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POST QUARRYISM – A study of the Rehabilitation of Sand and Gravel Quarries

This study has been completed in partial fulfilment of the requirements for the Diploma in Landscape Architecture.

Lincoln College, Canterbury, New Zealand 1989

WILLIAM HENRY FULTON  B.B.Sc (Vic)
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SPIRAL JETTY
Rock Products '87
STRUCTURE

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PREFACE
1. PREFACE

1.1 Rationale

This study of Rehabilitation of Quarried Areas is the result of an interest in Land-Use. Quarry Rehabilitation is also an opportunity for Landscape Architects. Their knowledge of land systems and their appreciation of Design can be applied to Quarry Rehabilitation to help create tomorrows landscape.

1.2 Objectives

The objectives of this dissertation are threefold:

(a) To investigate the 'concept' of Rehabilitation and relate it to a 'known situation'.

(b) To discuss the problems involved in the Rehabilitation of quarried areas and propose some solutions.

(c) To provide some practical advice useful to the Designer of a Rehabilitation Project.

1.3 Method

Research for this dissertation began with a review of the existing literature on Rehabilitation. This material considered a wide range of non-metal mineral extraction from existing strip mining of coal to derelict hard-rock quarries. Material was mostly concerned with the United Kingdom and the United States of America. To relate this information to the physical realities of Quarry Rehabilitation visits
were made to most Quarries around Christchurch. A variety of personnel were interviewed from Landscape Architects to Loader Drivers.

1.4 Presentation

This dissertation is presented in five parts. The first is an introduction to Quarry Rehabilitation. It describes and discusses both the Gravel Industry and the idea of Rehabilitation. It sets the scene by introducing international and national perspectives and finishes by focusing on the quarries around Christchurch. These are described as problems of both opportunity and constraint.

The second section addresses these problems using Design Methodology and considers potential after-uses. Some aspects of site design and the necessary practical considerations constitute the next two sections. Recommendations and a conclusive statement complete this dissertation.
INTRODUCTION
2. INTRODUCTION

2.1 The Gravel Industry

The Gravel Industry is an integral part of New Zealands economy. It provides jobs as well as 'aggregate', the primary ingredient of our countries civil developments.

2.11 Process

Gravel is the raw material and is the product of millenia of geological forces. Gravels result from erosive action on rock formations. They are carried by glaciers, rivers and oceans and range in particle size from boulders to silt. They are deposited on out wash plains and beaches. From these deposits they are quarried by surface extraction, crushing and washing to produce aggregates.
2.12 Location

Quarries are located where gravel deposits occur. So, fortunately, are our major population centres which have the greatest demand for aggregates. Quarries therefore tend to appear on the outskirts of towns and cities (often within the Green Belt). They are close enough to minimise transportation costs but far away enough to reduce land-use conflict.

2.13 Problems

As a result of its extractive nature Quarrying disturbs the land and in so doing effect the environments natural balance. Land forms are altered, drainage patterns disrupted, soil systems destroyed and habitats removed. The landscapes cultural balance is also upset. The lands aesthetic value is changed and continual or multifunctional land-use is placed under risk.

2.2 The Concept of Rehabilitation

To resolve the problems associated with the Gravel Industry, the imbalances it produces need to be corrected. This report is concerned with 'righting the balance'. This will enable continuous use of the land.
2.21 Definitions

Many words have been used to describe the act of 'righting the balance'. The words used have had close links with how differing cultures have related to their environment. In the United Kingdom, for instance, quarried areas are RESTORED in an effort to save the countryside. In the USA especially in highly valued landscapes quarried areas are RECLAIMED. In areas where the 'wild frontier' has passed Americans REHABILITATE their quarried areas.

New Zealand has inherited a mix of these words and meanings from both sides of the Atlantic. WARD best summarised these:

RESTORATION is returning the land to its previous topography and vegetation cover.

RECLAMATION is returning land from an abandoned or derelict state to an aesthetically pleasing and a 'safe' condition.

REHABILITATION is returning the land to a different and usually productive use.

(Ward '81)

Rehabilitation is the word which is most commonly used in New Zealand. Ward labels it as 'the most possible and practical' emphasising the return of the land to a useful condition.
2.22 Motivations

With an appreciation of the words involved an explanation of the motivations behind rehabilitation is necessary.

2.221 Economic Reasons

In an economic sense conflicting land-uses leads to competing land values. Quarried areas may be absorbed by the population centre they supply. Land becomes more highly valued for residential, recreational and commercial uses. Quarried areas or potential quarry areas may also become more valuable for rural based uses like Horticultural Cropping.

2.222 Ecological Reasons

Ecological reasons may drive rehabilitation. As part of an Increasing Global Environmental Awareness threatened natural systems have become more valuable. Endangered species, threatened habitats and vulnerable natural processes have all been placed at risk by Quarrying.

2.223 Aesthetic Reasons

As quarried areas have become larger and more accessible Aesthetic forces have stimulated rehabilitation. The public nuisance quarries cause in terms of dust and noise and their visual undesirability has encouraged corrective treatment.
2.224 Legislation

The above 3 social forces have been partially implemented through legislation. More effective Environmental Laws including water and soil legislation have set a framework. Regional land-use policies and local zoning attempt to reduce conflict and enable rehabilitation through ordinances and standards.

2.225 Image

It would seem that Quarry operators have been forced into the process of Rehabilitation. Rehabilitation, however, can give the land some value after quarrying. It is also an exercise in Public Relations. A clean and efficient operation reflects well on a company. Rehabilitation also offers personnel a 'worthwhile' working environment.

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PUBLIC RELATIONS
Cooley Gravel Co., USA.

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2.23 **Opportunity**

Rehabilitation offers special interest and satisfaction to the environmental designer. From their point of view Rehabilitation gives an opportunity for:

(1) The creation of a final topography which blends into the adjoining undisturbed landscape.

(2) The creation of a surface drainage pattern with no adverse effects.

(3) The creation of a soil condition capable of supporting plant and animal life equal to that of the regional landscape.

(4) Provision of ground cover for erosion control.

(5) Provision for land-use at some economic value.

(6) The Organisation of the various steps in the operating sequence for optimum operating efficiency.

(\textit{Coates '73})
2.3 Scanning the World Scene

2.31 Historical Perspective

Mankind’s evolution has had a close relationship with his quarrying endeavours. In fact the stone adze set prehistoric man apart from his primate cousins. Larger scale surface mining operations have been dated back to 140000 BC in South Africa, where it is believed that pits were dug and backfilled, perhaps in respect to the 'Earth Spirit'. (Watson '82).

It was with the destruction caused by WWII and consequent growth in both population and reconstruction that Rehabilitation became more common. It was no longer possible to extract the resource then move on to another area to repeat the process.

The Post War generation matured and events like the Environmental Conference of 1971 in Stockholm began to set precedents for world leaders.

The Surface Mining Control and Reclamation Act (77) was created in the USA to integrate rehabilitation into the quarrying industries objectives. Similar legislation in the UK through their Town and Country Planning insisted on standards for Rehabilitation.

