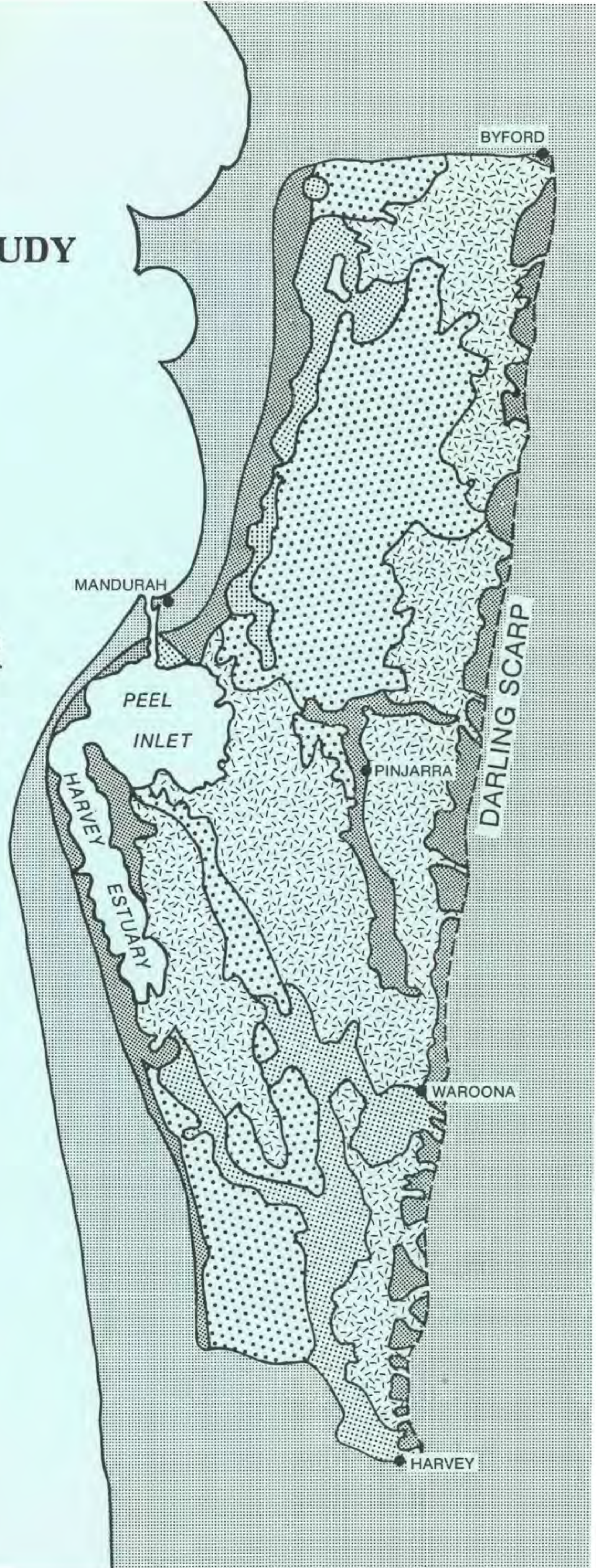
# PEEL — HARVEY
# ESTUARINE SYSTEM STUDY

## SYMPOSIUM

# PROSPECTS FOR MANAGEMENT






Department of Conservation
and Environment

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# PEEL-HARVEY ESTUARINE SYSTEM STUDY

## PROSPECTS FOR MANAGEMENT

SYMPOSIUM

held on

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at the University of Western Australia

REPORT OF PROCEEDINGS

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## CONTENTS

## INTRODUCTION

Ernest P Hodgkin
Research Co-ordinator, Peel-Harvey Study
Department of Conservation and Environment

Phase 2 of the Peel-Harvey Estuarine System Study aims to determine how best the present eutrophic condition of the estuary can be reduced to the point at which algae are no longer a nuisance. In 1982 the expanded research team concentrated on implementing the Estuarine and Marine Advisory Committee's recommendation No 1 (DCE Bulletin No 88, 1981):

> It is recommended that every effort be made to reduce the quantity of phosphorus discharged to the estuary from agricultural land. The Department of Agriculture and CSIRO Division of Land Resources Management should be asked to co-operate with the Department of Conservation and Environment in a study to determine methods by which release of phosphorus from coastal plain soils can be substantially reduced, whether by reduced application rates, modification of present application techniques, use of less soluble forms of phosphorus, or other methods. This study should be undertaken urgently.

The main purpose of this Symposium is to review progress of the study, with the assistance of other interested scientists.

The research report (DCE Report No 9, 1980) showed that about 80% of terrestrial input of phosphorus to the estuary came from coastal plain drainage, originating as superphosphate fertilizer. It also showed that there had been a great increase in phosphorus input since the 1950s, even though there was no corresponding increase in fertilizer application rates (Fig. 1). Since 1978, the input to Harvey Estuary has continued to increase, though this may be an artefact resulting from variation in rainfall and runoff because, as Birch has shown, the load of phosphorus entering the estuary has been directly proportional to the volume of flow during these five years.

McComb's plots (Fig. 2) indicate that the levels of Nodularia blooms (as measured by chlorophyll concentration) have been proportional to river flow (as indicated by estuarine salinity) and the consequent input of phosphorus. However, the Nodularia bloom experienced in 1982 (Oct - Dec) was somewhat greater than would be expected from McComb's analysis and this suggests that the estuarine sediment store may have made a bigger contribution to the phosphorus budget than previously. Whether this is because more phosphorus is now held in the sediments or because of more favourable environmental conditions for its release is an open question.

Be that as it may, it is clear that the sediments do play an important role in recycling nutrients to algae and it is necessary to understand this process and quantify the contributions they make to the phosphorus supply. In his talk

Gabrielson will bring us up to date on this in-estuary part of the studies.

Preliminary studies made by Birch during the winter of 1981 showed that the bulk of phosphorus entering coastal plain drainage came from the deep grey sands and sands over clays (Fig. 3), even though fertilizer application rates to heavy irrigated soils (37 kg P/ha) were generally double those to dry land sandy soils (18 kg P/ha). For this reason the 1982 experimental work has concentrated mainly on the deep grey sands and duplex soils from which about 75% of phosphorus released to drainage comes. The 1982 studies have refined the data, giving a more accurate measure of the source of phosphorus, but do not change the general picture.

On any estimate not more than 20% of phosphorus applied as fertilizer is exported as crops and another 30% lost to drainage, from sandy soils. This leaves 50% unaccounted for and it is obviously important to know what its potential is, both as a source of fertilizer for fodder crops and as a potential time bomb to nourish unwanted algae in the estuary.

Bettenay's studies provide an insight into what is happening to phosphorus as it moves through the different soil types and the factors controlling leaching to drainage. In his summation, Birch has budgeted the movement of phosphorus from spreader to discharge to the estuary, giving us a much better picture of what is happening in the catchment than was previously available and pinpointing important gaps in our understanding.

Clearly with such a poor return to farmers from the phosphorus applied and the annual loss of some $100,000 worth to the estuary it is as much in the interests of farmers as of those concerned with the welfare of the estuary to improve fertilizer application techniques. Yeates describes the experimental work undertaken by the Department of Agriculture with different fertilizers and fertilizer application techniques in field and laboratory. It will be evident from the results of the field trials that the potential for reducing loss by improved agronomic measures is great. However, successful implementation of recommendations arising from this research will depend on securing the co-operation of farmers. Russell discusses what will have to be done to secure this co-operation.

With recommendations being made for the use of new and different fertilizers on a limited scale we also have to be assured that adequate supplies will be available, at a price that farmers can be expected to pay. Southern discusses this from the point of view of the supplier.

Trials being made by ALCOA with the application of red mud to sandy soils to improve their water and nutrient holding capacity are very relevant to our objective, although not part of our study. These offer a different and promising approach to a more efficient use and retention of phosphorus, increased productivity from the land and less nutrient loss to the estuary. Tacey discusses these trials, which are being made on coastal plain sandy soils.

Clearly there is no possibility of stopping the input of phosphorus to the estuary forthwith, nor would it be desirable to do so. The increased nutrient input has improved productivity of the estuary, as shown by the increased fish catches. However we do need a realistic target to aim at and the team's immediate aim is to reduce input to the 1979 level (70 tonnes of phosphorus, 40 tonnes of it to Harvey Estuary), a level at which there was no *Nodularia* bloom. In 1981, when river flow was probably about average, phosphorus input to the estuary was 160 tonnes (120 tonnes to Harvey Estuary).

The 1982 studies have been concentrated in the catchment of Harvey Estuary for a number of reasons: because successive *Nodularia* blooms have initiated and been heaviest there, because about two thirds of phosphorus input to the estuary derives from Harvey River Main Drain and Mayfields Drain, which enter the south end of Harvey Estuary, and because their flow to the estuary can be measured more precisely than flow to Peel Inlet (via the Serpentine and Murray rivers).

## Questions

The appended questions are intended to focus discussion and to help us assess where we have got to in our attempt "to determine methods by which release of phosphorus from coastal plain soils can be reduced" in order to reverse the present eutrophic condition of the estuary by modifying present agricultural practices. Probably most of them cannot be answered factually at this stage, but they must be posed and serious consideration given to them.

QUESTIONS FOR CONSIDERATION

The following questions are pertinent to any attempt "to determine methods by which release of phosphorus from coastal plain soils can be reduced" in order to reverse the present eutrophic condition of the estuary by modification of present agricultural practices.

1. How much can the present phosphorus application rate be reduced by modifying present fertilizer application techniques - without loss of production?

2. Can this reduced application rate be achieved through the co-operation of the farming community? Or, will it be necessary to recommend some administrative action?

3. Assuming there is a 1:1 ratio between P applied and P released to drainage, how much will this lesser application rate reduce the input of phosphorus to the estuary?

4. Of the ∿1000 tonnes of phosphorus applied to the Harvey Estuary catchment <20% is accounted for as agricultural exports, <30% is lost to drainage. What happens to the unaccounted for 50+%?

5. What proportion of this missing 50+% remains as a store from which phosphorus will subsequently be released to drainage and end up in the estuary?

6. This store must be assumed to have been accumulating for 30+ years, how much phosphorus is now stored in catchment soils in a form in which it can be released to drainage?

7. If all phosphorus application was stopped forthwith, at what rate will this store be released to drainage?

8. How much phosphorus is now stored in surface sediments of the estuary and how much of this is available for algal nutrition?

9. Assuming the external supply of phosphorus is cut off, at what rate and over what period will the store continue to be released to algae?

10. To what figure must phosphorus input to the estuary be reduced before export from the estuary balances input to it?

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In the light of the answers to these questions:

11. What can we now say about the prospects for management by modifying present agricultural practices?

12. What modifications to the present research programmes should be recommended?

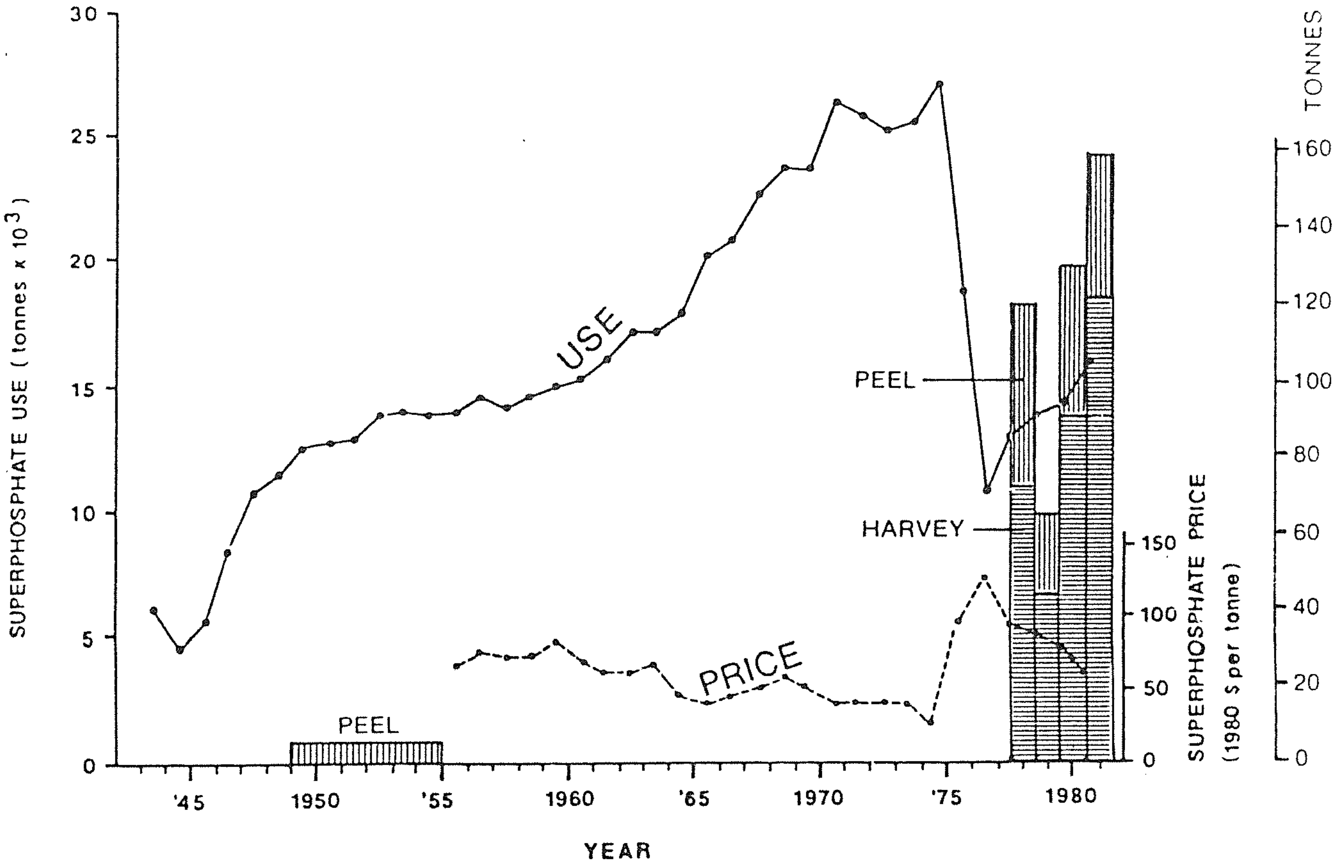



Figure 1. Superphosphate use (•——•) on coastal plain catchments of Peel-Harvey estuary, price (•---•) in 1980 $'s, and estimated phosphorus inputs to the estuary (histograms).

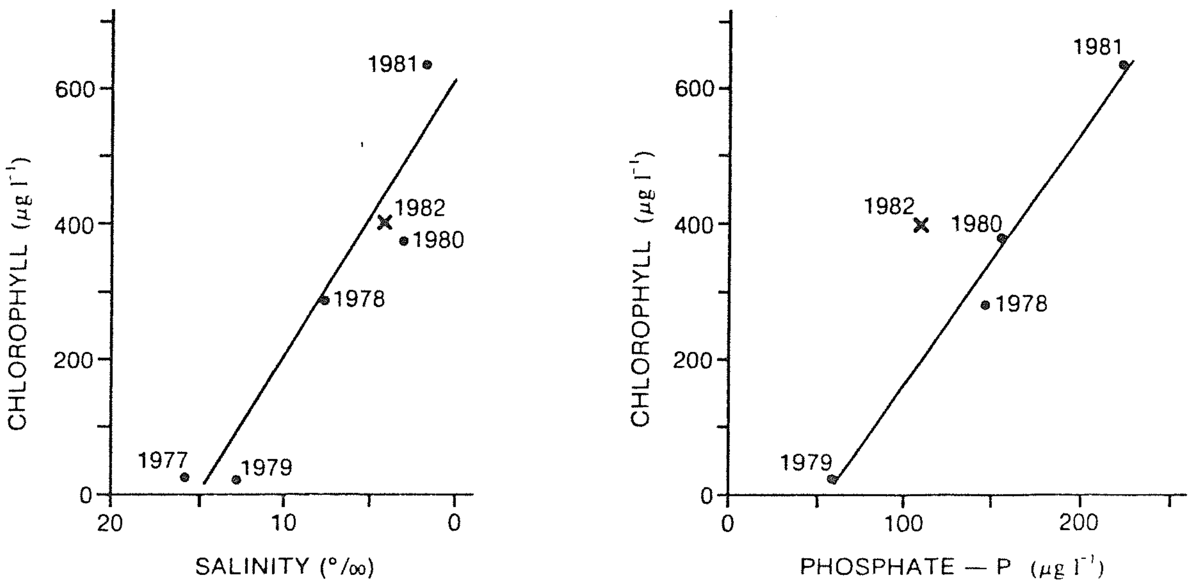



Figure 2. The maximum concentration of chlorophyll in Harvey Estuary each year, plotted against (a) the minimum salinity and (b) the maximum phosphate concentration, reached in the preceding winter (McComb, 1982). The 1982 data points have been added.

