



# **DEVELOPING A NATIONAL PHOSPHORUS BALANCE FOR AGRICULTURE IN IRELAND**

A DISCUSSION DOCUMENT

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Published by the Environmental Protection Agency, Ireland.

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ISBN 1 84095 055 2  
Price Ir£5.00 / €6.35

06/01/500

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## PREFACE

The Environmental Protection Agency (EPA) report *Water Quality in Ireland 1995-1997* demonstrated that surface water quality is continuing to deteriorate. The increase in the extent of slight and moderate pollution is attributable mainly to eutrophication, a process which is accelerated by an excess supply of nutrients such as nitrogen and phosphorus. There is very strong evidence to suggest that nutrient loss from agriculture, in particular phosphorus, is now a major cause of eutrophication in Ireland's rivers and lakes.

In light of this, the EPA has undertaken research aimed at establishing:

- a) the total amount of phosphorus (organic and chemical) applied to agricultural lands;
- b) the contribution of agricultural activities (e.g. cattle, sheep, pig etc.), agri-industry and sewage sludge to organic phosphorus loadings on land;
- c) the quantity of organic phosphorus which is managed (i.e. collected, stored and subsequently applied to land) and the quantity deposited directly by grazing animals; and
- d) the development of a national phosphorus balance for phosphorus applied to agricultural land based on various scenarios.

The document draws conclusions from the research undertaken and makes recommendations based on the findings.

The report clearly establishes that large quantities of organic wastes are produced by agriculture on an annual basis. While the nutrients contained in these wastes represent a valuable resource which should be put to beneficial use, it is clear that phosphorus loss from agriculture is contributing significantly to water quality deterioration; partly as a result of considerably greater quantities of phosphorus being applied to land than are required for optimal crop growth, and partly as a result of the practical difficulties involved in managing large volumes of organic wastes in a relatively wet environment.

The Agency considers it important that this report be presented as a discussion document, in order to canvass the views and suggestions of as wide a range of opinions as possible, prior to finalising its recommendations. It is therefore hoped, that comment and opinion will be expressed by all those wishing to make an input, especially those with interests or responsibilities in the agricultural and environmental field.

## ACKNOWLEDGEMENTS

The Agency wishes to acknowledge those who contributed to this draft discussion document and to acknowledge that the people who contributed in various ways to this document do not necessarily agree with the full contents of this report.

Dr Jim Bowman, EPA, Pottery Road, Dublin  
Dr Owen Carton, Teagasc, Johnstown Castle, Co. Wexford  
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# 1. INTRODUCTION AND OBJECTIVES

## 1.1 BACKGROUND

The Environmental Protection Agency (EPA) report on *Water Quality in Ireland* (Lucey *et al.*, 1999) and *Ireland's Environment: A Millennium Report* (Stapleton *et al.*, 2000) demonstrated that surface water quality in Ireland is continuing to deteriorate. Over the last decade the length of river classified as unpolluted has fallen from 77.3 percent to 66.9 percent with a corresponding increase in slightly to moderately polluted river channel from 21.7 percent to 32.2 percent. Table 1.1 summarises trends in river quality for a ten year period.

This increase in the extent of slight and moderate pollution is attributable mainly to eutrophication, a process which is accelerated by an excess of nutrients such as nitrogen (N) and phosphorus (P) which impairs water quality, fisheries and recreational use of these waters. There is very strong evidence to suggest that nutrient loss from agriculture, including farmyards, is now the single biggest source of pollution problems in Ireland's rivers, as indicated in Table 1.2. Increased eutrophication in surface waters is also attributable to direct discharges from municipal sewage treatments works and other sources such as septic tanks but to a lesser extent than agriculture (Lucey *et al.*, 1999). Siltation and other effects due primarily to soil erosion from overgrazing by sheep and to bog and forestry development, are responsible for much of the slight to moderate pollution recorded in the west of Ireland. Lake water quality has also declined in the last 10 years and the report emphasises that the most significant threat to lake water quality is enrichment by nutrients such as phosphorus and nitrogen leading to eutrophication.

The river water quality surveys carried out by the EPA cover 3,117 individual sampling points at approximately 4 km intervals on over 13,000 km of major Irish rivers (12,700 km in 1987-1990). The length of channel in the various water quality classes is determined by interpolation of data from the individual sampling points. These surveys are based on detailed knowledge of the rivers, location of pollution sources and changes in the catchments over a 30 year period.

Table 1.2 attributes the deterioration in water quality to various suspected sectors for the 1995-1997

TABLE 1.1: TRENDS IN RIVER QUALITY FROM 1987 - 1997

River Quality	percentage of 13,200 km baseline		
	1987-1990	1991-1994	1995-1997
Unpolluted	77	71	67
Slightly polluted	12	17	18
Moderately polluted	10	11	14
Seriously polluted	9	1	1

Lucey *et al.*, 1999

TABLE 1.2: NUMBER (AND %) OF SURVEYED LOCATIONS POLLUTED BY SUSPECTED SECTORS

River Quality	Suspected cause			
	Agriculture	Sewage	Industry	Other
Slightly Polluted	274 (47.3%)	137 (23.6%)	50 (8.6%)	119 (20.5%)
Moderately Polluted	276 (45.9%)	150 (24.9%)	64 (10.6%)	111 (18.6%)
Seriously Polluted	16 (24.6%)	31 (47.7%)	14 (21.5%)	4 (6.2%)

Lucey *et al.*, 1999

period (Lucey *et al.*, 1999). The term 'Agriculture' includes the adverse effects of overgrazing as well as the more usual organic pollution and eutrophication caused by diffuse and point source discharges of agricultural wastes. 'Sewage' includes waterworks effluents, septic tank effluent and diffuse urban inputs as well as sewage works discharges. 'Industry' includes bog and forestry development, mining and point source industrial discharges. 'Other' includes pollution caused by unknown causes and also the enriching effects on rivers and streams of organic-washout from eutrophic lakes. There has been a steady reduction in the category "seriously polluted" over the past three decades which can be attributed to substantial investment in sewage treatment facilities and to the introduction of integrated pollution control licensing of large industrial activities. As these point sources are further controlled, the percentage contribution from agriculture will increase if improved agricultural controls are not put in place.

There may in fact be a tendency to underestimate the agricultural contribution rather than to overestimate it, due to the conservatism in the approach used by the biologists. Downstream of towns for example, pollution sources will be attributed to sewage and/or industry depending on the town with any potential agricultural component being ignored. Also in cases

where point source discharges have been eliminated due to factory closures and rivers do not fully recover, this would indicate a background agricultural contribution previously masked. In such cases, the agricultural contribution would have been underestimated.

In addition, a different methodology is used to calculate the relative amount of pollutant loads (e.g. kg of phosphorus per annum) transported by a river. Pollutant load is calculated by multiplying the concentration of the pollutant (e.g. mg/l) by the volume of water passing downstream each second (l/s). The Oslo and Paris Commission (OSPAR) has measured end of river pollutant loads to seas and have developed a standard methodology to apportion pollutant components into natural background, point source and diffuse source. The background and point source components are calculated within a catchment and subtracted from the measured pollutant load discharged to sea to give the diffuse component. These calculations have been carried out on the Lough Conn catchment where about 60 percent of the pollutant load was attributable to agriculture. Losses from catchments have also been calculated. For example the Moy catchment loses 46kg of P to water each year per km<sup>2</sup> of catchment area, the intensively farmed River Maigue catchment in Limerick has very high losses of 224kg/km<sup>2</sup> of P per year. Similarly the River Deel (Newcastlewest) has a very high loss rate of 190kg/km<sup>2</sup> of P per year. While, in comparison, the River Liffey catchment has losses of 79kg/km<sup>2</sup> of P per year from the most heavily populated and industrialised part of Ireland. The greater percentages attributed to agriculture in pollution loads *vis a vis* the percentage channel impacted by agriculture is due to threshold effects and temporal effects (McGarrigle, 1999)

Although eutrophication can be caused by N and P, phosphorus is typically the more causative nutrient in inland, non-saline waters. Therefore, the report by the EPA concludes that the main problem affecting inland surface waters is eutrophication caused by the enrichment of rivers and lakes with phosphates arising mainly from agriculture and sewage. As point sources of pollution (sewage and industrial discharges) continue to be reduced or treated, the relative contribution of diffuse sources to eutrophication increases. Significant water quality improvements are unlikely to be possible or complete without controls on the phosphorus losses from agricultural and other land based activities. In agriculture, losses of phosphorus occur in the form of direct point-source discharges from farmyards and slurry stores and non-point (diffuse) losses from farm fields transported by surface overland flow

(runoff) and leaching of phosphorus from soils.

## 1.2 OBJECTIVES OF THIS REPORT

In light of these findings and the EPA concerns about phosphate losses from agriculture in the form of point source discharges from farmyards and non-point sources from landspreading of organic wastes and chemical fertilisers, the EPA has undertaken research aimed at establishing:

- the total amount of phosphorus (organic and chemical) applied to agricultural lands;
- the contribution of agricultural activities, agri-industries and sewage sludge to organic phosphorus loadings on land;
- the quantity of organic phosphorus which is managed (i.e. slurry, farm yard manure, sludges etc.) and the quantity deposited directly by grazing animals; and
- a national phosphorus balance for agriculture based on various scenarios.

## 1.3 SCOPE OF RESEARCH

The research undertaken focused primarily on agriculture, mainly phosphorus usage with reference to soil test phosphorus levels (STP). Issues which were not considered as part of this work include:

- determining the contributions of other activities such as forestry, detergent use, see page from septic tanks etc. to a national P balance;
- estimating actual P losses as against potential P losses;
- the relative contribution from both diffuse field losses (e.g. runoff, desorption and leaching) and point sources (e.g. farmyards, soak-away pits for dairy washings etc.); and
- other factors which influence the loss of phosphorus to water such as timing of fertiliser applications, run-off risk, soil type, proximity to water and farmyard conditions.

## 1.4 PHOSPHORUS - A NUTRIENT OR A POLLUTANT?

Phosphorus is an essential element for plant growth and its input has long been recognised as essential to maintain economically viable levels of crop production. In agricultural systems P is needed for

the accumulation and release of energy associated with cellular metabolism, seed and root formation, maturation of crops (especially cereals), crop quality and strength of straw in cereals. In natural (i.e. non-agricultural) systems, P is recycled to soil in litter, plant residues and animal remains and P is generally recycled efficiently. However, in agricultural systems P is removed in the crop or animal product. Chemical P fertilisers, crops and feed supplements are imported into agricultural systems to increase and maintain productivity (Haygarth, 1997). The need to supplement soils with water-soluble P fertilisers arises because the relatively small pool of native soil P is unable to supply and maintain adequate amounts of soluble orthophosphate ( $\text{H}_2\text{PO}_4^-$  and  $\text{HPO}_4^{2-}$ ) to soil solution for satisfactory crop growth and animal performance. However, the reactions which applied P undergoes in the soil, result in poor efficiency of uptake by the plants. It has been estimated that 25 percent or less of P applied annually is actually taken up in the growing crop (Morgan, 1997). The remaining 75 percent becomes bound in the soil profile or is lost to water. The crop uptake of P is in contrast to the crop use of N and potassium (K) fertilisers, where the recovery in the season of application can be as high as 80 percent.

In common with other major elements, the concentration of total P in soils is high relative to both crop requirements and to the available P fraction. The typical range for total P content of agricultural soils is estimated at between 0.20 to 2.0g/kg (McGrath, 1994). Phosphorus exists in soils either in the dissolved (i.e. solution) or solid form (particulate P), with the solid form being dominant. Dissolved P is typically less than 0.1 percent of the total soil P and usually exists as ortho-phosphate ions, inorganic polyphosphates and organic P (Magette and Carton, 1996). Phosphorus in solid form can be classified as:

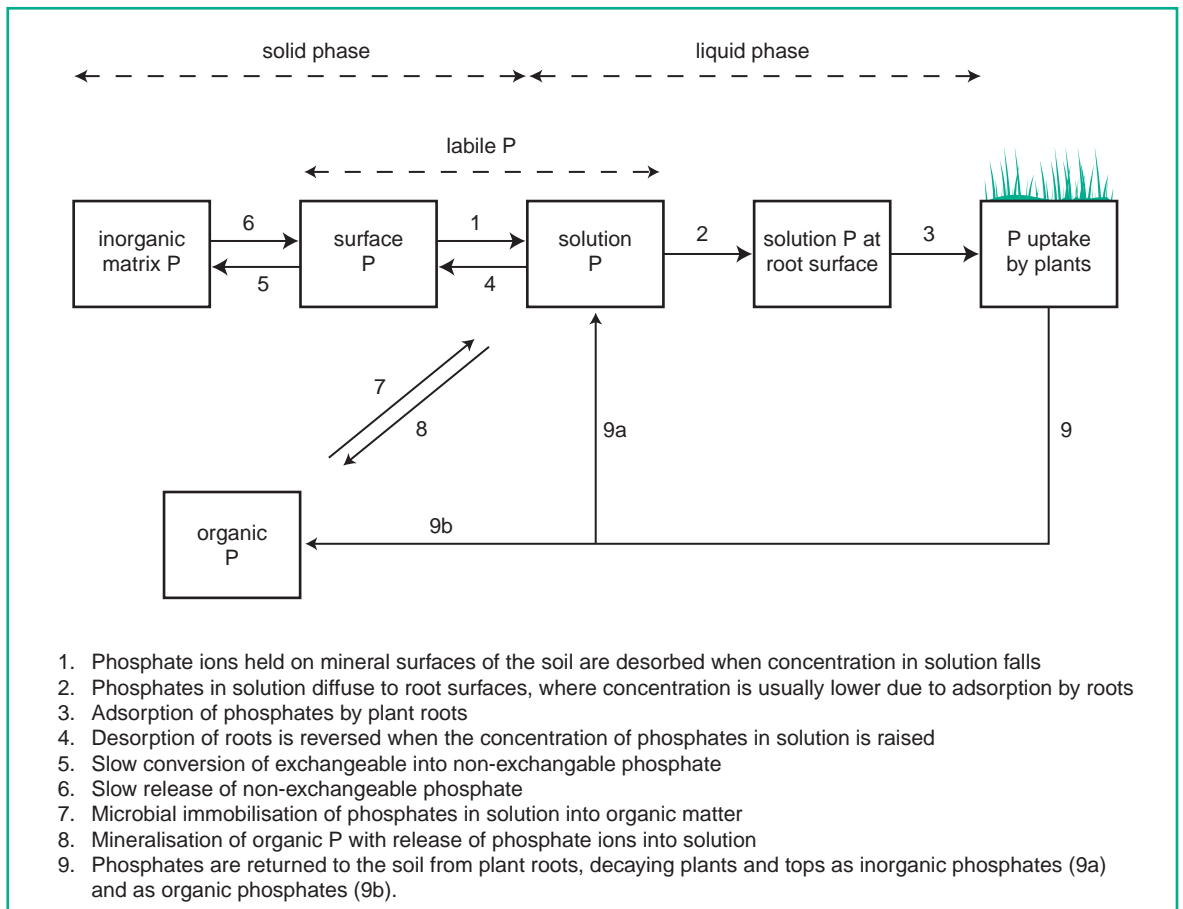
- inorganic P (i.e. bound to Al, Fe, Ca, Mg etc.); and
- organic P (P bound to organic material such as dead and living plant material and micro-organisms, soil organic matter etc.)