To a large extent, now a decade later, Rehabilitation in the Northern Hemisphere is an accepted part of the quarrying process.
In Britain where there is a strong tradition of a countryside aesthetic much of the rehabilitation projects returns quarried areas back to agricultural land. The second most common after-use is flooding pits to form recreational and wildlife reserves.

In the USA a less pragmatic approach to rehabilitation has been adopted and more creative after-use solutions have been explored. Hydroslides were invented when Oakwood Lake resort was developed in a quarried area in Modesto, California.

Land Sculpture has been experimented with by Michael Hiezers. He was funded by a National Reclamation Council to produce the Effigy Tumuli Sculpture as illustrated below. Community recreation facilities like the Black Diamond Golf Course, also illustrated, are a common feature of Rehabilitation Projects in the USA.
2.33 The New Zealand Position

Rehabilitation in New Zealand differs greatly from the international situation. Our scale of operation is firstly considerably smaller.

From 1930 to 1980 about 400,000 ha of land was used for sand and gravel quarrying in the USA. In Britain 1600 ha of land is quarried annually. In New Zealand less than 200 ha is taken for gravel extraction per annum. New Zealand's Industry is typified by small operating companies as compared with their multinational Northern Hemisphere cousins. The pressures of urban growth and conflicts with agricultural needs are also far less in New Zealand.

New Zealand is also a younger country. As such the gravel resource has only been scratched and we still maintain strong colonial attitudes towards the resource.
Early legislation under the 1926 Mining Act included reference to rehabilitation. Operators were given the option of rehabilitating or paying £7/10/acre into a consolidated fund in lieu of this. Rehabilitation however has not had a high profile in the New Zealand Quarry Industry. Many of our present quarries have been in operation for over 50 years and will remain viable well into next century. Some Hard Rock Quarries which supplied building material for our Dominion Buildings have ceased operating and a number have been rehabilitated eg: Eden Gardens in Auckland, Very few Gravel quarries though have received attention. The development of Mt Smart Stadium is one exception which is illustrated below.
Other examples of lesser success are the rehabilitating of quarried areas into agricultural uses at Waipipi and on the Waimea Plains also illustrated.

AGRICULTURAL REHABILITATION AT WAIPipi...

AND WAIMEA.
2.4 The Local Problem

2.41 The Canterbury Perspective

Quarries in the Christchurch region illustrate below, extract alluvial material. This has been laid down by the Waimakariri River as it changed its course over time as well as being blown across the plains by prevailing winds. Quarrying of this alluvial material as it occurs today has existed since the turn of this Century.

There are about 700 ha of Quarry Zone in the area most of which was constituted by small 2 to 8 ha quarries. Recent zoning changes have concentrated activity into 3 large blocks of about 200 ha each. A number of different operators exist together on these large blocks.
2.42 The Christchurch Quarry

Quarries around Christchurch are predominantly dry pits. Some are prone to occasional ponding and the few that operate close to the river are wet pits. Canterbury quarries process up to 95% of the gravel they extract. This is often done in combination with an Asphalt or Concrete plant. The unused overburden is made up of silt and clay sized particles which is filtered out in shallow lakes or deep ponds.

Miners Road pits in the quarry zone. Beyond are Pavroe pits in front of trees on Paparua Priory.

Typical Christchurch Quarry.
(Pics '89)
2.421 Physical Nature

Canterbury Quarries are up to 10 metres deep. Dry pits are restricted in depth by underground aquifers and create diverse changes in level, something unusual in the Canterbury landscape. Once the maximum depth is initially reached the Quarry floor remains relatively level. The Quarry is then enlarged by extracting gravel from a workable face until it confronts a boundary or becomes too far removed from Quarry Plant. Wet pits are created by a dredge removing gravel slowly pulling the shoreline away from the centre of the created lake, as illustrated.
2.422 Climatic Nature

There are both benefits and disadvantages in the microclimatic created within Christchurch's quarried areas. Protection from the wind is the result of sinking below the original ground level. This plus the high reflectivity of the exposed rock surfaces means that temperatures are higher in warm weather. The reverse is true in colder temperatures as the pits act as frost traps. Extremes in temperature are about 10% above and below the mean. While the amount of precipitation is consistent with the region lower water retention on the battered sides and excessive compaction to the pit floor compounds erosion and ponding problems.

2.423 Biotic Nature

The destruction of the ground leaving naked alluvial material means that little life can be supported in freshly quarried areas. The material that is left is lacking in any soil fauna, has no structure and virtually no nutrient status. The forms of life that do exist in these quarries are associated with water bodies or the colonising species on battered sides left undisturbed. The acquifers which flow under Christchurch's quarries are another living part of our quarries which must be recognised.
2.43 Conflicts in Christchurch Quarries

For well over 50 years quarries have existed out on the plains within the Green Belt which contains Christchurch City. For most of that time they have operated without complaint. Now that some operations are exhausting their supply and the legislation is becoming tighter questions are beginning to arise. Urban Growth is also coming into conflict with quarried areas as Rural lifestyles become more fashionable.

Land-Use conflicts have arisen from the dust and noise pollution of operations; the constant heavy vehicular movement and the poor visual quality of many of Christchurch's quarries. Some after-uses of quarried areas have also added to the problem. Quarried areas used as tips are not only unsightly and smell but are potential health risks.
2.44 Attitudes and Expertise

Most of the operators in the Christchurch region seem happy with the principles behind Rehabilitation. Perhaps as a reaction to pressures many are also taking steps to improve the situation. There still however exists problems in attitude which hinder the Rehabilitation process. Colonial attitudes to the land see it as a resource to be tapped. According to Leopold:

'We abuse the land because we regard it as a commodity belonging to us. When we see land as a community to which we belong we may begin to use it with love and respect.'

(Aldo Leopold '66)

As we grow to respect the land around Christchurch even if for our childrens sake Rehabilitation will become part of the Quarrying process. Up until now it has been regarded as an after-treatment which has fallen victim to economic vices.

Beyond the problems of attitude are those of expertise. Most operators lack the knowledge to make Rehabilitation a success. 'Random' Quarrying has often made the problem more difficult and trees have died and soil become infertile through poor management. Here-in lies the 'Golden Opportunity for Landscape Architects'.

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REHABILITATION
3. REHABILITATION

3.1 Introduction

With an understanding of the origins including some examples of Rehabilitation and the nature of the problem specific to the Christchurch Region this section attempts to come up with some answers. While these solutions relate to the quarries around Christchurch they do apply to similar sand and gravel pits around the country.

3.2 The Landscape Architect

The Landscape Architect brings to the problem of Rehabilitation, Imagination, Integration and Management skills. He/she can see the problem in its entirety and help others see Rehabilitation as part of the complete Quarrying process.

In many Northern Hemisphere examples a Landscape Architect is involved right from the beginning. His/her imput is required to determine feasibility and options of location, extent and after-use. This is especially true on large scale sites.

