Report No: CCC 020714

QUARRY REHABILITATION

Background Report for Christchurch City Council District Plan Review.

TWELFTH KNIGHT CONSULTING

Report prepared by Twelfth Knight Consulting for Christchurch City Council – July 2014

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Acknowledgement and thanks for the provision of information are due to staff of the following organisations:

- Christchurch City Council
- Fulton Hogan Ltd.
- Selwyn Quarries Ltd.

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SUMMARY.

S 1. Introduction.

S1.1 Project Background.

The Christchurch City Council (the Council) is currently reviewing both its Banks Peninsula District and Christchurch City Plans with the intention of amalgamating them into a single document.

A key issue with respect to quarrying activity relates to the rehabilitation and potential end use of excavated sites. The current approach to rehabilitation was formulated on the basis that land should be progressively reinstated to at least pastoral farming standard

Partial or full back filling with cleanfill to achieve contours at or near pre-quarrying levels was not considered to be a viable option due to a lack of appropriate cleanfill material and concerns over potential contamination of groundwater.

Finished contours of former quarry sites generally differ markedly from both their pre-quarrying state and those of the surrounding un-quarried land. Significantly the depth of the protective material between the floors of the quarries and the underlying unconfined groundwater, which is the source of Christchurch city's water supply, is much reduced.

It is understood that the Council believes that the current District Plan review provides an opportune moment at which to review the appropriateness, or otherwise, of the current approach particularly with regard to:

- Ensuring that land is not sterilised from a range of appropriate future uses.
- The protection of the city's groundwater resource.
- Maintaining visual amenity and landscape character.

S1.2 Project Objectives.

To provide an assessment of:

(1) The types and availability of potential rehabilitation materials.

(2) Central government policy on rehabilitation and directly related matters.

(3) Environmental issues pertaining to rehabilitation.

(4) Potential constraints on future sites.

(5) Three potential options for quarry rehabilitation:

- Status Quo – retain the current City Plan rule.
- Full remediation involving sites being backfilled to the land contours that existed pre-quarrying.
- Partial remediation where sites are substantially backfilled.

S1.3 The Christchurch City Cleanfill Licensing Bylaw.

The materials deposited at quarries are not only regulated by the site's consent conditions but also by the "Christchurch City Cleanfill Licensing Bylaw" which was introduced in 2004 with the overall objectives of increasing waste minimisation within the construction industry. A schedule appended to the Bylaw regulates the types of materials that may be deposited into cleanfills in the area under the Council's jurisdiction.

S2. Quarrying and Cleanfilling.

S2.1 Quarry Locations - Current.

Existing quarries are found in the vicinity of Pound and Barters Roads, Miners Road and McLeans Island Road.

S2.2 Quarry Filling and Rehabilitation - Current.

Of the fully excavated areas in recently or currently active quarries within the Council's territorial boundaries, less than 20% has been fully rehabilitated.

In summary only Taggarts at Miners Road, Road Metals at West Coast Road, Fulton Hogan at Pound Road and Isaacs north of Mcleans Island Road have completed any rehabilitation. Apart from the conservation area at Isaacs and a small block of forestry, completed rehabilitation has consisted of either battering side slopes with no filling or backfilling generally to or near previous land contours, followed by topsoiling and sowing with pasture grasses.

S2.3 Quantities and Types of Fill Materials - Current.

The quantities of materials entering quarries pre-earthquakes amounted to approximately 25% of overall study area land based production. Fill material originates from a range of construction, maintenance, demolition and site clearance activities and comprises, top soil and other natural materials such as clays and gravels, and inert manufactured materials, for example bricks, pavers and concrete.

S2.4 Quarry Locations - Future.

Permits and applications issued and / or under consideration by New Zealand Petroleum and Minerals provide an indication of where quarries may wish to develop in the future. The current data suggests that the industry may wish to develop new sites primarily in the area between Chattertons, Mcleans Island and Old West Coast Roads and between SH 73 and SH1 at Templeton and in the vicinity of the Paparua Prison.

S2.5 The Earthquakes.

The earthquakes disrupted the previous local pattern of cleanfill material production and deposition in respect to not only the location of deposition but also the types and quantities of materials being generated. Significant quantities of materials have been deposited at the Burwood Resource Recovery Park, the Lyttelton Port Company's port reclamation site and at Portlink Industrial Park, in Heathcote.

Whilst it is not possible to be definitive, an analysis of the data collected under the auspices of the Christchurch City Cleanfill Bylaw indicates that of the order of an 'additional' 0.75 million tonnes of materials have been received at the cleanfill sites post September 2010 to date. The quantum of earthquake related materials brought into cleanfills for deposition appears to have peaked in 2013. Quantities of 'additional' materials received in the period January to June 2014 appear to have reduced substantially.

S2.6 Quantities and Types of Fill Materials - Future.

With the exception of the current distortion in cleanfill material quantities and types consequent on the earthquakes, it is likely that the types of materials being received at the quarries for disposal and the ratio of returning fill to production will remain similar to that in the past.

2.7 Timescales for Rehabilitation - Future.

In the case of the local alluvial gravel quarries the time taken to rehabilitate a quarry is a function of a number of factors, the interplay of which will vary from quarry to quarry. In general quarries may require from one year upwards to complete rehabilitation. Rehabilitation plans that require more than five years to complete post closure may however not be economically viable and are therefore potentially conceptually flawed from the outset.

S3. Constraints.

S3.1 Environmental.

Consent conditions for cleanfilling, set by Environment Canterbury have become increasingly prescriptive with the passage of time. The Ministry for the Environment (MfE) "Cleanfill Guidelines" (the Guidelines) have been increasingly used as the default document with regards to the setting of consent conditions.

Whilst some aspects of the definition of "cleanfill" within the Guidelines have been, and continue to be the subject of debate, it has been agreed by the industry that certain materials should not generally be accepted into unlined cleanfills without strict controls should those materials originate from sites where known hazardous chemicals are or have been present in the past.

In the local context it is vitally important that the unconfined groundwater, which is Christchurch's sole source of potable water and which underlies all of the existing quarries, and potentially all of the future quarries in the Council area is protected from contamination. Accordingly local cleanfill consents are beginning to contain prescriptive chemically based waste acceptance criteria (WAC).

MfE are currently reviewing the Guidelines and are working towards integrating them with an existing parallel set of guidelines for landfilling. There are on-going discussions between MfE, WasteMINZ and industry in particular with respect to the setting of appropriate WACs.

It is possible that the current, local cleanfill acceptance processes may have to include a more rigorous chemical testing regime and although this may increase the cost of cleanfilling locally it is thought unlikely to have a major impact on the amounts of materials being deposited into cleanfills provided that a workable compromise can be achieved with MfE.

S3.2 Engineering.

There are generally no controls imposed on the mixture or sizing of materials deposited at quarries other than those necessary for compliance with consent conditions and the requirements of the Cleanfill Bylaw. The only compaction of the fill is incidental to the running of trucks and machinery over the surface as the face progressively moves forward.

Accordingly voids, softer material and varying levels of compaction are liable to occur more or less randomly across the filled area. In turn this will lead to varying rates and amounts of settlement, neither of which are desirable if any form of structure is to be constructed on the site at some time in the future.

