crop on level ground, tree heights sharply increased from less than one to over five metres in a ground distance of half a dozen metres for no reason that was visually apparent.

This variability of height growth must, by deduction, be attributed to soil factors rather than those of climate or treatment. Once the slopes are restored to a reasonably uniform profile, then microclimate becomes less variable and ploughing and fertiliser treatments tend to be standard. Mycorrhizas were found on the roots of all pines sampled at a number of sites, regardless of age, and over a wide range of health and growth rates (H.C. Dawkins, priv.comm.). Variations in soil fertility and compaction are thought to be mainly responsible, for where compaction is known to be severe, eg along coal extraction routes or where restoration occurred in very wet periods, growth was invariably poor and conversely where top- or subsoils were seen to lie on the surface, above average growth was noted. It was not possible to carry out soil compaction tests.

All immature soils are deficient in nitrogen and analysis of foliar samples confirmed that the outstanding characteristic was the generally low nitrogen concentration. The sites with poorest growth rates had the lowest nitrogen concentrations and the actual level was correlated with growth. Trees growing in close proximity to spontaneous broom and gorse, two shrubs capable of fixing nitrogen directly from the atmosphere, often showed better growth and colour.

There was no evidence that potassium or phosphate levels were particularly low on the sites under investigation, but it should be noted that pines are known to be less liable to potassium deficiency than other genera.

Moisture deficiency is a factor that might be expected to limit tree growth on opencast areas, but while it is clearly important in the first few seasons after planting, when prolonged dry spells can cause high losses, there was little evidence from this survey that it was in any way responsible for the variations in growth in older crops. Up to July 1976 there seemed to have been little damage from the long drought of 1975/76.

Soil reaction (pH) is an important factor because trees do not grow well if the soil is alkaline or extremely acid. Newly disturbed sites tend to be neutral or slightly alkaline in reaction but with time there is a marked fall in pH of the surface material and most surface layers become distinctly acid after several decades. Of several sites sampled, only at one - Cefn South - was there a positive relationship between soil pH and Yield Class. On this site the best growth occurred where soils were most acid.

Recent Experimentation

Several nitrogen trial plots using urea were set out in spring 1975 on Corsican and Lodgepole pine, and Japanese and Hybrid larches of various ages. By the end of the second season most plots displayed a substantial increase in height growth and a marked colour improvement. Foliar analysis revealed a good uptake of nitrogen and a big increase in needle weight when compared with samples from the control plots.

At Pantyfelin an experiment was laid out in 1972 to investigate the response of Corsican pine transplants to several rates of nitrogen, potassium and phosphorous. After three seasons the nitrogen applications appeared to be the only ones inducing a marked increase in height growth. No plots received nitrogen only, but those that received element N at 150 kg/ha in addition to element P at 50 kg/ha and element K at 100 kg/ha produced an 11 cm increase in height over the plots with P and K alone in 3 yrs, and 32 cm in 6 yrs. The plots with N also developed a richer ground flora. Phosphate without nitrogen appeared to depress growth slightly.

Another experiment at Pantyfelin, set out in 1972 to investigate the response of Corsican pine, Lodgepole pine, Japanese larch and Sitka spruce to three intensities of cultivation, was assessed after three seasons growth. This showed that complete cultivation using a sickle plough giving a tine depth of 70-110 cm and a furrow depth of 50-90 cm was the most beneficial treatment, better than single furrow ploughing or large bulldozed ridges (riggs and furrs).

Unploughed or shallow ploughed areas that may benefit from deep cultivation can be treated some years after planting, provided the trees are not too tall. At Tir Ergyd a crawler tractor with deep tine equipment 'ripped' an area of Lodgepole pine and Japanese larch 1.5 - 2.0 m in height by straddling the rows so that the trees were pushed harmlessly beneath the tractor. This area will be monitored for any measurable benefits.

Trials of seedlings grown in Japanese Paper Pots planted out on areas of pure shale in a dry period of the summer of 1973, have given survival rates higher than could be expected with conventional planting stock. At Abercrave, Corsican pine seedlings in Paper Pots gave an 85 per cent survival rate and at Pantyfelin the same species gave an encouraging 96 per cent survival rate after the first season's growth.

Conclusions

The conclusions in this section may be summarised:-

1. Surface restoration work should, if possible, be stopped in bad weather conditions to prevent the increased consolidation of the ground that results.

2. It is essential to fence sites against sheep, and fence maintenance should be given high priority. The near feral sheep of the region are notorious for their depredations in towns and gardens and cause great damage to young forest crops.

3. As much ground as possible should be ploughed, rather than ripped, prior to planting. A minimum ploughing depth of 50 cm is already specified but even deeper ploughing is recommended if at all possible. However, recent developments in deep tining equipment, which can completely loosen the soil to depth, may give the best compromise between rapid early growth, slope stability, and convenience for management.

4. Plants should be lifted and planted within the shortest possible time. This is especially important with Corsican pine.

5. The recommended planting position on ploughed ground is midway between the top of the ridge and the bottom of the furrow.

6. Pines perform better than any other genus. Spruces should be avoided. Larches should not be planted on pure shale. More trials are needed with broadleaved trees for landscaping.

7. Lodgepole pine is the best species for high elevation sites and sites in severe exposure. It can display great variability, probably due to a capacity to react to slight physical and chemical variations in the soil. South coastal provenance may be best.

8. Corsican pine develops into a uniform crop of good form where exposure is not too severe. It has the greatest timber production potential and providing it is not planted above the limits of its range (c. 300 metres) there should be no danger of dieback. Because of its tender root system it needs careful handling in both the nursery and the planting stages.

9. Though compaction and, at one site pH, appears to account for some of the variations in tree growth the most important factor seems to be nutrient availability.

10. The most important nutrient deficiency is that of nitrogen. When the nitrogen trials have run their course it should be possible to make recommendations for the use of nitrogen fertilisers.

11. Tree growth is better -

    a) on slopes than on level ground;

    b) on replaced sub- and topsoils than on pure shale;

    c) on the 'hill and dale' type soils than in the more exposed conditions of recontoured sites.

12. The growth on opencast sites is at least 2 Yield Classes (4 cu m/ha/year) below the expected growth for the undisturbed site.

13. As a remedial treatment it has been possible in some cases to cultivate areas by ripping several years after planting.

Chapter 3

COLLIERY SPOIL HEAPS

Origins and Characteristics

With very few exceptions, colliery spoil heaps in Wales planted by the Forestry Commission are confined to the south of the country. They are derived from two basic types of mining technique:-

a) **Level or drift mining**, used extensively in the early days to exploit those seams which outcropped onto hillsides. Most of the resulting relatively small spoil heaps have benefited from weathering over many years and some had vegetation cover prior to planting.

b) **Deep mining**, involving the sinking of vertical colliery shafts to exploit the seams of the Lower Coal Series and the Pennant Series. It accounts for many large spoil heaps on valley floors, hillsides and also on the mountain plateaux between the valleys. The most important seams occur in the Lower Coal Series (the shale spoils of which are generally soft or only moderately hard) and the Pennant Series (which produce a range of shales from soft argillaceous to hard micaceous). The former are extensively worked in both the eastern and western parts of the coalfield, while the latter are of importance chiefly in the western part.

The most rapid weathering occurs at the surface of the spoil heap, so that shale fragments tend to increase in size with distance from the surface. Softer shales break down into small flakes within a few years while others may take considerably longer.

The type of soil that develops varies according to the texture and amount of carbonaceous material that happens to be present. Spoil heap soils may be divided into:-

a) Clays and clay loams. These are the most common types.

b) Sandy loams. Occur only occasionally, mainly on the western side of the coalfield.

c) Loams with high proportion of coal. These soils are found on old spoil heaps throughout the coalfield. They are light, black and porous.

On the very exposed steep slopes, which are mainly bare of vegetation, the surface layer of weathered material is kept shallow by erosion, much of the finer material being washed down or blown away as soon as it is formed.

Topography

The shape of the spoil heap depends to a large extent on the type of machinery used for tipping. The following general shapes are recognised:-

a)	Terrace:	generally small mounds on hillsides, derived from drift mining.
b)	Aerial Flight:	generally large, long mounds with numerous peaks, derived from deep mining operations.
c)	Conical:	generally large mounds derived from deep mining operations - (a 'MacLane' tip is a specific asymetric type).

Until recent times few attempts were made to soften the outlines of spoil heaps prior to planting. In some cases the top or even the whole tip proved unstable and the steeper and higher portions were either not planted or failed through erosion throwing out the plants. Since about 1970 it has become feasible to recontour the tip so that topographically it more nearly relates to the local terrain. Up to the time of this survey only three such re-shaped tips had been planted.