In New Zealand however and especially in Canterbury most operations are relatively small with considerable life expectancies. In these instances it would seem better for a Landscape Architect to act as consultants to a number of operators helping them correct and direct activity towards planned after-uses. In some of the larger firms or local bodies a Landscape Architect may act within the structure of the organisation.
3.21 Objectives

Once the Landscape Architect has found a niche in the operating system it is then their directive to plan and design a process of Rehabilitation. It is the Landscape Architect's objective to demonstrate how the quarry operator can develop useful land rather than 'Scars on the Landscape'.

It is through the process of planning and design that the Landscape Architect can enable the producer to:

(a) Make more efficient use of his material and equipment in creating functional areas.

(b) Reduce earth moving costs.

(c) Reduce visual, noise and dust pollution.

(d) Make land development an investment rather than an expense.

(A. Bauer LA Jan 66)

This should be achieved with social acceptance within the region, assist the natural balance of the local ecosystems and in visual accordance with the surrounding landscape.

"The role of the Landscape Architect is the creation of a symbiotic arrangement among process and participants".

(J. Roderick LR Vol 3 No. 3)
3.22 Approaches

The Landscape Architect must consider the range of Rehabilitation approaches and decide upon an appropriate method. The approach chosen will direct the operation, effect the possible after-uses and determine the extent to which the Landscape Architect will be involved.

At a broad level 3 options of Rehabilitation exist:

(a) Do nothing. Once the quarrying is complete this option leaves the land to naturally colonise, revegetate and over time redevelop a soil structure and natural habitat.

(b) Extract then Rehabilitate. Rehabilitation is restricted, for a variety of reasons from attitudes to physical constraints, until quarrying has ceased.

(c) Progressive Extraction/Rehabilitation. Rehabilitation is seen as a necessary and integral part of the quarrying operation and occurs concurrently with gravel extraction.

The first option requires no input from a Landscape Architect but takes a very long time. The second option may use the skills of a Landscape Architect but often not until the end of quarrying. The third option is the most accepted leading to more successful Rehabilitation Projects. Options (b) and (c) can be further categorised into 3 varying techniques.
(a) Amelioration. This relies on fairly extensive improvements to soil and landform. It addresses the problems present in quarried areas by removing them. It is an expensive option which is often warranted by the benefits of an intended after-use.

(b) Adaption. This technique accepts the conditions within the quarried areas and selects uses suitable and species tolerant of such conditions. It is cheaper than the first option but less beneficial after-use options are available.

(c) Ecological Amelioration. This is a combination of the two above approaches and is perhaps the most useful. It uses the advantages of ecological principles to extensively improve the given conditions. An example would be using nitrogen fixing species to increase the rate of soil recovery.
3.3 **Methodology**

Once the type of approach or combination of approaches is decided upon the Landscape Architect must then rationalise that approach into some order. Flow charts best illustrate how rehabilitation fits into the whole process as well as proceeding itself.

3.31 **Land-Use Schema**

Figure one, using different terminology shows how rehabilitation can fit into the entire land-use schema.

![Diagram](Surface Mining Environmental Monitoring and Reclamation Handbook '76)

This chart highlights the fact that quarrying is just one land use in the continuing use of the land. It also assumes that rehabilitation works concurrently with quarrying.
3.32 Land-Use Decision

The second model, Figure Two, abstracts the rehabilitation process and described how future predictions, use compatibilities and rehabilitation procedures form subsequent steps in rehabilitation design.

FIGURE TWO
(Landscape Architect Jan '79)
3.33 Implementation

Figure 3 indicates how the design arrived at in figure 2 is implemented. Designing the operation will consider layout and access of an after-use. Site preparation must take into account land form and soils which will both in turn have effects on the hydrology of a quarried area. It is also important to note that a level of management is required to maintain an after-use.

3.34 Rehabilitation Plan

The tool which a Landscape Architect uses to formulate, explain and implement a Rehabilitation project is a Rehabilitation Plan. Models, photogrammetry or computer simulation are useful ways not only to communicate design solutions but also to test options.
3.4 After-Use

Identifying a Land-Use which will replace the quarrying activity is a key part of the Rehabilitation Process. The quarries around Christchurch are limited by their scale and rate of extraction but it is important to consider a wide range of options which may be viable in the future.

3.41 Decision

Rehabilitation should be considered as a cost of the overall quarrying activity. Therefore to minimise that cost the appropriate use must be decided upon at an early stage in the quarrying operation, ideally at the start. Predicting future patterns, however, to determine the best after-use raises a speculative dilemma.

'Final site condition is guided throughout the mining operation towards the needs of a reclamation use. Over specification, however, may produce a site suitable only for obsolete uses. The longer the mining period the greater the uncertainly.'

(McKenzie '79)

It seems more sensible to have an operation directive that allows for a number of possible alternatives. Temporary land-uses may form part of the process and having a range of options lends itself to multiple function land use.
3.42 Alternatives

The Alternatives are generally Urban related, Rural production or Recreation/Conservation. They have been identified as past examples or proposed as possible future uses.

3.421 Urban Related

Since quarries are governed by their proximity to population centres they lend themselves to urban development. This is especially so where urban growth begins to encroach and envelop quarry zones.

3.4211 Housing

Residential areas are often at the fringe of urban growth and quarry zones on that fringe are well suited for sub-division. Their rural aspect is also an opportunity in line with recent housing trends. The sunken pits provide shelter from the wind and privacy from neighbouring activities. Solar design principles can take advantage of sun-traps which produce favourable microclimates. Defined quarried areas can contain a community and also provide level areas of open space.
Housing, however, also requires a solid bearing surface with suitable surface run-off. The need for sewerage systems may deter housing development. Frost pockets will produce colder winters and the establishment of a reasonably quick vegetation cover may prove difficult. Residential uses creeping into the Rural Green Belt also conflicts with Canterbury's Regional Planning objectives.
For similar reasons the siting of industrial development in quarried areas may be advantitious. Urban fringe locations are ideal for such a use. Lower land values means that relatively large areas are available. Sinking unsightly yet necessary activities can be achieved in pits. Markets are accessible and more productive land is saved by locating industry in quarries.

Bearing surfaces and suitable drainage are required yet noxious bi-products may pollute ground water which aquifers can transport downstream. Conflicts in terms of noise, smell and dust pollution will arise with neighbouring activities. Those costs must be weighed against the benefits of removing industrial development from other areas.
3.4213 *Institutional*

From universities to prisons, institutional uses for quarried areas are another option. The creation of large areas of relatively flat land makes such a use possible. The location of quarried areas allows for access but also a degree of separation from major centres. The economics of land values also makes an institutional use favourable. The rural aesthetic may also be appropriate to hospitals or homes.

The problems associated with buildings and drainage and a detachment from the city constrain this after-use.

3.4214 *Landfill and Waste Disposal*

As with all urban settlements, dealing with unwanted material is becoming increasingly necessary. Quarry Areas seem convenient places to place metropolitan refuse, construction waste or public sewerage. In controlled instances areas to be used as rubbish tips can be lined with geotextile layers. The completed fill is then capped with a similar lining eg: clay and pipes laid progressively with filling can tap methane gas
produced by anaerobic decay. Sewerage settling ponds can produce sludge which has been a useful substance aiding soil recovery and plant growth when spread on cut slopes. Landfill is useful to return land to its former level.