If the site is to be used after rehabilitation to accommodate light structures it is preferable that the fill material and its placement conform, as a minimum, to the requirements of NZS 4431: 1989 – "*Code of Practice for Earth Fill for Residential Development"*. Alternatively, provided large sections of concrete and / or boulders are excluded from the fill or placed in specifically identified location(s) within the fill confines, it may be possible to use driven or bored piles, founded on the natural gravels at the base of the fill, to provide foundations for structures that may be constructed once rehabilitation is completed.

Comparison of the economics of these alternatives are however beyond the scope of this report suffice it to say that it is unlikely that compliance to NZS 4431 for other than relatively shallow fills would be economically efficient.

S3.3 Climatic.

Climatic conditions within a rehabilitated quarry will to an extent determine its end use. Current information suggests that local conditions in unfilled or partially filled quarries may be similar to the surrounding undisturbed land. Further research is required to confirm this.

S3.4 Soils.

Very few, if any, plant species are capable of economic production on the drought prone soils that consist much of the cleanfill material being deposited. Most species would require soil modification, adequate rooting volume and potentially irrigation for satisfactory plant growth to occur.

S3.5 Size, Shape and Depth.

The ultimate plan form and depth of a quarry will have a marked impact on rehabilitation options. In some cases areas where excavations are shallow, relatively little, if any, fill will be required – simple low angled batters would readily meld the excavated areas into the surrounding land. In the case of small, irregular shaped, relatively deep, isolated excavations however significant amounts of fill will be required to return the area to its original form. In the alternative, rehabilitation in the form of reconstructed side slopes only will result in an effectively unusable narrow area at the base of the excavation which may well pond. The latter could present a contamination risk to the underlying aquifer.

Where a number of quarries abut, an area wide rehabilitation plan would encourage a more efficient end use of the land.

S3.6 Quantum of Fill.

As noted in S2.3, the quantities of materials entering quarries amounts to approximately 25% of total land based production. In other words there is only enough material to totally refill approximately one quarter of the excavated areas. This will inevitably result in the majority of sites being only partially refilled, if at all, apart from the need to satisfy Council side slopes requirements.

S3.7 Economics.

Whereas pre Bylaw the quarries generally viewed cleanfilling as a marketing tool it is now seen as a viable stand-alone business. However those depositing materials prefer, for reasons of travel time, to unload fill material and reload with new product at one contiguous site. Accordingly once a quarry is exhausted cleanfilling will also cease unless an adequate incentive can be offered to those carting cleanfill materials to divert their routes.

S3.8 Compatibility with Surrounding Uses.

End uses should be compatible with existing, surrounding land uses wherever feasible.

S3.9 Regional Planning Environment.

In order to undertake cleanfilling consents are required from Environment Canterbury to enable deposition to land and discharge to air. These consents are normally obtained concurrently with those required for quarrying. Provided current "best practice" methodologies are used, the conditions pertaining to these consents are not problematic with respect to filling operations. Possible changes to acceptable materials criteria may require increased acceptance testing, however this is not currently expected to have a marked impact on the quantities of suitable material available as fill.

S4. Options.

S4.1 Status Quo.

The current City Plan requires that:

"(A)ny mineral extraction activity which results in an area of completed excavation exceeding 2ha in area and/or has been discontinued for a period of more than three years, without being re-soiled and left with an established vegetative cover, shall be a controlled activity unless the Council has approved a rehabilitation plan for the site(s)".

This may potentially lead to the loss of the productive use (or "sterilisation") of the land associated with smaller, isolated quarries that might have otherwise been valuable for a number of uses if fully filled.

Although the larger sites are unlikely to be fully backfilled they are potentially less problematic in that once the side slopes have been constructed the area at the base of the quarry (or partially filled site) will be of a sufficient size to be usable for at least their pre-quarried pastoral purposes.

S4.2 Rehabilitation – Full Backfilling.

Rehabilitation involving sites being fully backfilled to the land contours that existed pre-quarrying is unlikely to eventuate except possibly at the smaller sites if the owner is minded to do so for economic reasons. The latter might occur if the resulting land was required for residential, commercial or industrial purposes. None of the existing quarries are sufficiently close to the urban boundary to potentially fall into this category.

Alternatively for those new, small quarries that may wish to establish in those areas designated by the Council for future development it may be advisable to ensure that complete re-filling is achieved through the imposition of appropriate consent conditions and a sufficiently large performance bond.

S4.3 Rehabilitation – Partial Filling.

Rehabilitation where sites are substantially backfilled is again unlikely in the majority of cases owing to the paucity of suitable filling material.

Partial, or no filling, of those larger quarried areas in the eastern section of the Mcleans Island area, where excavation depths are commonly less than 5m, may, subject to groundwater levels, be appropriate as such will not impact markedly on the usefulness of the rehabilitated ground.

The larger and / or deeper, quarried areas, are likely only to ever be partially filled. Rehabilitation plans for these or any new similar quarries need to acknowledge this, unless specific effort is directed otherwise.

S4.4 Rehabilitated Land Uses.

An economic analysis of the options has not been conducted as the situation varies significantly from quarry to quarry.

Pastoral: The pre-quarrying activity of the majority of the sites was pastoral in nature. The partially or fully filled quarries would be suitable for a resumption of pastoral uses provide adequate topsoil is spread over the completed fill.

Cropping: The range of potentially economic crops will be limited by the degree of shelter, irrigation and soil improvement provided. The addition of soil amendment materials, such as composted municipal “green waste”, may be required to improve the soil structure and its water holding capacity.

Dairy: Dairying is potentially unsuitable on unfilled / partially filled sites due to the increased risk of nitrates and effluent leaching through the reduced thickness of materials sitting above the underlying unconfined aquifer.

Forestry: Forestry is unlikely to be economic on smaller blocks. Species chosen may require tolerance to high water-tables in those larger sites which are either not or are only partially filled.

Fish Farming: Isaac Construction have pioneered fish farming locally and have proved that it is an economically viable option. However it brings with it risks of groundwater contamination and potential problems with respect to encouraging bird life into the area which might then, in some cases, pose a threat to nearby airport operations.

Recreation: Numerous old quarries around the world have been transformed into generally passive, recreational areas, many with a botanical theme. More active pursuits such as running, horse riding, mountain and trail bike riding facilities could be developed by appropriate contouring of fill within the quarries. However, given the number and very extensive total area ultimately requiring rehabilitation, it is unlikely that the city would have the financial ability to sustain more than one or two sites for publicly funded recreation purposes.

Residential: Provided that suitable fill compaction is achieved, or alternative foundation methodologies are economically feasible, carefully contoured and landscaped sites within the larger, or preferably combined quarries where they are contiguous, would provide sites for “lifestyle” blocks. Care would need to be taken with the handling and treatment of sewage and stormwater to prevent groundwater contamination. However it is understood that Environment Canterbury’s Regional Policy Statement does not support “rural - residential” activities in the locale of the existing quarries.

Commercial and Industrial: Whilst this type of development would be physically possible the advisability of such uses sited directly over the unconfined aquifer that supplies Christchurch is, for some potential activities, questionable given the potential increased risk of contamination to groundwater. The existing, local planning framework may also inhibit establishment of these activities within the rehabilitated quarry sites.

S4.5 Hard Rock Quarry Rehabilitation.

