

# Report

Red Hill Mining Lease EIS

Subsidence Water Resources Hydrology Assessment

20 AUGUST 2013

Prepared for  
BHP Billiton Mitsubishi Alliance

42627136

**URS**

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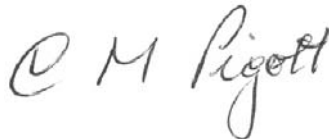


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## Abbreviations

Abbreviation	Description
AMTD	adopted middle thread distance
AWBM	Australian water balance model (stream flow or runoff modelling software)
BMA	BHP Billiton Mitsubishi Alliance
BRM	Broadmeadow underground mine
CHPP	coal handling and preparation plant
DEM	digital elevation model
DERM	<i>Former</i> Department of Environment and Resource Management
DNRW	<i>Former</i> Department of Natural Resources and Water (now NRM)
DTM	digital terrain model
EFO	environmental flow objectives
EIS	environmental impact statement
GRB	Goonyella Riverside Broadmeadow
IQQM	integrated quantity quality model (stream flow modelling software)
MIA	mine industrial area
MLA	mine lease area
NRM	Department of Natural Resources and Mines
RHM	Red Hill Mine
URS	URS Australia Pty Ltd

Units	Description
ha	hectares
km <sup>2</sup>	square kilometres
m	metre
m <sup>2</sup>	square metre
m <sup>3</sup>	cubic metre
m/day	metres per day
ML	megalitre
ML/day	megalitres per day
ML/year	megalitres per year
mm/day	millimetres per day
mm/year	millimetres per year

## Introduction

### 1.1 Overview

The Red Hill Mining Lease is located adjacent to the existing Goonyella, Riverside and Broadmeadow (GRB) mine complex in the Bowen Basin, approximately 20 kilometres north of Moranbah and 135 kilometres south-west from Mackay, Queensland.

BHP Billiton Mitsubishi Alliance (BMA), through its joint venture manager, BM Alliance Coal Operations Pty Ltd, proposes to convert the existing Red Hill Mining Lease Application (MLA 70421) to enable the continuation of existing mining operations associated with the GRB mine complex. Specifically, the mining lease conversion will allow for:

- An extension of three longwall panels (14, 15 and 16) of the existing Broadmeadow underground mine (BRM). Key aspects include:
  - No new mining infrastructure is proposed other than infrastructure required for drainage of incidental mine gas (IMG) to enable safe and efficient mining.
  - Management of waste and water produced from drainage of IMG will be integrated with the existing BRM waste and water management systems.
  - The mining of the Broadmeadow extension is to sustain existing production rates of the BRM and will extend the life of mine by approximately one year.
  - The existing BRM workforce will complete all work associated with the extension.
- A future incremental expansion option of the existing Goonyella Riverside Mine (GRM). Key aspects include:
  - underground mining associated with the RHM underground expansion option to target the Goonyella Middle Seam (GMS) on mining lease (ML) 1763;
  - a new mine industrial area (MIA);
  - a coal handling and preparation plant (CHPP) adjacent to the Riverside MIA on MLA1764 and ML1900 – the Red Hill CHPP will consist of up to three 1,200 tonne per hour modules;
  - construction of a drift for mine access;
  - a conveyor system linking RHM to the Red Hill CHPP;
  - associated coal handling infrastructure and stockpiles;
  - a new conveyor linking product coal stockpiles to a new rail load-out facility located on ML1900; and
  - means for providing flood protection to the mine access and MIA, potentially requiring a levee along the west bank of the Isaac River.
- A future Red Hill Mine (RHM) underground expansion option located to the east of the GRB mine complex to target the GMS on MLA70421, as well as development of key infrastructure including:
  - a network of bores and associated surface infrastructure over the underground mine footprint for mine gas pre-drainage (IMG) and management of goaf methane drainage to enable the safe extraction of coal;
  - the proposed mine layout consists of a main drive extending approximately west to east with longwall panels ranging to the north and south;
  - a ventilation system for the underground workings;
  - a bridge across the Isaac River for all-weather access. This will be located above the main headings, and will also provide a crossing point for other mine related infrastructure including water pipelines and power supply;

## 1 Introduction

- a new accommodation village (Red Hill accommodation village) for the up to 100 per cent remote construction and operational workforces with capacity for up to 3,000 workers; and
- potential production capacity of 14 million tonnes per annum (mtpa) of high quality hard coking coal over a life of 20 to 25 years.

The three project elements described above are collectively referred to as 'the project'.

URS Australia Pty Ltd (URS) was commissioned by BMA to undertake a range of technical studies for surface water management to support the EIS for the project. This report presents an assessment of the potential hydrological impacts of subsidence that will occur and remain upon completion of the longwall mining.

Flood hydrology predictions were modelled on the October 2011 mine plan sequence. A new mining sequence has since been developed for the RHM, Broadmeadow extension and the existing approved BRM. Further, both the BRM and the proposed Broadmeadow extension footprints have been revised. This has the potential to alter flood hydrology over the life of mine. However, the mine plan and revised schedule are indicative only and sequencing of production and annual production rates may vary. Regardless of this, the changes are not anticipated to have a significant impact on modelling predictions.

### 1.2 EIS Study Area

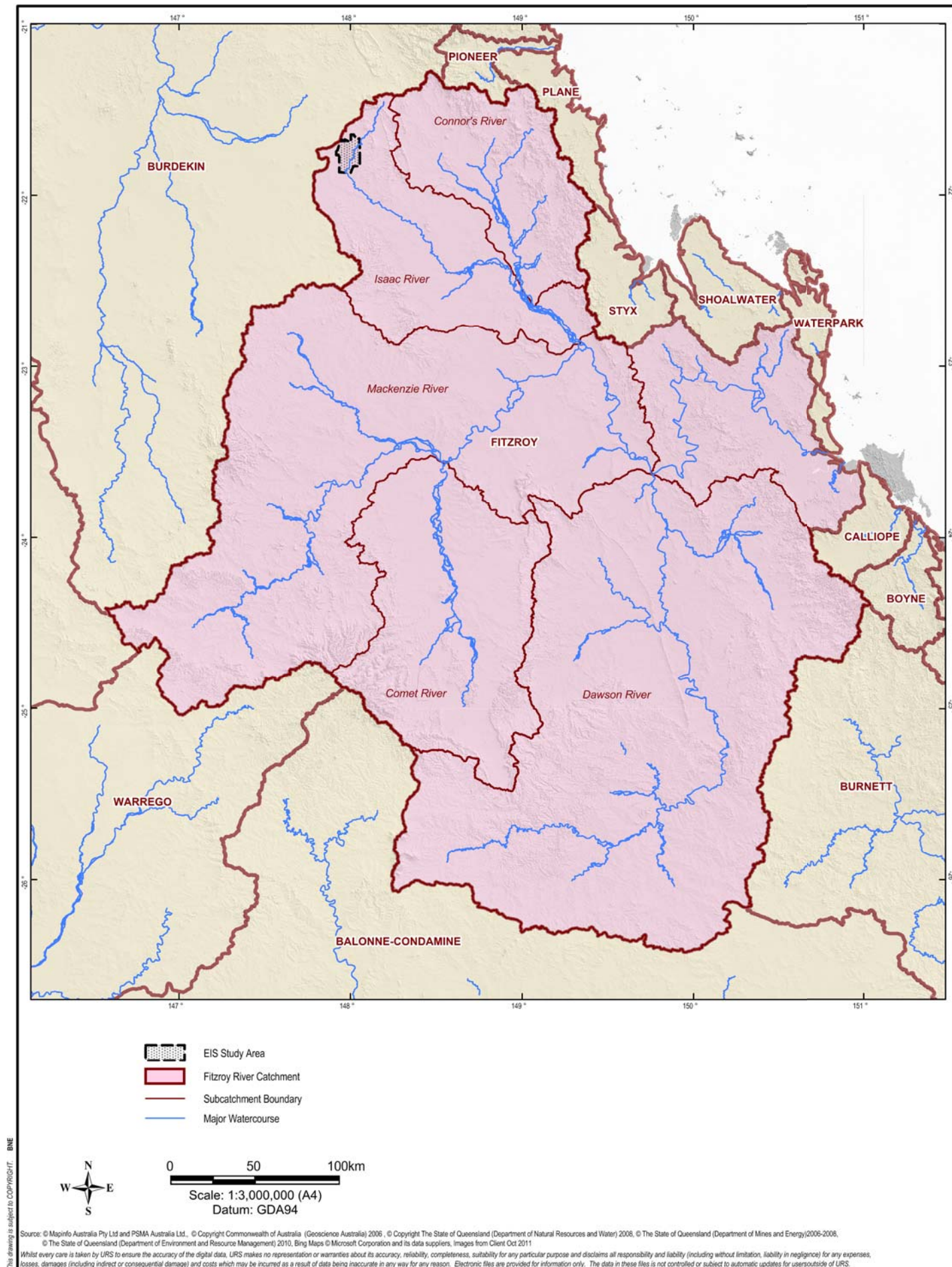
The regional context is shown on **Figure 1-1**, and the local catchment context is shown on **Figure 1-2**.

The EIS study area is located within the Isaac-Connors sub-catchment, of the greater Fitzroy Basin. In the greater regional catchment context, the EIS study area is in the far upstream headwaters of the Fitzroy Basin, and relatively high in the headwaters of the Isaac River sub-catchment.

The project activities will occur completely within the broader Isaac River catchment, and span across the tributary catchments of Goonyella Creek and 12 Mile Gully. Other nearby tributaries around the EIS study area include Eureka Creek, Fisher Creek and Platypus Creek. All watercourses are ephemeral and flow periods are limited to flow during rainfall events and limited recession periods for a few days up to a week after rainfall ceases.

It should be noted that the EIS study area is the main area of interest for hydrological assessment; however, the assessment of water resources within the EIS study area is intrinsically dependant on relevant stream catchment areas which extend beyond the EIS study area. Furthermore, the hydrological assessment has considered regional significance of the potential hydrological impacts and this matter also extends beyond the EIS study area.





BHP Billiton Mitsubishi Alliance

## RED HILL MINING LEASE SUBSIDENCE HYDROLOGY ASSESSMENT TECHNICAL REPORT

## REGIONAL CATCHMENT CONTEXT

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**SURFACE WATER**

Figure: **1-1**



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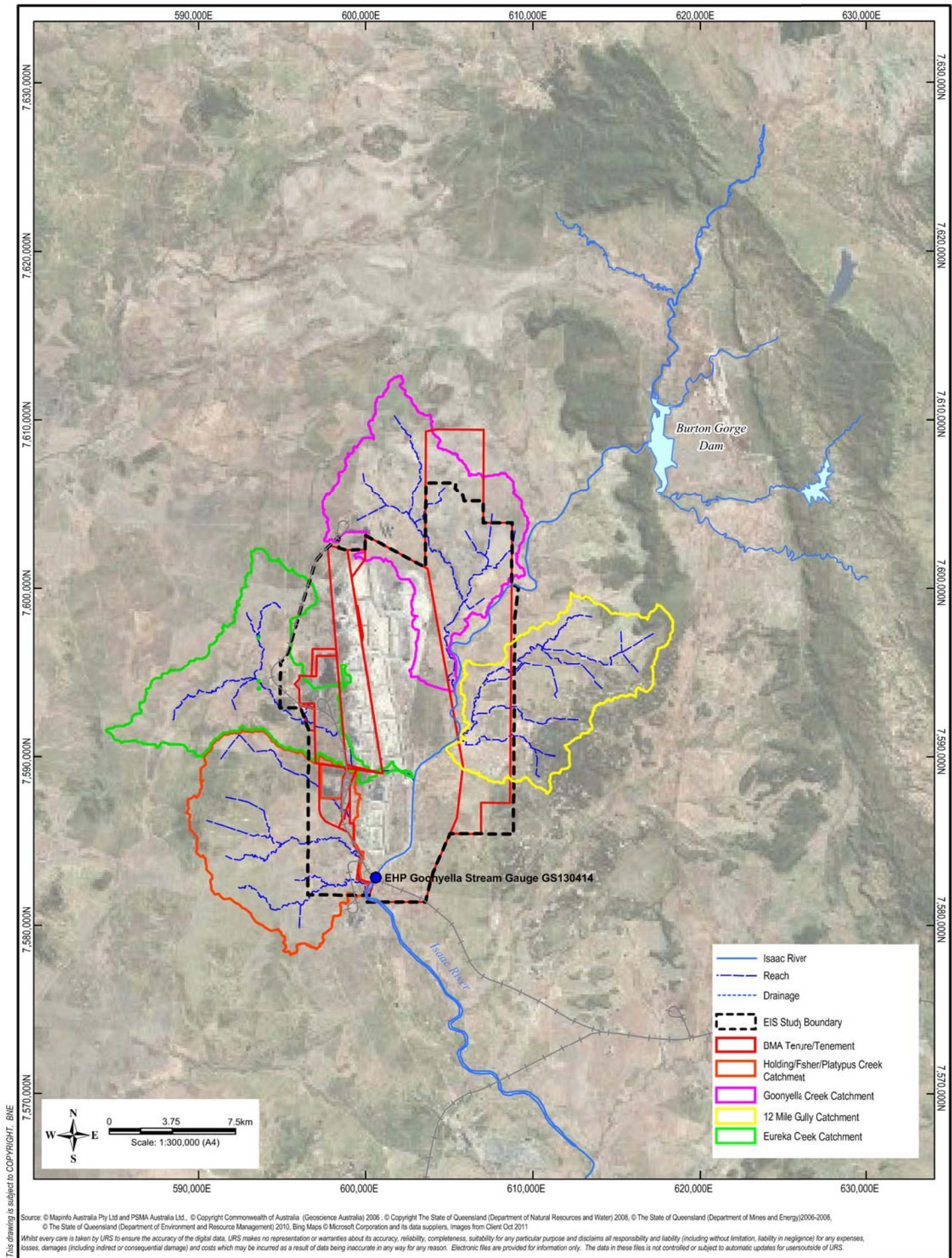
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## 1 Introduction

### 1.4 Climate Data

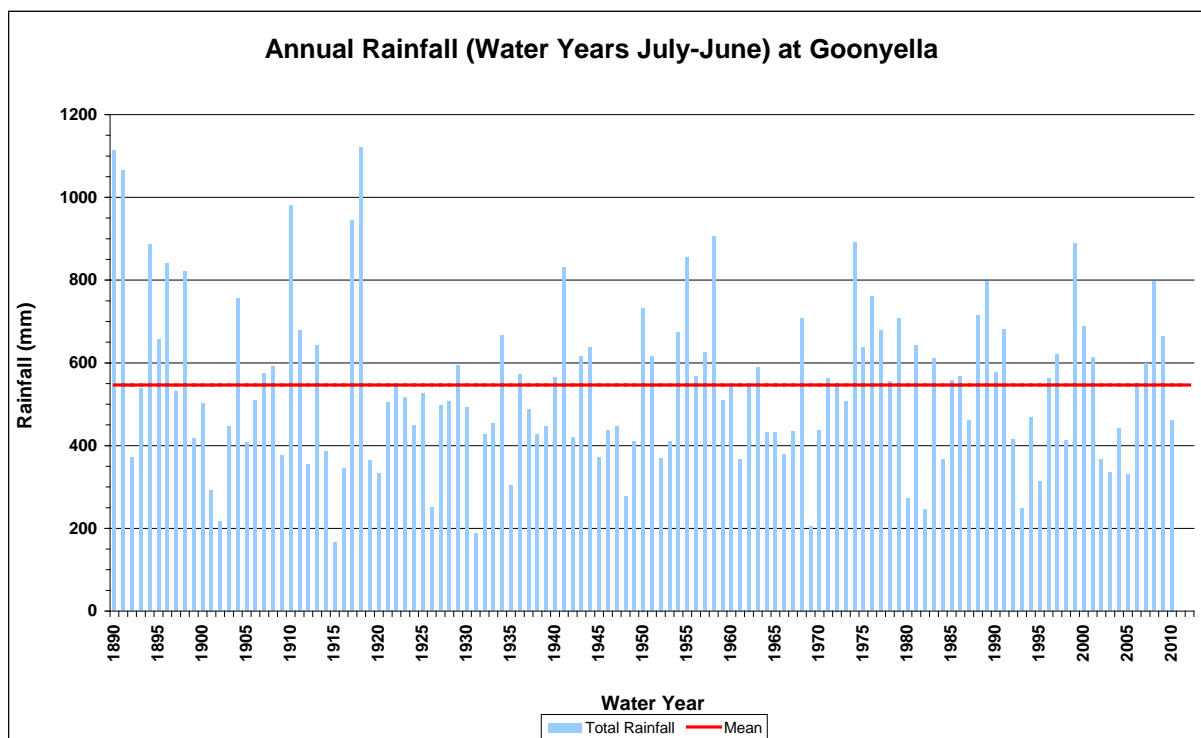
The primary climate influences on hydrology and surface water flows are rainfall and evaporation which are summarised herein.

Historic climate data was sourced from the Bureau of Meteorology SILO Data Drill using 123 years of records (1889 to 2011). **Figure 1-3** shows annual water year totals for the EIS study area and **Figure 1-4** shows mean monthly rainfall and evaporation.

Annual rainfall at the EIS study area is highly variable and subject to prolonged periods of above and below average rainfall. The mean monthly rainfall shows a distinct seasonal distribution with monthly rainfall totals greatest in the wet season extending from December through February, and peaking in January at just over 100 millimetres. The average monthly evaporation exceeds the average monthly rainfall throughout the year with a maximum of around 245 millimetres average monthly evaporation in December.

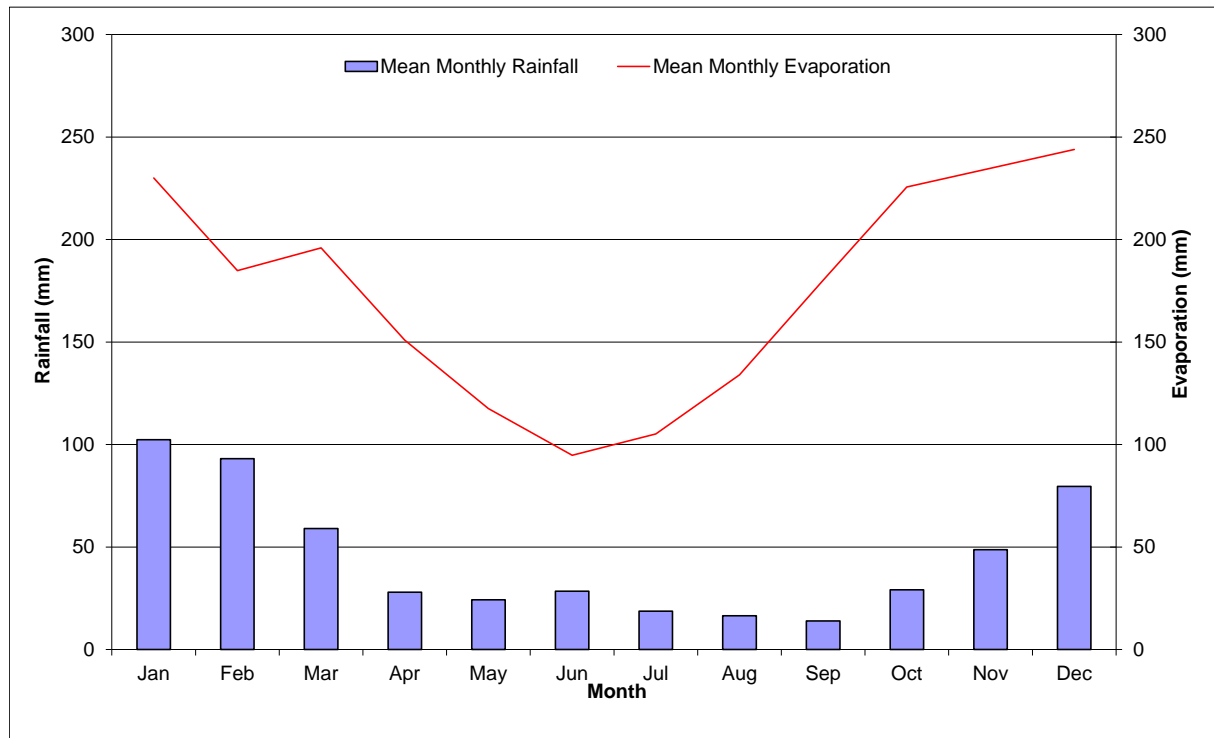
It is important to note that average monthly statistics are not used for the purpose of hydrological modelling as wet season rainfall in wetter years, which can be highly variable, can substantially exceed evaporation rates.

**Figure 1-3 Time Series Annual Rainfall Totals**



## 1 Introduction

**Figure 1-4 Mean Monthly Rainfall and Evaporation**



### 1.5 Subsidence Estimates

The potential extent and magnitude of subsidence as a result of the proposed underground longwall mining has been considered by a professional mining engineer (IMC 2011) and is presented in a separate technical report (refer to the Red Hill Mining Lease EIS Appendix I1). The proposed mining technology known as Thick Seam Mining results in greater coal recovery compared to conventional longwall mining and also greater depths of subsidence at the surface.

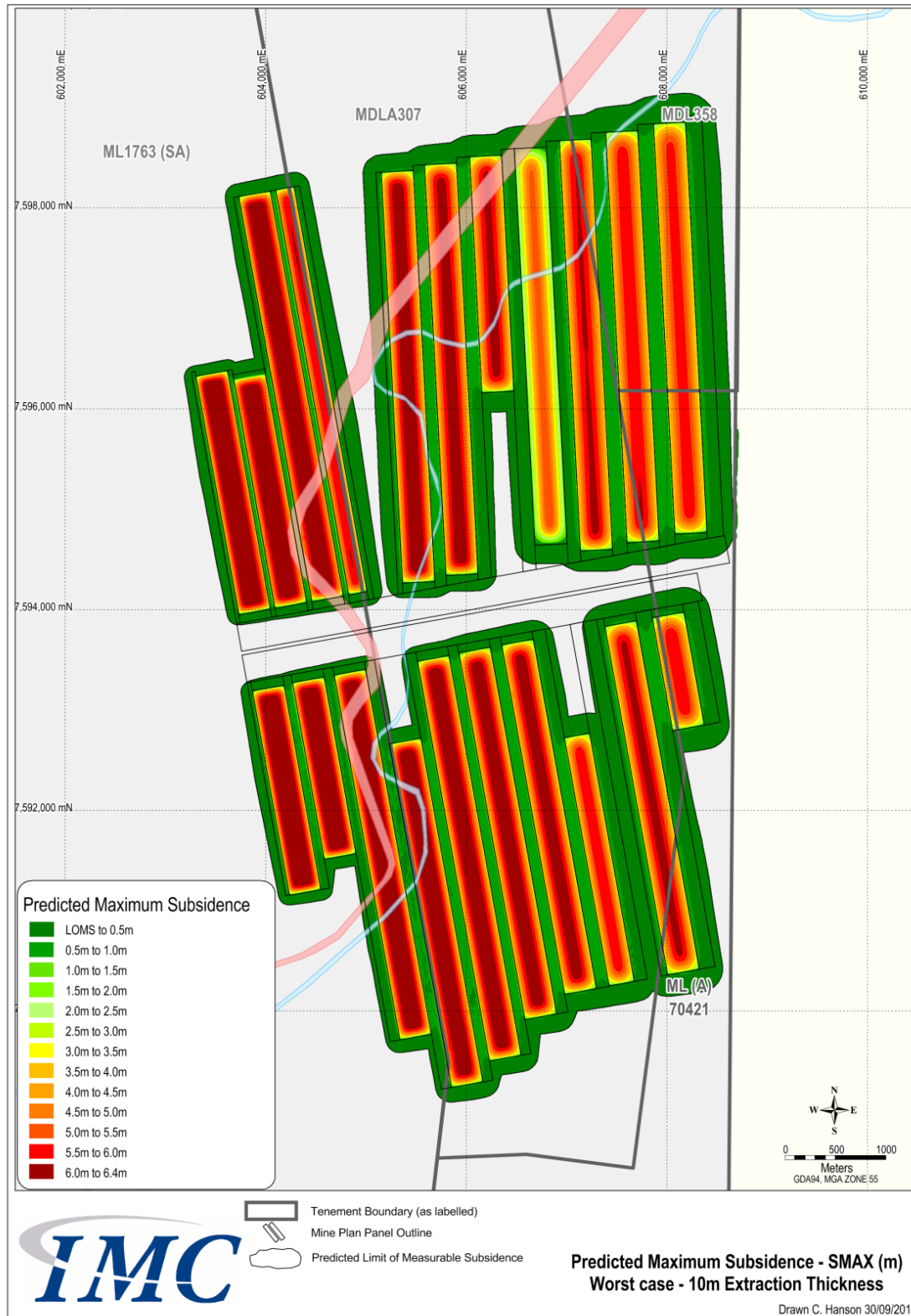
For the project a worst case assessment of subsidence has considered the subsidence that would occur as result of up to 10 metres of coal seam extraction across all long wall panels, which translates to surface subsidence of an average three to five metres and up to a maximum of approximately six metres. The actual subsidence that would occur at surface depends on several factors including strata and geology overlying the coal seam and the depth of extraction below the surface. Detailed description of these factors is presented in the Red Hill Mining Lease EIS Appendix I1.