This is by far the most common use of Christchurch's quarried areas. It has many unrecognised drawbacks. Obvious conflict arise with neighbours through heavy vehicles, smell and visual nuisance. Pests make such areas hazardous increasing health risks and bird strike to neighbouring airports. Pit filling is a slow process prolonging the problems and while most inert hard fill is appropriate putrescent waste concentrates the problems associates with waste disposal. Ground water is easily polluted and subsidence and differential settlement produces a poor bearing surface.
3.422 Rural Production

Most of Christchurch's quarries lie in a 'natural' setting. After uses concerned with Rural production are complementary with neighbouring uses. Food and fibre production supplies the same market that the operating quarries do giving such uses economical grounds as well.

3.4221 Agriculture and Cropping

Much of the land from which gravel is being extracted was historically pastoral and cropping land.
The titles of quarried areas may be rehabilitated and sold back to neighbouring farmers. Areas can be fenced as progressive rehabilitation occurs and cereal/fodder crops can be used in combination. These will assist in developing an organic horizon while roots help restore soil structure. Vegetating quarried areas leads to improved soil and water conservation and improves nutrient status. Visual amenity is improved as patterns of fences and ground texture and land use marry quarried land into the surrounding landscape. Shelter for stock, machinery and feed are other agricultural uses.

Poor soil structure and problems with drainage inhibits agricultural uses and an enormously reduced land capability index takes many decades to recover from.
Horticulture

Horticulture is only a recently developed use for quarried areas. Low land values, the proximity to local markets and the water table act in favour of this use. Glasshouse production using hydroponics is a means of controlling the already extreme microclimate of quarries. The flat pit floors with suitable water supplies provide large enough areas for Glasshouse production. A variety of vegetables, fruits and flowers are possible. This use relies on high inputs in terms of structures, water and soil to produce results.
Quarrying activities leave behind exposed or compacted soils of very poor quality and structure. Forestry as a land-use by default is a warranted after-use. Forestry suits the rural location of quarries and their small rather scattered nature means woodlots are appropriate. Trees initially control erosion and aid in the structural recovery of soils. Eventually they control winds creating favourable microclimates. Trees can also screen activities like ongoing quarrying or industrial uses. Forestry works well with other uses. Trees can provide for stock fodder, work in conjunction with two tier farming and provide recreation. Forestry options range from low to high soil amelioration coupled with short term to long term returns. Christmas tree production would require low soil amelioration and give short term return while Australasian hardwood forestry may require high soil amelioration giving long term return.

Problems arise in the establishment of trees. Protection from pests and stock is required as is initial irrigation. Early fertilizing will also improve the success of
forestry after uses. Seeds from wind drift can pollute aggregate stock piles when trees are established adjacent to continuing quarry activities.

3.4224 Fisheries

Fish farming is another use fulfilling the physical and economic constraints. Flowing water is often a characteristic of quarried areas especially when they are sited close to existing rivers or on springs. The latter water source is clear, fresh and flowing. Trout and salmon prefer the colder clean fast flowing water similar to our large mountain fed rivers. Eel production which has great potential in New Zealand require warmer water in shallow slow flowing courses. Native fresh water crayfish and carp are other possibilities.

Problems arise when water becomes polluted. Silt deposition and salinity effect the viability of fish farming.
3.423 **Recreational/Conservational**

Many possible after-uses for quarries have less direct economic benefits. Their success is measured in aesthetic, ecological and social gains. They can often act together with other uses which give economic benefits or as quarrying activities continue.

3.4231 **Water Conservation**

Quarry pits form ideal sites for storing water either for flood control, river management or reservoirs. Where they fall below the natural water table water bodies form naturally. Water filled quarries can act as aquifer rechargers and have the potential to allow secondary uses in conjunction with water conservation. Such uses will conflict with water conservation if they have the potential to pollute water.
Ironically many past examples of disused quarries left derelict eventually naturally colonise with volunteer species and secondary succession. This leads to diverse plant and animal communities. Such examples suggests that deliberate development of wildlife systems as possible after-use option. These would produce pockets of natural communities in the cultural Landscape in which quarries presently exist. Such pockets are a useful means of returning diversity into the Landscape. These areas would enhance the quality of life of the people living around Christchurch and become a great educational resource.

Natural areas may not, however, complement the aesthetic character of the locality and may also present a danger to children.
Quarried areas, on a more 'tamed' level, may be used as managed reserves. The topographical changes created by quarrying can help support differing microclimates which allow for differing species of flora and fauna. The existence of water bodies also helps create different Landscapes. These Reserves become educational and recreational as people participate in natural conservation and preservation.
Amenity parks for picnic areas and amusement activities are well sited in quarried areas. They are close to centres but separate enough to reduce conflicts of interest and to create an experience. There is enough space to sink car parking into and the necessary facilities and services will have been part of the previous quarry operation. Activities can vary from fishing to rifle ranges. Large scale public participatory earth sculpture is also appropriate. The question of safety arises as it does with any public use.
3.435 **Active Sports**

Quarried areas provide natural amphitheatres ideal for a range of less passive recreational activities. Flat ground can provide sheltered area for sports fields. Battered edges provide useful viewing platforms. Changes in level can produce bicycle/motor cross tracks. Interesting changes in level and water bodies can be useful for golf courses and training circuits. Large areas of water can be used by jet boats, yachts and waterskiers. A host of other similar sports from duckshooting to adventure playgrounds means quarried areas remain useful and less forbidding.
3.43 Criteria

With a range of after-uses available comes the problem of deciding upon one or a number of appropriate uses. There exist a number of criteria which can help in the decision making process and one means of applying them which is considered useful to the Christchurch situation.

3.431 Aesthetic

The nature of the surrounding Landscape will aid in an after-use decision. That Landscape has a particular character in respect to form, colour, scale and pattern. Its land use overlays that character.

Any after-use must consider that character especially at the boundaries of the quarry. The degree of visibility and the position from which a proposed after-use will be viewed from are other aesthetic considerations. The preferences and ideals of those people doing the viewing will also be important.

3.432 Ecological

The suitability of an after-use on a specific site will depend on the physical conditions of the soil found on that site and its ability to sustain growth. The landform will provide drainage of both air and water effecting an after-use. The existence of water and the relationship to aquifers will give clues to which
after-uses are suitable. The organisms which constitute the surrounding ecological system may have been disturbed and would be worth considering especially to show which species, both past and present, survived in the area.

3.433 Economic

In its broader context economics plays an important role in deciding an after-use for quarried areas. The true cost of rehabilitation must consider the demand of the intended use. This use will depend on projected populations and their associated demands. The proximity to that demand must be regarded. The economic resources of the organisation, usually the quarry operator will limit the range of after-uses. The materials on site, the volume of fill, the types of machinery and the methods used will each effect the total cost of Rehabilitation.