The operational methodologies and environment of hard rock quarries are substantially different from those of alluvial quarries. Unless the quarry is large, progressive rehabilitation whilst the quarry is operational is very difficult, if not impossible in many instances.

It is possible, through controlled blasting of the vertical production faces to pile up debris at the base of the face to form artificial slopes that to an extent mimic those of the surrounding area. Introduction of soil into some of the debris voids will allow vegetation to establish over time which will help to soften some of the harsher outlines of the quarry.

S5. Commentary.

The post-closure use of a quarry needs to be carefully assessed in both the early stages of business planning and when developing subsequent quarry management and rehabilitation plans.

The rehabilitation plan should be based on a clear set of objectives which include legislative requirements and encompass the local social, economic and environmental considerations for the future use of the site. The objectives must be both technically and financially sustainable.

Accordingly it is recommended that the preparation of an acceptable rehabilitation plan be a condition of consent approval together with the lodging of a monetary bond, or similar, to be released either progressively, which would encourage on-going rehabilitation, or on the completion of the previously accepted plan.

Local rehabilitation plans will need to acknowledge the relatively limited amounts of suitable fill material available which will inevitably lead to many sites being effectively unfilled or, in some cases, only partially filled. However, with the possible exception of hard rock quarries, rehabilitation should be undertaken as a planned, continuous process throughout the life of the quarry.

Options that are more viable from an economic sense are more liable to occur if area wide agreements can be arrived at by the quarry companies in the locale. On the other hand small, isolated quarries run a significant risk of steralising the land on which they sit. Accordingly it is suggested that the latter type of development be discouraged particularly where such would be located on the urban fringe.

The industry is currently in discussions with Environment Canterbury over the possibility of using “adaptive management” with respect to depths of excavation in relation to groundwater levels. A complicating factor in this is the potential for general groundwater level increases consequent on the effects of the Central Plains Water Enhancement Scheme.

Level increases in the areas of both present and possible future gravel extraction will not only have ramifications for the quantities of extractable materials but will also potentially significantly change the environments within the backfilled areas. Further work is recommended to quantify the level of increased risk, if any, this possibility poses to both the groundwater from contaminant leaching from within the fills and to the stability of the fills themselves.

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1.1 Project Background.

The Christchurch City Council (the Council) is currently reviewing both its Banks Peninsula District and Christchurch City Plans with the intention of amalgamating them into a single document.

A key issue with respect to quarrying activity relates to the rehabilitation and potential end use of excavated sites. The current approach to rehabilitation was formulated on the basis that land should be reinstated to at least pastoral farming standard and that boundary side slopes should be sufficiently battered to allow easy access to, use and maintenance of these areas.

Partial or full back filling with cleanfill to achieve contours at or near pre-quarrying levels was not considered to be a viable option due to a lack of appropriate cleanfill material and concerns over potential contamination of groundwater.

Current quarrying practice is to excavate to depth of 1m above the highest recorded groundwater level and as a consequence the finished contours of former quarry sites generally differ markedly from both their pre-quarrying state and those of the surrounding un-quarried land. Significantly the depth of the protective material between the floors of the quarries and the underlying unconfined groundwater, which is the source of Christchurch city's water supply, is much reduced.

Despite these issues this approach may be suitable for existing quarries that sit within the Council City Plan Rural Quarry (RuQ) Zones and those that have been more recently consented which are large, contiguous and generally rural in context. This might not be an appropriate approach however for smaller more isolated sites closer to the urban areas which, in the longer term, may be required for urban expansion.

It is understood that the Council believes that the current District Plan review provides an opportune moment at which to review the appropriateness, or otherwise, of the current approach particularly with regard to:

- Ensuring that land is not sterilised from a range of appropriate future uses.
- The protection of the city's groundwater resource.
- Maintaining visual amenity and landscape character.

1.2 Project Objectives.

To provide an:

(1) Assessment of the types and availability of potential rehabilitation materials.

(2) Overview of central government policy on rehabilitation and directly related matters.

(3) Assessment of environmental issues pertaining to rehabilitation.

(4) Assessment of potential constraints on future sites.

(5) Assessment of three potential options for quarry rehabilitation:

- Status Quo – retain the current City Plan rule.
- Full remediation involving backfilling sites to the land contours that existed pre-quarrying.
- Partial remediation where sites are substantially backfilled.

1.3 The Christchurch City Cleanfill Licensing Bylaw.

The materials deposited at quarries are not only regulated by the site's consent conditions, issued and monitored by Environment Canterbury, which are set to control environmental effects of the activity, but also by the "Christchurch City Cleanfill Licensing Bylaw". The Christchurch City Council introduced this Bylaw originally in 2004 with the overall objectives of increasing waste minimisation within the construction industry and encouraging recycling wherever economically feasible.

Specifically the Bylaw:

- Regulated the types of materials that may enter local cleanfills. *(Materials that were considered to be already readily recyclable were prohibited from deposition.)*
- Imposed a Waste Minimisation Levy on "non - natural" materials *(This both increased the cleanfill "gate fee", which discouraged deposition / encouraged source separation and recycling, and provided a source of income to fund new waste minimisation initiatives.)*
- Required the gathering of basic data on the quantities and origin of all cleanfill materials. *(This information provides a more complete picture of the industry's waste activities and aids in the development of further future waste minimisation strategies.)*

Whilst the levy component of the Bylaw was removed a number of years ago as a result of an indirectly related High Court case in Auckland, the Bylaw remains in place. Accordingly a schedule[(1)] appended to the Bylaw continues to regulate the types of materials that may be deposited into cleanfills in the area under the Council's jurisdiction.

(1) "*Schedule A - Licensed Materials; Christchurch Cleanfill Bylaw 2008*"

Section 2. Quarrying and Cleanfilling.

2.1 Quarry and Cleanfill Locations - Current.

The following figure illustrates the location of currently active quarry and / or co-located cleanfill sites within the Council area.