The estimated subsidence is presented on **Figure 1-5**.



## 1 Introduction

Figure 1-5 Estimated Subsidence Depths (IMC 2011)



## 1 Introduction

### 1.6 Summary of Subsidence Related Impacts

#### 1.6.1 Potential Subsidence Impacts on Hydrology

Subsidence resulting from the project mining activities may potentially impact on the broader catchment hydrology and water resources availability in the Isaac River downstream of the mine. As the panels subside, there is the potential that the volume of water that would have previously drained freely from the landscape and contributed to the downstream river flow could be lost from the downstream river flows. This is caused by formation of surface depressions (subsidence voids) which capture direct rainfall and surface runoff and no longer freely drain to the natural waterways. As water ponds in the subsidence depressions, water may be lost as:

- evaporation from the water surface of the ponded waters; and
- potential percolation to the groundwater including through surface cracking resulting from the subsidence.

#### 1.6.2 Mitigation of Potential Water Losses through Surface Cracking

The amount and magnitude of surface cracking that occurs as a result of subsidence varies depending on the geological strata overlying the coal that has been extracted, existing geological structures, coal seam thickness, and notably depth below the surface that coal has been extracted.

Subsidence predictions (IMC 2011) estimate that for a worst case scenario, cracking that can potentially express at the surface may be at widths up to 0.5 metres and depths to approximately 10 metres. In most areas, the surface cracking is anticipated to be less severe.

The general observations from recent experience of subsidence management of longwall mining in the Bowen Basin is that in gentle (low gradient) terrain with alluvial surface cover, subsidence surface cracking tends to self-seal after a few rainfall events as fine sediments wash into, and seal up the cracks. These observations are affirmed at the existing BRM operations where prolonged ponding in subsidence depressions following rainfall events has been observed. An example aerial photo showing recent ponding in the subsidence at the existing BRM is presented on **Figure 1-6**.

Where surface cracks are small it is not anticipated that intervention will be required. Where surface cracks remain open over time, or occur where the terrain has more distinct relief, intervention will be undertaken to remediate surface cracking. The typical remedial works would involve ripping, regrading to a smooth surface profile, and revegetating the cracked areas. Where necessary fine (clay) materials may be brought in to ensure that suitably low permeability sediment is available to seal the cracks. Surface cracking remediation measures and criteria will be specified in a subsidence management plan for the project. It is considered that the criteria to trigger intervention and remediation measures to seal cracks will be based on surface geology (particularly presence, or lack of, clays and loams) and terrain conditions rather than a prescribed crack width. With this approach, the remedial works will target areas where there is greatest likelihood that cracks will not self-seal.

With the implementation of these mitigation measures, it is anticipated that the losses of surface water resources via percolation through subsidence surface cracking will be insignificant.

## 1 Introduction

**Figure 1-6 Example of Ponding in Subsidence at BRM (January 2011)**



### 1.6.3 Evaporation from Water Ponding in Surface Subsidence Depressions

The potential water resources losses that may occur via evaporation from waters ponded in the subsidence depressions (voids) depends on the geometry of the subsidence void (particularly relationship between surface area and volume). The variation of the volume of ponded waters in subsidence voids over time will be responsive to rainfall, sub-catchment area, and corresponding runoff volumes draining into (and overflowing out) the subsidence void. When direct rainfall and runoff inflows into the subsidence voids exceed the storage capacity, the excess water will overflow and contribute to flow volumes in drainage paths and watercourses downstream.

Where the subsidence void storage capacity is limited in area and depth and as the contributing upstream catchment is large, it will typically only require a few millimetres of catchment runoff to fill and overflow the subsidence void. In these situations the impact of water ponding in subsidence voids will have immeasurably low impact on the downstream flow volumes and not impact on the broader catchment hydrology. This situation is relevant for the voids that will form in the main channel of the Isaac River where the upstream catchment is large and subsidence void volume is relatively small. Furthermore, based on the findings of the assessment of subsidence impacts on geomorphology it is expected that subsidence voids in the Isaac River will ultimately fill with sediment and their storage capacity will diminish (refer to the Red Hill Mining Lease EIS Appendix I6). On this basis, it is predicted that the subsidence voids that will be created within the Isaac River channel will have no appreciable impact on the hydrology of the Isaac River.

Where the subsidence void storage capacity is relatively large and has small or limited contributing upstream catchment area, the rainfall and runoff volumes may be insufficient to completely fill the subsidence void and these voids may rarely overflow, except in very high rainfall events or flood conditions. In these situations, the waters trapped in the subsidence voids in typical average climate will primarily be lost to evaporation and represent a loss of flow to the downstream watercourses.

This report presents an assessment that has been undertaken to quantify the potential losses of water resource, the significance relative to local and regional water resources, and potential mitigation.

## Methodology

### 2.1 Study Approach

The methodology and approach to assess the hydrological impacts and significance of potential ponding in subsidence involved the following steps:

1. Review of available surface water data and previous modelling studies to assess and quantify baseline hydrology at local and regional scale. The baseline water resources hydrology characterisation considered mean annual flow volumes and flow duration as a measure of flow variability. Note that this report has focussed on long term water resources hydrology, whereas a separate report presented in the Red Hill Mining Lease EIS Appendix I4 describes assessment of discrete flood event hydrology.
2. Analysis of existing topographic survey superimposed with (worst case) subsidence predictions to derive predicted post subsidence topography. This was then used to identify possible drainage patterns and potential ponding areas in subsidence outside of the Isaac River channel, and the storage-elevation-area characteristics of the subsidence voids. From this assessment (refer Section 4) it was identified that the 12 Mile Gully catchment would experience the greatest degree of subsidence impacts and this formed the focus of the remainder of the assessment.
3. Development of a hydrological simulation model for the 12 Mile Gully catchment. The model was developed to simulate runoff, estimate reduction due to subsidence voids, losses in the voids, overflows and net stream flow reaching the Isaac River.
4. Analysis of a worst case with no mitigation actions, and review of the significance of potential impacts on water resources.
5. Analysis of a potential mitigation case to partially drain some of the large ponding areas in subsidence voids, and reassessment of potential impacts on water resources for the mitigated case.



## Baseline Hydrology

### 3.1 Overview

The baseline hydrology of the 12 Mile Gully catchment and Isaac River through the EIS study area is of interest to establish reference information for impact assessment. Reviews of available data and previous catchment stream flow modelling were undertaken to characterise the baseline stream flow hydrology.

It is important to note that hydrology is not a precise science and the various sources of information each have limitations which prevent definitive assessment of stream flow. Each of the sources, limitations, and significance is described further herein.

### 3.2 Recorded Stream Flow Information

The Department of Environment Natural Resources and Mines (NRM) operates stream gauges on the Isaac River at several locations summarised in **Table 3-1** (NRM 2012). Summary information from the stream gauges has been downloaded from the NRM water monitoring website and is presented in **Appendix A**. There are no other official stream gauges on 12 Mile Gully or other tributaries in and around the EIS study area.

**Table 3-1 Summary of NRM Stream Gauges on Isaac River (to May 2012)**

Gauging Station	GS130414	GS130410	GS130401
Station Name	Isaac at Goonyella	Isaac at Deverill	Isaac at Yatton
AMTD <sup>(note 1)</sup>	242.8	174.7	43
Catchment (km <sup>2</sup> )	1,214 <sup>(note 3)</sup>	4,092	19,720
Start of records	May 1983	May 1968	October 1962
Mean Flow (ML/day)	160	468	5,395
Mean Flow (ML/year)	58,000	171,000	1,970,000
Mean Annual Runoff (mm/year) <sup>(note 2)</sup>	48	41	100

**Notes**

- (1) AMTD is Adopted Middle Thread Distance (measure of location along a stream)
- (2) Mean Annual Runoff calculated as Mean Annual Flow (ML) divided by catchment (km<sup>2</sup>)
- (3) Uncertainty exists regarding the true effective catchment at the Goonyella Gauge

The stream gauge at Goonyella is the most directly relevant gauge to use for characterisation of stream flow in the Isaac River through the EIS study area. However several potential uncertainties have been identified for the data from the Goonyella Gauge that require caution in the use of the Goonyella gauge statistics.

The river bed at the location of the Goonyella Gauge has significant depth of mobile sand which can vary the cease-to-flow level between individual flow events and lead to uncertainty in the low end of the gauge rating curve (refer gaugings versus rating plot in **Appendix A**).

The actual catchment area upstream of the Goonyella gauge may be less than reported on the NRM website (NRM 2012). Mapping was undertaken by URS in 2007 for the GRB mine water balance

### 3 Baseline Hydrology

model. This found that the catchment area downstream of Burton Gorge Dam to the Goonyella Gauge, including Eureka Creek, and excluding local mine sub-catchments contained within the GRB mine water management system, is approximately 520 square kilometres (km<sup>2</sup>). The catchment upstream of the Burton Gorge Dam is approximately 555 km<sup>2</sup>, which indicates that the total free draining catchment area to the Goonyella Gauge would be approximately 1,075 km<sup>2</sup>.

The difference between the official NRM Goonyella Gauge catchment area (1,214 km<sup>2</sup>) and the estimate above may be because the NRM catchment area estimate may not account for the GRB mine water management system contained catchments (approximately 82 km<sup>2</sup>). Further, the NRM catchment area possibly includes Fisher Creek and Platypus Creek tributary catchments (approximately 95 km<sup>2</sup>). A detailed review of topographic survey mapping shows that Fisher Creek and Platypus Creek tributaries join the Isaac River a short distance downstream of the Goonyella Gauge.

If the true catchment area of the Isaac River to the Goonyella Gauge is taken to be approximately 1,075 km<sup>2</sup>, and the stream flow data is taken to be correct, a revised estimate of the mean annual runoff in the Isaac River catchment to the Goonyella Gauge is approximately 54 mm/year.

The construction of Burton Gorge dam in the 1990s is another potential influence on the representativeness of the Goonyella Gauge streamflow data. The Burton Gorge dam capacity is approximately 18,000 ML and would likely have a moderate influence on data recorded at the Goonyella gauge since the dam construction.

It is notable that the NRM stream gauge data for the Isaac River at Yatton shows considerably higher mean annual runoff for the broader regional catchment. This gauge is downstream of the confluence of the Connors River and the higher mean annual runoff is likely to be attributable to higher rainfall and different geology in the Connors River catchment.

#### 3.3 NRM Modelled Stream Flow Information

As part of a study of the Isaac River in 2007-2008, Alluvium consultants (2008) obtained a time series data set of modelled stream flow from the Department of Natural Resources and Water (DNRW) (now NRM) based on IQQM models developed for Fitzroy Basin Water Resource Plan (1999). The modelled stream flow data presented in the Alluvium report (2008) is representative of the period 1898 to 1995 and shows a mean annual flow of 53,500 ML/year in the Isaac River reach through the EIS study area (Reach 2 in the Alluvium 2008 report).

This alternate estimate of the Isaac River mean annual flow can be considered reasonably reliable and main limitations would be related to modelling accuracy. It is expected that considerable effort is undertaken by NRM to ensure good calibration and validation of its IQQM models. The main potential limitation would be related to scale as the main focus of the IQQM models is for regional catchment water resource planning.

#### 3.4 BMA Site Specific Studies

Studies of local hydrology around the GRB mine complex were undertaken in 2007 by URS for an Environmental Evaluation and to support development of the GRB mine water balance model. URS completed stream flow model calibration for the natural catchment of Eureka Creek in 2007 using an Australian Water Balance Model (AWBM). The model was calibrated to available stream flow records at a gauge on upper Eureka Creek that is privately owned by BMA. The model parameters were then

### 3 Baseline Hydrology

validated against the NRM Goonyella Gauge records for a select period when it was known that the Burton Gorge Dam did not overflow and using the catchment area below Burton Gorge Dam in the AWBM.

The AWBM runoff model parameters were calibrated to available data are summarised in **Table 3-2**.

**Table 3-2 Calibrated AWBM Runoff Model Parameters for Natural Catchments around Goonyella**

Parameter	A1	A2	A3	BFI	C1	C2	C3	Kb	Ks
Value	0.134	0.433	0.433	0.35	12	71	414	0.6	0.1

Note: Refer to AWBM software documentation for explanation of parameters (<http://www.toolkit.net.au/tools/RRL>).

An assessment of the time series runoff outputs from the AWBM, using climate data representative for the Goonyella area, indicates a mean annual runoff of 53 mm/year (for the period July 1983 to June 2011). This estimate compares well with the estimate for the NRM stream flow data for the Goonyella Gauge (refer Section 3.2).

### 3.5 Summary

Based on review of the available information sources, and with due recognition of the potential limitations of respective data sources, the following conclusions are drawn for estimates of baseline hydrology used to establish reference flows for impact assessment:

- the long term mean annual catchment runoff is in the order of 50 to 55 mm/year (best estimate approximately 53 mm/year);
- the mean annual flow in the Isaac River through the EIS study area is estimated be at least 50,000 ML/year and potentially up to 55,000 ML/year; and
- the catchment area of 12 Mile Gully tributary is approximately 84 km<sup>2</sup>, and with the estimate of mean annual runoff (53 mm/year), the estimated mean annual flow from 12 Mile Gully catchment into the Isaac River is approximately 4,400 ML/year.

## Subsidence Voids Assessment

### 4.1 Subsidence Voids Mapping

The worst case scenario regarding extent and depth (up to 6 metres) of subsidence voids outside the Isaac River channel was assessed and mapped. Subsidence voids within the Isaac River channel were not considered because a separate assessment (refer Red Hill Mining Lease Appendix I6) identifies high probability that these voids will infill with sediment.

The process to identify subsidence voids that could pond water involved:

- creation of a digital terrain model (DTM) of the existing topography based on available survey data using 12D software;
- superimposing a surface representing the predicted longwall mine subsidence depths across the EIS study area to create a representative digital terrain model of the subsided topography;
- the subsided topography DTM was converted to a subsided topography digital elevation model (DEM) with a 10 metre grid spacing;
- 0.5 metre contours were then developed from the subsided topography DEM; and
- the subsided topography contours were then reviewed to identify void locations, void geometry, and estimate storage capacity of voids to the level at which the voids would overflow.

The mapping was limited to voids exceeding two hectares in surface area at the level at which the void could be considered to be full (i.e. overflow level). Considering the accuracy of both the available survey data (existing topography) and the accuracy of subsidence predictions, the void overflow levels were taken to the nearest 0.5 metre contour of the subsided topography.

The mapped extent of the worst case possible subsidence void ponding, without any mitigation works, is presented on **Figure 4-1**.

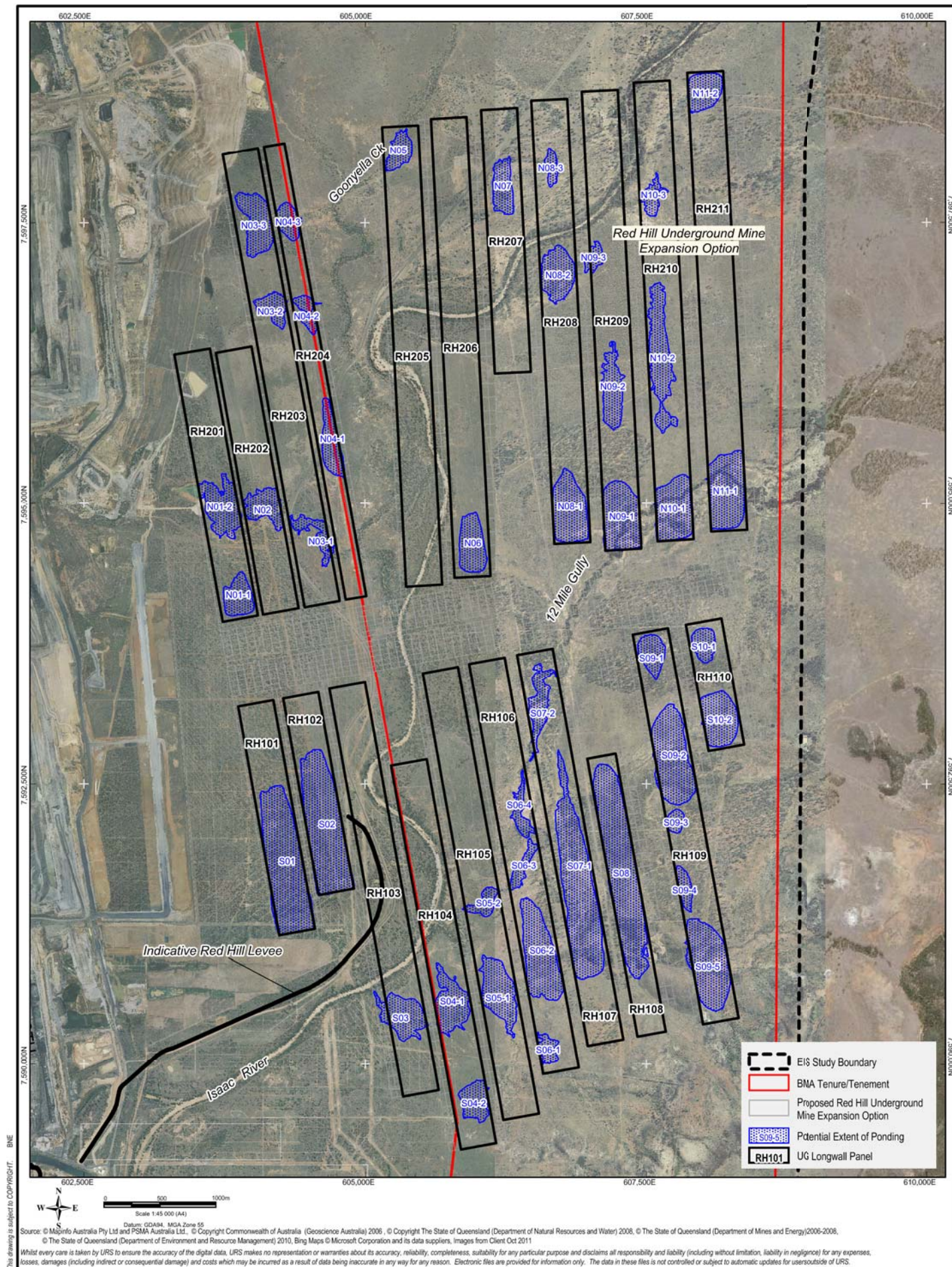
### 4.2 Key Assumptions

The mapped potential ponding extents in subsidence voids represents the worst case scenario because it assumes that no works would be undertaken to drain or partially drain the voids, and no erosion would occur of the overflow flowpaths, and no sedimentation would occur in the voids.

It is expected that if no works are undertaken to drain the subsidence voids, the void storage capacities could gradually diminish over time. This would result when erosion of the overflow flowpaths occurs, and sediment is deposited in the voids. This is similar to the processes described in the subsidence impacts on Isaac River geomorphology (refer to the Red Hill Mining Lease Appendix I6). In contrast to the geomorphological responses predicted for the voids in the Isaac River channel, it is unlikely that the subsidence voids outside the Isaac River channel would completely fill with sediment, and the erosion of the overflow levels and deposition of silt is expected to be relatively slow.

Despite these relatively simple assumptions to define a worst case scenario for potential ponding in the subsidence voids, the mapped potential ponding extents were considered a reasonable basis to assess worst case potential impacts of ponding on catchment hydrology specifically to assess the potential loss of water resources.







## 4 Subsidence Voids Assessment

### 4.4 Subsidence Void Storage Characteristics

The subsided topography digital elevation model data was then used to calculate the storage-elevation-area characteristics of each void for use in subsequent hydrological modelling assessment.

For each void, the storage-elevation-area data were fitted to a generalised storage curve equation in the form:

- Volume =  $A (H - H_o)^B + C$ ; where:
  - Volume is the volume below a given water level ( $m^3$ );
  - H is the water level (mAHD); and
  - parameters A, B,  $H_o$ , and C are specific to the geometry of each void.

This form of storage equation can be differentiated and rearranged to an area-elevation relationship; and also an area-volume relationship as follows:

- Area =  $A B (H - H_o)^{(B-1)}$ ; and
- Area =  $A B ((Volume - C)/A)^{(B-1)/B}$ ; where:
  - area and volume are in  $m^2$  and  $m^3$  respectively

The base data and equation fitting plots for each void are presented in detail in **Appendix B**. The parameters (A, B,  $H_o$ , and C) for each void, top (overflow) water level, and maximum void capacity for each void are summarised in **Table 4-1**.