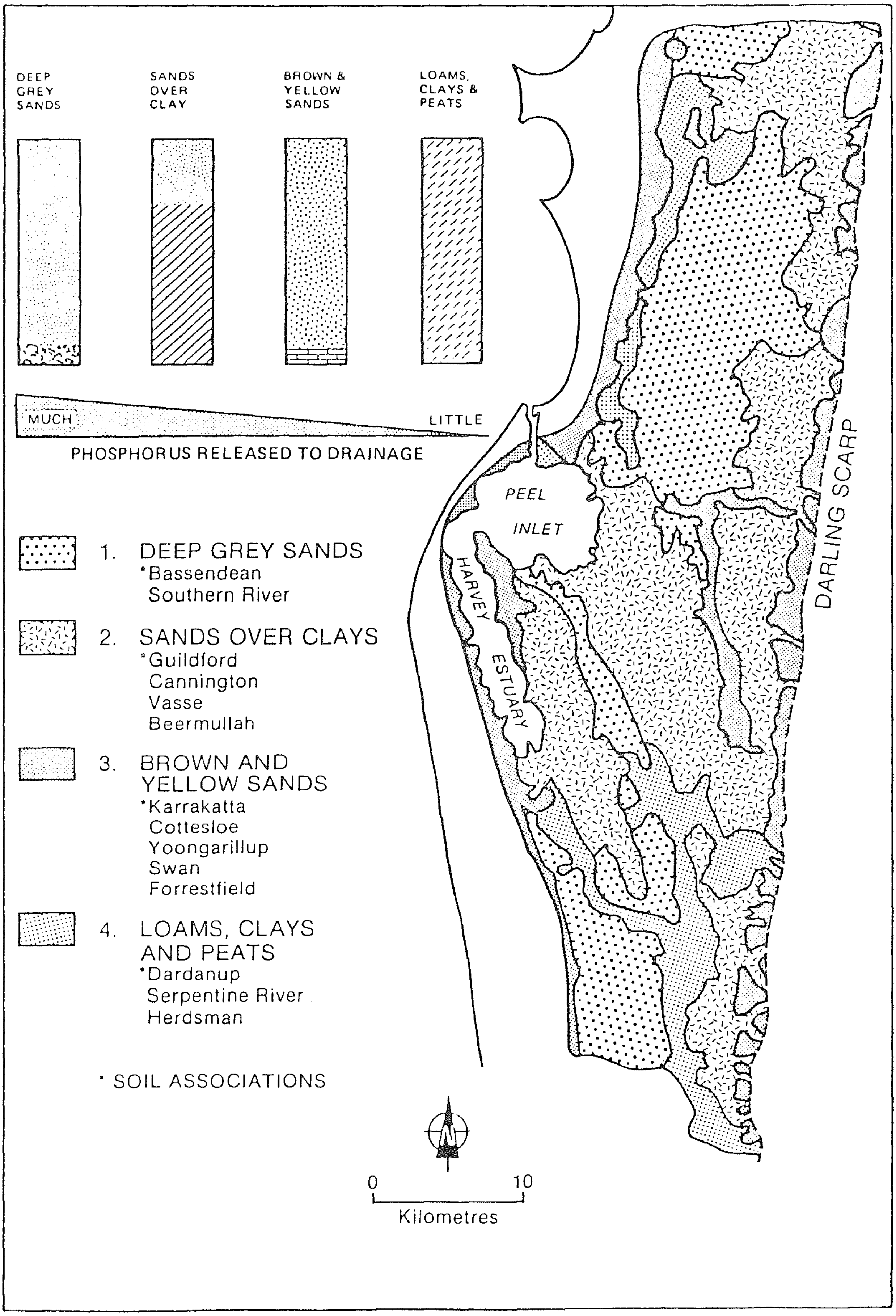



Figure 3. Soil categories on the coastal plain catchment of the Peel-Harvey estuary.

# PHOSPHORUS FERTILIZER TRIAL WORK ON THE DEEP SANDS

John Yeates
Plant Research Division
Department of Agriculture, WA

## Introduction

Five potential ways of reducing the phosphorus losses from fertilizer sources while still maintaining the current level of agricultural production on the Peel Harvey soils were considered possible at the commencement of the current phase of the Peel-Harvey study. These were: -

1. The use of accurate soil tests for predicting phosphorus requirements and thus ensuring that only phosphorus actually required is applied.

2. Modification of times of application of soluble phosphorus fertilizer to maximise the plant utilization of applied P, and to minimize losses.

3. Development of phosphorus fertilizers of lower water solubility than superphosphate (and hence with reduced leaching losses) while still providing adequate phosphorus for plant growth.

4. Use of deep rooted and/or perennial plant species which are better able to utilize applied soluble phosphorus.

5. Modification of the sandy soils of catchments to increase phosphorus adsorption capacity and hence reduce or eliminate leaching losses.

To date research has been chiefly concerned with the first three of these possibilities. Information obtained from research work by the WADA in the 1950s and from a programme commenced on the south coast in 1978 has provided a considerable data base for both interim recommendations and for work on the Peel Harvey catchment soils in 1982.

## Results and Conclusions of Research to Date:

### 1. Soil Tests.

On experimental sites on the deep grey sands, and from farm paddock P budget estimates, losses of phosphorus applied as superphosphate are commonly 40-50% after one season, and maybe as high as 80%. Precise reasons for the variation in estimated loss between sites is not understood.

Because P losses are less than 100%, soil P levels build up following superphosphate application. This residual is partially available to plants, enabling P application rates to be reduced on paddocks which have been previously (adequately) fertilized.

Experimental work relating bicarbonate extractable soil phosphorus measured prior to the break of season to subsequent plant growth has shown that, on old land deep grey sands, existing standards overestimated soil P levels required to achieve maximum growth. A new soil test calibration curve has been established from the current work (Figure 1).

Surveys conducted on farmer paddocks on these soils in 1981/82 show that approximately 50% have bicarb. P levels of > 10 ppm, thus allowing phosphorus applications to be ceased for one or more years and to be reduced in subsequent years. If all farmers on the deep sands used and followed the revised soil test based recommendations, indications from the limited data available are that an immediate reduction of 60% in phosphorus application can be achieved in 1983 compared to 1982, and reductions of 40-50% can be achieved in the longer term (at maintenance phosphorus application rates). These estimates, however, contain many assumptions, and more data are required to enable more accurate predictions to be made.

Problems exist, however, in accurately predicting responsiveness in the range 0-10 ppm due to the narrow range for sampling error, accurate soil type identification, large seasonal variation and generally poor production on the drier phases of these soils. The sulphur and potassium requirements (currently fairly well understood) must also be considered in recommendations of reduced superphosphate applications.

Further research is necessary on the accuracy of existing soil test standards on the other soils shown to be sources of phosphorus run-off (Coolup sands).

2. Time of application of superphosphate.

Trial results generally show an increase in plant uptake of phosphorus from superphosphate applied to pasture 6-12 weeks after the break of season compared to super applied at the break. (Table 1a). However, at one site (out of seven) the reverse was true (Table 1b).

Table 1. Estimated recovery in pasture tops of phosphorus applied as rates of superphosphate at different times during the season.

(a) Albany site. Cumulative % of 1980 applied P recovered 1980-81.

| P rate (kg/ha) | Super applied | | |
|---|---|---|---|
| | At the break of season | 6 weeks after the break | 12 weeks after the break. |
| 10 | 6 | 81 | 45 |
| 30 | 3 | 30 | 35 |
| 90 | 13 | (8) | 30 |

(b) Scott River site. Cumulative % of 1981 applied P recovered 1981-82.

| P rate (kg/ha) | Super applied | | |
|---|---|---|---|
| | At the break of season | 9 weeks after the break | 16 weeks after the break. |
| 10 | 60 | 51 | 53 |
| 20 | 34 | 21 | 30 |
| 40 | 42 | 21 | 53 |

It is likely that the effects of time of application will vary with different seasonal patterns of leaching rains and plant growth. It is hoped that to be able to better quantify these effects by the use of a predictive simulation model, which is currently under construction, rather than by conducting the very large number of experiments necessary to establish probabilities associated with time of application.

Other considerations in varying the time of application are the pasture requirement for phosphorus early in the season, the actual (quantitive) benefits to be achieved in terms of reduced phosphorus loss, practical problems associated with fertilizer application to waterlogged soils, and the sulphur and potassium requirements of the pasture. The time of application for maximum phosphorus uptake by the pasture will not necessarily coincide with the optimum time of application for pasture yield, or farmer preference.

## 3. Alternative sources of phosphorus.

A number of phosphorus sources of varying water, citrate and acid solubilities have been used in experimental work commenced in 1980 on the south and west coast grey sands. These are listed in Table 2.

Table 2. Phosphorus content of fertilizers used in experimental work.

| Phosphorus source | % Total P | % of P as Water soluble | Citrate soluble | Acid soluble |
|---|---|---|---|---|
| Superphosphate | 9.1 | 80 | 14 | 5 |
| Triple superphosphate | 19.7 | | | |
| Reverted superphosphate (CSBP)* 1. | 8.8 | 52 | 36 | 11 |
| 2. | 8.3 | 32 | 55 | 12 |
| 3. | 7.6 | 17 | 71 | 12 |
| Lime superphosphate (AFL)** | 4.6 | 17 | 76 | 7 |
| 'A' grade rock phosphate | 15.5 | 0 | 0 | 100 |
| 'A' grade rock phosphate + super + elemental sulphur 1. | 8.9 | 28 | 67 | 4 |
| 2. | 13.1 | 14 | 52 | 33 |
| Reactive rock phosphate | 13.5 | | | |
| 'C' grade rock phosphate | 11.2 | 0 | 0 | 100 |
| Calcined 'C' grade rock phosphate | 13.9 | 0 | 58 | 42 |

* Trial batches produced by CSBP
** Obtained from Australian Fertilizers Ltd, N.S.W.

Effectiveness of these sources relative to superphosphate in pasture yield and phosphorus uptake in the year of application has been measured in small plot pasture trials. Residual value, as bicarbonate and total soil phosphorus, and as growth in the year of application and in subsequent years has been measured. Data is currently available from some trials for three years following the application of various sources of P.

The data show that several sources of phosphorus have effectiveness equal or almost equal to superphosphate in the year of application (Table 3) and have only small losses from leaching (Table 4). Superphosphate P lost (not accounted for in the top 10cm of soil, or as product removed) ranged between 20% and 80% at different sites in the first year.

In the second and third year after application some sources of phosphorus (e.g. reverted (lime) superphosphate) were better than ordinary superphosphate per unit of P applied for pasture growth and had much lower leaching losses. However, for some sources differences in pasture growth were generally not as great as suggested by residual total soil phosphorus data at the end of year one. Complex relationships between source of P, bicarbonate extractable P and subsequent plant growth and P uptake are apparent and require further investigation, especially with respect to soil testing after application of non-superphosphate P sources.

In summary, the phosphorus sources research to date shows that the best of these (reverted superphosphate which also contains sulphur, essential on these soils) offers the potential to immediately reduce phosphorus leaching losses, and to reduce over time the rates of P needed to be applied to sandy soils (because of greater residual value). However, the long term implications of the use of less soluble sources in increasing soil organic and inorganic phosphorus pools which may provide soluble phosphate for leaching in later years require investigation.

Conclusions.

Results to date on the deep grey sandy soils indicate that it is possible to reduce the phosphorus losses from these soils while still maintaining the current level of agricultural production by the use of soil tests, delayed fertilizer application and/or less soluble phosphorus sources. In the absence of additional data it is not possible to accurately quantity these reductions, or to predict the immediate effect of adoption of these practices on quantities of drainage water phosphorus entering the Peel Harvey Estuarine system. In addition, the long term effects of these practices on the phosphorus budget of the system are unclear, and require further investigation.

Further research work is required on soil tests and alternative phosphorus sources on the Coolup sands.

Table 3 The relative effectiveness of various phosphorus sources compared with superphosphate at a number of deep grey sand pasture sites. Relative effectiveness was measured as for data in Table 1 (also see fottnotes below). Comparisons are valid only within columns.
IMPORTANT NOTE: Interim data only. Data and data analysis incomplete.

| P Source | Mt Barker applied 1980 ** | | Albany applied 1980 ** | | Denmark applied 1981 | | Keysbrook applied 1981 ** | Scott River applied 1981 | |
|---|---|---|---|---|---|---|---|---|---|
| | 1980 | 1981 | 1980 | 1981 | 1981 | 1982 | 1981 | 1981* | 1982+ |
| Superphosphate | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 |
| Lime superphosphate | 0.8 | 1.1 | 1.3 | 1.1 | 1.7 | 1.4 | 1.2 | 1.0 | |
| 'A' grade rock phosphate | 1.1 | 0.8 | 1.3 | 1.4 | 0.7 | 1.2 | 0.4 | 0.4 | |
| 'A' grade rock phosphate + super + elemental sulphur(1) | NT | NT | NT | NT | 1.1 | 1.4 | 0.7 | 1.0 | |
| 'C' grade rock phosphate | NT | NT | NT | NT | 0.3 | 0.3 | 0.1 | 0.3 | |
| Calcined 'C' grade rock phosphate | - | - | 1.2 | 1.5 | 1.2 | 1.3 | 1.0 | 0.6 | |

* = From % P in tops data ) means of all harvest within each year
\+ = From dry matter yield data)
** = No dry matter yield response to applied phosphorus
NT = No fertilizer treatment

Table 4 Estimated phosphorus leaching losses from the top soils of deep grey sand following application of various phosphorus sources. Percentage lost was estimated by fitting a linear regression of total P recovered (organic + inorganic) against P applied (0-180 kg/ha) where slope X 100 = % recovered. Data is expressed as % lost.
IMPORTANT NOTE: Interim data only. Data and data analysis incomplete.

| P Source | Mt Barker applied 5/80 Lost 0-10cm | | Albany applied 5/80 Lost 0-10cm | | Denmark app. 3/81 Lost 0-5cm | Albany app. 3/81 Lost 0-5cm | Keysbrook app. 3/81 Lost 0-5cm | Scott River app. 3/80 Lost 0-10 cm | Scott River app. 4/81 Lost 0-5 cm |
|---|---|---|---|---|---|---|---|---|---|
| | 1/81 | 1/82 | 1/81 | 1/82 | 1/82 | 1/82 | 1/82 | 4/81 | 1/82 |
| Superphosphate | 17 | 45 | 52 | 100 | 40 | 65 | 71 | 79 | 42 |
| Lime superphosphate | 0 | 27 | 0 | 0 | 0 | 3 | 14 | 26 | 20 |
| 'A' grade rock phosphate | 0 | 13 | 29 | 9 | 0 | 0 | 18 | 38 | 0 |
| 'A' grade rock phosphate + super + elemental sulphur | NT | NT | NT | NT | 39 | 0 | 20 | NT | 9 |
| 'C' grade rock phosphate | NT | NT | NT | NT | 0 | 0 | 0 | NT | 0 |
| Calcined 'C' grade rock phosphate | 2 | 0 | 3 | 28 | 0 | 0 | 0 | 0 | 0 |

NT = No fertilizer treatment.