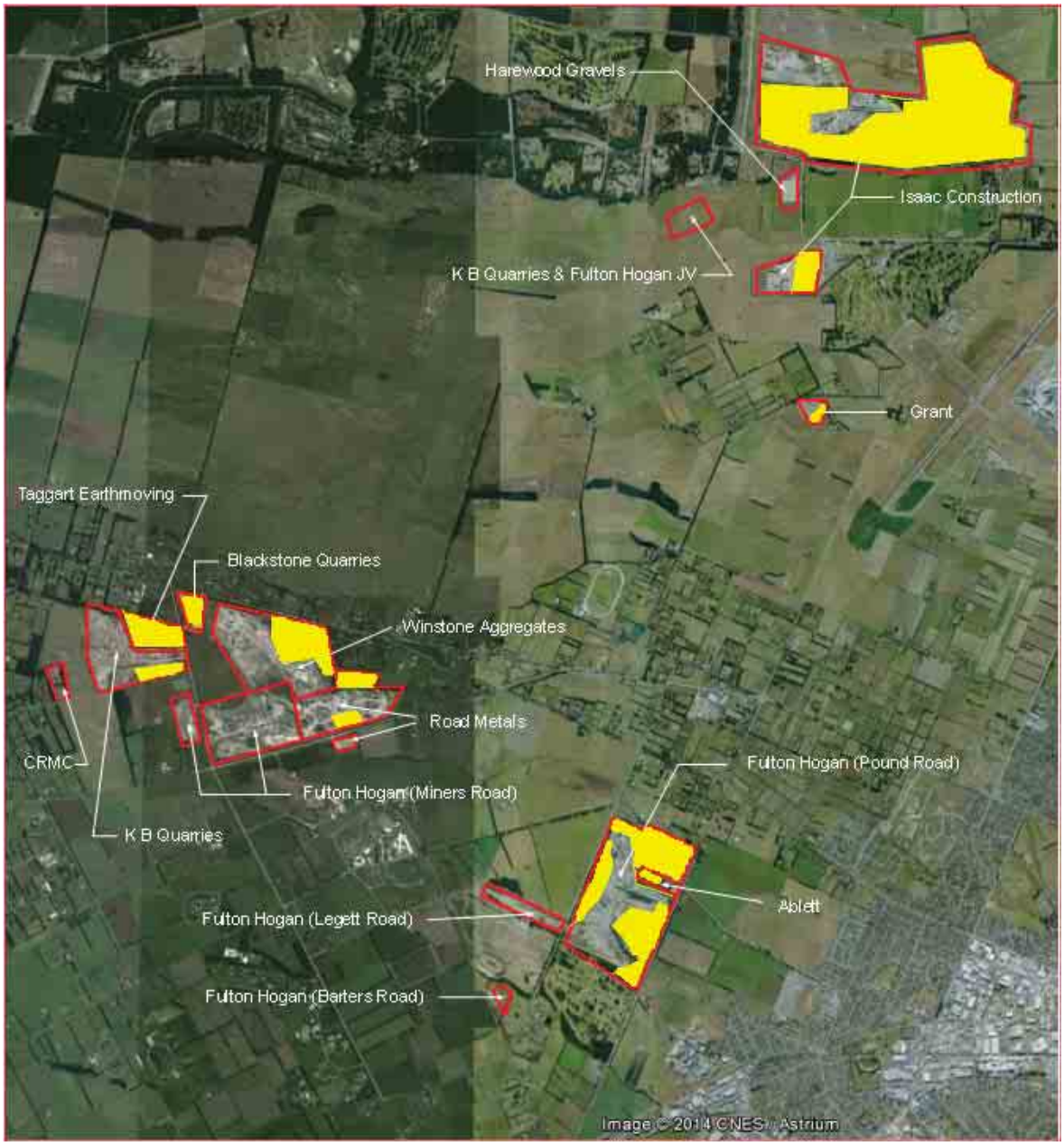

Fig 1: Location Map – Quarried Areas and Co-located Cleanfills.

2.2 Quarry Filling and Rehabilitation - Current.

Of the excavated areas in recently or currently active quarries within the Council's territorial boundaries, less than 20% has been fully rehabilitated. The following table describes the current situation in general terms.

Site	Per cent Fully Rehabilitated	Rehabilitation Use and Notes
Fulton Hogan – Pound Road	25	Grazing and forestry. Quarry Active. Filling on-going
Ablett – Pound Road	75	Quarrying complete. Filling on-going
Fulton Hogan – Leggett Road	0	Quarry active. No filling undertaken
Fulton Hogan – Barters Road	0	Quarry active. No filling undertaken
Fulton Hogan – Miners Road	0	Quarry active. No filling undertaken
Road Metals – North SH 73	15	Battered and grassed Quarry Active. Filling on-going
Road Metals – South SH 73	0	Quarry active. No filling undertaken
Winstone Aggregates	0	Quarry Active. Filling on-going
Blackstone Quarries	0	Quarrying complete. Filling on-going
Taggart Earthmoving	10	Quarrying complete. Filling on-going (spasmodic)
K B Quarries and Contracting	0	Quarry Active. Filling on-going
CRMC	50 (?)	Quarry and filling spasmodically active (?)
Grant	0	Quarrying complete. Filling on-going
Issac – South Mcleans Island Road	0	Quarry Active. Filling on-going
Isaac – North Mcleans Island Road	40	Grazing & conservation. Quarry Active .Filling on-going
Harewood Gravels	0	Quarry Active. New quarry No filling (?)
Fulton Hogan / K B Quarries JV	0	Quarry Active New quarry No filling (?)

Table 1: Summary of Quarries and Current Rehabilitation Activity.

In summary only Taggarts at Miners Road, Road Metals at West Coast Road, Fulton Hogan at Pound Road and Isaacs north of Mcleans Island Road have completed any rehabilitation. Apart from the conservation area at Isaacs and a small block of forestry, completed rehabilitation has consisted of either battering side slopes with no filling or backfilling generally to or near previous land contours, followed by topsoiling and sowing with pasture grasses. Isaacs, north of Mcleans Island Road are aided by the relatively shallow depth of excavations often requiring no fill, other than topsoiling, to complete rehabilitation.

2.3 Quantities and Types of Fill Materials - Current.

The quantities of materials entering quarries pre-earthquakes amounted to approximately 25% of overall study area land based production.

Fill material originates from a range of construction, maintenance, demolition and site clearance activities. Of these, fill related to sub-divisional construction and similar development activities constitute the largest proportion[2].

Fill material comprises, top soil and other natural materials such as clays and gravels, and inert manufactured materials, for example bricks, pavers and concrete[2].

The following photographs illustrate some typical fill materials.

Tiles and Blocks

Asphalt

Topsoil

Mixed soils, gravels and concrete

Fig 2: Typical Cleanfill Materials

(2) "*Review of the Operation of the Christchurch Cleanfill Bylaw 05 / 06*" - Twelfth Knight Consulting.

2.4 Quarry Locations - Future.

The following figure illustrates Exploration and Mining License permits and applications issued and / or under consideration by New Zealand Petroleum and Minerals (NZPAM) in early July 2014.

