



**THREE KINGS QUARRY**

**RESOURCE CONSENT 12977**

**ANNUAL DEWATERING MONITORING REPORT**

**May 2014**

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## **ANNUAL DEWATERING MONITORING REPORT**

### **Introduction**

The following report is made with regard to Section 9 of the Monitoring and Contingency Plan for Dewatering Three Kings Quarry dated September 2005.

This report contains a compilation of all monitoring data and documents any settlement alarm level events, reviews and remedial action undertaken for the period of 1 April 2013 to 31 March 2014 and includes the precise level survey completed in April 2014.

### **Monitoring Summary**

The monitoring of groundwater levels has been undertaken monthly for the year ending 31 March 2014.

Groundwater levels within the quarry have been held above RL34m since the lowering of the groundwater table ceased in October 2002.

In the 12 months to 31 March 2014, 3 pneumatic piezometers reached the end of their operating life and are not responding to monitoring (piezometers 25B1 and 25B2 located in BH25B on Hillsborough Road and 31A located within BH31 on Shackleton Road).

No new groundwater monitoring bores were installed in the 12 month period ending 31 March 2014.

The pneumatic piezometer in BH31 which ceased operating (31A) was substituted by the standpipe piezometer in BH33, and the pneumatic piezometers in BH25B (25B1 and 25B2) were substituted with the standpipe piezometer in BH25A.

A survey of all precise level benchmarks was undertaken in March-April 2014. Final results were received 9 April 2014.

Precise level surveys are currently being undertaken at 12 month intervals as dewatering (lowering of the groundwater table) has not been undertaken for more than 2 years, and there has been a cessation of settlement (no settlement as a result of dewatering greater than 5mm in any continuous 12 month period).

Two replacement marks were installed within the survey network, and differential settlement alarm values were continued to be recorded between marks within the general area of Mt Albert Road and Hillsborough Road. Differential settlement alarm values were also recorded to the north-west and south-west of Three Kings Quarry (on Duke Street and McCullough Avenue/Smallfield Avenue respectively).

Groundwater levels and precise level survey results are attached to this report.

## **Groundwater Levels**

Groundwater levels within the quarry continue to be maintained by pumping at between RL34m and RL35m. Groundwater levels in groundwater monitoring bores adjacent to and within Three Kings Quarry (especially BH6c, BH17, BH18A, BH19A and BH21 in the area surrounding Three Kings Quarry) continue to be drawn down by the dewatering of Three Kings Quarry.

Groundwater level monitoring elsewhere continues to record seasonal variations.

Groundwater level monitoring results (including graphs of monitoring results since December 1996) for the year ending 31 March 2014 are attached.

## **Precise Level Survey Results**

A survey of all precise level benchmarks was undertaken in March-April 2014. Results were received 9 April 2014.

All precise level survey marks were within 5mm of the previous reading.

Settlements recorded in the May 2013 and previous surveys along the northern edge of the survey area (from Dominion Road in the west to The Drive in the east) have corrected themselves. These marks are generally outside the dewatering area of influence and movements may be a result of survey accuracy.

Two replacement marks were installed:

- AP10A on Roskill Way (replaces AP10) and
- AP18B on Mt Eden Road (replaces AP18A).

Both marks were lost due to footpath/kerb replacement works.

## Differential Settlement

Differential settlement alarm values continue to be recorded between:

- AP92 and AP93, and AP92 and AP80 on Mt Albert Road,
- AP62A and AP88A at the intersection of Mt Albert and Hillsborough Road,
- AP110 and AP111 on Hillsborough Road,
- OCP68 and AP114, AP69 and AP114, AP115 and AP116, AP70 and AP117, and AP38 and AP117 on Budock Road,
- OCP90B and SM6241 on Duke Street, and
- RM3901 and RM3902 on Smallfield Avenue

In addition differential settlement alarm values were recorded between:

- AP74A and AP75 on Marie Avenue,
- AP71A and BP1977B on Hillsborough Road, and
- RM3900 and RM3901 on McCullough Avenue / Smallfield Avenue.