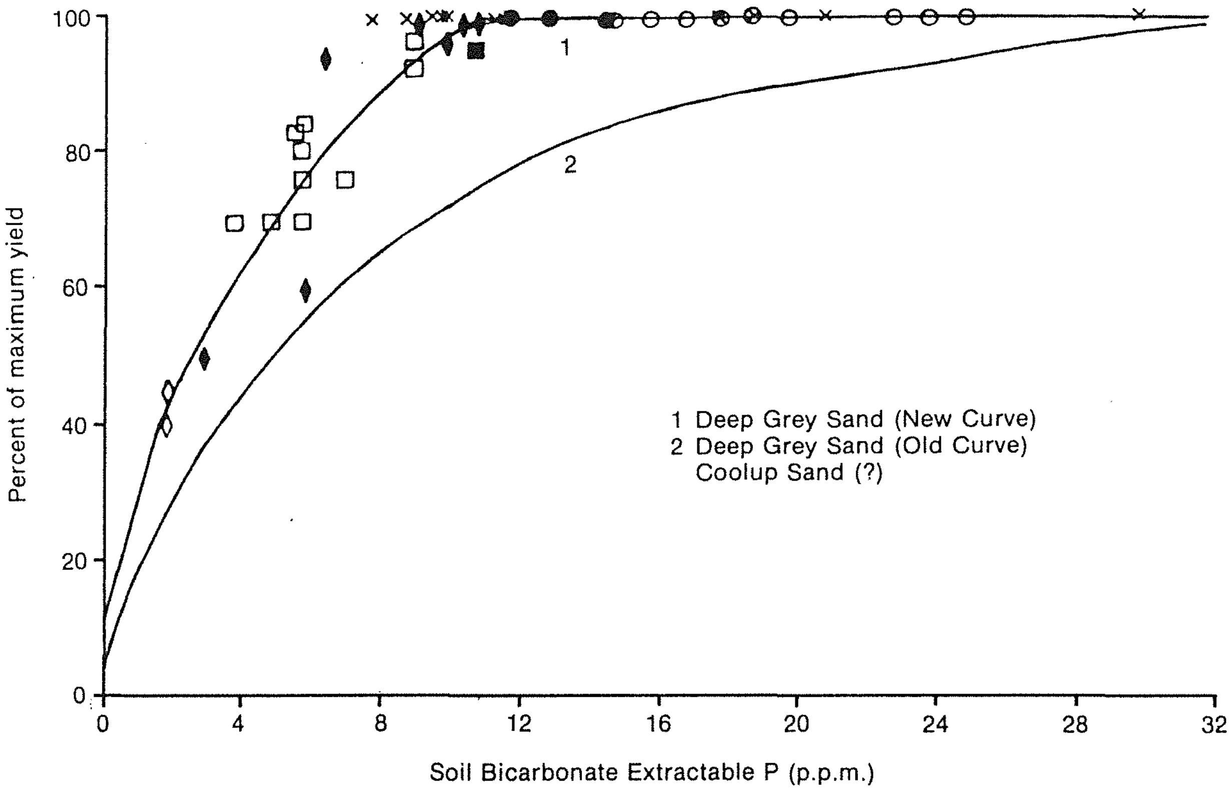



Figure 1 Percentage of maximum yield as a function of soil bicarbonate extractable phosphorus. Data is for growth in the season following summer soil sampling. The previously used soil test calibration curve (2) and that derived from recent experimental work (1) are both shown.

## PRODUCTION OF SLOWER RELEASE PHOSPHATE FERTILISERS

Phil Southern
Chief Agronomist
CSBP & Farmers Ltd

One of the major aims in the Peel-Harvey estuary research is to produce phosphate fertiliser which is still freely available to plants but which has lower leaching characteristics and will be held in the soil.

This can be achieved in a process in the superphosphate industry called reversion. Essentially this is a conversion of the water soluble monocalcium phosphate (the main phosphate compound in superphosphate) to the less soluble dicalcium phosphate. The latter compound is considered to have a fairly high availability to plants although not quite as available as the water soluble monocalcium phosphate. Dicalcium phosphate is soluble in a citrate solution and its analysis is shown as "citrate soluble".

The reversion process requires lime and the simplified chemical equation below shows the reaction involved.

$$CaH_4(PO_4)_2 + CaO \longrightarrow Ca_2H_2(PO_4)_2^{*} + H_2O$$

| mono-calcium phosphate | calcium oxide | di-calcium phosphate |
|---|---|---|

Reversion Reaction of Superphosphate. * or $2CaHPO_4$

Various lime sources can be used. In other countries, for instance New Zealand, limestone or calcium carbonate is used. Then the reversion process is slower and unless there is a very intimate mixture made and water is added it may not be complete.

Lime reverted superphosphate is made in other areas mainly for acid high fixing soils. It does not appear to have been used in high leaching situations to any extent.

Initial batches of reverted super were made by CSBP in concrete mixers using superphosphate, lime kiln dust from cement factories and a small amount of moisture. Three products were made, having different proportions of water soluble and citrate soluble phosphorus. Their analysis is shown on the table given by John Yeates. These materials have shown promise in trial work.

The next aim was to be able to make reverted superphosphate in larger quantities in the fertiliser works using equipment on hand. It was necessary to do this at minimum cost, produce a well reverted product with as high as possible P content and also the product must be suitable for spreading, preferably granulated. This did pose some difficulties as I will explain.

Normal superphosphate is manufactured from finely ground rock phosphate (insoluble in water) and sulphuric acid in a reaction den. The mixture is then moved by conveyor belts and conditioned or granulated in a large revolving drum. After appropriate screening and recycling the superphosphate then passes to large storage areas where the reaction is completed. Farmers take delivery of superphosphate at least several weeks after the initial reaction, the material being redressed before delivery.

Additives, e.g. trace elements, are conveniently added before the conditioning process (Fig. 1) to effect intimate mixing of components and it would be convenient to add the lime to the den mixture in the same way. However by doing this we could not get the mixture to granulate and it remained a very fine mixture no matter how much extra water was added, although it was comparatively well reverted. Field tests showed the material would not be suitable for topdressing with most farmers' equipment.

Lime is added to the freshly reacted den material in some factories in New Zealand and other areas but the resultant product is fine grained, subject to setting and very poorly granulated. Farmers in New Zealand are used to handling fine materials such as lime, which is used in large amounts, but it is considered that farmers in W.A. would not accept such a product as it would cause problems in convential equipment.

We next tried belt mixing lime with the granulated superphosphate after it had come from the conditioning drum. There was inefficient mixing and we produced a mixture of superphosphate balls and fine lime which was not well reacted. This product would also not be very suitable for spreading.

With the aim of simulating on a plant scale the early trials using concrete mixers, we then introduced freshly made superphosphate into the first granulating drum of the small granulating plant at Bunbury. We use this plant for the production of NPK and garden fertilisers and it is capable of turning out a well granulated homogeneous mixture. Figure 2 shows a diagram of the equipment.

Lime and water were added to superphosphate in the first drum and by leaving the material in the granulator for several minutes we were able to produce a much better granulated product which would be very acceptable to farmers and in fact did well in spreading tests. It was well reverted but we did have to add quite a large amount of water and the final product contained about 15%.

The next step is to try and remove some of this water and the second drier drum in the plant which is heated by oil burners will be used to attempt this. However we have to be careful not to use too much heat as the reversion process may stop. Also the product may be reduced to a much finer material.

Table 1 gives a summary of the materials and products used so far. The total P is obviously related to the type and amount of lime used. Quick lime (CaO) would be preferable as only about 12% addition would be necessary while ground limestone addition may have to be as much as 30% to give a final total P of 5% or so. The second last column shows the analysis of the 30 tonne batch we made at Bunbury but we hope to increase the total P and citrate soluble P by reducing the high moisture content.

In the meantime we are carrying out work using the many different types of lime available including quick lime, slaked lime, flue ash, limestone, precipitated lime, etc.

CSBP plans to prepare sufficient reverted superphosphate in February 1983 to cater for all farmers who wish to take delivery. These include others who are not in the estuary catchment area but who are on similar leaching soils and who have inquired about the product. We consider there will be a need for 1,000 tonnes or more.

In regard to costs it will be appreciated that the use of the granulating plant will increase the manufacturing costs. The fresh superphosphate must be shifted from the super plant to the top of the granulating plant, the lime has also to be conveyed there, and the granulating plant costs over $10 a tonne to run. The final cost to farmers has not yet been determined and will depend on what lime we use and how much we have to dry the product. But it is likely to be similar or a little more than normal superphosphate.

Leaching Tests

We have carried out some leaching trials on coastal plain sands using about 1kg of soil in plant pots. Results are shown in Figure 3. We used well reverted superphosphate (No 3 mix) and compared it to ordinary superphosphate. 91mg of total P was applied to the soil and 4 leachings totalling the equivalent of about 100mm of rain were made. Most of the water soluble P in the super (73mg) was leached through, and about 30mg of the P in the reverted super. So it seems that a small amount of citrate soluble P can be leached as there should have only been about 20mg water soluble P.

The other interesting point is that the untreated soil still leached out some phosphate and in fact the amount leached was greater than extracted by the bicarbonate soil test.

## Fertiliser Options For Catchment Areas

The use of reverted superphosphate has to be considered with the other requirements for the different types of soils in the catchment area. Table 2 gives a general list of the types of fertilisers to be considered. Not only phosphate is involved but also sulphur and potash and there is also the likelihood of economic responses to nitrogen in many situations.

Mixtures of reverted superphosphate and potash may be necessary and could be made up if there was sufficient demand for particular ratios. Additions of extra elemental sulphur pose some manufacturing problems but gypsum could be used in many cases to cater for sulphur needs in the latter part of the growing season. There are two problems, special spreading equipment is necessary for fine gypsum and often the land becomes too wet for vehicles. However contractors do not feel problems are insurmountable.

A general problem is that there are going to be too many situations in the catchment area each requiring different fertiliser strategies. It would seem best that until the main types of situations have been defined farmers should use reverted superphosphate, muriate of potash and gypsum as separate fertilisers according to soil tests and other knowledge.

TABLE 1

## SUPERPHOSPHATE ANALYSIS

| Product | | %P Water Soluble | Citrate Soluble | Acid Soluble | Total | Lime Added | % Moisture |
|---|---|---|---|---|---|---|---|
| Superphosphate | | 7.3 | 1.3 | 0.5 | 9.1 | - | 6-7 |
| Reverted (1) | Small Batches | 4.7 | 3.2 | 0.9 | 8.8 | 6 | 8 |
| Reverted (2) | Small Batches | 2.7 | 4.6 | 1.0 | 8.3 | 12 | 8 |
| Reverted (3) | Small Batches | 1.3 | 5.4 | 0.9 | 7.6 | 18 | 8 |
| Bunbury (30t batch) | | 0.4 | 4.6 | 2.1 | 7.1 | 20 | 15 |
| Bunbury (target) | | 0.5-1.0 | 5.5-6.0 | 1.0 | 7.5 | 18 | 10-12 |

TABLE 2

## FERTILISER OPTIONS

| Nutrient Source | Products | Analysis %P | %K | %S | Comments |
|---|---|---|---|---|---|
| PS | Superphosphate | 9.1 | - | 10.5 | Heavier Soils |
| | Reverted Super | 7.5 | - | 9 | Leaching Soils |
| S | Sulphur | - | - | 100 ) | Spreading ? |
| | Gypsum | - | - | 18 ) | |
| PS | Reverted Super + S | 6.5? | - | 20? | Manufacturing problems. Ratio? |
| PKS | Super Potash 5-1 | 7.4 | 7.4 | 9 ) | Sands over |
| | Super Potash 3-2 | 5.3 | 18.2 | 6 ) | clays ? |
| | Reverted Super/Potash | ? | ? | ? | What ratios ? |
| K | Muriate of Potash | - | 50 | - | |
| KS | Sulphate of Potash | - | 41 | 18 | Expensive. S very soluble. |

GENERAL

Large number of situations requiring different mixtures

Application - timing

Extension

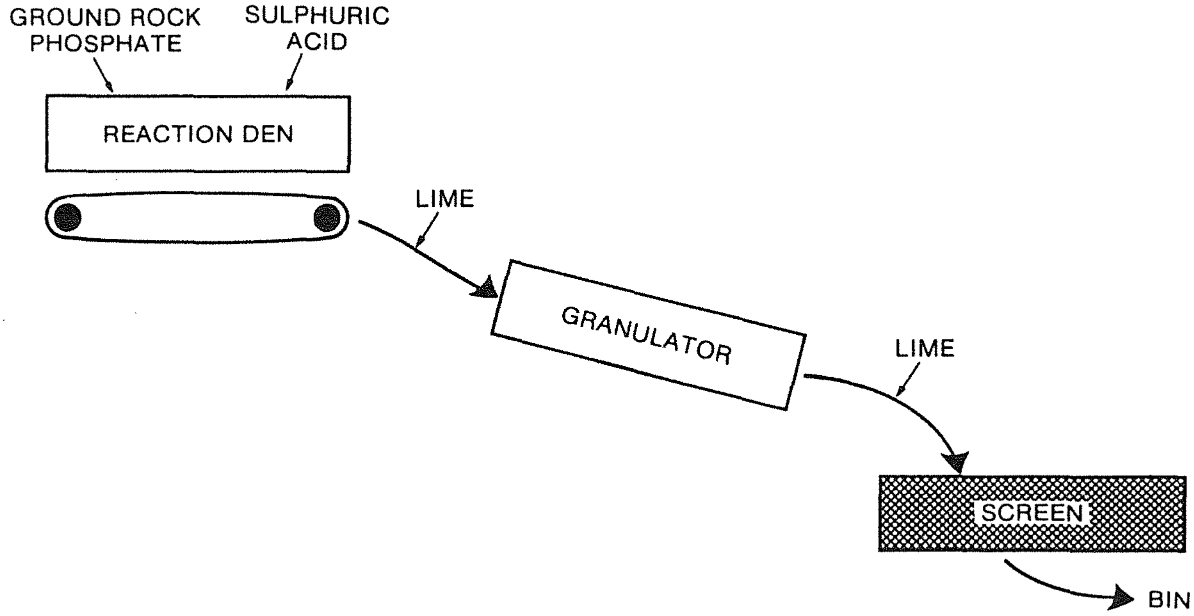



Figure 1. Lime + super manufacture. Not successful, poor physical quality.

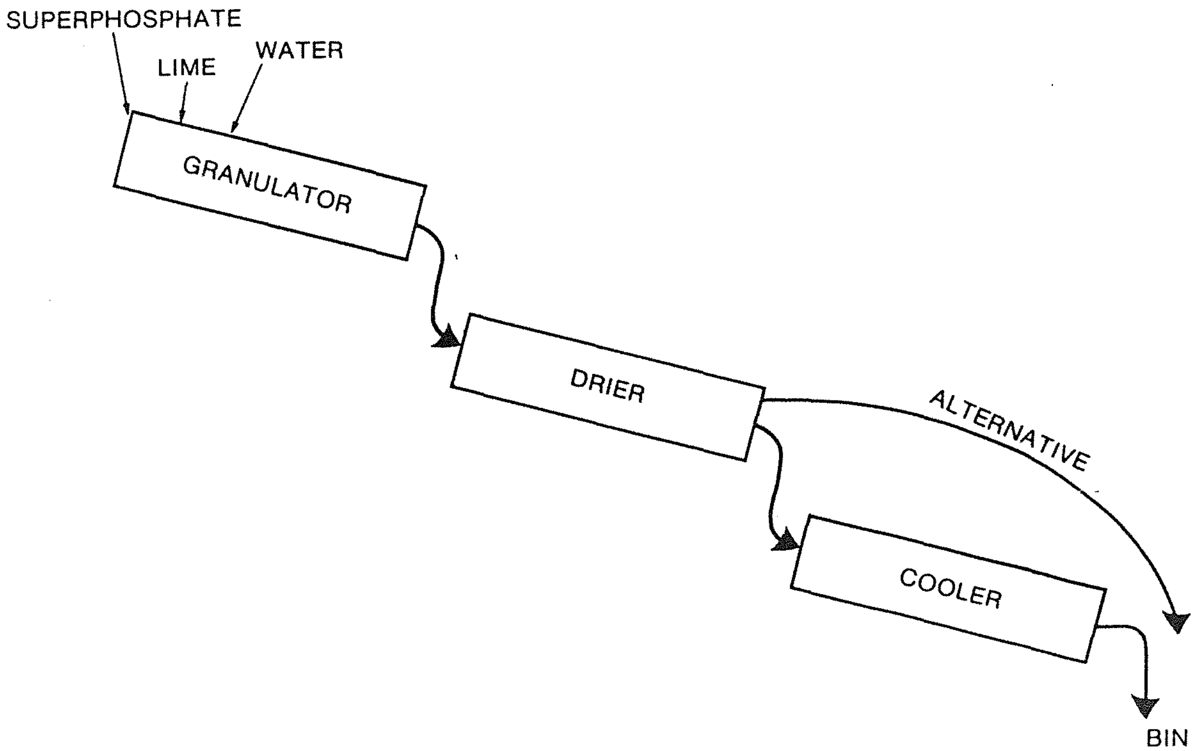



Figure 2. Compound manufacture at Bunbury. Reverted super, good quality but high moisture content.