Vegetation

The period required for the establishment of natural vegetation varies with the conditions prevailing at the site. According to Etherington (unpublished) the physical patterns which limit plant establishment are high surface temperatures, lack of fine particles on the surface, instability, and drought. The limiting chemical factors are nutrition, acidity, aluminium toxicity on older surfaces, sulphate acidity, and absence of soil organic matter.

Unstable surfaces retard the establishment of natural vegetation and the steep sides of some tips and also those in exposed places may remain uncolonised for years. Once vegetation becomes established, and this is to some extent dependant on the proximity of sources of seed, it helps to stabilise the surface. Roots bind together to prevent further disintegration, increase porosity, and improve the moisture holding capacity. They also add to the organic matter content and hence increase fertility. The roots of trees, whether natural or planted, further aid the stabilisation processes while the deposition of needle or leaf litter protects the surface against rain, drought and insolation. The plant communities that develop are similar to those of opencast sites.

Methods of Establishment

Most of the spoil heaps planted by the Forestry Commission from about 1939 onward were old and small and were planted as they stood in the course of normal forest operations without any special treatment. Apart from the difficulty of getting trees established on some of the steep unstable slopes no major establishment problem seems to have existed. The newly exposed surfaces of the re-shaped tips of more recent times are, unfortunately, less easily managed. The heavy earth moving machinery employed on the regrading operations compacts the upper layers of the tip which, if trees are to be successfully grown, require cultivation prior to planting. The benefits of years of weathering are lost and surfaces composed of fine particles which have slowly acidified over the years are replaced with coarser grained materials of neutral or slightly alkaline reaction. Furthermore, the shelter once afforded by irregular features, hollows and leeward slopes, is much reduced by the levelling operation and the completed re-shaped tip invariably occupies a more extensive surface area with, on average, greater exposure. Therefore, both above and below ground the newly planted trees have to content with a more exacting environment.

Crops are mainly pines; larches were seen less frequently, while spruces and broadleaved species were only rarely encountered. Fertilisers do not appear to have been used to any great extent.

Results of Survey

The many examples of good growth to be found on colliery spoil heaps indicate that weathered pit waste as such is a suitable medium for tree planting. Spoil material which is actually toxic seemed to be very rare. Some two thirds of the spoil heaps in South Wales planted by the Forestry Commission were inspected during the survey.

Such obvious differences exist in those tips planted *in situ* and those planted after re-shaping that they are discussed here separately.

a) **Tips planted** ***in situ*****.** This is the larger of the two categories with some 50 tips occupying a total planted area of about 100 hectares (250 acres). With only three exceptions the tips visited were planted with one or more of the following species:

   SCOTS PINE. Yield Classes ranged from 6 to 12, with an average of 9. Exposure was the greatest factor controlling its development and form was good only on the most sheltered sites, though health and colour of foliage tended to be good throughout.

   CORSICAN PINE. The most widely planted and the most successful tree. With Yield Classes from 8 to 14 it was found to be growing well, even at an elevation of 270m. The average Yield Class was 12, health and colour of foliage were almost invariably satisfactory and tree form was generally very good. It displayed a greater tolerance to soil variations than other species in that stands tended to be of a more uniform height.

   LODGEPOLE PINE. In terms of planted area, Lodgepole pine occupied an intermediate position between Corsican and Scots pines. With a mean Yield Class of 10 it has proved an invaluable choice on the more exposed tips and those at high elevations - indeed, on the more rigorous sites it is the only effective species. Yield Classes ranged from 6 to 14. Health and colour were usually good but form tended to be variable. Where Lodgepole and Corsican pine were found together on the same site Corsican was invariably of a higher Yield Class

JAPANESE LARCH. Not widely planted but where seen, health and colour were good. Yield Classes ranged from 6 to 10 with an average of 8. Form tended to be mediocre, especially where the site was exposed.

Norway and Sitka spruce and alder were encountered, but in much smaller numbers. Neither of the spruces showed any promise of developing into useful crops; Yield Classes were very low and growth in general was unsatisfactory. The alder was planted in 1974 and had made a satisfactory start.

Wherever possible, adjacent crops on undisturbed soils were measured so that a comparison could be made. Generally the crops on the 'normal' soils were of a higher Yield Class than those on the colliery waste, but seldom more than one or two Yield Classes, species for species. On one site the coal tip crop was of a higher yield than the adjacent stand and on one it was the same.

The main factors which appeared to influence tree growth were climate, situation and the activity of animals (particularly sheep). Those tips at high elevation where exposure and surface erosion were at their greatest, supported the poorest crops and, as noted already, in extreme cases on exposed conical tips there had been virtually complete failure.

b) **Tips planted after re-shaping.** Up to the time of this survey only three re-shaped tips had been planted by the Commission in South Wales and no crop was older than 5 years, thus no Yield Class assessments were possible. However, from subjective appraisals at three sites and from the evidence of research workers in other regions (Wood and Thurgood 1955), it would appear that regraded tips have much more in common with opencast sites than they have with undisturbed colliery tips. The increase in compaction, the decrease in shelter, the reversal of the surface pH from an acid to a neutral or slightly alkaline reaction, and the subjection of tree roots to a coarse, unweathered planting medium all correspond with the opencast environment. Establishment becomes much more difficult; initial losses can be high; and some high elevation sites may become virtually unplantable. The resultant tree growth is slow and form generally poor.

In the extreme case of the re-shaped aerial flight 'Ty-Draw' tip in the Rhondda (at 500 m and with no higher ground in the immediate vicinity so that exposure is extreme), the Lodgepole pine crop planted in 1973 is moribund - due mainly to root collar abrasion. The almost constant movement of the trees in the wind causes the bark to rub against the sharp unweathered shale fragments at the root collar and further damage to the stem is probably caused by wind driven shale particles. Many trees had been worn away to the point of collapse or even severence. Ty-draw tip before and after re-shaping is shown in Plate 4.

Conclusions

In an earlier survey, Pinchin (1953) (unpublished) reports on tree growth on undisturbed coal tips in South Wales including several planted by agents other than the Commission. The low elevation sites supported satisfactory growth of birch, Black and Canadian poplar, sycamore, Common alder and willow. Corsican pine, Lodgepole pine and birch grew well with few losses on some exposed tips at higher elevation, while larches appeared more suitable to intermediate positions.

In Table 6 a comparison is made of the mean Yield Classes of the four major species on opencast sites, on undisturbed colliery spoil heaps and on the 'normal' upland brown earth soils of the coalfield forests.

TABLE 6

Growth Comparisons by Site and Species

	Mean Yield Classes			
	Scots pine	*Corsican pine*	*Lodgepole pine*	*Japanese larch*
Opencast sites (and probably reshaped tips)	6	9	6	5
Colliery tips *in situ*	9	12	10	8
Upland brown earths	12	14	11*	11

* Estimate

The growth of trees on undisturbed spoil heaps is seen to occupy a midway position between the poorer growth of the opencast sites and the 'normal' growth on the major coalfield soil group. These Yield Classes have been converted into forecasts of crop top heights in Table 7.

TABLE 7

Forecast of Crop Top Heights (metres)

	Scots pine		*Corsican pine*		*Lodgepole pine*		*Japanese larch*	
	25 yrs	*50 yrs*	*25 yrs*	*50 yrs*	*25 yrs*	*50 yrs*	*25 yrs*	*50 yrs*
Opencast sites (reshaped tips)	7	14	9	17	8	16	10	16
Undisturbed colliery tips	9	17	11	20	12	21	12	20
Upland brown earths	12	20	12	20	13*	23*	15	23

* Estimate

Tips may be successfully planted *in situ* and it is unfortunate if they have to be regraded. Newer tips are generally larger and steeper and must be regarded as unplantable as they stand. The operations involved in their re-grading causes a deterioration of site conditions that are not easily overcome. Better results might be obtained if the new surfaces were allowed to weather for some years before planting is attempted. The similarity between these re-graded coal tips and opencast sites has already been noted and thus the conclusions on opencast sites equally apply to this sub-type.

Chapter 4

DEGRADED SOILS

Origins and Characteristics

The substrata considered in this section are indigenous soils *in situ* that have been degraded by prolonged periods of atmospheric pollution. In this category the Forestry Commission has planted land at Kilvey Hill, near Swansea and in the vicinity of Llansamlet, Cwm and Winsh Wen in the Lower Swansea Velley, also, 8 miles away at Foel Fynyddau (known locally as 'Copper Mountain') near Port Talbot - areas all once connected with the important metal smelting industry of South Wales.