Marks	Location	April-14 Differential Settlement	Distance between Marks	Adjusted Difference in Levels between Marks
AP92 and AP93	Mt Albert Road	1 in 852	16.7m	19.6mm
AP92 and AP80	Mt Albert Road	1 in 859	17.7m	20.6mm
AP62A and AP88A	Mt Albert and Hillsborough	1 in 3289	24.1m	7.3mm
AP110 and AP111	Hillsborough Road	1 in 3019	17.7m	5.9mm
BP1977B and AP71A	Hillsborough Road	1 in 4991	53.0m	10.6mm
OCP68 and AP114	Budock Road	1 in 1817	23.0m	12.6mm
AP69 and AP114	Budock Road	1 in 2368	26.4m	11.1mm
AP115 and AP116	Budock Road	1 in 4306	20.2m	4.7mm
AP70 and AP117	Budock Road	1 in 1688	21.5m	12.7mm
AP38 and AP117	Budock Road	1 in 1875	22.9m	12.2mm
AP74A and AP75	Marie Avenue	1 in 4843	52.8m	10.9mm
OCP90B and SM6241	Duke Street	1 in 3982	42.6m	10.7mm
RM3900 and RM3901	McCullough Avenue	1 in 4512	82.7m	18.3mm
RM3901 and RM3902	Smallfield Avenue	1 in 4496	82.6m	18.4mm

A trend analysis of each differential settlement alarm is attached to this report.

The actions required for Differential Settlement Alarms Values less than 1 in 5000 but greater than 1 in 2000 are to report these to the Auckland Council and Three Kings Quarry Manager, and to install additional survey marks at 50 metre centres between existing survey marks.

Please note that the spacing between marks with the exception of RM3900 and RM3901, RM3901 and RM3902, BP1977B and AP71A, and AP74A and AP75 are already less than 50 metres.

The differential settlement alarm between RM3900 and RM3901, and RM3901 and RM3902 are not considered to be the result of dewatering Three Kings Quarry. As reported in the April 2012 Annual Monitoring Report, settlements recorded in RM3901 was considered to be partly due to an adjacent leaking water main.

The differential settlement alarm between BP1977B and RM3901, and AP74A and AP75 are also not considered to be the result of dewatering Three Kings Quarry. Benchmarks BP1977B and AP75 have both recorded a rising level since February 2011 and March 2012 respectively.

The differential settlement between OCP90B and SM6241 on Duke Street has been just over 1 in 6000 since March 2008. The recent increase in the differential settlement has been a relative rise in OCP90B compared with SM6241. Trend analysis indicates this differential settlement between these two marks will remain at about 1 in 5000.

The actions required for Differential Settlement Alarm Values less than 1 in 2000 but greater than 1 in 1000 are to:

- Install additional survey marks at 25metre centres between existing marks,
- Report these settlements to the Three Kings Quarry Manager, affected property owners, South Epsom Planning, Three Kings United, Epsom Environmental Effects, and Mt Roskill and Eden-Albert Community Boards.
- Assess the potential impact of on-going settlements on building and services, and
- Undertake a review of the groundwater model and settlement predictions.

The Differential Settlement Alarms currently being recorded between AP38, AP70 and AP117 on Budock Road are not a result of dewatering Three Kings Quarry. AP38 and AP70 have recorded settlements consistent with other marks in this area, while AP117 has recorded a 9.8mm rise since it was installed in 2003.

The Differential Settlement Alarm currently being recorded between AP114 and OCP68 is also not a result of dewatering Three Kings Quarry. OCP68 has have recorded settlements consistent with other marks in this area, while AP114 has recorded an 8.5mm rise since it was installed in 2003.