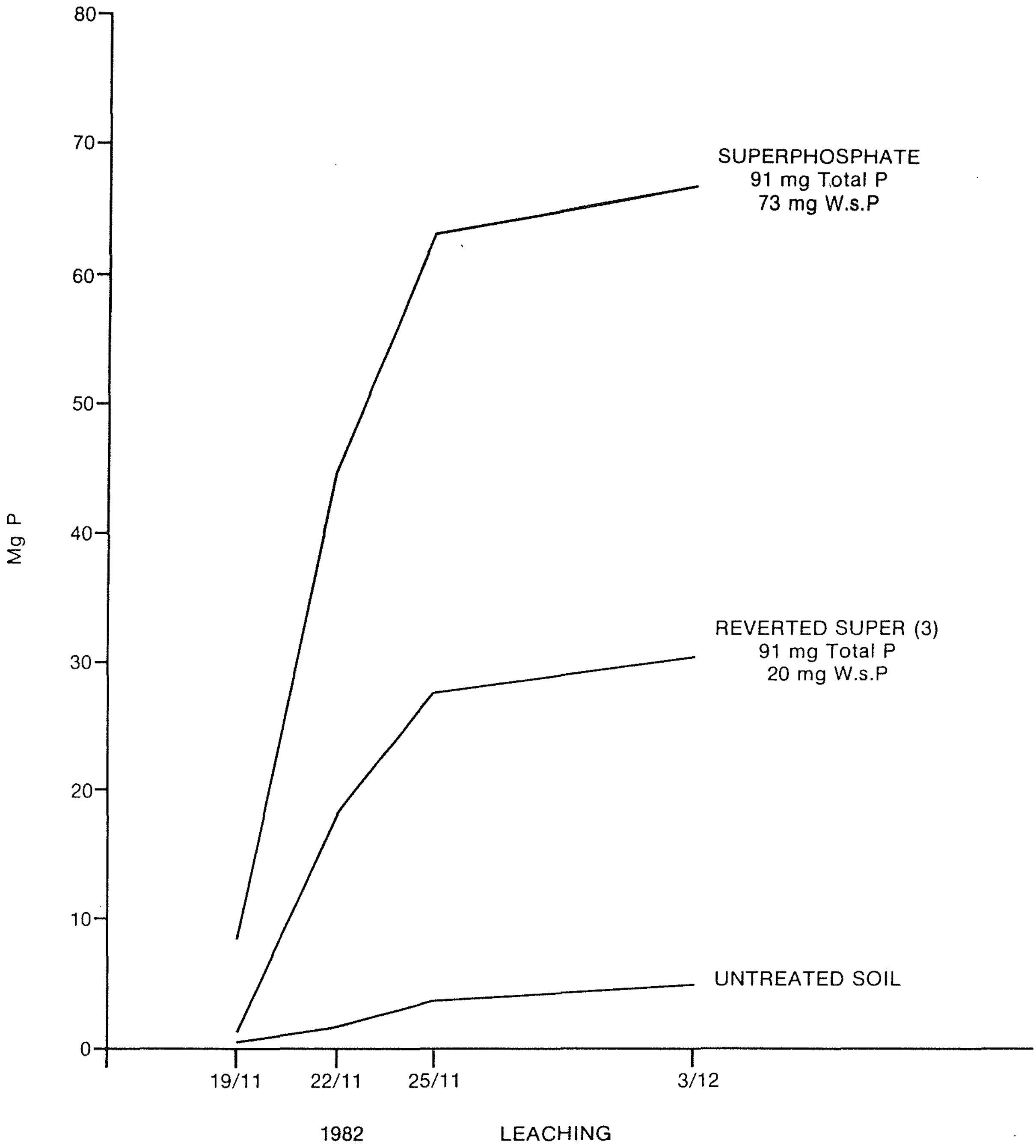



Figure 3. Comparison between super and reverted super in Harvey Estuary soil plots.

## THE EXTENSION PART OF THE PEEL-HARVEY STUDY

W K Russell
Officer in Charge Harvey District Office
Department of Agriculture

Accepting that the present eutrophic condition of the estuary system has been caused by phosphate leaching from farmland in the catchment of rivers and drains flowing into the estuary and that the bulk of this phosphate comes from fertiliser applied by farmers, the long term solution is to reduce the amount of phosphate leaching from farms.

There are a very large number of soil types in the catchment, ranging from deep sands - with practically no capacity to adsorb applied phosphate - to heavy clays and gravelly loams - with a very high capacity to adsorb phosphate. Although all soils will release some phosphate to drainage water, the sandy surface soils have been idenfified as the major source of phosphate entering the estuary.

Research has shown that the sandy soils of the Bassendean Association and duplex soils are the major sources of phosphate and that they differ in important aspects.

1. The duplex soils generally have greater capacity to adsorb applied phosphate than the Bassendean sands.

2. The duplex soils have been fertilised for much longer than the Bassendean sands and much bigger areas of them are fertilised each year.

Both soils need annual applications of sulphur and potassium for successful pasture growth; these are supplied by the superphosphate - muriate of potash mixtures applied by farmers on sandy soils.

It is common to find many soil types on each farm and individual paddocks on a farm can have two or three distinct soil types. Very few farmers vary rate or type of fertilizer with soil type, except that some farmers do not fertilise the very high, dry sandy areas.

Planning an extension programme is difficult in this case because the problem to be overcome - excessive weed growth in the estuary - does not directly affect farmers. They have little incentive to change long established fertiliser practices which they see as having worked satisfactorily for a number of years, which they are familiar with and which can be carried out at a convenient time of year.

The approach taken has been to emphasise the cash value of the phosphate entering the estuary each year and to suggest to farmers that they can substantially reduce this loss, and maintain pasture production, by adopting different fertiliser strategies. No attempt has been made to disguise the fact that the current interest in fertiliser use is a direct result of the problems in the estuary but the estuary has not been emphasised in the extension programme.

The extension programme has had several aspects:

1. An awareness phase where the background to the problems in the estuary and the on-farm research being carried out to find a solution were explained at public meetings.

   These meetings were heavily advertised and were intended to appeal to a wider audience than just farmers in the catchment areas. Included in these meetings was a tour of selected research areas by bus with research officers explaining the research being done at that site and where it fitted into the overall research programme.

Two of these meetings were held, one in Harvey and one at Coolup. Both were well attended and attracted considerable publicity.

2. Trial results and recommendations were presented at field days and a seminar directed at farmers. These were held late in the growing season when it became clear what recommendations could be made to farmers in the short term based on limited research results. It was decided that there was sufficient information on the phosphorus, potassium and sulphur requirements of pastures on catchment soils to enable recommendations to be made on the basis of soil test.

3. Individual contact was adopted as the best way of getting fertiliser recommendations accepted. Financial assistance was provided by Department of Conservation and Government Chemical Laboratories to run a free soil testing service for farmers in the catchment areas. Soil samples are collected from all parts of each farm, analysed for extractable P and K and fertiliser recommendations made for each area sampled. In this way, it is hoped that the amount of P applied can be reduced substantially while maintaining pasture production. There will be strong emphasis on applying sulphur as gypsum where superphosphate application is reduced.

   Four extension groups have been formed among farmers in the catchment areas. The 10-15 farmers in each group will meet every 2-3 months to talk about farming the sandy soils and to discuss research being done on local farms. Many of these farmers have trials of one sort or another on their properties.

   A newsletter has been produced which will be mailed to individual farmers living in the catchment areas. It is intended to produce four issues a year. The first issue summarised some of the work being done by each of the research groups working on the estuary problem. I intend to publish farmer comments on the research in future issues.

On the deep sandy soils, the use of reverted superphosphate produced by C.S.B.P. will be recommended. This "slow release" fertiliser has created a lot of interest among farmers and it will be widely used. It has not been used in trials on duplex soils so it cannot be recommended for these soils. It will, however, be used by farmers on these soils who are keen to try anything new.

This should lead to substantial reduction in the amount of phosphate leached from the deep sands.

The extension part of the study is ongoing. It will be essential to keep farmers informed on the progress of on-farm research - their co-operation is necessary for the research to take place. There have been no problems in getting farmer co-operation so far. It is essential that nothing be done which alters this.

# THE FATE OF PHOSPHORUS IN THE SOILS

Eric Bettenay and Maurice Height

CSIRO Division of Groundwater Research

## SOILS

Morphological, physical and chemical characteristics of the soils of the Swan Coastal Plain, which yields most P to the estuaries, have been described in some detail, and their distribution shown in the form of maps (McArthur and Bettenay 1960, Bettenay *et al.* 1960).

Figure 1, adapted from the above publications, shows a generalised picture of soil distribution in the Harvey area where most work on P leaching and adsorption is being carried out.

## PHOSPHATE STATUS

Because of the low nature P content of Coastal Plain soils, phosphatic fertilizers, principally superphosphate, have been applied for many years (>40 for many areas). Not all soils have had applications for this length of time. For an important area of deep grey sands flanking Merredith drain, agriculture commenced in the mid 1960's. Total amounts added may therefore vary considerably.

Phosphate adsorption has been found to be a useful measure of the capacity of soils to hold P against leaching. The term "phosphate adsorption" has been used to describe any process in which phosphate ions in solution react with atoms on the surface of soil particles (Barrow 1978). The amount absorbed depends upon laboratory conditions, but is also a function of soil characteristics such as particle size, content of iron and aluminium oxides, pH etc.

In Figure 1 soils have been divided into groups with differing leaching capacities - presumably some reciprocal function of adsorption - based on known or assumed P adsorption capacity.

Samples from profiles of representative soils have been subject to standardised laboratory tests for P adsorption. It is evident that despite long continued application of P, sometimes at high rates, soils such as Dardanup loams and Wellesley clays still have a capacity to adsorb P, whereas the soils of the Bassendean Association (Gavin sand and Joel sand) with their shorter time under agriculture have virtually no capacity to adsorb P except in the underlying "coffee rock" layer. Some examples are given in Figure 2.

Phosphate storage varies also from soil to soil and is closely related to fertilizer application and P adsorption capacity. In Figure 3 some comparisons in total P storage, as measured by the perchloric acid digestion method, between the major soil groups are made.

PHOSPHATE LEACHING

In order to study leaching to groundwater, nests of wells each sealed at the bottom, and with a single ring of narrow diameter holes drilled at from ground surface to depths of up to 2.5 m, have been installed in representative soils of the various soil groups (Dardanup loam, Wellesley clay, Coolup sand, Gavin sand, Joel sand). Fortnightly water samples from these indicate that again the recognizable soil groups vary markedly in the quantities of P which leach down through the soil profiles to the water table. Both seasonal and depth variations are observed (see Figure 4).

DISCUSSION

The soils of the Swan Coastal Plain may be placed into groups between which there are considerable differences in soil morphology, and in their capacity to adsorb P as tested under laboratory conditions. Those soils which adsorb P (Dardanup and Wellesley) have accumulated large quantities of phosphorus where they have a long history of agricultural usage, while those with limited capacities to adsorb P have not accumulated as much. Conversely soil with low capacities to adsorb (Gavin sand and Joel sand of the Bassendean association) are readily leached of P and large quantities pass to the groundwaters where they may form substantial reserves.

Duplex soils (Coolup types of the Guildford association) which have a sand to sandy loam surface, are intermediate in their capacity to adsorb P, although their mottled sandy clay subsoils have a high capacity. There is evidence that little P is stored in these soils, and this is consistent with the concentrations of P found in the perched waters above their clayey subsoils during winter. When the perched water completely saturates the A horizons phosphate is lost to drains by movement through the coarse textured surface layers and as overland flow.

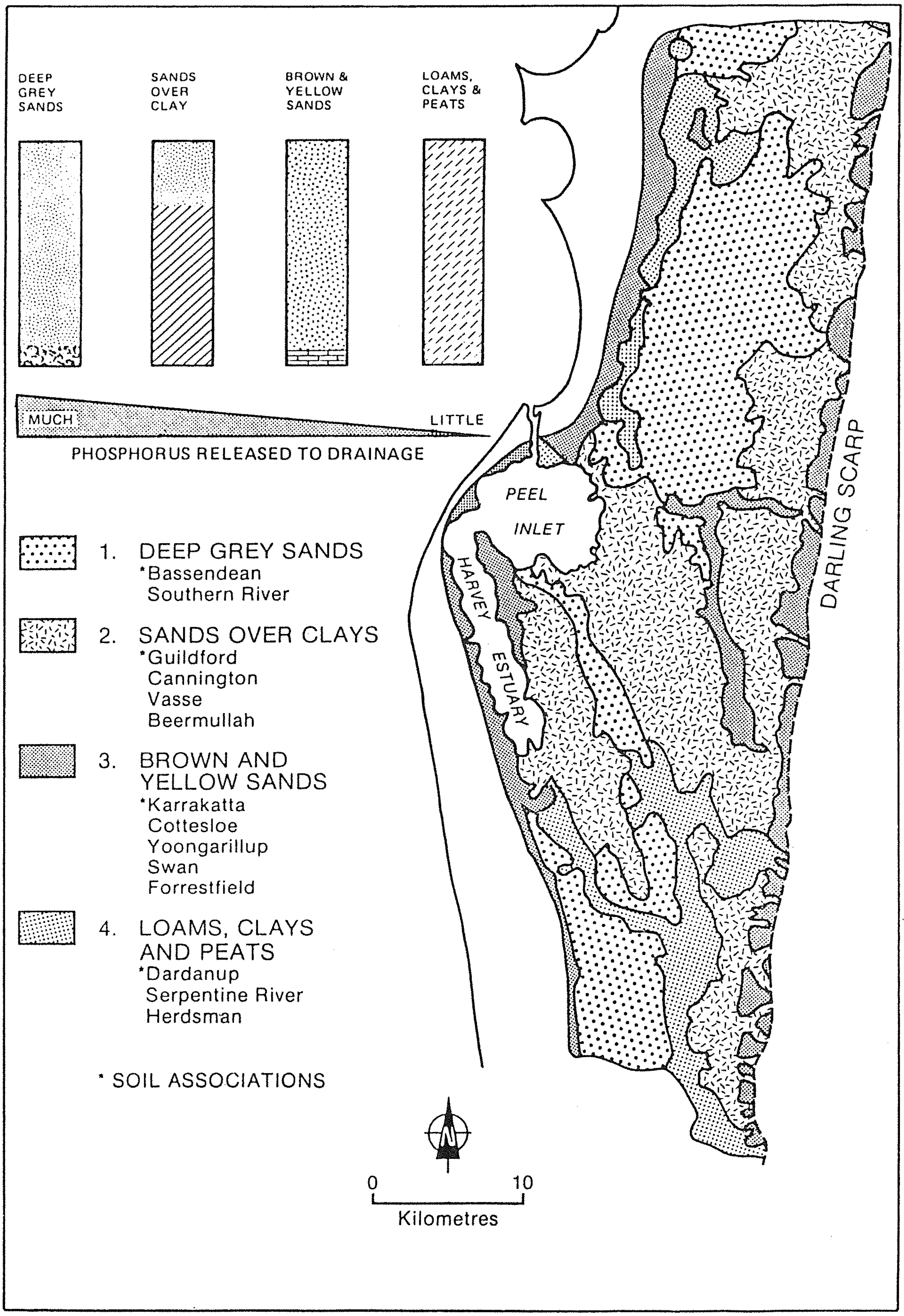



Figure 1. Soil categories on the coastal plain catchment.

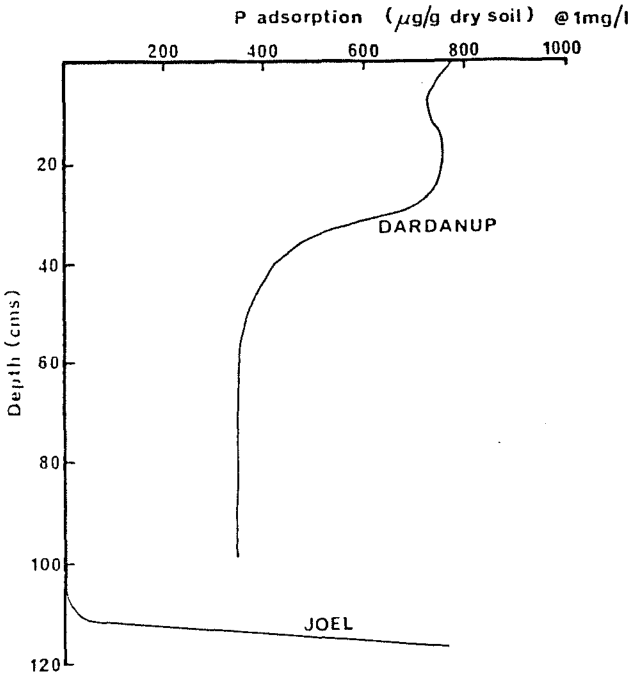



Figure 2. Examples of soil phosphorus profiles.

