WHANGAREI DISTRICT COUNCIL

MINE SUBSIDENCE HAZARD HIKURANGI AREA, WHANGAREI

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1.0 Introduction

Whangarei District Council (WDC) engaged Tonkin and Taylor Ltd (T&T) to undertake an assessment of the subsidence hazard resulting from the underground mining of coal in the Hikurangi area, Whangarei.

The purpose of this report is to provide WDC with a basis for the preparation of an updated and revised policy on development within the Hikurangi area.

2.0 Investigation

The information required for the subsidence hazard identification included determination of;

- the extent of the underground workings in the area
- the type of mining method,
- the depth of the workings,
- characteristics of the overburden strata,
- groundwater information

This information was collected from a number of sources that included;

- Department of Labour (ex Ministry of Mines) – maps
- Whangarei District Council (Hikurangi Office) – maps, books and reports, and museum records inspection
- Whangarei District Council (Head Office) – Lot Boundaries, contours, aerial photograph base
- Golden Bay Cement Co (Hikurangi Office, Wilsonville Quarry) – maps
- Tonkin and Taylor Ltd – archived plans and reports relating to the Wilsonville Quarry

Discussions were also held with a number of people, including Yvonne Stewart (WDC), and Herbie Isherwood who worked in the mines in the 1920's. Two site visits were also carried out. The first visit was accompanied

by Mrs Stewart, and included inspection of the town's museum, and the locations of the shafts, workings, and two examples of crown subsidence.

3.0 Regional Geology

The regional geology of the Hikurangi area comprises fault bound blocks of early Tertiary sediments generally consisting of Kamo Coal Measures (sandstones, carbonaceous mudstones, fireclay and coal seams) unconformably overlying weathered Waipapa Group greywacke and argillite. Overlying the Kamo Coal Measures are calcareous greensands containing lenses of muddy limestone and pure crystalline limestone. The latter is more commonly known as the Whangarei Limestone, and is mined from the Wilsonville Quarry. The thickness of the limestone ranges between 60 and 95m. Overlying the limestones and green sands are the tectonically sheared mudstones of the Onerahi Formation (Northland Allochthon). Pinnacles of the limestone outcrop to the east of the main highway, where the mudstones have been eroded away.

4.0 Mining Hazard

4.1 Background and Causes of Subsidence

Underground mining beneath Hikurangi was carried out between 1880 and 1948 by a number of small coal mining companies.

The coal was extracted by the "room and pillar" method. Room and pillar methods of coal extraction rely on the coal pillars being left to support the overburden. Such methods typically extract about 20% of the coal resource. However, it was common practice to further work the coal pillars after the initial extraction, leading to either collapse of the mine roof or punching of the pillars into the mine floor. Collapse of the mine roof can lead to the development of "crownhole subsidence", whereas punching failure or

collapse of the pillars can lead to the development of "trough subsidence". These failure mechanisms are shown in Figure 1.

4.2 Distribution and Characteristics of Mined Out Areas

4.2.1 Extent of Underground Mining

Drawing 18596-01, located in Appendix 1, shows the distribution of the worked out areas, based on the data collated. The information shows that most of the workings are to the north, northwest and west of the main township area.

There are some small worked out shallow coal seams beneath the Hikurangi Golf Club, and to the east of the intersection between Gomez Road and Marua Road, some 3km to the northeast of Hikurangi. These areas are outside the main coal mining area, and have not been included in this study.

While every effort has been made to obtain all available information, it must be appreciated that there may well be additional areas of workings that are unrecorded. This is either due to the loss of plans, or the absence of asbuilt drawings of the workings, particularly those seams that were worked by the smaller companies in the early development of the area.

4.2.2 Pillared Workings

Drawing 18596-01 also shows the areas that are known to have been "pillared" (represented by the hatching on the plan). As for the distribution of the mined out areas, there may be other areas that were pillared that are not shown. Pillaring should therefore be assumed for all undermined areas.

4.2.3 Pillar Dimensions

As-built plans show that the pillar dimensions ranged from 3 x 3m (in the Waro workings), up to 8 x 8m. The average pillar dimensions appear to be about 5.5 x 5.5m.

4.2.4 Coal Seam Thickness

The sourced information show that the coal seam ranges between 1 and 2.5m thick, although is on average about 2m thick. Mining of additional seams does not appear to have occurred. Overlap of displaced (faulted) seams is unlikely as the faults through the area are normal faults rather than reverse faults.

