AN ASSESSMENT OF THE EFFECTS OF ROAD DUST ON AGRICULTURAL PRODUCTION SYSTEMS

by

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THE AGRICULTURAL ECONOMICS RESEARCH UNIT

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Major sources of funding have been annual grants from the Department of Scientific and Industrial Research and the College. However, a substantial proportion of the Unit's budget is derived from specific project research under contract to government departments, producer boards, farmer organisations and to commercial and industrial groups.

The Unit is involved in a wide spectrum of agricultural economics and management research, with some concentration on production economics, natural resource economics, marketing, processing and transportation. The results of research projects are published as Research Reports or Discussion Papers. (For further information regarding the Unit's publications see the inside back cover). The Unit also sponsors periodic conferences and seminars on topics of regional and national interest, often in conjunction with other organisations.

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CONTENTS

LIST OF TABLES

Page

LIST OF FIGURES

PREFACE

It has been proposed that the dust drifting on to farmland adjacent to unsealed roads can reduce the volume and value of agricultural production from that land. The objective of this report is to describe an investigation into this proposal. The report also describes a method by which the magnitude of economic benefit from dust removal from unsealed roads may be assessed. The method is crude and needs further refinement but is the best method presently available.

One of the results of this study is that the magnitude of economic effects on some forms of horticultural production, in particular, may be substantial. Further investigation of biological and physical relationships is called for.

This study was undertaken by Mr P.R. McCrea, assistant research economist in the Unit. The study was financially supported by the Waikato, Rodney and Taurange County Councils and the Whakatane District Council. This assistance is gratefully acknowledged by the AERU.

P.D. Chudleigh
Director

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Special mention must also be made of the typists, Cathy Hill and Gillian McNicol, whose efficient typing throughout the study, prevented any dust from settling on the findings.

SUMMARY

A recent requirement of the National Roads Board is that all fund applications for roading improvement works must be ranked for priority on the basis of cost-benefit analyses.

This exploratory study attempts to place a value on a previously unquantified benefit from sealing roads; increased returns from agriculture and horticulture due to road dust removal.

Because of time and resource constraints, all information used in the report was gained indirectly, through a host of other partially related studies and in consultation with a wide range of technical and agricultural experts. Hence due to the uncertainty surrounding many of the assumptions used, all results of the study are expressed as a range of possibilities.

Chapter three outlines all possible physical effects of road dust on production systems along unsealed roads. The most significant of these include: (1) reduced photosynthesis leading to loss of plant yield; (2) increased pest and disease incidence causing yield losses and reduced quality of horticultural produce; (3) hindered pollination, especially in small seeded fruits; (5) animal health problems (e.g. ovine pneumonia and pinkeye).

Chapters four, five and six confront the factors affecting the generation and distribution of road dust and develop a model to predict the physical production losses.

Chapter seven quantifies the range of costs to a number of enterprise types and Chapter eight relates the findings to practical usage in roading economics.

The report concludes that high value, intensively grown horticultural crops suffer the greatest costs from road dust and that road dust damage through such areas may, in part at least, justify road sealing programmes. Certainly, further research into the subject is warranted.

Conversely, costs to traditional pastoral type farms incur only relatively minor costs.

CHAPTER 1

INTRODUCTION

"Ashes to ashes, dust to dust ..."

1.1 Background To Study

The economic boom, caused by high agricultural export prices during the 1960's and early 1970's, brought with it seemingly extravagant rural roading policies based largely on political rather than economic decisions. The increased expectations of rural dwellers during this period, combined with the substantial availability of roading funds, tempted many rural councils to pursue blanket roading objectives; to seal all roads.

This situation has changed drastically since 1973 due mainly to the effects of the oil price hike and to a severe downturn in agricultural export prices.

Roading funds as a percentage of total rural council expenditures have been substantially reduced and the trend is likely to continue. Hence, although approximately 62 percent of rural roads in New Zealand are still unsealed (excluding State Highways) (N.Z. Yearbook, 1983) rural roading programmes are being restricted chiefly to maintaining the existing structure rather than to upgrading it.

In response to these economic pressures, the National Roads Board (NRB) have introduced a requirement that all fund applications for roading improvement works must contain a cost-benefit analysis; from which project priorities are ranked.

For roads where sealing programmes are planned, the NRB presently acknowledges the inclusion of the following quantifiable benefits from sealing:

(1) accident reduction resulting from improved visibility and greater surface stability;

(2) lower vehicle operating costs due to decreased fuel consumption and less wear on parts;

(3) reduced travelling times facilitated by improved smoothness of roads;

However, other benefits identified include:

(4) increased returns from agriculture and horticulture due to dust removal;

(5) reduced road maintenance costs, especially on roads carrying high volumes of traffic;

(6) social improvements from dust removal e.g. health benefits and reduced cleaning times.

With competition for funds for roading improvements now very intense, 62 percent of New Zealand's rural roads still unsealed, and a recent large increase in high value horticultural production in rural areas, the fourth identified benefit (increased returns to agriculture and horticulture) has gained a greater level of recognition. In November 1982, four North Island county councils (Waikato, Whakatane, Rodney and Tauranga) commissioned the AERU to undertake an 'Assessment of the Effects of Road Dust on Farming Systems'.

This report sets out the findings and methodologies used in that investigation.

Although the findings for the four counties studied were similar, certain factors (e.g. silt content of roading materials and climatic factors) require that broad generalisations about the magnitude of effects of road dust on production, for the whole country should not be made. Hence in this report all figures used, pertain only to Tauranga County.

1.2 Previous Studies

Little previous research has been carried out on the effects of road dust on agricultural or horticultural production, although considerable work has been conducted concerning related topics.

1.2.1 Atmospheric levels of road dust pollution.

It has been generally accepted that dust originating from unpaved roads can aggravate respiratory ailments, create driving hazards and cause considerable discomfort to those living alongside these roads. However, it has only been recently that studies have been undertaken to establish the nature and extent of the road-dust problem.

With the imposition of strict air pollution regulations by both federal and state authorities in the United States during the last decade, environmentalists have concluded that road-dust emissions are of greater significance to air pollution levels than initially thought. This realisation led to a number of attempts to quantify the amount, concentration and distribution of dust coming off roads, including those by: PEDCO Environmental Specialists (1973), Handy et al. (1975), Roberts et al. (1975), Heinsohn et al. (1976), Dyck and Stykel (1976), Becker (1978), McCaldin and Heidel (1978), Hoover et al. (1981) and Ward et al. (1979).

The findings of these studies have been used in this report as the basis for estimating deposition levels of road dust on productive land.

1.2.2 The effects of various inert dusts on plant, animal and insect biological processes.

The Mount St Helens volcanic eruption during May 1980 initiated the most extensive research to date on the effects of particulate matter on a host of biological processes related to agriculture and horticulture. Most was conducted by the Washington and Oregon State Universities and also various environmental agencies within these states.

The effects of the volcanic ash on insect capacity, animal respiration and digestion, plant growth and fruit production were some of the major areas studied. The findings are of particular significance to the road dust study, as volcanic ash is one of the few forms of particulate matter studied to date which, like road dust, is relatively inert.[1]

Other related research areas include studies into the effects of inert field and road dusts on:

(1) Insect populations (Fleschner (1958), Alexandrakis and Neuenschwander (1979), Avocado Grower (1982)).

(2) Plant respiration, transpiration and photosynthesis processes (Auclair (1976), Eller (1972, 1977), Tabata and Tanabe (1977), Ricks and Williams (1974), Stanhill et al. (1975), Gourdriaan and van Laar (1978), Danno et al. (1980).

(3) Animal physiological processes (Kirton et al. (1976), Barnicoat et al. (1957), Healy and Ludwig (1965), Bruere et al. (1975)).

In addition to these published sources additional information was gained by personal correspondence with a number of the authors and other researchers.

The only known attempt to place a value on the costs of road dust to agriculture was a very basic attempt by Norton (1969). He based his calculations on the assumptions of:

(1) 'good' dairying land

(2) 200 metre dust drift from the road

(3) 5 per cent production loss for the affected area.

Although they were intended only as an illustration, Norton's figures have been used by several others since (Harkness (1976), Inglis and Dunlop (1980) and Taupo County (1981)) with no attempts made to extend or validate them. Obviously the figures are too crude to be used in any quantitative analysis.

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[1] Inert dusts include volcanic dusts, road dust and field dust, which do not react chemically with animal or plant matter, as opposed to toxic dusts such as coal, cement and sulphurous dusts.

Dust can affect, either directly or indirectly, both the yield and marketability of produce. It is the aim of this study to isolate all factors influencing economic returns, and to quantify them as benefits as far as possible, expressed in terms of gross margin per unit of productive land, adjoining each kilometre of newly sealed road.

CHAPTER 2

DATA AND METHODOLOGY

Because of time and resource constraints, most information used in this report was gained from published articles and the opinions and observations of a wide range of technical and agricultural experts. As much of the information received lacks proven validation and because there are so many external variables influencing the effect of road dust on production, a large number of assumptions and generalisations necessarily have been made. As a result, the final benefits from dust removal have had to be expressed as a range of possibilities, depending on circumstances and with the proviso that further scientific investigation is needed.

2.1 Sources of Data

A computer based 'on-line' search for published material concerning the emission, dispersion and effects of non toxic dusts on production was conducted using the Lockheed-Dialog system.

In addition, an extensive manual search of abstracts, indexes and directories was made in the Lincoln College, Christchurch Public, University of Canterbury, and the Department of Health (Christchurch) libraries for relevant information, which was then procured through the library Inter-loan system. Relevant bibliographical searches were also conducted.

Letters requesting information on all aspects of inert dusts and their effects were sent to individuals, research organisations and government departments, both in New Zealand and overseas. This approach yielded valuable specific information.

Staff in various departments of Lincoln College, the D.S.I.R., the Ministry of Agriculture and Fisheries and various other organisations around Canterbury were used as a constant information resource pool throughout the project. A field trip to the participating councils was conducted to gain specific knowledge of the dust problem.

2.2 Methodology

Due to the shortage of suitable information regarding the effects of road dust on rural production, this study entailed a search for raw data, both objective and subjective, which was adapted, integrated and extrapolated to provide a basis for making assumptions and for conducting sensitivity analyses of possible effects. The general procedure of the study is as follows.

2.2.1 Identification of possible effects.

As a starting point, it was decided to try and find exactly how road dust may affect agricultural and horticultural production.

A list of possibilities was established and each item researched for its potential significance to production. This research resulted in some further effects being added to the list, an idea of the degree of influence which could be expected from each, and also in some effects being deleted from the list.

2.2.2 Isolation of influencing factors.

All possible factors which may influence both the amount of road dust reaching productive land and the distance which it can travel were considered and investigated. These were grouped according to their ability to be used in a road dust model. Basic assumptions were made regarding those which could not be used, while those that could were later assigned values.

2.2.3 Estimation of area of productive land affected.

In order to estimate how much production is being lost, some idea of how much land is being affected by road dust had to be estimated.

Results from various studies into road-dust drift were extrapolated and combined to provide a basis for estimation. These were manipulated to allow for the influence of shelter-belts and different roughness heights of ground cover.

From this information, assumptions were 'guesstimated' regarding the distance of drift and amount of affected area per kilometre of metal road. They were assigned a high and low value in an attempt to overcome errors of estimation.

2.2.4 Quantification of road dust effects.

Unfortunately, time and resource constraints prohibited a thorough quantification of each effect of road dust on production. In fact only one, depressed plant yield due to decreased light intensity reaching leaf surfaces was able to be quantified and a model was thus set up to estimate this effect.

A road dust emission factor based on vehicle speed and road silt content, developed in the United States, was used as the basis for the model. From this, daily road-dust emission levels were calculated for three different intensities accounting for the differences in traffic volumes of various county roads. By dividing these emission levels by the amount of area affected, and taking into account type of ground cover and shelter belts, a range of daily deposition levels per unit area of ground was found for different land use types.

The average density of dust present on leaf surfaces, on any dry day, was then calculated. A range of high, medium and low numbers of expected days per month on which road dust could occur, together with the average number of days of dry weather after a rainfall event, with a road drying time difference for winter and summer, was computed to give the accumulated average amount of dust present per unit of ground area per day. A further allowance was made for the amount of leaf area per unit of ground area, and the type of leaf surface (i.e. pubescent or glabrous), providing the accumulated average amount of dust present on leaf surfaces per unit of ground area per day.

Tests replicating the leaf surface deposition levels were conducted, using a black box and light meter, to measure the amount of light intensity reaching leaf surfaces which is reduced by varying levels of dust deposition. The reduction in light intensity results were related to yield loss by the use of an asymptotic exponential function which gives the amount of photosynthetic reduction with decreasing levels of light intensity and then, by accepting the theory that yield and photosynthesis percentage changes correspond exactly.

All the other possible effects of road dust on production (e.g. increased pest and disease incidence, dust on fruit and poor pollination) were either too speculative as to their significance or too variable, without considerable experimentation and monitoring, to attempt placing precise values upon them. A few quick calculations were attempted using predicted losses by scientists but it was felt that these, in reality, were too high.

Thus, it was decided to use conservative estimates of:

(1) High = 1 per cent influence

(2) Low = 0.5 per cent influence

on either yield or downgrading, to show the magnitude of effects dust could have on returns within the affected area. The use of two figures is to show just how sensitive returns are to any losses over such an area and also partly, to illustrate the high degree of guesswork involved.

2.2.5 Enterprise analysis.

The gross margins for one year production systems and a single year of established long-term crops were used to assess the economic impact of road dust on production. The factors thought to be significant in terms of production returns for each enterprise type were identified and analysed individually to show the magnitude of economic effect which each may have. As an illustration, each effect was combined, using a conservative estimate for each, to show a possible loss of revenue due to road dust per kilometre of road.

CHAPTER 3

POSSIBLE EFFECTS OF ROAD DUST

Road dust is believed to be related to a number of factors affecting both the yield and/or marketability of produce grown alongside unsealed roads. An extensive list of possible effects of road dust on production is given below. Some of these relationships appear more realistic than others and whenever possible, some conclusion is drawn regarding the likelihood of significant effects of road dust.

3.1 The Effect of Dust on Leaf Surfaces with Regard To Plant Photosynthesis, Transpiration and Respiration Rates

Dust cover on leaf surfaces may affect yield in a variety of ways, with the yield reduction depending upon the thickness of cover and to an extent, the type of plant. The effect is likely to be greater on plants with pubescent leaves as these retain a greater amount of dust, even after a moderate rainfall.

3.1.1 Photosynthesis.

Photosynthesis is the process by which energy of sunlight is absorbed through the leaf surfaces of green plants and used to build up complex substances from carbon dioxide and water. This process provides the fuel for plant growth; any reduction in photosynthesis is accompanied by an approximate corresponding percentage loss of plant growth and yield.

Cook et al. (1980), investigating the impact of the Mt St Helens eruption on agricultural production, found that a coating of ash 1mm thick on a leaf surface reduced photosynthesis by 90 per cent and that a lighter coating reduced it by 25-33 per cent.

Exactly how plant growth and yield are affected appears to differ, depending on plant type and circumstances. Storey (1983, pers. comm) predicted that a probable major effect would be a cumulative retardation of plant growth and maturity time, thus diminishing expected crop yields each year. Cook et al. (1980) hypothesised that reduced photosynthesis may also be responsible for the early senescence of leaves, thus further retarding plant growth.

Jackson (pers. comm., 1983) noted that in the presence of adequate water and nutrients, a reduced photosynthesis rate could directly affect fruit production in three ways:

(1) by a reduction in the number of buds formed, resulting in lower flower initiation and hence, lower fruit setting;

(2) by reducing fruit size due to an inadequate supply of carbohydrates. This is important in fruits (e.g.apples and kiwifruit) which are graded for size. However, low bud formation may offset this effect;

(3) by lowering the sugar content of fruits. Some fruits (e.g. grapes and kiwifruit) are harvested according to sugar levels and low readings will delay harvesting. This may be a crucial factor in marginal areas which are susceptible to frosts.

Although it was too complex to isolate and quantify each effect caused by reduced photosynthesis in this study, an attempt has been made to predict the overall yield loss from road-dust related photosynthesis reduction. This is set out in Chapter 6.

3.1.2 Stomatal interference.

Dust particles of a size range less than 5µm in diameter can interfere with the mechanism of stomatal pores. These small openings are largely responsible for the basic respiration and transpiration functions of plants.

Work by Ricks and Williams (1971) and Eller (1977) indicate that plugging of stomatal pores by small particles may lower the rate of respiration and also the maximal stomatal diffusion resistance at night. However Gallagher (1983 pers. comm) held that these effects would be very small and likely to be of little significance to yield.

Further, Stanhill et al. (1975) found that Kaolin dust applied to crop foliage during a drought period in Israel, actually increased crop yield by 7 - 20 per cent over a three year period. The dust had the effect of increasing the reflectivity of plants and reducing their transpiration heat load, thus increasing transpiration resistance. Road dust, although not as reflective as Kaolin, may have a similar effect and it cannot be discounted that during dry summers, such as in 1982/83, road dust could actually aid yield by:

(1) alleviating drought damage to plants at critical growth stages;

(2) reducing the potential water demand from the atmosphere.

However, it is likely that few areas in New Zealand would ever experience the severity or length of droughts experienced in Israel.

Thus for now, all yield effects caused by road-dust induced stomatal interference are assumed to be negligible.

3.2 Increased Incidence of Plant Pests and Disease

Although there is little hard evidence on the subject of dust as a predisposing cause of plant disease and increased pest infestation, opinions and observations of several growers and scientists tend to support a relationship. The effects vary according to plant type and in some cases the type of fruit produced. However some of the major problems include the following:

3.2.1 Establishment of conditions conducive to disease initiation.

Dust accumulation in the nooks and crevices of fruit and plant surfaces aids moisture retention, thus providing, in the right conditions, a medium for the growth of bacteria and fungi.

3.2.2 Pest-beneficial insect population balances.

Studies by Alexandrakis et al. (1979), Fleschner (1958) and Bartlett (1982) prove that generally, road dust inhibits the activity of beneficial insects and consequently increases the damage from pests. The reason stems chiefly from the habits and structures of the respective types of insects [2] and the mode of action of dust.

Beneficial insects, primarily the predators and parasites of insect pests, are particularly susceptible to three modes of action of dust on their systems, which can be lethal.

(1) Dessication may be facilitated by dust by abrading the epicutular waxes, thereby increasing the permeability of the cuticle, by exposing the permeable intersegmental membranes, and by increasing the evaporative area of the body.

(2) Starvation may be caused by the formation of a mechanical barrier to the insects' food supply, by impeding their movement or by clogging their digestive systems.

(3) Respiration may be hindered where spiracles are clogged by dust particles.

The reasons for their vulnerability to these effects, compared to the pest insects, stems from a number of factors.

(1) Whereas most pests are relatively immobile, parasites and predators must search over the leaves and fruit of plants if they are to control the pest species satisfactorily. The more efficient the benefit insect is in this respect, the lower will be the host population and the greater will be the surface area of the plant over which the beneficial insect must travel. Hence, on dust covered plants, as the amount of travel required over dusty

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[2] For convenience, the term 'insect' is used loosely to include all mites, etc.

surfaces by beneficial insects begins to increase, so too does the death rate of beneficial insects, thus moving the population balance back in favour of the pest community.

(2) Some pests are well protected from dust deposits by wax covers or by hard, thick body walls. Conversely, few beneficial insects have any special protective covers to shield them from dust.

(3) In contrast to pest species, which are in constant contact with a food supply of living plant material which is high in moisture content, beneficial insects do not have a constant supply of food and water available. Adult parasites generally depend upon the chance supply of natural sugars (honeydew and nectar) as their main source of food and water, while predators supplement this by feeding off their host.

Thus (as in their search for hosts) beneficial insects must travel almost continuously over the surface of the plants in the search for food and water. This constant contact with dust becomes especially critical when the dust has a desiccating effect on the insect, as there is little opportunity for them to replenish vitally needed water.

(4) Most pest species have piercing mouthparts which penetrate the plant cuticle, so that these pests feed on clean, dust free plant sap. On the other hand the honeydew and nectar which parasites, and to a lesser extent predators, depend on for their food source, are found exposed on plant surfaces. These foods could be so covered by dust deposits that they are unavailable to beneficial insects, or they may be so contaminated with dust particles that digestion is impaired; both can result in death by starvation.

(5) Dust adhering to the beneficial insects delicate sensory organs, used to locate and recognise food and host insects, may dull the insects′ senses, agitate them and cause them to depart the area, or may slow down their rate of travel, so that their searching capacity is reduced. Each can ultimately lead to starvation.

These factors tend to support the findings of Alexandrakis et al. (1979) that the beneficial population increased and the pest population decreased further away from an unsealed road-dust source.

3.2.3 Spray effectiveness.

Closely aligned with the problems already mentioned, is the detrimental effect which dust has on the effectiveness of many agricultural sprays.

A basic aim when spraying plants is to gain maximum retention of spray droplets on the leaf surfaces. Dust may affect this retention ability and also reduce plant uptake of chemicals where applicable. Although producers would usually spray after rain when leaf surfaces are clean, lengthy dry spells during summer may necessitate spraying at suboptimum times in terms of spraying efficiency.

(1) Herbicides.

All except those which are soil applied must be absorbed by the leaf; thus a dust cover will impede this movement. Also, some herbicides (e.g. Roundup) are known to be deactivated on contact with the soil surface, due largely to the effect of soil micro-organisms. Although it has not been conclusively proven that road dust will produce this effect, producer observations and work by Dunn (pers. comm., 1983) at the Sariab Agricultural Research Station, Pakistan, support the view that spray effectiveness is severely reduced when road dust is present.

Dunn found that when Paraquat was applied to broad-leafed weeds at both single and double strength following dust storms, that the spray had little effect and further, that wetting agents did not improve the effectiveness.

Field (pers. comm., 1983) suggests that where no weed control is achieved in low growing crops (e.g. cereals and berryfruit) then production loss could be as high as 100 per cent for the affected area, due to either increased weed competition or to reduced harvesting efficiency. However he feels that a more realistic loss may be in the vicinity of 20 per cent.

(2) Pesticides and fungicides.

Only the systematic and eradicant action sprays may be affected, with their uptake by plants possibly being impeded by a dust layer. Resultant increases in pest or disease incidence can hinder plant growth, affect fruit set, or damage fruit appearance.

3.3 Reduced Light Intensity on Fruit

Highly coloured fruits (e.g. red apples, nectarines and peaches) require high light and low temperature to achieve full colour. Road dust present on fruit surfaces may reduce the light intensity reaching fruit so that expected colour levels are not achieved.

The Apple and Pear Marketing Board's grading schedule requires that coloured varieties of apples contain a minimum colour percentage for each grade. Standards for nectarines and peaches are not specified, but under-coloured fruit would probably be down-graded, at least from export designation to local market.

3.4 Pollination

Well pollinated flowers are a basic requirement for the development of large and well formed fruit. Although there have been no scientific investigations conducted into the effects of road dust on pollination, many growers and several Ministry of Agriculture and Fisheries Advisors, have strong suspicions that road dust on the flowers of small seeded fruit plants (e.g. kiwifruit, strawberries, blueberries and raspberries) can cause substantial losses in affected areas.

Of particular significance is the kiwifruit which, even without a dust coating, has a fairly unattractive flower to insects. It is suspected that a dust coating on flowers may dissuade bees from pollinating them effectively, leading to either:

(1) total flower abortion; or

(2) the development of 'scrub' fruit not suitable for export.

3.5 Rejection and Down-Grading of Horticultural Produce Due to Road-Dust Contamination

According to the horticultural marketing trade, little produce is rejected or downgraded because of dust contamination. However many growers, either trying to establish or to protect a good name, grade out any contaminated produce so that it does not reach the market.

Dust contamination affects different produce in different ways and to varying degrees. Pubescent fruits (e.g. peaches), berryfruit and leafy vegetables are perhaps the worst affected as dust particles cannot be removed effectively.

Kiwifruit for export undergoes a dehairing process which rids it of most dust, but sometimes enough dust can remain on the fruit to cause downgrading. This effect can be accentuated when the fruit has been wet. A combination of the dust and moisture can produce a stain on the fruit. Likewise, export apples are subjected to a waterdumping and polishing process. However, where dust has accumulated in the stem cavity at the end, this method may not be sufficient to pass the fruit for export.

Dust causes citrus fruit to lose its lustre, a problem which graders do not entirely solve. This impairment of the fruit's attractiveness tends to lower its market price.

Asparagus can be affected when grit gets down into the spears and cannot be removed. However, a major problem can occur when packing sheds are situated in the vicinity of metal roads. Asparagus is packed wet, with the insides of packing boxes kept moist. Hence a dusty atmosphere within a packing shed can involve a significant penalty to the grower.

Also as mentioned before, small, deformed or diseased fruit can necessitate quite large amounts of down-grading or even dumping. However because much of the grading is conducted informally, only rough estimates can be made of how much produce is actually down-graded or dumped due to dust.

Government regulations state that all produce for export, and its packaging, must be clean and free of disease and dirt. In addition, marketing authorities require that most produce meets set standards regarding , for example, size, shape, and colour.

Several producers mentioned that significant quantities of produce, grown alongside unsealed roads, are often not submitted for export, due to either the direct or indirect effects of road dust, and a further amount are graded out by marketing authorities. Depending upon the extent of the problem, there are a number of alternative ways of dealing with sub-export standard produce. These are given below.

3.5.1 Place in local auction market.

Top quality fruit sold on the local market generally returns to the producer from about 20 - 60 per cent of that gained on the export market, depending on fruit type. However, produce which has been contaminated by dust would on average, receive only about 66 per cent of that gained by premium produce submitted to the local market (Russel, pers. comm., 1983).

Further, if a grower were submitting a percentage of sub-standard fruit, this may have the effect of dragging down the price of even his best quality produce, as buyers often make decisions on the basis of grower reputation.

3.5.2 Gate sales.

Several growers agreed that gate sale prices of poorer quality produce, in general, are about 30 - 40 per cent below prices received for good quality produce in the market. Selling by this method has the advantage of protecting the growers′ name in the marketplace. However, it is often not a serious alternative for growers on metal roads, as many such roads do not get enough through traffic to sell sufficient quantities of produce, to make gate-selling economic.

3.5.3 Sell as process grade.

This involves a much reduced price but has the advantages of being quick, convenient and often a least cost method of clearing substandard fruit. There are several drawbacks however. Firstly, it is usually only a feasible alternative for growers situated in the vicinity of processing plants, and secondly, processors often require that contracts be signed before the produce is harvested. Hence any shortfalls must be met with high quality produce.

3.5.4 Dumping.

One method, used most frequently by market gardeners and berryfruit growers, is simply to dump or abandon dust damaged produce.

Several berryfruit growers mentioned having to abandon the harvest of berries, and two market gardeners cited cases where they had ploughed in or fed to pigs, leafy vegetables grown in the nearest few rows bordering unsealed roads, because of dust contamination

They felt that it was often cheaper, easier and more beneficial in the longer term to dispose of inferior produce in these ways, than to sell it off at minimal rates. This helps to ensure that good prices are gained by top quality produce and also protects the grower's name.

3.6 Road Dust as a Fertiliser

Although road dust is considered to be a relatively inert material, in some instances it may contain quantities of nutrients which can be taken up by plants through their leaf surfaces.