At Swansea, the local Corporation had been concerned about the fume problems as early as 1764, and by 1850 eye witness accounts described a great pall of sulphurous smoke hanging over the valley, often like a dense thundercloud and visible for 40 to 50 miles. This pollution affected all vegetation for miles around and large areas in the region were devoid of vegetation up to comparatively recent times, with consequent erosion of the top soil (Anon, 1973).

'Copper Mountain' owes its name to the activities of the now defunct Rio Tinto Copper works which were sited in Cwmavon at the foot of the hill. Smoke and gasses from the smelter ascended a chimney flue which had been constructed up the side of the mountain, to emerge from a smoke stack at the top. The toxic emissions killed off most of the mountain vegetation leaving a rocky detritus of flaggy sandstones with a thin eroding soil no more than a few centimetres deep.

These degraded soils are of several different origins. Generally, the upper and middle slopes of the hills are composed of upland brown earths which have developed *in situ* from the underlying Pennant Sandstone rock, while the lower slopes and valley bottoms are usually sandy clay deposits of glacial origin. Occasional accumulations of alluvial sand border the valley rivers and local pockets of peat may be found on any soil with a poorly drained profile.

Altogether some 200 hectares of plantation are involved.

Topography

Kilvey Hill and Copper Mountain are two almost conical hills in very exposed situations near the Bristol Channel coast, an area of high gale incidence (Mayhead, Broad and Marsh 1974). The exposed southern slopes, though planted in part, are unlikely to produce more than patchy scrub. At Copper Mountain the crops extend to the very top of the hill at 370 m, whereas at Kilvey Hill they reach only about half this altitude. These hillsides have steep slopes of 20-30^{o}. Conversely, the land around Llansamlet, Cwm and Winsh Wen is low lying, gently undulating and more sheltered.

Vegetation

A vegetation composed mainly of heather and bilberry has gradually developed on the once bare hillsides but rarely does it attain the vigour and luxuriance of a normal heath and the soil, often with a thin, black humic layer above, is typically visible between the plants. Wherever drainage is impeded, and this usually occurs on the glacial soils, Purple moor grass replaces the heath type vegetation.

Choice of Species

Pines, mainly Scots, Lodgepole and Corsican, predominate. Larches (both Japanese and Hybrid) are often present, while Sitka spruce has usually been confined to the moister peaty areas.

Methods of Establishment

Wherever practical, ground was initially ploughed, but because of the steep gradients only small areas of Copper Mountain were so treated. Much of Kilvey Hill and the more gentle slopes near Llansamlet, Cwm and Winsh Wen, were successfully ploughed. In this last case the land was first limed (in a bid to fix soilborne pollutants) and then phosphated. Planting then proceeded along conventional lines.

Results of Survey

A very wide span of Yield Classes was found for all the commonly planted species. Scots pine had a range of from 4 to 11, Corsican pine from 11 to 16, Lodgepole pine from 2 to 11, Sitka spruce from 4 to 12 and the larches from 2 to 12. The lower Yield Classes appeared to occur where contamination from atmospheric pollution had been at its greatest. For all the species except Corsican pine the average Yield Classes are low.

Of the two major soil types involved - Glacial clays and Upland Brown Earth, the Brown Earth supported trees of a slightly higher yield, in spite of usually occupying more exposed ground. Ploughing was shown to improve both growth and survival rates on the glacial clays but comparable crops were not available on Upland Brown Earths. Table 8 shows the forecast for the crops planted in 1970 and 1971 at Kilvey Hill and compares the results with the average Yield Classes for the same species on the important Brown Earth group in the forests of the South Wales Coalfield.

TABLE 8

Tree Growth Comparisons for Degraded Soils

Kilvey Hill, N. facing slope, Coed Abertawe SS 665 945 Estimated Yield Class and Stocking (per cent) at 5 yrs									*Major Coalfield forests Average Yield Class*
	Glacial Clays				*Upland Brown Earths*				
Species	*Ploughed*		*Unploughed*		*Ploughed*		*Unploughed*		*Brown Earth Group*
Scots pine	10	95	4	80	-		6	80	12
Lodgepole pine	9	95	10	90	-		9	80	11*
Sitka spruce	12**	80	4	10	-		-		14
Hybrid larch/ Japanese larch	5	95	2	50	6	85	4	70	11

* Estimate

** On peaty soils

At Copper Mountain the top of the hill showed the worst pollution damage. The growth near the bottom was probably unaffected. Planting took place in 1962 with several different tree species but only one, Lodgepole pine, was used over the whole range of altitude for which Table 9 gives the Yield Class.

TABLE 9

Exposure/Pollution Effect on Tree Growth

Foel Fynyddan 'Copper Mountain' Margam Forest SS 785 935		
Altitude (metres)	*Yield Class of Lodgepole pine*	
370	2	Note: Estimated average Yield Class of Lodgepole pine on Brown Earth group in the Coalfield Forests is 11.
360	4	
320	6	
300	8	
150	10	

At 13 years of age the trees at the top of the hill were a mere 0.5m high. Although severely exposed, the crest of this hill is known, through tatter flag records, to be less exposed than others in the region which are supporting crops of a higher Yield Class. The fall off in Yield Class with increasing altitude cannot therefore be wholly explained in terms of exposure.

Similarly at Llansamlet, Cwm and Winsh Wen - areas at one time almost completely devoid of vegetation - the ploughed glacial clay soils planted in 1971 support Lodgepole pine at Yield Class 10 and Japanese larch at Yield Class 6, both low for the reasonably sheltered conditions that exist there.

Survivals of plants in the first few seasons after planting were disappointing in some areas. Parts of Kilvey Hill and Copper Mountain required heavy beating-up and at Llansamlet, Cwm and Winsh Wen a report records heavy losses at the end of the first season which were thought to be due mainly to emissions from the Imperial Smelting Corporation's works at Llansamlet which, however, closed in June 1974, at about the time of the survey. Larch apparently turned brown from the tips inwards and damage decreased with distance from the works.

Conclusions

Two hundred years of intense airborne pollution in the industrialised regions of South Wales killed off much of the surrounding vegetation and recovery has been slow. To what extent the soil has been chemically contaminated by heavy metal fallout is not fully known. Research by the University College of Swansea showed that levels of heavy metals in the Swansea/Neath/Port Talbot area were higher than elsewhere but the study also showed that metal levels in vegetables grown in the Swansea area were in no way abnormal. Physically, the soil has certainly suffered and in places erosion has apparently continued since the vegetation disappeared.

The quantitative data appears to indicate a shortfall in tree growth over that which might reasonably have been expected for similar sites with a history of clean air conditions, while on a qualitative basis too, the crops are poor. The depressed Yield Classes, the variability in height growth and the frequently poor survival rates are thus considered to be the result of the degradation of the soil brought about by industrial pollution.

There is no evidence to suggest that the liming and phosphating operations had any therapeutic value for, unfortunately, no untreated control area could be identified for comparison, but ploughing almost invariably leads to improved Yield Classes and is worthwhile on all but the smallest sites.

Chapter 5

DERELICT WASTELANDS - THE LOWER SWANSEA VALLEY PROJECT

In this and the next two chapters the sites considered are mainly relatively small derelict areas that have in common a history involving some degree of soil disturbance.

Origins and Characteristics

Two hundred years of industrial activity in the Lower Swansea Valley left enormous quantities of waste residues - seven to ten million tons - from the smelting of copper, zinc, lead-silver, nickel-cobalt and iron ores, deposited on the valley floor. Although the non-ferrous industry steadily declined - the last copper being smelted in 1921 - the late 19th Century had seen the establishment of a tinplate and steelmaking complex of inter-related factories which remained viable until 1945. As a consequence the valley was transformed from an attractive wooded vale to a barren wilderness of slag heaps, derelict buildings, rubbish dumps, abandoned railways and canals.

In 1961 the University College of Swansea commenced work on a programme of reclamation known as the Lower Swansea Valley Project. Their report (Hilton, 1967) recommended the acquisition by Swansea Council of redundant and derelict sites and Council ownership has increased from 85 ha in 1967 to 400 ha by 1973. In the plans for the valley, emphasis is given to the selective planting of trees and shrubs, the provision of nature trails and walks, as well as to the general landscaping of the whole area, where there will be substantial development.

The derelict factory buildings have now been largely removed and their place taken by rubble strewn ground, some of which is composed of huge levelled slag heaps from earlier industry. Tip removal continues to the present day.