4.2.5 Depth of the Mined-out Areas

The depth of the mined out areas has been estimated primarily using borehole data. This is because the maps and plans showing the extent of the workings unfortunately do not show the levels of the coal seams. What several of the plans do show, however, are boreholes with depth to coal and coal seam elevation relative to a local datum. These have been used to estimate the depth of the coal beneath the surface. In addition, there are several other deep boreholes that were drilled in the Wilsonville Quarry area to assist in the estimations of the limestone resource. As the coal seam generally underlies the limestone, the coal seam depth can be approximated. The locations of the boreholes, including the approximate depth from the surface to the seam, are also shown on Drawing 18596-01.

The depth of the coal seam varies significantly due to fault offsets. Various geological maps produced by the mining companies, Wilsonville Quarry investigations, and the borehole information show that the area is very faulted, with one major north south trending fault apparently passing centrally through the area (see Drawing 18596-01). This fault has down-thrown the coal bearing strata to the west by some 30 to 40m. The are other faults with less offset, although these have not been precisely located as part of this study.

Generally, much of the Waro workings located beneath the eastern half of the state highway either side of Hikurangi Lake are very shallow, generally being less than 5 to 10m below the surface. Beneath Hikurangi Lake the mined out seam is between 10m to 20m beneath the surface. On the western side of the major NNW trending fault (see Drawing 18596-01) the coal seam is significantly deeper, generally ranging between 80 and 130m deep in the Wilsonville Quarry area, and 150 to 170m below the surface in the southwestern area.

4.3 Examples of Crown Hole Subsidence

Examples of crown hole subsidence and general roof collapse are widespread in the Waro area across the top of the hill along the northern side of the lake. Pocked landscape across the hill top along the southern side of the lake is also clearly evident in aerial photographs taken in 1946, although this area has since been subject to open cast mining by the old Hikurangi dairy company. Old as-built plans show that the Waro area was mined in the late 1800's. The depressions are consistent with the pillar dimensions, which ranged between 3 and 6.5m wide. The mined out seam was about 2.4m. Linear depressions following along main drives through the lattice workings can also be observed, in the positions shown by the old as-built plans. Settlement has also affected the properties in Waro adjacent to SH1, causing depressions in the lawns, and some structural deformation. A more detailed deformation survey of these houses is recommended.

Evidence of crown hole subsidence is also present in a number of places around the Waro Rocks. The depth to the coal from the surface in this area is estimated to be less than 20m.

A boarded over hole apparently exists adjacent to the transfer station, although it is unclear whether this is due to crown hole subsidence, or is a shaft.

According to Yvonne Stewart (WDC, Hikurangi Office), there are no other examples of subsidence in the area.

5.0 Mine Subsidence Hazard

5.1 Mine Subsidence Hazard Zones

The areas mined beneath the Hikurangi area have been divided into three zones based on low, medium and high potential for subsidence hazard relating to the presence of the underground workings. These areas are shown on Drawing 18596-02.

The zones have been based on the same methodology used to produce mining subsidence hazard maps for the Kamo area (ref Tonkin and Taylor, 1999), which are as follows:

- Zone 1 (high risk): areas where there is less than 10 x t cover, where t = seam thickness. At Hikurangi, this is about 20m, based on an average seam thickness of 2m. In these zones there is a potential for "crown-holing". The presence of crown hole subsidence between King Street and the Waro Rocks indicates that the zonation is appropriate. This zonation is especially applicable to the areas undermined to the north and southeast of Hikurangi Lake.

- Zone 2 (moderate risk): areas where the thickness of overburden is between 20 and 100m thick. Within these areas there is potential for "trough subsidence", which could result in ground surface deformation and damage to structures and services.

- Zone 3 (low risk): areas where the depth to the workings is greater than 100m below the surface. Minor surface deformation is possible, but is unlikely to result in significant damage to structures.

The worked areas have been projected to the surface at 60° to the horizontal (angle of draw) to allow for the increased area that would be affected should subsidence occur. Obviously the deeper workings will have greater projected area of potential subsidence than the shallower workings.

5.2 Development Recommendations

In terms of development of the area the following recommendations are made;

- Zone 1 (High Risk): Development in this area is not recommended, unless engineering measures are put in place to avoid the hazard, or to protect the structure from the hazard. An option that may be considered to eliminate the problem where the workings are very shallow is the complete removal of the workings by cut to fill earthworks. Alternatively, structures could be founded on specifically designed piles seated in competent rock underlying the worked out coal seam. However, servicing the buildings is an issue that would need to be satisfactorily addressed for the piled structures.