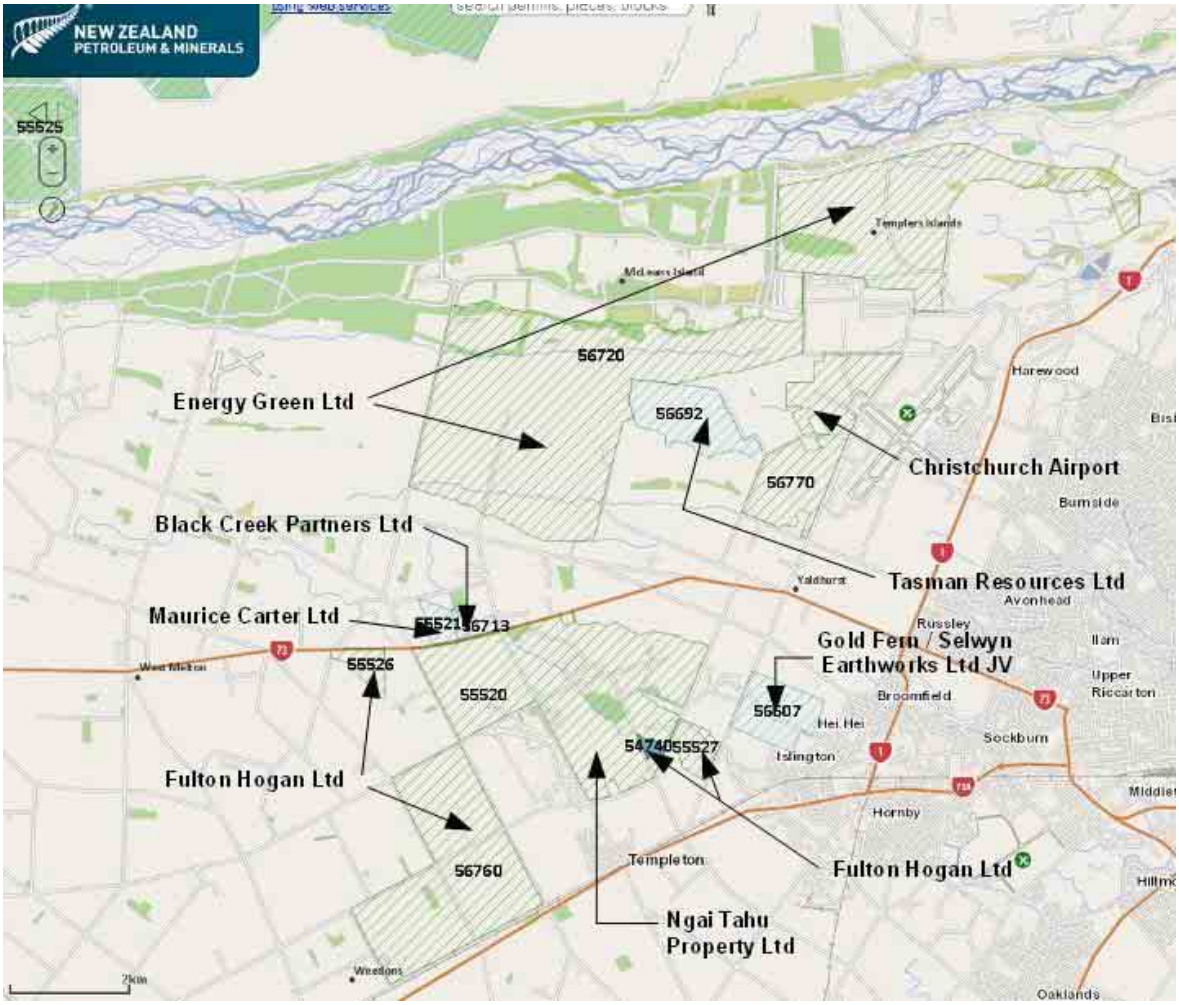

Fig 3: Location Map –NZPAM Permits and Applications as at early July 2014.

Whilst not all of these permits and / or applications will necessarily translate into actual quarries it does provide a general indication of where the industry is looking to source aggregate materials in the future once existing resources are exhausted. All the sites indicated are within reasonable proximity to both existing quarries receiving cleanfill and the Christchurch urban area.

2.5 The Earthquakes.

The earthquakes disrupted the previous local pattern of cleanfill material production and deposition in respect to not only the location of deposition but also the types and quantities of materials being generated. Significant quantities of mixed demolition materials, which were in the main unacceptable at the quarry cleanfill sites, were sent to the Burwood Resource Recovery Park. Large quantities of otherwise acceptable "rubble" materials (e.g. concrete, bricks, blocks, pavers, tiles, etc.) however were, and continue to be, deposited at both the Lyttelton Port Company's port reclamation site and at Portlink Industrial Park, in Heathcote.

Whilst it is not possible to be definitive, an analysis of the data collected under the auspices of the Christchurch City Cleanfill Bylaw indicates that of the order of an additional(3) 0.75 million tonnes of materials have been received at the cleanfill sites post September 2010 to date. The quantum of earthquake related materials brought into cleanfills for deposition appears to have peaked in 2013. Quantities of 'additional' materials received in the period January to June 2014 appear to have reduced substantially, total cleanfill volumes having returned approximately to those which might have been anticipated using pre-earthquake data relationships.

2.6 Quantities and Types of Fill Materials - Future.

Without step changes in consumption patterns, it is likely that the relationship between production output and returning cleanfill will remain on average of the same order in at least the medium term. However in the short term it is possible that the quantities of cleanfill returning as a percentage of production will reduce since the materials that would have been received from demolitions in the business as usual scenario have already in fact been deposited at the quarry cleanfill sites and elsewhere. Whilst it may be a little difficult to be certain, the recent fall in cleanfill volumes being received at the quarries may be an early indicator of this issue. Accordingly it is suggested that in the short to medium term no greater than the existing pre-earthquake cleanfill / production ratio be used for projection purposes. (See sub-section 2.3)

It is unlikely that new sources of bulk cleanfill will eventuate other than those that presently exist. Accordingly, with the exception of the current distortion in cleanfill material quantities and types consequent on the earthquakes, it is likely that the types of materials being received at the quarries for disposal and the ratio of returning fill to production will remain similar to that as in the past.

A greater emphasis on waste minimisation and recycling of materials in the future may reduce the quantities of materials available for cleanfilling. However it is envisaged that the demand for virgin aggregates would consequently decline in parallel with the increases in recycling and consequently the ratio of returning fill material to production would remain effectively of the same order as existed pre-earthquakes.

(Refer also notes under sub-section 3.1)

(3) In this context "additional" refers to the quantities over and above those that would have eventuated as a result of the normal production/ cleanfill quantities relationship. (refer sub-section 2.3)

The following chart provides an indication of the quantities of cleanfill materials anticipated to return to the cleanfill sites over the period to 2041.

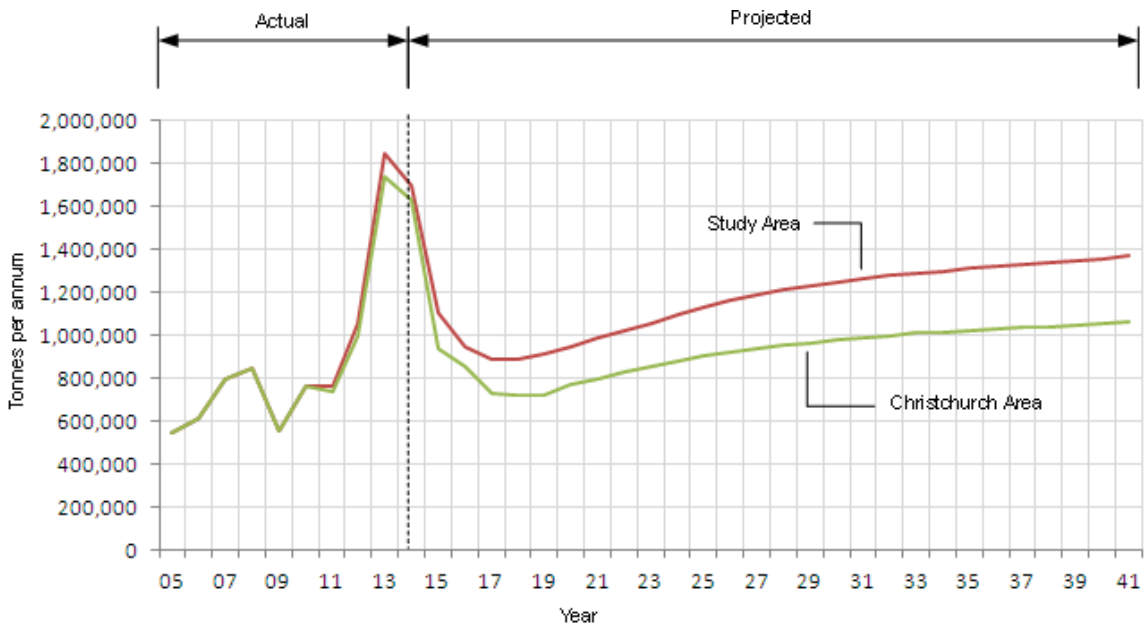

Fig 4: Study and Christchurch Area Cleanfill Quantities (tonnes)

2.7 Timescales for Rehabilitation - Future.

In the case of the local alluvial gravel quarries the time taken to rehabilitate a quarry is a function of:

- The ultimate value and planned form of the rehabilitated land.
- The sequencing of quarrying, itself a function of the shape, and ultimate depth of the quarry.
- The market for aggregates and the share of the market held by the quarry over its lifetime.
- The availability and cost of suitable cleanfill both during the quarries life and in some cases post closure.