## 4 Subsidence Voids Assessment

**Table 4-1 Subsidence Void Data (Unmitigated case)**

Void (pond) name	Storage Curve Equation Parameters				Full (overflow) level (mAHD)	Maximum depth when full (m)	Maximum volume when full (m <sup>3</sup> )	Maximum area when full (m <sup>2</sup> )
	H <sub>o</sub>	A	B	C				
N08-1	254.85	24688.3	1.898	0	258.5	3.5	288,000	150,000
N09-1	254.65	28896.2	1.892	0	259.0	5.0	466,000	203,000
N09-2	259.00	46340.7	2.022	0	260.0	1.2	46,000	94,000
N09-3	260.10	2663.7	2.751	0	262.0	1.5	16,000	23,000
N10-1	255.85	22679.8	1.990	0	260.0	4.0	385,000	185,000
N10-2	261.10	29072.0	3.024	0	262.5	1.3	80,000	174,000
N11-1	258.20	52103.8	1.690	0	261.5	4.5	392,000	201,000
S05-2	240.50	293.5	3.033	0	247.0	6.0	86,000	40,000
S06-1	251.50	5327.6	2.374	0	253.5	2.0	28,000	33,000
S06-2	245.50	1288.0	3.569	0	250.0	4.0	276,000	219,000
S06-3	241.70	413.3	2.928	0	247.5	5.0	71,000	36,000
S06-4	243.50	350.3	3.381	0	248.0	4.0	57,000	43,000
S07-1	247.80	32131.6	2.488	0	251.0	4.0	580,000	451,000
S07-2	246.60	813.2	3.165	0	251.5	4.5	124,000	80,000
S08	249.13	61686.3	2.003	0	253.0	4.0	927,000	480,000
S09-1	258.85	7267.7	2.607	0	261.0	2.4	53,000	65,000
S09-2	253.03	13852.8	2.389	0	257.5	4.5	496,000	265,000
S09-3	256.67	9443.7	2.065	0	258.0	1.4	17,000	26,000
S09-4	258.38	15580.0	2.090	0	259.5	1.1	20,000	37,000
S09-5	254.02	14105.1	2.240	0	259.0	5.0	514,000	231,000
S10-1	261.65	12536.7	2.543	0	263.0	1.5	27,000	51,000
S10-2	257.06	14205.5	2.110	0	261.0	4.0	256,000	137,000
N01-1	260.78	28780.0	2.048	0	262.0	1.3	43,000	73,000
N01-2	254.55	1209.1	3.139	0	260.0	5.5	248,000	143,000
N02	253.10	5111.4	2.317	0	257.5	4.5	158,000	83,000
N03-1	249.60	928.9	3.248	0	253.0	3.0	49,000	47,000
N03-2	257.80	14.0	4.720	0	263.5	3.5	52,000	43,000
N03-3	259.70	99.8	4.389	0	265.0	4.0	151,000	125,000
N04-1	260.55	12512.9	2.020	0	263.5	3.0	111,000	76,000
N04-2	253.00	0.0251	6.824	0	261.0	4.0	36,000	31,000
N04-3	258.10	1243.4	2.635	0	263.0	4.5	82,000	44,000
N05	255.60	2439.9	3.008	0	258.5	3.0	60,000	62,000
N06	254.00	31447.7	2.138	0	255.5	1.5	75,000	107,000
N07	258.50	13995.2	2.820	0	260.0	1.5	44,000	83,000
N08-2	255.50	4967.4	2.448	0	260.0	4.0	197,000	107,000
N08-3	260.95	28771.8	2.606	0	261.5	0.5	6,000	29,000
N10-3	253.65	46.5	4.254	0	258.5	4.0	38,000	34,000
N11-2	263.50	15634.4	1.919	0	266.5	3.0	129,000	82,000
S01	247.18	32050.3	2.033	0	253.0	5.5	1,151,000	402,000
S02	249.02	55314.1	1.880	0	253.5	4.5	927,000	389,000
S03	240.65	3923.8	2.404	0	247.0	6.0	334,000	127,000
S04-1	242.40	2394.8	2.701	0	247.5	5.0	195,000	103,000
S04-2	255.30	2188.2	2.881	0	259.0	3.5	95,000	74,000
S05-1	243.10	31.2	5.010	0	248.5	4.0	146,000	135,000

Note: overflow levels of each void were identified to nearest half metre contour, however the bottom level of shallow voids was identified to nearest 0.1m level, hence depths are presented to approximately 0.1 m for the shallower voids, and nearest 0.5 m for deeper voids.

## 4 Subsidence Voids Assessment

### 4.5 Summary of Identified Subsidence Voids

The mapping of potential subsidence void ponding extents and volumes outside the Isaac River channel identified 44 ponding areas (larger than two hectares). The subsidence voids are estimated to range from less than 10 ML capacity up to a maximum of approximately 1,100 ML. The average capacity would be approximately 210 ML. The areas of potential ponding would be up to 40 hectares, and the average area would be approximately 12 hectares.

It is important to note that although subsidence predictions estimate up to six metre depth of subsidence, not all subsidence voids will be this deep at the overflow level of the void. The maximum depth of subsidence void ponding depends on the geometry of the void which is influenced by the alignment of the longwall mine panels and topography of the existing landscape before subsidence. Only a few of the identified subsidence voids would have potential depths up to five or six metres, and most are typically in the range of three to four metres maximum depth of ponding.

The combined total storage volume of the worst case subsidence voids is estimated to be approximately 9,500 ML. This includes two of the largest voids in longwall panels RH101 and RH102 that are approximately 2,100 ML combined capacity and are located close to the proposed Red Hill MIA (**Figure 4-1**). The two voids in longwall panels RH101 and RH102 will need to be drained towards Isaac River by necessity because the potential overflow of these voids if filled in high or extreme rainfall events would otherwise flow towards the Red Hill MIA and contribute unwanted added water volumes into the mine water management system.

Assuming that the voids in RH101 and RH102 will be drained by necessity for operational requirements, the remaining total volume of the worst case subsidence voids would be approximately 7,400 ML. Of these, approximately 5,200 ML of the potential ponding volume in voids would occur within the 12 Mile Gully catchment.

### 4.6 Significance for Impact Assessment

The subsidence voids that are located in the Goonyella Creek catchment are considered to have minimal potential to impact on the hydrology of Goonyella Creek flows into the Isaac River. A key factor for this is that the void volumes in the Goonyella Creek catchment are small (approximately 900 ML total capacity) and the total catchment of Goonyella Creek to the Isaac River is large (approximately 100 km<sup>2</sup>). Only one void (N05) intercepts the main channel of Goonyella Creek. This void has approximately 60 ML capacity and the upstream catchment of Goonyella Creek to this void is approximately 87 km<sup>2</sup>. As such, the only void that intercepts the main channel of Goonyella Creek has limited capacity to intercept catchment flows (equivalent to less than one millimetre of catchment runoff), and the majority of Goonyella Creek catchment will flow relatively freely to the Isaac River. The void that intercepts Goonyella Creek channel is also the most likely to infill with sediment over time because of its limited capacity and large upstream catchment.

Based on the review of the distribution of potential subsidence voids relative to landscape and catchment context, it is considered that the subsidence voids in the 12 Mile Gully catchment would have the greatest potential for loss of water resources and impact on catchment hydrology if not drained. To assess this further, a hydrological simulation model of the 12 Mile Gully catchment was undertaken to quantify potential flow losses.

It is important to note that the subsidence voids will not be used to store mine water. The voids will primarily collect natural catchment runoff.



## Hydrological Simulation Model

### 5.1 Overview

A hydrological simulation model of the 12 Mile Gully catchment with subsidence void ponding was developed to estimate potential net flows from the 12 Mile Gully catchment into the Isaac River.

The hydrological model is a daily time step water balance type simulation that represents the runoff from the direct sub-catchment areas for each of the subsidence voids, direct rainfall onto the ponded area surface, and evaporation from the ponded area surface. No additional allowance, other than pre-mining groundwater recharge, was made for seepage losses on the assumption that seepage loss through cracking would be minimal either due to natural self-sealing of cracks, or with the implementation of measures (where required) to remediate subsidence cracking.

The model assessed the variability of ponding volumes in the subsidence voids, and when large rainfall events (or sequences of events) occur, the model calculated overflows from the subsidence voids into downstream voids or channel flow reaching the Isaac River. A time-series output of downstream flow from the 12 Mile Gully catchment was calculated as a key output.

### 5.2 Model Calculations

The hydrological model was developed in Microsoft Excel using a series of daily time-step water balance calculations for each void. The calculations for each void included:

- addition of runoff inflows into the void:
  - runoff depth calculated using the AWBM model (parameters as defined in **Table 3-2**);
  - inflow volume calculated as the product of runoff depth and direct catchment area; and
  - the direct catchment area is modified in each time-step to subtract the surface area of the pond storage;
- addition of direct rainfall onto the void pond area, calculated as the product of rainfall on that day and surface area of the pond storage;
- subtraction of evaporation from the void pond area, calculated as the product of evaporation on that day and surface area of the pond storage;
- subtraction of seepage loss from the void pond, calculated as the product of a defined vertical seepage rate and the surface area of the pond storage. This assumes that cracks will seal or actions taken to ensure that cracks seal to limit percolation through cracking; and
- addition of inflows occurring from upstream void ponds overflowing into the void.

The net sum of the water balance components described above for each daily time-step was added to the previous day pond volume. When the total inflows exceed the total losses and remaining available storage capacity, an overflow volume was calculated and added into the next downstream void pond. When the total losses are greater than the volume in the void pond, the void storage was set to zero to prevent negative values being calculated.

The allowance for seepage loss utilised a seepage (groundwater recharge) rate of  $10^{-4}$  m/day (0.1 mm/day) based on discussions with the EIS groundwater study team for likely vertical hydraulic conductivity values of the surface geology in the EIS study area. The adopted seepage rate is considered conservative and is relatively insignificant as the seepage rate is markedly less than

## 5 Hydrological Simulation Model

evaporation (i.e. 0.1 mm/day seepage compared to the average evaporation of approximately 5 mm/day). A sub-catchment map is presented on **Figure 5-1**.

### 5.3 Sequence of Model Calculations

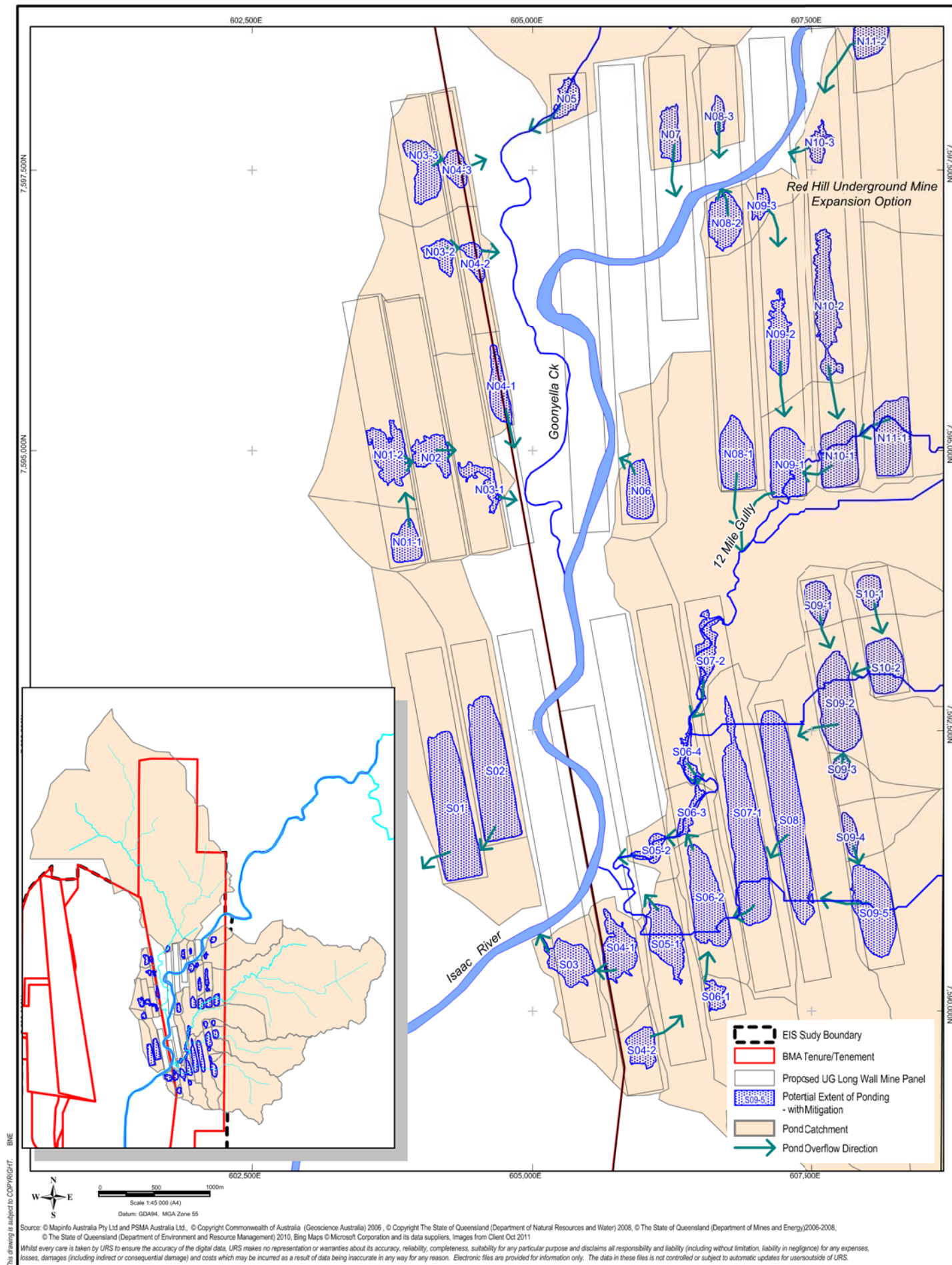
The model water balance calculations for each void pond (as described in Section 5.2) needed to be sequenced to allow appropriate representation of flow through the catchment. For each daily time step it was necessary to calculate the water balance of upstream ponds first so that overflows into downstream ponds could be included in the downstream pond water balance. The sequence of model calculations is summarised in **Table 5-1** together with the direct sub-catchment area data for each pond.

The most downstream void pond in the model structure is S05-2 which is immediately adjacent to the confluence of 12 Mile Gully and Isaac River. Calculated model overflows from void pond S05-2 represent the net flow reaching the Isaac River from the 12 Mile Gully catchment.

**Table 5-1 12 Mile Gully Hydrological Model Calculation Sequence and Catchment Data**

Sequence	Pond Void	Receives overflow from:	Overflows to:	Catchment (ha)
1	N11-1	n/a	N10-1	4,288
2	N10-2	n/a	N10-1	86.6
3	N10-1	N11-1, N10-2	N09-1	42.6
4	N09-3	n/a	N09-2	15.6
5	N09-2	N09-3	N09-1	83.3
6	N09-1	N09-2, N10-1	S07-2	40.7
7	N08-1	n/a	S07-2	87.7
8	S07-2	N09-1, N08-1	S06-4	737.4
9	S06-4	S07-2	S06-3	100.4
10	S10-1	n/a	S10-2	33.4
11	S10-2	S10-1	S09-2	897
12	S09-1	n/a	S09-2	25.5
13	S09-3	n/a	S09-2	19.1
14	S09-2	S10-2, S09-1, S09-3	S08	130.2
15	S09-4	n/a	S09-5	30.5
16	S09-5	S09-4	S08	1,098.2
17	S08	S09-5, S09-2	S07-1	293.7
18	S07-1	S08	S06-2	131.7
19	S06-1	n/a	S06-2	136.4
20	S06-2	S06-1, S07-1	S06-3	56.6
21	S06-3	S06-2, S06-4	S05-2	20.3
22	S05-2	S06-3	Isaac River	16.1

Note: n/a means there are no void ponds upstream.



## Hydrological Assessment No Mitigation

### 6.1 Analysis Summary

The hydrological model simulations were undertaken using SILO data drill climate data for the period July 1983 to November 2011.

The hydrological model analysis of the 12 Mile Gully catchment with subsidence voids (case with no drainage of subsidence voids) estimates a mean annual flow of 2,100 ML/year (period 1983-2011) from 12 Mile Gully into Isaac River.

For the base case (existing catchment) the mean annual flow is estimated to be 4,400 ML/year. It is estimated that the potential loss of water resources from the 12 Mile Gully catchment (if no action is taken to drain or partially drain voids) would be approximately 2,300 ML/year.

### 6.2 Significance of Hydrological Impacts - Case with No Mitigation

The hydrological analysis indicates that the potential loss of flow from 12 Mile Gully catchment due to ponding of waters in subsidence voids (worst case) could be in the order of 2,300 ML/year. This equates to approximately 52 per cent of the 12 Mile Gully catchment mean annual flow. There are no known human users of water relying on water directly from 12 Mile Gully and the potential loss is not considered significant in that context. The significance for aquatic ecology is addressed in the aquatic ecology technical report (Red Hill Mining Lease EIS Appendix K3).

#### 6.2.1 Potential Loss of Flow in the Isaac River at Goonyella

Beyond the 12 Mile Gully catchment, it is known that there is reliance on water from the Isaac River for human and livestock supply and that the Isaac River supports aquatic habitat values that are more extensive than present in the 12 Mile Gully watercourse.

When considered in terms of 'whole-of-project' hydrological impacts, the loss of flow in the Isaac River due to potential worst case subsidence void ponding in the 12 Mile Gully catchment (with no mitigation) will be partially offset by the increase in mean annual flow from Eureka Creek (through the GRB mine complex). This flow is predicted to increase by approximately 700 ML/year (refer to Red Hill Mining Lease EIS Appendix I2).

Thus, the net loss of mean annual flow in the Isaac River would be approximately 1,600 ML/year. The total Isaac River catchment mean annual flow is estimated to be approximately 50,000 ML/year (refer Section 3). The reduction of mean annual flow from the 12 Mile Gully catchment (approximately 2,300 ML/year), combined with the increase from Eureka Creek (700 ML/year), as net loss (1,600 ML/year) represents a small to moderate component of approximately three per cent loss of the Isaac River mean annual flow at Goonyella gauge.

#### 6.2.2 Regional Context - Potential Loss of Flow in the Isaac River at Yatton

The potential small loss of mean annual flow in the Isaac River will be practically immeasurable in a broader regional Water Resource Plan context.

In the statutory Water Resource (Fitzroy Basin) Plan 2011, the closest downstream location for which Environmental Flow Objectives (EFO) apply is in the Isaac River at Yatton (node 9 in Schedule 5). At this location, the pre-development case mean annual flow is reported to be 2,270,000 ML/year (Draft WRP Overview Report 2010). The EFO objective at this location is to ensure that mean annual flow is not less than 90 per cent of the pre-development mean annual flow.

## 6 Hydrological Assessment No Mitigation

The potential loss of 1,600 ML/year of mean annual flow in the Isaac River due to project impacts (with no mitigation to drain subsidence voids) represents less than 0.07 per cent of the mean annual flow in the Isaac River at Yatton. Hence, the project impact on Isaac River flow volumes will not materially impact on the State's ability to meet the Water Resource Plan environmental flow objectives.

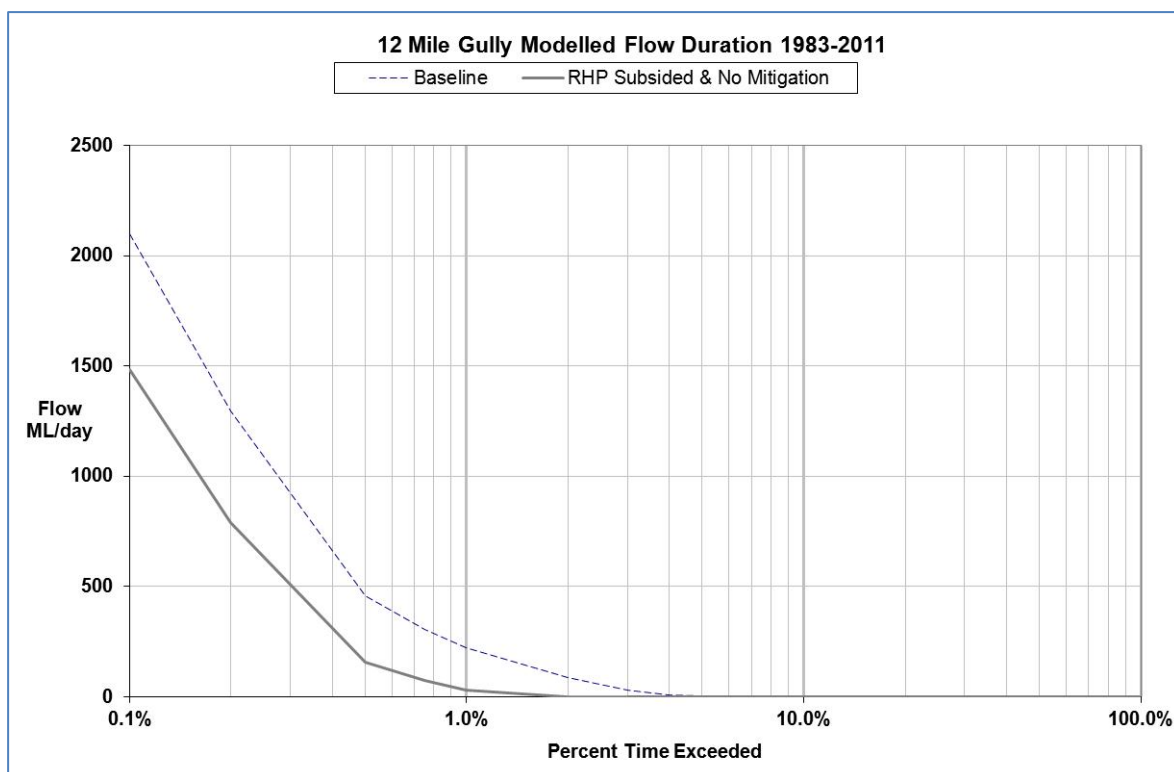
### 6.3 Temporal Hydrology (Flow Frequency) Impacts

The hydrological model outputs were reviewed to identify changes in the frequency of stream flows from 12 Mile Gully catchment. A comparison of flow duration curves is presented in **Figure 6-1**. The comparison shows that the frequency of low flows in the 12 Mile Gully lower reaches could potentially be significantly impacted. There would potentially be up to 50 per cent reduction in the frequency of flows less than 100 ML/day at the downstream end of 12 Mile Gully.

The flow frequency impacts suggest that some form of mitigation to at least partially drain some of the larger subsidence voids should be considered. However, there is no clear guideline or scientific principle to justify an essential need for mitigation. The recommendation for mitigation is primarily based on the observation that the potential reduction in flows and flow frequency (without mitigation) in the lower reaches of 12 Mile Gully appears significant.

A potential mitigation strategy is further described in Section 7.

**Figure 6-1 Comparison of Flow Duration Curves - No Mitigation Case**





## Hydrological Assessment with Mitigation

### 7.1 Determination of Mitigation Requirements

There is potential to mitigate the loss of flow from 12 Mile Gully due to ponding in subsidence voids by undertaking drainage works to drain, or partially drain, some of the voids created by subsidence. However, the works required to drain subsidence voids can also introduce further potential for adverse environmental impacts. This is a result of the degree of physical landscape disturbance required to construct the drains, and potential on-going instability of erosion of constructed drainage lines.

The works that would be required to completely drain the subsidence voids to a point of no ponding (i.e. free draining landscape) would be extensive and would represent a large and potentially unnecessary degree of physical disturbance. Further, it would potentially result in on-going land surface instability well beyond mine closure. The need or desire to completely drain subsidence voids is not considered sufficient to warrant such a degree of disturbance, relative to the benefit that would be achieved for downstream river flows.

It is desirable to consider a balanced approach between a reasonable degree of physical disturbance to create drains versus the benefit of maintaining flows to the downstream waterways. A potential mitigation which is considered a balanced approach was identified and assessed. In general, the potential subsidence ponding mitigation considers partially draining several of the larger subsidence voids. For example, if a subsidence void is up to five metres maximum depth, a drain would be cut to drain the top two metres, so the maximum ponding depth would be reduced to three metres.

The potential mitigation option to partially drain the larger subsidence voids is presented in **Table 7-1**. A subsidence ponding map for the mitigated case is presented in **Figure 7-1**. This potential case allows for partial draining of the voids to reduce maximum ponding depths to 2 and 2.5 metres. Further, it achieves greater consistency in potential ponding depths and significant reduction in maximum ponding volumes by focussing on partial drainage of the largest and greatest depth subsidence voids. This mitigation option is not definitive and is not optimised. Rather it is presented to demonstrate the benefit of implementing partial drainage of selected voids to mitigate impacts on water resources hydrology.

The implementation of this potential mitigation option would reduce the maximum total potential subsidence ponding of all voids in the 12 Mile Gully catchment from 5,200 ML (no mitigation) to 1,900 ML. It will be necessary to measure actual subsidence depths, rate of sediment infilling and rate of pond formation before finalising plans to drain any ponds.