Dust from glacial and recent soils have many primary minerals (e.g. phosphate and potash), which are relatively unweathered and available to plants, and these are likely to provide some benefit to plant growth. The predominant gravels used on most New Zealand roads however, are namely greywacke, volcanic and well weathered materials which are fairly low in primary minerals. But there are two other ways in which the nutrient supply to plants may be affected by road dust.

O'Connor (pers. comm., 1983) points out that organic matter on roads can be pulverised and included with the dust from roading materials. This has a significant effect on the growth of roadside plants growing on poor substrata (e.g. hard hill country sheep farms) but probably has little effect on plants growing on rich soils (e.g. horticultural properties).

Further, Dunn (pers. comm., 1983) notes that in areas where local materials are limestone derived, continual deposition of road dust can lead to increasing soil pH levels which can accentuate any trace element deficiencies. This is also true for roads which are lime stabilized.

Overall it is unlikely that these fertiliser effects have a great effect on plant growth and yield on the more intensive farming areas of New Zealand and hence, they have been assumed to be negligible for the purposes of this study.

3.7 Ovine Pneumonia

Pneumonia is one of the commonest diseases of sheep in New Zealand and may affect most young sheep during their first two years of life. The disease is usually subclinical or accompanied only by coughing, but serious outbreaks do occur.

Davies (1974) found that pneumonia accounted for 9% of deaths in adult sheep during a survey in the Hawkes Bay, and Pyke (1974) found a slightly higher incidence in the King Country. Sheep deaths in Tauranga County average around 5 per cent of the flock per annum (New Zealand Meat and Wool Boards' Economic Service, 1983). Thus, assuming that Davies and Pyke's results are reasonably representative of all North Island districts, it could be that pneumonia accounts for about 0.5 per cent of all adult sheep deaths on Tauranga farms.

Kirton et al. (1976) reported from a 5 year experiment with 3243 lambs at Ruakura Animal Research Centre, that moderate to severe pneumonia, on average, reduced carcass weight by 0.45 kg per lamb, but that only 6.5% of lambs were affected to this extent. (Total prevalence of pneumonia in the flock averaged about 60%).

Also, occasionally lesions cause damage to the visceral pleura. Secondary pleurisy follows with fibrous adhesions between the viscera and parietal pleura. This results in the down-grading of carcasses at meatworks. Over the 1982/83 killing season at all northern meatworks, on average 0.2% sheep and 0.1% lamb carcasses were condemned due to pleurisy.

The pathogenesis of pneumonia has not been finally elucidated. However the consensus of scientists is, that it is the result of an interaction between a primary virus and other infection, bacterial secondary invaders, and environmental factors (Kirton et al., 1976).

Further, Davies (pers. comm., 1983) deduced that dust could be one of these factors.

Although there is no hard information on the adverse effects of dust on ovine pneumonia, many scientists, including Davies and Manktelow (pers. comm., 1983) strongly suspect that dust particles up to 3 μm in diameter, reaching the respiratory tract in appreciable numbers, may overload the normal clearance mechanisms, thus preventing the removal of harmful bacteria.

Approximately 30-50 per cent (by weight) of all dust coming off Tauranga County's unsealed roads is 3 μm or less in diameter (Ministry of Works and Development, 1983). Thus assuming road dust deposition levels from 90,000 - 600,000 grams per kilometre per dry day (calculations shown in Chapter 6), a range from about 90,000 - 300,000 grams/kilometre of road, of fully respirable road dust is drifting onto pastures adjoining unsealed roads every dry day of the year.

This is an appreciable amount and it seems reasonable that where sheep are frequently grazing paddocks bordering unsealed roads, that road dust could be a factor in the development of ovine pneumonia.

3.8 Excessive Teeth Wear

There has been some speculation that road dust may also play some minor role in the wear of grazing animals' teeth leading to premature culling. However, dental researchers tend to agree that this effect is of no real significance, and that the major cause is soil ingestion. Experiments by Ludwig et al. (1966) confirm this opinion, showing that 70 per cent of teeth wear occurs between July and October, when there is a reduced dust problem.

3.9 Lowered Weight Gains in Animals

Physiologically it would appear that road dust ingested with normal pasture feed has little or no effect on either animal weight gain nor on the level of milk production. Preston (1980) investigating the after-effects of the Mt St Helens eruption found that:

(1) day old chicks suffered a 6 per cent growth reduction for each 10 per cent of ash and a 4 per cent reduction for each 10 per cent of sand included in total dry matter per cent intake;

(2) dairy calves with a 10 per cent ash content of dry matter exhibited completely normal growth patterns;

(3) dairy cows which were subjected to an increase of ash content from 0 per cent to 6.3 per cent of dry matter over 5 weeks, maintained constant levels of milk production.

The dairy cattle findings are most compatible with the New Zealand pastoral sector and the levels of contamination mentioned here would be far in excess of any likely amount due to road dust. Hence it is most unlikely that road dust has any physiological effect on animal growth and development.

However, where stock are grazing pastures adjoining metal roads, dust may have an indirect effect on retarded growth rate. Observations indicate a reluctance by animals to graze the pasture along roadsides. Elvidge (pers. comm., 1983) speculates that road dust may be a cause, especially as similar observations of reduced forage intake have been noted on silt covered pasture, due to border dyke irrigation. However, evidence is far from conclusive and other factors such as traffic noise may be of primary importance.

If in fact it is dust which causes the depressed appetites, Elvidge estimates that the very maximum allowance for retarded growth rate would be around 20 per cent for each day the animal is kept on the contaminated pasture. This figure roughly represents the difference between reasonable and good feeding patterns.

3.10 Pinkeye (Contagious Ophthalmia)

Pinkeye can cause ulceration and blindness of animals' eyes and also lead to pregnancy toxaemia in ewes and the mismothering of lambs.

There has been no experimental work undertaken to show that road dust is a predisposing cause of pinkeye in either sheep or cattle but Cooper (pers. comm., 1983) believes that it seems perfectly reasonable that subclinical infections may be rendered overt by dust irritation. His belief is reinforced by many farmers living along unsealed roads who state that the instances of eye infections in animals grazed along roadside paddocks, is higher than those in paddocks away from the road.

3.11 Wool Yield

Road dust may lower the yield of wool from sheep grazed alongside unsealed roads but this will have little effect on returns as the yield of all clippings are tested and farmers paid out on the clean weight. Thus any loss of yield is compensated for by an overall greater greasy wool weight.

3.12 Conclusions

The most significant physical effects of road dust on agricultural and horticultural production would appear to be;

(1) reduced photosynthesis leading to loss of plant yield ;

(2) increased pest and disease incidence causing yield losses and reduced quality of horticultural produce ;

(3) dust contamination reducing fruit and vegetable attractiveness ;

(4) dust hindering the pollination of small seeded fruits by insects causing flower abortion and deformed fruit; and also possibly

(5) animal health problems such as ovine pneumonia and pinkeye.

However, any attempt to isolate and assess the effects of road dust on production cannot ignore the economic consequences of the effects. Hence road-dust is likely to have a far greater impact on horticulture than agriculture for the following reasons;

(1) horticultural land usually returns a far higher gross revenue per hectare;

(2) horticulture generates a much higher traffic volume, and hence much more dust, per kilometre of unsealed road;

(3) the nature of horticultural produce and grading systems make horticultural crops far more vulnerable to the effects of road dust;

(4) horticultural enterprises are small scale and generally sited near to roads.

Hence, this report focuses chiefly on the effects of road dust on horticultural production.

CHAPTER 4

SOURCES, DISTRIBUTION AND DEPOSITION OF DUST

For the purposes of this study, dust is defined as all particles which are less than 75 μm in diameter.

In attempting to assess the effect of road dust on production, it is not only necessary to identify all possible sources of nuisance caused by dust but also to make certain assumptions regarding any physical factors which may influence the rate of road dust emission, distribution and deposition.

4.1 Sources of Dust

Dust can be carried onto agricultural land from almost any site containing free particulate matter. However, there are three principle types of particulate matter affecting agriculture and horticulture. These are:

4.1.1 Road dust.

Any dust which originates from an unsealed road source, including the unsealed verges of sealed roads. However, only totally unsealed roads are dealt with in this report.

4.1.2 Ambient dust.

This includes all dust present in the atmosphere other than that from metal roads. Most originates from exposed ground subject to wind erosion such as cultivated paddocks and riverbeds. The amount varies, largely according to soil type, the amount of ground cover and wind conditions.

Ambient dust may be present on a macro scale, with no specific source identifiable (e.g. dust from a region experiencing a drought) or it may be on a micro scale (e.g. dust deposited on an orchard from an adjoining cultivated paddock) with a readily identifiable source.

4.1.3 Rain splash.

Although not strictly a form of dust, dirt particles splashed up by the impact of falling rain can contaminate ground crops (e.g. lettuce) and sometimes cover pasture plants.

All the above-mentioned forms of dust may be of significance to agricultural and horticultural production. However, this study concentrates only on the effects of road dust, for three reasons:

(1) road dust is the only form for which dust control can reasonably be carried out on an extensive basis (i.e. by sealing);

(2) road dust occurs in sufficiently large and consistent quantities to be both relatively important to production and reasonably predictable in distribution and deposition; and

(3) because road dust is emitted from a fixed point public good over a long period of time, there is a need to value the cost of the dust in order to evaluate dust control measures.

Calculations to predict levels and costs of road dust are made with the assumption that other forms of dust are non-existent. Although this is not entirely correct, it is practical because most production estimates are made using assumptions of normality. These would include moderate ambient dust conditions. Nevertheless if necessary, the other forms of dust could be distinguished from road dust:

(1) Macro ambient dust levels may be isolated by measuring dust deposition levels transversely at distances away from a metal road. When readings stabilise to a constant level, this can be assumed to be the normal ambient level. This is the method used in most dust measurement studies conducted overseas.

(2) Micro ambient dust, like road dust, has a well-defined source with a distinctive deposition distribution from that source. Thus any cases can be easily identified.

(3) Rain splash on plant surfaces can be differentiated from other forms of dust deposition by:

    (a) particles on low surfaces only;

    (b) larger particles than wind blown dust ; and

    (c) a blotchy type cover effect where concentrated splashes have fallen.

4.2 Road Dust Drift, Deposition and Retention by Plant Surfaces

4.2.1 Rainfall.

Rain has the double effect of both laying the dust from dry roads and also of cleaning plant surfaces covered in dust, although the extent to which this occurs depends largely upon the prevailing weather.

The number of days on which rain would cancel out any effects from road dust on plant or animal physiological functions in Tauranga County was calculated and translated into best and worst estimates of the number of days for each month, on which dust may be a problem.

The November-March figures were combined to give a five month summer average of 74 per cent of dry days on which dust may occur, with a high estimate of 91 per cent and a low of 57 per cent.

The winter average, from April-October, was 56 per cent dry days with a high of 79 per cent and a low of 34 per cent.

The actual figures for these calculations are contained in Appendix I.

4.2.2 Irrigation.

Trickle irrigation, the major method of irrigation used by horticulturalists in Tauranga County, has no effect on the amounts of road dust present on plants.

However, spray irrigation used by some growers can have a marked impact on the amounts of dust on plant surfaces. Basically, the effects are the same as for rain, i.e.

(1) washing dust off leaves ,

(2) washing dust into nooks and crevices ,

(3) dirt splash,

but there can be complications. Because the road is still dry while plant surfaces are made wet, dust deposited immediately after irrigation tends to adhere more readily to surfaces, and becomes more difficult to remove.

This can accentuate the dust problem but because it is more the exception in Tauranga County, its effect is excluded from calculations.

4.2.3 Time of year.

Agricultural and horticultural production and marketing cycles are directly controlled by the time of year. Thus the effects of dust will be of greater economic significance at certain periods than at others.

Deciduous trees are dormant over the winter months and so are not affected by dust during this time. However, during the dustiest months over the summer, plants are generally experiencing rapid growth, crops are ready for harvest and pest and disease incidence is often at its height.

Hence, when assessing the effects of dust on different enterprise types, it is necessary to consider these time related factors.

4.2.4 Wind.

The effect wind has upon dust plume dispersion depends largely upon the prevailing wind direction and to a much lesser extent, its intensity.

Work by Handy et al. (1975), Ward et al. (1979) and Hoover et al. (1981) show that dust levels on either side of a metal road can be almost identical for up to the first 20 metres. However, further away from the road the prevailing downwind side appears to receive roughly twice the amount of dust deposition as the prevailing upwind side, depending upon conditions.

Wind speed as a determinant of road dust plume dispersion and distribution is highly dependent on a number of other factors, especially surface roughness [3] and an advection component. Becker (1978) found that except over smooth surfaces, such as clear pasture land, wind speed has little influence on the distance which a dust plume may travel. Dust deposition is largely a result of the amount of interaction a plume has with the deposition surface.

Hence over rough surfaces, when a light wind is blowing, the advection effect is stronger, thereby lifting the dust higher and giving it more time to interact with the deposition surface. Conversely, with a strong wind the advection is greatly restricted and the surface interaction time is decreased. Thus an inverse relationship exists between wind speed and the advection component over rough surfaces, and this results in an insensitivity of dust deposition to wind speed.

Where smooth surfaces (e.g. pasture land) border metal roads however, wind speed has a direct influence on the distance and distribution of dust plume deposition. Thus the stronger the wind, the greater the deposition will be at locations away from the road. [4]

4.2.5 Roughness height.

The height of vegetation on land adjacent to metal roads has a significant influence on the rate of road dust deposition. Deposition close to the road is always greater over rough surfaces than smooth surfaces.

Becker (1978) showed that deposition differences due to the different roughness heights may be very large. This can be explained by the fact that surface roughness causes a larger friction velocity which in turn, enhances the deposition velocity resulting in more deposition.

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[3] Surface roughness is determined by the height of vegetation, prevalence of buildings etc. situated alongside a metal road.

[4] This factor is endogenously accounted for in the dust deposition model by the use of sensitivity ranging.

For the purposes of this study, three different roughness heights have been assigned, relating to different types of vegetation grown. These are:

(1) Smooth - includes ground crops, pasture land and bare paddocks;

(2) Medium - includes cereals, taller vegetable crops and cane grown berry crops; and

(3) Rough - orchards.

No allowance has been included for the effects of roadside buildings on deposition; however, where present, these would have a considerable influence on the surrounding dust fall distribution.

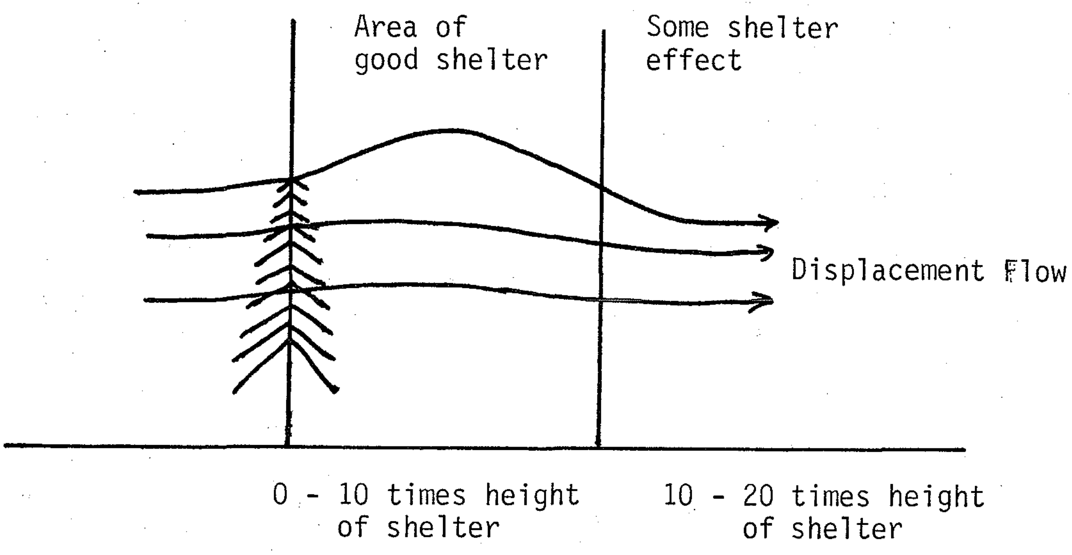
4.2.6 Shelterbelts.

The effect of shelterbelts on road dust deposition is virtually just an exaggeration of the concept of surface roughness. That is, they increase the surface friction velocity but to a larger degree than most rough surfaces, due to their greater height and continuous line.

Shelterbelts are designed to be 50 per cent permeable to wind (Batt, 1979) so that a smooth airstream is retained rather than pockets of turbulence.

FIGURE 1

Distance of Effect of a 50 Per Cent Permeable Shelterbelt on Flat Ground



It would seem reasonable to assume then, that a shelterbelt may reduce the amount of dust which reaches a paddock by up to 50 per cent. However, taking into account the displacement flow (Figure 1) which would cause some dust to be transported over the shelterbelt a realistic figure for the amount of dust retained by the shelterbelt may be 40 per cent.

Considering that wind speed has little effect on dust plume deposition except over smooth surfaces it is assumed that the remaining 60 per cent of dust, which gets past a shelterbelt, is deposited at a proportionally similar rate away from the road source, as dust when there is no shelterbelt present.

Another matter related to shelterbelts requires a brief mention. Although road dust is often a factor in poor plant growth and fruit production in the rows nearest to a road, two other possible factors should also be considered under different situations:

(1) When shelterbelts are present, they provide competition to fruit trees for sunlight, water and soil nutrients.

(2) Where there are no shelterbelts, the outside rows of trees may be stunted by wind stress.

Hence caution is needed to ensure that the magnitude of the effects of road dust on plant growth and crop yield are not overstated and that all possible influencing factors are examined.

4.2.7 Topography.

A metal road which winds through undulating countryside will not have a consistent distribution of dust deposition. The mechanics which apply to surface roughness also have an application here and there will also be areas of turbulence and wind funnelling. However, as topography constantly changes, the assumption has been made that the positive effects on dust depositions will cancel out the negative ones, thus leaving no overall effect of topography on plume deposition distribution.

4.2.8 Road maintenance.

Regular road grading and maintenance play an important role in reducing the level of dust which a metal road may emit. For convenience, the assumption is made that all roads are in reasonable condition, thus allowing emission factors developed by McCaldin et al. (1978) for well maintained metal roads in the United States, to be used.

4.2.9 Vehicle usage.

The types, speeds and numbers of vehicles using a metal road all affect the volume of dust emission from that road.

Vehicles travelling along metal roads cause airborne dust due to two mechanisms (Heinsohn et al. (1977)):

(1) the action of tyres that disturbs the road surface and causes it to adhere to the tyre and then be thrown from it, or to be directly made airborne by the motion of the car induced by the tyre or the vehicle;

(2) the action of aerodynamic wake behind the vehicle and the earth's surface wind that causes the airborne dust to be transported downwind.

Given these factors, it would follow that the amount of emission per vehicle pass would depend largely upon its:

(1) shape,

(2) weight,

(3) number of tyres,

(4) speed,

which would all affect both the aerodynamic wake and the amount of dust projection by tyres.

Unfortunately, due to lack of suitable data, no account could be taken of these factors in the study. Instead a rather crude daily emission level of road dust is used, which is the product of an emission factor (g/vehicle kilometre) and the daily traffic count.

4.2.10 Silt content of road.

The percentage of silt content contained in roading materials is a basic component of all dust generation models. It would appear that the amount of dust generated increases linearly per unit per cent increase of silt content (McCaldin and Heidel, 1979).

CHAPTER 5

ESTIMATION OF PRODUCTIVE AREA AFFECTED BY ROAD DUST DEPOSITION

Studies and experiments by Handy et al. (1976), Becker (1978), Ward et al. (1979) and Hoover et al. (1981) show that measurable quantities of road dust may be deposited at distances of up to 2,500 metres on the prevailing downwind side and up to 400 metres on the prevailing upwind side of a metal road. However, the amounts recorded at these distances would probably be too small to be of economic significance to any production system.

A comprehensive definition of the area of productive land adversely affected by road dust, is difficult to establish as the distributive mechanisms are rarely the same. However, by analysing, extrapolating, and manipulating data from previous studies and by applying the assumptions and expectations stated in Chapter 4 (i.e. for dust distribution, rainfall, shelterbelts, surface roughness etc.), it is possible to estimate a range of generalised distances from the roadway, within which road dust may be of economic significance.

5.1 Downwind Deposition

Becker (1978) estimated the total downwind deposition from an infinite instantaneous line source[5] of 1.0 g/m during neutral conditions at distances of 4, 8, 16, 32, 64, 128, 256 and 512 metres from the road.

Table 1 presents the averaged deposition levels recorded at each site, from sixteen tests in which the roughness height, atmospheric stability, deposition height, source height and wind speed were all varied.

These results are plotted on Figure 2 (solid line) and extrapolated to give a continuous line graph for the expected level of dust deposition downwind of an infinite instantaneous line source of 1.0 g/m, up to 550 metres.

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[5] A dust plume resulting from a vehicle traversing a dry unsealed road, may be considered as originating from a moving point source, or it may be treated, approximately, as an infinite instantaneous line source. Over large sampling periods, the difference in the two methods is negligible.

TABLE 1

Average Deposition Levels at Various Sites Downwind of an Infinite Instantaneous Line Source of 1.0 g/m

Distance from Road (m)	Average Deposition (g/m)
4	263
8	188
16	118
32	70
64	39
128	22
256	12
512	5

5.2 Upwind Deposition

Ward et al. (1979) studying the lead content[6] of pasture species adjacent to a highway and Hoover et al. (1981) measuring the level and distribution of road dust emissions prior to roading improvement programmes, discovered almost identical differences between upwind and downwind deposition levels at different distances away from the roadway. Their actual findings are graphed in Appendix II and the magnitudes of difference, as well as an average of the difference factors are presented in Table 2. These difference factors were applied to downwind deposition levels shown in Figure 2 (unbroken line) and extrapolated to give a prevailing upwind deposition curve (Figure 2 - dotted line).

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[6] Approximately 75 per cent of metallic lead in petrol exhausted from motor vehicles is in the form of lead particulates. These have similar aerosol properties as road dust particulates and thus, fairly similar deposition distribution patterns can be expected.

TABLE 2

Factor by Which Prevailing Downwind Road Dust Deposition Was Greater than that for Upwind Side

Distance from Road (m)	0	5	10	15	20	25	30
Ward's Experiments	1.06	1.74	2.0	1.93	2.0	2.1	2.5
Hoover's Experiments	1.01	1.70	1.5	2.40			
Average	1.35	1.72	1.75	2.10	2.0	2.1	2.5

5.3 Total Deposition Distribution

The areas under each curve on Figure 2 were calculated by physical summation and from these, the percentage depositions and cumulative percentage depositions on either side of the road, plus the contributing percentage of total deposition for each side at increasing distances away from the roadside, were calculated. These figures are tabled in Appendix III.

Calculations show that approximately 22.5 per cent of all road dust emitted is deposited back on the roadway area (assuming a 20 metre roadway width), that 57.6 per cent is distributed on the prevailing downwind side of the road, while only 19.9 per cent is deposited on the prevailing upwind side.

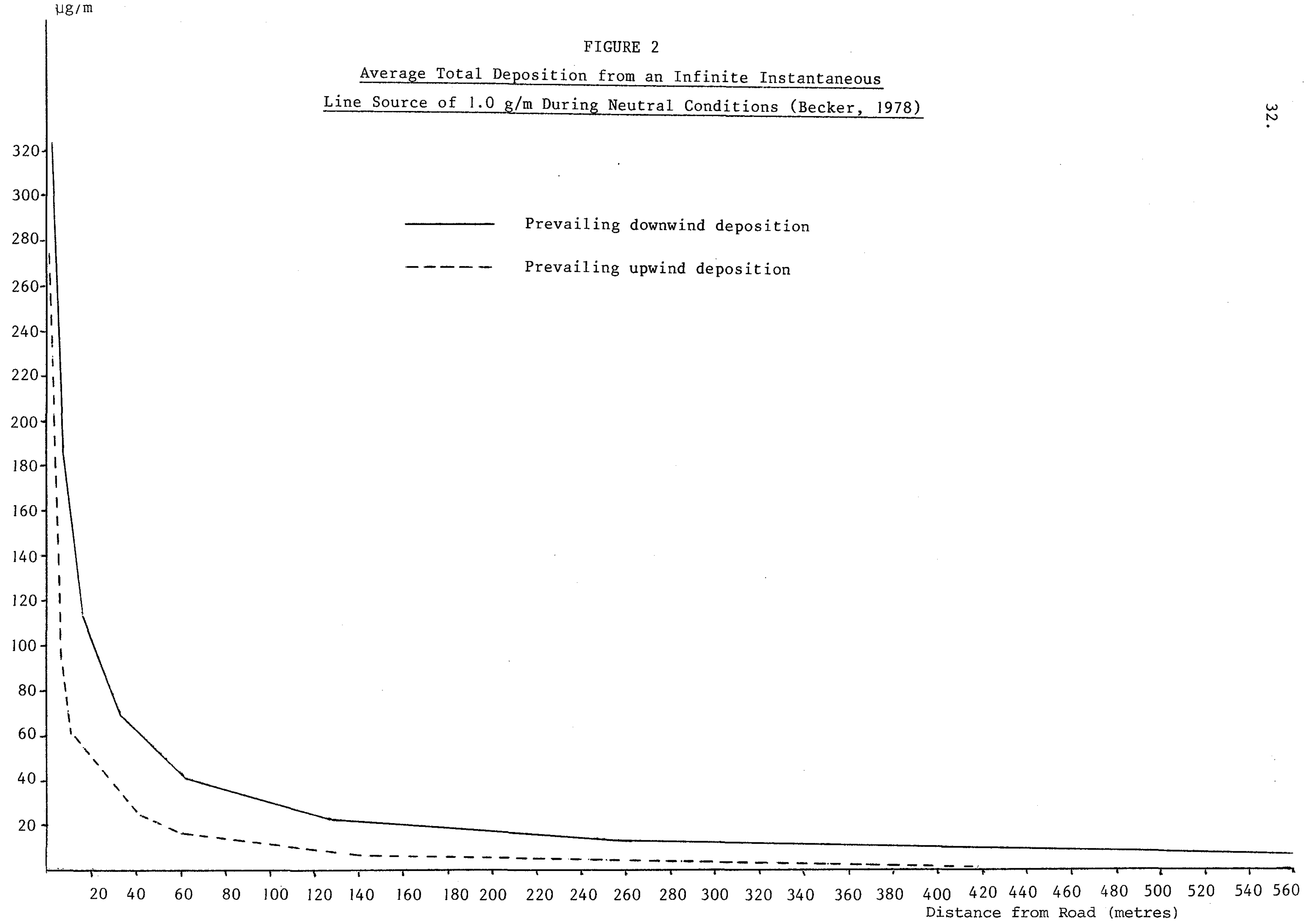
The deposition levels get gradually smaller away from the road with half of the downwind total being deposited within the first 70 metres of the road; half of the upwind total is assumed to be deposited within 30 metres.

5.4 Estimation of Significantly Affected Area

Because of the uncertainty and large number of variables influencing the rate and distribution of road dust deposition, high and low estimates of the productive area significantly affected by road dust have been used. Even so, the derivation of the figures for the distance from roads for which road dust may be significant, presented in Table 3, has necessarily involved a fair degree of guesswork based on the previous studies' findings and also on producer observations. However, these given areas are at least a first step towards an objective measure for road dust dispersion and are useful in conducting a sensitivity analysis of the effects of the dust on production.