3.434 Other Criteria

The physical dimensions of a quarry site is an important criterion. If a number of uses are to be used together their compatibility with each other is important. Successional land-use may help decide when certain land-uses are appropriate in a progressive rehabilitation model. Safety is an important criteria especially when the public is involved.
Criteria for selecting land-use alternatives balance the cultural needs with the natural compatibility.

'Sound use patterns must take into consideration the entire environmental complex, the quarrying community and the surrounding region.'

(Zube '82)

If rehabilitation is seen as unfeasible then it reflects back on the initial feasibility of the quarrying activity itself.

3.44 Zoning

To apply these criteria to the quarries around Christchurch the present District Schemes can be used. These schemes make reference to a number of economic, aesthetic and environmental criteria in their objectives. Zoning and levels of use are the means of implementing these objectives.

It therefore seems sensible to use zoning as a means of deciding on an after-use. If for instance a quarried area is bounded by residential zones then residential sub-division in that quarry would be appropriate. Similarly for commercial, agricultural and other zoning. Quarried areas may lie on the edge of urban growth. Green open space may be appropriate to define that edge and can be used as a recreational facility for neighbouring communities. District schemes may even have open space networks or wildlife corridors that quarry zones can form part of.
The standards that exist should be expanded to complement after-use decisions based on zoning.

(4) PERFORMANCE STANDARDS

1. PROTECTION OF ADJOINING PROPERTIES

No quarrying excavation shall take place within 20 metres of any property boundary, and except in the case of the Halswell Quarry, in such a way that it cuts below a surface with a maximum gradient of 1:3 measured from a point 10 metres from the property boundary as shown below.

Provided that where a Quarry zone is less than 4 hectares in size, the maximum gradient referred to above shall be 1:2.

3.5 Some Christchurch Examples

The existing examples of Rehabilitation in Christchurch quarries highlight the opportunities and constraints of Rehabilitation.

3.51 Peacock Springs

The Isaac Construction Group operates a large quarry in what is known as the McLeans Island Group. They have operated there since 1954. In that time they have Rehabilitated 50 ha of quarried land into a wildlife park called Peacock Springs.
The owners created a trust fund from capital obtained by a few cents/tonne of aggregate sold. The wildlife park is home to many species of animals, birds and fish. The native Canterbury Mud-Fish is now safe from extinction as are Cape Barren Geese. As well as continuing quarrying activities in another corner of the 150 ha site an uncovered aquifer and a change in the fish farming laws resulted in the Peacock Springs Salmon Farm in 1978. The farm is one of the few to be fed by natural artesian water. Its produce is exported all around the Pacific.

3.52 Pavroc Quarries Limited

Pavroc, who have a quarry operation in the Miners Road Group, use part of its quarry for alternative uses. For two years an old section of the Quarry floor has been used for the glass house production of hydroponically grown green peppers which supply the local market.
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The same company has also initiated a forestry programme in their quarried areas. Eucalyptus and Acacia species were planted directly into quarry surfaces and are intended to produce firewood.

Pavroc also use as their administrative base an old pit at Hornby which had operated from 1930 to the 1950's. The old quarry also houses garages and workshop facilities, emulsion laboratories and staff buildings.

3.53 **The Groynes**

The Groynes is a recreation and wildlife park which is administered by the Waimairi District Council and serves the Greater Christchurch population. It was once the quarry that supplied aggregate for the Northcote Expressway but now welcomes thousands of visitors, especially during the summer months, for picnics and water based activities. Over usage threatens the wildlife function it performs which highlights the need for more of its kind.
DESIGN APPROACHES
4. **DESIGN APPROACHES**

4.1 **Site Design and Organisation**

Once an after-use decision has been made or at least considered the specific design of a Rehabilitation programme can proceed. The site must be organised in such a way that it is directed, facilitating the proposed after-uses.

4.11 **Programming**

In the past Quarrying generally occurred in a haphazard manner. Gravels were extracted as quickly as possible. More recent changes have seen programmes drafted to rationalise operations. Such programmes help to progressively Rehabilitate Quarries. This means those doing the physical work take an active role in the Rehabilitation process. Problems such as soil compaction and poor soil structure can be ameliorated. These programmes direct the operation over the 'whole' site while also detailing activities such as tipping.

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*Figure 4. Experiment Programme and Master Plan*

**KEY**
- Banded Trench
- Trench Subarea 1
- Trench Subarea 2
- Channelled Area
- Excavated Area
- Fixed Area
- Trench Trenching Line
- Surface Face
- Joint Movement
- Direction of Filling

49 **PROGRAMME PLAN (Sept 94 + 95)**
4.12 Screening

The mitigation of visual intrusion, noise and dust pollution are problems associated with Quarried areas. Mere distancing may avoid many of these problems but often some form of screening is required. Perimeter Banks or Planting can screen from view quarry operations as they continue as well as noxious after-uses eg: industrial uses. They also absorb much of the dust and noise generated in quarried areas.

Banks and Planting are most effective when used in combination. They should be positioned with regard to important sight lines, the distance between source and receiver and the prevalent wind directions. Screening can also protect activities within a quarried area. Shelter from the wind is a priority around Christchurch.

4.13 Buildings and Structures

Some areas may prove difficult to screen while others will want to be in full view. If so an aesthetic standard must be set.
The scale, form and colour of buildings, be they existing quarry plant or residential housing, must be sympathetic to their context. In the case of most quarries around Christchurch a rural aesthetic is appropriate. Similar standards should exist for landform and vegetation which respond to geological, ecological and cultural patterns.

Visual organisation of the site relies not only on the appropriateness of the individual structures but the relationship between them. The space between objects is just as important as the objects themselves. Dominant structures or forms will act as foci which sited in relation to other objects will effect the composition of a layout. In the flat Canterbury landscape sinking structures into quarried areas helps in achieving a naturalistic aesthetic.

4.14 Other Layout Considerations

Siting waterbodies will depend on their connection to a proposed after-use and can direct depths of excavation. Access is another important aspect of site design. During a quarry's operating life only one or two points of access are required for safety and security. Resulting after-uses may need a number of access points especially down to the Quarry floor. Intermediate land-use which compliments the rehabilitation process eg: hardfill dumping should also be considered as an element in site design and organisation.

Site design is a function of the potentials of a specific site with respect to possible after-uses as well as the attitudes and resources of an operator to plan for future direction and uses.
4.2 Landform Design

Land formation is important to Rehabilitation in that it creates the 3 dimensional framework for an intended use. It is a good example of how integral rehabilitation is in the quarrying process. Quarrying itself alters the landform which will sustain the next land-use.

4.21 Economic Considerations

The question of cost is a significant part of landform design. Volumes of extractable material will leave the voids, and quantities of overburden or landfill will determine the amount of fill. If the cost of reforming the land to a usable state is considered as part of the cost of extraction then it should therefore be paid for by the income from the product. Charging for landfilling can also cover the costs of rehabilitation.