P exists in soils as an extremely active chemical element and up to 170 different phosphate-supplying minerals have been identified in soils; these vary greatly in their reactivity and solubility (Finkl and Simonson, 1979). Different forms of P are also partitioned between soluble P, labile soil P and non-labile soil P. *Soluble* P represents P in the soil

solution that is readily extracted with either water or weak salt. *Labile* P describes forms of P which are chemically mobile, exchangeable and reactive in soil and water. *Labile* P can replenish the soil solution P concentrations for uptake of P by the crop. The soluble P fraction measures the concentration of ortho-phosphate ions in solution, i.e.  $\text{H}_2\text{PO}_4^-$ ,  $\text{HPO}_4^{2-}$ . Molybdate reactive phosphate (MRP) measures the concentration of soluble P ions and some other compounds such as polyphosphates, which are chains of ortho-phosphate ions that disassociate during chemical analysis. *Non-labile* P is thought to represent a fraction of P which is physically encapsulated within a mineral compound (e.g. apatite). These latter forms of P are protected from chemical reactions and can only be released by very strong chemical treatments (Daly, 2000). In Ireland, Teagasc use Morgan's P test as a method to estimate the quantity of P available to crops. Further details on soil analysis are provided in Chapter 6.

Phosphorus is present in the soil solution as  $\text{H}_2\text{PO}_4^-$  and  $\text{HPO}_4^{2-}$  ions and is generally believed to be taken up by plants mainly as  $\text{H}_2\text{PO}_4^-$ . Phosphorus must be in solution before it can be absorbed by plant roots. After absorption into the plant much of the phosphate reacts very quickly to form organic compounds (Wild, 1988). Figure 1.1 illustrates the processes of transfer of phosphate between soil and plants. In a mineral soil, 33 percent up to 90 percent of the total P is in the inorganic form. Organic P compounds undergo mineralisation (into inorganic forms) and immobilisation with the aid of soil bacteria and growing plants (Magette and Carton, 1996).

Traditionally soil scientists and farmers have believed that P added to soil was readily immobilised and could not be leached (Haygarth, 1997). It was considered that the predominant pathway for P to be lost from agricultural systems was by transport in overland flow of particulate P with eroded soil and organic matter. However, it is now generally accepted that diffuse leakage of P from soils can occur and may be contributing to water quality deterioration in Ireland. The role of field drains, particularly on heavy gley soils, in transporting P to waters is also very important (Magette, 1998; Tunney *et al.*, 2000a; Heckrath *et al.*, 1995). **Phosphorus losses that are not regarded as significant in agronomic terms can be significant in environmental terms due to the fact that a very small concentration in water (c. 20 µg/l) in susceptible surface waters can lead to eutrophic conditions.**



Wild, 1998

FIGURE 1.1: TRANSFER OF PHOSPHATE BETWEEN SOIL, PLANTS AND WATER

The hydrological pathways of P movement from fields include surface runoff comprising of overland flow, and subsurface flow comprising of leaching (which is primarily vertical and includes preferential flow), interflow (which is primarily horizontal), and groundwater discharge (including base flow and springs) (Figure 1.2). Both particulate P and soluble P can be lost via these pathways and contribute to P levels measured in overland flow samples and

drainage water. In general, transport of particulate P by subsurface flow is not large. Slope, soil texture and structure, land use, proximity to drainage network and vegetation; control the hydrological transfer of P to water. Field drains from agricultural land also discharge directly into surface waters via drainage pipes or mole drains.

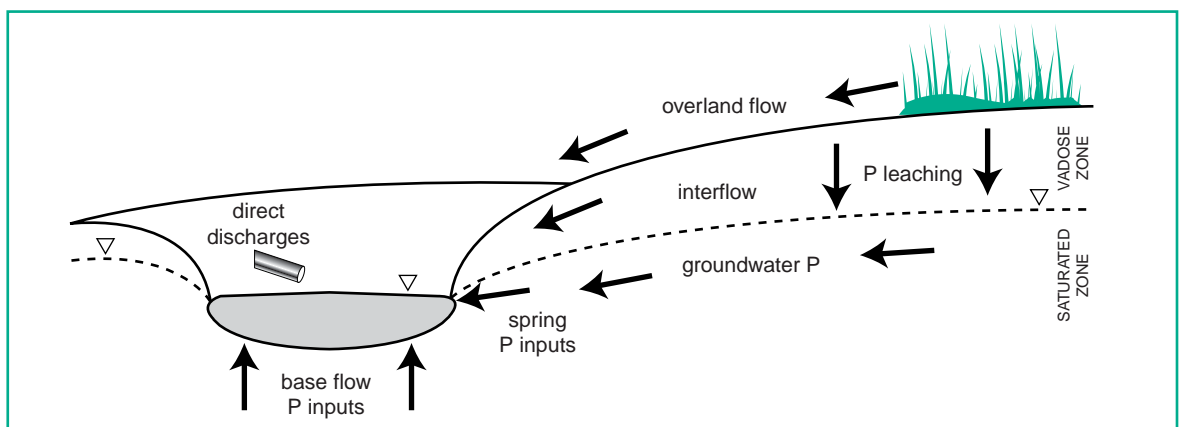


FIGURE 1.2: PHOSPHORUS PATHWAYS FROM LAND TO GROUNDWATERS AND SURFACE WATERS

Phosphorus inputs to inland surface waters increases the biological productivity in these waters. Although N and carbon (C) are also essential to the growth of aquatic biota, most attention has focused on P inputs because P is often the element limiting growth in the non-saline aquatic environment. Phosphorus is less abundant in freshwaters than nitrogen relative to plant needs and so its concentrations are reduced to very low levels by uptake during the growing season. Therefore, P regulates the extent of algal and other plant development in the aquatic environment. Also, some organisms such as cyanobacteria (blue-green algae) can fix N directly from the atmosphere.

Diffuse P and N leaking from agricultural land causes water quality deterioration by contributing to eutrophication. Eutrophication is the term used to describe the enrichment of waters beyond natural levels principally by the plant nutrients. Biological effects of eutrophication include increased growth of planktonic algae, cyanobacteria, macrophytes (aquatic weeds) and other attached plants. Compared to the terrestrial environment, the remarkable ability of algae to absorb and utilise P in the production of biomass makes the non-saline aquatic environment sensitive to small changes in P supply. Eutrophication of surface water has detrimental effects on the aquatic ecosystem interfering with the quality dependent beneficial uses of a waterbody. Excessive growths of attached algae and macrophytes can occur in shallow waters making them unsuitable for recreational use. In lakes, eutrophication commonly results in excessive growths of planktonic algae and cyanobacteria (blue-green algae) which have damaging effects on water quality. These organisms result in a destabilised oxygen regime and a reduction in water transparency, which has a detrimental effect on aquatic ecosystems, fisheries and associated recreational uses including angling. The production of toxins by cyanobacteria can represent a serious threat to human and animal health where contact or ingestion occurs. Planktonic algae and cyanobacteria may also cause objectionable taste and odour in abstracted water.

It has recently been demonstrated in Ireland that molybdate reactive phosphate (MRP) levels as low as 30 µg P/l in rivers and total phosphorus (TP) concentrations of less than 20 µg P/l in lakes have caused water quality deterioration and eutrophication (Clabby *et al.*, 1992; Bowman *et al.*, 1996; McGarrigle, 1993; McGarrigle *et al.*, 1993; McGarrigle, 1998).

The *Local Government (Water Pollution) Act, 1977 (Water Quality Standards for Phosphorus)*

*Regulation, SI. No.258 of 1998* require that water quality be maintained or improved by reference to quality rating/trophic status or phosphorus concentrations. These regulations require that the total phosphorus average concentrations for lakes shall be 20 µg P/l or less and for rivers, the total molybdate reactive phosphate median concentration shall be 30 µg P/l or less. The EPA lake monitoring programme found that if the annual median phosphate concentration of the inflowing rivers to lakes is greater than 20 µg P/l eutrophic conditions resulted. **With effective annual precipitation in Ireland being approximately 700mm (Stapleton, 1996) it would require catchment losses as small as 0.21 kg/ha/yr of total P to reach concentration of 30 µg /l total P in water and losses of 0.14 kg/ha/yr to reach concentrations of 20 µg/l total P in water.** For example total P losses from the Shannon catchment (i.e. export values) in the period 1976-78 were 0.18 kg/ha/yr and the receiving water, Lough Derg was classified as mesotrophic/eutrophic with total annual P concentration of 0.21 µg/l. In Lough Ramor export values of less than 0.4kg/ha/yr caused hypertrophic conditions with total P concentrations of 60 to 78 µg/l in the lake, although direct point source discharges may also have contributed to P load. Export values include contributions from all sectors such as sewage, rainfall, background losses and agriculture. **It is clear that P losses should be significantly less than 0.2kg/ha/yr from all activities in a catchment to preserve water quality and fulfil the requirements of the phosphorus regulation (SI No. 258 of 1998).** To maintain rivers and lakes which are currently classified as Q5 i.e. pristine, unpolluted, losses should be in the region of 0.1 kg/ha/yr as the regulations require no further deterioration in water quality.

## 1.5 INDEX SYSTEM FOR MANAGING FERTILISER APPLICATIONS

Teagasc has developed a four category index system as the basis for fertiliser P recommendations for tillage crops and grassland. The basis of the Teagasc system (Teagasc, 1994, Culleton *et al.*, 1997) is a set of soil indices based on the extractable P measured (by the Morgan's P chemical test) in the soil and the crops response to fertiliser applications as measured by field experimentation (Table 1.3).

## 1.6 TRENDS IN SOIL P LEVELS

During the period 1941 to 1946, P inputs to agriculture were lower than P removals. During this period soil P levels (i.e. Morgan's P) declined to an average of 1.0 mg/l and production potential was



**TABLE 1.3: SOIL P INDICES AND RESPONSE TO P**

Teagasc Soil Index	Soil test P level (Morgan s) mg/l	Plant response to applied P
1	0-3.0	Definite response
2	3.1-6.0	Response to P likely
3	6.1-10.0	Response unlikely
4	>10	None - P levels excessive

Culleton *et al.*, 1997

severely restricted. Teagasc developed P fertiliser recommendations to increase soil P levels rapidly to a level considered optimal for grass production. As P levels rose these recommendations were revised periodically, culminating in the nutrient advice which applied until 1998. Pre-1998 recommendations were designed to boost P levels in soils classified as Index 1 and 2, to achieve a maintenance P level at Index 3. For grassland, these recommendations did not fully account for the nutrients in slurry applied to silage ground and therefore P inputs tended to be considerably greater than P outputs (Teagasc, 1997). Figure 1.3 shows trends in soil P levels and chemical fertiliser P sales over a period from 1955 to 1998. It is clear from the graph that Teagasc advice to farmers has been successful in increasing soil P levels from 1955. However, although chemical fertiliser P use has declined since 1980, soil P levels continued to rise to a maximum in 1990, with a subsequent decline until

1995 from which they have risen once again to the level reached in 1985. A total reliance on Soil test P levels as an indicator of application rates of phosphorus to soils may not truly reflect the actual quantity of applied P to land. For example, when slurry is applied during unfavourable weather conditions e.g. during rainfall or onto wet waterlogged soils during the winter months, this slurry can be washed of land in a short period of time and therefore will not increase soil P levels.

It must also be emphasised that the soil test data are representative *only* of those soils from which farmers have chosen to send soil samples to Teagasc for analysis. Sample results from 1955 are representative of all farm types up until 1993, where results are recorded for farms participating in the Rural Environmental Protection Scheme (REPS) and non REPS farms. The data in Figure 1.3 for the years 1995 to 1998 represent an average soil P level for both REPS and non-REPS farms. Although the data used in Figure 1.3 are not a statistically unbiased sample population, they are nevertheless the best data available for estimating the status of soil P in Irish agricultural systems.

In 1997, Teagasc published a document entitled *Phosphorus Recommendations: Good Agronomic Practices* which outlined its revised fertiliser recommendations for grassland and these were introduced to farmers in July 1998. The current

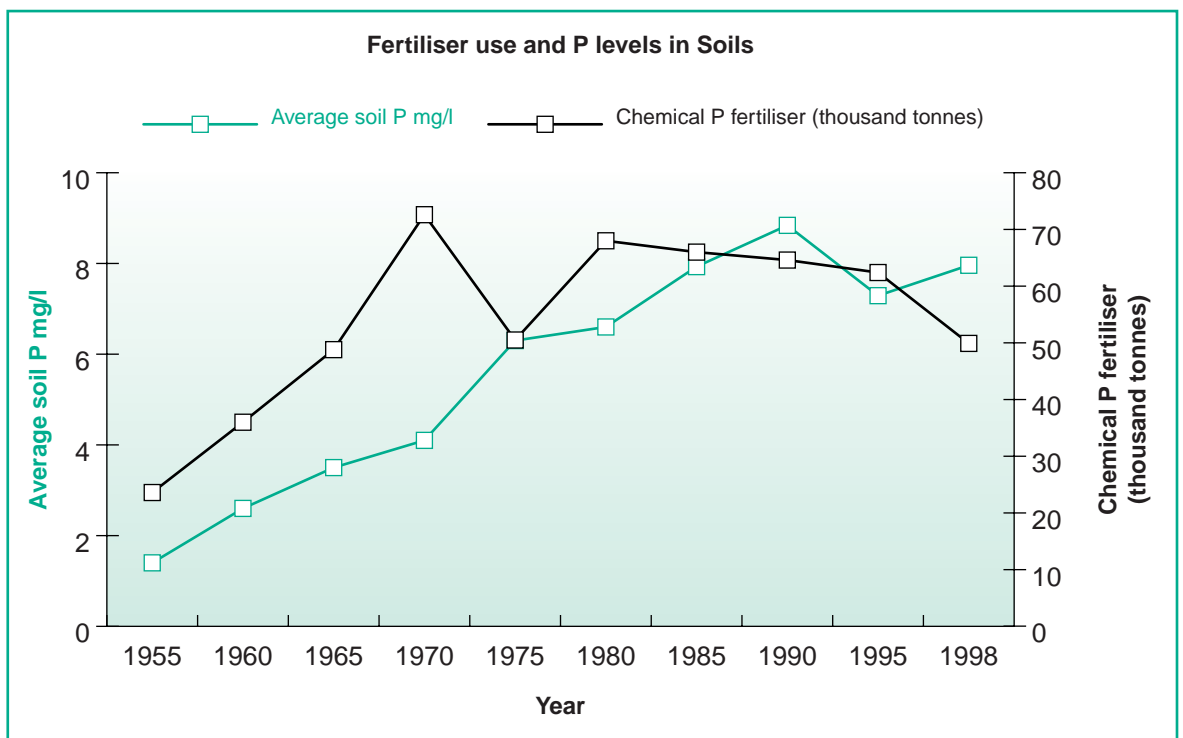


FIGURE 1.3: AVERAGE SOIL P LEVELS AND FERTILISER SALES 1955-1998

TABLE 1.4: SUMMARY OF TEAGASC CUT-OFF POINTS FOR P ON GRASSLAND

Grass System	Soil index	Morgan's P mg/l	Current advice
Silage areas	3	6.1 - 10 mg/l	No chemical fertiliser P required Slurry should be recycled
	4	> 10.0 mg/l	No chemical fertiliser P required Slurry not required for crop growth, but if spread preference should be given to low P status silage ground
Grazing areas	2	3.1 - 6 mg/l	No chemical P fertiliser required to build-up soil P levels where it is desirable to maintain a lower target soil P level i.e. soil index 2
	3	6.1 - 10 mg/l	No chemical P required to build-up soil P levels however, P is required for maintenance and application rates are based on stocking rates per hectare. The application rate varies from 3 to 9 kg/ha for drystock and 6 to 16 kg/ha for dairying
	4	> 10.0 mg/l	No chemical P required for build-up or maintenance

fertiliser advice takes into account stocking densities and the different types of farming systems, i.e. grazing, silage, dry stock or dairy animals. Fertiliser application rates for grassland have been revised downwards over recent years to take into account nutrients contained in feed concentrates and returned to the soil by grazing animals. Table 1.4 provides a summary of current cut-off points above which fertiliser application to grassland is not advised by Teagasc.