## 7 Hydrological Assessment with Mitigation

**Table 7-1 Potential Subsidence Ponding Mitigation – Partial Drainage of Larger Voids**

Void Pond	Longwall Panel	Unmitigated case voids (no drainage)			Mitigated case voids (partially drained)		
		Maximum Depth (m)	Maximum Volume (ML)	Maximum Surface Area (ha)	Maximum Depth (m)	Maximum Volume (ML)	Maximum Surface Area (ha)
N09-1	RH209	5.0	466	20.3	2.5	93	9.5
N10-1	RH210	4.0	385	18.5	2.0	104	9.6
N11-1	RH211	4.5	392	20.1	2.0	36	7.5
S06-2	RH106	4.0	276	21.9	2.0	34	4.8
S07-1	RH107	4.0	580	45.1	2.0	51	10.5
S08	RH108	4.0	927	48.0	2.0	216	23.1
S09-2	RH109	4.5	496	25.3	2.0	70	8.5
S09-5	RH109	5.0	514	23.1	2.5	108	9.7

### 7.2 Design of Channel Works to Partially Drain Subsidence Voids

The design of channels and associated works to partially drain subsidence voids will be implemented using natural channel design principles and also relevant aspects of contemporary best practice for stream diversion design. The approach should be considered as ‘rehabilitation engineering’ rather than conventional ‘civil design drainage engineering’. As the drainage would not be required until towards the end of mine life, specific standards are not specified here as it is likely that standards and requirements in relation to formation of channels will have changed.

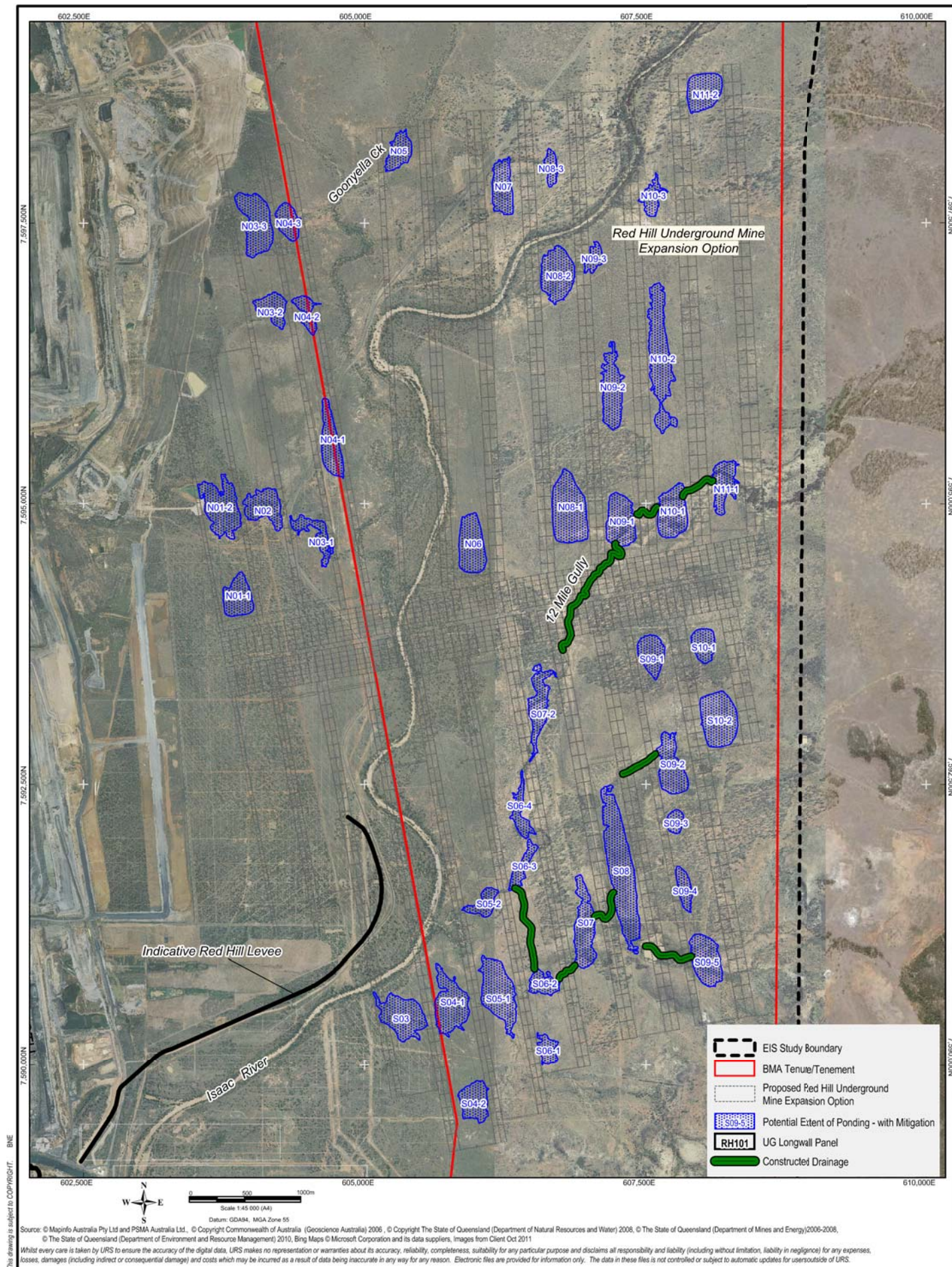
The channels would be designed using natural materials and geometric design that considers the characteristics of natural gully drainage features in the landscape and where relevant, water course features for larger channel works (for example along the existing 12 Mile Gully to drain ponds N11-1, N10-1, N09-1).

The channels would be designed with gradients limited to ensure that the drains are sustainable (protected against erosion damage), whilst also ensuring there is sufficient gradient to limit the potential for excessive sedimentation. At the downstream end where a moderate drop may occur into the downstream subsidence void, the use of rock armouring or if practical using natural bedrock to act as control structures to limit head cut erosion may be required.

The batter slopes would be designed to be stable, compatible with surrounding landform slopes, and also compatible with proposed rehabilitation treatment methods. Sub-soils that are vulnerable to erosion (e.g. dispersive or sodic soils) would need to be identified and measures implemented to either treat erodible soils or ensure adequate cover so that erodible soils are not left exposed.

There is no identifiable specific requirement that the drainage channels should necessarily be designed for a specific flow capacity (e.g. peak flow for a specific AEP event). Rather the design flow capacity should be selected to be compatible with landscape function of the drainage connection between subsidence ponds. It would be necessary to ensure that the proposed channel designs are hydraulically analysed for a wide range of potential peak flood flows (including up to the probable maximum flood event) to ensure that the channels will be stable for potential extreme flows.







## 7 Hydrological Assessment with Mitigation

### 7.4 Mitigation Case Hydrological Model Assessment

The potential mitigation of partially draining some of the larger voids was reassessed in the hydrological model. The model was rerun with the same storage geometry data for the subsidence voids and the maximum capacities and overflow levels were modified to represent the partial draining of the subsidence voids as described in **Table 7-1**.

The mitigated case assessment indicates that the mean annual flow from 12 Mile Gully into the Isaac River would be approximately 3,200 ML/year. This represents a loss of approximately 1,200 ML/year (or approximately 30 per cent of the 12 Mile Gully base case mean annual flow).

When considered in the context of 'whole-of-project' impacts (including the predicted 700 ML/year increase in mean annual flow from GRB mine complex into Eureka Creek), the net impact to the mean annual flow in the Isaac River would be a net loss of approximately 500 ML/year. This represents approximately one per cent of the mean annual flow of the Isaac River and is not considered significant (i.e. practically immeasurable).

It is important to note that there is no clear judgement that the unmitigated case would produce distinctly unacceptable impacts versus the potential mitigation case having reduced impact on flows whether this is deemed acceptable. Rather the recommendation for mitigation is based on the apparent observation that without mitigation, the reduction in flows in 12 Mile Gully is potentially significant.

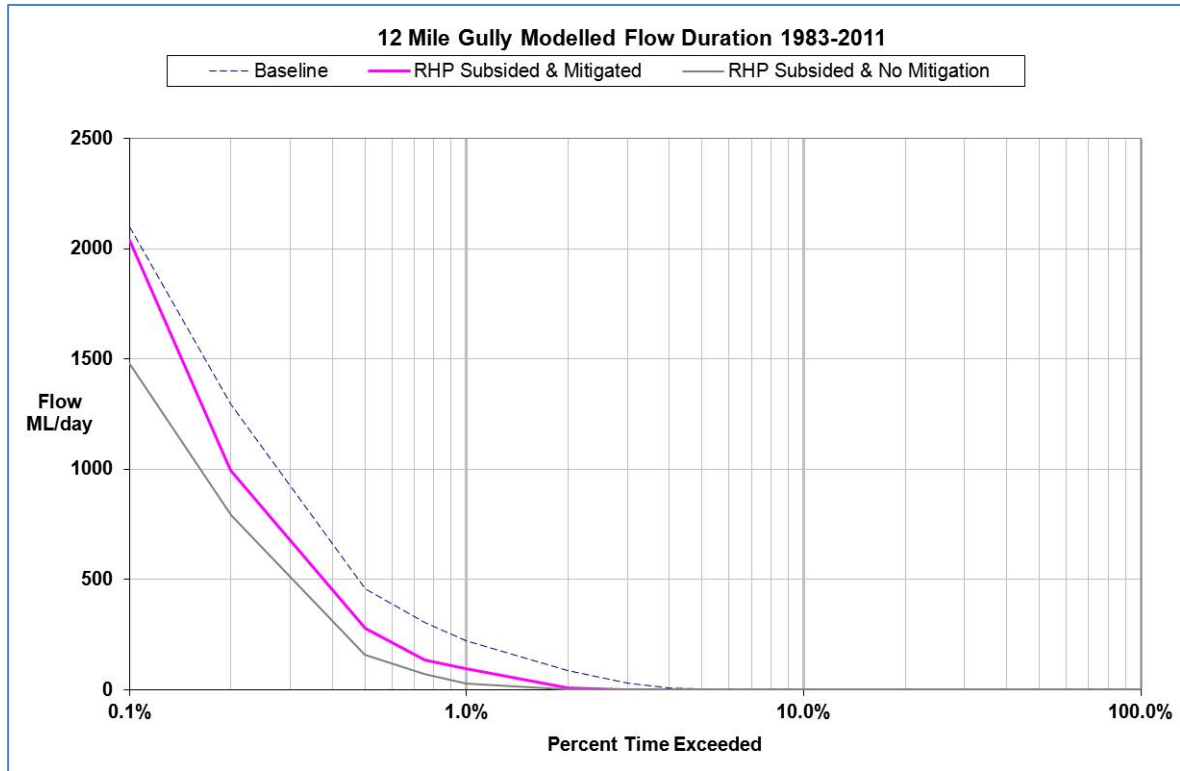
### 7.5 Mitigated Case Temporal Hydrology (Flow Frequency) Impacts

The hydrological model outputs of the mitigated case were reviewed to identify changes in the frequency of stream flows from the 12 Mile Gully catchment. A comparison of flow duration curves is presented in **Figure 7-2**.

The comparison shows that with mitigation to partially drain the larger voids the frequency of low flows in the 12 Mile Gully lower reaches would be only marginally less than the baseline case. The change in frequency of flows is considered a reasonably tolerable impact which maintains sufficient frequency of low flows from the 12 Mile Gully catchment. The comparison of **Figure 7-2** (mitigated case flow duration and no mitigation case flow duration) demonstrates that the mitigation works to partially drain several of the larger subsidence voids is effective to reduce impact on low flow frequency from the 12 Mile Gully catchment.

## 7 Hydrological Assessment with Mitigation

**Figure 7-2 Comparison of Flow Duration Curves - Mitigated Case**



## Conclusions and Recommendations

Based on this assessment it is considered that water resources hydrological impacts of subsidence from the project on water resources in the Isaac River will not be significantly impacted.

The assessment shows that without mitigation the ponding in subsidence voids in the 12 Mile Gully catchment appears to have a potentially significant impact on the hydrology of flows in the 12 Mile Gully watercourse. The flow frequency impacts suggest that some form of mitigation to at least partially drain some of the larger subsidence voids should be considered. However, there is no clear guideline or scientific principle to justify an essential need for mitigation. The recommendation for mitigation is primarily based on the observation that the potential reduction in flows and flow frequency (without mitigation) in the lower reaches of 12 Mile Gully appears significant.

The impacts can be adequately mitigated with a reasonable balance of partially draining of some of the larger subsidence voids as part of progressive mine closure.

This assessment does not represent a definitive mitigation case, but rather demonstrates that adequate mitigation to mitigate reduction in flows in 12 Mile Gully can be achieved by partially draining some of the larger subsidence voids. The eventual actual mitigation works to be implemented would be assessed and decided in more detail as part of progressive mine closure planning for the project. This assessment would consider the trade-off between minimising the degree of disturbance required to partially drain some of the subsidence voids and the hydrological benefit gained from this strategy. This assessment would also consider detailed geotechnical information and best practice rehabilitation methods to ensure that created drainage channels and associated works can be stable beyond mine closure.

It is considered that potential hydrological impacts are not sufficiently significant to warrant completely draining subsidence voids to minimise ponding. Works to subsidence void overflow flow paths may be necessary to stabilise geomorphological response of the 12 Mile Gully watercourse channel and would be decided based on a detailed monitoring and adaptive management program set out in a subsidence management plan.

There could potentially be positive ecological benefits of allowing ponding to occur in the subsidence voids. It is therefore considered that the need to partly drain subsidence voids should be considered in conjunction with ecological assessment of the relative benefits and impacts of ponding in the subsidence voids.

## References

Alluvium 2008, Isaac River Cumulative Impact Assessment of Mine Developments.

DERM 2010, Fitzroy Basin Draft Water Resource Plan Overview Report, Queensland Department of Environment and Resource Management.

IMC 2011, *Surface Subsidence Prediction for the Goonyella Coal Extension (GCE) Based on Updated Mine Plan*. Report prepared for BMA Coal. Report IMC01384. IMC Mining Group Pty Ltd.

*Fitzroy Basin Water Resource Plan 2011*. Queensland Government.

NRM 2012, Streamflow data – open stations. Department of Natural Resources and Mines. Available online at: <http://watermonitoring.derm.qld.gov.au/host.htm> (accessed May 2012).

URS 2007, Goonyella Riverside Mine Environmental Evaluation.

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### 130414A Isaac River At Goonyella

[Latest Values](#) | [Details](#) | [Prepared Outputs](#) | [Custom Outputs](#)

**Details**

Site no.	130414A
Site commence	24/05/1983
Zero gauge	230.06
Datum	AHD
Control	Sand
Cease to flow level	0
Maximum gauged level	6.5
Maximum gauge date	02/03/1988
Adapted middle thread distance	242.8 km
Distance from stream mouth	242.8 km
Catchment area	1214 sq. km
Gaugings	136 gaugings between 21/12/1982 and 07/12/2011

**Flow volume summary (ML)**


	Daily				Monthly
	Max	Min	Mean	Median	Mean
<b>Jan</b>	55911	0	297	0	8982
<b>Feb</b>	56881	0	563	0	15921
<b>Mar</b>	55610	0	341	0	10492
<b>Apr</b>	70811	0	182	0	5471
<b>May</b>	1812	0	18	0	548
<b>Jun</b>	1287	0	15	0	457
<b>Jul</b>	529	0	8	0	230
<b>Aug</b>	11575	0	19	0	582
<b>Sep</b>	2841	0	10	0	305
<b>Oct</b>	3736	0	14	0	423
<b>Nov</b>	5694	0	86	0	2581
<b>Dec</b>	52859	0	417	0	12933
<b>All months</b>	70811	0	160	0	4838

**Period of record**

Variable	Start date	End date	Days	Data type	Max value	Max date	Min value	Min date
100.00 Level (Metres)	24/05/1983	07/03/2012	10515	Instantaneous value	8.880	08/01/1991	-0.080	07/08/1983
140.00 Discharge (Cumecs)	24/05/1983	19/07/2011	10283	Instantaneous value	1733.907	08/01/1991	0	08/08/1983

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### 130410A Isaac River At Deverill

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**Details**

Site no.	130410A
Site commence	20/05/1968
Zero gauge	169.304
Datum	AHD
Control	Sand
Cease to flow level	0
Maximum gauged level	11.41
Maximum gauge date	02/03/1988
Adapted middle thread distance	174.7 km
Distance from stream mouth	174.7 km
Catchment area	4092 sq. km
Gaugings	239 gaugings between 03/07/1957 and 06/12/2011

**Flow volume summary (ML)**

	Daily				Monthly
	Max	Min	Mean	Median	Mean
Jan	160115	0	1396	0	41964
Feb	145302	0	1612	4	45532
Mar	194455	0	896	0	27761
Apr	112899	0	316	0	9468
May	58296	0	242	0	7374
Jun	6343	0	32	0	965
Jul	3254	0	11	0	346
Aug	102835	0	92	0	2848
Sep	18423	0	28	0	843
Oct	8154	0	30	0	934
Nov	10332	0	160	0	4734
Dec	122736	0	917	0	27886
<b>All months</b>	<b>194455</b>	<b>0</b>	<b>468</b>	<b>0</b>	<b>14143</b>

**Period of record**

Variable	Start date	End date	Days	Data type	Max value	Max date	Min value	Min date
10.00 Rainfall (mm)	30/03/1995	15/03/2012	6195	Daily total	229.0	30/08/1998	0	01/04/1995
100.00 Level (Metres)	20/05/1968	15/03/2012	16005	Instantaneous value	11.430	02/03/1988	0	29/09/1981
140.00 Discharge (Cumecs)	20/05/1968	13/01/2011	15578	Instantaneous value	2638.227	02/03/1988	0	18/06/1968
2010.00 E Conduct. (us/cm)	09/08/2011	15/03/2012	219	Instantaneous value	949	30/01/2012	0	09/08/2011
2080.00 Water Temp (Deg. C)	08/02/2008	15/03/2012	1497	Instantaneous value	35.0	07/02/2012	0	08/02/2008

- Flinders Basin
- Georgina Basin
- Gilbert Basin
- Haughton Basin
- Herbert Basin
- Jardine Basin
- Johnstone Basin
- Kolan Basin
- Leichhardt Basin
- Logan-Albert Basin
- Maroochy Basin
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130401A Isaac River At Yattoo

Latest Values Details Prepared Outputs Custom Outputs

**Details**

Site no.	130401A
Site commence	01/10/1962
Zero gauge	89.146
Datum	AHD
Control	Sand Gravel
Cease to flow level	0
Maximum gauged level	16.688
Maximum gauge date	17/02/2008
Adapted middle thread distance	43 km
Distance from stream mouth	43 km
Catchment area	19720 sq. km
Gaugings	257 gaugings between 13/07/1962 and 22/12/2011

**Flow volume summary (ML)**

	Daily		Monthly	
	Max	Min	Mean	Median
Jan	1526981	0	15905	484
Feb	1006222	0	19792	1188
Mar	1900509	0	13200	996
Apr	678295	0	4238	308
May	229581	0	2711	158
Jun	51571	0	911	95
Jul	50026	0	408	62
Aug	10428	0	110	35
Sep	78175	0	332	7
Oct	17571	0	179	1
Nov	159454	0	1373	2
Dec	1496659	0	6205	68
All months	1900509	0	5395	84

**Period of record**

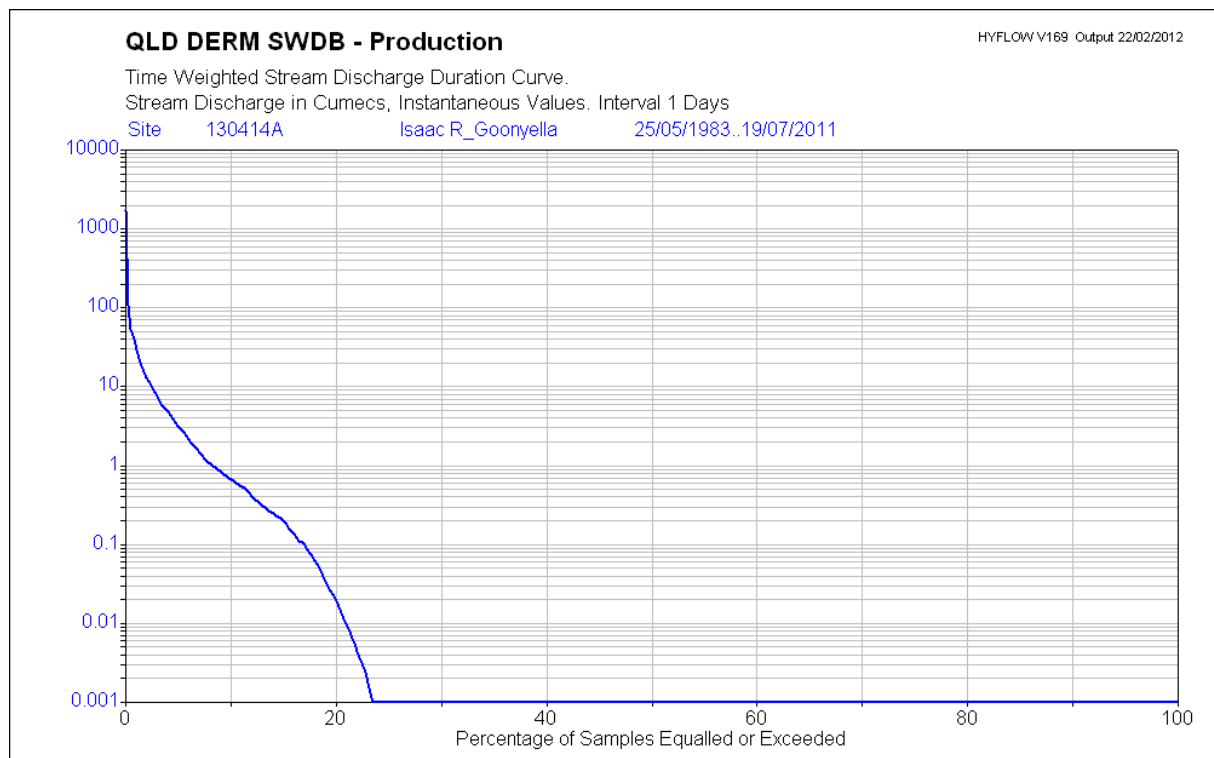
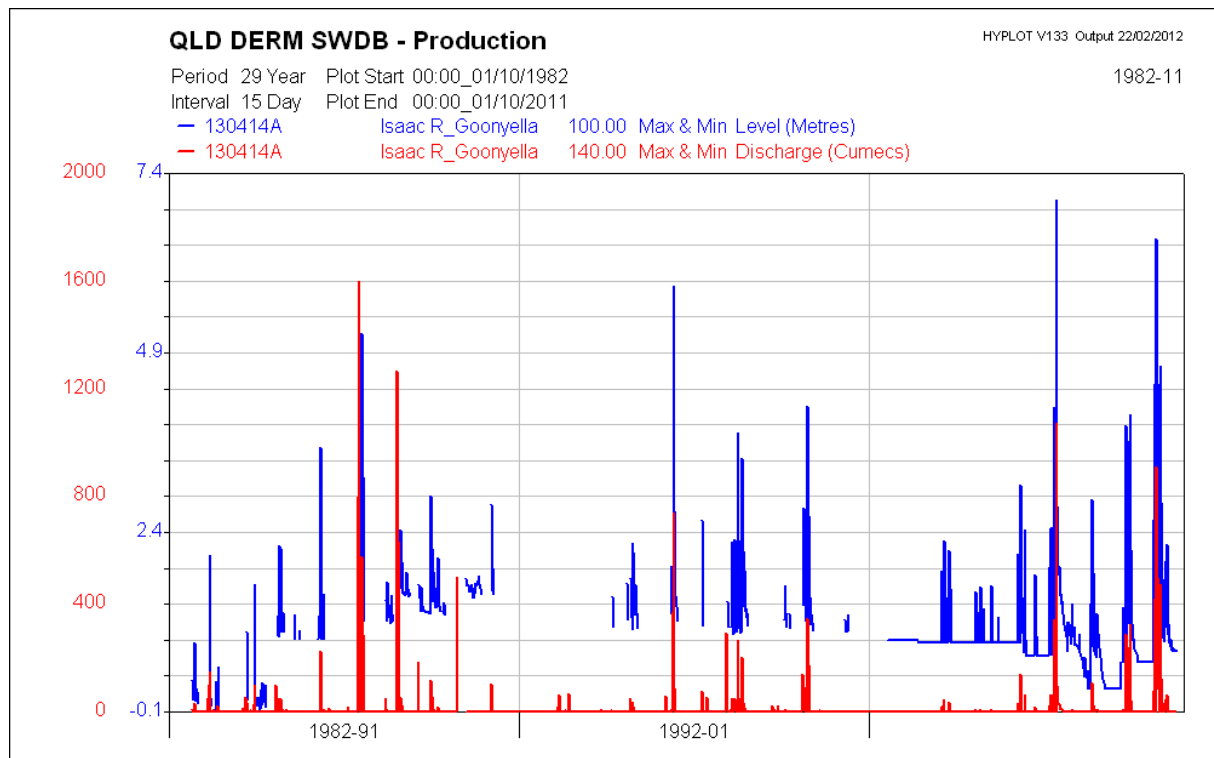
Variable	Start date	End date	Days	Data type	Max value	Max date	Min value	Min date
10.00 Rainfall (mm)	27/10/2006	07/03/2012	1958	Daily total	139.0	20/03/2011	0	28/10/2006
100.00 Level (Metres)	05/12/1962	07/03/2012	17990	Instantaneous value	19.620	02/03/1988	0	31/12/2005
140.00 Discharge (Cumecs)	01/10/1962	10/08/2011	17845	Instantaneous value	23404.153	02/03/1988	0	15/10/1962
2010.00 E Conduct. (us/cm)	11/09/1995	07/03/2012	6022	Instantaneous value	879	16/02/2003	-2	01/01/2006
2030.00 Turbidity (NTU)	19/11/2007	18/08/2011	1368	Instantaneous value	7999.000	29/01/2008	-3.000	16/12/2009
2080.00 Water Temp (Deg. C)	11/09/1995	07/03/2012	6022	Instantaneous value	36.0	14/02/2006	0	29/12/2002
2100.00 pH (pH units)	11/09/1995	27/10/2006	4064	Instantaneous value	9.600	31/08/1998	5.800	27/04/2000