One of the largest of the slag heaps was the White Rock Tip which was located at the foot of Kilvey Hill. Here, on the glacial clay soils, stood a slag heap of enormous proportions - 330,000 tons covering some 12 ha - being the residue from the extraction of copper at the White Rock Copper Works established in 1737. (The Forestry Commission first became involved in the Lower Swansea

Valley Project in 1963, ploughing and planting the 8 ha hill of glacial clay known as the Central Moraine. Due to its commanding position, this area has become the backdrop to the whole reclamation scheme. As other land became available the Commission continued to play a role, either by carrying out the work or by supplying the trees.

Except for the White Rock Tip area which occupies a comparatively sheltered re-entry on the lower slopes of Kilvey Hill, all the planting sites are in open situations on the relatively level plain of the valley floor. Generally the vegetation is sparse though there were exceptions; for instance, thick grass swards grew on domestic refuse sites but others, like the White Rock Tip, were in places almost completely devoid of vegetation and attempts at grassing had proved disappointing.

Results of Survey

The growth assessments of the species planted are given in Table 10.

The smaller plots of industrial and urban waste were mainly direct-planted with a minimum of ground preparation, often none at all, the object being to create a camouflage of tree cover to conceal the dereliction. On some materials, such as furnace ash, coal shale, sand and domestic refuse, it was usually possible to plant at normal forest spacing, but on the more stony site-types like building rubble it was often difficult to plant close enough to ensure a full cover of trees.

a) **Scalped soils.** From Table 10 it can be seen that yields on this substrate are very low. The removal of the upper soil horizons, the compaction of the subsoils by the bulldozing activities, the toxic after-effects of the copper slag (small amounts of which still remain) and the inherently low fertility of the glacial clay soils combined to produce extremely difficult sites.

   At White Rock Tip only occasional trees had survived and their growth was very poor. Scots pine, Lodgepole pine and Japanese larch had achieved about Yield Class 4. Occasional birch and alder had also survived but heights were very variable. The area had not been ploughed and results would probably have been better if it had been. The best growth was to be seen in a small plot of Corsican pine planted in the summer of 1973. At planting time these were tiny seedlings in Japanese Paper Pots. Their average height at the end of 1974 growing season, by which time their roots were exploiting the soil well outside the Paper Pots, was 0.2m and their survival rate was an encouraging 90 per cent. Regrettably, these were lost in the fires of 1976.

b) **Furnace ash.** Several small plots of furnace ash were planted with trees. Although survival rates were poor, growth rates were not too bad.

   Corsican pine had grown best with good form and healthy foliage. Lodgepole pine, birch and alder were making satisfactory but somewhat slower growth. Black locust grew vigorously with a bushy shape. Sitka spruce was short with small compact needles and was obviously ill-suited to the site.

c) **Rubble.** Two small examples of planting on rubble-strewn sites were seen. In both cases survival was poor and tree growth only mediocre. Japanese larch, birch, willow and oak were all slow growing and of poor shape. Alder showed the greatest potential at Yield Class 8.

TABLE 10

Survey Results - Lower Swansea Valley Project SS 670 960

Yield Classes Assessed at 11 years
Forecast of Height at 25 years (metres)

Species	*Scalped soils with slag*	*Furnace ash*	*Rubble*	*Domestic refuse*	*Sand*	*Coal shale*
Scots pine	4 (5)					8 (9)
Lodgepole pine	4 (6)	8 (10)		8 (10)	6 (8)	7 (9)
Corsican pine	8 (8)	12 (11)				12 (11)
Sitka spruce		6 (6)				
Japanese larch	4 (8)	7 (11)	4 (8)	9 (13)		
European larch				9 (14)		
Oak			2 (5)			
Sycamore				2 (9)		
Birch	6 (13)	5 (12)		7 (14)	8 (15)	
Alder		7 (14)	8 (15)	8 (15)	6 (13)	4 (11)

d) **Domestic refuse.** Two small domestic refuse sites were inspected and growth on both was acceptable. Japanese larch showed Yield Classes from 6 to 12, birch from 6 to 8, alder and Lodgepole pine were Yield Class 8. Present stocking varied from 30 to 70 per cent. Sitka spruce had been planted but none appeared to have survived.

e) **Sand.** Two different types of sandy material were recognised. On the naturally occurring alluvial sands on the banks of the River Tawe (disturbed to a greater or lesser extent by industrialisation) growth and survival rates were only moderate. European larch was the most productive species at Yield Class 9, birch and Grey alder were poorer. Lodgepole pine at Yield Class 6 was inclined to be bushy as a result of insect damage. Black locust was one of the tallest species but had a spreading form.

The other type of sand was of uncertain origin. An escarpment of sandy material containing abundant small rounded stones, including flints, had been planted with alder and Black locust, both of which had poor survival rates and growth. The alder at Yield Class 4 had much dead wood in the uppermost branches. The Black locust was healthy but of poor form.

f) **Coal shale.** A small heap of coal shale had been planted with Scots pine, Corsican pine, Lodgepole pine, alder and Black locust. Growth rates were similar to those of other *in situ* coal tips in the coalfield (see Chapter 3).

Corsican pine was healthy, attained Yield Class 12 and was of good form. Scots pine and Lodgepole pine were of more modest growth - Yield

Class 8 and 7 respectively. The alder was spindly and of poor potential at Yield Class 4, while Black locust was healthy but with a sprawling branching habit.

Conclusions

With such unusual substrates it is perhaps not surprising that tree growth has seldom been vigorous and that losses, on occasion, have been high. The main reason for this is undoubtedly the unsuitability of some species for some of the sites and repeated effort has been required to maintain adequate numbers. Some plots have disappeared to make way for new industrial developments, others are being removed tree by tree to other parts of the city. But those that remain, in addition to providing useful information on the growth and survival of trees on such diverse materials, are contributing in a positive way to the improvement of the general appearance of this once derelict area.

Chapter 6

INDUSTRIAL TREE SCREENS

Origins and Characteristics

Industrial screens are belts or rows of trees planted to shield from public view unsightly installations and also to reduce noise and dust levels. There have been two major schemes of this type undertaken in South Wales by the Forestry Commission. One now hides the Hirwaun Industrial Estate from the A456 Merthyr Tydfil to Neath Road, while the other, which is almost 5 km long, is intended to screen the massive Llanwern steelworks from housing on the other side of the main London to South Wales railway line just east of Newport.

Hirwaun Industrial Estate is on open moorland near the head of the Vale of Neath, an area of gley and peaty gley soils of glacial origin. It is a relatively level site at 217m altitude, and though some shelter is afforded by a mountain escarpment to the south, it is nevertheless a bleak, exposed site with well over 90 inches rainfall.

Llanwern is a level coastal site, less than 10m above sea level. The soils are rich, fertile, heavy clay loams of the Lower Lias series. There are hills to the north and the massive steelworks complex itself provides shelter to the south but the site is exposed to both easterly and westerly winds.

The sites had become much disturbed during the processes of industrial construction and, at Hirwain, from earlier occupation. Concrete foundations, roads, paths, dumps of hardcore, pylons and various other remains littered the surface.

Methods of Establishment

At both sites the dereliction created serious establishment problems. Wherever possible, the ground was ploughed making for easier planting, suppression of the weed growth and, in the case of the Llanwern screen, improvement of drainage. Even so, much of the ground proved difficult to plant and at Hirwaun it was necessary to use modified crowbars to get the trees into the debris-littered ground. It was decided at this site to apply ground mineral phosphate to the trees at planting time and also to fence the area against sheep. A high degree of exposure, a late spring frost following planting, sheep trespass and an exceptionally heavy weed growth, resulted in 40 per cent of the trees dying in the first season. Three years' beating up were required to bring the stocking up to acceptable standards and throughout the five year maintenance period a succession of minor mishaps, mainly connected with sheep trespass, contributed to the relatively slow establishment of the crop. Some impatience on the part of the factory management became evident during this period.

At Llanwern, in order to meet certain deadlines, insufficient time was allowed for the freshly prepared plough-furrows to settle. Consequently the roots of the newly planted trees were sandwiched between two layers of raw vegetation. Many trees died as a result of this, from rabbit damage; and from suffocation under the exceptionally heavy weed growth of these damp and fertile soils.

The Hirwaun screen is composed entirely of conifers: Scots pine, Lawson cypress, Japanese larch and Sitka spruce in the original planting in 1960 and Lodgepole pine in beating-up.

The Llanwern screen planted in 1968 involved the use of Lodgepole pine, Corsican pine and about eighteen species of broadleaved trees in the proportion 9:1 conifer to broadleaved. A subsequent heavy beat-up entirely of broadleaved trees reduced the proportion to 2:1.

Results of Survey

At Hirwaun, the growth of all species except Lawson cypress was found to be satisfactory. The only gaps in the screen occurred where the foundations of old Nissen huts still remained. Overall stocking was around 90 per cent and the industrial site has now been successfully excluded from view along the A456, though it remains completely open from the recently constructed dual carriageway to the north (showing the need of foresight in such long term affairs !). Table 11 summarises the Yield Classes and estimated top heights at Hirwaun.