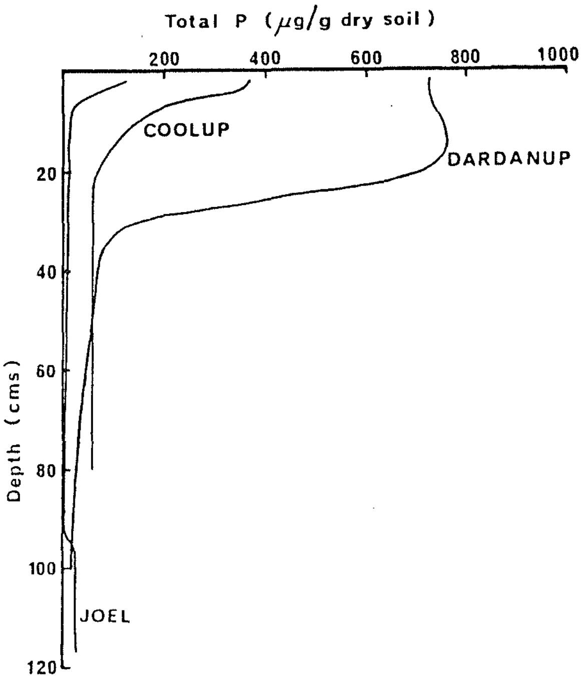



Figure 3. Comparisons of total phosphorus storage.

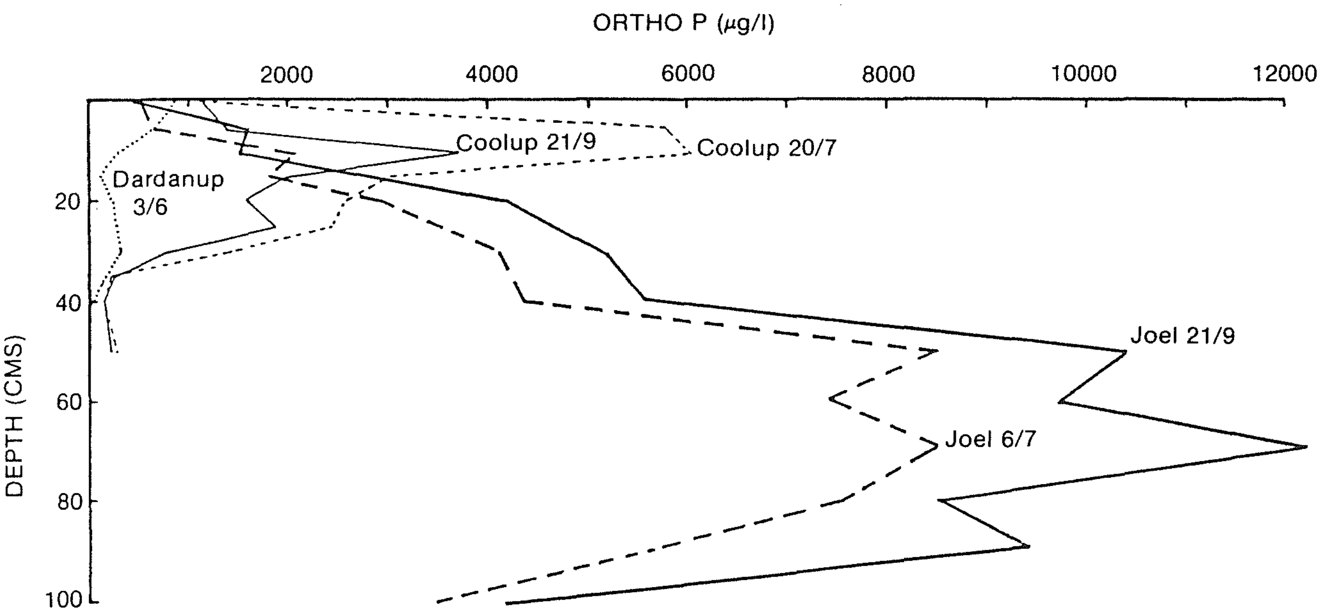



Figure 4. Soil phosphate storage in three soil types: deep grey sands (Joel), sands over clays

## BALANCING THE BUDGET

Peter Birch
Department of Conservation and Environment

### Budgeting phosphorus input to the estuary

Budgeting phosphorus in the Harvey Estuary Catchment is vital to our overall understanding of movement of phosphorus from farmlands to the estuary.

Preliminary budgets have been made for the Harvey River catchment and for selected sub-catchments, which represent the major soil categories in the region (Table 1). Applied fertilizer ranged from 6 to 15 kg P/ha year, with lowest applications on the deep grey sands and highest on the clays and loams. Conversely lowest loss rates of phosphorus were measured from the clays and loams (0.6 - 0.7 kg P/ha year) and highest from the sands (up to 1.9 kg P/ha year). As a proportion of that applied this represented a range of 4% - 31%. Export in the form of agricultural produce generally represented about one quarter of that applied. This left about one half to three quarters of the applied phosphorus unaccounted for which must have been added to the soil and groundwater.

Since the unaccounted for fraction is so large it is most important to determine the relative proportions that have been added to each of the above compartments. This will assist greatly in determing how much of this phosphorus could ultimately be transported into the estuary, how much is available for future plant growth, and how much will be locked away in an unavailable form or in other ways lost from the ecosystem.

Preliminary analysis of the surface 10 cm of the deep grey sands indicate that a variable fraction is retained, but most values were between 25-45% of the applied phosphorus suggesting that at least half of the unaccounted for fraction is in the soil. This soil fraction is expected to be greater for the heavier soils, but it would be only slowly available for loss to drainage.

This year's fertilizer or the soil phosphorus store?

One of the crucial questions for management of the estuary is: how much of the input of phosphorus to the estuary in any one year derives from fertilizer applied in that year and how much from phosphorus retained in the soil and groundwater from application over previous years?

Research in other parts of the world show that generally the greatest proportion of phosphorus runoff is derived from the current application of fertilizer (Table 2 and Fig. 1) even though these results are for heavy, silt loam soils on greater slopes, they are in general agreement with the results from plots on duplex soils at Coolup (Fig. 2 a). These results show a 4-5 times difference in the average concentration of phosphorus in groundwater in the fertilized compared to unfertilized plots. The difference was greatest at the heavier soil site (sandy loam over clay, Fig. 2b). The unfertilized (control) plots showed a marked decline in phosphorus concentrations over the season and it will be informative to see if concentrations increase again next autumn.

The above results suggest the importance of currently applied phosphorus, and this would be expected because of its relative availability to be transported to waterways (superphosphate has 80% water soluble phosphorus). Also because the most recently adsorbed phosphorus is the most easily desorbed (J. Barrow, pers. comm). However, possibly inconsistent with this are the results from monitoring the Harvey River since 1978 (Table 3).

These results show that there has been a threefold range in flow and phosphorus load even though fertilizer application rates have changed little over the same interval. There are three possible reasons for this:

(i) A greater proportion of the currently applied fertilizer is transported into waterways in wetter years.

(ii) There is a greater proportion of soil erosion and transport of particulate phosphorus in wetter years.

(iii) There is a large store of phosphorus in the soil and groundwater and in wet years a greater amount of this store is transported into waterways.

Further analysis of data and research is required to evaluate the relative importance of (i) - (iii) above.

TABLE 1      PHOSPHORUS BUDGETS IN Kg P/ha. YEAR

| Catchment | Soils | Fertilizer Appli. | Agric. Export | Loss to Drains | Soil + Ground-water Store |
|---|---|---|---|---|---|
| Harvey R. | All | 7.2 (100%) | 2 (28%) | 0.6 - 1.8 (8-24%) | 3.4 - 4.6 (47-64%) |
| Meredith Drain | Deep Sands | 6.1 (100%) | 1.7 (28%) | 1.5 - 1.9 (25-31%) | 2.5 - 2.9 (41-48%) |
| Mayfields Drain | Sand over Clay | 11 (100%) | 3 (27%) | 0.5 - 1.3 (5-12% | 6.7 - 7.5 (61-68%) |
| Samson Bk. N. Drain | Clay & Loam | 15 (100%) | 3-5 (20-33%) | 0.6 - 0.7 (4 - 5%) | 9.3 - 11 (62-73%) |

TABLE 2

Phosphorus runoff from fertilized and unfertilized paired catchments

| Reference | 1 | 2a | 2b |
|---|---|---|---|
| | | Kg P/ha | |
| Fertilized | 2.9 | 3.1 | 4.9 |
| Unfertilized | 1.4 | 0.2 | 0.8 |

References:

1. W. Nicholaichuk and D.W.L. Read 1978. J. Env. Qual. 7 : 542-4
2. A. Olness, E.D. Rhodes, S.J. Smith and R.G. Menzel. 1980. J. Env. Qual. 9 : 81-6

(a) Rotation grazed
(b) Continuously grazed

TABLE 3

Harvey River, winter (June-Sept) phosphorus loading

| Year | Rainfall* (mm) | Flow ($10^6$ $m^3$) | P load (tonnes) | P Conc (mg/L) |
|---|---|---|---|---|
| 1978 | 586 | 145 | 56 | 0.39 |
| 1979 | 525 | 86 | 34 | 0.40 |
| 1981 | 675 | 245 | 94 | 0.38 |
| 1982 | 651 | 119 | 52 | 0.44 |

* Waroona

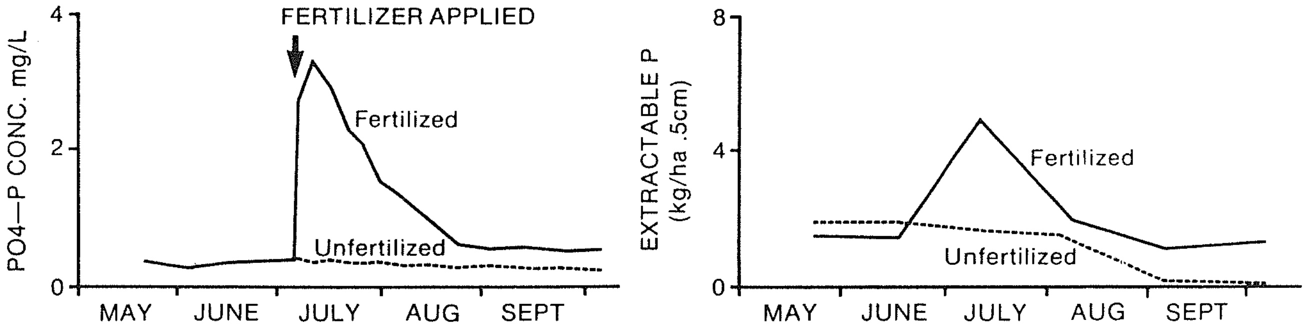



Figure 1. Runoff Plots (New Zealand) from Sharpley <u>et. al</u>. (1977).*

* Sharpley, A.N., Tillman R.W. and Syers J.K. 1977. <u>J. Env. Qual</u>. 6:33-36.

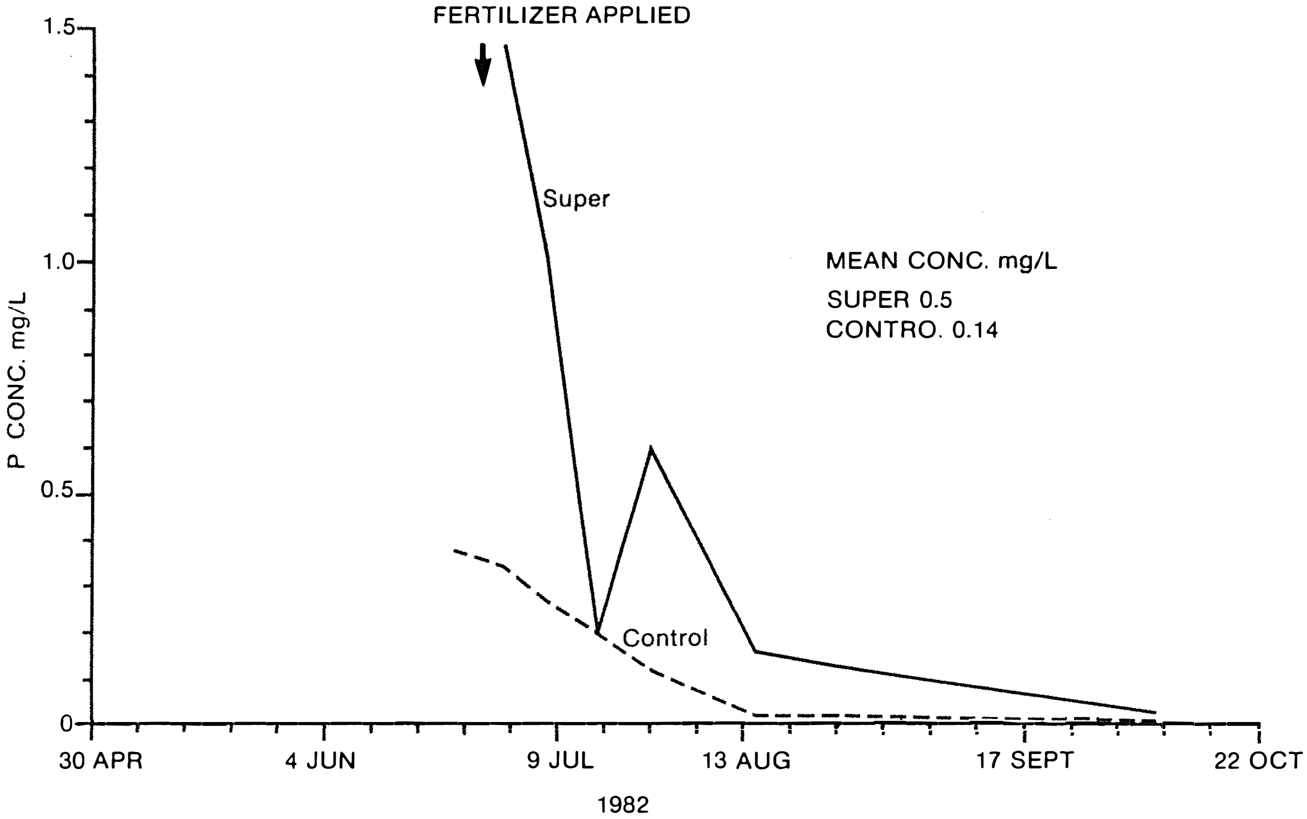



Figure 2a. Hodgson Plots - sand over clay.

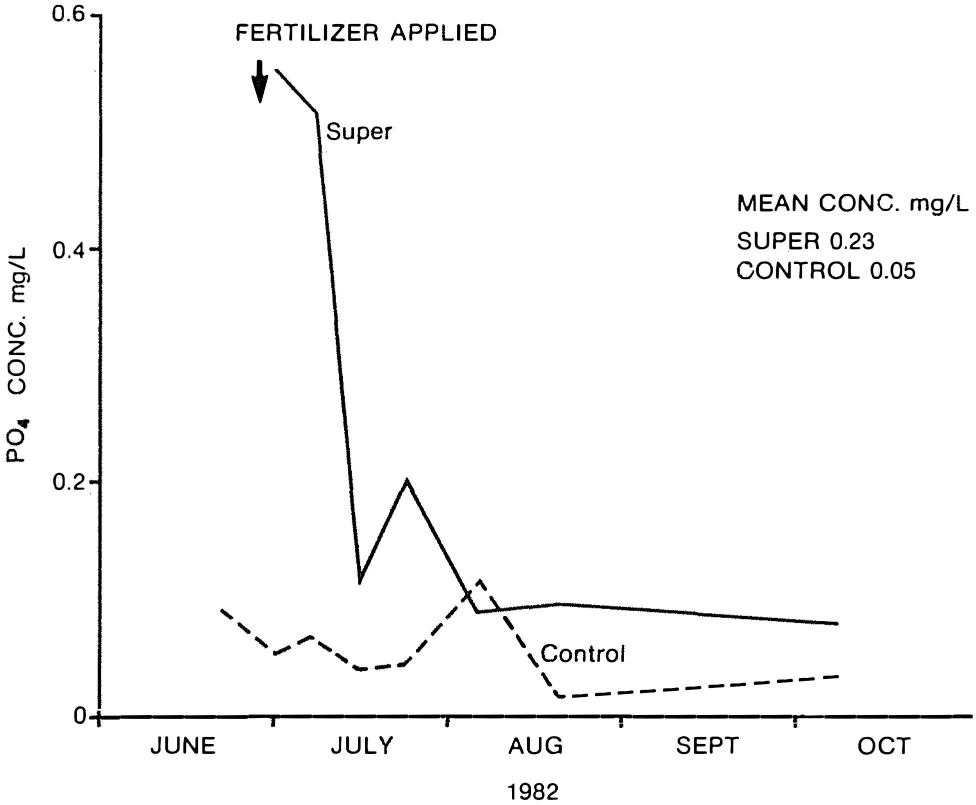



Figure 2b. Jenkins Plots - sandy loam over clay.