FIGURE 2

Average Total Deposition from an Infinite Instantaneous Line Source of 1.0 g/m During Neutral Conditions (Becker, 1978)



The first estimates of effective deposition distances were gained for the prevailing downwind side of smooth pasture.[7] The high estimate of 250 metres from the roadside is the point up to where approximately 80 per cent of all dust is expected to have fallen. This distance is also reasonably consistent with producer observations of dust nuisance.

A low estimate for dust affected land downwind of a road is 100 metres from the roadside. Within this distance, approximately 60 per cent of all the dust blown downwind is expected to have settled.

TABLE 3

Estimated Range of Distances from Roadside in which Road Dust may be Significant to Production

Type Ground Surface	Prevailing Downwind Side			Prevailing Upwind Side		
	Low		High	Low		High
Smooth [a]	100m	-	250m	25m	-	60m
Medium	50m	-	150m	15m	-	40m
Rough	25m	-	100m	10m	-	25m

a For definitions see Chapter 4.2.4

The upwind figures were gained by reading across from the downward deposition levels at 250 metres and 100 metres respectively on Figure 2, to the prevailing upwind curve. The upwind distances for similar deposition levels are approximately 60 metres and 25 metres.

To allow for greater deposition rates over rougher surfaces, the distance of significant dust fallout from roadsides was reduced by about 30 - 50 per cent for medium surfaces, and by a further similar amount for rough surface types.

Thus, using the estimates of dust drift given in Table 3, the total areas of land which may be significantly affected by road dust, per kilometre of unsealed road are presented in Table 4.

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[7] Smooth pasture is assumed to be the base level of surface roughness and calculations for other types of ground surface are calculated from this.

TABLE 4

Area Affected by Road Dust Per Kilometre of Unsealed Road

Surface Type	Affected Area (ha/km)	
	High Estimate	Low Estimate
Smooth	31	12.5
Medium	19	6.5
Rough	12.5	3.5

Any effect on agricultural or horticultural production caused by road dust is assumed to occur at a uniform level over the total affected area. Although this obviously is not the case, it seems a practical way to deal with likely extremes of effect at varying distances away from the road, when the actual effects are not known precisely anyway.

CHAPTER 6

QUANTIFYING THE PRODUCTION EFFECTS OF ROAD DUST

Of all the possible effects of road dust on agricultural and horticultural production, at this stage only the effect of reduced photosynthesis on plant growth and yield can be predicted to any degree of accuracy. A model to measure the degree of photosynthesis reduction has been constructed, while all other factors have been assigned hypothetical levels of effect only.

6.1 A Road Dust-Photosynthesis Reduction Model

This model involves the estimation of the amount of road dust coming off roads onto various types of pasture land, and the calculation of the effect of the dust cover on plant processes.

Considerable experimentation and modelling of road dust emission levels has been conducted in the United States (Cowherd et al. (1974), Midwest Research Institute (1974), PEDCO Environmental Specialists (1973), Becker (1978), McCaldin and Heidel (1979)). Their findings, in conjunction with a number of necessary assumptions, have been used as a basis for the calculations of quantities of road dust deposited on leaf surfaces of plants along roadsides.

6.1.1 Dust emission factors.

A crude estimate of road dust emission can be made by assigning roads an emission factor, which is an experimentally derived empirical factor representing the mass of dust generated per length of road on which the vehicle travels. The crudeness of the parameter is apparent since it masks the effects of:

(1) the speed, shape, number of tyres and type of vehicle ;

(2) physical characteristics of the road surface ;

(3) meteorological conditions that affect the transport of dust ; and

(4) the size, distribution and density of the dust particles.

McCaldin and Heidel (1979) showed that the rate of dust emission from metal roads varies as a square of speed rather than directly with speed as had been earlier thought. Their equation appears to be a better fit to most experimental data than any others developed to date. It is expressed as:

$$Ef = 0.035\ (s)\ x^2$$

where[8]

Ef = emission factor per vehicle mile;

s = silt content of road surface expressed as a fraction; and

x = traffic speed in miles per hour.

In developing a generalised emission factor for Tauranga County roads, the following assumptions were made:

(1) the average speed travelled on the County's metal roads is 45mph (72 kph)[9]; and

(2) the average silt content of the road surfaces is 6 per cent.[10]

Thus the emission factor is given by:

$$EF = 0.035\ (.06)\ (45^2)$$

= 4.25 lb/vehicle mile

which converted gives

1200g/vehicle km.

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[8] For convenience, British Standard measures, as used by McCaldin and Heidel (1979), were used for computation purposes. Final figures derived were then converted to the Standard International System.

[9] The estimate of 45 mph (72 km/h) was made by considering the following factors: (1) cars regularly travelling on metal roads often exceed the legal speed limit, with speeds of around 60 mph (100 km/h) on open sections being common. However taking into account the need to slow for curves, hilly sections and intersections, 45 mph would seem an appropriate average estimate of car speed. (2) although no explicit allowance is made for vehicle type in the emission model, heavy vehicles generate considerably larger quantities of dust than cars at similar speeds. Thus although trucks would actually travel slower than most cars, the 45 mph speed estimate allows for their greater aerodynamic wake, number of tyres and greater weight upon the road surface.

[10] Two samples, one from a county quarry and the other from a county road, showed that local roading materials contain an average of approximately 6 per cent dust.

Taking the upper limit of the normal range, allows for the effect of weathering and abrasion on road surfaces, thus further increasing the percentage of dust particles contained in any sample.

6.1.2 Daily emission levels.

The total daily amount of dust emitted from any given county road can be calculated by multiplying the emission factor by average daily traffic count, viz:

$$Q = Ef\ ADT$$

where

Q = daily dust emission level (g/km/day);

Ef = emission factor; and

ADT = average daily traffic count.

A range of possible daily dust emission levels for the county can be estimated. Assuming high, medium and low ADTs of 500, 250, and 75 respectively[11] the resultant daily emission levels are shown in Table 5.

TABLE 5

Daily Dust Emission Levels for Tauranga County

ADT	Daily Emission Level (g/km/day)
500	600 000
250	300 000
75	90 000

The figures shown for daily road dust emission levels (Table 5) correspond fairly closely with other findings and may even understate the true level of dust emission.

The New Zealand Institute of Engineers standing committee on rural roads (1937) reported that the traffic wear on metal roads is assumed to be 0.475m per kilometre per vehicle per day, a figure used as a general rule of thumb by many engineers in New Zealand for adding annual aggregate replacements.

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[11] Daily traffic volumes are estimated from the traffic counts on unsealed roads submitted by the four participant counties. These appear to be applicable to each county.

This figure, assuming a dry, loose density aggregate weight of 1500 kilograms per cubic metre (MOWD, 1983) and say, a traffic density of 500 vehicles per day, provides a daily emission level of

$$\frac{1500 \times 0.475 \times 500}{365} = 976 \text{ kg}$$

compared to 600 kg (600,000g) derived using the dust emission factor.

In addition, Hoover et al. (1981) quantified dust sources and emissions created by traffic on unpaved roads and found that the average dust generation was 1 ton per mile per vehicle per year (631 kg/km/vehicle/year).

For an ADT of 500 vehicles per day this gives a daily emission level of:

$$\frac{631 \times 500}{365} = 864 \text{ kg}$$

Thus the fact that these two findings are fairly similar and are greater than the emission levels used in this report, indicates that the McCaldin and Heidel dust emission factor can be used confidently as a conservative estimate for New Zealand conditions, at least at this exploratory stage.

6.1.3 Deposition density.

The average density of road dust deposited on productive land may be calculated using the formula:

$$D = \frac{Q\,(1-R).K}{(a_1 + a_2)}$$

where

D = deposition of road dust g/m^2 /day ;

Q = daily dust emission level g/km/day ;

R = fraction of dust deposited on roadway ;

a_1 = downwind distances of dust influence (m) ;

a_2 = upwind distance of dust influence (m) ; and

K = length of roadway (m)

Applying this to the given estimated range of distances from the roadway within which dust may significantly affect production and also applying the fraction for roadway deposition of 0.225, the daily dust emission levels, and the average deposition densities of road dust on productive land in Tauranga County can be calculated. Table 6 presents these results.

TABLE 6

Deposition Levels on Productive Land Adjoining Metal Roads

Type of Ground Cover	Total Affected Area ha/km	Daily Emission Levels (g/km/day) 600 000	300 000	90 000
		Deposition (g/m^2)		
Smooth (Worst)	31	1.50	0.75	0.23
Smooth (Best)	12.5	3.74	1.87	0.56
Medium - No Shelter Belt (Worst)	19	2.46	1.23	0.37
Medium - No Shelter Belt (Best)	6.5	7.20	3.60	1.08
Medium - Shelter Belt (Worst)[a]	19	1.47	0.74	0.22
Medium - Shelter Belt (Best)	6.5	4.32	2.16	0.65
Rough (Worst)[b]	12.5	2.25	1.13	0.34
Rough (Best)	3.5	8.02	4.01	1.20

a Where shelter belts exist, the amount of deposition on productive land is assumed to be reduced by 40 per cent

b Assume all rough surfaced areas have shelter belts.

However, the actual density of deposited road dust present on flat surfaces may get much higher than the levels presented in Table 6, especially after a succession of dry days, each of which, contributes an additional quantity of road dust to the adjoining productive land. In fact, dry spells of up to 40 consecutive days have been recorded over the last 10 years in Tauranga County.

To compensate for long dry periods, an average deposition density to be expected for any one day was calculated.

The average number of dry days after any significant rainfall (4mm/day or greater) is:

(1) 10 days over summer period; and

(2) 5 days over winter period.

Adjusting for the accumulated average number of days deposition which is present on any dry day, found by;

$$\frac{\text{Sum of consecutive dry days}}{\text{Number of consecutive dry days}}$$

gives:

(1) 6 days deposition per day during summer; and

(2) 3 days deposition per day during winter.

The resultant average deposition densities which could be expected on land adjoining unsealed roads are shown in Table 7.

Two additional adjustments to these figures have been made to allow estimations of the effects of dust deposition on leaf surfaces to be undertaken. These include assumptions that:

(1) The deposition density of road dust on leaf surfaces is 30 per cent less than would be expected on bare flat ground.

(2) Retention on leaf surfaces would be reduced by a further 15 per cent for plants with glabrous leaf types.

The main reason for the 30 per cent reduction on leaf surfaces is to allow for the greater surface area of plants, per unit area of flat ground. It is also partly to allow for the varying degrees of leaf angle which affect the retention of dust by leaf surfaces.

At first it was felt that the figure of 30 per cent reduction should be higher, but it is likely that the natural layering effect of plant canopies, combined with the angled movement of dust toward the ground, would cause a great deal of the suspended dust to be intercepted by plants. Also, the outer leaves which receive maximum sunlight and are responsible for much of the photosynthesis of plants also receive the greatest amounts of dust cover. Thus, reduced levels of dust on inner and lower leaves is not so crucial to overall photosynthesis level.

The 15 per cent dust density reduction allowed on glabrous leaves is an estimation of the extra amount of dust not retained by shiny leaf surfaces. Obviously, pubescent leaves will retain dust particles to a much greater extent.

TABLE 7

Average Deposition Density Per Dry Day

Type of Ground Cover	Total Affected Area ha/km	DEPOSITION (g/m^2) DAILY EMISSION LEVELS (g)					
		600 000		300 000		90 000	
		Summer	Winter	Summer	Winter	Summer	Winter
Smooth (Worst)	31	9.0	4.50	4.50	2.25	1.38	0.69
Smooth (Best)	12.5	22.44	11.22	11.22	5.61	3.36	1.68
Medium (Worst) No Shelter Belt	19	14.76	7.38	7.38	3.69	2.22	1.11
Medium (Best) No Shelter Belt	6.5	43.20	21.60	21.60	10.80	6.48	3.24
Medium (Worst) Shelter Belt	19	8.82	4.41	4.41	2.20	1.32	0.66
Medium (Best) Shelter Belt	6.5	25.92	12.96	12.96	6.48	3.90	1.95
Rough (Worst)	12.5	13.5	6.75	6.75	3.38	2.04	1.02
Rough (Best)	3.5	48.12	24.06	24.06	12.03	7.2	3.6

The adjusted average deposition density of road dust for plant surfaces per dry day is presented in Table 8.

6.1.4 Reduction of light intensity to leaf surfaces.

The amount of light intensity reaching leaf surfaces, reduced by dust deposition, was simulated under artificial sunlight conditions.[12]

Figure 3 shows the amount by which light intensity to leaves is reduced by various densities of road dust coatings. A deposition density level of 10 grams per metre squared caused a light reduction of approximately 20 per cent and the highest level estimated (33.7g/m^2 — Table 8) caused a light reduction of approximately 43 per cent.

6.1.5 Photosynthetic yield loss due to road dust cover.

The percentage reduction of plant photosynthetic rates, due to reduced light intensity reaching leaf surfaces, roughly corresponds to the percentage loss of plant yield (Scott pers. comm., 1983). The yield loss resulting from varying densities of road dust cover on leaf surfaces was calculated using the photosynthetic rates of temperate plants (Goudriaan and Van Larr, 1978), viz:

$$P = P\text{max} \left(1 - e - \frac{s}{Sm}\right)$$

where

P = percentage reduction of photosynthetic rate;

Pmax = the amount of photosynthesis in bright light;

s = the absorbed photosynthetically active radiation measured in watts/m^2;

Sm = the level of solar irradiance at 0.5 Pmax;

e = exponential

and

Pmax = 0.7mgCO$_2$ m^{-2} S^{-1}; and

Sm = 50.

---

[12] Roading material, sieved through a 75μm mesh screen, oven dried and weighed into quantities corresponding to predicted leaf surface levels, was spread evenly over a piece of clean glass measured to 25 square centimetres. Each treatment of dust coated glass was placed under a set of artificial bright lights. The amount of light intensity which was reduced by the dust coating was measured using a LICOR LI185 Photometer with a quantum sensor, placed in a black box under the glass sheet.

TABLE 8

Average Deposition Density on Plant Surfaces Per Square Metre of Ground Area Per Dry Day

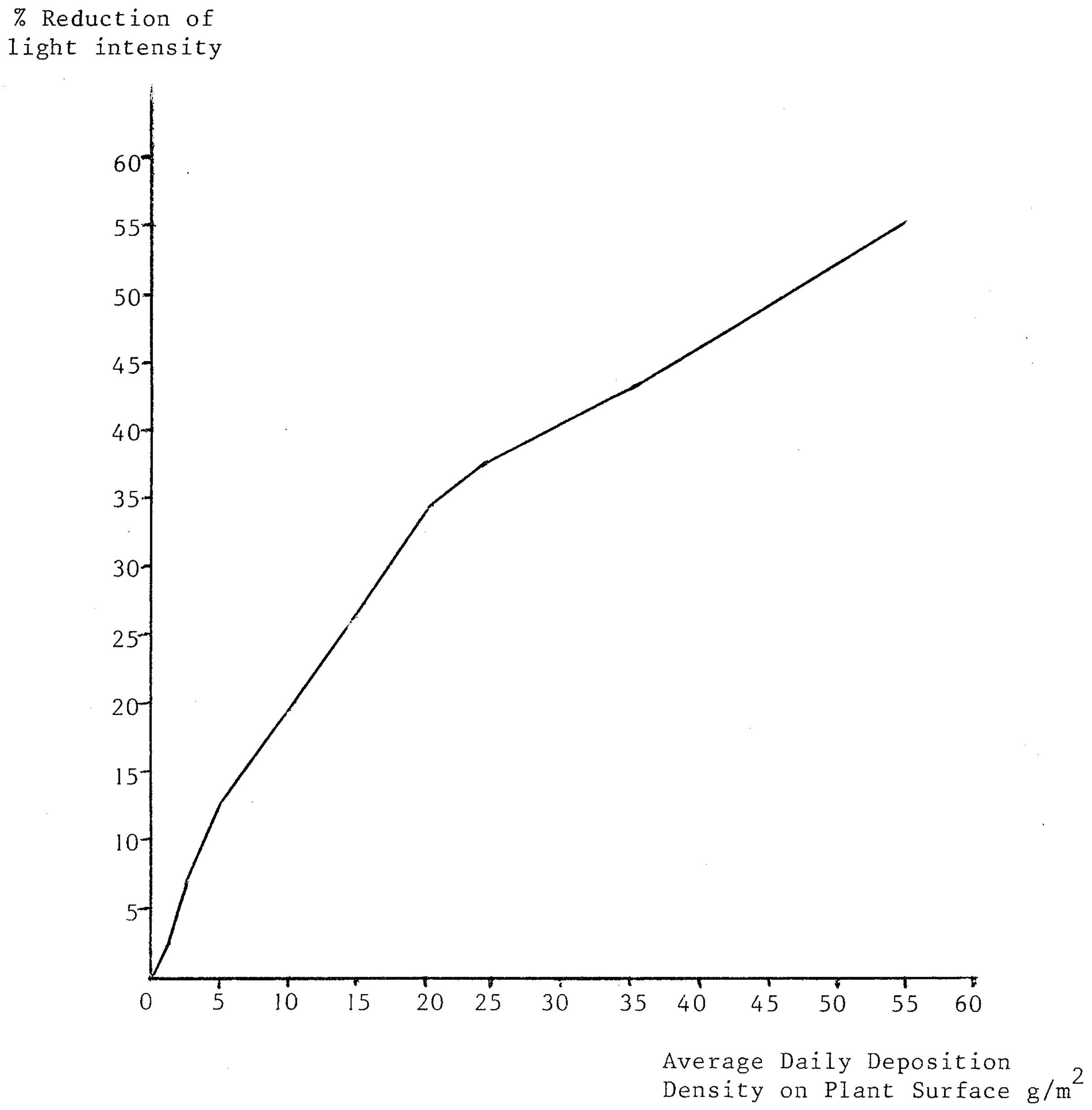
Type of Ground Cover	Total Affected Ground Area (ha/km)	DEPOSITION (g/m^2) DAILY EMISSION LEVELS (g)											
		600 000				300 000				90 000			
		Summer		Winter		Summer		Winter		Summer		Winter	
		H[a]	G[b]	H	G	H	G	H	G	H	G	H	G
Smooth (Worst)	31	6.3	4.9	3.2	2.5	3.2	2.5	1.6	1.2	1.0	0.8	0.5	0.4
Smooth (Best)	12.5	15.7	12.3	7.9	6.2	7.9	6.2	3.9	3.1	2.4	1.8	1.2	0.9
Medium (Worst) No Shelter Belt	19	10.3	8.1	5.2	4.1	5.2	4.1	2.6	2.1	1.6	1.2	0.8	0.6
Medium (Best) No Shelter Belt	6.5	30.2	23.8	15.1	11.9	15.1	11.9	7.5	5.9	4.5	3.6	2.3	1.8
Medium (Worst) Shelter Belt	19	6.2	4.9	3.1	2.5	3.1	2.5	1.6	1.2	1.0	0.7	0.5	0.4
Medium (Best) Shelter Belt	6.5	18.1	14.3	9.1	7.2	9.1	7.2	4.6	3.6	2.7	2.1	1.4	1.0
Rough (Worst)	12.5	9.5	7.4	4.7	3.7	4.7	3.7	2.4	1.8	1.4	1.1	0.7	0.6
Rough (Best)	3.5	33.7	26.5	16.8	13.3	16.8	13.3	8.4	6.6	5.0	4.0	2.5	2.0

[a] H = Hairy leaf surface

[b] G = Glaborous leaf surface

FIGURE 3

The Effect of Dust Deposition Density Levels on the Light Intensity Reaching Leaf Surfaces



The amounts of photosynthesis reduction found for various levels of light reduction are shown in Table 9.

The differentiation of summer and winter light intensity levels highlights the greater percentage effect which road dust has on photosynthesis rates, during the winter period of low light intensity. However, the actual levels of photosynthesis activity over the winter period are much lower than summer levels (i.e. $0.39 \div 0.69 = 56$ per cent) and thus, the differences in overall photosynthetic effect between winter and summer would be moderated to an extent.

Figure 4 shows the relationship of road dust deposition on leaf surfaces to percentage photosynthetic reduction. The amount of photosynthetic reduction from any given level of dust cover can be read directly from the graph and is used in Chapter 7 for each enterprise type analysis.

6.2 Accounting for Other Road Dust Effects

Apart from photosynthetic yield losses, it is not possible in this study to make an encompassing estimate of the amount of yield reduction or produce downgraded, due to road dust contamination. There are so many variables working upon both the road dust and any crops or animals alongside metal roads, that expensive simulation, experimentation and survey techniques would be required to gain reliable estimates of possible costs.

The qualified estimates of possible road dust effects on production cited by scientists and producers (e.g. 20 per cent loss of yield due to poor weed control (Field, pers. comm., 1983)) in Chapter 3 do provide a starting point but it is likely that these estimates are much higher than the average level of effect, over the total estimated areas of road dust significance to production, as defined in Chapter 5.

Hence, given the lack of adequate information regarding the effects of road dust on production, no attempt has been made to predict the actual extent of each effect. Instead, a figure of 1.0 per cent has been chosen as a high value and 0.5 per cent as a low value of possible effect, on either yield loss or quantity of produce downgraded.

The use of such hypothetical figures serves to illustrate the sensitivity in economic terms for each identified effect of road dust on production, whilst avoiding the danger of placing too much reliance on unsupported estimates.

The economic analyses of road dust effect on several major enterprise types in Tauranga County are contained in Chapter 7. All estimated costs are given subject to the assumptions, and conditions stated in Chapters 3, 4 and 5.

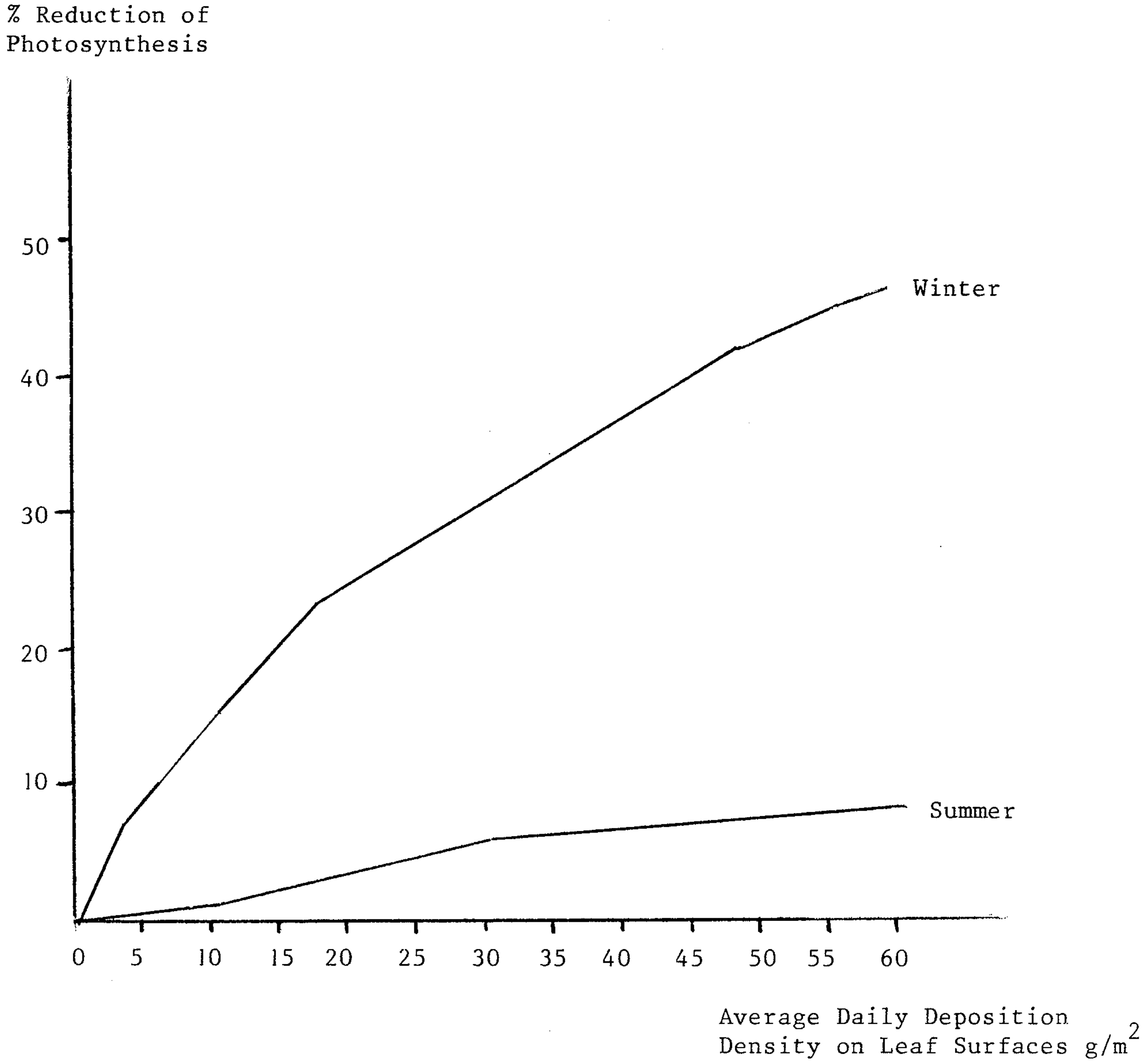
TABLE 9

Photosynthesis as a Function of Reduced Light Intensity

% Reduction of Light due to Dust	Photosynthesis Rate ($mgm^{-2}\ s^{-1}$)	% Reduction of Photosynthesis
(a) Average Summer Sun (225 Wm^{-2})		
0	0.69	0.0
10	0.69	0.0
20	0.68	1.5
30	0.67	2.9
40	0.65	5.8
50	0.64	7.3
(b) Average Winter Sun (40 Wm^{-2})		
0	0.39	0.0
10	0.36	7.7
20	0.33	15.4
30	0.30	23.1
40	0.27	30.8
50	0.23	41.1

FIGURE 4

Photosynthetic Response to Road Dust Cover on Leaf Surfaces



CHAPTER 7

ECONOMIC ANALYSIS OF THE EFFECTS OF ROAD DUST ON RURAL PRODUCTION BY ENTERPRISE TYPE

This chapter identifies the major effects of road dust on production for a number of enterprise types and shows the possible economic consequences of these effects. The costs are calculated from the respective enterprise gross margins and adjusted to reflect the size of the area affected by road dust per kilometre of road.

These costs which can be incurred from dust damage are the direct inverse of the benefits to be gained from dust removal from metal roads. It is assumed that any production increases, as a result of dust removal will not affect prices in the market place.

Where long-term crops are analysed, only the margin for a single year of a mature stand has been examined due to the bulkiness of calculating the effects over a series of years. This may understate the true benefits from dust removal as several establishment factors are disregarded. For instance, young trees are more susceptible to pest and disease damage and to weed competition than are mature trees and thus, poor control of these factors in the initial years of tree growth may delay the initiation of the first crop and consequently lower the expected crop yields for the ensuing years. This would affect the net present value of the production system and may place financial strains, especially on highly leveraged producers (see Appendix V for example of alternative calculations using compounding of effects).

However, the analysis of effects on the annual return from a mature crop, gives the most representative view of the potential benefits for agriculture and horticulture from road-dust removal.