At Llanwern the steelworks chimneys emit a thick smoke containing a heavy particulate matter which settles on the trees in a black, sooty deposit. Particularly noticeable on evergreen trees and shrubs, it was, in places, so thick that it became difficult to tell Lodgepole from Corsican pine. A small proportion (about 1 per cent) of the pine were seen to be recently dead, others showed some foliage discolouration consistent with pollution damage. It seems likely that this pollution will have some adverse physiological effect on evergreen plants in the long term. Broadleaved trees, on the other hand had, at the time of the survey (May 1975) a fresh healthy appearance. Because they shed their leaves annually, broadleaved trees can tolerate these site conditions. The increase in the proportion of broadleaved trees resulting from the 1969 beat up can thus be regarded as a fortunate result of pollution.

TABLE 11

Derelict Wastelands - Industrial Tree Screens - Results of Survey

Hirwaun Industrial Estate 14 years after planting SN 935 062

Species	*Estimated Yield Class*	*Estimated Top height (metres)* At 25 yrs	At 50 yrs
Scots pine	12	12.0	20.0
Lodgepole pine	10	12.0	21.0
Japanese larch	10	14.0	22.0
Sitka spruce	12	10.0	21.0
Lawson cypress	8	7.0	15.0

Table 12 gives brief notes on the height, Yield Class, present stocking, form and health of the trees and shrubs seen at Llanwern.

TABLE 12

Derelict Wastelands - Industrial Tree Screens - Results of Survey

Llanwern British Steel Corporation 7 years after planting ST 360 873

Species	*Top height in metres*	*Estimated Yield Class at 7 yrs*	*Stocking per cent*	*Form*	*Health*
Corsican pine	2.7	14	85	Good	Dusty foliage. Some recently dead.
Lodgepole pine	2.5	14	65	Good	Dusty foliage. Browning on older needles.
Wych elm	1.6	4	95	Bushy	Healthy. Slow growing.
Sycamore	3.0	6	80	Good	Healthy. Slow growing.
Birch	5.0	10	100	Good	Dense crop. Effective screening.
Whitebeam	3.2	-	-	Bushy	Healthy; only occasional specimens.
Poplar vars	7.5	7	95	Good	Variable heights. Healthy.
Ash	4.0	8	95	V.good	Uniform. Healthy. Very good potential.
Field maple	2.4	-	95	Bushy	Healthy. Slow growing.
Norway maple	3.5	-	15	Good	Poor 'take'. Variable hts.
Rowan	3.5	-	90	Average	Uniform heights.
Elder	1.5	-	95	Bushy	Sparse foliage. Not doing well.
Alder	5.0	10	90	Average	Healthy. Variable heights.
Turkey oak	1.8	4	90	Poor	Only occasional good specimens.
Cherry	2.0	-	-	Good)	Only occasional specimens
Cornish elm	3.5	10	-	Variable)	seen.

Four other species - Red oak, Holm oak, lime and willow - were not traced

Conclusions

The use, at Llanwern, of 20 individual species will culminate in a screen of widely varying heights and densities which, for some years yet, will not entirely hide from view the industrial scene beyond. At Hirwaun where the screen is composed mainly of pine and larch, a very effective barrier has grown.

Planners and industrialists who call upon the Forestry Commission to plant trees for them need to be told, before work commences, of any particular difficulties at the site and asked what they really want. Difficult sites will inevitably lead to some tree deaths however well the species are chosen, but patience is always required. 'Instant trees' stand little chance of success on derelict sites so that small, young transplants have to be used and while growth in the early years is likely to be slow, transplants usually become established sooner and will often outgrow standards.

Chapter 7

DERELICT WASTELANDS - QUARRIES

Origins and Characteristics

Quarries are found scattered throughout Wales. Planting sites are typically composed of heaps of disturbed soils, waste stone, etc, dumped in a random fashion around and about the working surfaces of the quarry excavations. Practically all the quarry sites whether of slate, sandstone, limestone or silica, are on exposed hillsides but the very methods by which the minerals are extracted and the ways in which the waste products are dumped, create a diverse, often deeply incised, topography which provides its own shelter to a greater or lesser extent.

These sites tend to be so rocky that trees have to be planted wherever favourable ground conditions permit with few opportunities for ground preparation; therefore an assessment of survival rate is not possible without a record of the numbers planted. The largest areas of surface rock exploitation are found in the slate quarries of North Wales. To produce one ton of saleable slate, over twenty tons of debris was produced. Formidable quantities of waste slate have thus been amassed, in some places hundreds of feet deep (Sheldon and Bradshaw 1976).

Generally the slates of north-east Wales, to which this survey was confined, are softer and more easily weathered than those of the north-west, but may still be of varying density and hardness. In some parts the shales are heaped in mounds of large, loose, separate slabs, while in others they have weathered down into a fine-textured soil. Short grasses, dandelion, briar, bramble, gorse, broom, scrub birch, rowan and willow flourish on the weathered clay soils. This vegetation gradually declined in numbers of species and luxuriance as the particle size of the substrate increased, so that the heaps of larger, loose slabs were often totally devoid of plant material. Sandstone and limestone quarries are generally extremely rocky and dumps of waste stone are found strewn about together with heaps of intermixed soils that have been stripped off the upper rock layers. The sandstones tend to separate in slabs of 'flags' while limestone is of a more 'blocky' shape. Sandstone quarry areas tend to support a scanty growth of mountain pasture grasses, dominated by *Deschampsia flexuosa*. Limestone quarry areas on the other hand are typified by a lush growth of bracken, ferns, nettles, foxgloves and thistles in addition to patches of heather and bilberry. Scrub tree growth of beech, sycamore, birch and elder was also a feature of the limestone sites.

The abandoned workings of the one silica quarry visited consisted of a mountain top site with a hollowed out working surface of compacted clayey soil with low dumps of waste material nearby. The soils had been colonised by a meagre growth of heather, bilberry, gorse, willow-herb and low birch and willow. In some places the soils were moss and lichen covered, in others completely bare.

Results of Survey

a) **Slate quarries.** Where soils had weathered sufficiently to provide a suitable planting medium, survival rates were usually high and crops were growing at a moderately fast rate. Scots pine, the most commonly planted species on the sites visited, was growing well - Yield Class 14 - on the damp, fine textured clay materials in sheltered zones, but in more exposed places and on the drier and rockier sites growth dropped off to Yield Class 7 and crops became patchy. Corsican pine with an average Yield Class of 12 was the least variable pine on these sites, while Lodgepole pine, Yield Class 6, had developed an unusual columnar form on some of the steeper slopes. Japanese larch ranged from Yield Class 8 to 12, Western hemlock had an average Yield Class of 12, while Noble fir attained Yield Class 16.

b) **Sandstone quarries.** Lodgepole pine was the only species seen growing on sandstone quarry areas. The crops tended to be patchy with poor growth rates. Yield Class 7 was the average; this compared with Yield Class 14 for similar Lodgepole pine crops on adjacent undisturbed soils. Sheep trespass was common and was probably responsible to some extent for the patchy crops.

c) **Limestone quarries.** Only one species was found growing on the limestone quarry lands - Scots pine. Survival rates were good - most of the losses could be attributed to sheep damage anyway - and growth rate a moderate Yield Class 10. Adjacent Lodgepole pine on undisturbed soils which were assessed for comparison had a Yield Class of 14. Since Lodgepole and Scots pine have quite similar modes of growth on moderately sheltered sites such as these, it is reasonable to assume that Scots pine too would have attained a Yield Class of 14 or thereabouts on undisturbed soils. There is a loss therefore of 2 Yield Classes through soil disturbance.

d) **Silica quarries.** Two species had been planted on the unploughed silica quarry soils. Corsican pine, concentrated on the central, level, compacted soils was extremely poorly developed, of a yellow colour and generally moribund. The occasional better patch attained Yield Class 6. Lodgepole pine, which had been reserved for the more favourable, lighter soils round about, was also assessed at Yield Class 6 while on adjacent undisturbed soils it had attained Yield Class 10.

Table 13 summarises the ranges of Yield Classes on the four types of quarry land.