To keep the process cost efficient the machinery used for the quarry operation should also be used for land formation. Progressive Rehabilitation makes use of the available machinery and skills of the Quarry workers. Minimal movement of material is both an ecological and economic factor. Self maintaining landforms will also reduce ongoing costs.
4.22 **Aesthetic Considerations**

Self maintaining systems suggest natural systems and lead to the question of the form of the framework. Artificial, geometric forms add interest, order and reflect the manipulated nature of quarried areas. They may be appropriate in certain situations eg: land sculpture. Natural landforms are sympathetic and integrate with the surrounding landscape. They conform with natural drainage systems of air and water. Maintenance becomes less of an expense with natural forms because of their inherent stability. The boundary conditions or edges (slope to flat, land to water) are other important areas where the natural versus artificial aesthetic must be addressed.

4.221 **Unity**

"No matter what else a visual configuration must have; it must possess unity."

(Cole et al '72)

The design of land formation in quarried areas, be they artificial or natural, is guided by aesthetic principles. Unity is the property which creates the entity as a whole. It is achieved through order and coherence of the whole yet enhanced by harmony and diversity between the parts.

4.222 **Interest**

The change of level created by quarried areas is an important aesthetic feature. Landform should take advantage of this.
Land formation can also manipulate the space between objects mentioned earlier. Confine, openness and scale contribute to the visual composition. Their relative rates of change plus level changes create interest and experience as you move amongst landforms.

4.223 Importance of Landform Aesthetic

Vegetation takes time to establish in those first number of years. The visual appearance of a rehabilitated area during those years will be directly influenced by the nature of the landform. Even years later it will remain as the basic structure underlying a new land-use.

4.23 Land-Use Considerations

Landform design must adapt itself to the various land-use constraints of after-uses. Each after-use option will have an appropriate land formation. A playing field requires up to 1 ha of level ground with suitable falls. A rolling naturalistic landform may be appropriate for a Rural lifestyle sub-division while large, rigid, squared landforms would suit an industrial Estate.

Landform design moves to increase the stability of the land, improve the aesthetic appearance suited to that land and be tailormade to a particular after-use.
4.24 Ecological Considerations

Landform provides the platform for vegetation cover and land-use. It plays an important role in creating overall drainage patterns for air and water. Such drainage will determine erosion patterns. Landform creates microclimates unique to a location. The success of planting is a measure of those microclimates ability to support growth.

Landform will be constrained by differing angles of repose. These are illustrated and are a function of particle size, moisture content and degree of consolidation. The least possible soil movement will minimise the loss of structure and degree of compaction allowing the material greater chance of sustaining growth.

- Dry sand
- Loam (well drained)
- Compacted clay
- Non-compacted clay
- Stones, gravel and coarse sand
- Compacted sand, forest covered
- Hard rock

ANGLES OF REPOSE (Lopin '83)
DESIGN TECHNIQUES
5. DESIGN TECHNIQUES

5.1 Hydrology

Bearing in mind quarries create pits up to 10m deep, often work close to rivers and aquifers and will eventually require a vegetation cover, hydrology plays a significant role in Rehabilitation.

5.1.1 Surface Water

Water is necessary to sustain the growth of a vegetation cover but in most quarried areas surface water will bring problems with erosion. The vulnerability of an exposed ground surface made more so by the manipulation to new landforms, often inclined slopes, results in gully and sheet erosion.

5.1.1.1 Drainage Systems

To fix unwanted erosion, especially before vegetation can establish itself and help prevent erosion, drainage systems will need to be installed. Drainage systems must cope with estimated run-off from a rehabilitated slope. Run-off is a function of topography, the soil and the catchment areas. Drainage methods try to correct erosion and encourage water penetration into the growing medium. Scarifying the surface roughens it to allow for more infiltration. This can be achieved by deep ripping the surface of a slope. Rips at an angle can also channel and direct water across a slope rather
than down it. Benches and terraces in a slope slow and retain water while ridges and ditches direct it. The drainage system must relate to the pattern of water movement over a site which is in turn manipulated by the landform design. More advanced drainage systems can help establish vegetation by acting as irrigators. The type of drainage system will depend on the various after-uses. Drains must be maintained to be continually effective but as the vegetation cover develops they will become less important.

5.112 Water Bodies

The drainage system eventually has to drain somewhere. In quarried areas this generally means low lying bodies of temporary or permanent water. Such areas will need careful siting in terms of layout and may form an important function in an intended after-use. These areas are also important nodes of life and growth. This means that water quality is of considerable importance and must be controlled for the sake of natural inhabitants, visual attractiveness and human safety.
5.12 Subterranean Water

Surface water leaves the site and eventually enters the ground water hydrological cycle through unconfined aquifers. Surface disturbance frees silt sized particles which can be leached into underground water systems. The presence of these suspended particles temporarily pollutes ground water. Rehabilitation should prevent this happening by controlling erosion and trapping these particles. Contamination of ground water from any toxic source especially from non-inert fill is a great problem Rehabilitation should resolve. The impending rise in the ground water by up to a metre due to the Green House effect should also be a consideration.
5.2 Soils

Soil is the medium that sustains growth. The main reason for substrate treatment is to modify, within limits, the negative growing conditions that occur in quarried areas. There are two steps involved in modifying the soil disrupted by quarrying activities.

5.21 Soil Movement

Soil movement begins with the first quarrying action. The top horizons which are of little use in terms of aggregate production are the very materials which are important in reconstituting the new soil base. Care must be taken to remove horizons separately, the top horizon (A) first then the subsoil (B horizon) and stored appropriately. Exposure to biochemical and physical degradation will slowly deem stored soil infertile. Some put this figure at one year but it will depend upon the area, volume, degree of exposure and siting of the stored material. Progressive Rehabilitation encourages this stripped material to be used immediately either to cover previous workings or to construct screening earthworks around the perimeter of a site. It is important to note that if soil is to support life it must be placed in the order that it naturally occurred.
5.2.11 Problems in Soil Handling

Soil movement results in structural damage and as mentioned should be kept to a minimum. Handling needs careful forethought and is dependent upon the weather. When the moisture content is high especially in soils with high clay content soil movement is physically more difficult. Problems with waterlogging and excessive compaction are more likely. Compaction can be avoided by reducing the number of passes heavy traffic makes over new or stored soil. Back acting or limiting vehicular routes confines compaction. The use of self laying tracks also reduces soil compaction compared with rubber tyred equipment.

5.2.2 Treatment

After soils have been moved and redeposited, ideally to their final position, cultivation is essential to improve their productivity as a growing medium.

5.2.2.1 Ripping Techniques

Ripping techniques increase water infiltration, help surface drainage as discussed and reduce the bulk density of a soil. Ripping should be done before the final surface preparation and also carried out in dry conditions. Ripping involves heavy machinery which adds to soil compaction problems. It is also a costly
exercise and tends to bring large aggregates to the surface.

5.222 Soil Additives

Amendments are often needed to improve the structure and fertility of top soil. The depth of top soil is dependent upon the subsoil structure. In Christchurch's quarries areas that A horizon is generally quite thin (less than 50 mm). Overburden, the unwanted silt and clay sized particles, can be added to topsoil to improve such soil qualities as water holding capacity, nutrient exchange and reducing leaching.