Flinders Basin

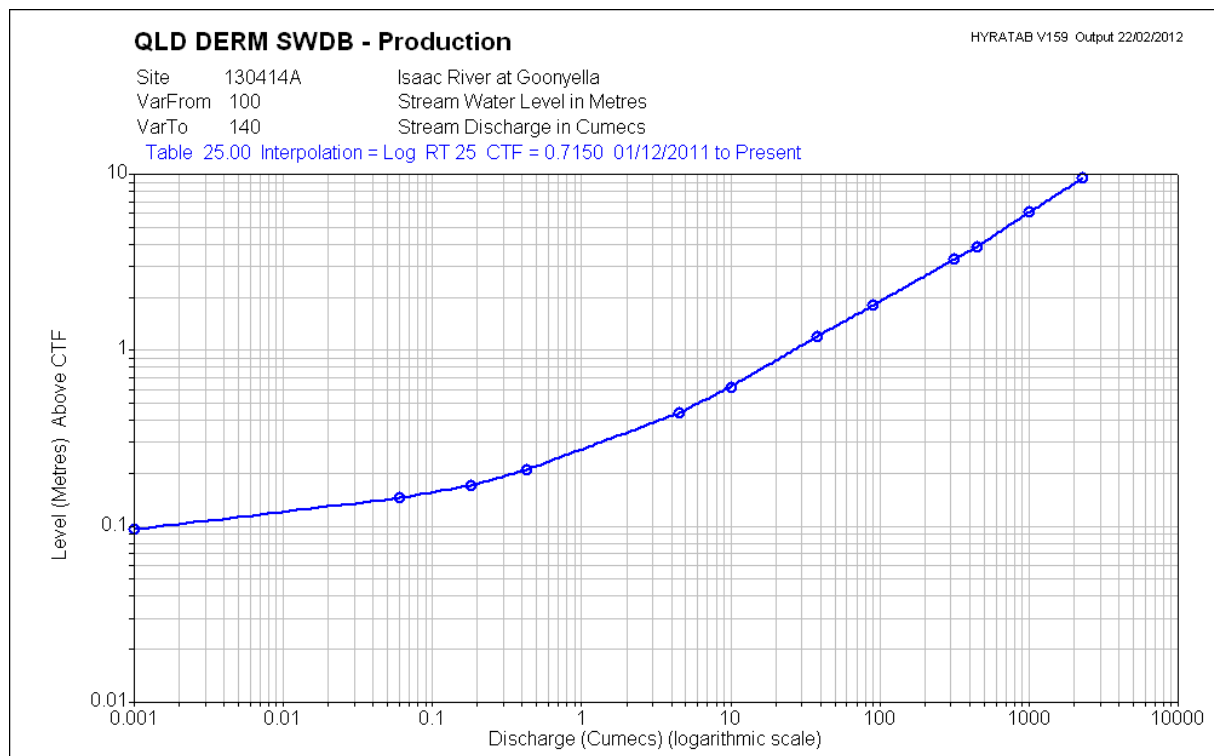
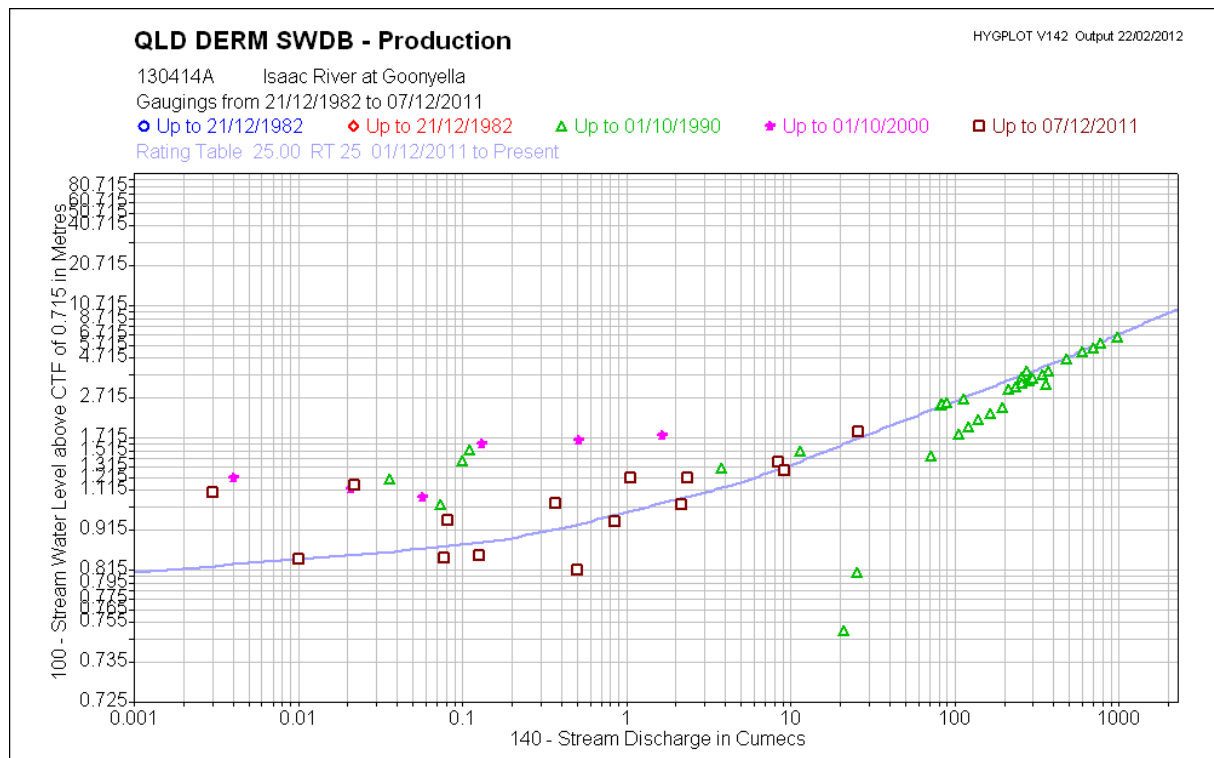
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## Appendix A - NRM Stream Gauge Data



## Appendix A - NRM Stream Gauge Data



## Appendix B Subsidence Void Storage Data

## Subsidence Pond Level-Storage Data and Curve Fitting

**N01-2**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	254.550	adjust Ho for best fit
<b>A=</b>	1209	
<b>B=</b>	3.139	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9995
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	255.50	1272.8
2	255.92	3019.4
3	256.34	6341.6
4	256.77	13499.0
5	257.19	24164.0
6	257.61	40487.3
7	258.03	63246.0
8	258.46	91949.7
9	258.88	126103.1
10	259.30	166996.1
11	259.72	214138.0
12	260.15	266868.3

Log Elev- Ho	Log Vol.
-0.022	3.105
0.137	3.480
0.254	3.802
0.346	4.130
0.422	4.383
0.486	4.607
0.542	4.801
0.592	4.964
0.636	5.101
0.677	5.223
0.714	5.331
0.748	5.426

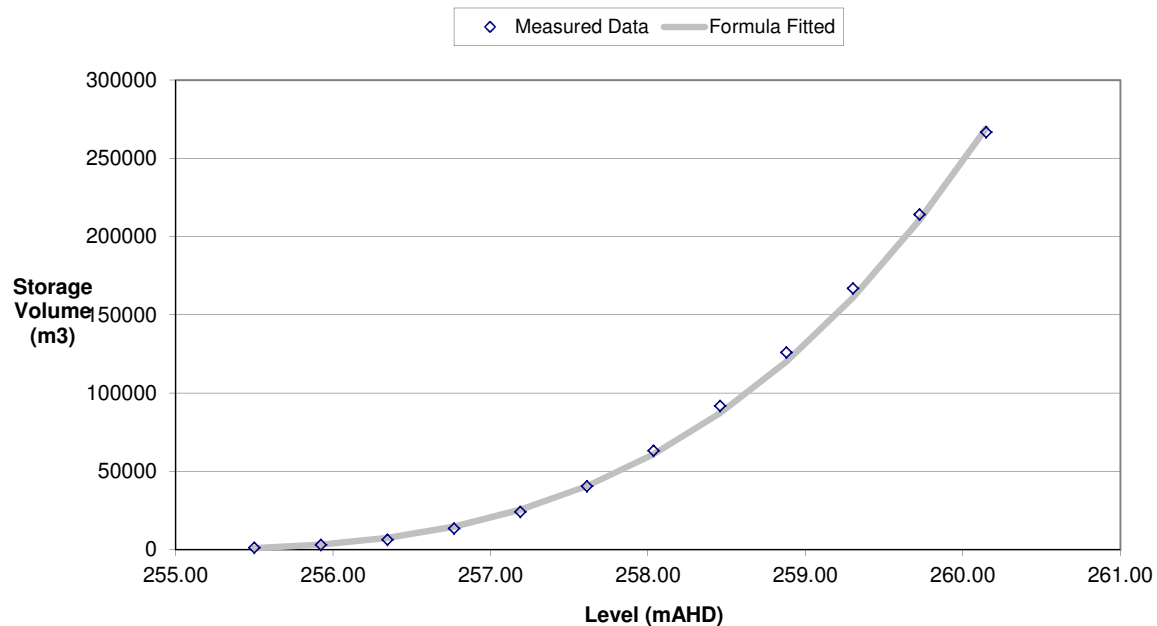
Formula Vol (m3)	Error (m3)	Error (%)
1029	-243	19.1%
3266	247	8.2%
7583	1241	19.6%
14721	1222	9.1%
25448	1284	5.3%
40552	64	0.2%
60838	-2408	3.8%
87128	-4822	5.2%
120257	-5846	4.6%
161073	-5923	3.5%
210435	-3703	1.7%
269215	2347	0.9%

### Volume formula

intercept	1209.133
slope	3.139

Max Error	19.6%
Mean Error	6.8%

### Storage vs Elevation Plot





## Subsidence Pond Level-Storage Data and Curve Fitting

**N01-1**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	260.780	adjust Ho for best fit
<b>A=</b>	28780	
<b>B=</b>	2.048	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	1.0000
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	260.95	788.7
2	261.05	1993.0
3	261.14	3689.5
4	261.24	5893.5
5	261.33	8650.7
6	261.43	11948.8
7	261.52	15703.4
8	261.62	19984.7
9	261.71	24827.3
10	261.81	30255.2
11	261.90	36372.3
12	262.00	43146.3

Log Elev- Ho	Log Vol.
-0.758	2.897
-0.569	3.300
-0.438	3.567
-0.338	3.770
-0.256	3.937
-0.188	4.077
-0.128	4.196
-0.076	4.301
-0.030	4.395
0.012	4.481
0.051	4.561
0.086	4.635

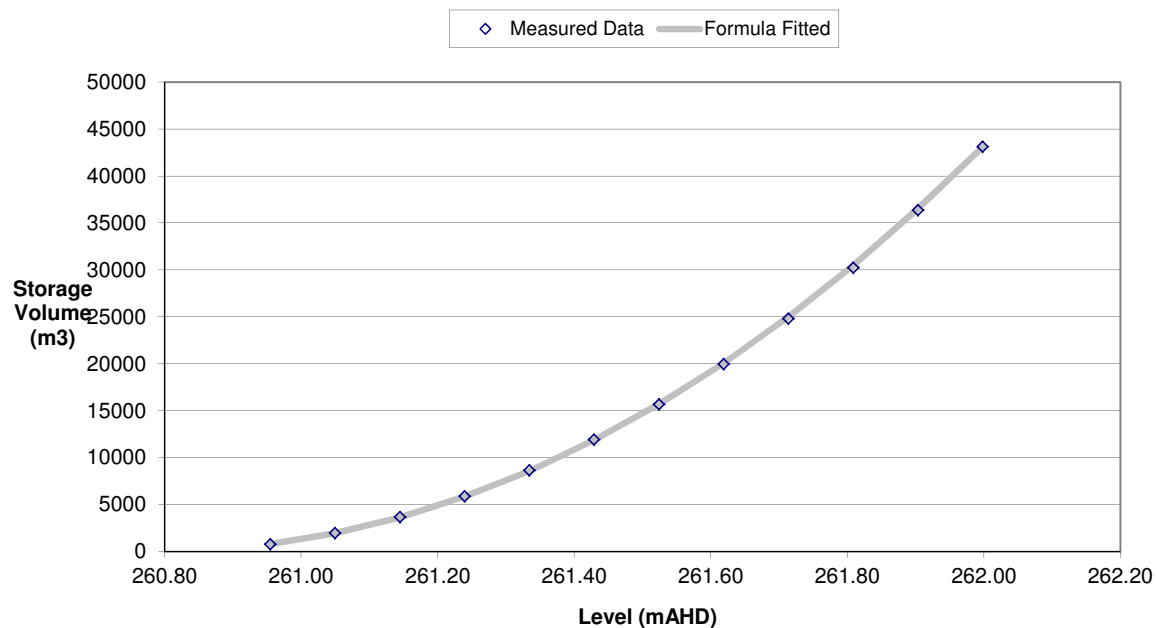
Formula Vol (m3)	Error (m3)	Error (%)
808	20	2.5%
1965	-28	1.4%
3643	-47	1.3%
5850	-43	0.7%
8593	-58	0.7%
11876	-73	0.6%
15703	0	0.0%
20078	93	0.5%
25003	176	0.7%
30483	228	0.8%
36519	146	0.4%
43113	-33	0.1%

### Volume formula

intercept	28780.009
slope	2.048

Max Error	2.5%
Mean Error	0.8%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N02**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	253.100	adjust Ho for best fit
<b>A=</b>	5111	
<b>B=</b>	2.317	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	1.0000
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	253.50	577.3
2	253.87	2868.4
3	254.24	7394.7
4	254.62	14030.2
5	254.99	22397.5
6	255.36	33409.6
7	255.73	47353.4
8	256.10	64295.1
9	256.48	84891.3
10	256.85	108751.7
11	257.22	135636.7
12	257.59	165257.0

Log Elev- Ho	Log Vol.
-0.398	2.761
-0.112	3.458
0.059	3.869
0.181	4.147
0.276	4.350
0.354	4.524
0.420	4.675
0.478	4.808
0.529	4.929
0.574	5.036
0.615	5.132
0.653	5.218

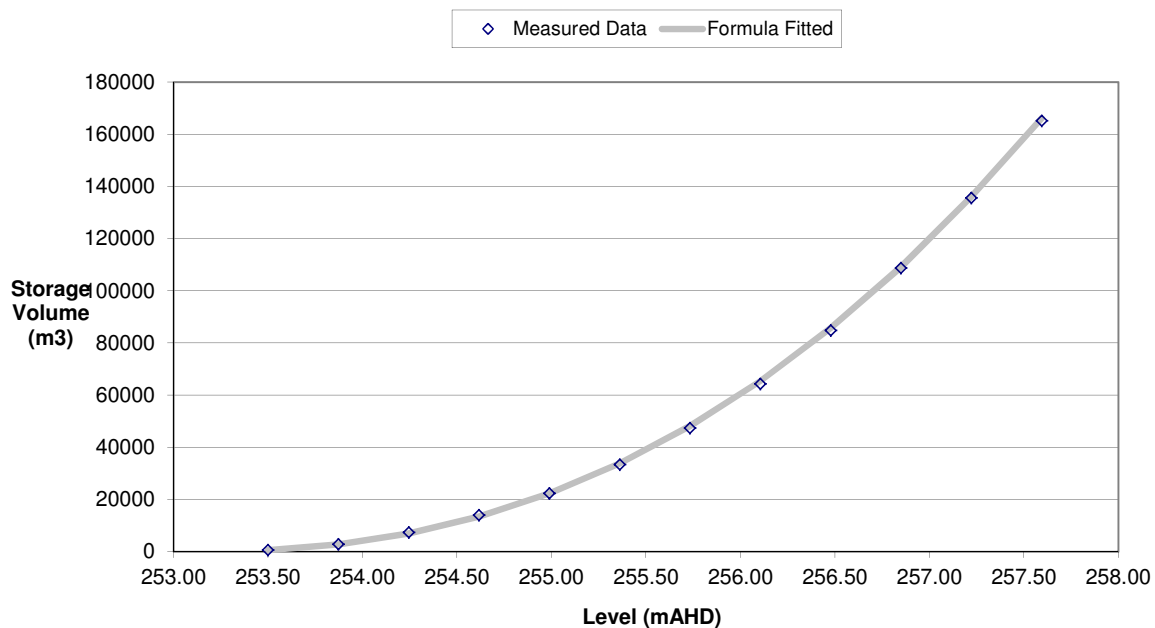
Formula Vol (m3)	Error (m3)	Error (%)
612	34	5.9%
2808	-61	2.1%
6985	-410	5.5%
13412	-618	4.4%
22302	-95	0.4%
33833	423	1.3%
48160	807	1.7%
65422	1127	1.8%
85746	854	1.0%
109246	494	0.5%
136030	393	0.3%
166198	941	0.6%

### Volume formula

intercept	5111.421
slope	2.317

Max Error	5.9%
Mean Error	2.1%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N03-1**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	249.600	adjust Ho for best fit
<b>A=</b>	929	
<b>B=</b>	3.248	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9995
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	250.50	726.8
2	250.78	1600.4
3	251.06	2949.3
4	251.33	5189.6
5	251.61	8562.9
6	251.89	13166.3
7	252.17	19359.6
8	252.44	27821.0
9	252.72	38596.5
10	253.00	51763.4
11	253.28	66240.5
12	253.55	80796.5

Log Elev- Ho	Log Vol.
-0.046	2.861
0.071	3.204
0.163	3.470
0.239	3.715
0.303	3.933
0.359	4.119
0.409	4.287
0.454	4.444
0.494	4.587
0.531	4.714
0.565	4.821
0.597	4.907

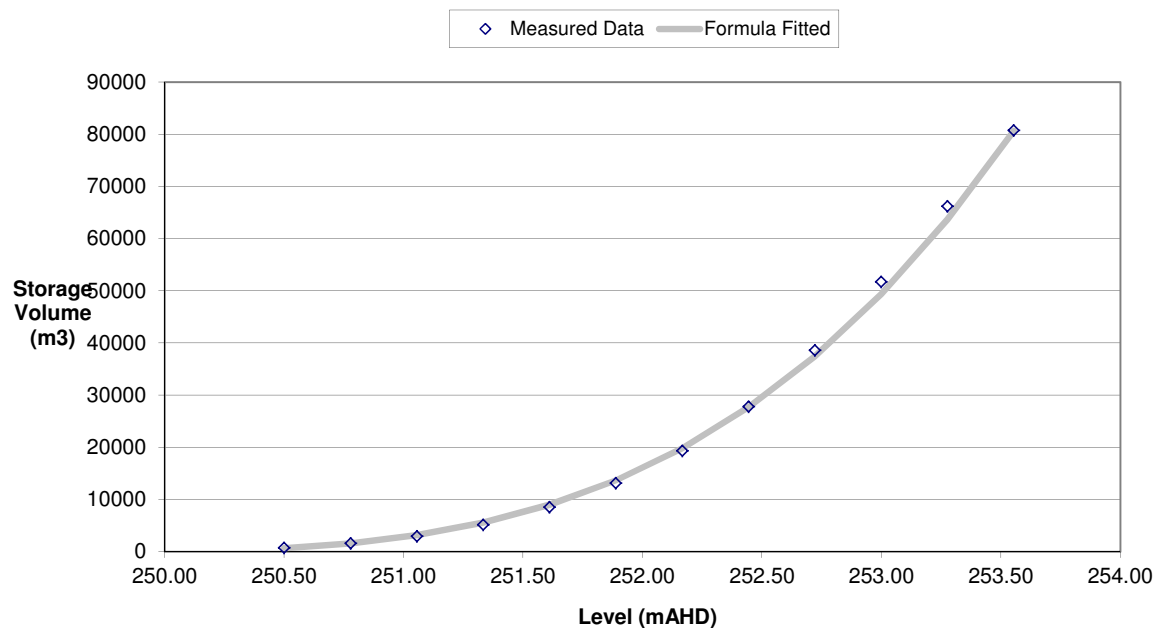
Formula Vol (m3)	Error (m3)	Error (%)
660	-67	9.2%
1580	-21	1.3%
3141	192	6.5%
5538	348	6.7%
8973	410	4.8%
13658	491	3.7%
19810	451	2.3%
27656	-164	0.6%
37427	-1169	3.0%
49361	-2403	4.6%
63698	-2542	3.8%
80688	-109	0.1%

### Volume formula

intercept	928.893
slope	3.248

Max Error	9.2%
Mean Error	3.9%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N03-2**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	257.800	adjust Ho for best fit
<b>A=</b>	14	
<b>B=</b>	4.720	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9992
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	261.00	3080.8
2	261.23	4692.9
3	261.45	6588.9
4	261.68	8883.6
5	261.91	11493.2
6	262.13	14581.5
7	262.36	18186.6
8	262.58	22438.4
9	262.81	27347.7
10	263.04	33256.8
11	263.26	41426.5
12	263.49	52016.0

Log Elev- Ho	Log Vol.
0.505	3.489
0.535	3.671
0.563	3.819
0.589	3.949
0.613	4.060
0.637	4.164
0.659	4.260
0.680	4.351
0.700	4.437
0.719	4.522
0.737	4.617
0.755	4.716