TABLE 13

Derelict Wastelands - Quarries - Results of Survey

Estimated Yield Classes

Species	*Slate*	*Sandstone*	*Limestone*	*Silica*
Scots pine	7-14		10	
Corsican pine	12			
Lodgepole pine	6	7		2-6
Japanese larch	8-12			6
Western hemlock	12			
Noble fir	12-16			

Conclusions

The finer textured soils of the north-east Wales slate quarries were found to support moderate to good tree growth - Corsican pine should attain 11m at 25 years of age (20m at 50 years). The silica site on the other hand was of poor standing. The pines there will probably be no taller than 7m at 25 years (13-14m at 50 years). Limestone and sandstone quarries occupy an intermediate position.

Chapter 8

ROADSIDE PLANTING SCHEMES

Origins and Characteristics

Roadside planting schemes undertaken by the Forestry Commission for the Welsh Office and the Dept of the Environment (and formerly for the Ministry, now Department, of Transport) are to be found in all the new Welsh counties other than Mid Glamorgan. The first plantings, which took place in 1965, constituted two small schemes in mid-Wales which involved no more than a few dozen ornamental trees. Since that time there have been numerous schemes, the largest of which - the planting of extensive stretches of the M4 London to South Wales motorway in Gwent - involved the use of hundreds of thousands of trees and shrubs.

Three general types of site result from the major earth-moving associated with trunk road construction:

a) **Cuttings.** Here the roadway has been cut through, often resulting in compaction of earth and rock by heavy machinery. The planting medium generally improves from the lower parts of the cutting, often raw shale and rock, to the upper parts which usually retains some topsoil.

b) **Embankments.** The planting sites on the sides are usually of a loose nature with little or no differentiation through the profile, being composed of an admixture of rocks, subsoils and topsoils of local derivation.

Roundabouts are considered a sub-type of the above, for although they may occur in cuttings or on embankments the soils have always been compacted during construction.

c) **Natural soils.** A proportion of the planting falls on sites which have remained more or less undisturbed during road building.

Obviously soil types alongside roads vary from region to region and can alter frequently or remain uniform for miles at a stretch. Soils derived from Old Red Sandstone, Keuper Marl, Carboniferous Limestone, Silurian and Ordovician Shale and Lower Lias were found in south Wales. Parent materials in areas planted in the north were Bunter Sandstone, Millstone Grit, Carboniferous Limestone and Silurian Shale.

The topography of cuttings and embankments tends to be similar, the vast majority having slopes of between 20° and 30°. In contrast, most of the undisturbed ground was near-level, with slopes of 2° to 5°. The stereotyped specifications give rise to predictable zones of exposure. The upper reaches of a slope, whether cutting or embankment, tends to be more exposed than the lower parts, while the roadway itself provides an unrestricted corridor for air movement. Exposure therefore tends to be high on the actual roadside wherever the location.

Methods of Establishment

All trees whether transplants, standards or feathered (an intermediate size) are pit planted. Pits were prepared by hand or mechanically and the size of pit determined by the height of the tree to be planted, the taller trees usually needing greater root space. Currently, holes are made by powered augers for transplants (less than 900mm) or by mechanical digger for larger 'feathers' and standards. In the early schemes, a planting medium for backfilling was made by adding peat or hopwaste, and sometimes a general fertiliser, to imported soil but later practice has been to spread topsoil to a depth of 15cm over the whole planting area and to add peat as a proprietary tree mulch to the soil removed from the hole. Transplants are used almost exclusively nowadays. Larger trees have always been staked for added stability during their early establishment.

A wide variety of plot design is utilised, irregularity being the keynote. Trees are planted in rows, strips, small informal groups and large blocks, sometimes pure and sometimes in mixture with one or more other species. Mixtures may be of conifer or broadleaved species or some combination of both, planted in small groups, mixed by row or at random. Planting distances vary according to tree size - standards may be several metres apart, transplants at 1.5m x 1.5m are generally rather closer than current forest spacing.

The boundaries of the plots were marked with short pegs so that they may be avoided during grass cutting or spraying operations. High maintenance costs and a wish to create a natural aspect to the roadsides has led to grass cutting being confined to necessary sightlines.

In the seasons following planting it is the responsibility of the Forestry Commission to see that any vegetation interfering with the growth of the trees is either cut back or sprayed.

Result of Survey

Table 14 shows the mean Yield Classes and compares 10 yr height growth of the more important species by site type. Figures in brackets at right hand of each column represent the number of sample units assessed.

TABLE 14

Roadside Planting Schemes - Results of Survey

(Mean Top Height (m) at 10 years) | Mean Yield Classes | (Number of Sample Units)

Species	*Embankments*			*Cuttings*			*Natural Soils*		
Scots pine	(4)	11	(2)	(3)	9	(4)		-	
Corsican pine	(2)	6	(1)	(3.5)	11	(4)	(4)	12	(3)
Lodgepole pine	(3.5)	10	(1)	(1.5)	4	(1)		-	
Sycamore	(5.5)	6	(4)	(4.5)	5	(4)	(6)	7	(2)
Birch		-		(6)	7	(6)		-	
Beech	(2)	4	(1)	(4)	8	(3)	(4)	8	(2)
Alder	(7)	9	(2)	(5.5)	6	(3)	(8)	12	(1)
Ash	(5.5)	6	(2)	(6)	7	(2)	(6.5)	8	(1)
Oak	(2.5)	4	(1)	(2.5)	4	(3)	(4)	6	(1)
Hybrid and Japanese larch	(5)	8	(1)		-		(6.5)	10	(1)
Average Yield Class		7.2			7.1			9.4	

There appears to be little overall difference in rates of growth on embankments and cuttings. Some species appear to do better on one type than the other but this is probably due to errors of low sampling. The best growth in most instances was on the natural soils. There appeared to be little difference in the survival rates of trees planted on embankments, cuttings and natural soils, though roundabouts, probably as a result of greater compaction and exposure, often had high failure rates.

Changes from one soil type to another were not related to any noticeable difference in height growth. This is thought to be due to the masking effect of the introduced planting medium and the inhibiting rye grass sward. As no scheme was older than 11 years at the time of the survey it may be several years yet before any effects due to the nature of the substrate may be judged.

The major influence controlling growth appeared to be climate, with exposure its most important element. On schemes near the coast exposure was sufficiently serious to restrict the growth of many of the more tender species. Indeed, in extreme cases, it prevented the growth of all but the hardiest trees, and even these had an irregular form which is not always unattractive.

It was sometimes noted that the trees nearest the roadway were shorter than their neighbours further up or down the slope. This could not be entirely explained in terms of shelter, moisture availability or quality of soil, so it may be that the turbulence caused by fast moving traffic or the salt from winter grittings are responsible. Recent studies on effect of road salt by the Imperial College have shown that concentrations are only significant within narrow central reservations and within a few metres of the hard shoulder.

Damage to trees by agencies other than those of climate were minor. Fires, vandalism, sheep, rabbits, voles and occasional damage during grass cutting and spraying of herbicides have all been reported as causing losses - certainly fires have been a much more serious cause of loss in the two summers of 1975 and 1976 following the survey.

Some Notes on Species Used

The Department of the Environment's official list of trees for use on roadsides includes 93 species, varieties and cultivars for all situations. Some 45 species were encountered during this survey. Some had been used in tens of thousands while others were represented by an odd individual here and there. The survey concentrated on those species used most frequently and these were, in order of numerical importance, pines, sycamore, birch, beech, alder, ash, willow, elm, oak and larch. The shrub species most often encountered were - hawthorn, Field maple, and hazel. The proportion of trees to shrubs was about 4:1.

Generally species are selected for compatibility with species already growing in the locality and for successful growth under the prevailing site conditions, ie new plantings are extensions of the existing arboreal landscape.

In the following notes, growth rates encountered are indicated by Yield Class and related estimated top height at 20 years (metres).

Scots pine. A tree of steady performance which attained moderate proportions over a wide range of site conditions. Growth however was seldom, if ever, vigorous, Yield Class 8/10 (7m) being usual. It does not tolerate competition from other species or open coastal situations exposed to sea winds. Survival rates were often quite high - 75-95 per cent - and it adapted well where soils were more compact than usual.

Corsican pine. The most vigorous conifer encountered with a Yield Class range of 10 to 14 (9m). Survival rates for this species were good. Although it performed best growing pure it appeared to grow better than Scots pine when in mixture with other vigorous species. Contrary to the results of the opencast site survey, it appeared somewhat less tolerant than Scots pine on the more compacted soils, but elsewhere it was very successful.

Lodgepole pine. This species had been used less frequently than the other pines and only on the better sites did it perform well. It did not thrive well on compacted sited though in exposed zones it was one of the best species. The average rate of growth was Yield Class 8 (7m).

Japanese and Hybrid larch. Not widely used. Yield Classes were in the range 8/10 (11m) and form was usually good. On the more difficult sites like roundabouts they performed better than many other species, but exposed coastal areas proved too exacting. In mixtures they tended to become dominant, often suppressing other trees.