Only the most significant potential effects of road dust identified in Chapter 3, for each enterprise type, have been included in the economic analysis. Some are too hypothetical to be included, whilst others appear to be too inconsequential to be of any great economic effect.

Each potential effect of road dust on producer returns for each enterprise type has been analysed individually and assigned a high and low level of effect, either upon yield or marketability. This isolation of effect allows greater manipulation of data in response to changing circumstances and is easier to comprehend than fully aggregated data.

A potential problem with the analyses is that no account has been taken of ambient dust levels. In some cases, especially during dry years the ambient dust level may be so high that it alone could markedly affect the yield or marketability of produce, relegating road dust into an accessory role only, rather than being the prime factor. However, in most cases where road dust is seen to be a problem this is probably not the case, as field observations show distinctly higher levels of dust present on plant surfaces nearer unsealed roads, than further away.

The only outlets of fruit distribution which have been included in the analyses are:

(1) Export fresh ;

(2) Local fresh, sold through the market system ; and

(3) Process grade.

Gate and 'pick your own' sales are disregarded, partly for computational ease but also partly because these methods of sale are often unfeasible on low volume unsealed roads. In any case, discounting of dust affected fruit in the auction system would compensate, at least partly, for these omissions.

Costs and prices used in the analyses are averaged for the 1982-83 season and originate from a variety of sources, including Ministry of Agriculture and Fisheries Economics Division, the 1983 Lincoln Farm Budget Manual and independent produce merchants and processors. The reliance on a number of sources for price data caused a number of inconsistencies in figures, but where possible these have been crosschecked. In cases where 1982-83 costs are not available, 1981-82 figures, compounded by the All Farm Cost Price Index (New Zealand Monthly Abstract of Statistics, December 1982) for the 1982 year, have been used.

Final figures derived for each enterprise type, for costs from road dust contamination are given in two forms:

(1) Cost per Kilometre.

This figure assumes that the enterprise continues consistently along both sides of the metal road for a whole kilometre and the figure given, represents the total cost which would be incurred from road dust by the particular enterprise type.

The use of this figure is necessary, because costs are calculated on the ranges of area affected per kilometre, which vary between enterprise types. These costs are later converted into costs per affected hectare.

The per kilometre costs also allow a meaningful comparison of road dust costs per length of road between different enterprise types.

(2) Per Hectare Costs

These are needed to calculate the actual costs to a particular enterprise along a given road (i.e. cost per hectare multiplied by the amount of dust affected area).

The economic analyses of road dust effect on agricultural and horticultural production which follow, are necessarily very generalised and highly simplified. However they do present, at the very least, an indication of the costs which road dust may be incurring upon primary producers in Tauranga County.

The procedures used in calculating the costs are set out fully for the first enterprise analysed (oranges), to provide the reader with an understanding of the methodology. However, results are summarised for the ensuing analyses to avoid unnecessary repetition.

7.1 Orange Production

Virtually all commercially grown oranges in Tauranga County are sold on the local fresh market, at an average price to growers of $576-00 per tonne. Variable costs which alter directly with yield (harvesting, freight and packaging) total $67-00 per tonne.

Table 10 shows the projected cash flow for the establishment of a typical orange orchard with a planting density of 900 trees per hectare. Year 10 of this projection is used for the analysis of road dust costs on production.

The major physical effects and their economic consequences are summarised in Table 11.

7.1.1 Reduced photosynthesis.

The estimated annual yield reduction from depressed photosynthesis for oranges grown along unsealed roads in Tauranga County, given a range of traffic densities and climatic conditions, is presented in Table 12. Table 13 examines the economic consequences for each estimated level of yield reduction.

The costs per kilometre range from $7,125 for a high volume road, during a dry year with the wide dust dispersion and $486 for a low volume road with the narrow dust dispersion and high rainfall.

For a medium volume road, assuming an average rainfall year the cost per annum is approximately $2,500 per kilometre for both estimates of dust dispersion.

7.1.2 Costs of pests and disease.

Oranges are plagued by a number of insect pests, notably scale insects, mites, mealy bugs and aphids. Also, road dust is believed to be a major predisposing cause of vericosis disease, a condition which results in skin blemishes on fruit.

TABLE 10

Orange Cash Flow ($/hectare)

Years	0	1	2	3	4	5	6	7	8	9	10
Yield/ha	-	-	-	-	5	12	20	27	35	42	51
TOTAL REVENUE	-	-	-	-	2,880	6,912	11,520	15,552	20,160	24,192	29,376
Costs											
Capital 900 trees	4,183										
Working											
Land Preparation	122	-	-	-	-	-	-	-	-	-	-
Mowing		-	151	151	151	151	151	151	151	151	151
Irrigation		35	35	35	35	35	35	35	35	35	35
Sprays		935	1,067	1,067	948	1,308	1,308	1,308	1,308	1,308	1,308
Fertilizer		105	210	315	420	535	651	802	988	1,220	1,511
Planting		813	-	-	-	-	-	-	-	-	-
Harvesting		-	-	-	203	488	813	1,098	1,423	1,708	2,074
Freight		-	-	-	87	209	349	471	610	732	889
Packaging		-	-	-	46	105	174	232	302	366	442
TOTAL COSTS	4,305	1,888	1,428	1,536	1,890	2,831	3,381	4,097	4,817	5,520	6,410
NET CASH FLOW	-4,305	-1,888	-1,428	-1,536	990	4,081	8,139	11,455	15,343	18,672	22,966

TABLE 11

Road Dust Effects on Orange Production and Its Economic Consequences

Effect	Consequence	
	Yield	Marketability
Reduced Photosynthesis	- retarded tree growth - lower bud initiation	- smaller fruit size - lower sugar content
Increased Pest and Disease	- retarded tree growth - flower abortion - loss of fruit	- marked fruit - reduced colour - smaller fruit size
Dust on Fruit		- reduced colour - loss of lustre
Increased Weed Incidence	- retarded tree growth	

TABLE 12

Reduction of Orange Yield Due to Reduced Photosynthesis

Vehicles per Day	500		250		75	
Daily Emission Levels	600 000g		300 000g		90 000g	
Affected Area	Summer	Winter	Summer	Winter	Summer	Winter
ha/km						
1. Amount of Road Dust Deposited on Leaf Surface (g/m^2)[a]						
12.5	7.4	3.7	3.7	1.8	1.1	0.6
3.5	26.5	13.3	13.3	6.6	4.0	2.0
2. Percentage Reduction of Photosynthesis per Dry Day[b]						
12.5	1.0	7.2	0.5	3.6	0.1	1.3
3.5	5.4	18.5	2.0	10.6	0.5	4.0
3. Adjust for Winter Photosynthetic Rate — 56 per cent of Summer[c]						
12.5	1.0	4.0	0.5	2.0	0.1	0.7
3.5	5.4	10.4	2.0	5.9	0.5	2.2
4. Take Ranges of Possible Dry Days and Adjust for Annual Percentage Loss of Photosynthesis[d]						
12.5						
(a) High	2.2		1.1		0.4	
(b) Medium	1.6		0.8		0.3	
(c) Low	1.0		0.5		0.2	
3.5						
(a) High	6.8		3.5		1.2	
(b) Medium	5.1		2.5		0.9	
(c) Low	3.3		1.6		0.6	

(see Notes on Table 12)

NOTES ON TABLE 12

[a] See Table 8. Figures are for rough ground cover (orchard) with glabrous leaf surfaces.

[b] See Figure 4. Percentage photosynthetic reductions are read from the appropriate deposition levels in (1).

[c] See Table 9. Normal winter photosynthesis rates without dust cover are only 56 per cent of the summer rate i.e.

$$\left(\frac{\text{Winter rate}}{\text{Summer rate}} = \frac{0.39\ \text{mgm}^{-2}\text{s}^{-1}}{0.69\ \text{mgm}^{-2}\text{s}^{-1}} = 56\%\right)$$

Thus all winter figures are multiplied by 0.56. Summer figures stay the same.

[d] These figures are found by multiplying the figures in stage 3 by the respective percentage of dry days (Table 89) and number of seasonal months (i.e. summer and winter). Each figure is found via the following calculation method.

	Summer	+	Winter
Dry	.91		.79
Normal	.74 x 5 months		.56 x 7 months
Wet	.57		.34
		12	

e.g. Derivation of per cent reduction (Stage 4, high estimate for 500vpd and 12.5ha affected area).

$$\frac{(1.0 \text{ x } .91 \text{ x } 5 + 4.0 \text{ x } .79 \text{ x } 7)}{12} = 2.2$$

<u>Note</u>

'a', 'b' and 'c' apply directly to similar calculations for other enterprise types shown later. 'd' is similar, but where the growing period for a particular plant is less than 12 months, the number of months allocated to winter, summer and the total number of months respectively, is reduced accordingly. e.g. for a September to May growing period

	Summer	+	Winter
Dry	.91		.79
Normal	.74 x 5 months		.56 x 4 months
Wet	.57		.34
		9	

and using the example as before:

$$\left(\frac{1.0 \text{ x } .91 \text{ x } 5) + (4.0 \text{ x } .79 \text{ x } 4)}{9}\right) = 1.91$$

TABLE 13

Possible Economic Effects of Orange Yield Loss Caused by Photosynthesis Reduction

Year 10

Yield 51t/ha

Gross Margin $22966

Traffic Volume per Day	Affected Area ha/km	Type of Year	% Redn Yield	(tonnes) Yield Loss per ha	($) Yield Loss Cost/ha	($) Less Reduced Charges	($) Total Cost per ha of Affected Land	($) Cost/km
500	12.5	Dry	2.2	1.12	645	75	570	7125
		Normal	1.6	0.82	472	55	417	5212
		Wet	1.0	0.51	294	34	260	3250
	3.5	Dry	6.8	3.47	1998	232	1766	6181
		Normal	5.1	2.60	1498	174	1324	4634
		Wet	3.3	1.68	968	113	855	2992
250	12.5	Dry	1.1	0.56	323	38	285	3562
		Normal	0.8	0.41	236	27	209	2612
		Wet	0.5	0.26	150	17	133	1662
	3.5	Dry	3.5	1.79	1031	120	911	3188
		Normal	2.5	1.28	737	86	651	2278
		Wet	1.6	0.82	472	55	417	1459
75	12.5	Dry	0.4	0.20	115	13	102	1275
		Normal	0.3	0.15	86	10	76	950
		Wet	0.2	0.10	58	7	51	638
	3.5	Dry	1.2	0.61	351	41	310	1085
		Normal	0.9	0.46	265	31	234	819
		Wet	0.6	0.31	179	40	139	486

The increased presence of any pests and diseases, due to road dust, can have a double economic effect both on yield and on the price received for produce:

(1) Yield.

Using the sensitivity figures quoted earlier of 1.0 and 0.5 per cent effect, the range of costs from reduced yield due to increased incidence of pests and disease are calculated in Table 14.

TABLE 14

Yield Costs from Pests and Diseases on Oranges

	DOLLARS	
	1.0%	0.5%
Normal net revenue ($)	22,966	22,966
MINUS		
Yield loss	230	115
	22,736	22,851
PLUS		
Reduced Costs	34	17
	22,770	22,868
COST OF YIELD LOSS PER HECTARE	196	98
COST OF YIELD LOSS PER KILOMETRE		
(a) 12.5 hectares affected	2,450	1,225
(b) 3.5 hectares affected	680	343

(2) Marketability.

Oranges being sold on the domestic market are not as badly affected by size, colour or skin impediments as many other fruits. Because oranges are not a viable export crop for New Zealand, incentives for growers to produce immaculately presented oranges are not so high, with spray programmes generally not as rigidly applied as for export crops. Consequently the New Zealand orange has always been perceived by the consumers as being inferior to the more highly coloured, clearer skinned and uniformly sized imported varieties. Thus fruit imperfections due to dust related pest and disease problems may not cause particularly high levels of economic cost to growers, especially when packed with other non-dust affected oranges whose visual appearance is not faultless anyway.

Nevertheless it is probable that undue fruit imperfections would cause at least a subtle downward movement of price to the grower. Thus using the 1.0 and 0.5 per cent figure for possible price change, only an 11c and 6c change per bushel carton at market, the following range of costs would be incurred by the grower (Table 15).

TABLE 15

Marketing Costs from Pests and Disease on Oranges

	PRICE REDUCTION	
	1.0%	0.5%
	($)	($)
COST PER HECTARE	230	115
COST PER KILOMETRE		
(a) 12.5 hectares affected	2,871	1,435
(b) 3.5 hectares affected	804	402

7.1.3 Total costs to orange production.

Using only figures derived above the highest possible annual cost which could accrue to orange producers sited continuously on both sides of one kilometre of unsealed road is $12,446 and the lowest, assuming each stated effect actually occurs, is $1,231.

A more moderate figure is presented in Table 16. This example assumes a medium traffic volume (250vpd), an average rainfall for the year, and the narrow dust dispersion range.

The total loss per kilometre of unsealed road of 5.37 tonnes of production and $3,022 in revenue represents only a 3.0 per cent loss of production and a 3.75 per cent loss of net income for the affected area. These amounts would probably go unnoticed by most growers.

TABLE 16

Example of Total Costs to Orange Production

	YIELD (T)	REVENUE ($)
Net Returns Without Dust (per kilometre)	178.5	80,381
MINUS 2.5% Photosynthetic Yield Reduction	4.48	2,278
	174.02	78,103
MINUS 0.5% Pest and Disease Yield Reduction	0.89	342
	173.13	77,761
MINUS 0.5% Price Reduction from Spoiled Fruit		402
Adjusted Net Return	173.13	77,359
TOTAL LOSS PER KILOMETRE	5.37	3,022
TOTAL LOSS PER HECTARE	1.53	863
PERCENTAGE LOSS	3.0%	3.75%

7.2 Apple Production

Although only a low percentage of total apples grown in Tauranga County are sold to the Apple and Pear Marketing Board, it is likely that a much greater proportion of those grown on properties adjoining metal roads are submitted for Board distribution (see Section 3.5.2). Thus the following calculations relate only to figures for Board suppliers, however they should, if anything, understate the true costs to non-Board suppliers.

Approximately 50 per cent of all apples submitted to the Board are sold on the export market with growers receiving an average price of $191-00 tonne. A total of 17.7 per cent are sold as fancy grade on the local fresh market at an average price of $166.00 per tonne, with the remaining 32.3 per cent being sold either as standard grade on the local fresh market or as process grade. Both return an average price of $70.00 per tonne. Calculations show that the weighted average price received by growers is $147-00 per tonne.

Variable costs which alter directly with yield total $65-00 per tonne.

The Apple and Pear Marketing Board maintain a strict grading schedule with the main criteria for grading including:

(1) SOUNDNESS - fruit should be free from decay, rots, down, breakdamage and similar defects which may cause rapid breakdown and decay.

(2) CLEANLINESS - fruit should be free from dirt, dust, insect stains or other foreign substance or material.

(3) FORMATION - fruit should be well formed and typical of the variety.

(4) MATURITY - all apples in a similar line should be at a similar stage of maturity.

(5) DEFECTS - apples should be free of pests, diseases and toxic materials.

(6) COLOUR - red and striped apples must contain minimum percentage areas of colour.

(7) RUSSET AND BLEMISH - maximum percentage areas are allowable for each grade.

(SOURCE: NZAPMB Grading Schedule)

It is conceivable that road-dust could be a factor in the downgrading of apples due to any one of these criteria.

The following cost calculations are based on the projected returns for a Granny Smith[13] Orchard in its fifteenth year of establishment. This shows a yield of 168.7 tonnes per hectare with a net return of $14,550 per hectare.

7.2.1 Reduced photosynthesis.

The estimated annual yield reduction due to reduced photosynthesis includes allowances for a nine month growth period for apples (September until May) and pubescent leaf surfaces.

The highest calculated cost to apple production due to photosynethic reduction is $3,975 per kilometre per annum and the lowest is $175 per kilometre per annum. For an average year on a medium volume road, the cost is around $1,500.

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[13] Granny Smith are the dominant variety of apple grown in Tauranga County

7.2.2 Costs of pests and disease.

Apples are particularly susceptible to a wide range of pests and diseases, especially mites, scale insects and the codling moth. Control is achieved mainly through the use of chemical sprays although an integrated form of pest management, using biological control in conjunction with sprays, is becoming more widely used. However, as stated in Chapter 3, neither method is immune from dust problems.

Possible costs due to increased levels of pest and disease incidence on apples trees could be due to:

(1) Yield

These costs are set out in Table 17.

TABLE 17

Yield Costs of Pests and Diseases on Apples

	DOLLARS	
	1.0%	0.5%
COST OF YIELD LOSS PER HECTARE	138	69
COST OF YIELD LOSS PER KILOMETRE		
(a) 12.5 hectares affected	1,725	863
(b) 3.5 hectares affected	483	242

(2) Marketability

The Apple and Pear Board administer a strict set of grade standards for all apples submitted to them, from export grade down to processing grade.

One local grower estimated that 30 per cent of his apple crop close to an unsealed road either can't be sold to, or is heavily downgraded by the Board. The chief causes appear to be insufficient control of mites and rot in the stem cavities.

Excessive downgrading, even without dumping, involves a significant cost. For example, if dust related problems were to necessitate downgrading of an apple crop by even 1 per cent, from export to local fancy, and by 0.5 per cent from local fancy to process, the weighted average price per tonne received would be reduced, thus incurring further costs on production of $123 per hectare and either;

(a) $1,538 per kilometre for 12.5 hectares; or

(b) $431 per kilometre for 3.5 hectares

of dust affected area.

7.2.3 Other costs.

Factors such as road-dust in the stem cavities of apples and increased weed competition to young trees may involve further discrete costs to production. The significance of their effects however, are still uncertain and are likely to be fairly similar in nature to those from pest and disease problems. Thus these effects are assumed for now to be endogenously accounted for in the pest and disease analysis, although their possible significance should not be completely discounted.

7.2.4 Total cost to apple production.

Combining the costs from each analysis above, the highest cost which could accrue to apple production is $7,238 per kilometre per annum and the lowest is $848 per kilometre per annum.

Table 18 presents an example of a more moderate estimate of the costs to production caused by road dust. The assumptions of 250vpd traffic density, average rainfall, and the narrow dust dispersion range (3.5 hectares per kilometre) are used.

TABLE 18

Example of Total Costs to Granny Smith Apple Production

	YIELD (t)	REVENUE ($)
Net returns without dust (per kilometre)	590.45	50,925
MINUS		
4.9% Photosynthetic Yield Reduction	17.12	1,404
	573.33	49,521
MINUS		
0.5% pest and disease yield reduction	2.95	243
	570.38	49,278
MINUS		
Downgrading		431
Adjusted Net Return		48,847
TOTAL LOSS PER KILOMETRE	20.08	2,078
TOTAL LOSS PER HECTARE	5.73	594
PERCENTAGE LOSS	3.4%	4.1%

7.3 Kiwifruit Production

Approximately 80 per cent of the kiwifruit crop is sold on the export market, with growers receiving an average price of $3,320 per tonne. Only 5 per cent are sold on the local fresh market at a price of $1,220 per tonne, with the remaining 15 per cent allocated to processing at $1,070 per tonne. Thus, under normal conditions, the weighted average price to growers is $2,878 per tonne.

Variable costs which alter directly with yield differ between the three grades[14] of kiwifruit. These are summarised in Table 19.

TABLE 19

Kiwifruit - Variable Costs

	COST PER TONNE ($)		
	Export	Local Fresh	Process
Harvesting	73	73	73
Transport to Packing Shed	16	16	16
Packhouse Charge[a]	929	300	214
TOTAL	1,018	389	303

[a] Packhouse charges are derived for export kiwifruit from figures of $2.25 per 3.5 kg tray plus $1.00 cost of tray (Lincoln College Budget Manual). As packhouses did not provide a suitable breakdown of costs involved, charges for local and fresh process grades are estimated as the export cost minus reduced labour and packaging charges.

Export fruit incurs a variable cost of $1,018 per tonne, due mainly to the high standard of presentation and packaging required for overseas markets. The lower standards required for the local market are reflected in much lower variable costs, $389 per tonne for fresh and $303 for process grade kiwifruit.

Export grade standards administered by the Kiwifruit Authority are very strict and fruit may be rejected for export, due to a wide range of imperfections. Those for which road dust may be a cause, either directly or indirectly, are specified in Appendix IV (Table 56).

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[14] The term 'grade' is used loosely here to distinguish between the three major end uses of kiwifruit. It does not relate to the more specific grading system used by the Kiwifruit Authority.

Cost calculations are based on year 10 of the projected cash flow for the establishment of a 'Hayward' variety kiwifruit orchard, using the 'T bar' training method. This shows a yield of 21 tonnes and a net revenue of $37,916 per hectare.

7.3.1 Reduced photosynthesis.

The yield effect is the most significant aspect of reduced photosynthesis on kiwifruit. However, it may also influence the marketability of fruit under certain conditions.

Kiwifruit are graded largely on weight, thus an abnormally high proportion of underweight fruit caused by reduced photosynthesis will involve a considerable cost, but because there is an uncertain amount of interplay between fruit size and the number of fruit set, this aspect is not quantified exogenously in the analysis. Instead it is assumed that any effect is accounted for in the yield-cost calculations.

The minimal acceptable level of maturity for kiwifruit picked for export is 6.2 per cent soluble solids. Reduced photosynthesis may delay the maturity date of crops alongside metal roads. This could increase the risks of damage to fruit on two counts:

(1) Kiwifruit that remains on vines late in the season tends to soften and become prone to bird damage.

(2) Early frosts (see Appendix IV, Table 56).

These could both involve downgrading or even dumping of quantities of produce, although the probability of an occurrence in any one year is fairly low.

The highest calculated cost to kiwifruit due to photosynthetic reduction, given extreme circumstances, is $11,988 and the lowest is $500 per kilometre per annum. For an average year on a medium volume road the expected cost from photosynthesis reduction is around $4,500 per kilometre. These costs are based on a 9 month growing period (September till May).

7.3.2 Costs of pests and disease.

The principal pests and diseases of kiwifruit include the Greedy Scale, Leafroller and Sooty Mould, the slightest presence on fruit surfaces of which results in immediate rejection of fruit for export. Until recently, kiwifruit have been relatively free of pests and the amount of fruit destroyed because of them has been quite small, even in neglected orchards. However this is beginning to change and with the large monoculture areas present, pest and disease problems may increase fairly rapidly.

(1) Marketability

The chief costs resulting from increased levels of pests and disease due to road-dust cover is likely to be a downgrading from export to local or process grades.

The effect of downgrading upon the expected returns to growers is illustrated in Table 20 using examples of a 0.5 and a 1.0 per cent downgrading of kiwifruit from export grade to local fresh.

TABLE 20

Downgrading Effect on Kiwifruit Returns

	PERCENTAGE			Weighted
	Export	Local Fresh	Process	Average Price
	$3320	$1220	$1070	Per Tonne
Normal	80	5	15	$2,878
0.5 Per Cent Reduction	79.5	5.5	15	$2,867
1.0 Per Cent Reduction	79	6	15	$2,857

Table 20 shows a loss of $11 and $21 per tonne respectively for a 0.5 per cent and a 1.0 per cent downgrading.

At a yield of 21 tonnes per hectare the costs to the grower are:

(a) For 0.5 per cent downgrading:
* $231 per hectare; and
(1) $809 per kilometre for 3.5 hectares; or
(2) $2,888 per kilometre for 12.5 hectares affected by road dust.

(b) For 1.0 per cent downgrading:
* $441 per hectare; and
(1) $1,544 per kilometre for 3.5 hectares; or
(2) $5,513 per kilometre for 12.5 hectares affected by road dust.

(2) Yield

Inadequately controlled pest infestations of kiwifruit orchards, especially by the greedy scale, long tailed mealy bug and red scale, may inflict severe damage, particularly to the growing tips of young vines. The resultant effect on vine growth rate could cause depressed yields for which possible costs are: (Table 21)

TABLE 21

Yield Costs of Pests and Diseases on Kiwifruit

	Dollars	
	1.0%	0.5%
(1) COST OF YIELD LOSS PER HECTARE	423	212
(2) COST OF YIELD LOSS PER KILOMETRE		
(a) 12.5 hectares affected	5,288	2,650
(b) 3.5 hectares affected	1,481	742

However, kiwifruit yield losses from road-dust related pest incidence do not appear to be a widespread problem. Thus, until further information is known about the effects, or specific cases can be given, it may be preferable to omit the yield effect from economic calculations and concentrate on the marketability aspect.

7.3.3 Pollination effects.

A high degree of pollination is essential for kiwifruit for two basic reasons:

(1) The kiwifruit only produces a comparatively small number of flowers.

(2) The formation of large and uniformly shaped fruit is dependent upon the thorough pollination of each of the many small seeds present.

However, the kiwifruit flower is not very attractive to the honeybees which are responsible for most pollination, as it produces no nectar. It is probable that the road dust causes the flowers to be even less attractive to bees, thus resulting in losses to growers from both:

(1) Downgrading of 'scrub' fruit caused by inadequate pollination of flowers.

Using the 0.5 per cent and 1.0 per cent assumptions for downgrading, the costs from inadequate pollination of flowers is similar to those calculated for the effects of increased incidence of pests and disease on marketability (Section 7.3.2).

(2) Loss of yield through total flower abortion.

Likewise, the costs are similar to those calculated for yield in Section 7.3.2.

7.3.4 Other costs.

Several other road-dust related factors which may impose additional costs on kiwifruit producers should be mentioned:

(1) Dust on fruit.

The Kiwifruit Authority claim that their dehairing operation rids kiwifruit of any dust and hence, that road-dust is no problem. However a recent case occurred where a Bay of Plenty grower sued the Tauranga County Council for the rejection of 520 trays of produce for export due to road dust contamination. This case, if successful, may become a precedent for further claims.

(2) Packing Sheds and Coolstores.

Health Department regulations stipulate minimum standards of cleanliness for packing and storage facilities. Packhouses sited close to unsealed roads receive substantial deposits of road-dust fallout which gets into machinery, packing materials and coolstores and must be cleaned up regularly to meet Health Department requirements. However this would represent a minor cost only. For instance, three extra man hours of cleaning per week for say 8 weeks per year, at $5 per hour, represents a cost of $120 per annum.

(3) Flower Induction.

Additional to the photosynthesis, pest and disease, and pollination effects, road dust may also further reduce flower induction by restricting light to young shoots. The shoots to be retained on the vine at pruning time, from which next year's fruiting shoots arise, must mature in a reasonably light position to be fully fruitful. A reduction of light reaching these shoots, caused by road-dust cover, may reduce the yield potential of the vines nearest to an unsealed road.

The extent to which this occurs however is uncertain and thus any reduction of yield is assumed to be accounted for in the afore-mentioned calculations.

7.3.5 Total costs to kiwifruit production.

Combining all the costs from each effect analysed above, the highest cost which could accrue to kiwifruit production is $33,520 per kilometre per annum and the lowest $3,938 per kilometre per annum.

It is unlikely though, that every effect would be of economic consequence at any one time and thus, the example presented in Table 22 (for a 250 vpd, average rainfall and narrow dust dispersion assumption) may be more realistic.