Teagasc advises that slurry produced on grassland farms should be recycled to silage areas in the first instance, otherwise it can be applied to tillage ground or grazing areas of low fertility. Advice for grazing assumes no slurry is applied to grazing ground and that the only P recycled is that deposited directly by grazing animals.

Soil samples received and analysed by Teagasc in 1998 show that the 1998 average soil P status from REPS and non-REPS farms is 7.9 mg/l, i.e. Soil Index 3. During that year 60,229 soil samples were analysed and the percentages of soils falling under each soil index group are illustrated in Figure 1.4. Samples taken from REPS farms have slightly lower soil P levels at 7.2 mg/l while non-REPS farms had an average soil test P of 8.5 mg/l. The true average soil P status for the country may be higher or lower than 7.9 mg/l depending on whether soil samples sent by farmers to Teagasc for analysis are more representative of intensive or less intensive farms. It would be anticipated that less intensive farms would have lower soil P values. Having said this however, the analysis does show that 24 percent of the soils analysed fall into Index 4, i.e. P > 10.0 mg/l, which is considered excessive. Nearly half the soil samples analysed (49%) are either Index 3 or 4, where a response to applied P would be unlikely according to

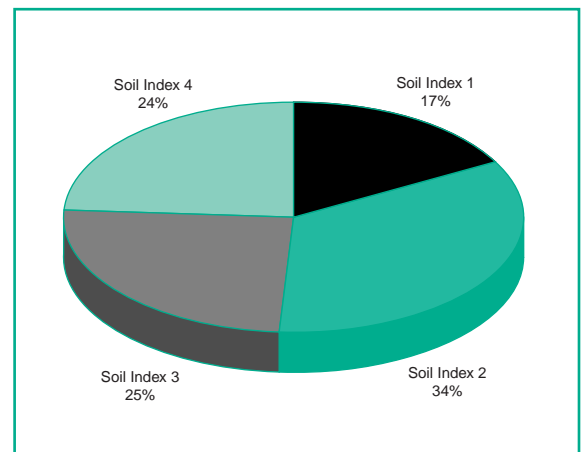


FIGURE 1.4: DISTRIBUTION OF SOIL SAMPLES BY SOIL INDEX (MORGAN'S P) VALUES FOR SOILS UNDER GRASS AND TILLAGE IN 1998

Teagasc research (Culleton *et al.*, 1997).

The upward trend in soil P levels appears to be continuing and is verified by the soil samples analysed by Teagasc during 1999. A total of 49,801 soil samples were analysed and show an average soil P status of 8.1 mg/l for both REPS and non-REPS farms. The average soil P status for non-REPS farm was 8.7 mg/l with samples from REPS farms averaged at 7.3 mg/l. These results would suggest that on all farms where soil samples were analysed, soil P levels are continuing to rise. In the past 6 years soil P levels on non-REPS farms sampled have risen from an average of 8.0 mg/l P to 8.7 mg/l P with REPS farms rising from 6.6mg/l in 1994 to 7.3 mg/l in 1999. It is important to reiterate that the average P content of the soil samples received for analysis may not reflect completely the P status of all soils around the country, however, they provide the best available information.

## 2. SOURCES AND QUANTITIES OF P APPLIED TO LAND

### 2.1 BACKGROUND TO ESTIMATES FOR 1998

The EPA estimated the quantity of organic wastes (i.e. manures from farm animals and sludge from agri-industry and sewage treatment) applied to agricultural land in Ireland for the year 1998. The quantities of wastes arising from the various categories of animals are based on the Central Statistics Office Statistical release - Crop and Livestock Survey, June 1998 (CSO, 1998a). As the last full census of agriculture was undertaken in June 1991, the data used in this analysis are more current figures for livestock than those provided in 1991 census. The annual crop and livestock surveys for 1998 are based on returns from 15,900 farms, which are selected by the CSO to be representative of farms in Ireland.

Various sources of information were used to calculate the amount of organic waste generated by each category of livestock and to estimate the quantity of nitrogen and phosphorus contained therein. The Department of Agriculture, Food and Rural Development (DAFRD) and Teagasc provided useful information and figures particularly in relation to the pig and poultry sectors. Figures for the quantity of N and P contained within slurries and manures were taken from the *Rural Environment Protection Scheme - Agri-Environmental Specifications, 1999* (Department of Agriculture and Food, 1999). Average housing periods of 20, 6 and 26 weeks were used for cattle, sheep and horses, respectively to calculate the quantities of manure indoors which requires management. These figures were then used to calculate the volumes and quantities of nutrients that were deposited directly by grazing animals and that which required management. For pigs and poultry it was assumed that all the slurries or litter produced would require management. It was also assumed that all dirty water and silage effluent arising would require management.

Approximately 280,000 tonnes of mushroom compost were manufactured and used in 1998 (Teagasc, 1998), generating a similar quantity of spent mushroom compost. This organic waste was not included in the calculations for total quantity arising or N and P calculations as poultry manure is a major component of mushroom compost.

Figures for the quantity of agri-industry sludges and sewage sludge were taken from Inventory of non-hazardous sludges in Ireland, which was a study undertaken by Fehily Timoney & Co. (Fehily, Timoney & Co., 1998) on behalf of the Department of Environment and Local Government. The quantities are based on returns made from various industries participating voluntarily in the survey, and refer to non-hazardous sludge quantities for 1997. Estimates of the N and P content of various sludges are based on information obtained from a report prepared by the Environment Agency, UK (1996) entitled *Investigations of the criteria for, and guidance on, the landspreading of industrial wastes - R&D Technical Report P193*. Section 6.3 provides details on calculations.

### 2.2 CONTRIBUTIONS FROM VARIOUS SECTORS

It was estimated that a combined total of 135 million tonnes of organic wastes arose from agriculture (in 1998), the agri-industry and sewage treatment (in 1997) (Table 2.1). Of this total, 130.7 million tonnes (97%) are generated by agriculture. The total quantity of agri-industry organic waste and sewage sludge arising were 4.2 million tonnes of which 1.3 million tonnes are estimated to be applied to land by landspreading. Therefore the total quantity of organic wastes applied to land is estimated at 132 million tonnes. Approximately 63.2 million tonnes of agricultural wastes i.e. animal slurry, farmyard manure, effluent etc. are collected annually from the various farm enterprises and require subsequent management (i.e. collection, storage and application to land) with the remaining 67.5 million tonnes deposited directly by grazing animals.

### 2.3 SEWAGE SLUDGE AND SEWAGE EFFLUENT

The total quantity of sewage sludge arising in 1997 was estimated at 957,250 tonnes wet weight (38,290 tonnes dry solids) which represents 0.7 percent of the total organic wastes arising (Fehily Timoney & Co., 1998). As a percentage of the total organic wastes applied to land (i.e. 132 million tonnes), sewage sludge represents 0.08 percent or 0.13 percent of the total tonnes of P in organic wastes applied to land as it is estimated that about 10 percent of sewage sludge arising is currently applied to land. The quantity of sewage sludge requiring disposal is likely to increase



TABLE 2.1: QUANTITIES OF ORGANIC WASTES ARISING AND SPREAD ON AGRICULTURAL LAND IN 1998

Category	Tonnes wet weight generated	*Tonnes wet weight managed	Tonnes dry solids	Tonnes dry solids managed	Total tonnes N	Total tonnes P	Tonnes N managed	Tonnes P managed
Cattle	96,456,022	37,098,470	9,645,602	3,709,847	482,280	74,271	185,492	28,565
Sheep	8,131,749	338,063	2,032,937	84,516	82,943	12,034	3,448	500
Horses	730,621	365,310	219,186	109,593	3,653	562	1,826	281
Pigs	2,623,350	2,623,350	157,401	157,401	12,082	3,970	12,082	3,970
Poultry	454,151	454,151	165,286	165,286	11,518	2,859	11,518	2,859
Silage effluent	2,684,500	2,684,500	134,225	134,225	5,369	859	5,369	859
Dirty water (dairy only)	19,621,500	19,621,500	784,860	784,860	5,886	588	5,886	588
Agri-industry	1,237,291	1,237,291	102,572	102,572	5,271	1,578	5,271	1,578
Sewage sludge	105,321	105,321	4,208	4,208	211	126	211	126
<b>Total tonnes</b>	<b>132,044,505</b>	<b>64,527,956</b>	<b>13,246,277</b>	<b>5,252,508</b>	<b>609,213</b>	<b>96,847</b>	<b>231,103</b>	<b>39,326</b>

\* managed wastes are those that are collected, stored and applied to land.

with estimations of between 100,000 to 120,000 tonnes dry solids requiring disposal by 2005.

Table 2.1 summarises the quantities of organic wastes arising in Ireland and spread on agricultural land in 1998, including wastes generated by intensive agricultural enterprises (IAE) such as pigs and poultry. The figures for agri-industry and sewage sludge are for 1997, and these were assumed to be representative of the amount arising for 1998.

The percentages of wastes generated by the various sectors are illustrated in Figure 2.1. Cattle enterprise (dairy and beef) accounts for 90 percent of the total organic wastes arising from agriculture if silage effluent and dirty water generated from the dairy sector are included in the total. It is important to remember that much of the organic waste generated by the dairy and beef sector is deposited directly by grazing animals (62%) while the remaining is managed (38%).

Although the pig and poultry sector account for 2.3 percent of the total amount of organic wastes arising i.e. 3.1 million tonnes wet weight, the regional concentration of these industries increases the risk of environmental pollution. The counties Cork and Cavan together host 38 percent of national sow numbers and where site specific conditions are unfavourable for safe disposal of organic waste e.g. on gley soils, this aggravates the problem of regional concentrations further (Teagasc, 1999). It is obvious therefore that although the absolute quantity of waste arising is important, other factors such as enterprise location, intensity of production (e.g. systems based on imported feeds versus grass based systems) and waste management system employed are also important.

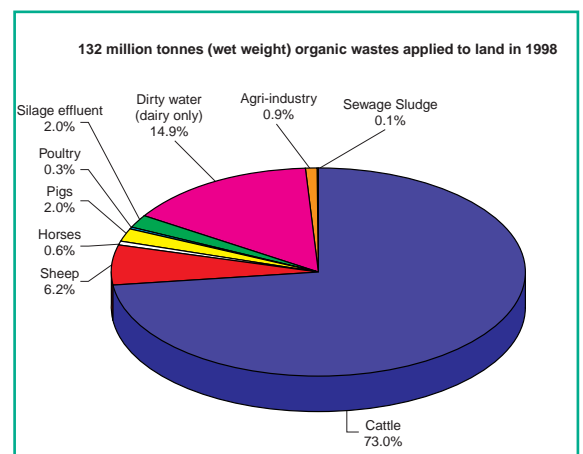


FIGURE 2.1: TOTAL TONNES (WET WEIGHT) AND PERCENTAGES OF ORGANIC WASTES (MANAGED AND DEPOSITED) APPLIED TO LAND

In relation to direct discharges to water, the EPA has estimated the loads of organic matter and nutrients N and P entering surface waters as part of a submission made in 1998 to the OSPAR convention for the protection of the marine environment of the North Atlantic (Cunningham, 2000). Urban waste water is domestic waste water or it can be a mixture with industrial waste water and/or runoff rainwater. At a national level the domestic contribution to the total urban waste water load is much larger than the industrial component. Towards the end of the 1990's, most of the main urban waste water discharges to freshwaters were subject to secondary treatment, while the majority of discharges to estuaries and coastal waters remained untreated. A major investment programme in sewerage capacity is currently underway, and all significant urban waste water discharges will receive at least secondary treatment within a few years. Septic tanks are the main form of waste water management in

**TABLE 2.2: NATIONAL URBAN WASTE WATER ESTIMATED LOADS OF N AND P**

		N tonnes per annum			P tonnes per annum		
		Domestic	IPC Industry	Non-IPC Industry	Domestic	IPC Industry	Non-IPC Industry
<b>Total</b>	Generated load	7843	1321	1561	2353	329	380
	Discharged load	7162	1266	1466	2105	309	354
<b>Inland waters</b>	Generated load	2259	154	272	678	35	59
	Discharged load	1866	124	219	508	23	43
<b>Marine waters</b>	Generated load	5584	1167	1289	1675	294	321
	Discharged load	5297	1142	1247	1597	286	311
<b>Septic tanks</b>	Estimated discharge load	2980	--	--	310	--	--

(Cunningham, 2000)

rural Ireland, though a significant number of these do not function properly.