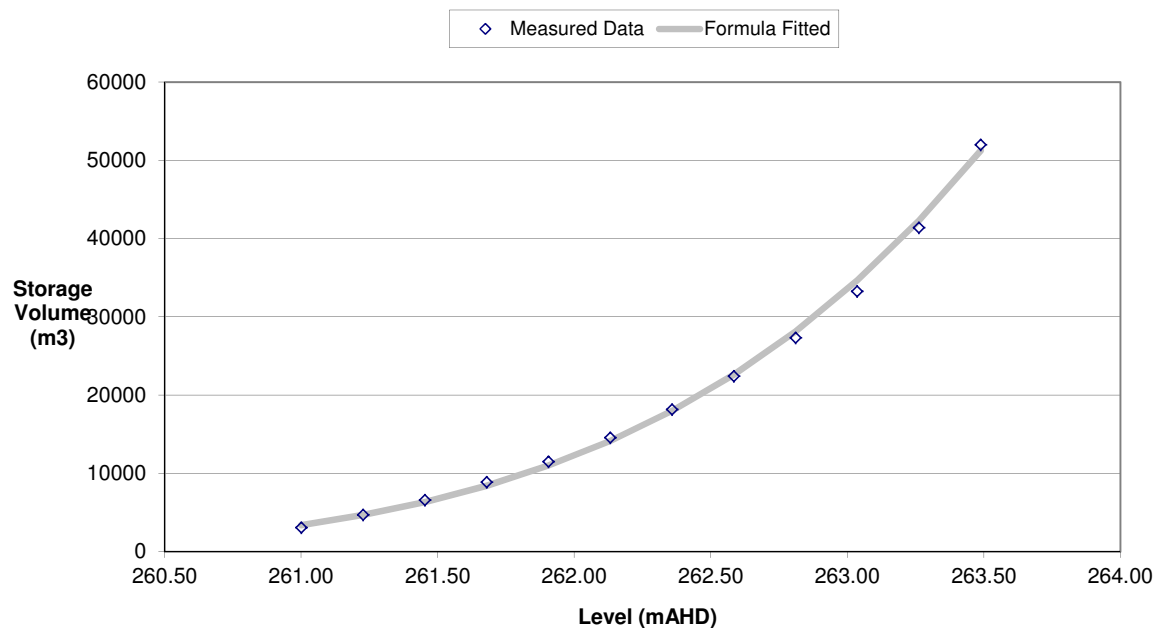
Formula Vol (m3)	Error (m3)	Error (%)
3392	311	10.1%
4682	-10	0.2%
6332	-257	3.9%
8409	-474	5.3%
10989	-504	4.4%
14156	-426	2.9%
18002	-185	1.0%
22627	189	0.8%
28142	794	2.9%
34665	1409	4.2%
42326	899	2.2%
51262	-754	1.4%

### Volume formula

intercept	14.002
slope	4.720

Max Error	10.1%
Mean Error	3.3%

### Storage vs Elevation Plot





## Subsidence Pond Level-Storage Data and Curve Fitting

**N03-3**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	259.700	adjust Ho for best fit
<b>A=</b>	100	
<b>B=</b>	4.389	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9998
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### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	261.00	301.6
2	261.38	1052.6
3	261.76	2498.8
4	262.14	4933.2
5	262.51	8779.1
6	262.89	15244.0
7	263.27	25562.0
8	263.65	41466.1
9	264.03	63242.5
10	264.41	92245.5
11	264.78	128531.4
12	265.16	172390.2

Log Elev- Ho	Log Vol.
0.114	2.479
0.225	3.022
0.313	3.398
0.387	3.693
0.449	3.943
0.504	4.183
0.553	4.408
0.597	4.618
0.636	4.801
0.673	4.965
0.706	5.109
0.737	5.237

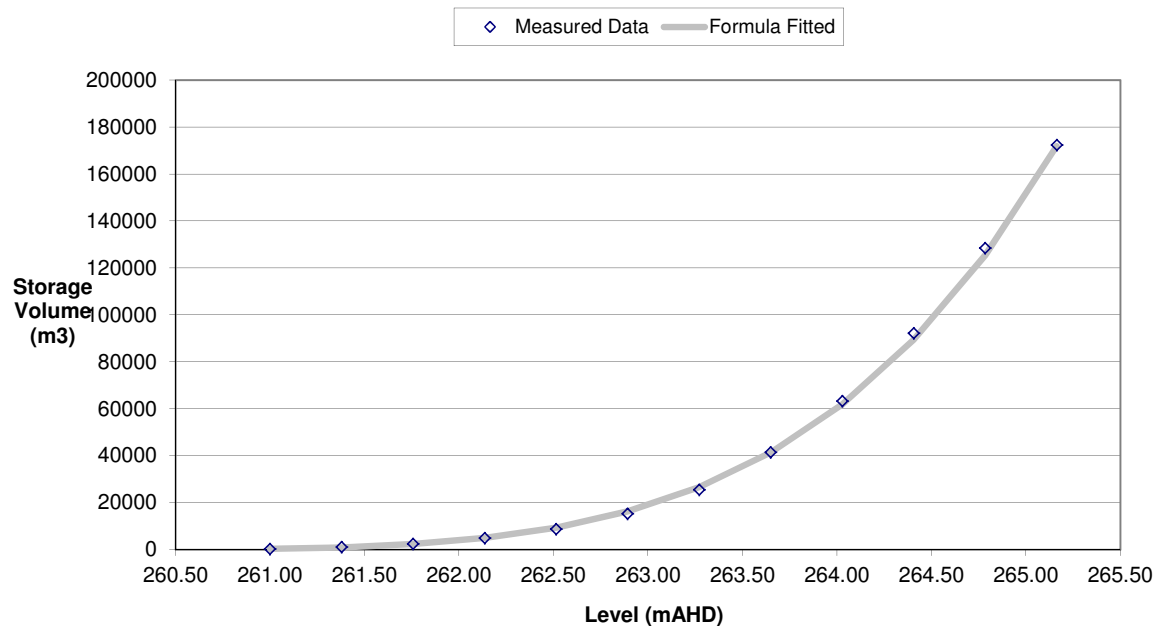
Formula Vol (m3)	Error (m3)	Error (%)
316	14	4.7%
969	-84	8.0%
2364	-134	5.4%
4962	29	0.6%
9353	574	6.5%
16273	1029	6.7%
26607	1045	4.1%
41400	-66	0.2%
61862	-1381	2.2%
89374	-2872	3.1%
125497	-3035	2.4%
171975	-415	0.2%

### Volume formula

intercept	99.796
slope	4.389

Max Error	8.0%
Mean Error	3.7%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N04-1**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	260.550	adjust Ho for best fit
<b>A=</b>	12513	
<b>B=</b>	2.020	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	1.0000
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	260.70	299.9
2	260.95	1786.4
3	261.21	5081.6
4	261.46	10323.7
5	261.72	17145.4
6	261.97	25697.4
7	262.23	35875.9
8	262.48	47729.4
9	262.73	61287.5
10	262.99	76271.7
11	263.24	93400.8
12	263.50	113174.8

Log Elev- Ho	Log Vol.
-0.824	2.477
-0.393	3.252
-0.181	3.706
-0.040	4.014
0.067	4.234
0.153	4.410
0.224	4.555
0.285	4.679
0.339	4.787
0.387	4.882
0.430	4.970
0.469	5.054

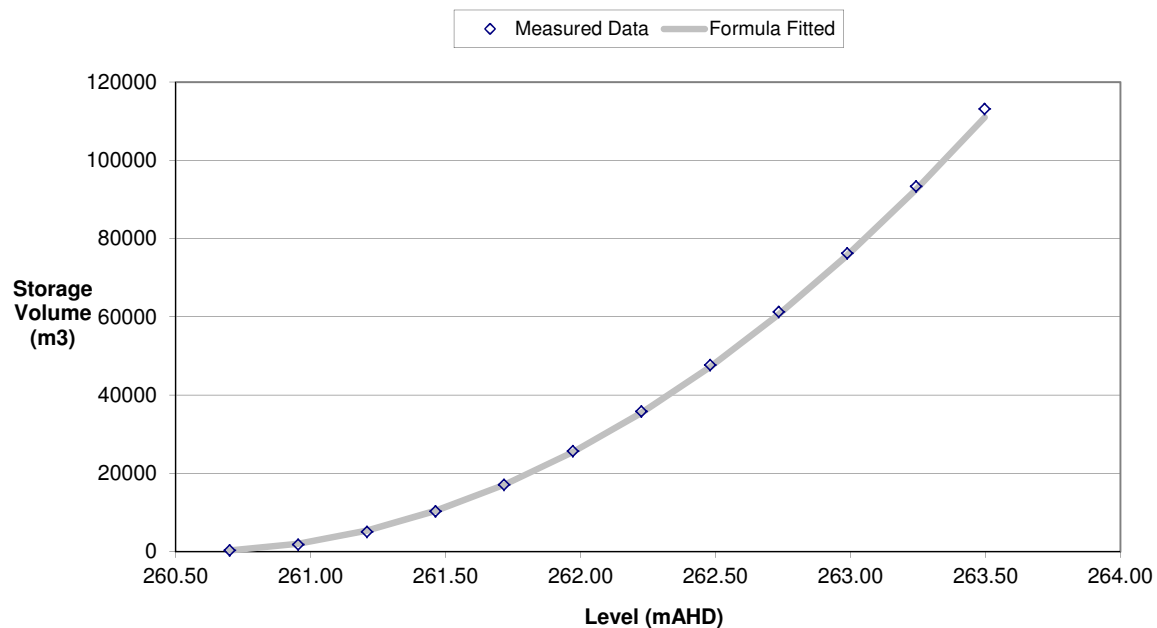
Formula Vol (m3)	Error (m3)	Error (%)
271	-29	9.6%
2008	222	12.4%
5381	299	5.9%
10405	82	0.8%
17093	-52	0.3%
25453	-244	0.9%
35491	-385	1.1%
47213	-516	1.1%
60624	-663	1.1%
75727	-544	0.7%
92528	-873	0.9%
111028	-2147	1.9%

### Volume formula

intercept	12512.927
slope	2.020

Max Error	12.4%
Mean Error	3.1%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N04-2**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	253.000	adjust Ho for best fit
<b>A=</b>	0.02508	
<b>B=</b>	6.824	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9994
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	257.70	810.7
2	258.00	1512.1
3	258.30	2374.4
4	258.60	3501.2
5	258.90	4909.8
6	259.20	6637.6
7	259.50	8838.1
8	259.80	11659.9
9	260.10	15388.0
10	260.40	20458.7
11	260.70	27474.4
12	261.00	36705.1

Log Elev- Ho	Log Vol.
0.672	2.909
0.699	3.180
0.724	3.376
0.748	3.544
0.771	3.691
0.792	3.822
0.813	3.946
0.832	4.067
0.851	4.187
0.869	4.311
0.886	4.439
0.903	4.565

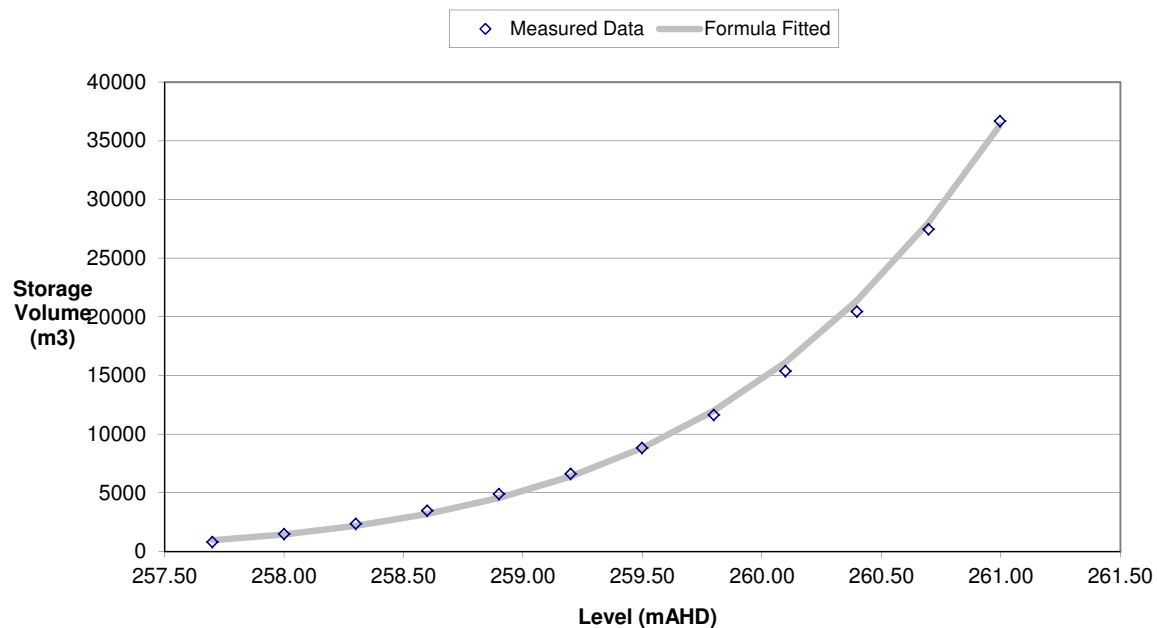
Formula Vol (m3)	Error (m3)	Error (%)
968	157	19.4%
1476	-37	2.4%
2195	-179	7.5%
3195	-306	8.7%
4560	-349	7.1%
6395	-242	3.6%
8826	-12	0.1%
12006	346	3.0%
16116	728	4.7%
21370	912	4.5%
28022	548	2.0%
36366	-339	0.9%

### Volume formula

intercept	0.025
slope	6.824

Max Error	19.4%
Mean Error	5.3%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N04-3**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	258.100	adjust Ho for best fit
<b>A=</b>	1243	
<b>B=</b>	2.635	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9996
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### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	258.80	451.5
2	259.18	1525.2
3	259.56	3497.7
4	259.94	6732.8
5	260.32	10835.3
6	260.71	15826.7
7	261.09	22011.2
8	261.47	29613.7
9	261.85	38968.7
10	262.23	50468.5
11	262.61	64731.5
12	262.99	82184.7

Log Elev- Ho	Log Vol.
-0.155	2.655
0.034	3.183
0.165	3.544
0.266	3.828
0.347	4.035
0.416	4.199
0.475	4.343
0.527	4.471
0.574	4.591
0.616	4.703
0.654	4.811
0.689	4.915

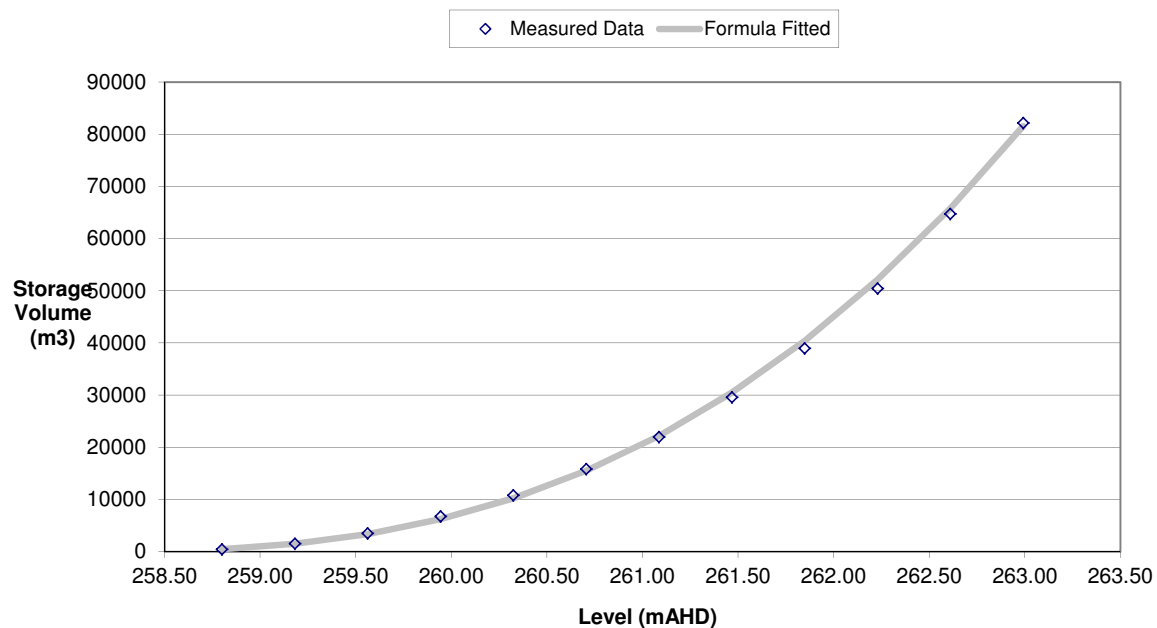
Formula Vol (m3)	Error (m3)	Error (%)
486	34	7.6%
1527	2	0.1%
3383	-115	3.3%
6228	-505	7.5%
10218	-617	5.7%
15500	-326	2.1%
22210	199	0.9%
30478	864	2.9%
40427	1458	3.7%
52175	1707	3.4%
65837	1106	1.7%
81524	-661	0.8%

### Volume formula

intercept	1243.428
slope	2.635

Max Error	7.6%
Mean Error	3.3%

### Storage vs Elevation Plot





## Subsidence Pond Level-Storage Data and Curve Fitting

**N05**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	255.600	adjust Ho for best fit
<b>A=</b>	2440	
<b>B=</b>	3.008	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9994
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	256.50	2188.2
2	256.68	2999.2
3	256.86	4272.4
4	257.04	6491.9
5	257.22	9830.1
6	257.41	14203.2
7	257.59	19566.0
8	257.77	25908.2
9	257.95	33237.4
10	258.13	41428.8
11	258.31	50242.9
12	258.49	59737.6

Log Elev- Ho	Log Vol.
-0.046	3.340
0.034	3.477
0.101	3.631
0.159	3.812
0.211	3.993
0.257	4.152
0.298	4.292
0.336	4.413
0.371	4.522
0.403	4.617
0.433	4.701
0.461	4.776

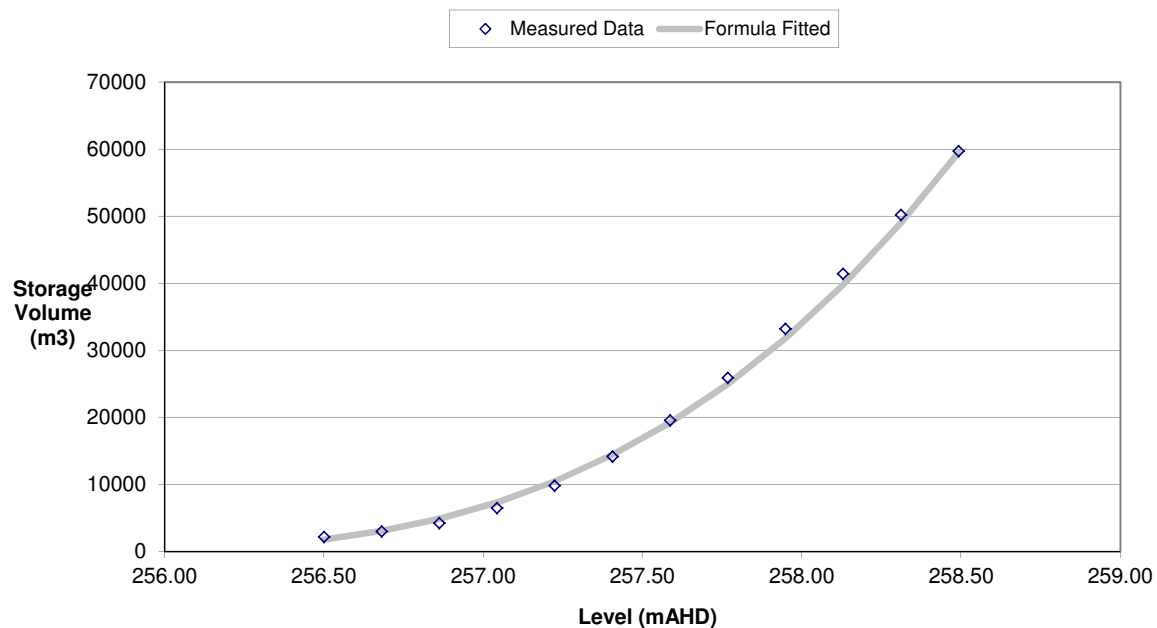
Formula Vol (m3)	Error (m3)	Error (%)
1777	-411	18.8%
3085	85	2.8%
4915	642	15.0%
7356	864	13.3%
10496	666	6.8%
14425	222	1.6%
19230	-336	1.7%
24999	-909	3.5%
31823	-1414	4.3%
39789	-1640	4.0%
48987	-1256	2.5%
59504	-233	0.4%

### Volume formula

intercept	2439.907
slope	3.008

Max Error	18.8%
Mean Error	6.2%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N06**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	254.000	adjust Ho for best fit
<b>A=</b>	31448	
<b>B=</b>	2.138	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	1.0000
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	254.20	959.1
2	254.32	2752.1
3	254.44	5520.8
4	254.55	9151.9
5	254.67	13661.3
6	254.79	19124.8
7	254.91	25633.2
8	255.03	33141.1
9	255.14	41750.2
10	255.26	51312.6
11	255.38	61903.3
12	255.50	73510.0

Log Elev- Ho	Log Vol.
-0.699	2.982
-0.497	3.440
-0.360	3.742
-0.256	3.962
-0.172	4.135
-0.102	4.282
-0.042	4.409
0.011	4.520
0.059	4.621
0.101	4.710
0.140	4.792
0.176	4.866

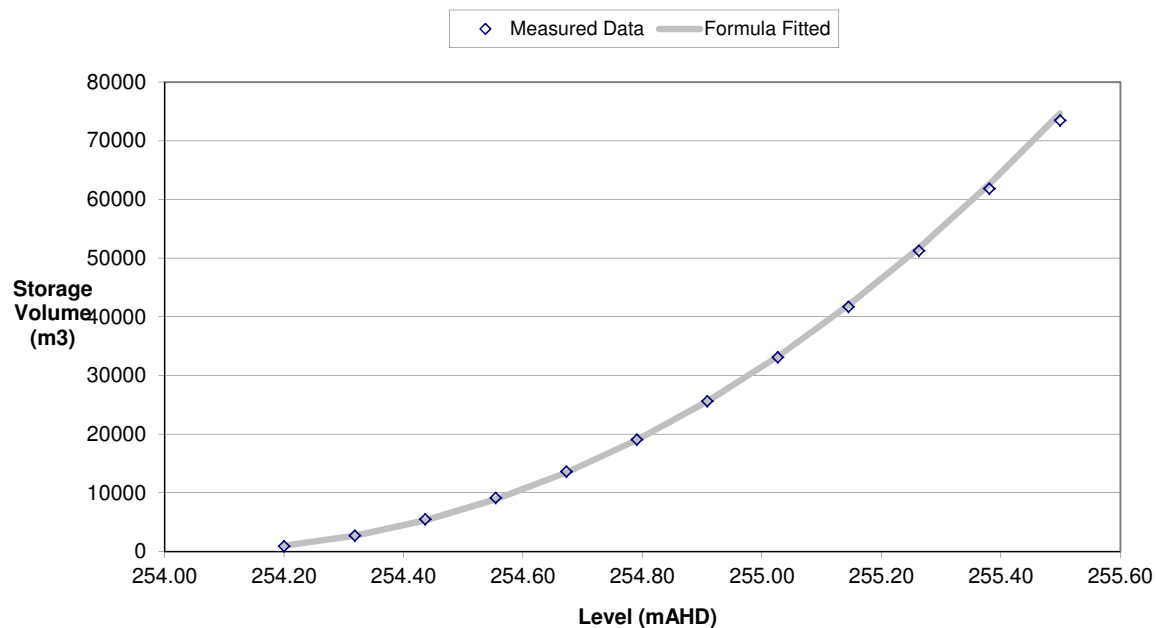
Formula Vol (m3)	Error (m3)	Error (%)
1008	49	5.1%
2717	-35	1.3%
5336	-185	3.3%
8905	-247	2.7%
13457	-204	1.5%
19018	-107	0.6%
25611	-22	0.1%
33257	116	0.3%
41972	222	0.5%
51773	461	0.9%
62676	773	1.2%
74693	1183	1.6%