The interplay of these factors will vary from quarry to quarry. In general, quarries may require from one year upwards to complete rehabilitation. Rehabilitation plans that require more than five years to complete post closure may however not be economically viable and are therefore, it is suggested potentially conceptually flawed from the outset.

Section 3. Constraints.

3.1 Environmental.

Consent conditions for cleanfilling, set by Environment Canterbury under the auspices of the Resource Management Act, have become increasingly prescriptive with the passage of time. This has occurred primarily as a result of a similarly increasing awareness that the potential environmental impacts of cleanfilling should wherever possible be minimised.

The Ministry for the Environment (MfE) "Cleanfill Guidelines"(4) (the Guidelines) has been increasingly used as the default document with regards to the setting of consent conditions. The MfE document defines "cleanfill material" as:

"Material that when buried will have no adverse effect on people or the environment. Cleanfill material includes virgin natural materials such as clay, soil and rock, and other inert materials such as concrete or brick that are free of:

- *combustible, putrescible, degradable or leachable components*
- *hazardous substances*
- *products or materials derived from hazardous waste treatment, hazardous waste stabilisation or hazardous waste disposal practices*
- *materials that may present a risk to human or animal health such as medical and veterinary waste, asbestos or radioactive substances*
- *liquid waste"*

Whilst some aspects of the definition have been, and continue to be the subject of debate, it has been agreed by the industry that materials should not generally be accepted into unlined cleanfills, such as those in the Council area, without strict controls should those materials originate from sites where known hazardous chemicals are or have been present in the past. This process has been significantly aided by the relatively recent introduction nationally of the Hazardous Activities and Industries List (HAIL)(5) produced by MfE and locally by Environment Canterbury through the publication of their "Listed Land Use Register (LLUR)(6)

In the local context it is vitally important that the unconfined groundwater, which is Christchurch's sole source of potable water and which underlies all of the existing quarries, and potentially all of the future quarries in the Council area is protected from contamination. Accordingly local cleanfill consents are beginning to contain prescriptive chemically based waste acceptance criteria (WAC).

MfE, through a contract with WasteMINZ, are currently reviewing the Guidelines and are working towards integrating them with an existing parallel set of guidelines for landfilling. There are on-going discussions between MfE. WasteMINZ and the industry in particular with respect to the setting of appropriate WACs.

(4) *"A Guide to the Management of Cleanfills";* Ministry for the Environment – 2002
(5) Refer: www.mfe.govt.nz/issues/managing-environmental-risks/contaminated-land/is-land-contaminated/hail.html
(6) Refer: www.llur.ecan.govt.nz/

Current discussions centre around the applicability of the "National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health" (NES Soil) and its associated MfE guidance document[7] In particular the determination of the end use scenario is important in setting the WAC's. Whether such standards should be required throughout the full depth of the fill is a matter of current debate. (Refer Appendix B for details of the NES Soil exposure scenarios.)

It is possible that the local cleanfill acceptance processes may have to include a more rigorous chemical testing regime and although this may increase the cost of cleanfilling it is thought unlikely to have a major impact on the amounts of materials being deposited into cleanfills locally provided that a workable compromise can be achieved with MfE[8].

3.2 Engineering.

Filling operations in a working quarry environment normally involve the tipping and / or bulldozing of material directly over a working face. There are generally no controls imposed on the mixture or sizing of materials deposited other than those necessary for compliance with consent conditions and the requirements of the Cleanfill Bylaw. The only compaction of the fill is incidental to the running of trucks and machinery over the surface as the face progressively moves forward.

Accordingly voids, softer material and varying levels of compaction are liable to occur more or less randomly across the filled area. In turn this will lead to varying rates and amounts of settlement, neither of which are desirable if any form of structure is to be constructed on the site at some time into the short, mid or even, under some circumstances, the long term future.

For any one particular fill, the amount, type and rate of settlement will depend on a variety of factors including fill depth, moisture and compaction conditions during placement and potentially groundwater conditions after placement.

If the site is to be used after filling to accommodate light structures it is preferable that the fill material and its placement conform, as a minimum, to the requirements of NZS 4431: 1989 – "*Code of Practice for Earth Fill for Residential Development"*. This Code of Practice imposes strict controls on materials, placement and compaction which are unlikely to be met by the materials being deposited in, or the filling methodologies currently employed by, local quarries.

Alternatively, provided large sections of concrete and / or boulders are excluded from the fill or placed in specifically identified location(s) within the fill confines, it may be possible to use driven or bored piles, founded on the natural gravels at the base of the fill, to provide foundations for structures that may be constructed once rehabilitation is completed.

Comparison of the economics of these alternatives are however beyond the scope of this report suffice it to say that it is unlikely that compliance to NZS 4431 for other than relatively shallow fills would be economically efficient.

(For further discussion on this topic refer sub – section 4.4)

(7) Ministry for the Environment Users Guide for the "*National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health*" - April 2012

(8) Testing of representative samples of local cleanfill materials is currently being conducted by the industry

3.3 Climatic.

Heuristically it could be assumed that cold air would pool in the base of excavations. However there is evidence that suggests that minimum temperatures experienced within local quarry excavations are in fact on a par with those experienced on the surrounding undisturbed land. It would be useful if this information could be verified by further investigation.

Given the flat and generally open nature of the Canterbury Plains it is reasonable to assume that the environment within the quarry would, advantageously, be more sheltered from winds than its immediate surrounds. As with temperature it would be useful to undertake some basic investigations to gain a better understanding of the climatic conditions within the quarries.

3.4 Soils.

Very few, if any, plant species are capable of economic production on the drought prone soils that consist much of the cleanfill material being deposited. Most species would require soil modification, adequate rooting volume and potentially irrigation for satisfactory plant growth to occur. (refer sub-section 4.4 for further comment.)

3.5 Size, Shape and Depth.

The ultimate plan form and depth of a quarry will have a marked impact on rehabilitation options. For example excavations north of McLeans Island Road tend to be shallow, but extensive. These areas require relatively little, if any, fill – simple low angled batters readily meld the excavated areas into the surrounding land. A layer of suitable top soil is only required to return the area to pastoral use. In contrast, small, irregular shaped, relatively deep, isolated excavations, such as at Leggett Road, will require significant amounts of fill to return the area to its original form. In the alternative, reconstruction of the side slopes only will result in an effectively unusable narrow area at the base of the excavation which may well pond. The latter could present a contamination risk to the underlying aquifer.