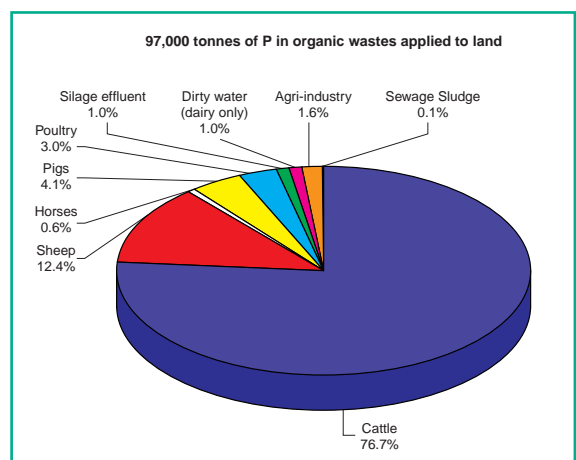
Table 2.2 summarises the national urban waste water estimated loads for N and P for 1998 discharging to inland and marine waters for 1998. Also included are figures for estimates of the N and P load from septic tanks (OSPAR, 1999).

While it is recognised that urban waste water discharges directly into surface water, the total quantity of N and P arising from domestic and sewage sludge (which is applied to agricultural lands) is 5057 tonnes of N and 944 tonnes of P per annum (i.e. 508, 310 and 126 tonnes). In comparison to the total amount of N and P arising from agriculture (i.e. 603,731 tonnes of N and 95,143 tonnes of P) urban waste waters discharges and sewage sludge applied to land account for less than 1 percent of the total N and total P applied to land (i.e. 0.83% N and 0.99% P). The quantity of N and P discharging to waters from septic tanks is also very small.

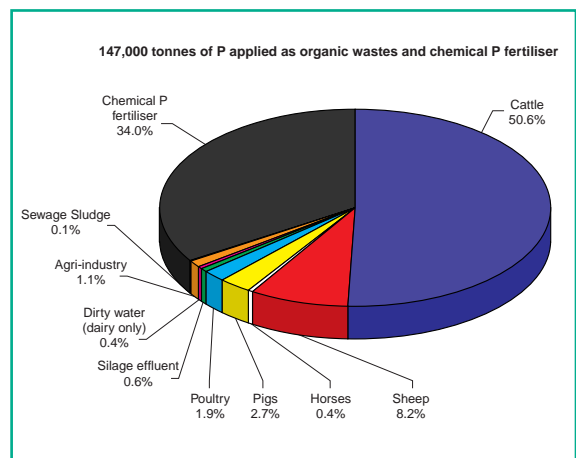
The total quantity of phosphorus contained in the organic wastes generated in Ireland in 1998 has been estimated at 97,000 tonnes. Figure 2.2 illustrates the various contributions from each sector. Dairy and beef enterprises account for nearly 77 percent of the total P contained in organic wastes, with the sheep sector being the second biggest contributor at 12.4 percent. Although silage effluent and dirty water account for nearly 17 percent of the total quantity of organic wastes arising, their contribution to total P is minimal. The pig and poultry sector account for 7.1 percent of the total P contained in organic wastes.

During the period 1997-1998, 49,900 tonnes of chemical P fertiliser were sold. Figure 2.3 illustrates the contribution of the various P sources to the total P applied including chemical P fertiliser.

The total amount of P applied to land is estimated at



**FIGURE 2.2: SOURCES AND PERCENTAGES OF PHOSPHORUS IN ORGANIC WASTES APPLIED TO LAND**

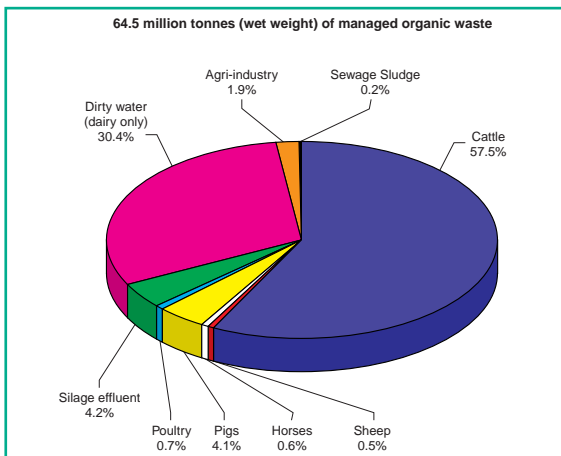


**FIGURE 2.3: TONNES AND PERCENTAGES OF P APPLIED TO LAND INCLUDING CHEMICAL P FERTILISER**

147,000 tonnes for 1998 which includes managed slurries and organic wastes, wastes deposited directly by grazing animals and chemical P fertiliser. Chemical P fertiliser accounted for 34 percent of the total P applied in that year.

**2.4 MANAGED WASTE AND DEPOSITED WASTE**

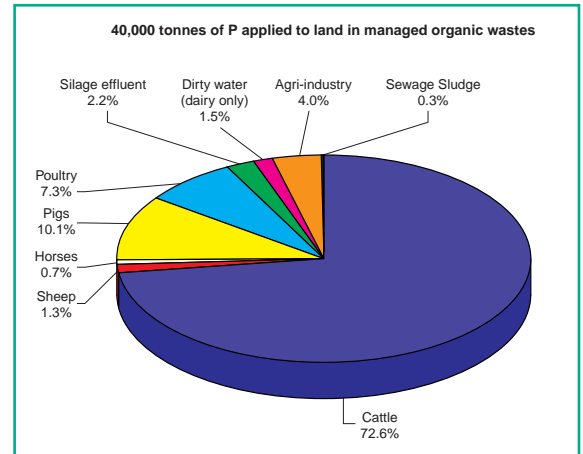
As stated previously, approximately 132 million tonnes of organic slurries and sludges were produced and applied on land in 1998. Of this total approximately 64.5 million tonnes require active management i.e. the wastes must be collected, stored over a period of time, and subsequently spread on land. The remaining 67.5 million tonnes are deposited directly by grazing animals (cattle, sheep and horses) in the form of urine and faeces. The cattle sector (dairy and beef) account for 87.9 percent (including dirty water from the dairy sector) of the total quantity of managed wastes arising. In addition, if silage effluent was attributed solely to the dairy and beef sector, over 92 percent of the total managed organic wastes arising would be attributable to this sector. Pigs and poultry account for 4.8 percent of the remaining managed organic wastes with sewage sludge representing 0.2 percent (Figure 2.4).



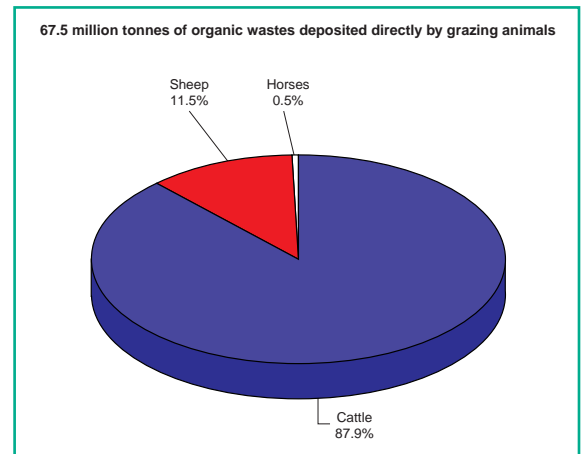
**FIGURE 2.4: SOURCES AND PERCENTAGES OF MANAGED ORGANIC WASTES**

Figure 2.5 illustrates the amount of P in managed wastes and attributes this to the various sectors. Dairy and beef account for 72.6 percent of the P in managed wastes, with the pig and poultry sectors accounting for 17.4 percent of the P contained in managed wastes. Sewage sludge represents 0.3 percent of P in managed organic wastes applied to land.

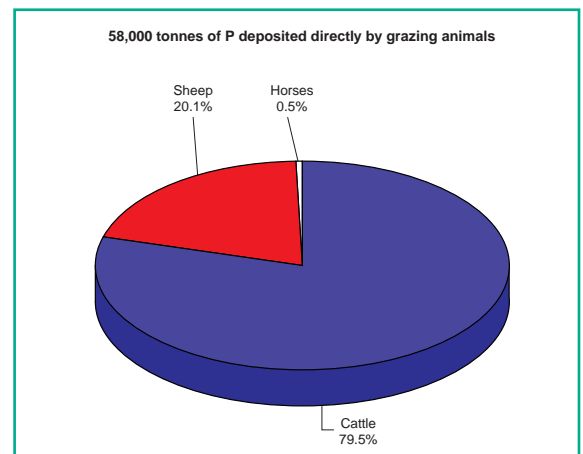
Nearly 68 million tonnes of organic wastes are deposited directly by grazing animals, and these wastes contain approximately 58,000 tonnes of P. Organic wastes deposited directly by the grazing animals account for 51 percent of total tonnes of organic wastes applied to land in 1998 and 59 percent of total organic P applied in the same year. Figure 2.6 and Figure 2.7 illustrate the quantities and



**FIGURE 2.5: SOURCES AND PERCENTAGES OF P IN MANAGED ORGANIC WASTES**



**FIGURE 2.6: SOURCES AND PERCENTAGES OF ORGANIC WASTES DEPOSITED DIRECTLY TO LAND BY GRAZING ANIMALS**



**FIGURE 2.7: QUANTITY AND PERCENTAGES OF P DEPOSITED DIRECTLY BY GRAZING ANIMALS**

percentages of wastes deposited directly to land by grazing animals and their contributions to P load on agricultural land.

The cattle sector is by far the biggest contributor to the total quantity of organic wastes deposited directly on land and accounts for approximately 88 percent of the total volume of deposited organic waste and almost 80 percent of the total tonnes of deposited organic P.

## 3. NATIONAL P BALANCE

### 3.1 INTRODUCTION

Various methods and sources of information were used to estimate a national P balance for agriculture in Ireland, and these are detailed in various scenarios below. The main sources of information include the Department of Agriculture Food and Rural Development (DAFRD), the Central Statistics Office (CSO) and Teagasc. Figure 3.1 illustrates the sources of inputs and outputs of phosphorus for a hypothetical farm.

Farm animals do not produce plant nutrients, they merely transform nutrients contained in feed into produce such as milk, meat, eggs and wool. During this process, the portion of nutrients such as N, P and K that are not used in animal maintenance or produce are returned to the land in the form of faeces and urine. The amount of plant nutrients contained in fresh faeces and urine represents the difference between the amount fed and the amount removed in produce and for animal maintenance. The types of animals, the intensity of production, the types of rations fed and the managerial practices in animal husbandry determine the amount of nutrients excreted in faeces and urine. In general, as production levels rise, both the quantity and concentration of nutrients in the organic wastes also

increase (Claesson and Stieneck, 1996). Plants likewise do not manufacture nutrients. In general, plants transform nutrients occurring naturally in the soil and those added to the soil into plant biomass. Although some plants have the ability to extract N from the air, this source of nutrient input is not significant in grassland systems that do not have leguminous species e.g. clover.

### 3.2 METHODOLOGY AND ASSUMPTIONS

Several approaches have been used internationally to calculate P balances of inputs and outputs in agricultural systems. The main inputs and outputs to the national P balance in agriculture are indicated in Figure 3.1. Animal manures are recycled either directly to grazed grass or later as slurry produced during the winter months when animals are housed. The total P in animal faeces, urine, effluents and dirty water from the agricultural sector is calculated to be 95,143 tonnes of P with 57,521 tonnes deposited directly by grazing animals and 37,622 tonnes collected, stored and applied subsequently to land.

Three different scenarios were used to calculate a national agricultural P balance for Ireland's agricultural sector. A combination of figures from

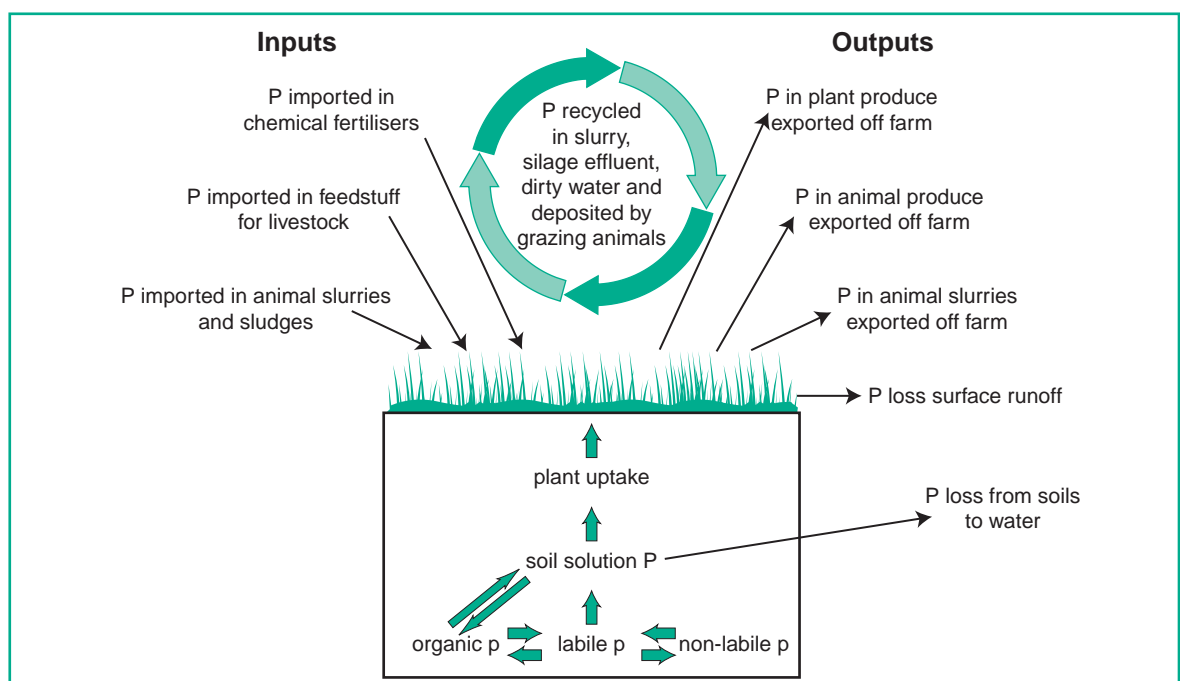


FIGURE 3.1: INPUTS AND OUTPUTS OF P FOR A HYPOTHETICAL FARM

CSO, DAFRD and Teagasc were used in the calculations and advice was sought from within these organisations. Each of the three scenarios used to calculate a national agricultural P balance show an excess of P inputs over P outputs. Scenario 1 shows a surplus (or excess) amounting to 48,022 tonnes of P in 1997. Scenario 2 shows a surplus of 48,619 tonnes of P in 1998, and scenario 3 shows a surplus of 60,291 tonnes of P in 1998. While many different assumptions (described below) have been used in these calculations, all three scenarios demonstrate that amounts of P in excess of needs are being applied to agricultural land and this is contributing to the upward trend in soil P levels. Research in Ireland (Tunney, *et al.*, 2000b) and elsewhere (e.g. Sharpley *et al.*, 1994) has documented that both surface and subsurface losses of P are positively correlated to the levels of P in soils and that excessive P applications are currently contributing to water quality deterioration and eutrophication. These surpluses not only represent a considerable threat to the environment but also a loss of money to farmers. The three scenarios are outlined below.