TABLE 22

Example of Total Costs to Kiwifruit Production

	YIELD (t)	REVENUE ($)
Net returns without dust (per kilometre)	73.50	132,706
MINUS		
2.9% Photosynthetic yield reduction	2.14	4,270
	71.36	128,436
MINUS		
0.5% downgrading for pests and diseases		809
		127,627
MINUS		
0.5% yield loss (pollination, pests and disease and flower induction)	0.37	741
	70.99	126,886
MINUS		
0.5% downgrading (pollination and staining)		809
	70.99	126,077
TOTAL LOSS PER KILOMETRE	2.51	6,629
TOTAL LOSS PER HECTARE	0.72	1,894
PERCENTAGE LOSS	3.4%	5.0%

7.4 Peach Production

Virtually all peaches grown in Tauranga County are sold on the local fresh market at an average price of $810/tonne. Variable costs which alter directly with yield total $196/tonne. Cost calculations are based on the sixth year of the projected cash flow for the establishment of a peach orchard. This shows a yield of 22.61 tonnes and a net return of $10,801 per hectare.

7.4.1 Reduced photosynthesis

The highest calculated cost (Table 35) to peaches given extreme circumstances is $3,300 per kilometre per annum and the lowest is $150 per kilometre per annum. For an average year on a medium volume road, the expected cost from photosynthesis reduction is around $1,200 per kilometre per annum. These estimates include allowances for a 9 month growing period (September till May).

7.4.2 Costs of pests and disease

Major pests and diseases of peaches include: silver leaf, leaf curl, scab, bacterial spot, leaf roller and mites. Any increase in their incidence may lead to costs from either:

(1) Yield Loss

These costs are set out in Table 23.

TABLE 23

Costs from Peach Yield Loss Due to Pests and Disease

	DOLLARS	
	1.0%	0.5%
COST OF YIELD LOSS PER HECTARE	139	70
COST OF YIELD LOSS PER KILOMETRE		
(a) 12.5 hectares affected	1,738	875
(b) 3.5 hectares affected	487	245

(2) Marketability

Damage to fruit from pests and disease may move the price for affected fruit downward by about 33 per cent. Using the 1.0 and 0.5 per cent affected assumptions, costs are shown in Table 24.

TABLE 24

Costs from Downgrading Peaches

	DOLLARS	
	1.0%	0.5%
COST PER HECTARE	60	30
COST PER KILOMETRE		
(a) 12.5 hectares affected	755	382
(b) 3.5 hectares affected	210	105

7.4.3 Dust on fruit.

Peaches are particularly susceptible to road dust (or any dust) contamination. The furry skins tend to trap the dust causing a grubby appearance on the fruit surface which cannot be washed off. This reduces the price received for contaminated fruit on the local market by about 33 per cent, depending upon the extent of the cover.

Although the assumptions of 1.0 and 0.5 per cent of crop affected within the road dust dispersion range are retained (Section 7.4.2) in calculations, for consistency, it is likely that where road dust contamination of peaches does occur, the proportion affected may be more like 50 per cent. This would represent a cost of $3,022 per hectare or $37,776 per kilometre for 12.5 hectares affected and $10,577 for 3.5 hectares affected.

7.4.4 Total costs to peach production.

Combining all the costs above using the prior assumptions, the highest cost which could accrue to peach production from road dust is $6,548 per hectare per annum and the lowest is $690.

A more moderate example is displayed in Table 25.

However bear in mind that this figure may seriously understate the true cost, especially in cases where fruit has become badly contaminated by dust cover.

TABLE 25

Example of Total Costs to Peach Production

	YIELD (t)	REVENUE ($)
Net Returns without dust (per kilometre)	79.14	37,804
MINUS 2.3% photosynthetic yield reduction	1.82	1,116
	77.32	36,688
MINUS 0.5% yield loss from pests and disease	0.40	245
	76.92	36,443
MINUS 0.5% x 33% price reduction for pests and disease		105
		36,338
1.0% x 33% price reduction for dust on fruit		210
	76.92	36,128
TOTAL LOSS PER KILOMETRE	2.22	1,676
TOTAL LOSS PER HECTARE	0.63	479
PERCENTAGE LOSS	2.8%	4.4%

7.5 Blueberry Production

Blueberries are another of the 'new-wave' horticultural crops and can be severely affected by road dust. Returns to growers are high with approximately 70 per cent of the 1982-83 crop exported at a price of $6,440-00 per tonne. A further 25 per cent of the crop was sold on the local fresh market for $5,000-00 per tonne and the remaining 5 per cent for processing at $2,000.00 per tonne. This gives a weighted average price to growers of $5,858-00 per tonne.

The weighted average variable cost of production is $1,950 per tonne. This includes charges of $1,000 per tonne for export packaging, $200.00 per tonne for local market packaging and a zero cost assumption for process grade packaging.

A mature crop averages a yield of around 7.0 tonnes and a net return of $25,723 per hectare, assuming a planting density of 1300 plants per hectare.

7.5.1 Reduced photosynthesis.

The range of possible costs from photosynthetic yield reduction varies from $7,862 to $338 per kilometre, with an average cost for a medium volume road of around $3,000 per kilometre. Calculations include an allowance for a nine month growth period (September till May).

7.5.2 Cost of pests and diseases.

Apart from birds, the main pests of blueberries are the leaf roller, mites, black vine weevil, mealy bug and grass grub beetles. They are also troubled by a number of fungi which can cause flower and berry rots. Thus a regular spray programme is required for adequate pest and disease control.

Any increase in their incidence due to road-dust problems may lead to costs of either:

(1) Yield Loss

These costs are shown in Table 26.

TABLE 26

Costs of Blueberry Yield Loss Due to Pests and Disease

	DOLLARS	
	1.0%	0.5%
COST OF YIELD LOSS PER HECTARE	274	137
COST OF YIELD LOSS PER KILOMETRE		
(a) 12.5 hectares affected	3,425	1,712
(b) 3.5 hectares affected	960	480

(2) Marketability

With say a 1 per cent downgrading from export to local fresh and a further 0.5 per cent from local fresh to process grade because of increased pest and disease damage, both the returns and variable costs to growers will be affected.

The average price received will drop by $33-00 to $5,825 per tonne and the average packaging costs will be reduced by $9-00 per tonne. Thus a net drop in average price of $34-00 per tonne occurs. This gives a total cost from downgrading of $238 per hectare or:

(a) $2,975 per kilometre for 12.5 hectares affected; or

(b) $833 per kilometre for 3.5 hectares affected.

7.5.3 Dust on berries.

Dust present on berries can detract from the quality of the produce due to both:

(1) The physical appearance of dust particles which render the berries unsuitable for export. Because blueberries are a soft fruit with a waxy bloom, they cannot be cleaned without spoiling their appearance.

(2) Poor colour resulting from reduced light intensities reaching berries, due to road dust cover.

Any costs involved are most likely to be in terms of marketability, calculated above for pests and disease.

7.5.4 Reduced pollination.

Blueberries have small delicate flowers containing a number of small seeds. If dust prevents any seeds being pollinated then fruit size is affected and in bad cases, can even cause flower abortion. The costs involved in such losses are similar to those calculated for pests and disease.

7.5.5 Total costs to blueberry production.

The highest calculated cost, from quantified effects, which could accrue to blueberry production is around $17,200 and the lowest, $2,720 per kilometre.

A more moderate estimate is presented in Table 27.

TABLE 27

Example of Total Costs to Blueberry Production

	YIELD (t)	REVENUE ($)
Net Returns without Dust (per kilometre)	24.50	90,030
MINUS		
2.9% Photosynthetic Yield Reduction	0.71	2,775
	23.79	87,255
MINUS		
0.5% Yield Loss from Pest and Disease	0.12	480
	23.67	86,775
MINUS		
0.5% Downgrading from Dust on Berries	-	833
		85,942
MINUS		
0.5% Yield Loss from Pollination Reduction	0.12	480
	23.55	85,462
TOTAL LOSS PER KILOMETRE	0.96	4,568
TOTAL LOSS PER HECTARE	0.27	1,305
PERCENTAGE LOSS	3.9%	5.1%

7.6 Avocado Production

Avocado prices varied during the 1982/83 season from between $7,000 and $10,000 per tonne. An average price of $7,000 per tonne is used for the analysis in this report and costs which vary directly with yield average $493 per tonne.

A yield of 20.4 tonnes with a net revenue of $131,880 per hectare is used for the avocado analysis. This relates to the twelfth year of an orchard establishment cash flow.

7.6.1 Reduced photosynthesis.

The highest calculated cost to avocados due to photosynthetic reduction, given extreme circumstances is $36,600 per kilometre and the lowest is $2,733 per kilometre. For a medium volume road with average rainfall, the cost is around $11,500 - $13,000 per kilometre.

7.6.2 Costs of pests and disease.

The avocado has a broad spectrum of pests and a smaller number of diseases. Good control must be achieved for export fruit and also for fruit to be fully competitive on the local market. Lack of control due to road dust may result in the following costs:

(1) Yield.

The range of possible costs due to increased incidence of pests and disease are shown in Table 28.

TABLE 28

Yield Costs of Pests and Diseases on Avocado

	DOLLARS	
	1.0%	0.5%
COST OF YIELD LOSS PER HECTARE	1,328	664
COST OF YIELD LOSS PER KILOMETRE		
(a) 12.5 hectares affected	16,600	8,300
(b) 3.5 hectares affected	4,648	2,324

(2) Marketability.

Assuming that damaged fruit is sold on the local market at a 33 per cent reduction from premium price, costs to growers are:

(a) For 0.5 per cent downgrading $236 per hectare; and
  (i) $826 per kilometre for 3.5 hectares, or
  (ii) $2,950 per kilometre for 12.5 hectares affected by road dust.

(b) For 1.0 per cent downgrading $471 per hectare; and
  (i) $1,648 per kilometre for 3.5 hectares, or
  (ii) $5,887 per kilometre for 12.5 hectares affected by road dust.

7.6.3 Dust on fruit.

Excessive dust on fruit may spoil the appearance of the fruit and if not adequately removed, cause rejection of product for export. Costs involved would be similar to those calculated for downgrading losses due to pests and disease.

7.6.4 Total costs to avocado production.

Combining all the costs above, the highest cost which could accrue to avocado production from road dust is $67,974 per kilometre and the lowest is $6,709 per kilometre.

Table 29 presents a more moderate example of what the costs may be.

TABLE 29

Example of Total Costs to Avocado Production

	Yield (t)	Revenue ($)
Net Returns without Dust (per kilometre)	71.40	461,580
MINUS		
2.5% Photosynthetic Yield Loss	1.79	11,616
	69.61	449,964
MINUS		
0.5% Downgrading for Pests, Diseases and Dust on Fruit		826
		449,138
MINUS		
0.5% Yield Reduction for Pest and Disease	0.10	2,324
	69.51	446,814
TOTAL LOSS PER KILOMETRE	1.89	14,766
TOTAL LOSS PER HECTARE	0.54	4,218
PERCENTAGE LOSS	2.6%	3.2%

7.7 Maize Production

Maize is mainly grown as a stock feed returning an average price to growers of around $190 per tonne. Variable costs which alter with production average $45 per tonne. Average yield is eight tonnes with a net return of $662 per hectare.

Photosynthetic yield reduction is the major likely cost to maize production, although increased levels of pests and disease and even weed incidence may produce further losses.

7.7.1 Reduced photosynthesis.

Costs due to photosynthetic yield reduction range from $533 to $38 per kilometre, with an average cost for a medium volume road of approximately $200 per kilometre. These calculations allow for an eight month growing period from October till May.

7.7.2 Pests, diseases and weeds.

Poor control of pests, diseases or weeds, especially during crop establishment, due to road dust could cause yield losses. These losses are set out in Table 30.

TABLE 30

Costs to Maize from Pests, Disease and Weeds

	DOLLARS	
	1.0%	0.5%
COST OF YIELD LOSS PER HECTARE	11	6
COST OF YIELD LOSS PER KILOMETRE		
(a) 19 hectares affected	209	114
(b) 6.5 hectares affected	72	39

7.7.3 Total costs to maize production.

Using the stated assumptions, the greatest cost which could be imposed upon maize production by road dust, is $722 per kilometre and the lowest is $78 per kilometre. A moderate cost on a 250 vpd road is around $240 per kilometre.

7.8 Asparagus Production

Approximately 35 per cent of the asparagus crop is exported at an average price of $4,000 per tonne, with the remaining 65 per cent sold for processing at an average price of $1,656 per tonne. This gives a weighted average price to growers of $2,476 per tonne.

Variable costs which alter directly with production include costs of $300 per tonne for harvesting and $1,000 per tonne for the packaging and handling of export produce. All handling and packaging costs for process grades are met by the processor. Thus the weighted average variable cost is $600 per tonne.

The sixth year of an asparagus cash flow budget is used in the analysis. This shows a yield of 7 tonnes with a return of $12,093 per hectare.

7.8.1 Reduced photosynthesis.

Assuming a five month period of plant growth (November till March), the costs from photosynthetic yield reduction vary from $2,489 to $152 per kilometre with an average for a medium volume road of around $1,000 per kilometre.

7.8.2 Dust on spears.

If a sufficient quantity of dust and grit gets down into the asparagus spears, it cannot be easily removed and renders the produce unsuitable for export. Any downgrading from export to process grade is associated with a cost as demonstrated in Table 31.

TABLE 31

Costs of Downgrading Asparagus

	DOLLARS	
	1.0%	0.5%
PER HECTARE	14	7
PER KILOMETRE		
(a) 19 hectares affected	266	133
(b) 6.5 hectares affected	91	46

7.8.3 Weed competition.

Competition by weeds for nutrients, moisture and space severely restricts the growth of asparagus, particularly in the establishment years. Much reliance is placed upon chemicals for control and should their effectiveness be reduced by road dust then costs could accrue to growers mainly through reduced yields. Possible costs are set out in Table 32.

TABLE 32

Costs to Asparagus from Weed Competition

	DOLLARS	
	1.0%	0.5%
COST OF YIELD LOSS PER HECTARE	131	66
COST OF YIELD LOSS PER KILOMETRE		
(a) 19 hectares affected	2,489	1,254
(b) 6.5 hectares affected	852	429

7.8.4 Other costs.

(1) Dust in Packing Sheds.

Where packing sheeds are sited close to unsealed roads, road dust may cause problems of contamination during the wet packaging process. In such cases, costs of packaging for export would already be sunk and thus the full costs of price reductions would be faced. These are set out in Table 33, with the assumption that export rejected produce is sent for processing.

TABLE 33

Costs from Dust in Packing Sheds

	DOLLARS	
	1.0%	0.5%
COST PER HECTARE	168	84
COST PER KILOMETRE		
(a) 19 hectares affected	3,192	1,596
(b) 6.5 hectares affected	1,092	546

(2) Pests and Disease.

Road dust is unlikely to be an important factor in increased levels of pests and disease incidence in asparagus as most problems occur during warm moist conditions, or on waterlogged soils when dust is not present.

7.8.5 Total costs to asparagus production.

Excluding the costs of dust in packing sheds, which would not be typical of most growers, the highest calculated cost which could accrue to asparagus production is $5,244 per kilometre and the lowest is $651 per kilometre. Table 34 presents the costs when the moderate assumptions are used.

TABLE 34

Example of Total Costs to Asparagus Production

	YIELD (t)	REVENUE ($)
Net Returns without Dust (per kilometre)	45.50	78,605
MINUS		
1.1% Photosynthetic Yield Loss	0.50	942
	45.00	77,663
MINUS		
0.5% Downgrading for Dust in Spears	-	46
	45.00	77,617
MINUS		
0.5% Yield Loss from Weeds	0.46	429
	44.54	77,188
TOTAL LOSS PER KILOMETRE	0.96	1,417
TOTAL LOSS PER HECTARE	0.15	218
PERCENTAGE LOSS	2.1%	1.8%

7.9 Pumpkin Production

Market gardening is another industry which is affected by road dust. However, because the range of vegetables grown is so expansive, only two, pumpkins and lettuces have been chosen in order to illustrate the possible costs of road dust to market gardeners.

Even so, it is difficult to accurately assess the true costs to the market gardener largely because prices fluctuate so markedly throughout the year and also, because production rarely has a definitive beginning and ending. Vegetable growing is usually conducted on a year round basis, with a rotation of vegetables grown and a staggering of planting times for each vegetable type grown, so as to spread the risk of market returns for each crop.

The calculations to follow for pumpkins and lettuces (Section 7.10) are an analysis for one production cycle only, assuming a single planting date, and are not an annual cost as with all other analyses. Nevertheless, a very rough estimate may be gained by combining the costs to either pumpkin or summer lettuce production with the costs to winter lettuce production. However, it must be stated again that this is extremely simplified and likely to underestimate the true costs to the grower, as the continuous cycle of production is not accounted for.

7.9.1 Pumpkin analysis.

Pumpkins are relatively free of pests and disease and under normal conditions, the only major cost to pumpkin production from road dust would be photosynthetic yield reduction.

There may be minor costs involved with dusty produce but this would likely be reflected in slightly higher packing costs, to include wiping badly contaminated pumpkins. Also where pumpkins are grown out of pasture, dust may be a factor in the control of pasture weeds. However this analysis looks only at production on land which has been previously cropped.

The average price received by growers in 1982 was $200 per tonne with average variable costs which alter with yield of $68 per tonne. The gross margin used for calculations is $970 which results from a yield of 16 tonnes per hectare.

7.9.2 Assessing costs from reduced photosynthesis.

Given a 4 month growing period (October to January), the possible costs which could accrue to pumpkin production range from $910 to $38 per kilometre, with a moderate costing (using 250vpd, narrow dust dispersion and average rainfall) of $306 per kilometre. This represents a 2.2 per cent yield reduction and a cost of $47 per dust affected hectare.

7.10 Lettuce Production

Lettuces are grown all year round-- and as with most horticultural crops, prices fluctuate markedly throughout the year. To illustrate the differences in cost that road dust may have on lettuce production throughout the year, two separate analyses are given:

(1) Summer planting - with a 70 day growing period from November to early January.

(2) Winter planting - with a 90 day growing period from May till July.

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15 Most growers would stagger their planting to give greater continuity of supply and to minimize risk. However as an illustration of possible costs, for this analysis, using the assumption of block planting is adequate.

It is assumed that all lettuces are sold through the local auction market and that planting for each crop is undertaken as a single operation at a rate of 36,000 plants per hectare. A normal harvest of 50 per cent is expected. A further assumption is made that market gardeners along unsealed road would use some form of shelterbelt to help eliminate dust problems.

The two major effects of road-dust on lettuce production are likely to be photosynthetic yield reduction and dust contamination of the leaves causing a price reduction. In some cases a poor weed kill may cause problems of weed competition for water and soil nutrients. Also, an increase in pest and disease incidence could cause problems to growers.

7.10.1 Economic evaluation of summer lettuce production.

The average price to growers is about $3.60 per case of 8 lettuces, with variable costs that alter directly with yield of $1.81 per case. The gross margin used for summer lettuces is $2,623 per hectare.

(1) Reduced Photosynthesis

The range of possible costs, due to photosynthetic yield reduction, varies from $450/kilometre to $25/kilometre with an average cost for a medium volume road of around $150/kilometre.

(2) Dust on Lettuces

Although lettuces are washed in their cases after harvest, this does not adequately remove heavy coatings of road dust and has little or no effect on the dust which reaches into the inner leaves. This contamination could have a twofold effect on growers returns, either;

(a) Yield to Market

Effectively this means dumping of produce rather than sending it to market. The normal margin was calculated using a 50 per cent harvest rate. If a lesser amount was harvested because of dust contamination, then the costs could be similar to those shown in Table 35.

TABLE 35

Yield Costs to Summer Lettuce Production from Pests and Disease

	DOLLARS	
	1.0%	0.5%
COST OF YIELD LOSS PER HECTARE	40	21
COST OF YIELD LOSS PER KILOMETRE		
(a) 31 hectares affected	1,240	651
(b) 12.5 hectares affected	500	263

or (b) Price Reduction

Dusty lettuces sent to market may reduce the overall price per case received by growers. For example, if the overall average price moved down by 1.0 and 0.5 per cent, respectively costs incurred are (Table 36):

TABLE 36

Costs from Downgrading Summer Lettuces

	DOLLARS	
	1.0%	0.5%
COST PER HECTARE	81	41
COST PER KILOMETRE		
(a) 31 hectares affected	2,511	1,271
(b) 12.5 hectares affected	1,013	513

Similar costs could be incurred for any increases of pest and disease, or weed incidence.

(3) Total Costs

Combining the costs from the two most likely problems of road dust on lettuce production, the highest cost which could occur is $4,123/kilometre and the lowest is $801/kilometre. Table 37 presents a possible cost using average conditions and the narrow dust range.

TABLE 37

Example of Total Costs to Summer Lettuce Production

	YIELD (cases)	REVENUE ($)
Gross Margin without Dust (per kilometre)	28,125	32,788
MINUS		
0.5% Photosynthetic Yield Reduction	141	263
	27,984	32,525
MINUS		
0.5% Price Reduction for Dust		513
	27,984	32,012
MINUS		
0.5% Yield Loss for Pest and Disease	141	263
	27,843	31,749
TOTAL LOSS PER KILOMETRE	282	1,039
TOTAL LOSS PER HECTARE	23	83
PERCENTAGE LOSS	1.0%	3.2%

7.10.2 Economic Evaluation of Winter Lettuce Production.

An average price to growers of $6.50 per case is used, with variable costs that alter directly with yield of $2.10. The gross margin used is $8,852 per hectare.

(1) Reduced photosynthesis

The range of possible costs, due to photosynthetic yield reduction, varies from $3,937 per kilometre to $124 per kilometre with an average cost for a medium volume road of around $900 per kilometre.

(2) Dust on Lettuces

Costs:

(a) Yield to Market (Table 38)

(assumptions as for summer lettuce)

TABLE 38

Yield Costs to Winter Lettuce Production from Pests and Disease

	DOLLARS	
	1.0%	0.5%
COST OF YIELD LOSS PER HECTARE	99	49
COST OF YIELD LOSS PER KILOMETRE		
(a) 31 hectares affected	3,069	1,519
(b) 12.5 hectares affected	1,238	613

(b) Price Reduction (Table 39).

TABLE 39

Costs From Downgrading Winter Lettuce

	DOLLARS	
	1.0%	0.5%
COST PER HECTARE	145	73
COST PER KILOMETRE		
(a) 31 hectares affected	4,526	2,263
(b) 12.5 hectares affected	1,825	913

(3) Total Costs

The highest total cost which could occur, using all the above calculations is $11,532 per kilometre and the lowest is $838 per kilometre. In-between total costs are presented in Table 40. Note that losses due to increased pests and disease are omitted from this example as this is unlikely to be a major problem over winter months.

TABLE 40

Example of Total Costs to Winter Lettuce Production

	YIELD (cases)	REVENUE ($)
Gross Margin without Dust (per kilometre)	28,125	110,650
MINUS		
1.2% Photosynthetic Yield Loss	336	1,475
	27,789	109,175
MINUS		
0.5% Price Reduction for Dust		913
	27,789	108,262
TOTAL LOSS PER KILOMETRE	336	2,388
TOTAL LOSS PER HECTARE	27	191
PERCENTAGE LOSS	1.2%	2.2%

7.11 Pastoral Production

Costs to pastoral farming from road dust are even more difficult to assess than those accruing to horticultural crops, mainly because animals are never grazed consistently along the area adjoining a metal road and thus, any effects are not as clearly defined as for plant systems.

It is simple enough to calculate the theoretical loss of pasture production due to reduced photosynthesis and theoretically it would appear to follow that a specific reduction of pasture production per hectare can be related to animal production losses. However there are a number of complicating factors which make this virtually impossible:

(1) Pasture growth is not uniform through the year and does not fit entirely to animal feed requirements. Thus at certain times there are excesses of feed, during which any retarded pasture growth due to road dust is insignificant to animal production. Also, during some dry periods, pasture growth is minimal due to lack of water, rather than to any effects of dust.

(2) The amount of effect which any retarded pasture growth has upon animal production depends very much upon the quality of the herbage, the composition of the sward and also the stage of grass growth. Hence the degree of influence may vary markedly from paddock to paddock.

(3) Animal production figures vary widely and it is difficult to attribute any reductions of production directly to road dust effects. In addition, because the animals are rotated about paddocks, any loss of production is likely to be spread at an

almost unrecognisable level over the total flock (or herd) so that losses are not easily measured.

Thus, it would appear that any animal production losses due to road dust depend very much upon the management factor, especially how the farmer utilizes his available feed and organises his stock rotations.

Acknowledging the difficulties involved in attempting to assess the losses to pastoral farming systems from road dust, two major assumptions are made:

(1) That animals are distributed at a static uniform stocking rate over the entire farm.

Although not realistic in the physical sense, this assumption seems reasonable in that it assumes an averaged annual loss for a set number of animals grazed on the dust affected area. The total losses should correspond at least roughly to the losses which could be expected over a year from heavy stocking rates for relatively short and periodic intervals.

(2) Because of the prementioned difficulties involved in directly measuring any animal production losses due to road dust, the sensitivity figures of 0.5 per cent and 1.0 per cent are used in all calculations of potential losses to animal production.

7.11.1 Factory supply dairy production.

The probable major effect of road dust of economic significance to dairy production is the effect on milk yield.

(1) Milkfat Yield

The average milkfat price received by farmers for the 1982/83 season was $3-50 per kilogram, with a gross margin of $1,097 per hectare.

It is possible that the reduction of milk production on road-dust affected pasture could result from two factors:

(1) Depressed pasture yield; and

(2) Reluctance of cows to eat contaminated pasture.

A sensitivity analysis of these effects reveals the possible costs to growers from each source (Table 41).

TABLE 41

Costs of Depressed Milkfat Yields

	DOLLARS	
	1.0%	0.5%
Normal Gross Margin (ha)	1,097	1,097
Cost Milkfat Yield Loss per hectare	11.50	5.75
COST OF YIELD LOSS PER KILOMETRE		
(a) 31 hectares affected	356	178
(b) 12.5 hectares affected	144	72

Thus if both the above mentioned factors were to influence milk yield then the cost to growers (using the sensitivity figures) could range from $72 to $144 per kilometre per annum. This represents a total milkfat yield loss of from 1.0 to 2.0 per cent.

(2) Other Effects.

In addition to the effects of road-dust on milkfat yield other possible costs to growers would include:

(a) Lower Payout Prices.

Where dairy sheds are sited close to metal roads, contamination of milk by dust may cause the dairy companies to reduce their payout prices.

(b) Animal Health.

The effect of road dust on animal health may inflict two types of costs:

(i) direct costs of animal health charges to treat viral bronchitis, conjunctivitis etc. caused by dust irritation;

(ii) costs involved in culling cows due to bronchitis or similar problems, that would otherwise be high producers;

(iii) lower returns for cull cows due to poorer condition; and

(iv) slightly higher feed costs to supplement depressed pasture yields.

However, all of these listed costs are highly speculative and likely to be relatively inconsequential. Thus they are omitted from economic calculations at this stage.

7.11.2 Sheep production - prime lamb.

The effect of road dust on sheep production is difficult to predict and is unlikely to be of any great significance in terms of roading economics. The most likely costs which may be incurred are:

(1) lower lambing percentages;

(2) downgrading at processing works; and

(3) opportunity costs of holding stock longer than normally necessary.

The gross margin for a prime lamb sheep flock stocked at a rate of 18 stock units per hectare is used for the analysis. This margin, of $254-00 per hectare, is so low that it is unlikely road dust would have much economic effect on sheep producers. However, some possible costs are set out below.

(1) Lower Lambing Percentages.