Where a number of quarries abut, an area wide rehabilitation plan would encourage a more efficient end use of the land.

3.6 Quantum of Fill.

As noted in sub-section 2.3, the quantities of materials entering quarries amounts to approximately 25% of total land based production. In other words there is only enough material to totally refill approximately a quarter of the excavated areas. This will inevitably result in the majority of sites being only partially refilled, if at all, apart from the need to satisfy Council side slopes requirements.

3.7 Economics.

Immediately prior to the introduction of the Cleanfill Bylaw in 2004 cleanfill material dumping charges were approximately $0.5 per tonne. With the imposition of the Bylaw levies gate fees rose to average approximately $5 per tonne. However once the levies were removed the cleanfill charges did not fall commensurately. Charges for depositing cleanfill materials currently average approximately $7 per tonne. This would suggest that whereas pre Bylaw the quarries viewed cleanfilling as a marketing tool it is now seen as a viable stand-alone business. (Topsoil destined as "cover material" is currently generally admitted free of charge as in the past.)

Those depositing these materials prefer, for reasons of travel time, to unload fill material and to reload with new product at one contiguous site. Accordingly once a quarry is exhausted cleanfilling will also cease unless an adequate incentive can be offered to those carting cleanfill materials to divert their routes. These incentives could for example be by the way of reduced gate fees and / or the availability of co-located new materials supplied from operating quarries elsewhere. The overall economic viability of such an operation should include a re-valuation of the land once fully rehabilitated.

3.8 Compatibility with Surrounding Uses.

End uses should be compatible with existing, surrounding land uses wherever feasible.

3.9 Regional Planning Environment.

In order to undertake cleanfilling, consents are required from Environment Canterbury to enable deposition to land and discharge to air. These consents are normally obtained concurrently with those required for quarrying. Provided current "best practice" methodologies are used, the conditions pertaining to these consents are not problematic with respect to filling operations.

At the time of writing the most recent cleanfill consent (June 2014) issued by Environment Canterbury contains the following clause [(9)] pertinent to this report:

"Any cleanfill material deposited at the site shall not be sourced from:

1. *A site where activities included in Schedule WQL3 of Chapter 4 of the Natural Resources Regional Plan or the Ministry for the Environment's Hazardous Industries and Activities list have been, or are being, undertaken; or*
2. *Any site on the Listed Land Use Register; unless the soil has been shown to contain compounds at or below maximum values for human health listed under the scenario "Rural / lifestyle block 25% produce" Appendix B -"Soil Contaminant Standards" of the Ministry for the Environment Users Guide for the "National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health" - April 2012 ....."*

This clause is potentially in line with the proposed new MfE guidelines and is probably unlikely to cause a significant reduction in the quantities of materials being received for deposition, although as noted earlier may result in increased gate charges.

(9) Environment Canterbury Consent Number: CRC145183.

Section 4. Options.

4.1 Status Quo.

The current City Plan requires that[10]:

"(A)ny mineral extraction activity which results in an area of completed excavation exceeding 2ha in area and/or has been discontinued for a period of more than three years, without being re-soiled and left with an established vegetative cover, shall be a controlled activity unless the Council has approved a rehabilitation plan for the site(s)".

As noted in sub-section 3.5, this may potentially lead to the loss of the productive use (or "sterilisation") of the land associated with smaller, isolated quarries that might have otherwise been valuable for a number of uses if fully filled. This is particularly the case where sites are located close to the urban fringe and which may be required for urban expansion in the future.

Although the larger sites are unlikely to be fully backfilled they are potentially less problematic in that once the side slopes have been constructed the area at the base of the quarry (or partially filled site) will be of a sufficient size to be usable for at least their pre-quarried pastoral purposes.

4.2 Rehabilitation - Full Backfilling .

Rehabilitation involving sites being fully backfilled to the land contours that existed pre-quarrying is unlikely to eventuate except possibly at the smaller sites if the owner is minded to do so for economic reasons or if it were made a condition of consent. The former might occur if the resulting land was required for residential, commercial or industrial purposes. (i.e. the underlying value of the rehabilitated land was sufficient to justify the potential additional costs involved.) None of the existing quarries are sufficiently close to the urban boundary to potentially fall into this category.

Alternatively for those new, small quarries that may wish to establish in those areas designated by the Council for future development it may be advisable to ensure that complete re-filling is achieved through the imposition of appropriate consent conditions and a sufficiently large performance bond[11].

4.3 Rehabilitation - Partial Backfilling.

Rehabilitation where sites are substantially backfilled is again unlikely in the majority of cases owing to the paucity of suitable filling material. For example if all quarries were uniformly filled across their entire plan area of the order of three quarters of the original depth would remain unfilled.

Partial, or no filling of those larger quarried areas in the eastern section of the Mcleans Island area, where excavation depths are commonly less than 5m, may be appropriate (subject to groundwater levels) as such will not impact markedly on the usefulness of the rehabilitated ground.

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(10) Clause 3.2.3: *"Staged restoration of quarried land - mineral extraction activities"* – City Plan – CCC

(11) At a minimum, bonds would need to cover the full costs of the completion, monitoring and liabilities associated with the proposed rehabilitation.

The larger and / or deeper, quarried areas, such as in the vicinity of Miners Road, are likely only to ever be partially filled. Rehabilitation plans for these or any new similar quarries need to acknowledge this, unless specific effort is directed otherwise.

4.4 Rehabilitated Land Uses.

The following paragraphs outline a range of potential uses for the ex-quarry land once rehabilitated. An economic analysis of the options has however not been conducted.

Pastoral: All of the current quarries and their future replacements lie, or are anticipated to lie, within the more geologically recent channels of the Waimakariri River. The soils in these areas are generally thin and drought prone. As a consequence the pre-quarrying activity of the sites was pastoral in nature. The partially or fully filled quarries would be suitable for a resumption of pastoral uses provide adequate topsoil is spread over the completed fill.

It should be noted that in those areas close to the airport, recent consents have required that only pasture species not attractive to bird life be planted.

Cropping: The range of potentially economic crops will be limited by the degree of shelter, irrigation and soil improvement provided. The soil must have sufficient water-holding capacity to prevent plant growth from being significantly reduced during periods of low rainfall. This is directly dependant on the organic matter in the soils. The addition of soil amendment materials, such as composted municipal “green waste”, may be required to improve the soil structure and its water holding capacity. (The long term storage of topsoil in large stockpiles is understood to be not conducive to its viability.)

Care may be required if certain crops are planted to ensure that possible nitrate, herbicide, and potentially pesticide contamination of groundwater does not occur.

Dairy: Dairying is potentially unsuitable on unfilled / partially filled sites due to the increased risk of effluent and to a lesser extent nitrates leaching through the reduced thickness of materials sitting above the underlying unconfined aquifer. Access to sufficient water for irrigation may be problematic.

Forestry: Forestry is unlikely to be economic on smaller blocks. Species chosen may require tolerance to high water-tables in those larger sites which are either not or only partially filled.

Fish Farming: Isaac Construction have pioneered fish farming locally and have proved that it is an economically viable option. However it brings with it risks of groundwater contamination and potential problems with respect to encouraging bird life into the area which might then pose a threat to nearby airport operations.