- Zone 2 (moderate risk): Development in this zone should be carried out with caution. Only light timber framed buildings should be considered in this zone, with foundations specifically designed to accommodate potential differential settlements. Concrete or plaster masonry should be avoided. Similarly, services to buildings should be designed and constructed using materials that are unlikely to crack or separate due to differential settlement.

- Zone 3 (low risk): As a precaution, any building located in this zone should follow the recommendations given for Zone 2.

6.0 Conclusions and Recommendations

- Under ground mining of coal at Hikurangi was carried out in by a number of companies between 1880 and 1948.
- Some 2.5km x 1.8km of land has been undermined, generally beneath the Waro and Wilsonville areas to the north of Hikurangi.
- The depth to the 1m to 2.5m thick coal seam ranges considerably, due to significant normal faulting through the area. In the hillside either side of Hikurangi Lake the workings are very shallow, being generally less than 5m to 10m below the surface. Beneath the lake the mined seam is between 10m and 20m below the surface. Beneath the Wilsonville area, and the southwestern area the mined out seam ranges between 80m and 170m depth.
- Pillaring was generally carried out, and has been assumed for all undermined areas. Pillar widths ranged between 3m and 8m, with the average pillar dimensions being about 5.5m x 5.5m.
- In the Waro area evidence of crown-hole subsidence is widespread across the shallowest workings, either side of Hikurangi Lake. Further crown hole subsidence also appears to be continuing in this area. Some of the houses in Waro (adjacent to SH1), are located above these old workings, and may either have been affected by subsidence, or are at risk of future subsidence. We recommend that a detailed deformation survey of these houses be carried out.
- The areas that were undermined have been divided into three zones based on low, medium, and high potential for subsidence hazard, based on the depth below ground surface to the workings. Approximately one third of the area is zoned "High Risk", generally being the Waro area east of SH1. Development in this area is not recommended, unless the hazard can be avoided or remedied. Any buildings in "Moderate Risk" zones and "Low Risk" zones should be light timber framed structures only. Concrete and plaster masonry should be avoided, and services to the buildings should be specifically designed and constructed to accommodate differential settlements.

7.0 Applicability

This report has been prepared for the benefit of Whangarei District Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

TONKIN & TAYLOR LTD
Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor by:
.....	.....
Georg Winkler (MSc Engineering Geology)	Nick Rogers (Project Co-ordinator)

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29 January, 2002
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APPENDIX A

DRAWING 18596-01: EXTENT OF UNDERMINING AT HIKURANGI

APPENDIX B

DRAWING 18596-02: HIKURANGI MINING SUBSIDENCE HAZARD ZONATION PLAN

T&T job no: 17464.002
05 December 2005

Whangarei District Council
Forum North
Private Bag 9023
Whangarei

Attention: Harvey Schroyen

Dear Harvey

Review and Usage of Mine Subsidence Hazard Zones for Kamo and Hikurangi

1 Introduction

Following your request 28th November we have reviewed the Mine Subsidence Hazard Zonations for the Kamo and Hikurangi, in order to produce an Addendum to our earlier reports for of 1999[1] and 2001[2] and 2005[3].

2 Method

The Review involved:

- Searching our archives for data relating to the creation of mine subsidence hazard zones, investigation of the necessity for/methods of defining error bars/buffers on the zones.
- Production of a summary sheet of how the zones are defined and council's building requirements for each zone.

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1 "Mine Subsidence Hazard, Kamo Area, Whangarei"; Report for Whangarei District Council, March 1999; T+T reference 17464.

2 "Mine Subsidence Hazard, Hikurangi Area, Whangarei"; Report for Whangarei District Council, January 2001; T+T reference 18596.

3 "Mine Subsidence Hazard, Kamo Area, Whangarei"; Report for Whangarei District Council, March 2005; T+T reference 17464.001 (update of the October 1999 report).

- Indication of appropriate use of mine subsidence hazard zones with respect to any uncertainty/error bar in the data.

We present our summary sheet in Appendix One.

We trust that this addendum clarifies the issues that relate to appropriate application of the mine zones we defined in our earlier reports. If you have any further questions, please do not hesitate to contact us.

3 Applicability

This report has been prepared for the benefit of Whangarei District Council with respect to the particular brief given to us and it may not be relied upon in other contexts or for any other purpose without our prior review and agreement.