There are visual signs of deterioration or disturbance to the footpath along Budock Road (all marks along Budock Road are survey nails in the footpath or driveways). There is a noticeable deterioration in the footpath at the location of AP117 (photographs attached).

A detailed analysis of precise level survey marks in the vicinity of AP38, AP70 and AP117, and AP114 and OCP68 is presented in the following table. The locations of precise level survey marks are shown on the attached drawings. The adjusted change in level is undertaken to correct for any movement arising from the dewatering of Three Kings Quarry prior to the precise level mark being installed.

<i>Precise Level Mark</i>	<i>Change in Level since First Survey (mm)</i>	<i>Adjusted Change in Level (mm)</i>	<i>Precise Level Marks</i>	<i>Differential Settlement</i>	
				<i>Spacing (metres)</i>	<i>Differential Settlement</i>
AP 38	-6.70	-6.70			
AP 117	+9.83	+5.49	AP38-AP117	22.9	1 in 1875
AP 70	-4.77	-7.23	AP117-AP70	21.5	1 in 1688
AP 116	-2.27	-8.45	AP70-AP116	18.7	1 in 15362
AP 115	-5.73	-13.14	AP116-AP115	20.2	1 in 4306
AP 69	-6.43	-12.85	AP115-AP69	22.0	1 in 75856
AP 114	+8.47	-1.72	AP69-AP114	26.4	1 in 2368
OCP 68	-4.90	-14.37	AP114-OCP68	23.0	1 in 1817
AP 113	-1.63	-14.52	OCP68-AP113	21.2	1 in 14396
AP 112	-4.80	-19.53	AP113-AP112	25.7	1 in 5127
AP 67	-8.70	-22.41	AP112-AP67	17.6	1 in 6112

The results show that the change in level of AP117 and AP114 (and to a lesser extent AP116 and AP113) is anomalous and not consistent with the settlement arising from the dewatering of Three Kings Quarry. The relative rise in level is not considered to be a result of dewatering Three Kings Quarry.

The actions required for Differential Settlement Alarm Values less than 1 in 1000 are to:

- Cease taking groundwater from Three Kings Quarry,
- Report these settlements to the Three Kings Quarry Manager, the Auckland Council, affected property owners, South Epsom Planning, Three Kings United, Epsom Environmental Effects, and Mt Roskill and Eden-Albert Community Boards.
- Assess the potential impact of on-going settlements on affected structures, and
- Assess and repair any damage in accordance with condition 21B of the consent to dewater Three Kings Quarry.

The Differential Settlement Alarms currently being recorded between AP80, AP92 and AP93 on Mt Albert Road adjacent to the St Andrews Reserve are not a result of dewatering Three Kings Quarry. AP80 and AP93 have recorded settlements consistent with other marks in this area while AP92 has risen 10mm since it was installed in 2003.

There are signs of deterioration or disturbance to the footpath at the location of AP92. There is a noticeable upward bowing in the concrete footpath compared with the kerb (photographs attached).

A detailed analysis of precise level survey marks in the vicinity of AP80, AP92 and AP93 is presented in the following table. The locations of precise level survey marks are shown on the attached drawings. The adjusted change in level is undertaken to correct for any movement arising from the dewatering of Three Kings Quarry prior to the precise level mark being installed.

<i>Precise Level Mark</i>	<i>Change in Level since First Survey (mm)</i>	<i>Adjusted Change in Level (mm)</i>	<i>Precise Level Marks</i>	<i>Differential Settlement</i>	
				<i>Spacing (metres)</i>	<i>Differential Settlement</i>
RM 6813	-26.73	-26.73			
AP 97	-7.7	-26.36	RM6813-AP97	25.0	1 in 66907
AP 96	-7.4	-26.45	AP97-AP96	25.5	1 in 283532
AP 8B	-16.6	-28.03	AP96-AP8B	25.0	1 in 15823
AP 79	-9.1	-22.03			
AP 94	-7.27	-24.90	AP79-AP94	21.8	1 in 7601
AP 8B	-16.6	-28.03	AP94-AP8B	23.2	1 in 7396
AP 93	-8.93	-27.53	AP8B-AP93	23.7	1 in 47727
AP 92	+10.07	-7.95	AP93-AP92	16.7	1 in 852
AP 80	-14.53	-28.60	AP92-AP80	17.7	1 in 859
AP 91	-10.43	-28.25	AP80-AP91	20.9	1 in 59820
AP90	-10.4	-28.65	AP91-AP90	21.8	1 in 54972
RM 7647	-27.37	-27.37	AP90-RM7647	21.0	1 in 19327