### Volume formula

intercept	31447.662
slope	2.138

Max Error	5.1%
Mean Error	1.6%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N07**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	258.500	adjust Ho for best fit
<b>A=</b>	13995	
<b>B=</b>	2.820	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9999
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	258.80	476.8
2	258.91	1128.7
3	259.02	2200.5
4	259.13	3730.1
5	259.24	5788.6
6	259.35	8496.8
7	259.45	12098.1
8	259.56	16623.1
9	259.67	22165.5
10	259.78	28653.6
11	259.89	35954.9
12	260.00	43793.0

Log Elev- Ho	Log Vol.
-0.523	2.678
-0.388	3.053
-0.286	3.343
-0.203	3.572
-0.133	3.763
-0.073	3.929
-0.020	4.083
0.027	4.221
0.069	4.346
0.108	4.457
0.143	4.556
0.176	4.641

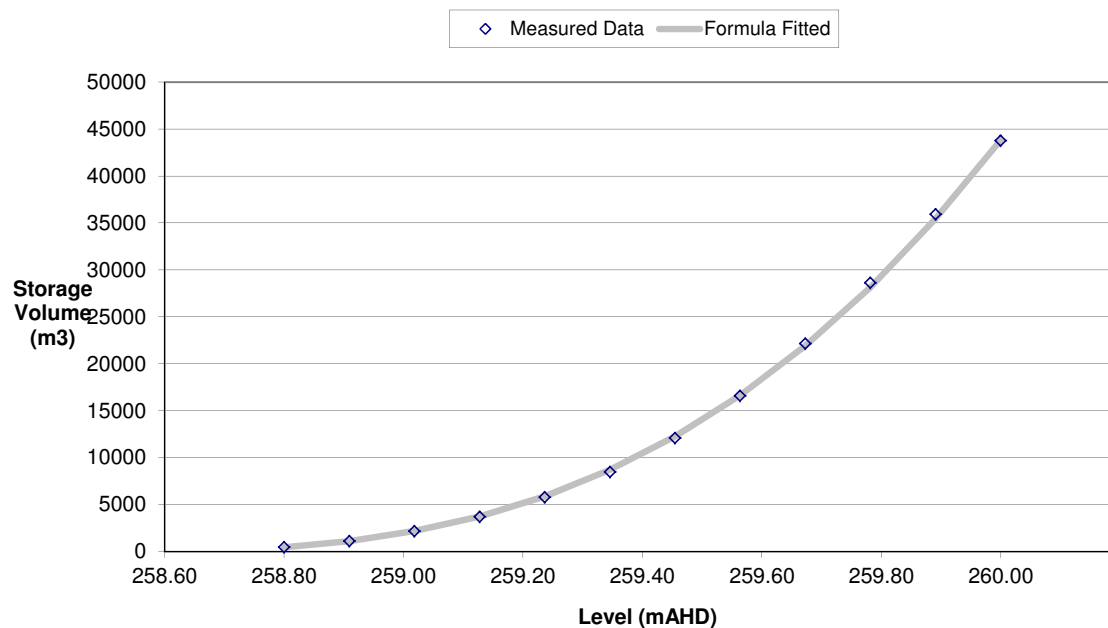
Formula Vol (m3)	Error (m3)	Error (%)
469	-7	1.5%
1125	-3	0.3%
2191	-9	0.4%
3755	24	0.7%
5900	112	1.9%
8710	213	2.5%
12263	165	1.4%
16637	14	0.1%
21910	-256	1.2%
28154	-499	1.7%
35445	-510	1.4%
43854	61	0.1%

### Volume formula

intercept	13995.159
slope	2.820

Max Error	2.5%
Mean Error	1.1%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N08-1**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	254.850	adjust Ho for best fit
<b>A=</b>	24688	
<b>B=</b>	1.898	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9998
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	255.00	571.7
2	255.32	6833.6
3	255.64	17495.1
4	255.95	31511.5
5	256.27	48909.6
6	256.59	69834.4
7	256.91	94506.2
8	257.22	122994.8
9	257.54	155711.3
10	257.86	193357.5
11	258.18	236121.2
12	258.50	284358.0

Log Elev- Ho	Log Vol.
-0.824	2.757
-0.330	3.835
-0.105	4.243
0.043	4.498
0.153	4.689
0.240	4.844
0.313	4.975
0.376	5.090
0.430	5.192
0.479	5.286
0.522	5.373
0.562	5.454

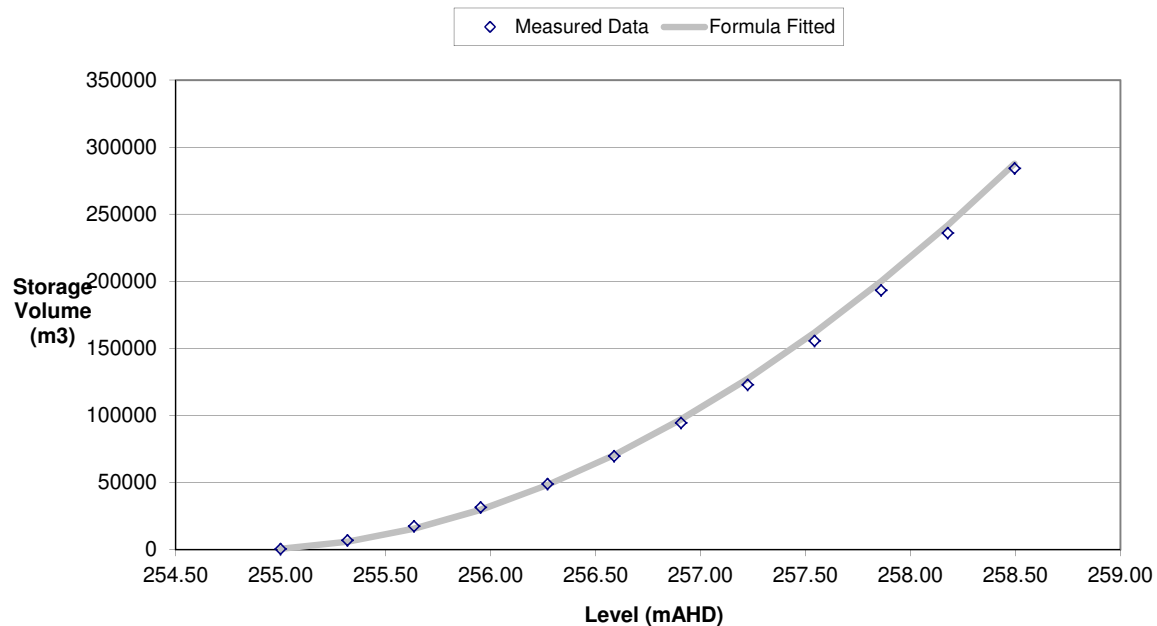
Formula Vol (m3)	Error (m3)	Error (%)
674	102	17.8%
5836	-997	14.6%
15615	-1880	10.7%
29757	-1754	5.6%
48112	-797	1.6%
70572	737	1.1%
97051	2545	2.7%
127483	4488	3.6%
161809	6097	3.9%
199979	6622	3.4%
241951	5830	2.5%
287686	3328	1.2%

### Volume formula

intercept	24688.335
slope	1.898

Max Error	17.8%
Mean Error	5.7%

### Storage vs Elevation Plot





## Subsidence Pond Level-Storage Data and Curve Fitting

**N08-2**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	255.500	adjust Ho for best fit
<b>A=</b>	4967	
<b>B=</b>	2.448	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9999
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	256.00	819.8
2	256.37	3738.4
3	256.73	8817.5
4	257.10	16401.2
5	257.47	26560.0
6	257.83	39680.8
7	258.20	56025.8
8	258.57	75662.7
9	258.93	98860.0
10	259.30	127070.6
11	259.67	161431.5
12	260.03	200556.6

Log Elev- Ho	Log Vol.
-0.301	2.914
-0.062	3.573
0.091	3.945
0.204	4.215
0.294	4.424
0.368	4.599
0.431	4.748
0.487	4.879
0.536	4.995
0.580	5.104
0.620	5.208
0.656	5.302

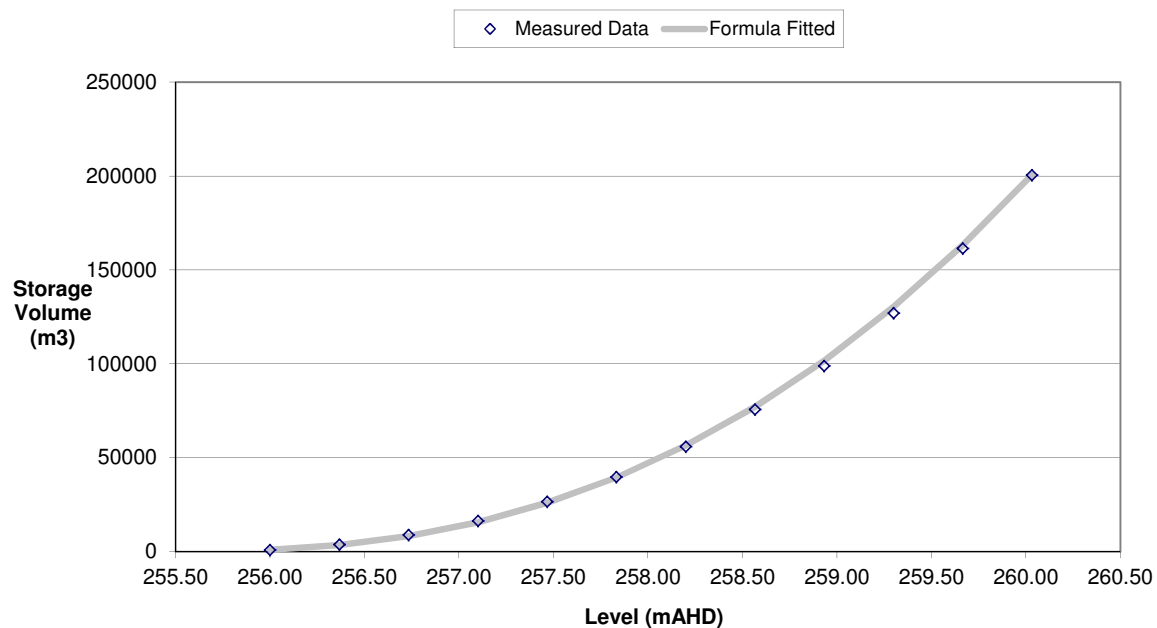
Formula Vol (m3)	Error (m3)	Error (%)
911	91	11.1%
3499	-240	6.4%
8297	-521	5.9%
15688	-713	4.3%
25996	-564	2.1%
39503	-178	0.4%
56465	439	0.8%
77115	1452	1.9%
101670	2810	2.8%
130333	3263	2.6%
163296	1864	1.2%
200738	182	0.1%

### Volume formula

intercept	4967.431
slope	2.448

Max Error	11.1%
Mean Error	3.3%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N08-3**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	260.950	adjust Ho for best fit
<b>A=</b>	28772	
<b>B=</b>	2.606	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9998
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	261.10	228.7
2	261.14	348.1
3	261.17	527.8
4	261.21	792.1
5	261.24	1130.6
6	261.28	1561.2
7	261.31	2096.3
8	261.35	2702.8
9	261.39	3387.6
10	261.42	4124.7
11	261.46	4950.3
12	261.49	5850.1

Log Elev- Ho	Log Vol.
-0.824	2.359
-0.731	2.542
-0.655	2.722
-0.590	2.899
-0.533	3.053
-0.484	3.193
-0.439	3.321
-0.398	3.432
-0.361	3.530
-0.327	3.615
-0.295	3.695
-0.266	3.767

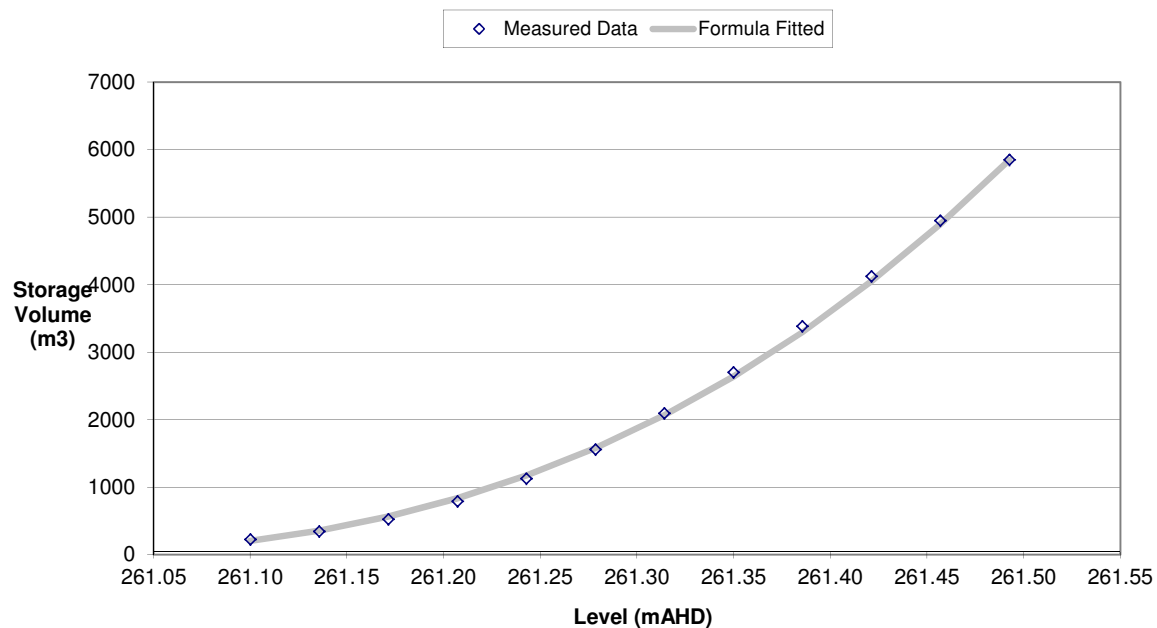
Formula Vol (m3)	Error (m3)	Error (%)
205	-23	10.3%
358	10	2.8%
566	38	7.2%
835	43	5.5%
1172	41	3.7%
1582	20	1.3%
2069	-27	1.3%
2640	-62	2.3%
3299	-88	2.6%
4051	-74	1.8%
4899	-51	1.0%
5850	0	0.0%

### Volume formula

intercept	28771.840
slope	2.606

Max Error	10.3%
Mean Error	3.3%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N09-1**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	254.650	adjust Ho for best fit
<b>A=</b>	28896	
<b>B=</b>	1.892	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9996
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	255.00	4579.5
2	255.36	13051.6
3	255.73	30582.0
4	256.09	56196.0
5	256.45	88700.4
6	256.82	127976.9
7	257.18	172917.7
8	257.54	222791.4
9	257.91	276439.1
10	258.27	333978.9
11	258.63	394803.4
12	259.00	458934.7

Log Elev- Ho	Log Vol.
-0.456	3.661
-0.147	4.116
0.032	4.485
0.158	4.750
0.256	4.948
0.336	5.107
0.403	5.238
0.461	5.348
0.513	5.442
0.559	5.524
0.600	5.596
0.638	5.662

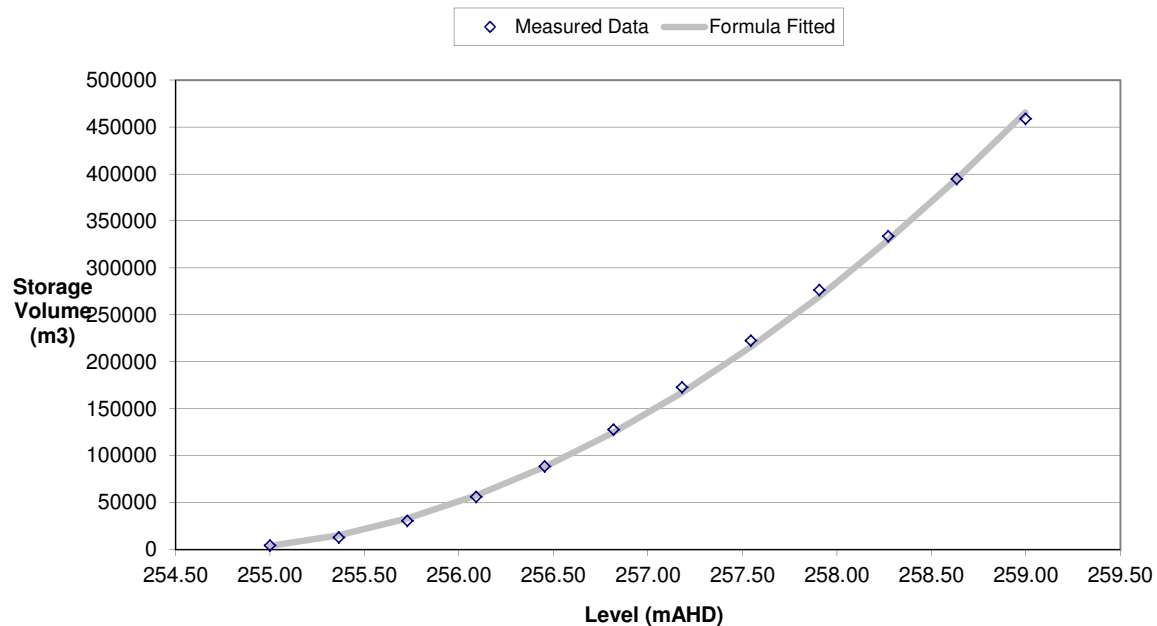
Formula Vol (m3)	Error (m3)	Error (%)
3967	-613	13.4%
15255	2203	16.9%
33237	2655	8.7%
57611	1415	2.5%
88175	-525	0.6%
124779	-3198	2.5%
167302	-5616	3.2%
215645	-7146	3.2%
269725	-6714	2.4%
329467	-4512	1.4%
394808	5	0.0%
465689	6754	1.5%

### Volume formula

intercept	28896.196
slope	1.892

Max Error	16.9%
Mean Error	4.7%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N09-2**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	259.000	adjust Ho for best fit
<b>A=</b>	46341	
<b>B=</b>	2.022	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9996
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	259.10	555.6
2	259.21	1530.3
3	259.31	3772.3
4	259.42	7467.8
5	259.52	12450.9
6	259.63	18517.7
7	259.73	25644.9
8	259.84	33786.8
9	259.95	42986.5
10	260.05	53139.0
11	260.16	63501.1
12	260.26	73931.1

Log Elev- Ho	Log Vol.
-1.000	2.745
-0.687	3.185
-0.507	3.577
-0.380	3.873
-0.282	4.095
-0.202	4.268
-0.134	4.409
-0.076	4.529
-0.024	4.633
0.022	4.725
0.063	4.803
0.101	4.869

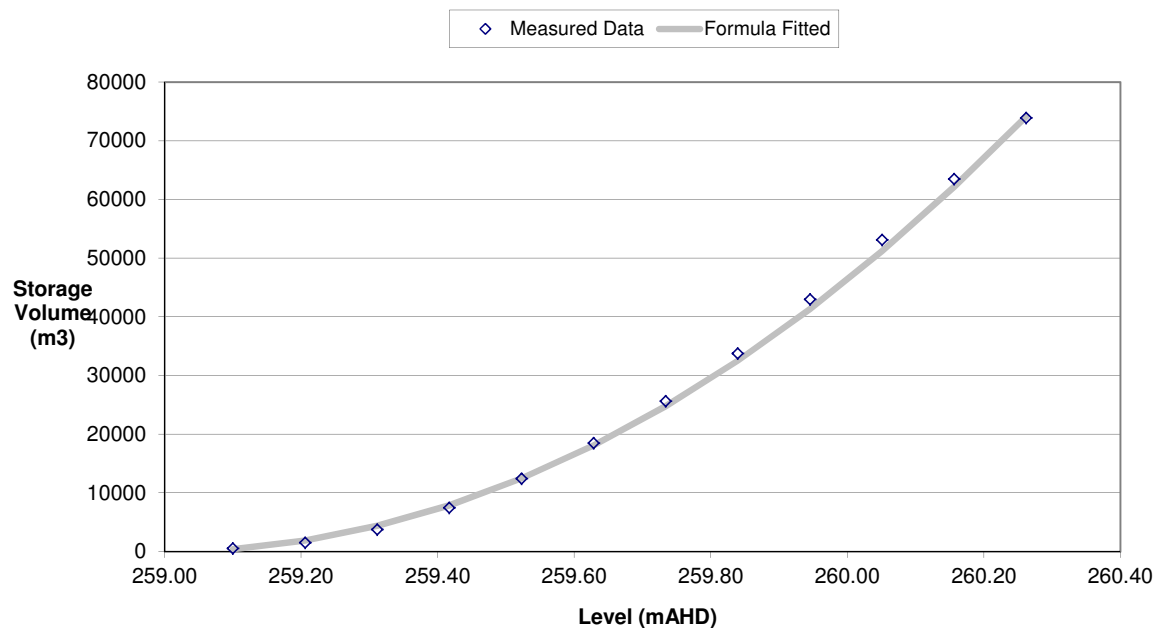
Formula Vol (m3)	Error (m3)	Error (%)
440	-115	20.7%
1893	362	23.7%
4377	604	16.0%
7902	434	5.8%
12476	25	0.2%
18103	-415	2.2%
24788	-857	3.3%
32535	-1252	3.7%
41346	-1640	3.8%
51225	-1914	3.6%
62174	-1327	2.1%
74195	264	0.4%

Volume formula

intercept	46340.731
slope	2.022

Max Error	23.7%
Mean Error	7.1%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N09-3**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	260.100	adjust Ho for best fit
<b>A=</b>	2664	
<b>B=</b>	2.751	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9994
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	260.70	571.7
2	260.82	1096.4
3	260.94	1744.4
4	261.05	2504.2
5	261.17	3395.4
6	261.29	4433.5
7	261.41	5615.4
8	261.53	6966.8
9	261.64	8502.1
10	261.76	10338.6
11	261.88	12693.0
12	262.00	15536.7

Log Elev- Ho	Log Vol.
-0.222	2.757
-0.144	3.040
-0.078	3.242
-0.020	3.399
0.030	3.531
0.076	3.647
0.117	3.749
0.154	3.843
0.189	3.930
0.221	4.014
0.250	4.104
0.278	4.191