TONKIN & TAYLOR LTD

Environmental and Engineering Consultants

Report prepared by:	Authorised for Tonkin & Taylor by:
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Marion Irwin	Nick Rogers
Engineering Geologist	Project Co-ordinator

19-Dec-05
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Appendix A: Addendum to Tonkin and Taylor Reports:

1 “Mine Subsidence Hazard, Kamo Area, Whangarei”; Report for Whangarei District Council, March 1999; T+T reference 17464.

2 “Mine Subsidence Hazard, Hikurangi Area, Whangarei”; Report for Whangarei District Council, January 2001; T+T reference 18596:

3 “Mine Subsidence Hazard, Kamo Area, Whangarei”; Report for Whangarei District Council, March 2005; T+T reference 17464.001 (update of the October 1999 report).

<table>
<tr><th><u>Mine Zone</u></th><th><u>Definition of Mine Zone</u></th><th><u>WDC Policy for Building in Kamo and Hikurangi Mine Zone</u></th></tr>
<tr><td><u>Zone 1</u>
(high risk of subsidence)</td><td>Areas where there is less than 10xt cover, where t=seam thickness. Average tends to be about 20m, based on seam thickness of 2m. Within these areas there is a potential for “crown holing”.</td><td><u>Zone 1</u>

<u>A) Building Control Policy for Building In Mine Zones</u>

<u>December 1995</u>

1. Building consents are only to be issued for:
i) Repair of existing buildings.
ii) Minor extensions to existing buildings.
iii) Erection of single storey accessory buildings not exceeding 50m2 in area (e.g. carports, garages etc).
iv) Erection of fences, walls and retaining walls.
v) Single storey housing that can be transported intact, constructed using light weight building materials with the proviso that buildings or part thereof, located within a 20 metre radius of air shafts and mine entrances are supported with a full geotechnical appraised by a suitable qualified engineer.

2. Building Consents are to be issued only to the owner of the property, under Section 36(2) of the Building Act, with an entry on the Certificate of Title to the land that a building consent has been issued in respect of a building on land subject to subsidence.

<u>B) Policy Ammendment, 2000 adds</u>

1. That areas in zones one and two indicated in the Tonkin and Taylor report (figure 1 zones 1 and 2 to the west of zone 3) will require building consents be granted under 36(2) with the appropriate engineer’s report, unless the engineer can show council (subject to expert review by council’s consultant) that Section 36 is not applicable or that the hazard can be mitigated:

AND

subdivision and landuse requests associated with building development, will require an appropriate engineer’s report, subject to expert review with regard to the Tonkin and Taylor report.

2. That no building will be permitted within 20 m of a mine shaft, crown hole or mine entrance unless it can be demonstrated that the hazard can be mitigated or that building damage can be prevented.

3. That in all areas which are undermined (zones 1, 2 and 3) building design and construction must make allowances for potential subsidence.</td></tr>
<tr><td><u>Zone 2</u>
(moderate risk of subsidence)</td><td>1)Areas where overburden is between 20 and 10m thick. Within these areas there is a potential for “trough subsidence”, which could result in ground surface deformation, and damage to structures and services.

2) areas where there has been 2 seam pillaring and greater than 100m cover exists. Possible problems associated with this zone would be surface settlement, horizontal strains and</td><td><u>Zones 2 and 3</u>

A) <u>Building Control Policy for Building In Mine Zones</u>

<u>December 1995</u>

1. In all cases construction methods adopted must allow for potential subsidence and may require specific design.
2. Proposed Building Works or part thereof located within a 20 metre radius of air shafts and mine entrances are to be supported with a full geotechnical appraisal by a suitably qualified engineer.

The Council <u>may</u> issue Building Consents to the owner of the property, under Section 36(2) of the Building Act, with an entry on the Certificate of Title to the land that a building consent has been issued in respect of a building on land subject to subsidence.