The results show that the change in level of AP92 is anomalous and not consistent with the change in levels in the surrounding precise level survey marks. Its relative rise in level is not considered to be a result of dewatering Three Kings Quarry.

These differential settlement alarm values are being carefully tracked and any further assessments will be undertaken as required by the Monitoring and Contingency Plan for Dewatering Three Kings Quarry.

## Stage Control Levels

A review of the Stage Control Levels has been undertaken (Table 1, Section 7.0 of the Monitoring and Contingency Plan). Intermediate triggers have been recorded for total settlement in Settlement Zones I, II, and III.

Section 7.1 of the Monitoring and Contingency Plan requires that if a Stage Control Trigger is recorded, dewatering (lowering of the groundwater table) is to cease. Section 7.2 requires a review of groundwater levels and precise level survey data. Section 7.3 requires that the results of this review be forwarded to the Auckland Council prior to dewatering recommencing.

Graphs showing the adjusted total settlements exceeding the Intermediate Trigger (any pre-existing settlement has been added to marks installed after dewatering commenced) of precise level marks in each Settlement Zone are attached together with the drawing showing the Settlement Zones.

In summary, the Immediate Trigger for Zone 1 for quarry groundwater drawdown at RL30m is 10mm, 20mm for Zone II, 45mm for Zone IIA, 15mm for Zone IIB, 10mm for Zones III and IV, 25mm for Zone IIIA and 5mm for Zone V. There are no precise level marks in Zone IIIB.

These triggers and the current maximum settlement recorded in each zone are summarised as follows:

Settlement Zone	Intermediate Trigger (mm)	Current Maximum Total Settlement (mm)
Zone 1	10	17 (35)
Zone II	20	29 (33)
Zone IIA	45	29
Zone IIB	15	15
Zone III	10	12
Zone IIIA	25	14
Zone IIIB	20	-
Zone IV	10	7
Zone V	5	4

Please note, precise level mark M220 in Zone 1 is currently recording 35mm of settlement, and in Zone II, two precise level marks (RM3901 and RM3895) are currently recording 33mm of movement. These settlements however are not considered to be solely a result of dewatering Three Kings Quarry.

The movement in M220 occurred following works undertaken on the footpath and its level was adjusted upwards in March 2006 by 22.5mm.

The movement of RM3895 is considered to be a result of the removal an adjacent large tree at some time in the past, and the recent movement in RM3901 is considered to be in part due to a leaking water main.

Although further dewatering is not being proposed, a review of groundwater levels and survey data has been undertaken.

Groundwater levels have generally stabilised since dewatering (lowering of the groundwater table) ceased in October 2002. Groundwater levels have generally only varied due to season

fluctuations since dewatering ceased with some rebound of groundwater levels following the reduced pumped rates being measured in isolated piezometers (bores 23, 26, 28a, 29, 30 and 33).

Precise level benchmarks surveyed levels have stabilised since dewatering ceased with cessation of settlement of precise level survey marks (no settlement as a result of dewatering greater than 5mm in any continuous 12 month period) having been recorded since September 2005.

In summary, the primary consolidation associated with dewatering ceased mid-2004. Precise level survey marks in Areas I, II, IIA and IIIA are recording some secondary consolidation but at a much reduced rate compared with the primary consolidation (3 to 4mm per year primary consolidation compared with 0.6 to 0.9mm per year secondary consolidation).