### 3.2.1 SCENARIO 1

Scenario 1 is calculated for the year 1997 (as data from 1997 were the most up to-date figures available from the CSO at the time of this analysis). Scenario 1 follows a similar method to that used by Tunney (1990), who calculated a nutrient balance for agriculture in 1988. He estimated that there was a surplus in 1988 of more than 46,000 tonnes of P. Nutrients returned directly by grazing animals and those returned in applied slurries were not included in this calculation. Instead, Tunney (1990) assumed that because animals do not produce nutrients, the P contained in their faeces and dung comes from the soil via P uptake by plants. The P is simply recycled back to the soil. The amount of P removed in grassland was also not included in the outputs section, as P contained in grass and silage that is fed to the animals is subsequently recycled back to the land from which it originated. The amount of P exported is calculated from the plant and animals products produced on farm and then exported.

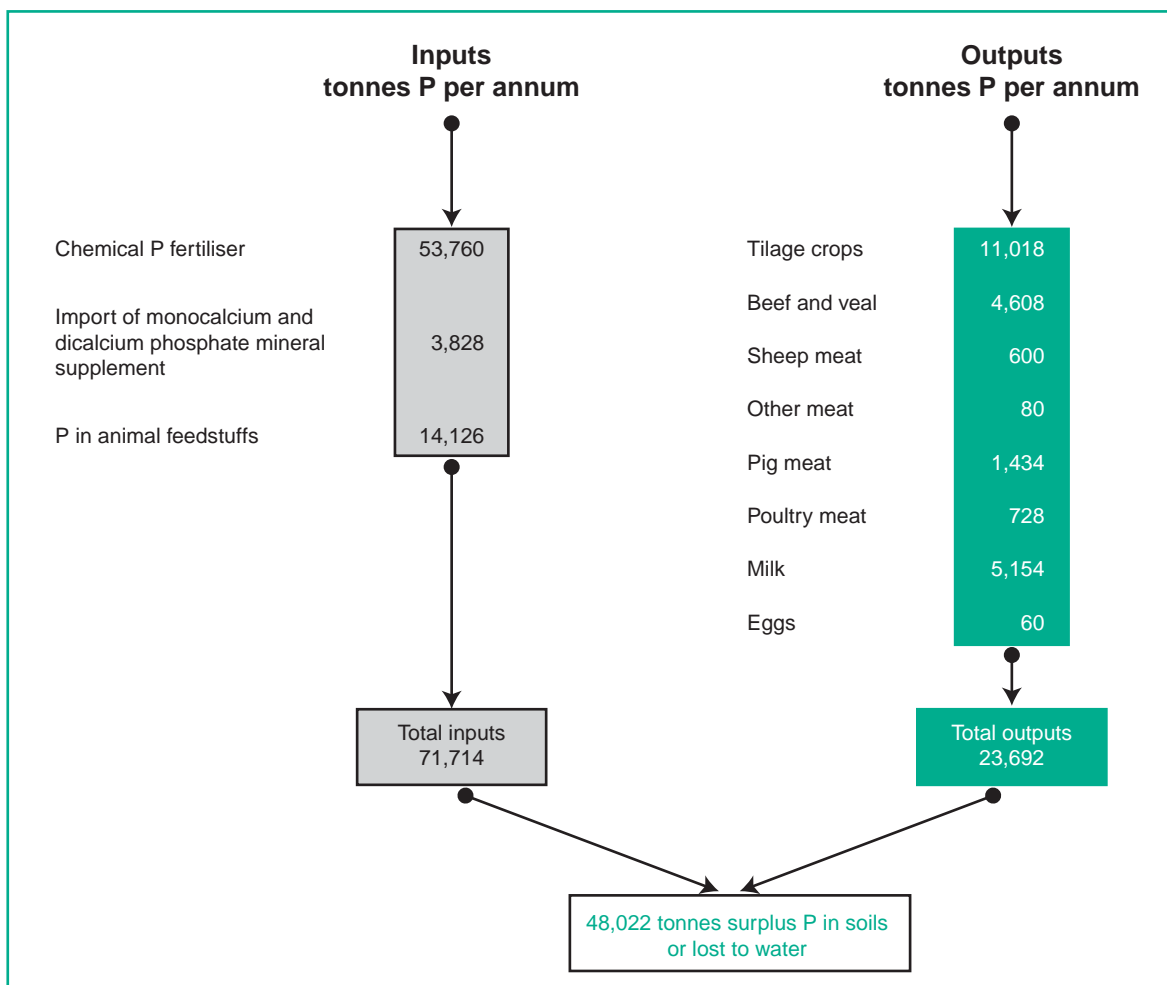


FIGURE 3.2: NATIONAL P BALANCE FOR AGRICULTURE (1997) - SCENARIO 1

This "balance sheet" approach is relatively straight forward in Ireland where 91 percent of all farmed land is devoted to grassland and only 9 percent sown to cereals and field crops. Figures used in the calculations were obtained from the Department of Agriculture Food and Rural Development (DAFRD) and Central Statistics Office (CSO, 1998a). The results shown in Figure 3.2 indicates a surplus of 48,022 tonnes of P were applied to the area farmed in 1997.

The CSO estimated that the area farmed in 1997 was 4,431,600 hectares (CSO, 1998b). Assuming a P surplus of 48,022 tonnes was applied uniformly to this area, it would appear that a surplus of 10.8 kgs of P per hectare was applied to agricultural areas in 1997. The higher P inputs relative to P outputs could be due to a number of reasons including the following:

- Teagasc revised its P fertiliser recommendations in 1997-1998 and there may be a delay in adopting these reduced rates, however, further reductions may still be required;
- Many farmers apply chemical fertilisers to meet crop requirements and may not take into account the P applied in animal slurries (Tunney, 1990); and
- A lack of awareness by some farmers who may believe that at high soil P levels, additional P applied will result in higher yields.

The analysis carried out for scenario 1 would suggest that virtually no progress has been made over the 10 years 1988-1997 in correcting the P imbalance identified by Tunney (1990).

### 3.2.2 SCENARIO 2

For scenario's 2 and 3 the national P balance for agriculture was calculated using CSO figures from the *Crop and Livestock Survey* for June 1998 (CSO, 1998c). The balance sheet approach adopted for Scenario 2 and 3 included as inputs the quantity of P applied directly by grazing animals and P applied in slurries and sludges only. Chemical fertiliser added was not taken into account in scenarios 2 and 3. Calculations in these scenarios assumed that the quantity of P in animal faeces and dung represents a combination of P fed to animals in imported feedstuffs (which is not utilised and passes through the animal), and soluble P, which is taken up by plants from soils reserves. The P in plants is consumed and a proportion of P is then returned directly by grazing animals or collected and

subsequently spread on the land in the form of slurry. Animals retain only approximately 15 percent of the nutrients contained in feedstuffs converting them into animal product while the remaining 85 percent is excreted (Magette and Carton, 1996).

In Scenario 2, P outputs were calculated using the most recent fertiliser recommendations outlined in the revised agri-environmental specifications for REPS 2000 under the Rural Environmental Protection Scheme (REPS) (Department of Agriculture and Food, 2000). At soil index 3, the REPS fertiliser recommendations best represent the P actually removed by a crop. At this index, no additional P is required to maintain or increase soil P levels i.e. the P applied at soil index 3 is a maintenance dressing that only replaces the P removed by crop uptake. Thus, the P fertiliser recommendations at soil index 3 can be used to estimate the P *outputs* in crops from soils at any soil P index where a *status quo* in P levels is desired. Figure 3.3 illustrates Scenario 2, using for outputs in plant produce, those amounts of P required to maintain soil P levels at their current soil indices 1, 2, 3 or 4.

The CSO estimated that the area farmed in 1998 was 4,414,800 hectares (CSO, 1998c). In Scenario 2 where P levels are maintained at status quo for all indices, this national P balance would represent a net surplus of 11.01 kg of P applied per hectare of the area farmed if the surplus was distributed uniformly. This surplus of P is either held in the soils or lost to water.

### 3.2.3 SCENARIO 3

The approach adopted in scenario 3 is similar to that of scenario 2 in that only the P applied directly by grazing animals and applied as slurries and sludges is considered as inputs. However, on the outputs side an attempt was made to quantify the amount of P required for crops grown on soils with various soil indices. Teagasc received and analysed 60,229 soil samples in 1998 and 17 percent of soils sampled were in soil index 1, 34 percent were in soil index 2, 25 percent were in soil index 3 and 24 percent were in soil index 4. It is important to remember that the average P content of the soil samples received for analysis may not truly reflect the P status of soils around the country. However, the assumption in Scenario 3 was that the soils analysed by Teagasc give a good indication of the current P status of soils under grass and tillage.

In Scenario 3, the amount of P required for each crop type, i.e. wheat, barley, oats, potatoes, silage, pasture



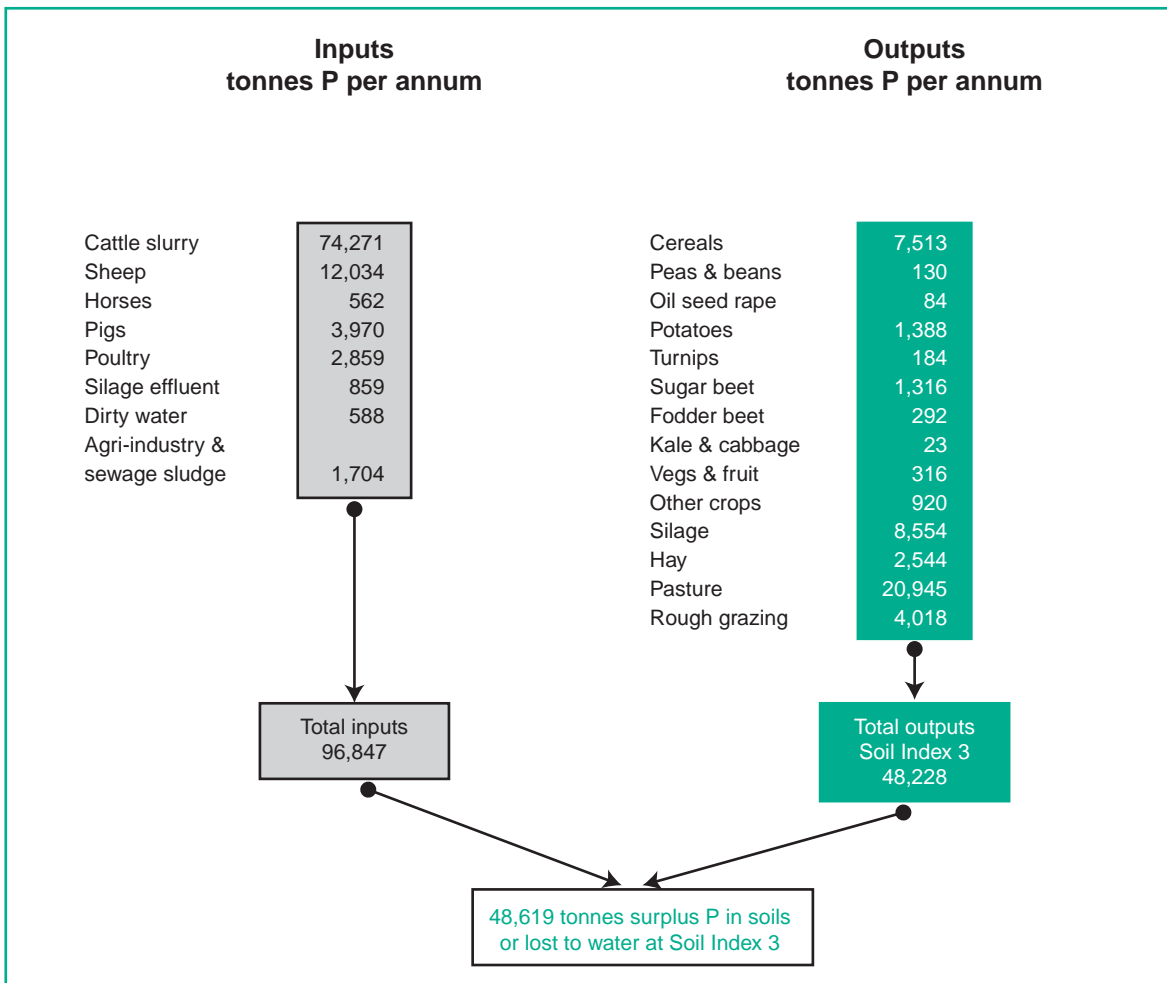


FIGURE 3.3: NATIONAL P BALANCE FOR AGRICULTURE (1998) - SCENARIO 2

etc. at each soil index was calculated. For example at soil index 1, oil seed rape requires 35 kg of P per hectare according to the most recent fertiliser recommendations outlined in the revised agri-environmental specifications under REPS (DAF, 1999). In 1998, 5,600 ha of oil seed rape were grown, giving a national requirement for 196 tonnes of P to grow 5,600 hectares and to increase soil P levels above soil index 1 towards soil index 2 (i.e. 35 kg P/ha x 5,600 ha /1000kg/t = 196 tonnes P). This calculation was repeated for each crop type and soil index resulting in a total P value for each crop type assuming that all soils were at index 1. This calculation was then repeated assuming that all soils in the country are at either index 1, index 2, Index 3 or Index 4 and that all soils should achieve or be maintained at soil index 2. The percentage of soils within the four soil indices were then applied to the total tonnes of P required for each soil index to come up with the P requirement for crops grown in 1998. Figure 3.4 illustrates these calculations.

As with Scenario 1 and 2 many assumptions were used reaching these figures in Scenario 3. Again the area farmed in 1998 was 4,414,800 hectares. In Scenario 3, where P removed in crops and P required to maintain or build up soil P levels to soil index 2 is accounted, a net surplus of 13.65 kg of P per hectare of the area farmed was calculated assuming a uniform distribution of the P over this area. This surplus P is either held by the soils or lost to water via overland flow.

Table 3.1 summarises the findings of the three scenarios which indicate that there is a surplus of P being applied to farmed land in Ireland. The table outlines the key assumptions made during the calculations and indicates the surplus in tonnes per annum and kgs per hectare for the area farmed.