Sycamore. This species grew well on most sites, although the more level and compacted roundabouts gave some trouble. Survival rates were generally high, Yield Class 6 (11m) was usual. Tree form was nearly always good. Except when mixed with ash, with which it grew at a comparable rate, sycamore soon becomes the dominant member of a mixture, suppressing most other species other than alder and birch.

Birch. This was found to be growing admirably even on the more difficult sites. Trees nearly always looked healthy and growth was vigorous. It had become the dominant species in most mixtures, especially with pine, which was a common combination. Yield Class 8 (20m) was normal and survival was generally very good. There were however considerable losses in the drought of 1976, since the survey.

Beech. Heights were usually more variable than other species and growth on average was only moderate, Yield Class 6/8 (8m) was the norm. Survival rates were not always good. It performed well in intimate mixtures owing to its shade tolerance but did not tolerate severe exposure to sea winds. It will probably excel on the Carboniferous Limestone, but otherwise is probably too demanding for widespread use.

Alder. Although, together with willow, the natural choice for the damper sites, alder had grown successfully on most of the sites on which it had been planted, including some very exposed areas near the sea and also on the upper drier reaches of some steep cuttings. In mixtures it soon assumed dominance, even outgrowing sycamore. Yield Class 8/10 (12m) was the usual assessment on best sites. Survival rates were not always good and it did not do well on compacted sites like roundabouts. Form was generally good.

Ash. This proved to be a useful tree on many sites but is intolerant of compacted soils. Yield Class 6/8 (12m) was normal and form was typically good. It performed well in mixture with sycamore and birch but tended to outgrow oak.

Willow. Generally planted on the damper sites alongside rivers and streams occupying a niche where only alder or poplar could be substituted. Where seen it was growing well. Golden willow was thriving in exposed coastal conditions in North Wales.

Elm. Rate of growth was slow to moderate, Yield Class 8 (10m) was typical. Survivals were moderate and form was generally good. It had not been widely planted and it may be of doubtful future value while Dutch elm disease persists.

Oak. Of doubtful value for roadside schemes, even when planted pure. In most of the mixtures seen it was in danger of becoming suppressed. Growth was generally slow - Yield Class 2/6 (6m) - and form was indifferent. On exposed and coastal sites it was poor. It has not been widely planted.

One other tree, although only encountered at one site, is worthy of mention. Monterey pine *(Pinus radiata)* showed itself to be a tree capable of tolerating severe coastal exposure. Form and height growth left something to be desired but it has the ability to remain green and healthy where most other species perish.

Table 15 indicates the top heights which some of the more important species are likely to attain in 25 and 50 years on average sites.

TABLE 15

Roadside Planting Schemes - Results of Survey

Species	*Mean Yield Class*	*Estimated Top Height (metres)* at 25 years	*at 50 years*
Scots pine	9	9	17
Corsican pine	11	10	21
Lodgepole pine	8	11	18
Hybrid and Japanese larch	9	14	21
Sycamore	6	13	18
Birch	7	14	19
Beech	7	10	19
Alder	9	15	21
Ash	7	14	19
Elm	8	12	20
Oak	4	7	14

Conclusions

Though the roadside plantings in Wales are still in their infancy this survey has highlighted the need for more long term planning.

The following points should be considered:-

a) Could, or should, the species list be reduced ?

b) What are the most useful species for mixed stands?

c) What are the most effective planting distances?

d) Will the grown trees be a hazard as they stand?

e) Will they be a danger if they fall (some species will be upwards of 20m (65 ft) at 50 years of age) ?

f) What should be the geometric relationship between tree and road?

These silvicultural/landscape considerations are quite distinct from those relating to road conditions viz. light, shade, leaf/needle fall, wildlife etc. which concern the Road Research Laboratory of the Department of the Environment.

Chapter 9

GENERAL CONCLUSIONS

This survey report has attempted to bring together all the information on landscape planting on man-made sites in Wales, mainly from the South Wales coalfield. There is no point in trying to summarise in detail the conclusions at the end of each chapter, but some general comments and guidelines may be helpful.

On coal mining sites, whether deep mined or opencast, extreme variations in soil reaction (pH) may be found. The soils may start neutral or alkaline, becoming extremely acid after some years, then gradually returning to a less extreme condition as the chemical reactions come to an end and the acids are leached out of the soil. Large variations in pH may be encountered over quite small distances in the first few years following disturbance. It is important to realise that reshaping of spoils, even of great age, brings us back to the beginning of the cycle. Liming has been used in agricultural restoration but there is little evidence as yet of its efficacy in forestry.

All use of machines compacts the soil, so efforts to achieve an even gradient may do more harm than good, if one is only considering growth rates. Deep ripping to relieve the compaction is probably worthwhile on most restored sites, but it is not yet possible to define the conditions within which it is essential, beneficial, or unnecessary.

Because all the soils under consideration are raw, except some of those on industrial waste-lands and degraded sites, they generally contain adequate amounts of the mineral nutrients such as phosphorus and potassium. However, their rawness and lack of organic matter means they are almost always deficient in nitrogen. One would therefore expect nitrogen deficiency but no deficiencies of phosphorus or potassium. What work has been done tends to bear out this generalisation.

Weeds are seldom a problem on the restored soils, mainly because of the over-riding deficiency of nitrogen, although this will depend on the amount of top soil which has been returned to the site. However, when weeds do become a problem the normal measures of weed control must be used.

Secure fencing, properly maintained, is essential to ensure survival and success of planting on most sites, particularly those close to towns and where sheep trespass is common. It is foolish to spend large sums of money on restoring and planting sites, only to allow the trees to be eaten or burnt through lack of subsequent care. Proper maintenance must be arranged before the scheme gets under way.

Grassing of sites prior to planting trees has not been much done in this region, though common in other parts of Britain, being normal practice on roadside sites. Grassing, if successful, will bind the soil and prevent surface erosion on steeper slopes or over impervious soils. Furthermore, if clover is incorporated in the seed mixture there should be an eventual improvement in nitrogen supply. However, because it may be necessary to add lime and phosphorus if clover is to succeed, it may be expensive. The main reason adduced against grassing sites is that this will attract sheep; also if too successful it may mean more weeding (though this would appear to be unlikely on most of the soils in question). However, observations suggest that sheep trespass wherever the trees are growing well, whether the site is grassed or not, and this merely serves to reinforce the need for good fencing well maintained. Whether the instant greenness that results from successful grassing is worthwhile will be a matter for local consideration. It is noteworthy that in the roadside plantings reported on, although many are grassed, there is no damage from sheep because of the secure fencing.

Species should always be chosen on their ability to survive on the site; variety of appearance, relation to native flora, or usefulness as timber producers should be secondary considerations. Where substantial forest blocks are to be planted Corsican pine is the first choice with Lodgepole and Scots pine; where conditions are more severe and in extremely exposed coastal situations Monterey pine may well have a place. Spruces, Silver firs, Douglas fir and other conifers are in general unsuitable, unless the soil is good and the exposure only moderate. Among the broadleaves, birch, alders, willows, sycamore, whitebeam are all useful. Oak and beech are not usually worth trying, unless again the situation is very favourable. It is unlikely that hardwood timber, apart from pulpwood, can be produced from any of these sites, with the exception of the best undisturbed soils, eg on trunk roads.

On very extreme sites it is probably best not to attempt to plant trees at all but to establish shrubs, herbs and grasses to initiate the slow processes of soil development and improvement.