It is possible that road dust effects may at least play a small part in lowering lambing percentages. Three aspects of the dust problem may be responsible for this loss:

(a) depressed pasture yield ;

(b) depressed appetites for dust covered plant material; and

(c) scouring caused by dust on plant material.

If these effects cause a delay in the fattening of lambs for works consignment, due both to poor lactation by the ewe and lack of post weaning feed for the lamb, insufficient time and/or feed may be left for the flushing of ewes before the oncoming tupping.

Low bodyweights of ewes and low plane feeding around flushing could result in low lambing percentages due to either:

(a) decreased ovulation rate; or

(b) lack of condition to sustain sufficiently healthy lamb foetal growth and development.

If these factors are taken into account and in the absence of experimental data, an allowance is made that road dust reduces lambing percentages by 1.0 per cent, the costs would be similar to those shown in Table 42.

TABLE 42

Costs to Sheep Production from Lowered Lambing Rate

1% loss per 1,000 ewes - 10 lambs

FOR 31 HECTARES PER KILOMETRE AFFECTED
Total ewes carried - 310
Number of lambs lost - 2 $20
Total Cost - $60 per kilometre

FOR 12.5 HECTARES PER KILOMETRE AFFECTED
Total ewes carried - 125
Number of lambs lost - 1 $20
Total Cost - $20

(2) Pneumonia.

Section 3.7 sets out the level of ovine pneumonia in New Zealand and rates of rejection in freezing works due to pleurisy.

If Davies and Manktelow's (pers. comm., 1983) suspicions, that dust is a predisposing cause of pneumonia, are assumed to be correct, then it follows that the rate of pneumonia attributable to road dust is actually higher than the national averages per flock.

Hence using a number of inferences and assumptions a cost to farmers from road dust related ovine pneumonia can be estimated (Table 43, 44 and 45).

(a) Sheep deaths.

The costs resulting from sheep deaths due to pneumonia are set out in Table 43.

TABLE 43

Costs from Sheep Deaths Due to Pneumonia

	1.0%	0.5%
31 HECTARES AFFECTED		
Number of sheep lost	3	1
Cost of Loss (at $20 ewe) ($)	$60	$20
12.5 HECTARES AFFECTED		
Number of sheep lost	1	1
Cost of Loss ($)	$20	$20

(b) Reduction of lamb carcass weights.

Nationally, 6.5 per cent of lambs are affected by pneumonia to the extent of an average carcass weight reduction of 0.45kg per affected lamb. If road dust causes the affliction in say 10 or 5 per cent of lambs alongside metal roads, then costs incurred by farmers are as shown in Table 44.

TABLE 44

Costs from Reduction of Lamb Carcass Weights

	10% Pneumonia Affliction	5% Pneumonia Affliction
31 HECTARES AFFECTED		
Number of fat lambs carried	206	
Number of lambs affected	21	10
Total Cost (0.45 kg x $1.45/kg x No. of lambs) =	$14	$6.50
12.5 HECTARES AFFECTED		
Number of fat lambs carried =	83	
Number of lambs affected	8	4
Total Cost	$5	$2-50

(c) Condemnation of carcasses at processing works.

Approximately 0.2 per cent of sheep carcasses and 0.1 per cent of lamb carcasses are condemned at freezing works due to fibrous adhesions resulting from pleurisy. This results in a drop in price from 145c/kg to 85c/kg for lamb and from 41c/kg for sheep meat to 12c/kg.

If an assumption is made that 1.0 per cent of sheep carcasses and 0.5 per cent of lamb carcasses originating from areas alongside metal roads are condemned because of pleurisy, the costs shown in Table 45 result.

TABLE 45

Costs from Carcass Rejection Due to Pleurisy

31 HECTARES AFFECTED		
0.5% of 206 lambs @ 15kg	=	1 lamb
Cost = 15 x (145c - 85c)	=	$9-00
PLUS		
1.0% of 60 ewes @ 26kg	=	1 ewe
Cost = 26 x (41c - 12c)	=	$7-50
Total Cost		$16-50
12.5 HECTARES AFFECTED		
0.5% of 83 lambs @ 15kg	=	1 lamb
Cost =		$9-00
AND/OR		
1.0% of 25 ewes @ 26kg	=	~ 1 ewe
Cost =		$7-50
Averaged Total Cost		$8-00

Thus total costs resulting from ovine pneumonia, using the given assumptions could range from as high as $90 down to $30 per kilometre of unsealed road.

(3) Other Costs.

(a) Opportunity cost of holding fat lambs.

Where farmers have an excess of feed between their normal lamb fattening period and flushing, they often buy in extra lambs for fattening. This practice yields an average margin of around $5-00 per head.

If fattening of the farmer's own lambs is delayed, the buying in policy would normally be abandoned to save feed for flushing. In some instances, road dust may be a factor in this prolongation of fattening and thus, cause a direct cost to the farmer.

Because buying in is not a uniform practice by all farmers and further, because it is difficult to predict how much and how often the delay would be attributable to road dust, a quantitative figure is excluded from this report.

(b) Dirty sheep.

Road dust deposited on store sheep, both from drift across pastureland and also whilst being transported along dusty roads in sheep trucks, may detract from their appearance at saleyards. This may have some influence on the prices attained, although any estimate would be subjective.

(c) Pink eye.

If indeed road dust is a predisposing cause of pink eye then further costs from animal health and losses could result.

(4) Total Costs.

Using the sensitivity figures derived for costs of road dust to sheep production, the highest annual cost which could accrue to farmers is $150 per kilometre and the lowest $50 per kilometre. This is an almost insignificant amount, especially in terms of roading economics, and even if costs were included for the opportunity cost of holding lambs, dirty sheep and pink eye, the total cost is unlikely to exceed $250 per kilometre, a still relatively small amount.

7.11.3 Beef production.

The gross margin for beef production at a stocking rate of 12 stock units per hectare is approximately $430 per hectare. This is a little higher than the margin for breeding ewes ($254) but the effects of road dust are likely to be of less consequence to beef production than sheep, as cattle are less susceptible to the effects of both pneumonia and pink eye.

Thus, in the absence of any conclusive or accurate data pertaining to the effects of road dust on sheep or beef production, it seems reasonable to work on a maximum cost of $250 per kilometre, when valuing the damage to either type of enterprise from road dust.

Any costs which may result from dust are relatively minimal when compared to the costs involved in removing dust from roads.

7.12 Summary

The preceding enterprise analyses highlight the fact that high value, intensively grown horticultural crops (e.g. kiwifruit and avocados) incur the greatest costs from road dust. Conversely the major pastoral farming types (sheep, beef and dairy) suffer only relatively minor costs.

Table 46 summarises the range of possible costs to each enterprise type analysed, on a per hectare basis. Because the area of land affected by road dust, per section of road, varies with different enterprise types, a further range is given in Table 47, expressed in

TABLE 46

Estimated Costs to Major Rural Enterprise Types in Tauranga County: per Hectare

Enterprise Type	Area Affected (ha/km)		Cost ($) /ha					
			Wide Dust Range			Narrow Dust Range		
	Wide Estimate	Narrow Estimate	Highest	Medium	Lowest	Highest	Medium	Lowest
Avocado	12.5	3.5	6526	2841	2060	12643	5119	2581
Kiwifruit	12.5	3.5	2687	1266	966	4927	2106	1106
Blueberry	12.5	3.5	1891	1234	1015	3341	1781	1126
Orange	12.5	3.5	996	422	264	2025	864	352
Winter Lettuce	31	12.5	371	152	126	552	240	136
Apple	12.5	3.5	579	316	206	1050	593	274
Peach	12.5	3.5	523	229	142	1150	449	211
Asparagus	19	6.5	276	125	81	684	218	100
Summer Lettuce	31	12.5	173	87	85	181	95	85
Dairying	31	12.5	24	18	12	24	18	12
Pumpkin	19	6.5	41	15	2	140	47	6
Maize	19	6.5	38	17	8	93	37	11
Sheep	31	12.5	5	—	4	5	—	4
Beef (a)			5	—	4	5	—	4

(a) Estimate only

TABLE 47

Possible Costs per Kilometre to Major Rural Enterprise Types in Tauranga County

	Cost per Kilometre ($)		
Enterprise Type	High	Medium	Low
Avocado	67974	14766	6709
Kiwifruit	33520	6625	3938
Blueberry	17200	4568	2720
Orange	12446	3022	1231
Winter Lettuce	11532	2388	838
Apple	7238	2078	848
Peach	6548	1676	690
Asparagus	5244	1417	651
Summer Lettuce	4123	1039	801
Dairying	712	356	144
Pumpkin	910	306	
Maize	722	240	78
Sheep	250	150	50
Beef	250	150	50

terms of kilometres of metal road, assuming continuous production on either side of the road. This illustrates the absolute differences in cost per section of road between the different enterprise types.

The per hectare costs and the distance of road dust effect away from the roadway (which has been expressed as the area affected per kilometre of unsealed road in this chapter) form the basis from which costs to producers can be assessed for any section[16] of unsealed road in Tauranga County.

The method and an example of these calculations is set out in Chapter 8.

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[16] Subject to the constraints of enterprise types analysed.

CHAPTER 8

APPLICATION OF STUDY FINDINGS TO ROADING ECONOMICS

8.1 Use in Cost-Benefit Analyses

The application of the study findings to cost-benefit analyses for the ranking of roading projects is based on per hectare costs from road dust, relevant to respective enterprise types. Although at the moment restricted only to the enterprise types evaluated, it can easily be extended in the future to include any other type of enterprise.

8.1.1 Calculation procedure.

For any particular section of unsealed road which is to be evaluated, the assessment of costs to production could be calculated via the following steps:

(1) Decide upon the appropriate level or ranges of traffic density, rainfall and dust dispersion measures for the road.

(2) Measure the road frontages for each enterprise type along the section of road and calculate the total affected area for each, with respect to the prevailing wind and selected dust dispersion range.

If the field nearest the road finishes within the distance of road dust effect, then calculate only to the distance of the fence and disregard the next paddock (except for pastoral farms) because, as the calculated level of effect is an averaged estimate for the total affected area, the actual level of effect on the outer extremities of the dust dispersion range are likely to be very small and not worthy of a special calculation.

(3) For each enterprise type, calculate the per hectare costs, with respect to selected parameters, and multiply by the total affected area.

Sum the costs of each enterprise type along the section of road to gain total costs to production from road dust.

8.1.2 Case study.

The following example sets out the procedure for calculating costs to production from road dust for a hypothetical one kilometre stretch of road. Several calculations are carried out to demonstrate the sensitivity of the final costings to variance in each of the parameters.

Figure 5 presents a farm layout plan of the land adjoining a section of roadway and the calculating of total area affected by road dust, for each enterprise type, are shown in Table 48.

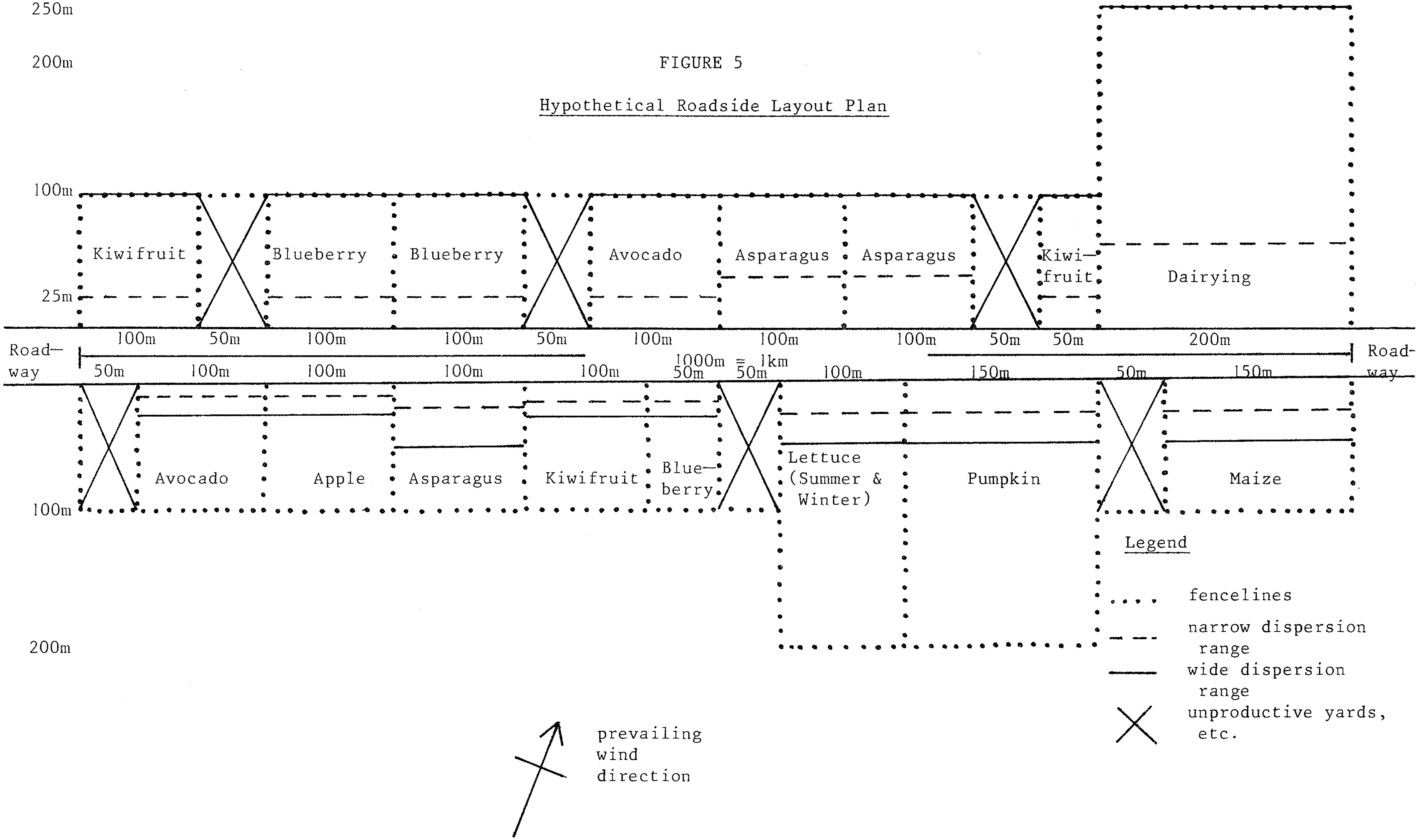
TABLE 48

Enterprise Contamination by Road Dust

ENTERPRISE TYPE	WIDE DISPERSION		NARROW DISPERSION		TOTAL AREA AFFECTED	
	ROAD FRONTAGE (m)	DISTANCE OF EFFECT (m)	ROAD FRONTAGE (m)	DISTANCE OF EFFECT (m)	WIDE (ha)	NARROW (ha)
KIWIFRUIT						
Downwind	150	100	150	25	1.500	0.375
Upwind	100	25	100	10	0.250	0.100
					1.750	0.475
BLUEBERRIES						
Downwind	200	100	200	25	2.000	0.500
Upwind	50	25	50	10	0.125	0.050
					2.125	0.550
AVOCADOS						
Downwind	100	100	100	25	1.000	0.250
Upwind	100	25	100	10	0.250	0.100
					1.250	0.350
ASPARAGUS						
Downwind	200	150	200	40	3.000	0.800
Upwind	100	50	100	15	0.500	0.150
					3.500	0.950
DAIRYING						
Downwind	200	250	200	60	5.000	1.200
APPLES						
Upwind	100	25	100	10	0.250	0.100
LETTUCE						
Upwind	100	100	100	25	1.000	0.250
PUMPKIN						
Upwind	150	50	150	15	0.750	0.225
MAIZE						
Upwind	150	50	150	15	0.750	0.225

FIGURE 5

Hypothetical Roadside Layout Plan



(4) Average Rainfall
250 vpd
Wide dust dispersion*

	1.0%	0.5%
Total Cost =	$13845	$9105

(5) Low Rainfall*
250 vpd
Narrow dust dispersion

	1.0%	0.5%
Total Cost =	$6312	$5002

(6) High Rainfall*
250 vpd
Narrow dust dispersion

	1.0%	0.5%
	$4608	$3298

The variance of costs may be even more dramatic where the extreme values of parameters are relevant, viz:

(7) Low rainfall*
500 vpd*
Wide dust dispersion*

	1.0%	0.5%
Total Costs =	$18453	$13713

(8) High rainfall*
75vpd*
Narrow dust dispersion

	1.0%	0.5%
Total Costs =	$3582	$2275

The annual costs to production from road dust for this hypothetical one kilometre stretch of road, range from approximately $8,500 down to around $2,000, with a substantial amount of variance between, depending upon the variables and assumptions used.

The magnitude of costs derived appears to be reasonable, especially as the total gross margins for the affected areas total $338,450 and $92,450 respectively for the wide and narrow dust dispersion estimates. Dividing costs by total gross margins results in percentage losses from normal gross margin of around 2 - 11 per cent. For the relatively small distance affected by dust from the roadside, these figures do not appear to be too excessive. Several cases have been cited in the past where producers have lost substantial quantities (usually from 50 - 100 per cent) of their produce on the first few rows adjoining unsealed roads and so it is logical that all growers may be losing much smaller quantities (as estimated) which would often go largely undetected.

8.2 Significance of Road Dust Costs to Roading Improvement Costs

Sealing is still the major method of upgrading metal roads in New Zealand with the average cost of sealing (including a second coat seal) for Tauranga County of around $80,000 per kilometre, with an expected seal life of 15 years.

The significance of annual road dust costs to production, compared to the capital cost of sealing, is found by converting the annual costs from road dust, over the expected 15 years of seal life into present value equivalents at the Treasury discount rate of 10 per cent. This is expressed by the formula

$$P = A \frac{(1 + i)^n - 1}{i(1 + i)^n}$$

where P = present value ;
A = annual costs from road dust ;
i = Treasury discount rate (10%) ; and
n = number of years.

If this present value factor is applied to some selected costs found in the preceding case study (8.1.2) the present values of costs from road dust shown in Table 50 could result.

Both the high present value costs shown here ($140,427 and $104,355) are greater than the capital cost of sealing ($47,500) and would be in themselves enough to justify sealing, in cost-benefit terms.

TABLE 50

Examples of Net Present Value Costs from Road Dust

	ANNUAL ROAD DUST COST ($)	PRESENT VALUE COST ($)
(1) High Cost		
(a) 1% assumptions	18,453	140,427
(b) 0.5% assumptions	13,713	104,355
(2) Moderate Cost		
(a) 1% assumptions	5,432	41,337
(b) 0.5% assumptions	4,122	31,368
(3) Lowest Cost		
(a) 1% assumption	3,582	27,259
(b) 0.5% assumption	2,275	17,312

The lower present value costs ($41,337 - $17,312) although not sufficient to warrant sealing on their own could still be significant to the evaluation of roading projects. As well as the costs to production from road dust, a number of other costs resulting from unsealed roads need to be valued and contained in the cost-benefit analysis. These include:

(1) vehicle maintenance costs;
(2) longer travelling times;
(3) greater accident risk;
(4) road maintenance costs; and
(5) social nuisance of dust.

Hence, the inclusion of the present value of production costs resulting from road dust in analyses, may often be the crucial factor in deciding whether sealing programmes should proceed.

In addition, there has been a considerable amount of recent development in relatively low-cost surface stabilisation techniques and formulations, especially suitable for lower volume rural roads. Thus, in some cases although road sealing may not be economically feasible, the lower cost alternatives may still be justifiable on a cost-benefit basis with dust-production costs included.

CHAPTER 9

CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

The purpose of this study was to ascertain whether road dust from unsealed rural roads has any significant economic effect on the production systems adjoining them. The method was to quantify any effects and to express them as costs per unit of productive land, adjoining each kilometre of unsealed road.

Because the report is only an exploratory study based on previous works and informed observations and opinions, no definitive conclusions can be drawn. However, throughout the report, every effort has been made to quantify each factor analysed. Also, figures used in assumptions and sensitivities have been chosen conservatively so that the costs calculated in the study, although not necessarily estimated to any great degree of precision, should be able to be used with a fair degree of confidence, at least in terms of not overstating the true costs.

The study found that high value, intensively grown horticultural crops suffer the greatest costs from road dust but that traditional pastoral type farms incur only relatively minor costs.

The major causes of road dust cost are: photosynthetic yield loss, increased levels of pest, disease and weed incidence, dirty produce and poor pollination (although only on small seeded fruits). The extent of costs are determined largely by environmental factors (e.g. rain, shelter, traffic volume), biological factors (e.g. length of growing season, type of plant surface, etc.) and also partly by the destination of produce (i.e. whether it is an export product or not). Each influencing factor is open to variation depending upon circumstances and these are accounted for in the analyses.

The costs to production derived for road dust have direct application to cost-benefit studies for the ranking of roading projects and can be applied to any given road.

Annual production costs from road-dust along roads through horticultural areas may reach thousands of dollars per kilometre and when these costs are multiplied by a suitable present value factor, they go a considerable way towards justifying the necessity for increased expenditure on roading improvement works.

Thus this report highlights the fact that road dust should be included as an important consideration in the assessment of roading projects and that it also has a definite cost to the nation, especially in terms of lost overseas earnings.

The magnitude of the costs derived suggests that further research should be undertaken both to establish some of the hypothesized physical effects of road dust and also, to predict more accurately, the extent and costs associated with road dust on agricultural and horticultural production systems. Suggestions are presented in the following section.

9.2 Recommendations for Further Research

Because this appears to be the first project of its type undertaken anywhere, data directly pertaining to both biological and engineering aspects of the study were almost non-existent. The collation and integration of a large number of 'snippets' of information enabled a relatively cohesive report to be compiled which, on a generalised basis, should be fairly useful.

However, further research is required, both for refinement and validation of the road dust model. This should be carried out in three stages:

(1) Development of a Modular Computer Simulation Model.

This would allow; functional relationships to be adequately handled, analyses of dust problems in any locality to be undertaken and easy adaption and refinement of the model, as improved data comes to hand.

(2) Field Measurements of Crop Economic Yields Away from Unsealed Roads.

Although this method can reveal only a rather crude estimate of the losses due to road dust because of other influencing factors (e.g. shelterbelt interference, natural crop variability, etc.), it is most appropriate as a first step in the economic validation of the overall model.

If field tests conclude that road dust does not in fact have any significant effect on crop returns, then further research may be economically unjustifiable. However, if an effect is verified then more specific research projects should be undertaken.

(3) Scientific Investigations of Model Components.

(i) Measurement of road dust drift and distribution.

A more accurate model is required to predict the quantity of road dust drifting onto the surfaces of plants on productive land. The development of this model will require research into several related aspects:

(a) Dust deposition responses to surface roughness, shelterbelts, wind speed, atmospheric stability and deposition heights.

(b) Retention of road dust by different plant surfaces under varying conditions.

(c) Effects of moisture levels on the dustiness of roads.

(d) Some work differentiating the levels of road dust from ambient dust and also in determining the levels of dust needed to cause any significant effect on production processes.

(e) A measure of dust deposition density for different plant canopy structures.

(f) Analysis of the dustiness of different roading materials.

A good starting point may be the mathematical model developed by Becker (1978) which predicts the particle effective area coverage of smooth surfaces.

(ii) Effect of dust cover on plant leaf functions.

Tests of plant photosynthetic, transpiration and respiration rates under field conditions and varying levels of dust cover should be carried out and any effects found related to plant growth rates and yields.

(iii) Pollination.

The effect of dust on pollination and fruit formation, especially for small seeded crops should be a priority research area.

(iv) Insect levels.

A study to determine the changes of pest-benefit insect population balances under New Zealand conditions would be useful. This should also include some analysis of crop damage from any changes.

(v) Spray effectiveness.

There is a lack of specific information on the effects of road dust on all forms of agricultural sprays.

(vi) Fruit colour.

An investigation into the effects of reduced light intensity from dust cover on fruit colour should be conducted, especially for pip and stonefruit.

(vii) Direct costs.

Some monitoring needs to be made of explicit costs being incurred by growers from road dust related problems on produce.

This could include a survey of both markets and growers of any price discounting, grade rejections and dumping.

Also perhaps, some specific case studies would be useful to add substance to such a study.

(viii) Animal diseases.

Further study is required on the possible effects of road dust as a predisposing cause of both ovine pneumonia and pink eye. If the dust is found to be a contributing factor, then some way of quantifying the extent of the effect should be sought.

(ix) Road surfacing.

Considerable research should be conducted into both the technical and economic aspects of various forms of road surfacing for rural roads. There are a number of commercial preparations and lime stabilization techniques which virtually eliminate the dust problem and also stabilize the road surface.

In many instances these methods may be far more attractive economic alternatives than either costly sealing programmes or persevering with traditional metal roads.

(x) Social costs.

Throughout the investigations for this report considerable concern was expressed by many people about social problems (e.g. health and cleanliness) experienced in houses adjoining metal roads from road dust. As land use intensifies, creating greater traffic volumes and more housing along rural roads, the problems can only increase.

There are methods available to value these effects and it would seem reasonable that every benefit from dust removal should be included in cost-benefit studies.

LIST OF REFERENCES

Anon (1963), "Dust Laying on Unsurfaced Earth and Gravel Roads". Department of Environment, U.S.A.

Anon (1967), "The Effects of Air Pollution on Plants and Soil". Agricultural Research Council, London.

Anon (1975), "The New Zealand Grown Fruit and Vegetables Regulations, 1975". Government Printer, Wellington.

Anon (1979), "Fire Particulate Pollution : A Report of the United Nations". Economic Commission for Europe, New York.

Anon (1980), "Volcano Health Report". Department of Health and Human Services, Washington.

Anon (1981), "Agricultural Statistics 1980-81". Department of Statistics, Wellington.

Anon (1981), "Sheep and Beef Farm Survey 1980-81". New Zealand Meat and Wool Boards' Economic Service, Wellington.

Anon (1982), "Annual Report : New Zealand Meat Producers' Board". Wellington.

Anon (1982), "Annual Report, New Zealand Dairy Board". Wellington.

Anon (1982), "Effects on Animal Health of Contamination of Pastures by Dusts". Commonwealth Bureau of Animal Health.

Anon (1982), "Economic Survey of Factory Supply Dairy Farms in New Zealand, 19881-82". New Zealand Dairy Board, Wellington.

Anon (1982), Monthly Abstract of Statistics. New Zealand Department of Statistics, Wellington.

Anon (1982), "One of Growers' Worst Enemies is Dust : It Kills Beneficials". Avocado Grower 6(9) : 20-43.

Anon (1982), "Road Name and Place Name Index". Rodney County Council.

Anon (1982), "Strawberry Gross Margin". Ministry of Agriculture and Fisheries, Auckland.

Anon (1983), "Cropping and Livestock Gross Margins". Ministry of Agriculture and Fisheries, Auckland.

Anon (1893), "Kiwifruit Export Grade Standards : Guidelines". New Zealand Kiwifruit Authority, Auckland.

Anon (1983), "Local Market Grade Standards for Apples and Pears". New Zealand Apple and Pear Marketing Board, Wellington.

Anon, "Aglink Series". Ministry of Agriculture and Fisheries, Wellington. Publications: FPP: 68, 161, 164, 213, 234, 302, 326, 490, 781 HPP: 13, 32, 55, 94, 97, 99, 120, 158, 169, 197, 229, 230, 233, 236, 238, 246, 301 NZA: 29

Anon, "Studies on Physiological Effects of Soil Dust Adhesion to Plants". Journal of the Faculty of Agriculture, Shinshu University, 14(1) : 13-21.