The Intermediate Stage Control Triggers are shown on the attached graphs with the location of the triggering points shown on the attached plan. The location of the triggering points are scattered but are generally grouped to the northwest and southeast of Three Kings Quarry.

Differential settlement triggers associated with these Intermediate Stage Control Triggers have been recorded between OCP90B and SM6241 on Duke Street (1 in 3982), and between RM3900 and RM3901 and RM3901 and RM3902 on the corner of McCullough Ave and Smallfield Ave (1 in 4512 and 1 in 4496 respectively).

Please note that the settlements associated with precise level mark RM3901 is considered to in part due to a leaking water main, and the recent movements recorded in RM3900, RM3902 and OCP90B are all slightly upwards.

With regard to section 7.2 of the Monitoring and Contingency Plan, ground settlements are not greater than 10mm per year; there are no differential settlement (as a result of the dewatering) greater than 1 in 2000; and there is no settlement greater than 100mm for points established prior to 30 September 2002, or greater than 75mm for points established after 30 September 2002.

There is no proposal to recommence dewatering. As required by section 7.3 of the Monitoring and Contingency Plan, should dewatering be recommenced, the results of a review undertaken prior to dewatering recommencing will be forwarded to the Auckland Council.

## Seasonal Variation Calculations

As required by Section 6.7 of the Monitoring and Contingency Plan, seasonal variation calculations were defined for bores 37, 38, 39 and 40 in the 2007 Annual Report. Seasonal variation for the deep and shallow piezometers respectively in bores 37, 38, 39 and 40 are as follows:

Table 1: Seasonal Variation - Deep Piezometers

	BH37a	BH38a	BH39a	BH40a
99% Confidence Limits	RL54.17m	RL54.73m	RL55.31m	RL62.07m
	RL53.60m	RL53.80m	RL54.82m	RL61.23m
99.9% Confidence Limits	RL54.25m	RL54.85m	RL55.37m	RL62.19m
	RL53.53m	RL53.67m	RL54.76m	RL61.12m



Table 2: Seasonal Variation - Shallow Piezometers

	BH37b	BH38b	BH39b	BH40b
99% Confidence Limits	RL54.03m RL53.56m	RL53.80m RL53.33m	RL57.42m RL56.50m	RL63.86m RL63.31m
99.9% Confidence Limits	RL54.09m RL53.50m	RL53.87m RL53.26m	RL57.55m RL56.38m	RL63.94m RL63.23m

Seasonal variation triggers are the greater of the 0.2 metres below the bottom level of the natural groundwater level range (99% confidence level), or the bottom 99.9% probability limit calculated from the first two years of data.

Table 3: Seasonal Variation Triggers

	BH37	BH38	BH39	BH40
Deep Piezometer	RL53.40m	RL53.60m	RL54.62m	RL61.03m
Shallow Piezometer	RL53.36m	RL53.13m	RL56.30m	RL63.11m

The groundwater levels in BH40a and BH40b have been in excess of seasonal variation trigger since early 2008. A trigger was recorded in BH39a in April 2013.

BH40 is the southern most of the Three Kings Quarry groundwater monitoring bores located on Hillsborough Road just to the north of the SH20. BH39 is located approximately 450m to the northwest of BH40.

Groundwater monitoring bores located closer to the Three Kings Quarry (boreholes 35, 36, 28 and 29) have generally recorded slightly rising groundwater levels since installation (boreholes 28, 29 and 36). Borehole 35 has recorded a slight fall. Seasonal variations are less than a metre.

The groundwater level in BH40a (deep piezometer) has fallen approximately 0.95metres from an average level of approximately RL61.65m (to March 2007) to an average level for the year ending 31 March 2014 of approximately RL60.70m.

The groundwater level in BH40b (shallower piezometer) has fallen 0.85m from an average level of approximately RL63.6m (to March 2007) to an average level for the year ending 31 March 2014 of approximately RL62.75m.