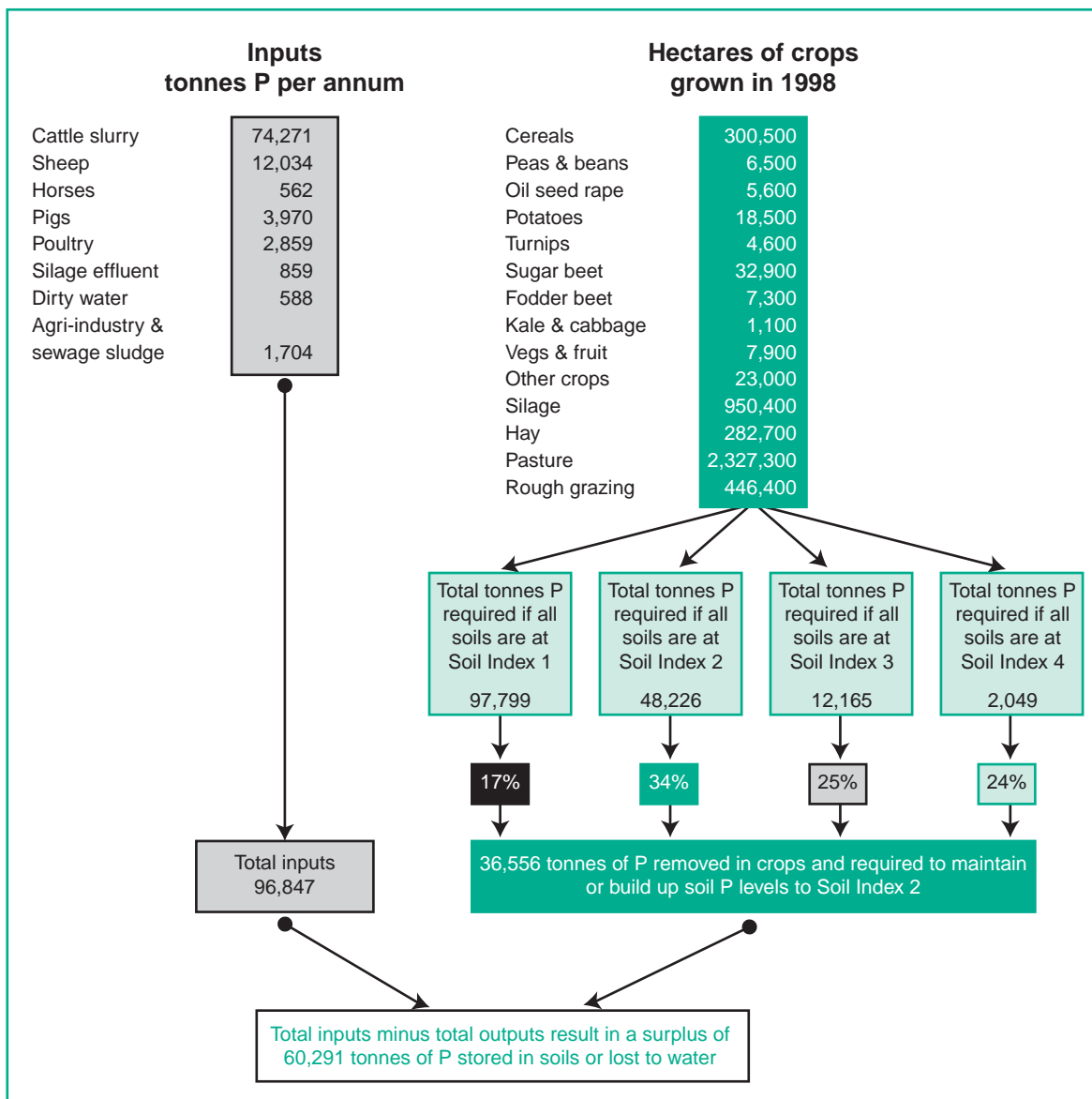


FIGURE 3.4: NATIONAL P BALANCE FOR AGRICULTURE (1998) - SCENARIO 3

TABLE 3.1: SUMMARY TABLE OF NATIONAL P BALANCE					
Scenario	Key assumptions	P inputs (tonnes)	P outputs (tonnes)	P surplus (tonnes)	P surplus kg/ha for AAU
<sup>1</sup> Scenario 1	Nutrients returned by grazing animals and in slurries are not accounted for as this represents recycling of nutrients	71,714	23,692	48,022	10.83
<sup>2</sup> Scenario 2	Nutrients returned by grazing animals and in slurries are accounted for in the calculation. Chemical P and feed imports are not directly accounted for in inputs.				
	P outputs based on the most recent fertiliser recommendations under REPS. Assumed that soil P status remains at status <i>quo</i> .	96,847	48,228	48,619	11.01
<sup>2</sup> Scenario 3	Inputs same as for scenario 2.  P outputs based on most recent fertiliser recommendations but all soils to achieve soil index of 2	96,847	36,556	60,291	13.65

<sup>1</sup> figures for 1997; <sup>2</sup> figures for 1998

## 4. CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

### 4.1 INTRODUCTION

The EPA report, *Water Quality in Ireland 1995-1997* clearly demonstrates that surface water quality in Ireland is continuing to deteriorate. The Agency attributes the increase in slight and moderate pollution mainly to eutrophication by nutrients (primarily P) from organic manures, slurries, sludges and chemical fertilisers used in agriculture. Despite a decrease in sales of chemical P fertiliser, soil P levels are continuing to increase; approximately 24 percent of soils analysed by Teagasc contain P in excess of that needed to produce suitable crop yields. The EPA report concluded that improvements in surface water quality were unlikely to be achieved without controls on phosphorus losses from agricultural activities. The analyses described herein were undertaken to quantify the current scale of the problem, particularly in relation to diffuse P loss from agricultural land to water.

### 4.2 CONCLUSIONS

The main conclusions which can be drawn from these analyses are:

- There was a surplus of P applied to agricultural land in 1997 and 1998. The magnitude of the surplus was estimated to be 48,022, 48,619 and 60,392 tonnes of P for scenarios 1, 2 and 3 respectively. These annual surpluses, if spread uniformly over the area farmed correspond to a net surplus of 10.83, 11.01 or 13.65 kg of P for every hectare farmed. These surpluses compare well with other P balance studies undertaken on catchment and mini-catchment basis. The Lough Derg and Lough Ree Catchment Monitoring and Management System P balance study of the Bellsgrrove and Clarianna mini-catchment indicated that there was a P surplus application of 14kg/ha/yr and 8kg/ha/yr respectively for each area (Kirk, McClure Morton, 1999).
- A total of 58,000 tonnes of P were deposited directly by grazing animals in 1998. A further 40,000 tonnes of P were applied to land in the form of managed organic wastes and 49,900 tonnes of chemical P fertiliser were also applied. Therefore almost 150,000 tonnes of organic and chemical P fertiliser were applied to the farmed land in 1998 of which 39 percent was deposited directly by grazing animals. The timing and quantity of manure deposited directly by grazing animals can be controlled to a limited extent by removing stock or adjusting stocking densities. The remaining 61 percent of P is applied to land using spreading equipment such as slurry tankers and fertiliser spinners.
- The cattle sector (dairy and beef) account for 73 percent of the total organic wastes (wet weight) arising or up to 90 percent if dirty water and silage effluent is attributed to this sector only. Much of the organic waste generated by the cattle sector is deposited directly by grazing animals (62%) while the remaining is collected, stored and subsequently applied to land. This sector also accounts for approximately 73 percent of the total P contained in organic wastes or up to 77 percent when you include the P contained in dirty water and silage effluent is included.
- The pig and poultry sectors account for 2.3 percent of the total amount of organic wastes arising and 7.1 percent of the total quantity of P contained in organic wastes applied to agricultural lands. However, in contrast to the cattle sector, the production of slurry and litter on these farms does not represent nutrient recycling as generally there is no link between crop and animal production and nutrients on these farms are mostly imported (Carton and Magette, 1998). In addition, regional concentration, spatial separation from crop farms, use of third party spreadlands, haulage, and the fact that nearly all waste generated requires subsequent management increases the potential for P loss to water from this sector.
- The sheep sector accounts for 6.2 percent of the total amount of organic wastes arising and 12.4 percent of the total quantity of P contained in organic wastes applied to land. Almost 96 percent of sheep sector organic waste is deposited directly during grazing.
- The agri-industry (0.9%) and sewage sludge (0.1%) account for 1 percent of the total organic wastes arising which are applied to agricultural land. Agri-industry accounts for 1.6 percent of the total quantity of P contained in organic wastes applied to land while sewage sludge accounts for 0.13 percent.

### 4.3 ANALYSIS OF RESULTS AND FACTORS CONTRIBUTING TO P LOSS TO WATER

- Tunney (1990) has estimated that a surplus of 46,041 tonnes of P were applied to agricultural soils. If a similar surplus of P was applied annually in the intervening years from 1988 to 1998, an excess of more than 500,000 tonnes of P would have been applied to Ireland's farmland during that period. Various studies undertaken in the Dripsey, Conn and Shannon catchments (Tunney *et al.*, 2000a; McGarrigle *et al.*, 1993, Kirk, McClure Morton, 1999) would suggest that up to 12 percent of the surplus P applied in any one year is entering water courses, with the remaining P being stored in the soils and increasing soil P levels. It is important to note that for any given level of fertiliser P inputs (organic and chemical), the potential for P losses will be higher for soils with high P status than for soils with lower P status. Therefore, if soil P levels continue to increase, even greater quantities of P could be lost to water in the future.
- The total P applied in 1998 is estimated at approximately 147,000 tonnes which includes managed slurries and sludges, wastes deposited directly by grazing animals and chemical P fertiliser (49,900 tonnes). Research would indicate that approximately 25 percent or less of an annual P application is actually taken up by the crop in the growing season. This would suggest that approximately 110,000 tonnes of P annually is either stored in the soil, used by the soil organisms to maintain the soil ecosystem or potentially lost to water. The actual annual P build-up in soils may be much higher than indicated in scenarios 1, 2 and 3.
- Excessive use of P in agriculture has resulted in a build-up of P in soils. Teagasc soil analysis results would verify this as currently 49 percent of all soil samples sent for analysis in 1998 were index 3 and 4. Current Teagasc advice states that on grassland an agronomic response to applied P is unlikely at soil index 3 and that at soil index 4 there would be no response to applied P. It is also important to note that the soil indexing system and fertiliser advice is agronomically based and does not consider the environmental consequences of P loss to water.
- The distribution of water soluble phosphate in the rooting zone is dependent upon P additions, P placement, cultivation operations and soil organisms, including plant roots. In the case of grassland where tillage operations are virtually

absent (i.e. 91% of farmed land in Ireland is devoted to grassland), soil P distribution is dependent on processes within the soil. This can lead to stratification of available P, with larger concentrations near the surface. The concentration of P in the soil layer exposed to water flowing over the soil surface is, therefore, higher than what would be indicated by tests on 100 mm deep soil samples taken for agronomic analyses (Murphy and Culleton, 1997). Current soil sampling and testing practices, which have been developed and verified for making agronomic recommendations, may therefore significantly underestimate the degree of P enrichment in the uppermost soil layers. As only the top 2-3 mm of soil is suspected of interacting with surface runoff (Sharpley *et al.*, 1994) it could be argued that only the top few centimetres of soil should be sampled for environmental protection purposes.

- There is evidence that diffuse leakage of P is occurring, through overland flow, to water. The higher the soil P levels, the higher the risk of P loss to waters. P losses which are not regarded as significant in agronomic terms, are significant in environmental terms (Tunney, *et al.*, 2000a).
- Controlling P loss from soil to water is complex. The transfer of P from soil to water via overland flow or subsurface flow is controlled by field characteristics such as slope, soil texture and structure ( i.e. influence on soil permeability), land use, proximity to drainage, vegetation cover and soil P levels (AGMET, 1992). However, one of the most important factors affecting the concentration of nutrients in runoff was shown to be the number of days which elapse between slurry or fertiliser spreading, and the occurrence of rainfall which caused the first runoff event after application (AGMET, 1992; Sharpley & Rekolainer, 1997; Lennox, *et al.*, 1997; Tunney, *et al.*, 2000a).
- The types of animals, the intensity of production, animal husbandry and the rations fed determine the amount of nutrients in the faeces and urine. In general, as production levels rise, both the quantity and concentration of plant nutrients in the organic wastes also increase.

### 4.4 RECOMMENDATIONS

The control of diffuse P loss from farmed land represents a major challenge to farmers, advisory services, regulators, water resource managers and the general public. It is clear that there is an imbalance between nutrient inputs and outputs and

that this situation is not sustainable. To address this problem the following recommendations are made.

#### 4.4.1 EDUCATION AND AWARENESS

The importance of education and awareness programmes aimed at the farming community cannot be overstated. Ultimately, if phosphorus loadings to Irish soils are to be reduced to a sustainable level, farmers must be convinced, not only that it is the environmentally "right", but also that those reductions are economically viable. Fears that farmers have in relation to the potential for yield loss (as a result of reduced P application rates) must be acknowledged and addressed before any noticeable reductions in fertiliser use will be achieved. Farmers have to be convinced that crop yields will not suffer as a result of reducing application rates. They also have to see that economic savings can be achieved from utilising nutrients in manures more efficiently through more timely and accurate application. The potential for achieving cost reductions by reducing chemical P fertiliser purchases must be emphasised.

A new integrated national awareness campaign should be undertaken by the relevant authorities and farming bodies to highlight the continuing decline in water quality, the increase in eutrophication and the consequences of this decline both in environmental and economic terms. This campaign would augment the measures currently being undertaken by local authorities under the Local Government (Water Pollution) Act, 1977 (Water Quality Standards for Phosphorus) Regulations, 1998 (SI No. 258 of 1998).

A strong educational component must be incorporated into advice and guidance on nutrient management planning. It is important that organic wastes generated on farms must be considered as a resource rather than a waste and recycled so that the valuable nutrients contained within these organic fertilisers are used efficiently. The importance of the timing of fertiliser applications in relation to the potential for nutrient loss needs to be emphasised in conjunction with the environmental and economic costs of P loss from agriculture.

#### 4.4.2 NUTRIENT MANAGEMENT PLANNING

Nutrient management planning (NMP) should become an integral part of modern farming practice on all farms. NMP is an organised process for guiding the use of nutrients in agricultural production systems and it can be applied at any spatial scale from national, regional and catchments down to individual fields (Magette, 1999). The

objective of NMP is to integrate and balance nutrient inputs such as organic wastes and chemical fertilisers against crop requirements and nutrient exports off farm in order to use nutrients efficiently, thereby increasing both profitability and environmental protection. At the farm level, the quantity of N, P, K and lime required to grow a particular crop, in a particular field is determined by soil analysis and agronomic fertiliser recommendations. These requirements (for crop growth or soil fertility build-up) are then met through the application of nutrients in organic wastes and chemical fertilisers. Where animals manure is available, the nutrients contained therein should be used first, before purchases of chemical fertilisers are considered.