Akre, R.D. (1980), "Effects of Volcanic Ash on Insects". Proceedings of Conference on Aftermath of Mount St Helens (P.14-15). Washington State University.

Alexandrakis, V. and Neuenschwander, P. (1979), "Influence of Road Dust on Pests and Parasites of Olives". Annales de Zoologie-Ecologie Animale 11(2) : 171-184.

Barnicoat, C.R. (1957), "Wear in Sheep's Teeth". New Zealand Journal of Science and Technology, April 1957 : 583-585.

Barnicoat, C.R. (1963), "Attrition of the Hypospondent Tooth: Mechanisms of Hard Tissue Destruction". American Association for the Advancement of Science, 75: 155-170.

Barret, L.B. and Waddel, T.E. (1973), "The Cost of Air Pollution Damages : A Status Report". U.S. Environmental Protection Agency, Publication No. AP85.

Becker, D.L. (1978), "Quantifying the Environmental Impact of Particulate Deposition from Dry Unpaved Roadways". Thesis submitted for Master of Science, Iowa State University.

Blacktin, S.C. (1934), "Dust". Chapman and Hall Ltd., London.

Bradway, R.M. (1972), "Monitoring and Modelling of Resuspended Roadway Dust Near Urban Arterials". Transportation Research Record 670 : 25-32.

Bustad, L.K. (1980), "Biomedical Effects of Mt St Helens Ash". Proceedings of Conference on the Aftermath of Mt St Helens, Washington State University.

Clark, M.B. and Rennie, G.P. (ed) (1983), "Farm Budget Manual". Lincoln College.

Clinch, P. (1979), "Honeybees and Kiwifruit Pollination". Proceedings of New Zealand Kiwifruit Seminar, Tauranga.

Colwill, D.M. (ed) (1979), "The Impact of Road Traffic on Plants". Transport and Road Research Laboratory : Supplementary Report 513, London.

Cook, R.J., Barron, J.C., Papendick, R.I. and Williams, G.W. (1981), "Impact on Agriculture of Mt St Helens Eruptions". Science, Vol. 211 (January) : 16-21.

Cowherd, Chatten et al. (1974), "Development of Emission Factors for Fugitive Dust Sources". EPA Publication No. 450/3-74-037.

Crump, D.R., Barlow, P.J., Van Rest, D.J. (1980), "Seasonal Changes in the Lead Content of Pasture Grass Growing Near a Motorway". Agriculture and Environment (Netherlands) VII (3) : 213-225.

Danno, A., Miyazato, M. and Ishiguro, E. (1980), "Effect of Volcanic Ashes from Mt Sakurajima on Spectoral Reflectance of Plants". Bulletin 30 : 217-224, Kagoshima University Faculty of Agriculture.

Davies, C.N. (ed) (1967), Aerosol Science, Academic Press, New York.

Davison, R.M. (1977), "Some Factors Affecting Flowering and Cropping in Kiwifruit". Proceedings of New Zealand Kiwifruit Seminar, Tauranga.

Dyck, R.J. and Stakel, J.J. (1976), "Fugitive Road Dust Emissions from Trucks on Unpaved Roads". Environmental Science and Technology 10(10) : 1046-1048.

Eller, B.M. (1977a), "Road Dust Changed Energy Balance of Leaves". Angew Botanik 51 : 9-15.

Eller, B.M. (1977b), "Road Dust Induced Increase of Leaf Temperature". Environmental Pollution 13 : 99-107.

Engibous, J.C. and Papendick, R.I. (1980), "Impact of Mt St Helens Volcanic Ash on Northwest Agriculture". Proceedings from Annual Meeting of American Society of Agronomy, Detroit.

Esman, A.N. (1973), "A Direct Measurement Method of Dustfall". Journal of Air Pollution Control Association 23(1) : 34-36.

Fedon, J.S. (1981), "Effects of Mt St Helens Ash on the Response of Rat Trachea to Smooth Muscle Agonist". Environmental Research 26 : 497-499.

Ferro, D.N. (ed) (1976), New Zealand Insect Pests. Lincoln College.

Fisher, R.B. (1978), "Background to Factors Included in Economic Analysis of Roading Projects". Report presented to meeting of National Roads Board.

Forbes R.N. (ed) (1983), "Product Price Assumptions, 1983". Ministry of Agriculture and Fisheries, Palmerston North.

Frank, J. and Loomis, W.E. (1950), "Photosynthesis in Plants". Iowa State University.

Fye, R.E. (1982), "The Impact of Volcanic Ash on Pear Psylla and Associated Predators". Unpublished Report, Yakima Agricultural Research Laboratory.

Goudriaan, J. and Van Larr, H. (1978), "Calculation of Daily Totals of the Gross CO2 Assimilation of Leaf Canopies". Netherlands Journal of Agricultural Science 26 : 373-382.

Green, F.H.Y. (1983), "Health Implications of the Mt St Helens Eruptions : Laboratory Investigations in Inhaled Particles". Unwin Bros. Ltd., England.

Handy, R.L., Hoover, J.M., Bergeson, K.L. and Fox, D.E. (1975), "Unpaved Roads as Sources of Dust". Transportation Research News 60(75) : 6-9.

Harkness, N.R. (1976), "To Seal or Not to Seal". Ministry of Works and Development Internal Publication.

Healy, W.B. and Ludwig, T.G. (1965), "Wear of Sheep's Teeth: The Role of Ingested Soil". New Zealand Journal of Agricultural Research 8(4) : 737-752.

Heine, D.G. (1980), "Rural Roading Improvements - Are They Worth the Hay." Road Research Unit (RRU) Newsletter 68: 16-18, National Roads Board.

Heinsohn, R.Y., Birnie, C. and Cuscino, T.A. (1975), "Fugitive Dust from Vehicles Using Unpaved Roads". Proceedings from the National Conference on Energy and the Environment, Ohio, 393-404.

Hoover, J.M., Pitt, J.M., Lustig, M.T. and Fox, D.E. (1981), "Mission Orientated Dust Control and Surface Improvement Processes for Unpaved Roads". Iowa State University.

Howell, S. (1982), "Kiwifruit : Crop Costing". Unpublished Report, Lincoln College.

McCaldin, R.O. and Heidel, K.J. (1978), "Particulate Emissions from Vehicles Travelling Over Unpaved Roads". Proceedings from Annual Meeting of Air Pollution Control Association. Abstracts of Papers.

Montieth, J.L. (1975), "Vegetation and the Atmosphere, Volume 1 : Principles". Academic Press, London.

Moyle, G.L. (ed) (1982), "An Economic Survey of Factory Supply Dairy Farms in New Zealand, 1981-82". New Zealand Dairy Board, Wellington.

Parera, F.P. and Ahmeo, A.K. (1979), "Respirable Particles : Impact of Airborne Fire Particles on Health and the Environment". Ballinger Publishing Co., Cambrige.

Preston, R.L. (1980), "Results of Research on Volcanic Ash in Farm Livestock". Proceedings of Conference on the Aftermath of Mt St Helens, Washington State University : 7-8.

Reeves, R.J. (1982), "Sweet Oranges : Cash Flow". Unpublished Report, Lincoln College.

Ricks, G.R. and Williams, R.J.H. (1974), "Effects of Atmospheric Pollution on Deciduous Woodland Part 2 : Effects of Particulate Matter upon Stomatal Diffusion Resistance in Leaves of Quercus Pataea (Mattuschka) Leibl". Environmental Pollution 6 : 87-109.

Roberts, J.W. (1973), "Benefits to the Community from Reducing Dust in the air in Seattle's Duwamish Valley". Proceedings from Annual Meeting of the Pacific North West International Section of Air Pollution Control Association, Seattle. Paper No. 73-AP-33.

Roberts, J.W., Watters, H.A. Mangold, C.A. and Rossano, A.T. (1975), "Costs and Benefits of Road Dust Control in Seattle's Industrial Valley". Air Pollution Control Association Journal, 29(9) : 948-952.

Roberts, J.W., Rossano, A.T., Basserman, Hofer and Watters (1972), "The Measurement, Cost and Control of Traffic Dust in Seattle's Duwamish Valley". Proceedings from Annual Meeting of the Pacific North West International Section of the Air Pollution Control Association. Paper No. 72-AP-5.

Robinson, E. and Robbins, R.C. (1971), "Emissions, Concentrations and Rate of Particulate Atmospheric Pollutants". American Petroleum Institute, Washington DC. Report No. 4076.

Sampson, P.A. and Stretton, M.I. (1981), "Economic Appraisal of Seal Extension". Taupo County Council.

San Pietro, A. (ed) (1967), "Harvesting the Sun : Photosynthesis in Plant Life". Academic Press, New York.

Scott, D.J. (et al.) (1980), "Sheep and Cattle Nutrition". Ministry of Agriculture and Fisheries, Wellington.

Sievers, H.E. (1978), "Modified Line Source Models for Predicting 24 Hour and Annual Particulate Concentrations Resulting from Re-entrainment of Roadway Dust". Abstracts of Papers from Air Pollution Control Association, Annual Meeting and Exhibition: 3-16.

Stanhill, G., Moreshet, S., and Fuchs, M. (1976), "Effect of Increasing Foliage and Soil Reflectivity on the Yield and Water Use Efficiency of Grain Sorghum". Agronomy Journal 68 (April): 329-332.

Stern, A.C. (ed (1968), "Air Pollution (2nd Edition): Volume 1, Air Pollution and Its Effects". Academic Press, New York.

Stevens, R.B. (1983), Economics of Grape Production. Unpublished Report, Department of Horticulture, Lincoln College.

Tabata, S. and Tanabe, M. (1976), "Studies on the Physiological Effect of Soil Dust Adhesion to Plant Surfaces". Shinshu University.

Teskey, B.J.E. and Shoemaker, J.S. (1972), "Tree Fruit Production". (2nd Edition). Avi Publishing Co., Connecticut.

Veltman, A. (1982), "Apples: Crop Costings, Cash Flows and Net Present Values". Unpublished Report, Lincoln College.

Ward, N.I., Roberts, E. and Brooks, R.R. (1979), "Seasonal Variation in the Lead Content of Soils and Pasture Species Adjacent to a New Zealand Highway Carrying Medium Density Traffic". New Zealand Journal of Experimental Agriculture 7: 347-351.

Ward, N.I., Reeves, R.D. and Brookes, R.R. (1975), "Lead in Soil and Vegetation Along a New Zealand State Highway with Low Traffic Volume". Environmental Pollution 9: 243-251.

APPENDIX 1

CALCULATION OF NUMBER OF DAYS ON WHICH ROAD DUST IS LIKELY TO BE A PROBLEM ON PLANT SURFACES

Basic assumptions were made that:

(1) rainfall of at least 4mm on any day is needed to remove road dust from plant surfaces (Storey, pers. comm., 1983); it takes 6-12mm of rain to remove agricultural sprays; and that the effect of road dust on plant physiological processes on these days is nil.

(2) one extra day after rainfall is allowed for roads to dry during the period from November to March (Summer) and two days for the April to October (Winter) period (averaged from producer observations of drying patterns).

Calculations were then based on the daily rainfall figures for the Tauranga[18] Airport Meteorological Station for the past 10 years (1973 to 1982) and involved:

(1) adding up the total days per month with greater than 4mm rainfall plus the appropriate number of drying days;

(2) subtracting these figures from the number of days in the month;

(3) calculating the mean number of 'dusty' days for each month over the ten years ; and

(4) estimating the 'best' and 'worst' possible number of dusty days by using a 90% confidence interval (1.64 standard deviations). Assuming rainfall figures are normally distributed, then actual numbers of days on which dustiness occurs should only exceed the confidence estimates in one year out of ten, for any month.

These are shown in Table 51.

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18 This was given as the most representative station for Tauranga County.

TABLE 51

Average Number of 'Dusty' Days per Month for Period 1973 until 1982

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1973	24	26	21	22	8	14	23	10	10	19	18	26
1974	29	23	24	22	20	14	4	8	8	15	18	14
1975	18	24	26	18	15	20	11	13	24	5	16	21
1976	21	22	23	14	18	12	10	10	15	9	22	20
1977	27	23	28	18	14	12	16	16	13	16	21	17
1978	27	22	29	18	25	15	10	13	17	23	24	13
1979	27	18	19	20	19	24	9	6	15	16	20	18
1980	19	18	21	14	25	11	10	14	15	20	12	22
1981	21	23	25	21	24	5	8	10	11	17	20	21
1982	24	22	23	21	14	22	19	22	15	16	26	22
Mean	23.7	22.1	23.9	18.8	17.7	14.9	12	12.2	14.3	15.6	19.7	19.4
Standard Deviation	3.60	2.34	3.01	2.82	5.51	5.39	5.36	4.30	4.17	4.9	3.79	3.74

Table 52 presents the range of expected number of dry days per month, rounded to 1.64 standard deviations, and also the expected annual and seasonal percentage numbers of dry days.

TABLE 52

Number of Days Per Month on Which Road Dust May Be Significant in Tauranga County

	SUMMER			WINTER							SUMMER				
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Yearly Total	Yearly % Dry Days	Summer % Dry Days	Winter % Dry Days
HIGH	29	27	28	26	25	20	26	25	18	26	26	26	302	84	91	79
MEDIUM	24	21	21	19	18	15	17	16	15	18	21	22	229	64	74	56
LOW	19	15	15	12	11	10	8	7	12	10	16	18	156	43	57	34

APPENDIX II

FINDINGS OF WARD ET AL. (1979) AND HOOVER ET AL. (1981) ON PREVAILING UPWIND AND DOWNWIND DEPOSITION DIFFERENCES

FIGURE 6

Average Lead Concentration on Leaves of Lolium Perenne Bordering a Rural Road

(Ward et al., 1979)

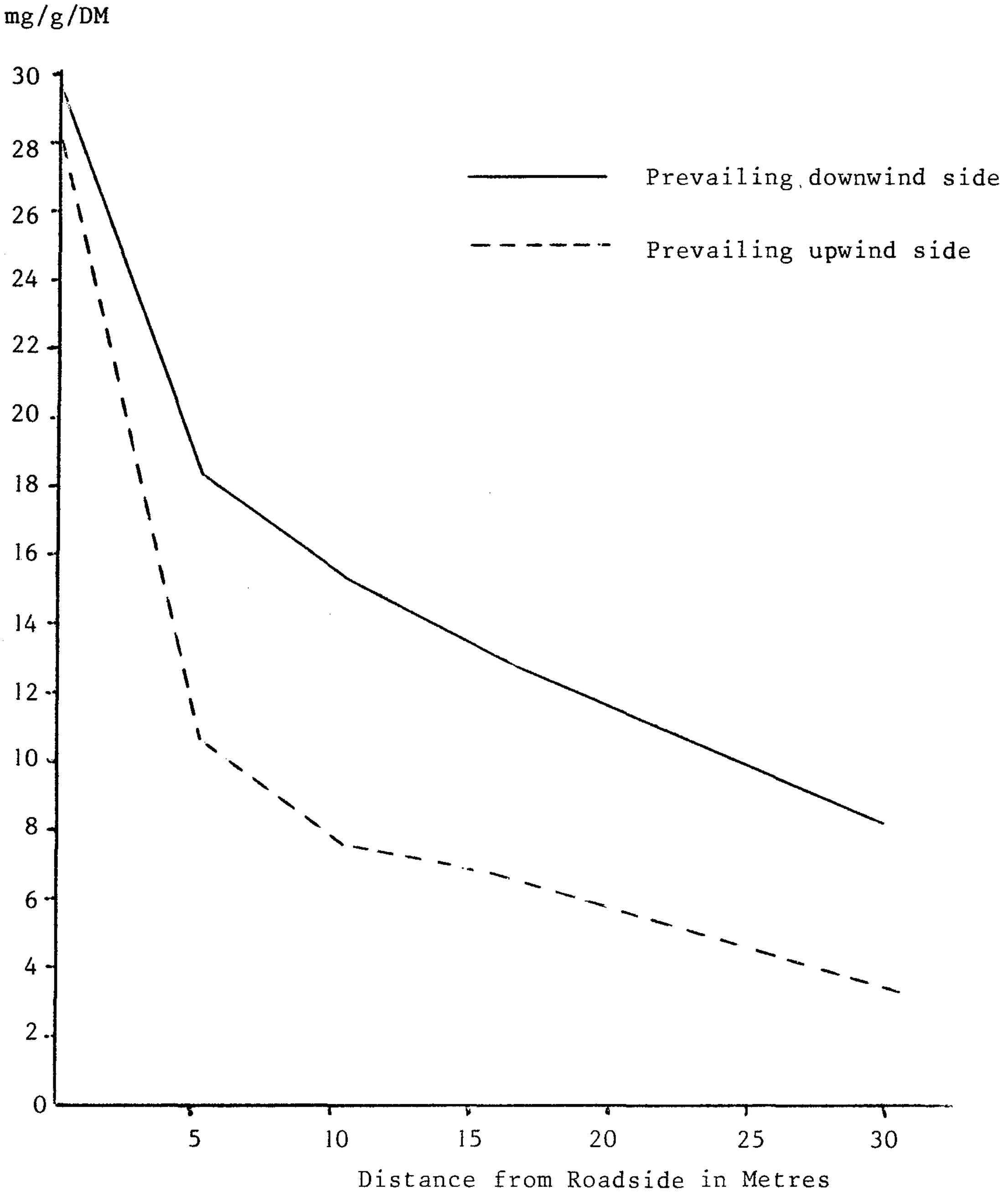
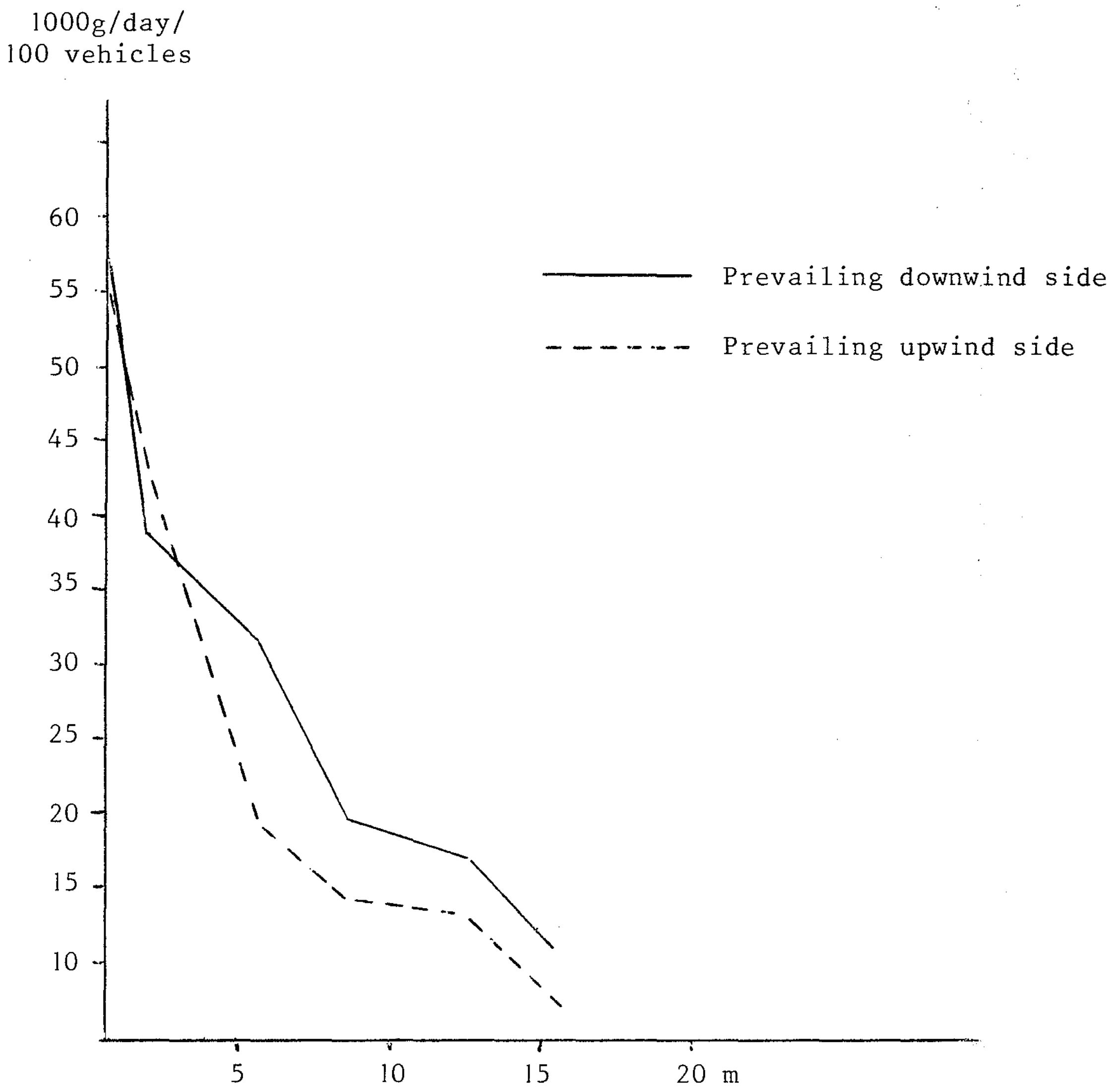


FIGURE 7

Average Dustfall Away From Metal Roads

(Hoover et. al., 1981)



APPENDIX III
TABLE 53

CUMULATIVE AVERAGE ROAD DUST DEPOSITION AND PERCENTAGE DEPOSITIONS ADJOINING A METAL ROADWAY [19]

Distance From Road (m)	Downward Deposition			Upwind Deposition			Total Deposition	
	Actual Cumulative (μg/m)	Percentage	Cumulative Percentage	Actual Cumulative (μg/m)	Percentage	Cumulative Percentage	Downwind Percentage	Upwind Percentage
0								
		18.9			31.3		13.4	9.1
10	2,500		18.9	1,700		31.3		
		5.8			6.1		4.1	1.8
15	3,272	-9.9	24.7	2,027	-11.8	37.4	7	-3.5
		4.1			5.7		2.9	1.7
20	3,816		28.8	2,336		43.1		
		3.5			4.7		2.5	1.4
25	4,292	-6.9	32.3	2,590	-9.2	47.8	4.9	-2.7
		3.4			4.5		2.4	1.3
30	4.732		35.7	2,835		52.3		
		5.2			5.9		3.7	1.7
40	5,424		40.9	3,154		58.2		
		4.6			5.1		3.3	1.5
50	6,020		45.5	3,432		63.3		
		3.7			3.5		2.6	1.0
60	6,520		49.2	3,620		66.8		
		3.1			2.8		2.2	0.8
70	6,928		52.3	3,772		69.6		
		2.5			2.6		1.8	0.7
80	7,266		54.8	3,913		72.2		
		2.4			2.1		1.7	0.6
90	7,590		57.2	4,029		74.3		
		2.1			2		1.5	0.6
100	7,852		59.3	4,135		76.3		
		9.1			7		6.5	2.0
150	9,073		68.4	4,516		83.3		
		7					5.0	
200	9,993		75.4					
		5.8					4.1	
250	10,765		81.2					
		4.3					3.1	
300	11,329	23.9	85.5		-16.1			-4.8
		3.4					2.4	
350	11,789		88.9					
		3.4					2.4	
400	12,229		92.3	5,414		99.9		
		3					2.1	
450	12,625		95.3					
		2.5					1.8	
500	12,965		97.8		0.1			
		1.8					1.3	
550	13,193		99.6					
		0.4					0.3	
Total	13,250*	100%	100%	5,420*	100%	100%	71%	29%

---

[19] Becker's findings are not entirely compatible with Ward's and Hoover's as he looked only at downwind deposition from a specified number of vehicle passes; whereas Ward and Hoover looked at deposition over time, with respect to the <u>prevailing</u> wind direction. Thus, comparing actual figures is meaningless, but it seems logical that the difference factors, applied to Becker's figures, would give a fair indication of deposition percentages over time. Hence the percentage figures listed in Table 4 are an average for any day, and are not specific to any one day or wind direction

APPENDIX IV

ENTERPRISE DATA AND CALCULATIONS

TABLE 54

Granny Smith Apple Cash Flow ($/hectare)

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Yield/ha (tonnes)	-	-	-	3.2	15.1	36.1	56.1	58.1	65.0	71.7	93.2	113.7	134.1	150.2	162.2	168.0
Revenue ($)																
Export	-	-	-	301	1434	3442	4820	5541	6191	6827	8875	10828	12776	14310	15453	16072
Local Fresh	-	-	-	93	441	1059	1482	1704	1904	2100	2730	3330	3929	4401	4752	4942
Process	-	-	-	71	340	817	1144	1315	1470	1621	2106	2570	3032	3396	3668	3815
Total Revenue	-	-	-	465	2215	5318	7446	8560	9565	10548	13711	16728	19373	22107	23873	24829
Costs ($)																
Harvesting	-	-	-	130	620	1489	2081	2397	2678	2953	3838	4684	5527	6190	6685	6952
Capital																
Land Prep.	232	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Trees	3082	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Fencing	1710	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Production																
Fertiliser	58	136	150	165	178	178	178	178	178	178	178	178	178	178	178	178
Spray	178	143	219	1224	1694	1824	1824	1824	1824	1824	1824	1824	1824	1824	1824	1824
Pruning	-	42	27	15	-	-	-	-	-	-	-	-	-	-	-	-
Irrigation	-	34	34	42	54	66	66	66	66	66	66	66	66	66	66	66
Labour	469	448	532	784	865	697	697	697	697	697	697	697	697	697	697	697
Machinery	54	151	151	415	430	461	461	461	461	461	461	461	461	461	461	461
Misc. Pre-Harvest	-	-	-	101	101	101	101	101	101	101	101	101	101	101	101	101
Total Costs ($)	5783	954	1113	2876	3942	4816	5408	5724	6005	6280	7165	8011	8854	9517	10012	10279
Net Cash Flow ($)	-5783	-954	-1113	-2411	-1727	502	2038	2836	3560	4268	6546	8718	10883	12590	13861	14550

TABLE 55

Possible Economic Effects of Apple Yield Loss Caused by Photosynthesis Reduction

Year 15

Yield 168.75/ha

Gross Margin $14550/ha

Traffic Volume per Day	Affected Area ha/km	Type of Year	% Redn Yield	(t) Yield Loss per ha	($) Yield Loss Cost/ha	($) Plus Reduced Charges	($) Total Cost per ha of Affected Land	($) Cost/km
500	12.5	Dry	2.3	3.88	570	252	318	3975
		Normal	1.7	2.87	422	187	235	2938
		Wet	1.1	1.86	273	121	152	1900
	3.5	Dry	7.6	12.82	1885	833	1052	3682
		Normal	5.7	9.62	1414	625	789	2761
		Wet	3.9	6.58	967	428	539	1886
250	12.5	Dry	1.3	2.19	322	142	180	2250
		Normal	0.9	1.52	223	99	124	1550
		Wet	0.6	1.01	148	66	82	1025
	3.5	Dry	3.9	6.58	967	428	539	1886
		Normal	2.9	4.89	719	318	401	1404
		Wet	1.9	3.20	470	208	262	917
75	12.5	Dry	0.3	0.51	75	33	42	525
		Normal	0.2	0.34	50	22	28	350
		Wet	0.1	0.17	25	11	14	175
	3.5	Dry	1.3	2.19	322	142	180	630
		Normal	0.9	1.52	223	98	125	437
		Wet	0.6	1.01	148	66	82	287

TABLE 56

Extract of 'Kiwifruit Export Grade Standards, Guidelines 1983' Relating to Aspects Which May Be Associated With Road-Dust Contamination

Allowance for skin defects: Each kiwifruit is permitted skin defects within the following limits, provided that the aggregate area of all defects, when two or more are present, shall not exceed 1 sq.cm.