## ESTUARINE SEDIMENTS AS A SOURCE OF PHOSPHORUS

John O Gabrielson
Soil Science Department
University of WA

A large quantity of phosphorus is added to the estuarine sediments each year. What contribution does this sediment store make to the phosphorus available for algal growth? What role do the sediments play in initiating and driving the algal blooms, especially *Nodularia*?

Before attempting to make quantitative estimates of the significance of the sediments to algal growth, it is important to look at the sediments in the context of the P cycle of the estuary as a whole. The strongly seasonal nature of the external P input to the estuary is reflected in the mean surface phosphate concentrations in the Harvey Estuary, as shown by the solid line in Figure 1. The peak values are caused by the Harvey River flows. There is a time lapse between these inputs and the nuisance growth of planktonic and benthic biomass: planktonic biomass, as represented by mean surface chlorophyll *a*, is shown stippled in Figure 1. In years of *Nodularia* blooms there are two series of peaks: the first and lesser peaks represent diatom blooms and are followed by the even greater peaks caused by the *Nodularia* blooms. The *Nodularia* blooms appear after the collapse of the diatom blooms, well after the end of significant riverine input, at a time when the sediments are the only large source of phosphorus in the system capable of supplying the P necessary to yield the observed *Nodularia* biomass.

The sediments must therefore be feeding these blooms. The mechanisms by which they trap and later release phosphorus in large quantities when needed can be understood by examining the estuarine phosphorus cycle during the winter/spring and summer/autumn periods under mixed and non-mixed conditions (Figures 2 & 3).

Figure 2a. During relatively calm periods in the winter, river runoff tends to form a layer on the surface and continue out to sea. There is minimal mixing and no significant contact with the sediment. Under these conditions, the only way of trapping dissolved nutrients (the predominant form in Harvey River water) is through biological uptake by organisms which subsequently sediment out of the water column. In Harvey Estuary this in fact occurs via the diatom blooms that are common during this period. At present we don't know how efficient a trapping mechanism this may be.

Figure 2b. If, however, there is a mixing event, bottom sediment is resuspended into the water column and there is the opportunity for phosphate adsorption onto sediment particles, the majority of which resettle in the estuary with their newly obtained phosphorus. Biological uptake would of course continue to occur under well-mixed conditions. Although laboratory studies have shown that Harvey Estuary sediments strongly adsorb phosphate under oxygenated conditions, we cannot at present estimate to what extent this occurs in the field.

Figure 3a. In a summer bloom situation, calm conditions lead to a floating mass of Nodularia with all underlying water being without light and therefore with net respiration. This leads to low oxygen levels and high rates of phosphorus release from the sediments. This can be further enhanced by the existence of a dense saltwater wedge which remains stable even under mildly stirred conditions. Intrusions of dense marine water can also increase phosphate release from the sediments by displacing less dense (lower salinity) interstitial water which is high in phosphate. These salt water wedges can occur only while salinity in the estuary is less than that of sea water.

Figure 3b. Under well-mixed conditions sediment is resuspended enabling desorption into the now phosphate-depleted water, as well as advection of high-phosphate bottom water and interstitial water. At the same time, however, this mixing will reoxygenate the water and any phosphate that is not quickly taken up by organisms may return to the bottom when mixing stops.

These diagrams have emphasised that while the sediments constitute a large store of phosphorus in the system, they may be acting primarily as an intermediary between the riverine input and the summer growth period. Table 1 shows that the sediment bank of N & P was quite consistent during the first four grid studies conducted in '78-'79. Sediments collected in March '81 (after a large Nodularia bloom) were greatly enriched with respect to P, but not N, relative to the earlier studies. There was a lapse in grid studies for a while and the most recent grid studies have not been analysed. Based on small number of samples taken in October '81 it appears that the sediments had returned to the earlier levels by that time. At present it is, therefore, not possible to verify long-term enrichment of the sediments due to recent riverine loading and subsequent Nodularia blooms.

Table 1 Mean N and P content of the top 2 cm of sediment in the Peel and Harvey.[1]

| | Peel Inlet | | Harvey Estuary | |
|---|---|---|---|---|
| | Total P ($g/m^2$) | Total N ($g/m^2$) | Total P ($g/m^2$) | Total N ($g/m^2$) |
| March 1978 | 2.0±0.2 | 22.6±1.7 | 2.1±0.2 | 21.9±1.0 |
| August 1978 | 2.2±0.3 | 21.7±2.1 | 2.5±0.2 | 23.6±2.5 |
| March 1979 | 2.3±0.2 | 22.1±2.0 | 2.3±0.2 | 19.2±5.0 |
| Sept. 1979 | 2.4±0.2 | 18.1±3.1 | 2.1±0.2 | 15.5±1.7 |
| March 1981 | 4.1±0.4 | 20.2±2.9 | 4.1±0.2 | 16.5±1.8 |
| Oct. 1981 | 2.1±0.2 | | 2.2±0.3 | |

[1] ± standard error of mean

How much of the sediment store of phosphorus may be ultimately available for algal growth is difficult to estimate. Based on station 1 sediment taken in February 1981 approximately 8% of the total P (916 ppm) was in organic forms and 24% was extractable under reducing conditions. These two forms, constituting 32% of the total, could be made available under the right conditions, but whether this percentage of the total sediment bank could ever be lost is uncertain. It is also important to point out that the rate of release as well as the absolute amount can limit biomass attainable by restricting growth rates.

The sediments seem to be the source from which *Nodularia* starts each year's new bloom. Resting cells, called *akinetes*, exist in the sediments down to a considerable depth as shown in Figure 4. Sediment samples from various depths were cultured to measure viable colony forming units (cfu's). Not only are there many such viable akinetes in the sediment, but not surprisingly, their numbers have increased as a result of the last few blooms (Fig. 5). Small "blooms" were produced by incubating a combination of station 1 (middle of the Harvey Estuary) sediment collected April 1982, Harvey River water (with P removed) and a complete media with varying levels of P (K.S. Hamel and A.L. Huber, unpublished). After six weeks, *Nodularia* had germinated in the sediment, moved into the *overlying* water and grown in all vials. The amount and health of the biomass was related to the level of P added in the medium. An initial phosphate concentration of between 1 and 2 mg P/l was needed to maintain a healthy biomass for 6 weeks. This supports the hypothesis that a recent addition of available P is necessary to yield a substantial *Nodularia* bloom.

Intact sediment-water column cores taken during the early stages of the current *Nodularia* bloom have shown (Fig. 6a,b) that the sediments are *capable of* releasing phosphate at rates in excess of that necessary to sustain previously observed growth. A Harvey Estuary mean of about 10 mg P released/$m^2$/day would have supported the '80-'81 bloom during its 42 day growth phase. Data from the two cores displayed here represent 43 days of release averaging well in excess of 10 mg P/$m^2$/day. Dissolved oxygen levels were measured at 10 cm above the sediment surface to avoid resuspending the sediment and oxygen levels were undoubtably close to 0 at the sediment-water interface.

The effects of *Nodularia* blooms do not end with their death. A significant *amount of* dying cells settle to the bottom and through decomposition enrich the sediment again and provide a rich source of nutrients for benthic macrophytes such as *Cladophora* and *Chaetomorpha*.

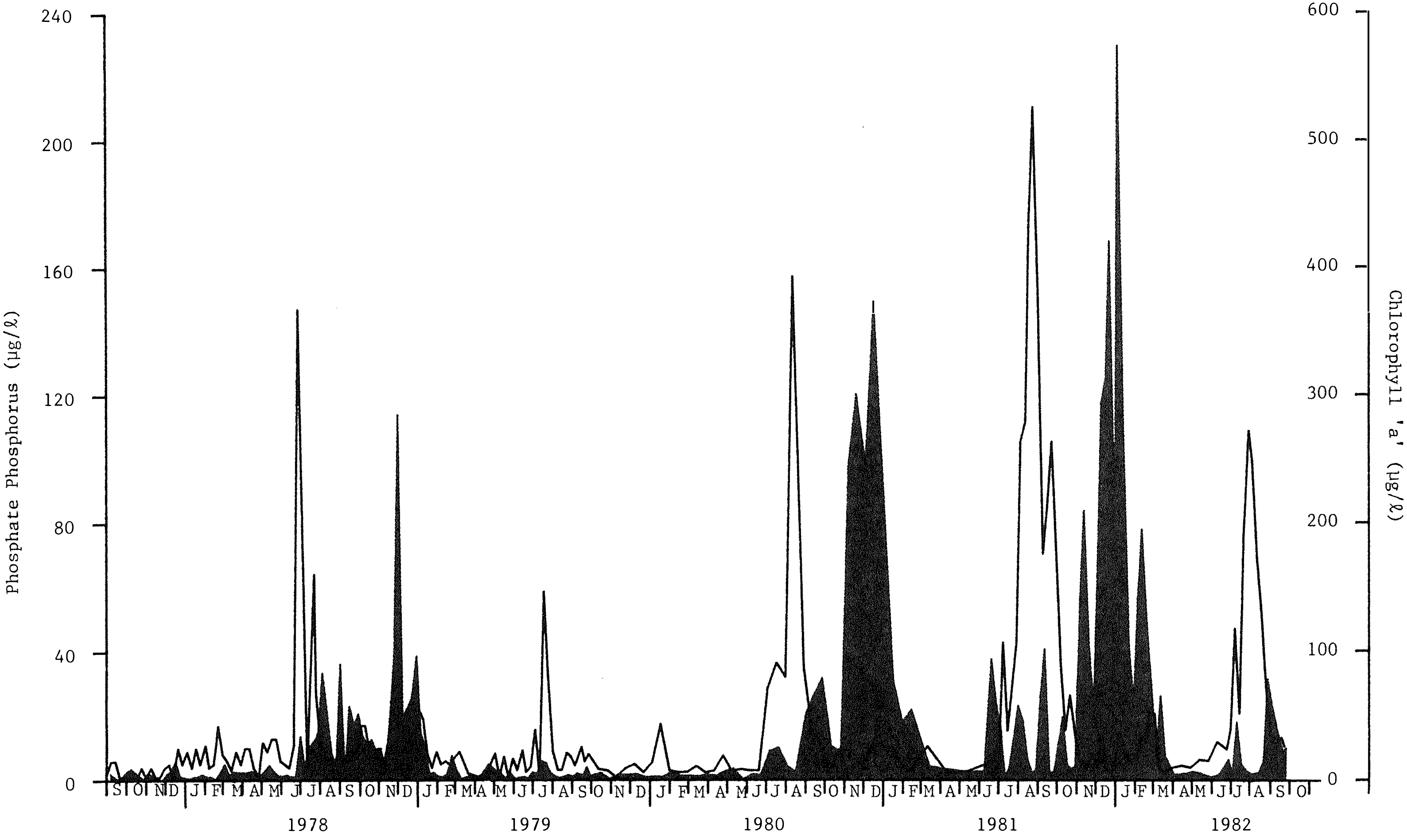
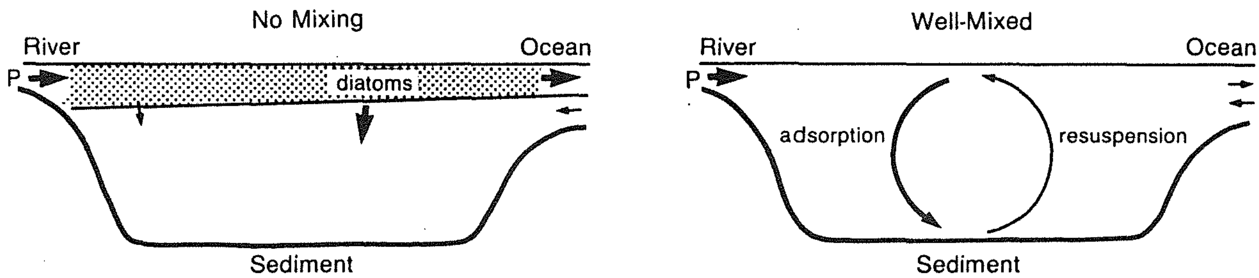
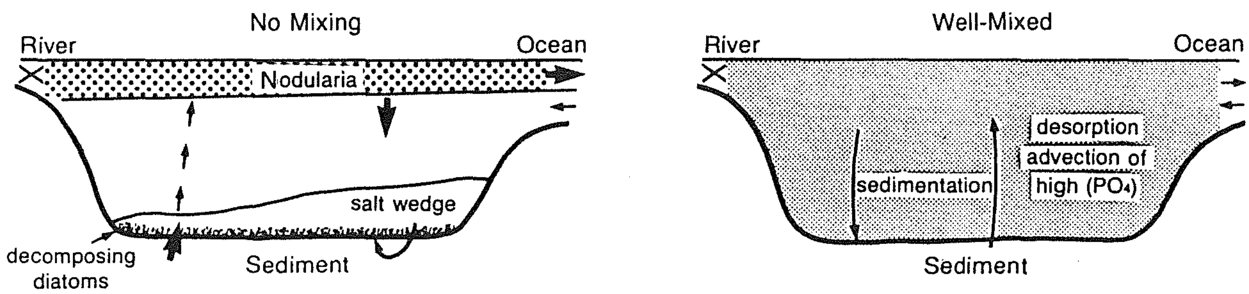



Figure 1. Phosphate phosphorus (solid line) and chlorophyll a (stipple) in Harvey Estuary 1977-82. (Centre for Water Research, UWA).



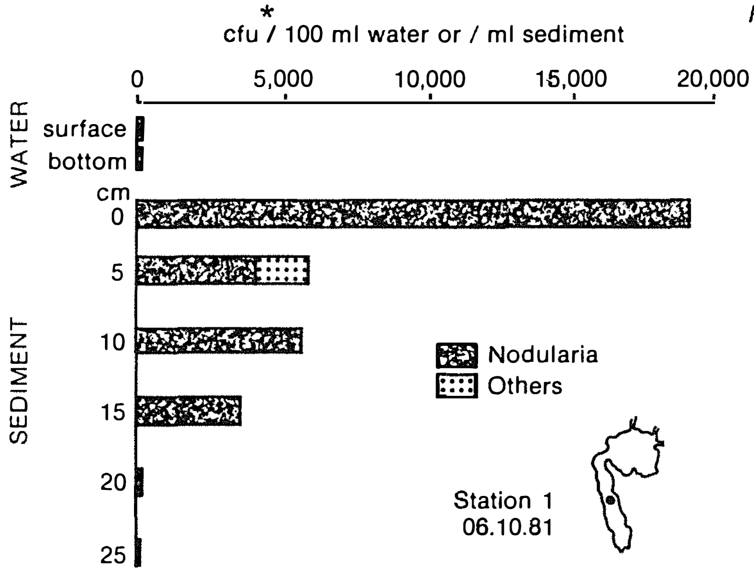

a. b.

Figure 2. Estuarine phosphorus cycles in winter/spring: a) no mixing, b) well mixed.




a. b.

Figure 3. Estuarine phosphorus cycles in summer/autumn: a) no mixing, b) well mixed.