<u>B) Policy Ammendment, 2000 adds</u>

4. That areas in zones one and two indicated in the Tonkin and Taylor report (figure 1 zones 1 and 2 to the west of zone 3) will require building consents be granted under 36(2) with the appropriate engineer’s report, unless the engineer can show council (subject to expert review by council’s consultant) that Section 36 is not applicable or that the hazard can be mitigated:</td></tr>
</table>

	subsidence fracturing. (ref T+T 17464.001 (2005))	*AND* *subdivision and landuse requests associated with building development, will require an appropriate engineer's report, subject to expert review with regard to the Tonkin and Taylor report.* 5. *That no building will be permitted within 20 m of a mine shaft, crown hole or mine entrance unless it can be demonstrated that the hazard can be mitigated or that building damage can be prevented.* 6. *That in all areas which are undermined (zones 1, 2 and 3) building design and construction must make allowances for potential subsidence.*
Zone 3 (low risk of subsidence)	Areas where depth to the workings is greater than 100m below the surface. Minor surface deformation is possible, but is unlikely to result in significant damage to structures.	**Zones 2 and 3** **A) Building Control Policy for Building In Mine Zones** **December 1995** 3. In all cases construction methods adopted must allow for potential subsidence and may require specific design. 4. Proposed Building Works or part thereof located within a 20 metre radius of air shafts and mine entrances are to be supported with a full geotechnical appraisal by a suitably qualified engineer. 5. The Council may issue Building Consents to the owner of the property, under Section 36(2) of the Building Act, with an entry on the Certificate of Title to the land that a building consent has been issued in respect of a building on land subject to subsidence. **B) Policy Ammendment, 2000 adds** 7. *That areas in zones one and two indicated in the Tonkin and Taylor report (figure 1 zones 1 and 2 to the west of zone 3) will require building consents be granted under 36(2) with the appropriate engineer's report, unless the engineer can show council (subject to expert review by council's consultant) that Section 36 is not applicable or that the hazard can be mitigated:* *AND* *subdivision and landuse requests associated with building development, will require an appropriate engineer's report, subject to expert review with regard to the Tonkin and Taylor report.* 8. *That no building will be permitted within 20 m of a mine shaft, crown hole or mine entrance unless it can be demonstrated that the hazard can be mitigated or that building damage can be prevented.* 9. *That in all areas which are undermined (zones 1, 2 and 3) building design and construction must make allowances for potential subsidence.*
Notes	(The worked areas have been projected to the surface at an angle of 60 to the horizontal (angle of draw) to allow for the increased area that would be affected should subsidence occur. This means that deeper workings will have a greater projected area of potential subsidence than shallower workings.)	A) The 1995 Policy also states that: "No building work is permitted where the risk of subsidence is increased by the proposal. All Building Consents for building work in mining zones are to be considered in terms of Section 36(2) of the Building Act. Construction methods used are to be compatible for any possible subsidence that may occur." B) WDC Policy is now outdated, since the new Building Act 2004 took effect in its entirety on 31 March 2005. The relevant parts of Section 36(2) of Building Act 1991 are now replaced by Sections 72 and 73 of the Building Act 2004. C) Please note that although the rules are the same for both Zones 2 and 3, it is useful to maintain these

		zones to indicate the different potential for damage to a property owner considering development of the land. D) T+T ref. 17464.001has the additional suggestion that: "WDC should adopt a cautious approach on subdivision of green-field sites for urban development in areas which are undermined. We recommend that no further subdivision of land in Zone 1 or Zone 2 be permitted, and that the extent of subdivision of land in Zone 3 be restricted."
T+T reference	Mine Subsidence Hazard, Hikurangi area, Whangarei. Report for Whangarei District Council, 2001). T+T ref. 18596	Mine Subsidence Hazard, Kamo area, Whangarei. Report for Whangarei District Council, 2005). T+T ref. 17464.001
Application of Mine Zonations	**A) The mine zones are drawn conservatively, so that their boundary represents the outermost limit of possible subsidence. In other words, any error bar/ uncertainty buffer is included within the zone itself.** **B) The rules that apply to any proposed building work are defined by taking the highest hazard zonation that affects the proposed building and its amenities (not the whole property).** **C) For example, if only part of a property is defined as being within a mine subsidence hazard zone, then the above rules will only apply if any part of the proposed building and/or its amenities lie(s) within the zone. If the proposed building and its amenities lie entirely outside the mine hazard zone, then these rules do not apply: the proposed building works are to be treated as not being at hazard of mine subsidence.** **D) Likewise, if part of the property is defined as being within a high mine subsidence hazard, and part is defined as being of moderate hazard, the rules for high hazard will only apply if the proposed building and/or its amenities lie(s) within the high hazard zone. If the proposed building and its amenities lie entirely within the moderate mine hazard zone, then the proposed building works are to be treated as being at moderate hazard of mine subsidence.**	