NMP involves several essential steps which include: 1) assessment of the farm resources (soils, nutrient content and availability in slurries and sludges, crops, animals numbers, adequacy of storage facilities, condition of farmyards including yard drainage system and availability and condition of spreading equipment); 2) analysis of the assessed data and measurement of soil nutrient status and nutrient sources; 3) decision making about crop needs and meeting these needs for identified management units; 4) evaluation of the effectiveness of the nutrient management plan once implemented through the use of accurate record-keeping; and 5) periodic review and refinement of the plan ensuring effective implementation. In tandem with the preparation and implementation of NMP, an "emergency" action plan should be developed providing details of what immediate actions should be undertaken in response to accidental spillages or leakages on farm.

As part of the implementation of NMP on-farm, slurry and sludge analysis should be undertaken at an appropriate frequency to assess more accurately nutrient content.

Local authorities have powers under Section 21 of the Local Government (Water Pollution) (Amendment) Act, 1990 to require farmers to undertake NMP on their farms in order to prevent, eliminate or minimise the entry of polluting matter to waters. Agricultural activities covered include collection, storage, treatment and disposal of silage effluent, animal slurry, manure, fertiliser, pesticides or other polluting matter.

A training programme in NMP needs to be developed and implemented to ensure that local authority personnel have the necessary skills to evaluate NMP and to monitor their implementation

and effectiveness. The feasibility of a national training and certificate programme on NMP is currently being assessed by FAS in association with the EPA and Monaghan County Council.

#### 4.4.3 CHEMICAL P FERTILISER APPLICATION TO GRASSLAND

The EPA recommends that the current Teagasc agronomic fertiliser recommendations i.e. July 1998 and any future amendments be implemented on all non-REPS farms. On REPS farms the nutrient limits specified under Measure 1 of the "*Agri-Environmental Specification for REPS 2000*" (DAFRD, 2000) are required to be implemented in full by participating farmers in the scheme.

However, in relation to water quality deterioration and applying the precautionary principle, the EPA recommends that the following options be considered as part of the process of publishing this discussion document with a view to selecting a set of definitive recommendations.

##### OPTION 1

On grassland, *chemical-P fertiliser should not be applied* where Morgan's P is greater than 6.0 mg/l (i.e. soil index 3 or 4). The application of chemical-P fertiliser to soils above this level *should be phased out over a period of one to two years*.

OR

##### OPTION 2

On grassland, chemical-P fertiliser should not be applied where Morgan's P is greater than 6.0 mg/l (i.e. soil index 3 or 4). The application of chemical-P fertiliser to soils above this level should be phased out over a period of one to two years, other than in situations where it can be demonstrated to the satisfaction of the relevant competent authority that the addition of P, on a site-specific basis, to soils above this level is required for agronomic reasons and will not cause environmental pollution.

#### 4.4.4 OFF-FARM ORGANIC WASTE MANAGEMENT ON GRASSLAND

The EPA recommends that the current Teagasc agronomic fertiliser recommendations i.e. July 1998 and any future amendments be implemented on all non-REPS farms. On REPS farms the nutrient limits specified under Measure 1 of the "*Agri-Environmental Specification for REPS 2000*" (DAFRD, 2000) are required to be implemented in

full by participating farmers in the scheme. However, as a consequence of water quality deterioration and applying the precautionary principle, the EPA recommends that the following options be considered as part of the process of publishing this discussion document with a view to selecting a set of definitive recommendations.

##### OPTION 1

On grassland, **imported organic wastes that contain P** (i.e. wastes which were not generated on the farm and therefore do not represent the recycling of nutrients on the farm from which they arose) should not be applied where Morgan's P is greater than 6.0 mg/l (i.e. soil index 3 or 4). The application of imported organic wastes to soils above this level **should be phased out over a period of five years or sooner**. A longer phasing out period of up to five years is required for imported organic wastes than chemical-P fertiliser to allow for the development of alternative treatment options for such wastes or their reduction at source.

OR

##### OPTION 2

On grassland, *imported organic wastes* (i.e. wastes which were not generated on the farm and therefore do not represent the recycling of nutrients on the farm from which they arose) *should not be applied* where Morgan's P is greater than 6.0 mg/l (i.e. soil index 3 or 4). The application of imported organic wastes to soils above this level *should be phased out over a period of five years or sooner*, other than in situations where it can be demonstrated to the satisfaction of the relevant competent authority that the addition of P, on a site-specific basis, to soils above this level is required for agronomic reasons and will not cause environmental pollution. A longer phasing out period of up to five years is required for imported organic wastes than chemical-P fertiliser to allow for the development of alternative treatment options for such wastes or their reduction at source.

#### 4.4.5 WINTER SPREADING OF ORGANIC WASTES

The spreading of organic wastes on agricultural lands during the period from November to February inclusive should be prohibited (EPA, 1996). Slurry spreading on wet, waterlogged or frozen ground should be prohibited at all times. Spreading should also be prohibited on fields that are pipe or mole drained and the soil is cracked down to the drains or backfill; fields that have been pipe or mole drained



in the last 12 months; and fields that have been subsoiled over a pipe or mole drainage system in the last 12 months.

On REPS farms the spreading times specified under Measure 1 of the "*Agri-Environmental Specification for REPS 2000*" (DAFRD, 2000) are required to be implemented in full by participating farmers. REPS 2000 specifies that in each year of the plan, all slurry and dungstead manure produced during the winter housing period is landspread by 31st August. Slurry applications shall not take place between 1st October and 15th January. In addition, landspreading shall only take place where weather and land conditions permit and in January shall be restricted to dry land in early grass growing areas.

#### 4.4.6 NATIONAL REGULATIONS ON LANDSPREADING OF ORGANIC WASTES

Although the storage and application of organic wastes is covered under existing legislation, it appears that this legislation is not effective in controlling the loss of nutrients to waters from agriculture. Controls which already exist include the provision for making bye-laws under s 21 of Water Pollution (Amendment) Act, 1990; requirement to undertake nutrient management planning under section 21 A of Water Pollution (Amendment) Act, 1990; EPA Act, 1992, Waste Management Act, 1996; the designation of Nitrate Vulnerable Zones under the Nitrates Directive (Council Directive 91/676/EEC) which will result in the Code of Good Agricultural Practice becoming mandatory in these areas; and the controls which exist for farms participating in REPS.

Proposals need to be developed that specifically address the need for the provision of adequate winter storage of organic wastes on farms and the subsequent landspreading on agricultural lands in accordance with nutrient management planning. The types of landspreading equipment used and some landspreading practices should also be addressed e.g. the use of umbilical system to apply slurry during winter months on wet soils and spraying slurry off-roads and farm lanes using high trajectory spreading equipment.

#### 4.4.7 FUTURE RESEARCH NEEDS

1. Soil samples for agronomic fertiliser recommendations are currently taken from a depth of 0 - 10cm on grassland. From an environmental perspective this depth may need to be revised so that soil test results more accurately reflect the concentrations of available P in the

uppermost soil layer, which is the most vulnerable layer contributing to P loss via overland flow (Haygarth *et al.*, 1998). Research should be undertaken to establish an appropriate soil sampling depth for environmental protection. However, should an 'environmental P' test be established, it should be correlated, if possible, to existing agronomic tests.

2. There should be a move away from sole reliance on a soil test P i.e. Morgan's P as the determinant of P applications. Site specific factors which control P losses such as slope, proximity to surface waters, drainage etc., in addition to soil test P should be integrated to derive for example a phosphorus site index. This site specific approach is being implemented as part of integrated pollution control licences issued by the EPA for the pig and poultry enterprises which require licensing under the Environmental Protection Agency Act, 1992. It is also more widely practised in the USA.
3. A comprehensive literature review should be undertaken of vegetated buffer strips, both managed and unmanaged. Buffer strips are perimeter controls which act as last line of defence to retard the movement of nutrients and eroded soils lost from the land. They can act as nutrient sinks but also under certain conditions they become nutrient sources. Following the literature review, a code of good management practice for buffer strips should be developed.

#### 4.4.8 TREATMENT OPTIONS FOR ORGANIC WASTES

A number of processing and treatment options have been researched and developed for high strength organic wastes, which include physical (separation) and biological processes (aerobic digestion, anaerobic digestion and composting), pyrolysis/gasification and incineration (Carton and Lenehan, 1998). Options, including reed-bed systems and artificial wetlands are also either available or under development for low strength wastes such as dirty wastewater. These unless well managed have the potential to cause serious water pollution.

Biological treatments are those in which the naturally occurring micro-organisms are facilitated to break down the organic matter in the manure or slurries. Some of the benefits from biological treatment include: reduced odour nuisance; reduced greenhouse gas emissions; energy generation and blending and mixing of slurries and sludges to

produce a more consistent fertiliser value resulting in improved utilisation of nutrients. This will enable a better match of nutrients with crop requirements. Other benefits from centralised biological treatment include the pasteurisation/sterilisation of the slurries. This will reduce the potential for the spread of diseases such as salmonella and brucellosis. Some of the potential problems are significant capital and operational costs, traffic, noise and visual impacts. Research is currently being undertaken to assess the benefits and potential problems associated with centralised anaerobic digestion in Ireland particularly in areas where there is a surplus of organic wastes which are normally associated with intensive agricultural enterprises (IAE) such as the pig, poultry and mushroom industries.

The future development of both centralised treatment processes and on-farm treatment processes for the treatment of both high strength and low strength organic wastes requires serious attention.

#### 4.4.9 COMPREHENSIVE ANALYSIS OF SOIL P LEVELS

There is a requirement for a comprehensive analysis of soil P levels across the country. This should be undertaken on a grid basis and the information used to determine an accurate national P balance for Ireland. As previously discussed the soil test data currently available are representative only of those lands from which farmers have chosen to send soil samples to Teagasc for analysis. These data may not accurately depict the true soil P levels across the range of soil types in the country. The soil type mapping should be completed in the remainder of the state.



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## 6. INFORMATION NOTES

### 6.1 MEASURING P LEVELS IN SOILS AND WATER

Soil testing is an excellent method for establishing a sound fertility management programme and determining the fertility status of the soil. The level of available P and K in the soil can be determined from a representative sample. In Ireland, Teagasc the Agriculture and Food Development Authority responsible for agricultural research, advice and education, offer a soil sampling and analysis service to farmers. Soil testing by Teagasc at Johnstown Castle Estate commenced in the late 1940s. Soil analyses are used to predict the amount of lime and fertilisers necessary to obtain a specific crop yield from a particular soil. In Ireland, over 90 percent of the area farmed (AAU) is under grassland (silage, hay, pasture and rough grazing); this figure of approximately 4 million hectares does not include commonage lands.

There are three fundamental elements to soil sampling and analysis. A soil test result is only useful if it is reproducible i.e. the same result must be obtained if the sampling and analysis is repeated. The three main areas of soil testing are:

- soil sampling procedure;
- laboratory analysis; and
- interpretation of results and fertiliser recommendations

#### 6.1.1 SOIL SAMPLING

Teagasc have developed a code of good practice for soil sampling which outlines the correct approach to soil sampling in the field. The main recommendations include:

- mapping out discrete areas of the farm that are uniform in soil type, slope, drainage, cropping history etc. and a sample should on average be taken from every 2 to 4 hectares;
- taking a composite sample of 20 cores in each designated area to a depth of 10 cm (4") which are mixed to form a sample;
- taking cores in a "W" pattern across the sampling area to avoid unusual spots such as old ditches and fences etc.;

- avoiding dung and urine patches; and
- soil sampling for P and K should not be undertaken for 4-6 months after last fertiliser application and two years after liming (Teagasc, 1997).

It is important that the identification form is completed for each sample and accurate information on crops, stocking densities and map grid reference or land parcel number accompany the sample to the laboratory.

#### 6.1.2 LABORATORY ANALYSIS

Phosphorus exists in the soil in many forms, both organic and inorganic, and it is also added to the soil in manures, slurries and chemical fertilisers. The majority of soils contain plant nutrients in excess of plant requirements but in a form which the plant cannot use, so estimates of total nutrients are valueless from an agronomic perspective. Of the total phosphorus in soils, less than 1 percent is available to plants and Morgan's solution is designed to dissolve an amount of phosphorus proportional to this available fraction. Teagasc at Johnstown Castle use Morgan's P extracting solution which is designed to take from the soil an amount of nutrient proportional to that which the plant can use in any growing season i.e. plant available P.

Once a soil sample arrives at the laboratory it is dried and sieved. Soils are sieved to remove stones and plant debris and mixed thoroughly to obtain a representative sample. A volume of soil (6.5 ml) is mixed with 30 ml of Morgan's extracting solution (combination of NaOH, water and glacial acetic acid adjusted to pH 4.8). The soil and reagent is mixed for 30 minutes and the suspension is then filtered.

The "plant available P" is now in the solution and is analysed colorimetrically using the chemical reaction between P and ammonium molybdate. A characteristic blue colour is produced when the molybdate reacts with plant available P (molybdate reactive P (MRP)) and the intensity of the colour relates to the concentration of plant available P in solution (Byrne, 1979).

### 6.1.3 MEASURING P LEVELS IN WATER

Phosphorus occurs in waters and wastewaters almost solely as phosphates. These are classified as orthophosphates, condensed phosphates e.g. polyphosphates, and organically bound phosphates. They occur in solution, in particles or detritus, or in the bodies of aquatic organisms. Phosphates that respond to colorimetric tests without preliminary hydrolysis or digestion of the sample are termed "reactive phosphorus" i.e. molybdate reactive phosphorus. While reactive phosphorus is largely a measure of orthophosphate a small fraction of condensed phosphate will also be measured. Reactive phosphorus occurs in both dissolved and suspended forms (Greenberg *et al.*, 1992).

In the laboratory 0.05 ml of a combined reagent which contains ammonium molybdate is added to 50 ml of the sample of water. This is mixed thoroughly and left for 10 to 30 minutes. After this time, the molybdate reactive P will have produced the characteristic blue colour which is analysed by a spectrophotometer.

### 6.2 RECENT RESEARCH FINDINGS BY TEAGASC

The upward trend in water pollution and eutrophication attributed to organic slurries and chemical fertiliser use in agriculture has highlighted the contribution of this sector to water quality deterioration. In the past, attention has focused on controlling P loss from farmyards and slurry stores, however more recently attention has shifted to controlling diffuse sources of P losses from agriculture. Teagasc in conjunction with Trinity College Dublin and University College Cork undertook a research project in 1996 on "Quantification of Phosphorus Loss from Soil to Water". The main aim of the project was to quantify the loss of P from soil to water where point source contributions from farmyards was not high. Some of the main findings are summarised below (Tunney *et al.*, 2000b).