The groundwater levels in BH40a and BH40b are currently recording seasonal variation of about 0.5metres (refer attached graphs).

The average groundwater level in BH39a for the year ending 31 March 2014 was RL54.71m with the lowest recorded level (April 2013) being RL54.59m compared with a trigger level of RL54.62m. Seasonal variation was less than 25cm. Groundwater levels in the upper piezometer (BH39b) have been rising slightly.

Up until March 2008, Transits groundwater monitoring bores adjacent to the "Hillsborough Road cut" SH20 works recorded a similar or greater amount of change although the monitoring record is not complete as the Three Kings Quarry groundwater monitoring record. Transits BH15 on the crest of the Hillsborough Road cut recorded a fall in groundwater level of 1.9m since December 2006 (from RL64.44m to RL62.53m).

The Transit monitoring bores do not extend to the same depth as the Three Kings Quarry groundwater monitoring bores but all bores are located in East Coast Bays Formation (Waitemata).

As reported previously, although the monitoring results are not conclusive (with the deeper groundwater level in BH40a being drawn down more than the shallower groundwater level – BH40b), as the groundwater monitoring bores closer to the Three Kings Quarry are not being drawn down, it is considered unlikely that the falling groundwater levels being recorded in BH40a and BH40b are the result of dewatering Three Kings Quarry.

With regard to BH39a, given the absence of drawdowns being recorded in bores closer to the Three Kings Quarry, the trigger recorded in BH39a in April 2013 is considered to be a result of either a natural variation of groundwater levels or a propagation of the drawdown being recorded in BH40.

## **REVIEWS**

### Groundwater

The results of the groundwater level monitoring are checked and reviewed as the results are received. A review of groundwater levels and precise level survey marks has been undertaken as required by Section 7.2 of the Monitoring and Contingency Plan.

### Surface Levels

The results of precise level surfaces are checked and reviewed when the results are received, with the results forwarded to the Auckland Council and Three Kings United Inc.

A review of precise level survey data was undertaken by Tonkin and Taylor in 2005. This report reviewed settlement data to the March 2005 survey and included the findings of the Pattle Delamore Annual Groundwater Report dated January 2005.

The Tonkin and Taylor report concluded that while surface settlement monitoring indicates that surface settlement is typically on-going about the quarry, it is at a much reduced rate.

The on-going settlement close to the quarry was concluded to be the result of secondary consolidation induced by changes in groundwater pressure associated with past quarry dewatering. At increased distances from the quarry, Tonkin and Taylor concluded that it is possible that the ongoing surface settlement includes some delayed consolidation as a result primarily consolidation of soil strata not currently monitored by piezometers. In addition Tonkin and Taylor concluded that any groundwater drawdown effects at distance from the quarry are small and surface settlement data at the fringe of drawdown are within expected settlement tolerances.

A further review of the precise level survey information was undertaken in August 2005 to determine if cessation of settlement had occurred. It was found that cessation of settlement (as defined by the consent to dewater Three Kings Quarry) had occurred and this was reported more fully to the Auckland Regional Council in September 2005. As such, and because more than two years has elapsed since dewatering has been undertaken, precise level surveys are now required to be undertaken at 12 month intervals.

A review of the precise level data has been undertaken as required by Section 7.2 of the Monitoring and Contingency Plan – exceedance of an Intermediate Settlement Trigger. The

review concluded that settlements are not in excess of 10mm per year; that the differential settlement between any two monitoring points caused by the exercise of the consent to dewater Three Kings Quarry is not greater than 1 in 2000; and total settlement is not greater than 100mm (or 75mm for precise level survey marks installed after 30 September 2002).

There is currently no proposal to further dewater Three Kings Quarry and groundwater levels will be held at or above RL34m.

### **REMEDIAL ACTION**

No remedial action was required or undertaken for the period ending 31 March 2014.