Organic additives improve nutrient status and provide the living component of a soil often missing or removed from Quarried soils. An outside source of organic material such as sewerage sludge may be added. Trace elements may also be required before successful growth is ensured. Fertilizers are a cheap method of applying nutrients to soils. They will depend upon the nutrient requirements, the pH of the soil plus the range of machinery, fertilizers and application techniques available.
5.223 Final Surface

The final surface and seed bed preparation is another vital part of treating substrate. This depends upon the gradient of a surface. Generally a rough surface microtopography provides a better growing environment. The final surface will depend upon the type of after-use and its requirements of slope and vegetation.

5.224 Microfauna

The microfauna which give soils their life are another critical part of reconstituting a growing medium. Soil fauna breakdown organic material assisting in nutrient recycling. They mix and aerate soils and are a good indicator of a soils health. Microfauna and larger mesofauna are killed when soils are removed and stored and when moisture content, temperature and chemical conditions become extreme.
An understanding of soil fauna as an integral part of a soil system and the changes in populations as soils develop, can increase soil recovery during Quarry Rehabilitation.

5.225 Alternative Methods

Redeveloping soils can employ other techniques that go beyond traditional methods. Conveyor belts can be used to reduce handling. Techniques such as broadcast fertilizer application or poldering (applying soil as a slurry mix) are other approaches. Education of the people involved in the work is again paramount. Their attitudes will ultimately determine the success of the soil as a growth medium. Soil movement and treatment are of course an integral part of Rehabilitation. Physical, chemical and biological processes relate soil to landform and vegetation and it should not be seen in isolation.
5.3 Vegetation

Planting forms the tip of the Rehabilitation 'iceberg'. It is the more visible component but its success relies on the planning, design, groundwork and management which have gone into creating it. Planting can be considered in two stages. Suitable species must be selected and then physically established.

5.3.1 Selection

The types of species suitable for a Rehabilitation Project will be greatly reduced by the extreme conditions encountered in quarried areas. This narrow range will be further reduced by the requirements of the after-use. Agricultural plants will need to be palatable or productive. Plants for wildlife reserves may need to be endemic to create suitable habitats. Sportsgrounds will need wear resistant grasses. Where plants are limited by the nature of quarries they can also help improve those conditions. Plants can assist the soil's physical, chemical and biological properties. Pioneer species also stabilise soils and act as nurse crops for successional development of plant species.
5.311 Aesthetics

The aesthetic qualities of plants should also be considered. When selecting the right species, colour, form and texture can be used to harmonise or contrast. Planting can define space and manipulate scale. They can emphasise boundaries or indicate changes in landform. Planting can also screen areas or frame views.
5.32 Establishment

The best method of establishing vegetation will depend on the following factors:

(a) The type of vegetation appropriate;
(b) The type of after-use;
(c) The constraints of time;
(d) The weather and season;
(e) The ground conditions and topography.

Plants can be established by either seeding, planting or turfing.

5.32.1 Seeding

Seeding is the cheapest and quickest method but is only appropriate for certain types of plants. Seeds can be applied by burying in the ground or spread on the surface. The timing of seeding depends on individual species but generally should be conducted during August and September. Seed drilling or furrowing buries the seed, giving it a greater chance of survival. Broadcasting is a cheaper alternative for larger areas. Two passes at right angles to one another ensures an even distribution. Fertilizer or a ratio of soil can be added to seed mixes.

Hydroseeding is a method used on difficult terrain. A slurry medium consisting of seed, fertilizer and mulch is applied through a water pump. Laying of slash eg: manuka is another method of providing a seed source.
5.322 Planting and Turfing

Planting gives visible results more rapidly than seeding. Material may be bare rooted or container grown depending on species, function, quality and cost. The growing and handling of nursery stock must consider the harsh conditions plants will be expected to grow in. The initial stress can be lessened by adding topsoil around the root ball and irrigating the young seedlings.

Turfing fragments can be used to establish grass and herbacious vegetation. A good contact with the surface increases stability and root penetration.

5.323 Amendments

The following improvements increases the chance of survival of newly established vegetation. Mulches can improve soil moisture, conserve temperature and suppress competition. They can also improve the organic horizon of the soil.

Mulches can either be granular like stones, bark; or sheets of polythene or newspaper. Perimeter fences may be necessary to control pests but old crusher meshes, drums or tyres provide good individual tree protection. Temporary irrigation systems are often necessary in the first few growing seasons and microrhizal inoculation greatly increases a plants capacity to absorb fluid. Spreading a layer of fertile humus is a common way of doing this.
5.4 Management and Cost

If a site is to develop once substrates, surfaces and vegetation have been considered a level of management is essential. Management is another cost and should therefore be proportional to the benefits of an after-use. Management strategies should consider short term establishment needs and long term goals and objectives.

5.41 Maintenance

Part of management is a regular monitoring programme which follows the progress of a rehabilitated site. Soil tests and vegetation surveys are part of this. Comparisons with previous results and expected conditions can detect and alleviate problems. The upkeep of drains and control of pests are other aspects of maintenance.
5.42 **After-Use**

Different after-uses will require different levels of management. Rehabilitating quarried areas to agricultural pasture must consider crop rotations and grazing regimes. Forestry uses will require pruning and thinning as part of their management plans. Land filling must consider standards of fill and monitor and police the quality of material.

5.43 **Responsibility**

If the Quarry Operator is to retain ownership of the land then with that goes the responsibility to ensure that land is looked after. British studies show that larger or expanding firms are the most successful in Rehabilitation Projects. They have greater resources, wider public concerns and attempt more projects. A rehabilitation officer with an office on site and who has good relations with local authorities helps in successful Rehabilitation.

5.44 **Cost**

Rehabilitation must be viewed as a cost of the quarrying process. This means that ultimately the consumer of aggregates and the users of an after-use pay for Rehabilitation. Funding can come from a cut of every metre of aggregate sold or from the earnings of an after-use eg: percentage of a landfill charge. In the end it is the value of the land or the value of an after-use which determines the success of Rehabilitation.
6. RECOMMENDATIONS AND CONCLUSIONS

6.1 Recommendations

In the USA and UK Rehabilitation, largely through legislation, is considered to be an integral part of the Quarrying Process. Here in New Zealand we have until recently been stuck in the Post War Planning System we inherited from Britain. Rehabilitation, as a result, has been controlled by statements like this.

'The sites of excavation, heaps, dumps, soil or other material at any workings or plant which cause or are likely to cause damage to property or disfigurement to the countryside shall be progressively restored, in accordance with a programme approved by the county Engineer, to a reasonably natural state by levelling or backfilling where possible and by the planting of grass or trees and on completion of the work by the removal of plant and buildings.'

(Heathcote County District Scheme '80)

If New Zealand is to dig itself from the 'Pits' Earl Bennett reported it to be in at the 1981 NZILA Conference then we must consider alternative measures of developing rehabilitation.