* colony forming units

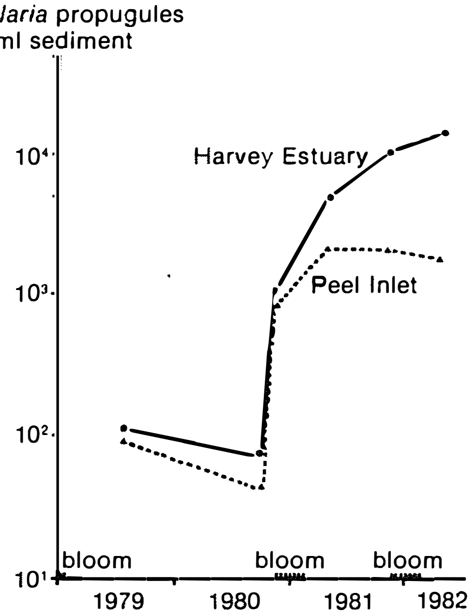
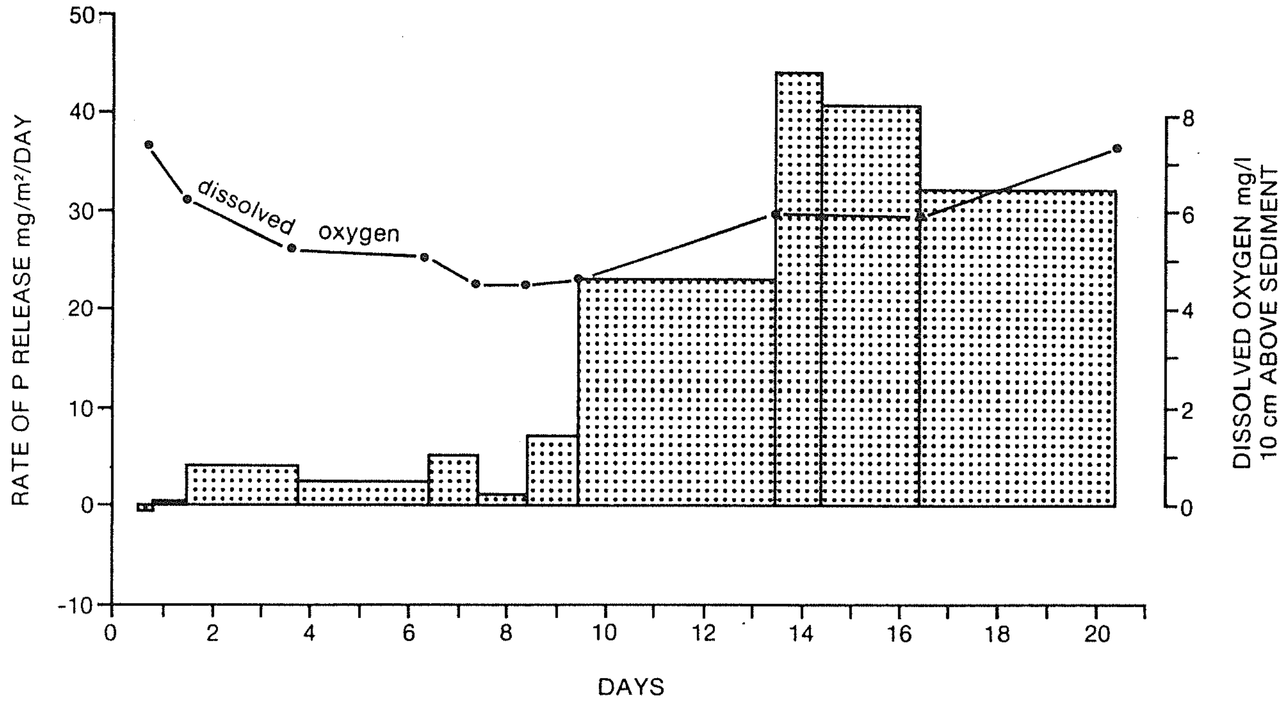
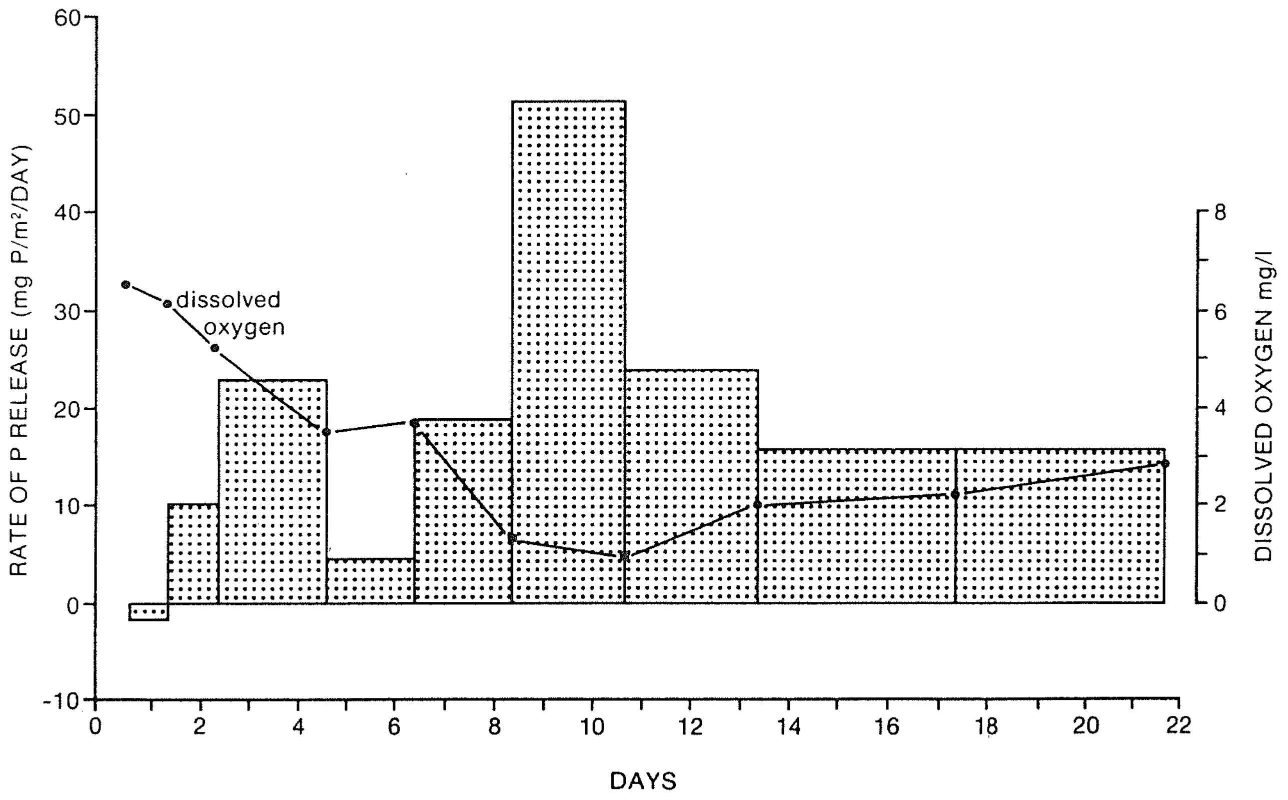



Figure 4. Akinetes present in estuarine sediments at different depths. (from A.L. Huber)

Figure 5. Nodularia akinetes in surface sediment 1979-1982 (logarithmic scale). (from A.L. Huber)




a.




b.

Figure 6. Phosphate release from sediment:
a) mean of two intact cores taken 27 September 1982,
b) mean of two intact cores taken 28 October 1982.

*(NOT A PUBLICATION. NOT TO BE CITED AS A REFERENCE).*

## PROSPECTS FOR RESIDUE INCORPORATION INTO COASTAL SANDS

Warren Tacey
Alcoa of Australia Limited, Pinjarra, W.A.

Research under the auspices of the Department of Conservation & Environment has concentrated on reduction of loss of phosphate from Coastal Plain soils by:

* reduced application
* modified timing of application
* using less soluble forms of phosphate

These approaches are logical since they are most likely to be possible because they are not too expensive.

I would like to stimulate thought on retaining P on the farm by the use of gypsum amended bauxite residue. The benefit of this is the potential for increased productivity on the Gavin Sands - a major selling point when it comes to implementing changed practices I believe.

The questions you are going to ask are:

1. DOES IT WORK?
2. HOW MUCH IS NEEDED?
3. WHAT DOES IT COST?

1. Barrow (1982) has shown that:

   - residue has a high capacity to adsorb phosphorous
   - plant available water retention increased from about 5% in Joel sand to about 15% in an equal mix of sand and residue.

2. On Gavin sands with added residue there is potential for six to ten times increases in pasture production

(Ward, pers.comm). Almost any amount is beneficial. We favour 1000 to 2000 t/ha as a rate of usage commensurate with the production rate but lesser to much greater rates are quite feasible.

3. Cost depends on how you look at it. Obviously cost per hectare increases with increasing application rate. However, cost per tonne of residue utilised decreases with increasing application rate (Figs 1 & 2). The figures are preliminary at the moment but it appears that operating costs may be similar to now if 1000 t/ha or more is used.

   The potential looks sufficiently attractive for Alcoa to have committed significant resources to researching this concept. We are very enthusiastic and would like to co-operate with other workers particularly on:

   - what is required for residue incorporation to become a reality,
   - how can it be implemented
   - what extension is required if it is to be accepted for general use.

In summary, the advantages and disadvantages are:

**Advantages:**

- Phosphate retention on the farm,
- potential productivity increases,
- residue use offers a potential long term solution to the nutrient loss problem.
- Potential for cost sharing as several parties benefit,
- potential increase in capital value of Gavin sands on farms.

**Disadvantages:**

- logistics

- further research needed to establish field scale effectiveness and absence of side-effects.

I'd like you to think that retention of P on the farm by residue addition is possible because:

* there is potential for increase in productivity and the capital value of land,

* there is potential for cost sharing by Alcoa.

**Reference:**

Barrow, N.J. 1982. Possibility of using caustic residue from bauxite for improving the chemical and physical properties of sandy soils. Aust. J. Agric. Res. 33 : 275-285

Editorial note

It is understood that phosphorus retention will be similar on Joel sands to those on Gavin sands. Experiments will be conducted on both sand types in 1983.

PRELIMINARY ESTIMATES
(NOT A PUBLICATION. NOT TO BE CITED AS A REFERENCE)

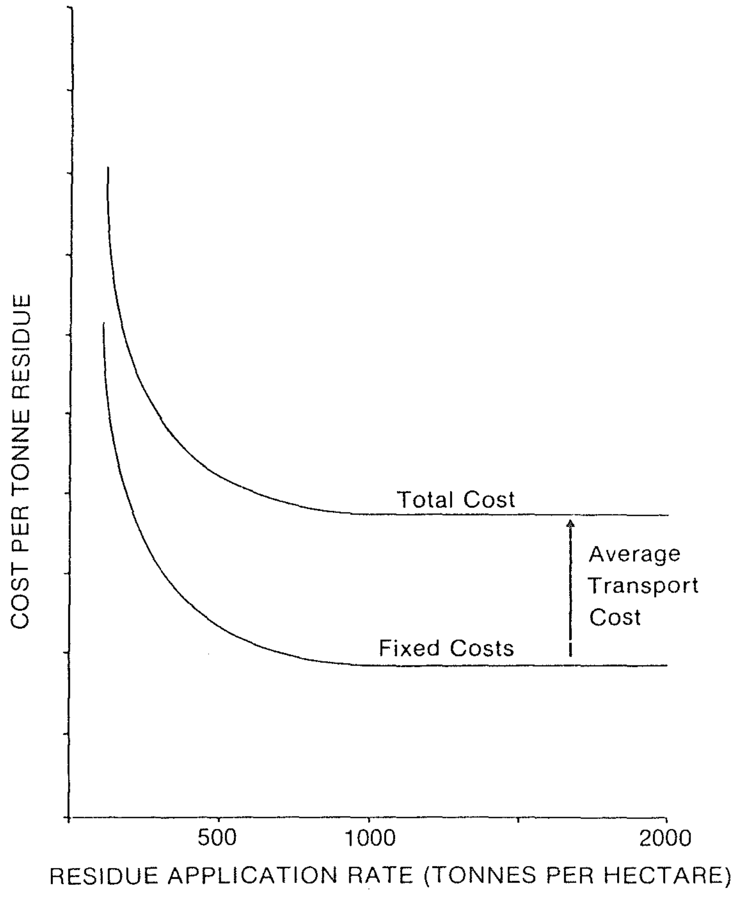



Figure 1. Agricultural incorporation, cost per tonne of residue.

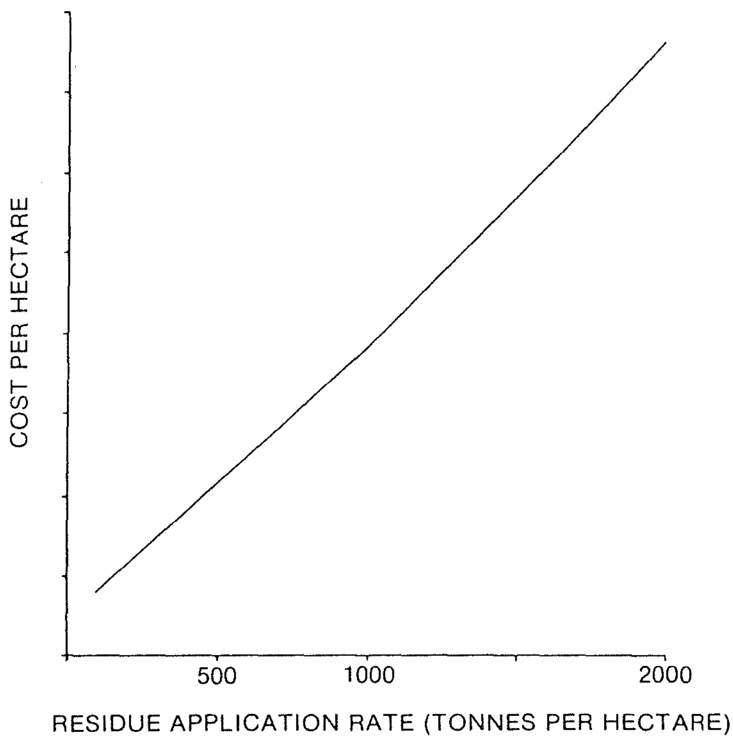



Figure 2. Agricultural incorporation, cost of residue application per hectare.

## REPORTS OF GROUP DISCUSSIONS

### Yeates' Group

The group discussed problems related to fertilizer usage and field trials and experimental work being undertaken. It recommended that further consideration should be given to the following five topics.

1) The need to be able to better define the nature of the residual phosphorus in the soils, and particularly in the deep grey sands: its chemical form, what its relation is to the plant available phosphorus, and its potential to leach out at some future date.

2) Work of the fertilizer group has so far concentrated largely on the deep grey sands and more work now needs to be done on the duplex soils. This is because the area of such soils is great and they contribute a large proportion of phosphorus input to the estuary, even though the leaching rate per hectare is less than from the deep grey sands. As stressed earlier, the duplex soils may present the most serious problems with respect to long term leaching. Further work is also needed on modifying the absorption capacity of duplex soils by the use of lime - an extension of earlier work by Barrow (1965).

3) Consideration needs to be given to the use of alternative pasture species and perhaps also introduction of microrhizae or other microbial flora that can make better use of phosphorus present in the soil.

4) It is still difficult to put a figure on the contribution estuarine sediments make to maintaining the eutrophic condition of the estuary. If the application of phosphorus to the catchment was stopped, how long would it take for the sediment supply to run down? How much phosphorus is there in the sediments that can continue to contribute to the estuary's problems for a long time?

5) The application of red mud to sandy soils may have considerable potential for providing a long-lasting solution to the problem of phosphorus leaching. There should be further discussion between those involved (ALCOA, Department of Agriculture, CSIRO, Murdoch University) with respect to extension of this research.

Several other speakers agreed on the need for more research on the use of red mud. A field day is being organised by Russell in conjunction with ALCOA, to be held at Pinjarra.

Russell's Group

The group suggested looking at the possibility of using red mud as a filter to trap phosphorus released from paddocks.

In partial answer to Question 1 the group concluded that, given the necessary assistance with soil testing in field and laboratory, it should be possible to achieve a 75% reduction in the application of water soluble phosphorus (i.e. superphosphate). This would require all farmers on both the deep sands and duplex soils to use lime-reverted super. There should be no problem in achieving this on the deep sands where reverted super has been shown to give at least as good results as super in the first year. We don't yet know how good reverted super will be on duplex soils, but probably no worse than super, and therefore preferable from the point of view of leaching. Without assistance for the soil testing programme we would be lucky even to get a 50% reduction in application of super.