FRUIT DEFECTS	BLEMISH
Water Stain	
Appearance:	Single or multiple streaks/stains running part way or the full length of the fruit from the calyx to the flower of the fruit.
Cause:	Usually dust or dead matter lodged in the vine canopy decaying and as a result of water running over this material and onto the fruit, a stain occurs.
Reason Removed:	A cosmetic defect that detracts from appearance of the fruit.
Allowance:	Staining that merges with the colour of the fruit, is permitted. Fruit that has dark streaks/stains exceeding one square centimetre, is NOT permissible.
Fungal Damage (Sclerotinia/Botrytis)	
Appearance:	Usually a teardrop shaped scar resulting in a cavity in the fruit. Often found in the shoulder or the side of the fruit.
Cause:	The action of the fungus growing on the fruit as a result of spores being deposited and becoming aggressive in suitable climatic conditions. Can occur at any time conditions are favourable during the period of fruit growth.
Reason Removed:	A cosmetic defect that detracts from the appearance of the fruit.

MIS-SHAPEN FRUIT

Flats/Fans

Appearance: A fruit which is wider than it is long.

Cause: A mutation in bud development which leads to the production of a distorted flower, resulting in a "flat" fruit following pollination.

Reason Removed: Cosmetic - these fruit cannot easily be packed in a pocket, are not the typical shape of the variety and spoil the overall appearance of the tray.

Allowance: To be acceptable for export, a fruit must be at least as long as it is wide. A square fruit, i.e. length = width is acceptable for export but should be placed in the corner of the tray.

Fruit that is Fan shaped is NOT acceptable for export.

Dropped Shoulder

Appearance: One shoulder of the fruit is not perpendicular to the calyx stem junction but falls away at an angle greater than 15 degrees from horizontal.

Cause: Thought to be due to one of the sepals hanging over one side of the flower, preventing complete pollination.

Reason Removed: Not the typical shape of the variety.

Allowance: A shoulder with a slope which is less than 15 degrees from the horizontal is acceptable for export.

SURFACE DEPOSITS

Dirty Fruit

Appearance: Soil, grease, bird droppings, or other foreign matter on the fruit.

Cause: Fruit sitting on ground, soil thrown up by mowers, oil from forklifts and bird droppings.

Reason Removed: A cosmetic defect that detracts from the appearance of the fruit.

Allowance: None.

UNSOUND FRUIT

Frost Damage (Close to Harvest)	N.B. For frost damage during bud development refer to frost damage under "Mis-Shapen Fruit"
Appearance:	A surface burn and premature softening of fruit.
Cause:	Exposure to frost close to harvest.
Reason Removed:	This type of frost damage usually leads to premature softening or reduced storage life.
Allowance:	None .

TABLE 57

Kiwifruit Cash Flow ($/hectare)

Year	0	1	2	3	4	5	6	7	8	9	10
Yield/ha (tonnes)	-	-	-	-	6	85	12.5	17	20	21	21
Revenue ($)											
Export	-	-	-	-	15939	22576	33200	45152	53120	55776	55776
Local Fresh	-	-	-	-	366	519	763	1037	1220	1281	1281
Process	-	-	-	-	963	1364	2006	2729	3210	3371	3371
Total Revenue ($)	-	-	-	-	17265	24459	35969	48918	57550	60428	60428
Costs ($)											
Establishment	11950	60	1150	-	-	-	-	-	-	-	-
Production											
Fertiliser	-	180	180	90	75	75	75	75	75	75	75
Spray	-	37	37	57	92	149	149	149	149	149	149
Machinery	-	140	185	255	255	270	270	270	270	270	270
Labour	-	250	1070	955	1000	1090	1090	1340	1640	1690	1690
Miscellaneous	-										
Harvesting	-	-	-	-	438	621	913	1241	1460	1533	1533
Freight	-	-	-	-	96	136	200	272	320	336	336
Packing[a]	-	-	-	-	5274	7472	10987	14943	17580	18459	18459
Total Costs ($)	11950	667	2622	1357	7230	9813	13684	18290	21494	22512	22512
Net Cash Flow ($)	-11950	-667	-2622	-1357	10035	14646	22285	30628	36056	37916	37916

TABLE 58

Possible Economic Effects of Kiwifruit Yield Loss Caused by Photosynthesis Reduction

Year 10

Yield 21t/ha

Normal Net Revenue $37916

Traffic Volume per Day	Affected Area ha/km	Type of Year	% Redn Yield	(t) Yield Loss per ha	($) Yield Loss Cost/ha	($) Plus Reduced Charges	($) Total Cost per ha of Affected Land	($) Cost/km
500	12.5	Dry	2.3	0.48	1381	422	959	11988
		Normal	1.7	0.36	1036	316	720	9000
		Wet	1.1	0.23	662	202	460	5750
	3.5	Dry	7.6	1.60	4605	1406	3199	11197
		Normal	5.7	1.20	3454	1055	2399	8396
		Wet	3.9	0.82	2360	720	1640	5740
250	12.5	Dry	1.3	0.27	777	237	540	6750
		Normal	0.9	0.19	547	167	380	4750
		Wet	0.6	0.13	374	114	260	3250
	3.5	Dry	3.9	0.82	2360	720	1640	5740
		Normal	2.9	0.61	1756	536	1220	4270
		Wet	1.9	0.40	1151	352	799	2746
75	12.5	Dry	0.3	0.06	173	53	120	1500
		Normal	0.2	0.04	115	35	80	1000
		Wet	0.1	0.02	58	18	40	500
	3.5	Dry	1.3	0.27	777	237	540	1890
		Normal	0.9	0.19	547	167	380	1330
		Wet	0.6	0.13	374	114	260	910

TABLE 59

Peach Cash Flow ($/hectare)

Year	0	1	2	3	4	5	6
Yield/ha (tonnes)	-	-	-	11.34	18.83	22.61	22.61
Revenue ($)							
Export	-	-	-	-	-	-	-
Local Fresh	-	-	-	9185	15252	18314	18314
Process	-	-	-	-	-	-	-
Total Revenue ($)	-	-	-	9185	15252	18314	18314
Costs ($)							
Capital	5254	-	-	-	-	-	-
Production							
Fertiliser	-	304	695	695	695	695	695
Sprays	-	146	470	856	860	860	860
Irrigation	-	25	25	30	40	40	40
FSC	-	110	130	168	192	192	192
Machinery	-	115	135	150	175	175	175
Prune	-	50	168	336	560	840	1120
Harvesting	-	-	-	1247	2071	2487	2487
Freight	-	-	-	975	1619	1944	1944
Total Costs	5254	750	1623	4457	6212	7233	7513
Net Cash Flow	-5254	-750	-1623	4728	9040	11081	10801

TABLE 60

Possible Economic Effects of Peach Yield Loss Caused by Photosynthesis Reduction

Year 6
Yield 22.6t/ha
Gross Margin $10801

Traffic Volume per Day	Affected Area km/ha	Type of Year	(t) % Redn Yield	($) Yield Loss per ha	($) Yield Loss Cost/ha	($) Plus Reduced Charges	($) Total Cost per ha of Affected Land	($) Cost/km
500	12.5	Dry	1.9	0.43	348	84	264	3300
		Normal	1.4	0.32	259	63	196	2450
		Wet	0.9	0.20	162	39	123	1538
	3.5	Dry	6.4	1.45	1175	284	891	3118
		Normal	4.8	1.08	875	212	663	2320
		Wet	3.3	0.75	608	147	461	1613
250	12.5	Dry	1.0	0.23	186	45	141	1763
		Normal	0.7	0.16	130	31	99	1238
		Wet	0.5	0.11	89	22	67	838
	3.5	Dry	3.1	0.70	567	137	430	1505
		Normal	2.3	0.52	421	102	319	1116
		Wet	1.5	0.34	275	67	208	728
75	12.5	Dry	0.3	0.07	57	14	43	538
		Normal	0.2	0.05	41	10	31	388
		Wet	0.1	0.02	16	4	12	150
	3.5	Dry	1.0	0.23	186	45	141	493
		Normal	0.8	0.18	146	35	111	388
		Wet	0.5	0.11	89	22	67	235

TABLE 61

Blueberry Cash Flow ($/hectare)

Year	0	1	2	3	4	5	6	7	8
Yield/ha (tonnes)		-	-	0.8	2.60	4.40	5.07	5.40	7.00
Revenue Export				3660	11700	19800	22815	24300	31500
Local Fresh				1000	3250	5500	6338	6750	8750
Process				80	260	440	507	540	700
TOTAL REVENUE ($)				4680	15210	25740	29660	31590	40950
COSTS Establishment	438	8822							
Production									
Fertilizers			164	223	242	242	242	242	242
Sprays			513	630	827	917	917	917	917
Pruning			117	180	234	292	292	292	292
Miscellaneous		39	61	120	120	120	420	270	120
Marketing									
Harvesting				480	1560	2643	3043	3243	4203
Grading				480	1560	2643	3043	3243	4203
Packaging				600	1950	3300	3802	4050	5250
TOTAL COSTS ($)	438	8861	855	2713	6493	10157	11759	12257	15227
NET CASH FLOW	-438	-8861	-855	1967	8717	15583	17901	19333	25723

TABLE 62

Possible Economic Effects of Blueberry Yield Loss Caused by Photosynthesis Reduction

Year 8

Yield 7t/ha

Gross Margin $25723

Traffic Volume per Day	Affected Area ha/km	Type of Year	(t) % Redn Yield	($) Yield Loss per ha	($) Yield Loss Cost/ha	($) Plus Reduced Charges	($) Total Cost per ha of Affected Land	($) Cost/km
500	12.5	Dry	2.3	0.161	943	314	639	7862
		Normal	1.7	0.119	697	232	465	581
		Wet	1.1	0.077	451	150	301	3762
	3.5	Dry	7.6	0.532	3116	1037	2079	7276
		Normal	5.7	0.399	2337	778	1559	5456
		Wet	3.9	0.273	1599	532	1667	3734
250	12.5	Dry	1.3	0.091	533	177	356	4450
		Normal	0.9	0.063	369	123	246	3075
		Wet	0.6	0.042	246	82	164	2050
	3.5	Dry	3.9	0.273	1599	532	1067	3734
		Normal	2.9	0.203	1189	396	793	2775
		Wet	1.9	0.133	779	259	520	1820
75	12.5	Dry	0.3	0.021	123	41	82	1026
		Normal	0.2	0.014	82	27	55	687
		Wet	0.1	0.007	41	14	27	338
	3.5	Dry	1.3	0.091	533	177	356	1246
		Normal	0.9	0.063	369	123	246	861
		Wet	0.6	0.042	246	82	164	574

TABLE 63

Avocado Cash Flow ($/hectare)

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Yield/ha (tonnes)		—	—	—	0.6	6.4	1.6	14.6	2.1	19.5	2.1	29.8	20.4	29.8	29.8	16.3
TOTAL REVENUE					4200	44800	11200	102200	14700	136500	14700	208600	142800	208600	208600	114100
Costs																
Establishment	4873															
Production																
Fertilizer		205	248	352	517	517	517	517	517	517	517	517	517	517	517	517
Mowing		96	96	96	96	96	96	96	96	96	96	96	96	96	96	96
Sprays		65	120	184	260	260	260	260	260	260	260	260	260	260	260	260
Tree Removal									200	200	200					
Marketing																
Harvesting					30	320	80	730	105	975	105	1490	1020	1590	1490	815
Packing					120	1280	320	2920	420	3900	420	5960	4080	5960	5960	3260
Labour					26	272	68	620	89	829	89	1266	867	1266	1266	693
Transport					120	1280	320	2920	420	3900	420	5960	4080	5960	5960	3260
TOTAL COSTS	4873	366	464	632	1169	4025	1661	8063	2107	10677	2107	15549	10920	15549	15549	8901
NET CASH FLOW	–4873	–366	–464	–632	3031	40775	9539	94137	12593	125823	12593	193051	131880	193051	193051	105199

TABLE 64

Possible Economic Effects of Avocado Yield Loss Caused by Photosynthesis Reduction

Year 12

Yield 20.4t/ha

Gross Margin $131880

Traffic Volume per Day	Affected Area ha/km	Type of Year	(t) % Redn Yield	($) Yield Loss per ha	($) Yield Loss Cost/ha	($) Plus Reduced Charges	($) Total Cost per ha of Affected Land	($) Cost/km
500	12.5	Dry	2.2	0.45	3150	222	2928	36600
		Normal	1.6	0.33	2310	163	2147	26838
		Wet	1.0	0.20	1400	99	1301	16262
	3.5	Dry	6.8	1.39	9730	685	9045	31658
		Normal	5.1	1.04	7280	513	6767	23685
		Wet	3.3	0.67	4690	330	4360	15260
250	12.5	Dry	1.1	0.22	1540	108	1432	17900
		Normal	0.8	0.16	1120	79	1041	13012
		Wet	0.5	0.10	700	49	651	8138
	3.5	Dry	3.5	0.71	4970	350	4620	16170
		Normal	2.5	0.51	3570	251	3319	11616
		Wet	1.6	0.33	2310	163	2147	7514
75	12.5	Dry	0.4	0.08	560	39	521	6512
		Normal	0.3	0.06	420	30	390	4875
		Wet	0.2	0.04	280	20	260	3250
	3.5	Dry	1.2	0.24	1680	118	1562	5467
		Normal	0.9	0.18	1260	89	1171	4098
		Wet	0.6	0.12	840	59	781	2733

TABLE 65

Maize Gross Margin

GROSS REVENUE PER HECTARE	$	$
8 Tonnes @ $190 per tonne (dry weight)		$1,520.00
<u>Direct Cost Per Hectare</u>		
Preparation	237	
Fertilizer	111	
Sprays	148	
Harvesting	130	
Drying	160	
Cartage	72	
TOTAL COSTS		$858.00
GROSS MARGIN PER HECTARE		$662.00

TABLE 66

Possible Economic Effects of Maize Yield Loss Caused by Photosynthesis Reduction

		Traffic Volume per Day	Affected Area ha/km	Type of Year	(t) % Redn Yield	($) Yield Loss per ha	($) Yield Loss Cost/ha	($) Plus Reduced Charges	($) Total Cost per ha of Affected Land	($) Cost/km
		500	19	Dry	2.4	0.192	36	9	27	513
				Normal	1.8	0.144	27	6	21	399
				Wet	1.2	0.096	18	4	14	266
			6.5	Dry	7.1	0.568	108	26	82	533
				Normal	5.4	0.432	82	19	63	409
				Wet	3.7	0.296	56	13	43	280
		250	19	Dry	1.3	0.104	20	5	15	285
				Normal	1.0	0.08	15	4	11	209
Yield	8t/ha			Wet	0.6	0.048	9	2	7	133
Gross Margin	$622/ha		6.5	Dry	3.5	0.28	53	13	46	299
				Normal	2.6	0.208	40	9	31	201
				Wet	1.8	0.144	27	6	21	136
		75	19	Dry	0.4	0.032	6	2	4	76
				Normal	0.3	0.024	5	1	4	76
				Wet	0.2	0.016	3	1	2	38
			6.5	Dry	1.1	0.088	17	4	13	84
				Normal	0.8	0.064	12	3	9	58
				Wet	0.5	0.04	8	2	6	39

TABLE 67

Asparagus Cash Flow ($/hectare)

Year		1	2	3	4	5	6	7
Yield/ha (tonnes)		-	-	3	4.5	6	7	4.5
Revenue	Export	-	-	4200	6300	8400	9800	6300
	Process	-	-	3228	4842	6456	7532	4842
TOTAL REVENUE ($)		-	-	7428	11142	14956	17332	11142
COSTS	Capital Costs	100		220				
Production Costs								
	Cultivation	141	103	103	103	103	103	103
	Fertilizer	589	52	471	471	471	471	471
	Sprays	15	40	40	40	40	40	40
	Machinery	360	34	50	50	50	50	50
	Labour	664	14	25	25	25	25	25
	Harvesting			900	1350	1800	2100	1350
	Marketing			1050	1575	2100	2450	1575
TOTAL COSTS ($)		1869	243	2859	3614	4589	5239	3614
NET CASH FLOW		-1869	-243	6378	7528	10267	12093	7528

TABLE 68

Possible Economic Effects of Asparagus Yield Loss Caused by Photosynthesis Reduction

	Traffic Volume per Day	Affected Area ha/km	Type of Year	(t) % Redn Yield	($) Yield Loss per ha	($) Yield Loss Cost/ha	($) Plus Reduced Charges	($) Total Cost per ha of Affected Land	($) Cost/km
Year 6 Yield 7t/ha Gross Margin $12093	500	19	Dry	1.0	0.070	173	42	131	2489
			Normal	0.8	0.056	139	34	105	1995
			Wet	0.6	0.042	104	25	79	1501
		6.5	Dry	4.1	0.287	711	172	539	3504
			Normal	3.3	0.231	572	139	433	2815
			Wet	2.5	0.175	433	105	328	2132
	250	19	Dry	0.5	0.035	87	21	66	1254
			Normal	0.4	0.028	69	17	52	988
			Wet	0.3	0.021	52	13	39	741
		6.5	Dry	1.4	0.098	243	59	184	1196
			Normal	1.1	0.077	191	46	145	942
			Wet	0.8	0.056	139	34	105	683
	75	19	Dry	0.1	0.007	17	4	13	247
			Normal	0.1	0.007	17	4	13	247
			Wet	0.05	0.004	10	2	8	152
		6.5	Dry	0.4	0.028	69	17	52	338
			Normal	0.3	0.021	52	13	39	254
			Wet	0.2	0.014	35	8	27	176

TABLE 69

Pumpkin Gross Margin

	YIELD (t)	REVENUE ($)
Yield per hectare	16	
Gross Revenue		$3,200
Less Costs		
Preparation		138
Fertilizer and Lime		560
Spraying		229
Weeding		218
Harvesting		768
Commission Levy		320
Total Costs		$2,230
GROSS MARGIN PER HECTARE		$970

TABLE 70

Possible Economic Effects of Pumpkin Yield Loss Caused by Photosynthesis Reduction

Yield 16t/ha

Gross Margin $970/ha

Traffic Volume per Day	Affected Area ha/km	Type of Year	(t) % Redn Yield	($) Yield Loss per ha	($) Yield Loss Cost/ha	($) Plus Reduced Charges	($) Total Cost per ha of Affected Land	($) Cost/km
500	19	Dry	1.9	0.30	61	20	41	779
		Normal	1.5	0.24	48	16	32	608
		Wet	1.0	0.16	36	10	26	494
	6.5	Dry	6.5	1.04	208	68	140	910
		Normal	5.0	0.80	160	52	108	702
		Wet	3.6	0.567	113	37	76	494
250	19	Dry	1.0	0.16	32	10	22	418
		Normal	0.7	0.112	22	7	15	285
		Wet	0.5	0.08	16	5	11	209
	6.5	Dry	2.9	0.464	93	30	63	410
		Normal	2.2	0.352	70	23	47	306
		Wet	1.6	0.256	51	17	34	221
75	19	Dry	0.3	0.048	10	3	7	133
		Normal	0.2	0.032	6	2	4	76
		Wet	0.1	0.016	3	1	2	38
	6.5	Dry	0.9	0.144	29	9	20	130
		Normal	0.6	0.096	19	6	13	85
		Wet	0.4	0.064	13	4	9	59

TABLE 71

Summer Lettuce Gross Margin

	YIELD (Cases)	REVENUE ($)
Yield per hectare	2,250	
Gross Revenue		$8,100
Less Costs		
Preparation		267
Fertilizer		217
Sprays		434
Irrigation		150
Weeding and Thinning		335
Harvesting		2,412
Washing (in cases)		126
Cases		338
Freight		395
Commission		810
Total Costs		$5,477
GROSS MARGIN PER HECTARE		$2,623

TABLE 72

Possible Economic Effects of Summer Lettuce Yield Loss Caused by Photosynthesis Reduction

Year

Yield 2250

Gross Margin $2623

Traffic Volume per Day	Affected Area	Type of Year	(t) % Redn Yield	($) Yield Loss per ha	($) Yield Loss Cost/ha	($) Plus Reduced Charges	($) Total Cost per ha of Affected Land	($) Cost/km
500	31	Dry	0.3	6.75	24	12	12	372
		Normal	0.2	4.50	16	8	8	248
		Wet	0.1	2.25	8	4	4	124
	12.5	Dry	0.9	20.25	73	37	36	450
		Normal	0.7	15.75	57	29	28	350
		Wet	0.2	4.50	16	8	8	100
250	31	Dry	0.2	4.50	16	8	8	248
		Normal	0.1	2.25	8	4	4	124
		Wet	0.05	1.13	4	2	2	62
	12.5	Dry	0.4	9.0	32	16	16	200
		Normal	0.3	6.75	24	12	12	150
		Wet	0.2	4.50	16	8	8	100
75	31	Dry	0.1	2.25	8	4	4	124
		Normal	0.1	2.25	8	4	4	124
		Wet	0.05	1.13	4	2	2	62
	12.5	Dry	0.1	2.25	8	4	4	50
		Normal	0.1	2.25	8	4	4	50
		Wet	0.05	1.13	4	2	2	25

TABLE 73

Winter Lettuce Gross Margin

	YIELD (Cases)	REVENUE ($)
Yield per hectare	2,250	
Gross Revenue		$14,625
Less Costs		
Preparation		260
Fertilizer		318
Sprays		208
Weeding & Thinning		253
Harvesting		2,412
Washing (in cases)		126
Cases		338
Freight		395
Commission		1,463
Total Costs		$5,773
GROSS MARGIN PER HECTARE		$8,852

TABLE 74

Possible Economic Effects of Winter Lettuce Yield Loss Caused by Photosynthesis Reduction

	Traffic Volume per Day	Affected Area ha/km	Type of Year	(t) % Redn Yield	($) Yield Loss per ha	($) Yield Loss Cost/ha	($) Plus Reduced Charges	($) Total Cost per ha of Affected Land	($) Cost/km
	500	31	Dry	1.3	29	188	61	127	3937
			Normal	1.0	22	143	46	97	3007
			Wet	0.6	13	84	27	57	1767
		12.5	Dry	3.1	70	455	147	308	3850
			Normal	2.2	49	318	103	215	2687
			Wet	1.3	29	188	61	127	1587
Yield 2250 cases/ha Gross Margin $8852/ha	250	31	Dry	0.5	11	71	23	48	1488
			Normal	0.3	7	45	15	30	930
			Wet	0.2	4	26	8	18	558
		12.5	Dry	1.7	38	247	80	167	2087
			Normal	1.2	27	175	57	118	1475
			Wet	0.7	16	104	34	70	875
	75	31	Dry	0.2	4	26	8	18	558
			Normal	0.1	2	13	4	9	279
			Wet	0.05	1	6	2	4	124
		12.5	Dry	0.5	11	71	23	48	600
			Normal	0.3	7	45	15	30	375
			Wet	0.2	4	26	8	18	225

TABLE 75

Gross Margin
Factory Supply Dairying

	$	$
GROSS INCOME PER COW		
150 kg milkfat per cow @ $3.50/kg		525.00
0.65 bobby calf @ $22.00		14.30
0.15 cull cows @ $220.00		33.00
Total Gross Income Per Cow		$572.30
DIRECT COSTS PER COW		
Animal Health	15.00	
Electricity	10.00	
Shed Expenses	6.50	
AI and herd testing	14.00	
Feed (20 bales equivalent/cow)	25.00	
Freight	3.00	
Total Direct Costs per Cow		73.50
GROSS MARGIN PER COW		$498.00
and at a normal stocking rate of 2.2 cows per hectare:		
GROSS MARGIN PER HECTARE		$1,097.00

SOURCE: Ministry of Agriculture and Fisheries.

TABLE 76

Gross Margin - Breeding Flock

Policy: Breeding ewes, shorn twice/year.

Assume: 95% lambing (survived to sale). Wool 5.3 kg/stock unit. 70% of lambs sold fat, 30% store.

Stock on Hand (June)			Purchases:	4	Rams	
1000 Ewes	$20	$20,000	Natural Increase:	950	Lambs	954
250 Hoggets	$25	$6,250				
15 Rams	$125	$1,875	Sales:	200	Ewes	
				700	Lambs	
(1200 Stock Units)		$28,125	Losses, Killers:	54		954

GROSS MARGIN

Income		
Wool: 1200 SU x 4.8 kg/SU 5760 kg @ $3.00	$17,280	
Lambs: 700 @ $15.00 average	10,500	
Ewes: 200 @ $10.00	2,000	
		$29,780
Expenditure		
Shearing: 1200 SU @ $2.35/SU (= 81c/shearing)	2,820	
Animal Health: 1200 @ 90c/SU	1,080	
Ram Purchases: 4 @ $125	500	
		4,400
GROSS MARGIN PER 1000 EWES		$25,390
GROSS MARGIN PER STOCK UNIT		$21.15
GROSS MARGIN PER HECTARE (at 12 SU/ha)		$254

SOURCE: Ministry of Agriculture and Fisheries

APPENDIX V

COSTS TO PRODUCTION WHEN PERCENTAGE EFFECTS OF ROAD DUST ARE COMPOUNDED DURING ESTABLISHMENT OF HORTICULTURAL ENTERPRISES

Doubts as to the applicability of using mature horticultural crop margins for all calculations prompted the following example of costs to a kiwifruit orchard from road dust, throughout its establishment years. The aim was to establish whether or not the mature crop costings are in fact valid.

For a comparison, it was assumed that an annual 5 per cent yield reduction is caused by road dust to kiwifruit production. All other costs were disregarded.

Applying the mature crop costing approach, the annual cost is $2,115/hectare/annum which yields a net present value cost over fifteen years (minus 3 years for no harvest) of $10,826.

Alternatively, applying a 5 per cent yield reduction from year 1 of the kiwifruit net cash flow (Table 57) and then compounding this loss for each year until the ninth year of establishment, whence full production levels are normally assumed to have been reached, the following costs to producers result (Table 77).

TABLE 77

Compounded Costs to Kiwifruit Production

YEAR	PERCENTAGE AFFECTED	COSTS PER HECTARE
0	-	-
1	0.500	-
2	0.551	-
3	0.579	-
4	0.0608	696
5	0.0638	1,035
6	0.0670	1,599
7	0.0704	2,285
8	0.0739	2,822
9	0.0776	3,112
10	0.0776	3,112
11	0.0776	3,112
12	0.0776	3,112
13	0.0776	3,112
14	0.0776	3,112
15	0.0776	3,112

These result in a net present value cost over the 15 years of $12,478.

Thus if the 'compounding' method does give a more accurate figure for the costs of road dust than the mature crop costing approach, then all the costs stated in Chapters 8 and 9 of this report may understate the actual costs of road dust. However, because there is so much uncertainty surrounding the effects of the dust and because a relatively simple to use set of figures are needed for use by council staff in their cost-benefit analyses, it is preferable at this stage to use the more conservative and convenient figures found by the mature crop costing approach.

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