- (1) Soil test phosphorus (P) levels increased tenfold in Irish soils over the past 50 years. From 1980 until 1997 fertiliser P use was about 60,000 tonnes per year. However, the average soil P test continued to increase. This indicates that the quantity of P fertiliser is higher than necessary to maintain soil fertility. Fertiliser P use decreased to 49,000 tonnes in 1998, this is a positive sign both for the competitiveness of farming and for the environment. There is room for further reductions.
- (2) The higher the soil test P (STP), the higher the potential for P loss to water. Based on the limited number of sites in this study, there was a positive relationship between soil test P and P loss to water. This is in agreement with results from other countries. The results from this study indicate that, for good water quality, the STP should be at the lower end of the scale for optimum or near optimum agronomic production (Teagasc soil index 2).
- (3) The higher the degree of P saturation in the soil, the higher the risk of P loss to water. Soils have a capacity to hold P and this varies depending on soil properties, such as organic matter, Al and Fe. For example, soils with a high content of iron and aluminium have a high capacity to bind P, while sandy and peat soils will generally have a lower capacity to bind P. Peat soils have lower sorption and desorption values than mineral soils, at broadly similar STP levels. This indicates that peat soils, with lower amounts of P binding cations (e.g. Al and Fe), are unsuitable for heavy applications of P fertiliser or manure. In this work mineral soils were up to 79 percent saturated with P, with high desorption rates at elevated STP. These soils are particularly susceptible to P loss to water.
- (4) In Ireland, over 90 percent of agricultural land is devoted to grassland. Fertiliser and animal manures are added to the soil surface each year, and most of it tends to accumulate in the top couple of centimetres (top inch). In this situation, the soil surface can easily become saturated or nearly saturated with P. In many soils, when heavy rainfall occurs, water can run over or infiltrate through this P-enriched surface soil and carry significant amounts of P with it. This, in turn, can enrich surface water and contribute to eutrophication.
- (5) Water soluble P (DRP) loss to water from an intensively grazed grassland field, at Johnstown Castle Research Centre, was found to be over 4 kg P per ha per year. This field received 30 kg fertiliser P per ha per year for the past 30 years and had a soil test of 17 (mg P per litre soil). This was about six times higher than on a less intensively farmed grassland field that received very little P fertiliser in the past and had a soil test of 4. The average DRP concentration in the water from the high P site was about ten times higher than the low one.

- (6) In 1997, there were several events of high summer rainfall and these events resulted in high P concentrations in the overland flow water. In general, the higher the level of overland flow the higher the concentration of P in the water. This means that high flows are coupled with high P concentrations. The P loss load is highest after a relatively small number of heavy rainfall events during the year. Most of the P loss can occur in about ten days of the year after very heavy rainfall.
- (7) At one site, in Co. Cork (Dripsey), where the contribution from the farmyard was investigated, it was estimated that about 30 percent of the total P losses for the farm came from the farmyard and the remaining 70 percent came from the fields. This included losses from soil P and loss after spreading fertiliser and animal manure.
- (8) Phosphorus datasets were collected for 35 river subcatchments, using water quality and stream flow data in conjunction with agricultural and land use datasets. In this initial study, which modelled P loss from soils in Ireland, there appeared to be a good relationship between catchment characteristics and measurement of P concentrations.
- (9) Hydrological studies at one site (Dripsey, Co. Cork) showed 1,443 mm of annual rainfall, 416 mm evapotranspiration and 1,081 mm of stream flow. Sub-surface flow accounted for 80 percent and surface overland flow accounted for 20 percent of the total annual streamflow. An interflow layer, mainly at a depth of between 10 and 40 cm below the soil surface, appeared to be responsible for the transport of a significant proportion of the dissolved P to the stream at this site. The shallow type of water table found in this hillslope predisposes the riparian zones (about 100 m on either side of the stream) to frequent periods of saturation. Phosphorus spread on such riparian zones is highly susceptible to being lost to streams. The assessment of the water table depth should be part of any strategy for nutrient management because of the high risk that water tables close to the surface pose for nutrient transport.



### 6.3 METHODOLOGY USED TO CALCULATE ORGANIC WASTES ARISING AND P SCENARIOS

Calculations	
Volume for cattle to give tonnes wet weight	<p>Used CSO statistical release dated 22/12/98 <i>Crops and Livestock Survey for June 1998</i>.</p> <p>Cattle volume/head/week            Dairy cows 315 litres            Other cows 280 litres            Dairy heifers 250 litres            Other heifers 250 litres            Bulls 280 litres            Cattle 2yo and &gt; 250 litres            Cattle 1-2yo 250 litres            Cattle under 1yo 140 litres</p>
Volume for sheep to give tonnes wet weight	<p>DAFRD suggested that there were marginally more lowland sheep than hill sheep i.e. 4/9 hill, 5/9 lowland. This split was used to calculate volumes. CSO Figures for sheep were given as ewes 2yo and over and ewes under 2yo. This was then split into hill and lowland.</p> <p>Ewes 2yo &amp; over – lowland - 28l/week            Ewes 2yo &amp; over – hill – 17l/week            Ewes under 2yo – lowland – 28l/week            Ewes under 2yo – hill 17l/week            Rams – 28l/week            Other sheep – 13l/week</p> <p>Assumed that 1000 l = 1000kgs to convert to weight</p>
Volume for horses	Horses 193litres/week.
Volume for pigs	<p>Figures for pig industry were obtained from Teagasc. The figures were from Teagasc Survey of Commercial Pig Units in Ireland, January 1999. Teagasc suggested that the most accurate way to calculate N and P for pig industry is to use the N and P per head figure rather than use volume and then x by concentration of N and P in a tonne of pig slurry.</p> <p>To estimate the volume Teagasc suggested that if you multiply the number of sows in the country by 15 m<sup>3</sup> that will give a good indication of the quantity produced by the total industry i.e. include dry sows, gilts, farrowing sows, sows with litter, weaners, fatteners etc. Survey 174,890 sows x 15m<sup>3</sup> = 2,623,350 tonnes wet weight.</p>

Calculations	
Volume for poultry	<p>Figures for numbers for 1998 were supplied by DAFRD. Figures for quantity were calculated using the following.</p> <p>Broilers – numbers x 0.45 l per week (quantity per bird place) x 52/1000/5.5. In broiler industry it takes approx. 35 to 49 days to fatten a broiler so each place will be filled 5.5. times per year i.e. 1 place = 5.5 broilers.</p> <p>Layers ( battery) - numbers x 0.81 l/week (quantity per bird place) x 52/1000 Layers (free range) - numbers x 0.89 l/week (quantity per bird place) x 52/1000</p> <p>Breeding stock (broilers) – numbers x 0.45 l/week x 52/1000 Breeding stock – (layers) – numbers x 0.851 /week x 52/1000 (0.851 taken as in-between figure for battery and free range)</p> <p>Commercial turkeys – numbers x 0.72 l/week x 52/1000/2.5 (turkeys fatten at 120 day interval therefore 1 place equal 2.5 birds)</p> <p>Breeding stock – numbers x 0.72 l/week x 52/1000</p>
Tonnes dry solids	<p>Figures DM% were supplied by DAFRD</p> <ul style="list-style-type: none"> <li>Cattle 10% (roofed and slatted)</li> <li>Sheep 25%</li> <li>Horses 30%</li> <li>Pigs 6% (housed slatted)</li> <li>Poultry (layers and broilers) 30% DM</li> <li>Poultry breeding stock 60% DM (assumed litter rather than droppings)</li> <li>Turkeys 70%</li> </ul>
Managed	<p>Storage periods</p> <ul style="list-style-type: none"> <li>Cattle 20 weeks</li> <li>Sheep 6 weeks ( for lowland ewes only)</li> <li>Horses 26 weeks</li> </ul> <p>Assumed for poultry and pigs that all organic wastes generated require management</p>



Calculations	
Tonnes of N + P generated	<p>Figures used for N and P for cattle, sheep, and horses supplied by DAFRD.</p> <p style="padding-left: 40px;">Cattle – 5 kgs N and 0.77 kgs P /tonne wet weight            Sheep – 10.2 kgs N and 1.48 kgs P/tonne wet weight            Horses – 5 kgs N and 0.77 kgs P/tonne wet weight</p> <p>For pig and poultry industry was advised to use the REPS figure for N and P produced per head or place rather than to use concentration of N and P in slurry and then x by volume produced. This was advised due to variability in feeding systems i.e. dry and slurry based systems.</p> <p><b>Pigs</b>            Integrated breeding &amp; finishing units – 67 kgs N and 22 kgs P/hd/yr (sow to finish)            Specialist breeding units – 29 kgs N and 9 kgs P /hd/yr. (sow to weaner)            Specialist finishing units – 8.8 kgs N and 3 kgs P /hd/yr (finishing pig – average weight 58kg)</p> <p><b>Poultry</b>            Commercial Broilers – 0.12 kgs/hd/yr N and 0.024 kgs/hd P (bird place 0.6 kgs N/5.5 birds per place)            Commercial layers – 0.64 kgs/hd/yr N and 0.22 kgs/hd/yr P</p> <p>Breeding stock broilers – 0.6 kgs N/hd/yr and 0.19 kgs P/hd/yr            Breeding stock layers - 0.64 kgs/hd/yr N and 0.22 kgs/hd/yr P</p> <p>Commercial turkeys – 0.4 kgs N/hd/yr and 0.16 kgs P/hd/year (figures for per bird place divided by 2.5)            Breeding stock – turkeys – 1.0 kgs N/hd/yr and 0.4 kgs P/hd/yr</p>
Silage effluent	<p>Figures for silage quantities from Teagasc, Grange. Estimated that 4.14 million tonnes of grass dry matter harvested per year and put into silage pit. This equates to approximately 20.65 million tonnes fresh grass producing 130l effluent per tonne. Kgs N and P taken from Agmet publication, 1992.</p> <p style="padding-left: 40px;">Average DM of 5%            2kgs N/tonne wet weight            0.32 kgs P/tonne wet weight</p>
Dirty water (dairy only)	<p>Figures for soiled water produced from the national dairy herd were taken from REPS. Estimated that 45 l/cow /day produced and an allowance of 5 l /hd/day for slurry produced during milking period.</p> <p>1,308,100 x 50 litres/day x 300 days for average lactation ÷1000.            Kgs of N and P taken from Agmet using            Average DM% 4%            0.3 kgs N/tonne wet weight            0.03 kgs P/tonne wet weight</p>

Calculations for P Scenario 1	
Scenario 1	<p>Chemical P inputs – figures supplied by Teagasc, Johnstown Castle</p> <p>Imports of monocalcium (21.8% P) and dicalcium phosphate (18% P) feed mineral supplement – figures from DAFRD for 1997</p> <p>P in animal feedstuffs – this figure was calculated from information from DAFRD – Cereals " Production of Compound Feeding Stuffs Manufactured for Sale in the year ending 31/12/1997" supplied by DAFRD. Total 2,875,784 minus exports 50,617 tonnes giving total of 2,825,167 tonnes with background level of P taken at 0.5%.</p> <p>Assumed that home produced feeds represented nutrient recycling on farm and therefore were not included in calculations. Mineral supplementation covered under monocalcium and dicalcium phosphate.</p> <p>Outputs</p> <p>Tillage crops (cereals, fruit and horticulture crops) – used figure that on average these crops remove 27kgs P /ha/yr. This figure was recommended by Hubert Tunney, Teagasc.</p> <p>The figure for Tillage crops was taken from CSO bulletin- 408,100 hectares. P removed in grassland was excluded as this is considered to be represent nutrient recycling.</p> <p>Figures for meat produced was taken from CSO Meat Supply Balance for 1997</p> <p>Milk – 5,154,000 litres produced for 1997 average P content of 1gram per litre</p> <p>Eggs – CSO 1997 Output, Inputs and Income in Agriculture, June 1997. 455 million eggs at average weight of 60 gm each. The average P content of eggs is 200mg P per 100 gm weight. Figure supplied by National Food Centre, Dunsinea, Castlenock.</p>

### Calculations for P Scenario 2

#### Scenario 2

#### Inputs

P supplied directly by grazing animals and in slurries were considered on the inputs side only. Chemical P inputs and inputs from feedstuffs were not included as the quantity of P in animal faeces and dung represents a combination of P fed to animals in imported feedstuffs, and soluble P which is taken up by plants from soil reserves. The quantity of P was calculated as per above.

#### Outputs

P outputs based on REPS fertiliser recommendations (1999). At soil index 3, these fertiliser recommendations best represent the P actually removed by crop uptake. At soil index 3 no additional P is required to increase soil P levels. The output of P for all crops grown in 1998 (CSO – Area, Yield and Production of Crops 1998) was calculated by x the number of hectares for each crop by the P fertiliser recommendation for a crop at soil index 3.

e.g. Wheat 83,800 hectares, fertiliser recommendation at soil index 3 is 25kgs P/ha = 2,095 etc.

Figures for vegetables and fruit – used figure for swedes and turnips i.e. 40kgs/ha  
 Figures for grassland i.e. silage, hay, pasture and rough grazing. Used a figure of 9 kgs/ha removed. This is the figure in the REPS recommendations for grazing/silage and hay where soil index 3 and target index 3.

### Calculations for P Scenario 3

Scenario 3

Inputs same as for Scenario 2

#### Outputs

Attempt made to quantify the amount of P required for crops grown in 1998 at various soil indices i.e. 17% soils at soil index 1, 35% soils at soil index 2, 25% soils at soil index 3 and 24% soils at soil index 4 (i.e. based on samples taken by Teagasc in 1998).

The fertiliser recommendations used were based on REPS, 2000 recommendations at that all soils should achieve target of soil index 2. i.e. soils at 1 go to 2, soils at 2 stay at 2, and soils at 3 and 4 revert to soil index 2. The fertiliser requirement for all crops at each soil index was calculated. The following assumptions were made:

Soil Index 1: used REPS figures for soil index 1 assuming that these fertiliser recommendations represent the quantity of P fertiliser required to grow the crop and increase soils from index 1 to index 2.

Soil Index 2: Used REPS figures for crop maintenance which is best represented by the fertiliser requirements of crops at soil index 3 i.e. maintenance for all crops except grass. REPS specification gives fertiliser recommendations for soils at soil index 2 achieving a target index of 2 i.e. 9 kgs/ha/year.

Soil Index 3: Used REPS figures for soil index 3 i.e. maintenance application although this may over estimated the quantity of P required where the target index for all soils is 2.

Soil Index 4: Used REPS figures for all crops.

The total quantity of P required for all crops at each soil index was calculated i.e. 97,799 tonnes for index 1; 48,226 tonnes for index 2; 12,165 for index 3; and 2,049 for index 4. The % of soils at each soil index (from Teagasc Soil analysis results) was applied giving a total P requirement of 36,556.

Vegetables, fruit, nursery, horticulture crops and other - used fertiliser recommendations for turnips

Silage, hay, pasture and rough grazing used 19 kgs/ha for soils at 1 to go to 2 and used 9 kgs/ha for soils at 2 to stay at 2. For soil index 3 and 4 no P applied as per REPS figures.