In answer to Question 2, yes, this reduction in the use of super can be achieved through the co-operation of the farming community. However, it is most undesirable to achieve this by administrative action.

The potential for planting deep-rooted crops on the deep grey sands should be investigated, especially lucerne and tree lucerne which are perennials. The Department of Agriculture proposes to experiment with these in 1983. The desirability of planting more trees on farms should also be studied.

In response to a question, Russell gave it as his opinion that there is a good chance farmers will be willing to use red mud on the sandy soils. However this will depend very much on cost; if free yes, if $300 per ha no. It should be remembered that as yet little is known about what ecological effects red mud may have, other than retaining water and reducing leaching of phosphorus.

The estuary problems have been caused by the wasteful use of inappropriate fertilizers and alienation of land unsuited to the type of agriculture developed, these were done in the state of knowledge at the time of release.

Bettenay's Group

The group discussed the origin of the phosphorus released to drainage from coastal plain soils and concluded that groundwater is probably a more important source than the soil phosphorus. This is probably true both in respect to the permanent groundwater table of the deep grey sands and of the annual perched water table of the duplex soils.

In order to determine the rate at which the soil phosphorus stores are released to drainage (Question 7) it will be necessary to gain a full understanding of the soil hydrology.

This group also stressed the prospects for reducing loss of fertilizer by application of red mud to sandy soils and considered that the agronomic use of deep rooted plants, including trees, needs further study.

Finally, it was recommended that the symposium should be repeated in six months time.

Commenting on this report, Bowden stressed the need for first order of magnitude calculations on water movements through the soils to drainage, on the basis of known constants and experience elsewhere on the coastal plain. This should be done before planning further research on the hydrology. The need for such modelling was accepted. However, it will also be necessary to sample from appropriately placed bores and this is being discussed with Geological Survey and Government Chemical Laboratories.

Gabrielson's Group

The concensus view of the group was that the *Nodularia* blooms are largely dependent on the current year's input of sediment nutrients and that the older nutrient store is not of great significance to the problems of the estuary. Therefore, if the nutrient input can be significantly reduced the estuary will probably recover quickly. The only circumstance in which this conclusion would be wrong is if the last two major *Nodularia* blooms have changed the sediment in a way which has not yet been detected, so that phosphorus is now being released more rapidly.

This conclusion was questioned by Platell in discussion, on the basis that it will take many years to deplete the vast store of phosphorus in the sediments (say 400 tonnes in the top 2cm or 100,000 tonnes in the total sediments) and discharge this to the ocean in the form of *Nodularia* biomass at the rate of say 50 tonnes a year.

Gabrielson pointed out that it is the rate of release of phosphorus from the sediment which determines its availability to plants, not the quantity present. Unless it is released fast enough there will be no bloom. The rate of release is dependent on the oxygen concentration at the sediment-water interface which in turn depends on the BOD resulting from recent input of organic matter (diatoms and zooplankton).

There does not appear to have been any significant addition to the already large sediment phosphorus store in the last five years. There were no significant *Nodularia* blooms before the 1978-79 bloom and in the following summer, 1979-80, there was no bloom because there had been only a small phosphorus input to the estuary and not enough was released from the sediments to cause a bloom.

McComb reminded participants that the size of Nodularia blooms has been linearly correlated with the amount of phosphorus entering the estuary (Hodgkin, Fig. 2). This suggests that there is very little "memory" in the system from year to year and that if the amount of phosphorus entering the system can be reduced there will be a proportionately smaller Nodularia bloom in the following summer. While it is not possible yet to predict with certainty that there will be no further blooms if the input of phosphorus is stopped, all the evidence we have points in that direction.

Atkinson pointed out that the total amount of phosphorus stored in Harvey Estuary sediments is probably little greater than in other estuaries. Shark Bay sediments hold a similar load of phosphorus.

# PEEL-HARVEY ESTUARY STUDY
# CATCHMENT STUDIES GROUP
# SUMMARY OF RESEARCH TO DECEMBER 1982

by

P.B. BIRCH

EMAC's management option 1 states

> It is recommended that every effort be made to reduce the quantity of phosphorus discharged to the estuary from agricultural land. The Department of Agriculture and CSIRO Division of Land Resources Management should be asked to co-operate with the Department of Conservation and Environment in a study to determine methods by which release of phosphorus from coastal plain soils can be substantially reduced, whether by reduced application rates, modification of present application techniques, use of less soluble forms of phosphorus, or other methods. This study should be undertaken urgently.

In essence this management option seeks to increase efficiency of phosphorus utilization in a productive agricultural eco-system to reduce pollution of an estuary. At present approximately 10-20% of the annual application of phosphorus is lost to drainage (depending on rainfall and runoff) and this loss causes a serious algal growth problem in receiving waters, namely the Peel-Harvey Estuary. The goal is to reduce the loss rate to an average of 5% or less, a level which should greatly ameleorate the algal problem, as well as being of considerable agricultural benefit. This could be achieved by more efficient use of fertilizer, by changing land use or the use of soil additives, and it is equally important to know how much of an increase in efficiency can be achieved as it is to know how long it will take to achieve. This time factor relates not only to rate of adoption of new practices by farmers but also to how long it will take for these practices to have an effect on loss rates.

The evaluation of this option began in earnest in 1982 after a pilot study in 1981 revealed that the major portion of phosphorus entering the Harvey Estuary is derived from the deep grey sands (Bassendean Association) and the sand over clay soils (Guildford Association) of its catchment (Fig. 1). To achieve in-depth evaluation the following inter-related study segments were set up.

1. Catchment Runoff Studies (DCE, WAIT, PWD).

2. Mechanisms of Phosphorus Movement in Soils (CSIRO).

3. Phosphorus Fertilizer Studies (Department Agriculture, CSBP, UWA).

## Catchment Runoff Studies

This segment undertook a detailed investigation of sub-catchments representing the major soil types in the Harvey Estuary catchment and confirmed that approximately 75% of the phosphorus is derived from sandy surfaced soils; 25% from clays, loams and foothills soils.

Experiments on micro-runoff plots on two duplex soils (sand and sandy loam over clay) revealed that soil water concentrations were on average four times lower on unfertilized plots than those fertilized with superphosphate at 200 kg/ha. Addition of lime at 2 tonnes/ha with superphosphate reduced concentrations by 60% on the sandy loam over clay site but by only 20% on the sand over clay site. The experiments were on non phosphorus responsive sites (extractable P > 25 ppm). Therefore the results are encouraging, indicating a rapid response in loss rates to drainage following reduction in phosphorus application.

On the other hand, monitoring of the Harvey River from 1978-82 showed phosphorus loads varied by the same amount as the observed threefold range in runoff. There are three possible reasons for this:

1. There is a greater proportion of fertilizer transported into waterways in wet years.

2. There is a large soil storage available to be leached and more is leached from the soil in wet years.

3. There is more soil erosion in wet years which results in a greater amount of particulate phosphorus being transported in wet years.

Only further research will indicate the relative importance of the three alternatives.

An overall phosphorus budget of the Harvey River catchment showed that of an average of 7.2 kg/ha applied, approximately 28% was exported as produce and 8-24% was lost to drainage. This left 47-64% which is added to soil storage or groundwater. The ultimate availability of this storage for subsequent release to drainage is not known, but would be closely related to soil type. Loams and clays would retain the highest proportion of added phosphatic fertilizer and release a little over a long period. Deep grey sands would retain the least in the soil, but most in groundwater. The rate at which this phosphorus rich groundwater pool will run down is not yet known. Duplex soils would probably be intermediate with regard to storage, although the runoff plots suggest a rapid rundown is possible.

Mechanisms of Phosphorus Movement in Soils

The CSIRO group have provided valuable information on the distribution of soil groups, in terms of phosphorus leaching capacity, for the coastal plain drainage system (Fig. 1 attached). Work on the adsorption capacity of these soils has shown a great range in their ability to hold phosphorus. Loams and clays (about 20% of the Harvey River catchment) have a large capacity to adsorb phosphorus, and despite heavy superphosphate applications over the years, still have a capacity to adsorb further phosphorus. The deep grey sands have virtually no ability to adsorb phosphorus, except for the "coffee rock" layer below at about 1-2m depth which has an adsorption capacity similar to loams. Phosphorus concentrations in groundwater below the coffee rock are low (~40 μg/L) compared to an average of about 6000 μg/L in groundwater above it. It is this pool of phosphorus-rich groundwater that needs further investigation: For example, how much of the phosphorus is sieved as the water percolates vertically through the "coffee rock"? Since the "coffee rock" has such a high capacity to adsorb phosphorus it could represent a substantial sink in Bassendean soils.

Duplex soils (sands - sandy loams over clay) have been shown to be intermediate in phosphorus adsorption in the A horizon while the sandy clay B horizon has high adsorption capacity. However very little phosphorus appears to be adsorbed by the clay layer, and since about 30-40% is lost via drains and agricultural produce, the remaining 50-60% must be stored in the sandy A horizon. This needs confirming.

Experiments with nests of shallow groundwater wells have been installed in the major soil groups and confirmed the pattern of leaching expected from the above comments. Highest soil water concentrations were found in deep grey sands and lowest in loams and clays. The overall seasonal pattern for the deep grey sands has yet to emerge since the perched water table (above coffee rock) was still present and being monitored at this time. (Note: by January 18 the groundwater table had receeded below the coffee rock at the two experimental sites on Gavin and Joel sands).

Phosphorus Fertilizer Studies and Extension to Farmers

Major progress was made in this segment in two areas: the redefinition of the relationship between extractable phosphorus in deep sands and yields, and the development of a new slow release superphosphate suitable for leaching sands. An active extension program is now underway to maximise rate of adoption of the new fertilizer practices which stem from this work.

Previous soil test relationships had loosely grouped all sands together and indicated that 25ppm extractable phosphorus was required in soil to ensure phosphorus does not limit growth. This limit now applies only to the sand over clay types, with a new limit of 10ppm for deep grey sands. Using these new limits combined with the results of an extensive soil testing survey of 95 farms in autumn 1982, it was found that 90% of farms on duplex soils were above 25ppm and did not need added phosphorus; for deep sand farms 40% were above the 10ppm limit. Thus despite great leaching losses, fertility levels have gradually built up on the sands to the point where substantial reductions on application rates are now possible, and on those paddocks still needing phosphorus, reverted superphosphate can be used. This means that potentially there could be a significant reduction in losses to drainage. However sulphur and to a lesser extent potassium will still be required on most farms every year. These elements are normally supplied in the 5:1 superphosphate: potash fertilizer which is widely used. The alternatives are gypsum which needs a special spreader or potassium sulphate which is relatively expensive. Special subsidies could assist here.

Two major hurdles remain - adoption of new practices by farmers and quantification of the contribution of phosphorus reserves now in the soils to present losses to drainage. Progress is being made on both fronts. A free soil testing service to speed up adoption is now being offered to farmers with follow up advice coming late summer. If enough farmers reduce application and use reverted superphosphate the effect can be measured (given reasonably average seasonal conditions) by comparing this winter's P load and water flow in the Harvey River with the four years of data already collected.

Other areas of research being covered include:

(1) Modification of time of application of fertilizers

(2) Use of deep rooted and/or perrenial plants which are capable of better utilizing soluble phosphorus

(3) Modification of sandy soils to increase phosphorus retention eg. Alcoa's red mud

Research on (1) indicates that late or split applications generally increase yields but that results depend on seasonal conditions.

Pilot studies by Alcoa with red mud look encouraging and large scale trials are planned for this year in collaboration with the Department of Agriculture.

## SYNOPSIS

Rapid progress has been made in determining new fertilizer strategies for farms on sandy coastal plain soils, from which comes most phosphorus to the estuary. Phosphorus application rates can be reduced by approximately 50% in the long term without loss of production, provided adequate sulphur is supplied as gypsum. Where phosphorus is needed, slow-releasing (lime reverted) superphosphate can be used, virtually eliminating leaching losses. Farmers can be best persuaded to adopt the new practices by a free soil test which is being offered this summer. Pilot studies on duplex soils (sand - sandy loam over clay) indicate a rapid decline in phosphorus concentrations in soil water when phosphatic fertilizer is not applied, but further work at the paddock scale is required to better estimate effects of changed fertilizer practices on loading of phosphorus to the estuary.

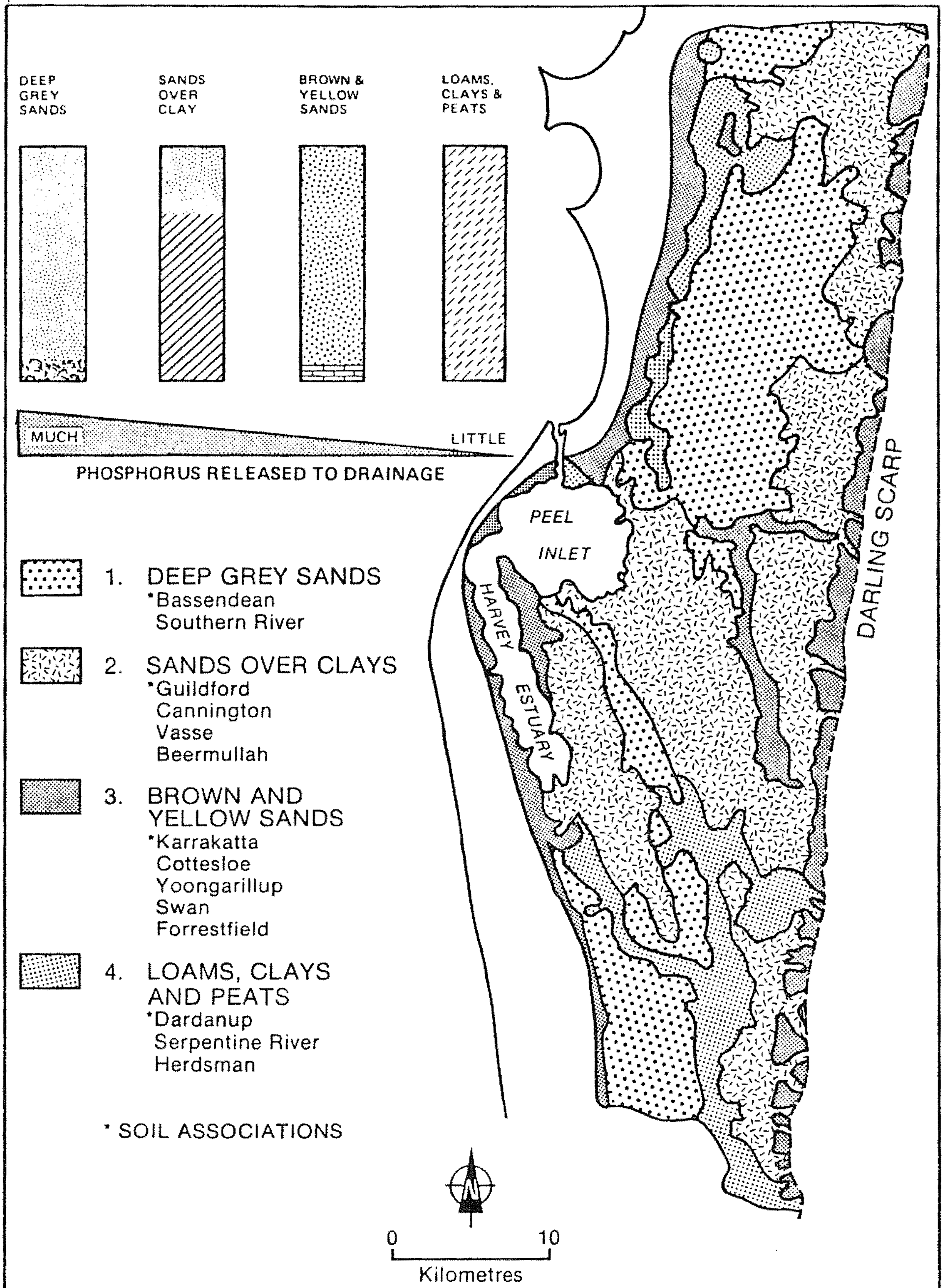



Figure 1. Soil Categories on the Swan Coastal Plain