Recreation: Numerous old quarries around the world have been transformed into generally passive, recreational areas, many with a botanical theme. A number of old sand and gravel quarries in England for example have been used to form lakes and ponds for use for recreational fishing. These have proved to be popular but in the local context they bring with them issues of potential groundwater contamination and threats of bird strike at the airport, as per fish farming described above. More active pursuits such as running, horse riding, mountain and trail bike riding facilities could be developed by appropriate contouring of fill within the quarries.

However, given the number and very extensive total area ultimately requiring rehabilitation, it is unlikely that the city would have the financial ability to sustain more than one or two sites for publicly funded recreation.

Residential: Provided that suitable fill compaction is achieved, or alternative foundation methodologies are economically feasible, carefully contoured and landscaped sites within the larger, or preferably combined quarries where they are contiguous, would provide sites for "lifestyle" blocks. There is likely to be a good demand for this type of development but care would need to be taken with the handling and treatment of sewage and stormwater to prevent groundwater contamination. However it is understood that Environment Canterbury's Regional Policy Statement does not support "rural - residential" activities in the locale of the existing quarries.

Commercial and Industrial: Whilst this type of development would be physically possible the advisability of such uses sited directly over the unconfined aquifer that supplies Christchurch is, for some potential activities, questionable given the potential increased risk of groundwater contamination. The existing, local planning framework may also inhibit establishment of these activities within the rehabilitated quarry sites.

4.5 Hard Rock Quarry Rehabilitation.

The operational methodologies and environment of hard rock quarries are substantially different from those of alluvial quarries. Unless the quarry is large, progressive rehabilitation whilst the quarry is operational is very difficult, if not impossible in many instances. Examples of successful rehabiltations do however exist, Halswell Quarry being the best know local example.

Fig 4: Halswell Quarry Park – Restoration Plan and Photograph.

It is possible, through controlled blasting of the vertical production faces to pile up debris at the base of the face to form artificial slopes that to an extent mimic those of the surrounding area. Introduction of soil into some of the debris voids will allow vegetation to establish over time which will help to soften some of the harsher outlines of the quarry.

By virtue of the general topography in which worked-out hard rock quarries are generally situated (i.e. on the sides of steep hillsides) recreational use is often favoured as an end of life use. Whilst a number of hard rock quarries have been converted to gardens and botanical sanctuaries other uses are however found within New Zealand. For example Mt Smart Stadium in Auckland.

Section 5. Commentary.

The post-closure use of a quarry needs to be carefully assessed in both the early stages of business planning and when developing subsequent quarry management (QMP) and rehabilitation plans, even if both the latter evolve over the lifetime of the quarry. The rehabilitation plan needs be a core element of the QMP.

The rehabilitation plan should be based on a clear set of objectives which include legislative requirements and encompass the local social, economic and environmental considerations for the future use of the site. The objectives must be both technically and financially sustainable.

A rehabilitation plan should be developed prior to the start of quarrying but should also be developed for operating quarries, where such a plan does not already exist.

Accordingly it is recommended that the preparation of an acceptable rehabilitation plan be a condition of consent approval together with the lodging of a monetary bond, or similar, to be released either progressively, which would encourage on-going rehabilitation, or on the completion of the previously accepted plan.

Local rehabilitation plans will need to acknowledge the relatively limited amounts of suitable fill material available which will inevitably lead to many sites being effectively unfilled or, in some cases, only partially filled. However, with the possible exception of hard rock quarries, rehabilitation should be undertaken as a planned, continuous process throughout the life of the quarry.

Options that are more viable from an economic sense are more liable to occur if area wide agreements can be arranged by the quarry companies in the locale. It is recommended that the Council explore the possibility of facilitating such discussions through the Memorandum of Understanding that is in place with the local industry.

On the other hand small, isolated quarries run a significant risk of steralising the land on which they sit. Accordingly it is suggested that the latter type of development be discouraged particularly where such would be located on the urban fringe.

The industry is currently in discussions with Environment Canterbury over the possibility of using “adaptive management” with respect to depths of excavation in relation to groundwater levels. It is understood that the industry proposal, in broad terms, involves, in the absence of groundwater, excavating below the predicted highest groundwater level down to the highest seasonal level more commonly experienced in recent years.

A complicating factor in this is the potential for general groundwater level increases consequent on the groundwater mounding effects of the Central Plains Water Enhancement Scheme (CPWES). Level increases varying between 0m and 1.5m are predicted in the areas of both present and possible future gravel extraction[12]. Not only will this have ramifications for the quantities of extractable materials but will also potentially significantly change the environments within the fills. Further work is recommended to quantify the level of increased risk, if any, this possibility poses to both the groundwater from contaminant leaching from within the fills and to the stability of the fills themselves.

(12) Fig 17: Report No R14/16; Environment Canterbury – February 2014

APPENDICES.

(A) Christchurch City Licensing Bylaw Cleanfill Data – Activity Analysis.

(B) Extract from: *Users Guide - National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health;*
Ministry for the Environment – 2012.

Appendix A.

Activity Analysis (2005 / 06).*

ACTIVITY	COVER	NATURAL HARDFILL	OTHER	TOTALS
Roading	4,000 (4,000)	40,000 (32,000)	28,000 (30,000)	72,000 (66,000)
Trenching	500 (500)	14,500 (27,500)	7,000 (5,000)	22,000 (33,000)
Site Clearance	31,000 (31,000)	143,500 (110,000)	93,000 (55,000)	267,500 (196,000)
Demolition	500 (0)	500 (0)	8,500 (35,000)	9,500 (35,000)

***Notes:**

- *"Review of the Operation of the Christchurch Cleanfill Bylaw 05 / 06*" - Twelfth Knight Consulting
- . Data in parenthesis taken from 2004 / 05 Bylaw returns

Appendix B

Extract from: *Users Guide - National Environmental Standard for Assessing and Managing Contaminants in Soil to Protect Human Health; Ministry for the Environment – 2012. – Appendix B*

Table B1: Land-use scenarios

Scenario	Description
Rural / lifestyle block	Rural residential land use, including home-grown produce consumption (25 per cent). Applicable to the residential vicinity of farm houses for protection of farming families, but not the productive parts of agricultural land. Note: Consumption of eggs, milk and meat from animals raised on site is excluded. Produce consumption is limited to home-grown vegetables. Sites for which consumption of home-grown eggs, milk or meat is important will need to be evaluated on a site-specific basis.
Residential	Standard residential lot, for single dwelling sites with gardens, including home-grown produce consumption (10 per cent).
High-density residential	Urban residential with limited soil contact, including small ornamental gardens but no vegetable garden (no home-grown produce consumption); applicable to urban townhouses, flats and ground-floor apartments with small ornamental gardens, but not high-rise apartments.
Parks / recreational	Public and private green areas and reserves used for active sports and recreation. This scenario is intended to cover playing fields and suburban reserves where children play frequently. It can also reasonably cover secondary school playing fields but not primary school playing fields.
Commercial / industrial outdoor worker (unpaved)	Commercial / industrial site with varying degrees of exposed soil. Exposure of outdoor workers to near-surface soil during routine maintenance and gardening activities with occasional excavation as part of maintaining subsurface utilities (ie, a caretaker or site maintenance personnel). Also conservatively applicable to outdoor workers on a largely unpaved site.