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TREES IN THE SURVEY AREA

	English Name	Scientific Name
CONIFERS	Scots pine	*Pinus sylvestris*
	Corsican pine	*Pinus nigra* var *maritima*
	Lodgepole pine	*Pinus contorta*
	Sitka spruce	*Picea sitchensis*
	Norway spruce	*Picea abies*
	European larch	*Larix decidua*
	Japanese larch	*Larix kaempferi*
	Hybrid larch	*Larix* X *eurolepis*
	Western hemlock	*Tsuga heterophylla*
	Red cedar	*Thuja plicata*
	Lawson cypress	*Chamaecyparis lawsoniana*
	Grand fir	*Abies grandis*
	Noble fir	*Abies procera*
	Monterey pine	*Pinus radiata*
BROADLEAVES	Oak	*Quercus robur/petraea*
	Turkey oak	*Quercus cerris*
	Red oak	*Quercus borealis*
	Holm oak	*Quercus ilex*
	Beech	*Fagus sylvatica*
	Sycamore	*Acer pseudoplatanus*
	Field maple	*Acer campestre*
	Ash	*Fraxinus excelsior*
	Birch	*Betula pubescens/pendula*
	Alder	*Alnus glutinosa*
	Grey alder	*Alnus incana*
	Elm	*Ulmus procera/glabra*
	Cornish elm	*Ulmus stricta*
	Willow	*Salix* spp.
	Whitebeam	*Sorbus aria*
	Rowan	*Sorbus aucuparia*
	Poplar	*Populus* spp.
	Elder	*Sambucus nigra*
	Cherry	*Prunus avium*
	Lime	*Tilia europaea*
	Black locust	*Robinia pseudacacia*

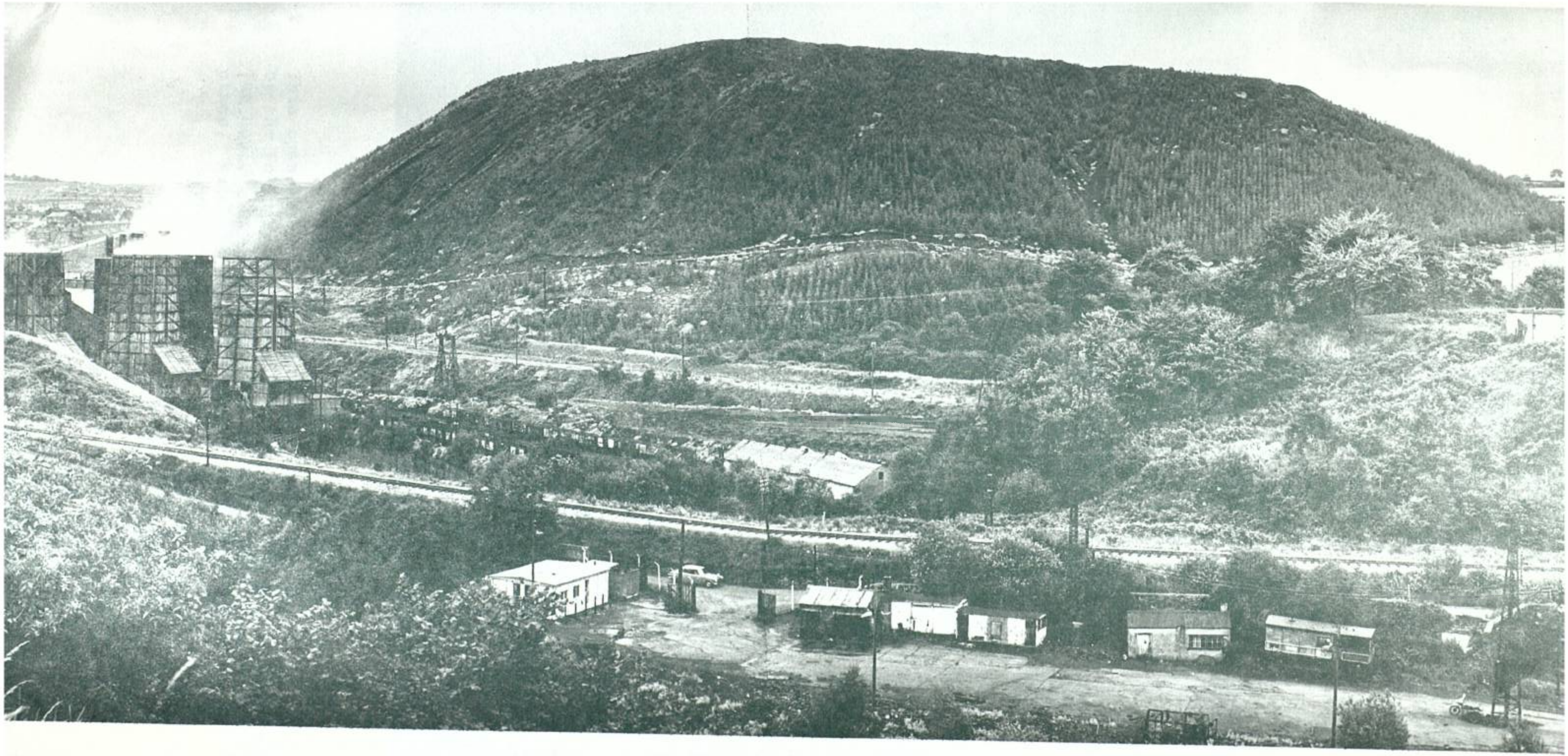

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Plate 1. Aberbargoed Tip, Rhymney Valley, Mid Glamorgan, planted *in situ* ten years earlier in 1960 mainly with larch and pine.

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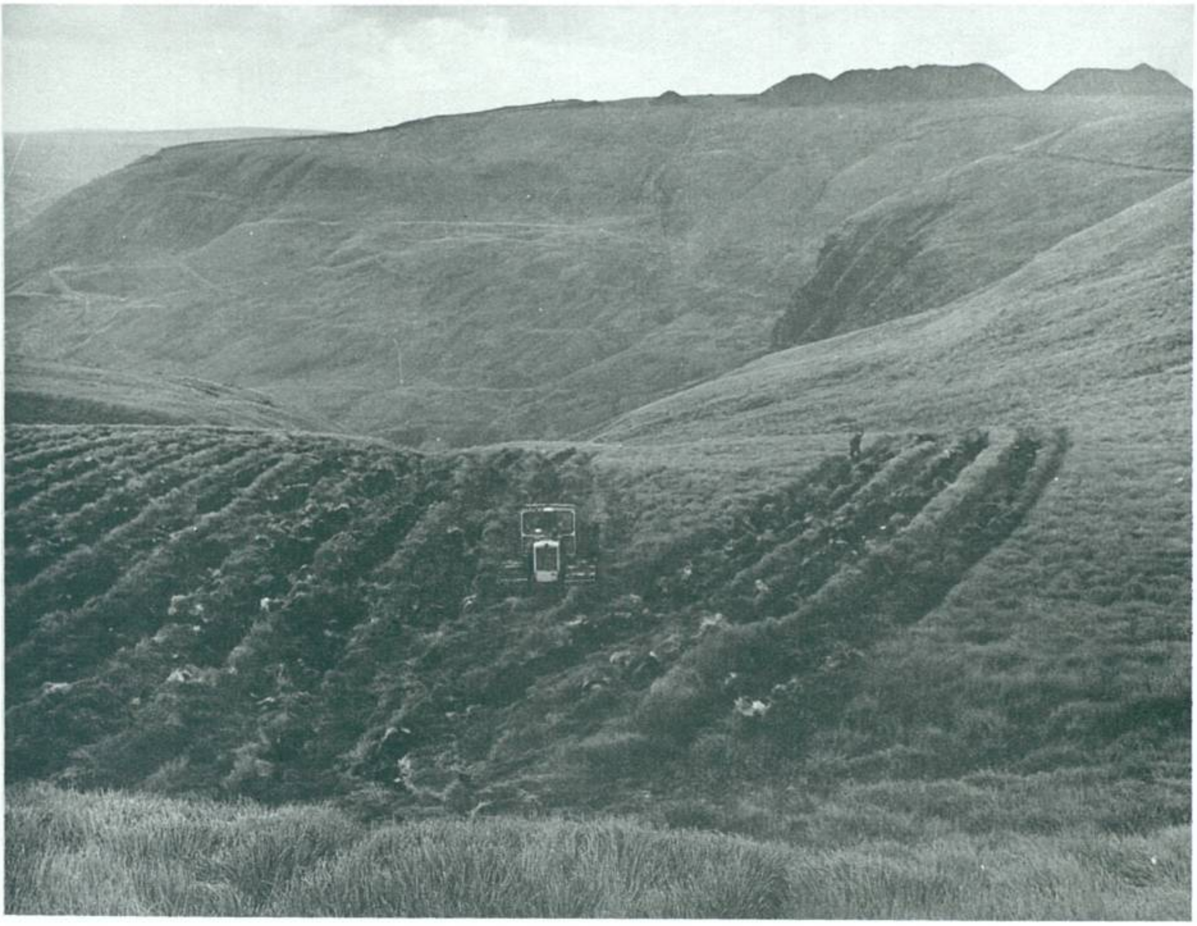
Plate 2. This opencast site at Tirpentwys, Ebbw Forest, Gwent, was planted by the Forestry Commission in 1964 for the National Coal Board. The boulder strewn surface can still be seen between the 6-year-old pines. Note the high wall left in the final void.



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A C Lauritus

Plate 4. Ty-draw Tip, Rhondda Forest, Mid Glamorgan.

Above - The tip, beyond the valley, in original condition (1970).
Below - After reshaping by bulldozer and ridging for planting. Traces of coal working may be seen on the slopes of Blaenrhondda which surround the source of the river.

OCCASIONAL PAPER 3

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