6.11 Legislation

Non-interventionism has a place in New Zealand's laisse-faire attitude to politics and life. Up until the 1980's such attitudes applied directly to quarry Rehabilitation.
With British Post War Planning came intervention methods which still today clash with colonial and Maori ideals. Such a collision accounts for New Zealand's unique mining laws and views towards Rehabilitation.

Interventionism however produces results and comes in different levels of control.

Mandatory policy, rather like the English example, creates laws which insist on rehabilitation as the responsibility of the Quarry Operator. Enabling legislation, rather than insisting, places a framework which encourages rehabilitation. Such a method may also include monetary assistance to initiate rehabilitation. A bond scheme exists in Britain for such a purpose.

The least extreme form of intervention would be to generate awareness. This has been achieved overseas by involving professional bodies to support Rehabilitation competitions. Peacock Springs has been successful in such competitions. Education is another way of increasing awareness. The following extract from a District Scheme is an example.

'To emphasise that quarrying is regarded as an interim land-use and that when extraction is completed it should be left in or developed into a form such that it can be continued to be used for another permitted use in the future.'

PAPARUA DIST. SCHEME CHANGE 1988.
6.2 Conclusion

This study has addressed a situation which has been given a lot of attention in developed Northern Hemisphere countries. Like many things New Zealand's relative isolation, size and lifestyle has meant quarry rehabilitation has only recently become recognised.

In 1981 at an NZILA Conference it was described as a 'with it' topic. Not a lot has happened since then but growing concern from the public and Local Authorities is presenting Landscape Architecture with a great opportunity.

Quarries are becoming a problem. Our land based profession seems well equipped with land system knowledge, communication skills and intuitive imagination to solve these problems.

We can be helped by Regional and District schemes, which are already reacting to public concerns in a variety of ways.

This study has pooled together overseas material and applied it through meetings with the people and places involved in the quarries around Christchurch.

I have highlighted the problems and presented some solutions. My argument for rehabilitation is based on economics, aesthetics and ecological principles as well as the moral issue of land-use.

Land-Use is Good.
Wise Land-Use is Better.
Continuous Land-Use is Better Still.

(W. Fulton '89)
BIBLIOGRAPHY

Bennett E H 
Are We In The Pits NZILA Conference 1981

Bennett E H 
Rehabilitation of Sand and Gravel Quarries Paparua County 1982

Bradshaw A D and Chadwick M J 
Restoration of Land - The Ecological and Reclamation of Derelict and Regraded Land Blackwell Scientific Press 1980

Coates and Scott 
A Study of Pit and Gravel Rehabilitation in Southern Ontario Ontario Geological Society Misc Paper No.83 1979

Coles NF etal 
Visual Design Resources for Surface Mine Reclamation University of Massachusetts Annherst 1976

Coppin N J and Bradshaw A D 
Quarry Reclamation Mining Journal Books 1982

Hackett B etal 
Landscape Reclamation Practices IPC Press 1979

Haywood S 
Quarries in the Landscape British Quarry & Slag Fed 1974

Holmberg G V etal 
Land Disturbances and Reclamation Ohio Ag Research Station 1976
Hutnime and Davies
Ecology and Reclamation of Derelict Land
Vol 2
Blackwell Scientific Press 1978

Johnson and Pascoe
Land Utilisation and Reclamation in the Mining Industry 1930-1980
Dept for the Interior 1982

Landerman et al
The Development and Rehabilitation of Sand and Gravel Lands
Dept of LA, University of California 1972

Lucus D
Sandy Point Domain Invercargill
Lincoln College Press 1973

Malloy et al
The Land Alone Edures
DISR Soil Bureau 1983

McKenzie D J
Landscape and the Larger-Scale Surface Mining of Lignite
Lincoln College Press 1981

McQueen
Land Reclamation after Gravel Extraction on Ranzau Soils
NZ Soil Bureau 1983

Philips, Brant, Orange Reserves Sand and Gravel Extraction
Reddick EIR
City of Orange, Cal 1979

Sims et al
Land Surface Reclamation
Ontario Geological Survey 1984

Ward M
Environmental Perspectives of Mining in NZ
Ministry of Engergy 1986
Ward M  
*Mined Lane Rehabilitation in New Zealand*  
NZILA Conference 1981

Weeber Y  
*Landscape Implications of Coastal Aggregate Extraction*  
Lincoln College Press 1987

AIMM  
*Landscaping and Land-Use Planning as related to Mining Operations*  
Australian Inst. of Mining and Metallurgy 1976

Dept. M & E (Australia)  
*Mine and Quarry Rehabilitation in South Australia*  
Dept. Mines and Energy (Aust.) 1980

Mines Division  
*Rehabilitation of Mined Land*  
Ministry of Energy (NZ) 1986

NZMEA  
*Restoring Mined Land*  
NZ Mining Exploration Association

Sand and Gravel Asso.  
*Land Restoration Experiments*  
Dept. of Environment (UK) 1977  
Report No. 1

UDSA Forest Service General Technical Reports  
No. 57 *Tailings, Ponds and Dumps*)  
64 *Vegetation* ) 1979  
68 *Soils* )

Journals

Environmental Quality Journal  
No. 4 1987 *Relative Effectiveness of Sewerage Sludge as a Nitrogen Fertilizer for Tall Fescue*  
Kiemnec
<table>
<thead>
<tr>
<th>Publication</th>
<th>Date</th>
<th>Issue/Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landscape Architecture Magazine</td>
<td>Jan '66</td>
<td>Landscape Reclamation Vambus</td>
</tr>
<tr>
<td></td>
<td>Jan '79</td>
<td>Planning a Quarries Re-Use McKenzie</td>
</tr>
<tr>
<td></td>
<td>June '85</td>
<td>Still Life in a Quarry Dalton</td>
</tr>
<tr>
<td>The Landscape</td>
<td>Spring '88</td>
<td>At the Groynes Greenup</td>
</tr>
<tr>
<td>Landscape Design</td>
<td>Feb '83</td>
<td>Good Practice for Agricultural Restoration of Sand and Gravel Workings McRae</td>
</tr>
<tr>
<td></td>
<td>Dec '86</td>
<td>Land-Use on Reclamation Sites Lindley</td>
</tr>
<tr>
<td></td>
<td>April '88</td>
<td>Restoration of Heather Moorland Putwain</td>
</tr>
<tr>
<td></td>
<td>Feb '89</td>
<td>A Hard Future for Derelict Land Micheal</td>
</tr>
<tr>
<td>Landscape Planning</td>
<td>No. 1 1974</td>
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<tr>
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<td>Vol. 11 No. 1</td>
<td>How to achieve Good Quality Land Restoration Street</td>
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Water and Soil Journal (NZ)
  June '79  Sand and Gravel Survey in Taranaki Glass
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  No. 2 '85  Gravel and Grants Brougham
  No. 4 '86  Rocks from the Rivers N.W.A.S.C.A.

Quarry Management
  June '88  Quarry Restoration Wins 3 Awards

Rock Products Magazine
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  Sept '87  New Reclamation Ideas Proposed Katz
  July '88  Quarry to Golf Course Culbertson
  Aug '88  Using Computers in Reclamation Rukarina