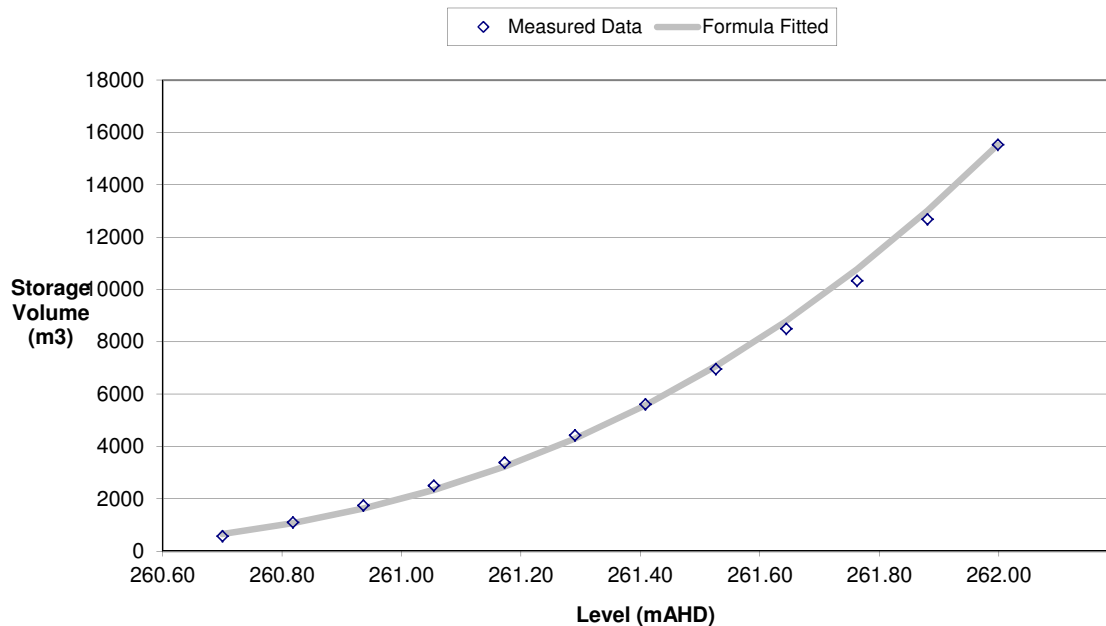
Formula Vol (m3)	Error (m3)	Error (%)
653	82	14.3%
1071	-26	2.3%
1628	-117	6.7%
2340	-164	6.5%
3226	-170	5.0%
4299	-134	3.0%
5576	-39	0.7%
7072	105	1.5%
8801	299	3.5%
10778	439	4.2%
13016	323	2.5%
15529	-7	0.0%

### Volume formula

intercept	2663.745
slope	2.751

Max Error	14.3%
Mean Error	4.2%

### Storage vs Elevation Plot





## Subsidence Pond Level-Storage Data and Curve Fitting

**N10-1**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	255.850	adjust Ho for best fit
<b>A=</b>	22680	
<b>B=</b>	1.990	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9996
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	256.00	646.1
2	256.36	4455.7
3	256.73	15533.8
4	257.09	34304.6
5	257.45	59470.7
6	257.82	90658.7
7	258.18	127561.0
8	258.55	170095.9
9	258.91	217733.9
10	259.27	269522.0
11	259.64	324601.9
12	260.00	382873.8

Log Elev-Ho	Log Vol.
-0.824	2.810
-0.289	3.649
-0.057	4.191
0.094	4.535
0.205	4.774
0.294	4.957
0.368	5.106
0.431	5.231
0.486	5.338
0.534	5.431
0.578	5.511
0.618	5.583

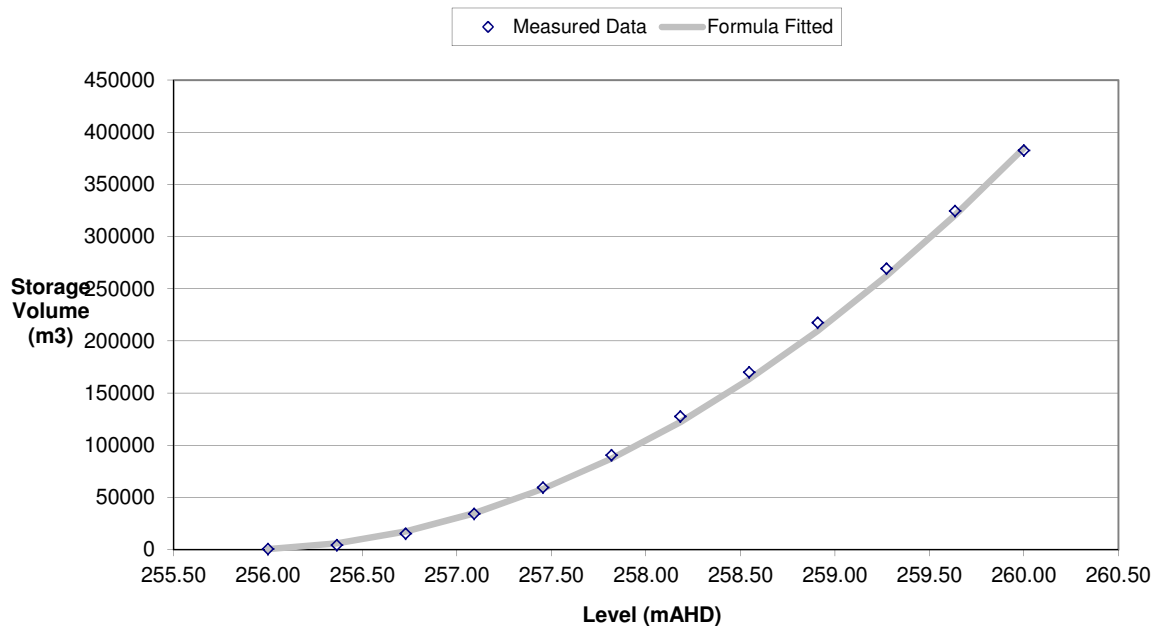
Formula Vol (m3)	Error (m3)	Error (%)
520	-126	19.5%
6023	1567	35.2%
17473	1939	12.5%
34838	534	1.6%
58096	-1375	2.3%
87231	-3427	3.8%
122232	-5329	4.2%
163088	-7008	4.1%
209790	-7944	3.6%
262331	-7191	2.7%
320705	-3897	1.2%
384905	2032	0.5%

Volume formula

intercept	22679.754
slope	1.990

Max Error	35.2%
Mean Error	7.6%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N10-2**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	261.100	adjust Ho for best fit
<b>A=</b>	29072	
<b>B=</b>	3.024	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9992
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	261.30	281.2
2	261.43	819.2
3	261.56	2433.9
4	261.69	5655.3
5	261.82	10723.9
6	261.95	18199.3
7	262.08	28395.5
8	262.21	41419.1
9	262.34	57665.5
10	262.47	77508.0
11	262.60	100146.6
12	262.73	123013.5

Log Elev- Ho	Log Vol.
-0.699	2.449
-0.482	2.913
-0.338	3.386
-0.229	3.752
-0.143	4.030
-0.071	4.260
-0.009	4.453
0.045	4.617
0.093	4.761
0.136	4.889
0.176	5.001
0.212	5.090

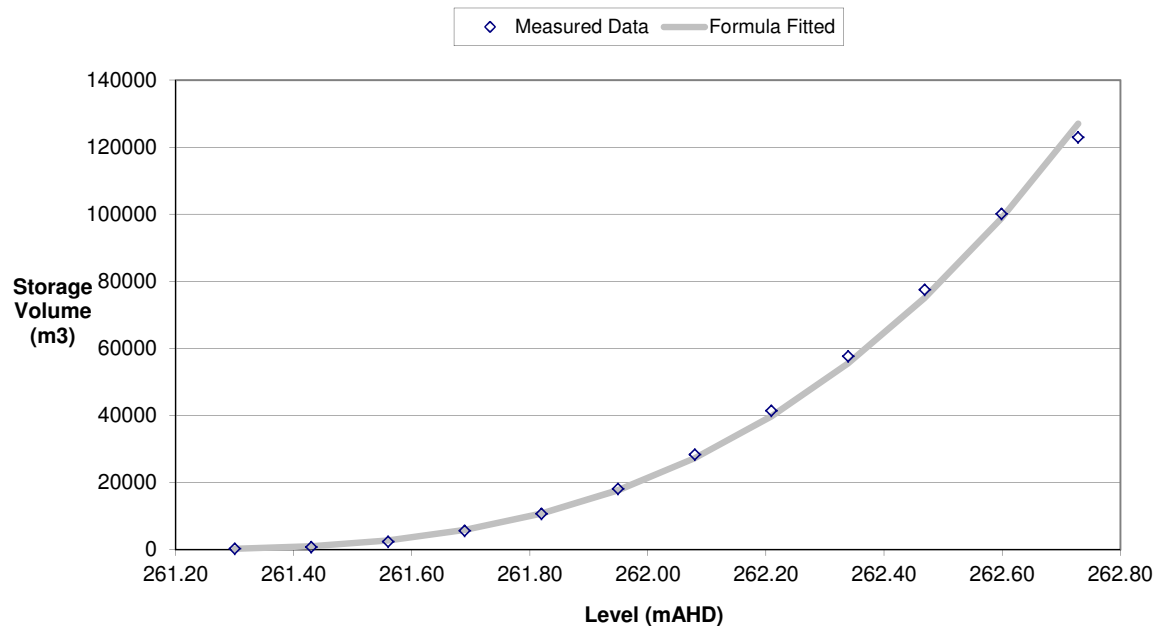
Formula Vol (m3)	Error (m3)	Error (%)
224	-57	20.4%
1016	197	24.0%
2772	338	13.9%
5882	227	4.0%
10739	15	0.1%
17738	-461	2.5%
27275	-1120	3.9%
39749	-1670	4.0%
55559	-2106	3.7%
75105	-2403	3.1%
98789	-1357	1.4%
127014	4001	3.3%

### Volume formula

intercept	29071.995
slope	3.024

Max Error	24.0%
Mean Error	7.0%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N10-3**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	253.650	adjust Ho for best fit
<b>A=</b>	46	
<b>B=</b>	4.254	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9996
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	255.20	329.4
2	255.54	720.7
3	255.88	1300.7
4	256.22	2377.1
5	256.55	4106.7
6	256.89	6678.0
7	257.23	10428.6
8	257.57	15754.0
9	257.91	22790.9
10	258.25	31895.2
11	258.59	42886.7
12	258.92	54636.7

Log Elev- Ho	Log Vol.
0.190	2.518
0.276	2.858
0.348	3.114
0.409	3.376
0.463	3.613
0.511	3.825
0.554	4.018
0.593	4.197
0.629	4.358
0.662	4.504
0.693	4.632
0.722	4.737

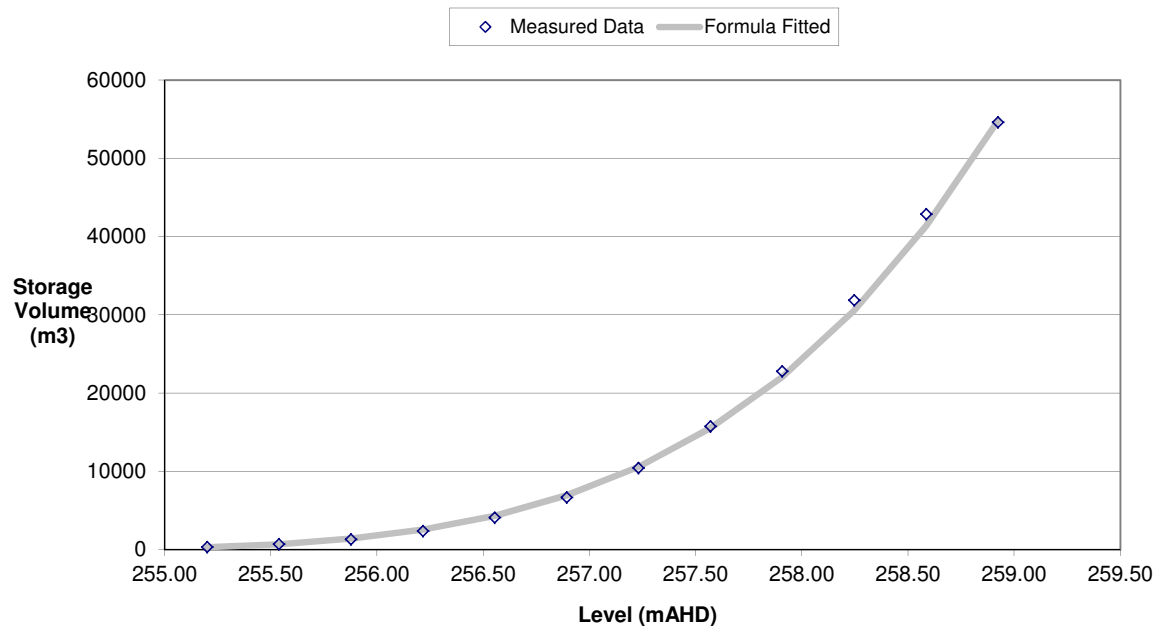
Formula Vol (m3)	Error (m3)	Error (%)
300	-30	9.0%
695	-26	3.6%
1401	100	7.7%
2558	181	7.6%
4334	227	5.5%
6928	250	3.7%
10570	141	1.4%
15522	-232	1.5%
22080	-711	3.1%
30572	-1323	4.1%
41363	-1524	3.6%
54851	214	0.4%

### Volume formula

intercept	46.473
slope	4.254

Max Error	9.0%
Mean Error	4.3%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N11-1**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	258.200	adjust Ho for best fit
<b>A=</b>	52104	
<b>B=</b>	1.690	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9999
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	258.50	7685.9
2	258.79	19876.1
3	259.08	38844.5
4	259.37	63917.7
5	259.66	95722.3
6	259.95	133624.7
7	260.24	175669.2
8	260.53	221469.5
9	260.82	270965.1
10	261.11	323728.2
11	261.40	379180.7
12	261.69	436341.0

Log Elev- Ho	Log Vol.
-0.523	3.886
-0.229	4.298
-0.056	4.589
0.068	4.806
0.164	4.981
0.243	5.126
0.309	5.245
0.367	5.345
0.418	5.433
0.463	5.510
0.505	5.579
0.542	5.640

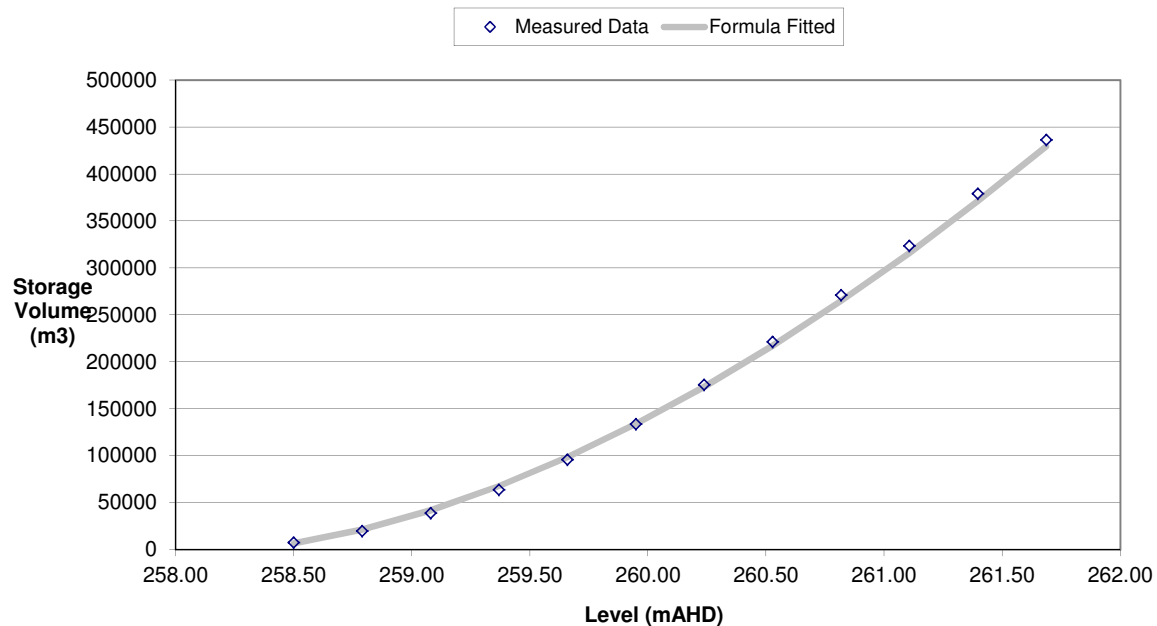
Formula Vol (m3)	Error (m3)	Error (%)
6815	-871	11.3%
21342	1466	7.4%
41920	3075	7.9%
67816	3899	6.1%
98573	2851	3.0%
133865	240	0.2%
173441	-2228	1.3%
217101	-4369	2.0%
264680	-6285	2.3%
316037	-7692	2.4%
371050	-8130	2.1%
429614	-6727	1.5%

### Volume formula

intercept	52103.767
slope	1.690

Max Error	11.3%
Mean Error	4.0%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**N11-2**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	263.500	adjust Ho for best fit
<b>A=</b>	15634	
<b>B=</b>	1.919	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9999
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	263.70	716.4
2	263.95	3421.9
3	264.21	8117.8
4	264.46	14559.3
5	264.72	22651.0
6	264.97	32456.7
7	265.22	43968.1
8	265.48	57279.4
9	265.73	72591.0
10	265.99	89874.9
11	266.24	109141.4
12	266.49	130154.2

Log Elev- Ho	Log Vol.
-0.699	2.855
-0.343	3.534
-0.150	3.909
-0.017	4.163
0.085	4.355
0.167	4.511
0.236	4.643
0.296	4.758
0.349	4.861
0.395	4.954
0.438	5.038
0.476	5.114

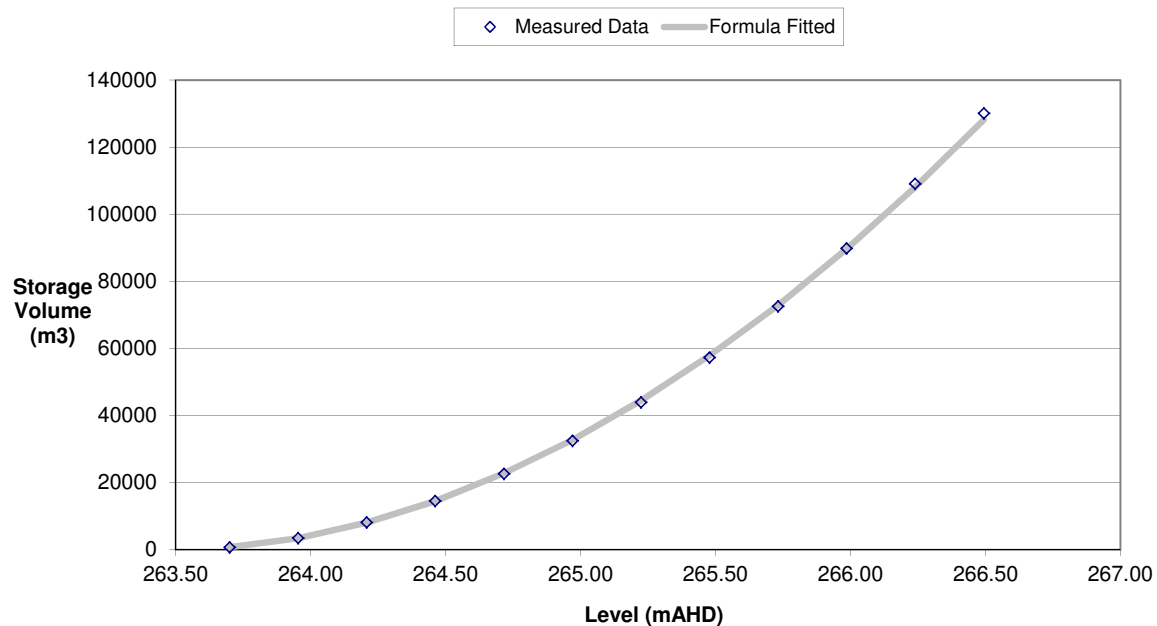
Formula Vol (m3)	Error (m3)	Error (%)
713	-4	0.5%
3436	14	0.4%
8059	-59	0.7%
14511	-48	0.3%
22748	97	0.4%
32735	278	0.9%
44444	476	1.1%
57854	575	1.0%
72946	355	0.5%
89704	-171	0.2%
108112	-1030	0.9%
128157	-1997	1.5%

### Volume formula

intercept	15634.444
slope	1.919

Max Error	1.5%
Mean Error	0.7%

### Storage vs Elevation Plot





## Subsidence Pond Level-Storage Data and Curve Fitting

**S01**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	247.180	adjust Ho for best fit
<b>A=</b>	32050	
<b>B=</b>	2.033	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9999
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	247.30	461.7
2	247.82	11914.1
3	248.34	40454.7
4	248.85	89070.3
5	249.37	157471.9
6	249.89	243445.2
7	250.41	352447.3
8	250.93	480224.6
9	251.45	626820.6
10	251.96	787840.3
11	252.48	964765.1
12	253.00	#####

Log Elev- Ho	Log Vol.
-0.921	2.664
-0.195	4.076
0.063	4.607
0.224	4.950
0.341	5.197
0.433	5.386
0.509	5.547
0.574	5.681
0.630	5.797
0.680	5.896
0.724	5.984
0.765	6.064

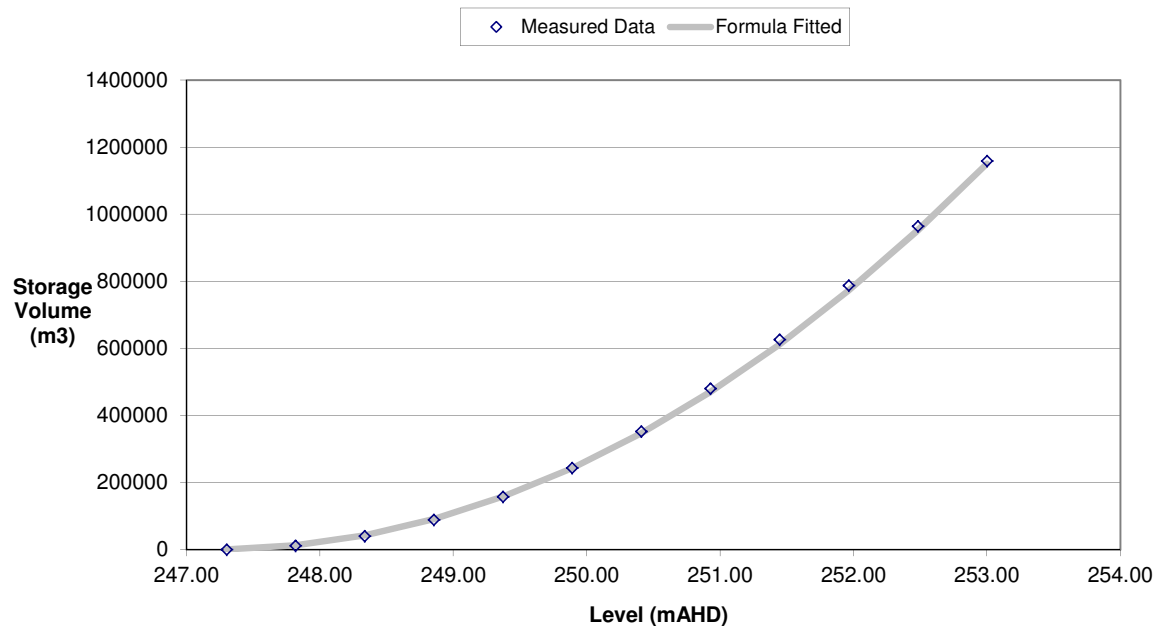
Formula Vol (m3)	Error (m3)	Error (%)
430	-32	6.9%
12857	943	7.9%
43060	2605	6.4%
91422	2352	2.6%
158175	703	0.4%
243487	41	0.0%
347491	-4956	1.4%
470298	-9927	2.1%
612001	-14820	2.4%
772683	-15157	1.9%
952416	-12349	1.3%
1151268	-7897	0.7%

### Volume formula

intercept	32050.337
slope	2.033

Max Error	7.9%
Mean Error	2.8%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S02**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	249.020	adjust Ho for best fit
<b>A=</b>	55314	
<b>B=</b>	1.880	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9996
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	249.10	581.2
2	249.50	10190.8
3	249.90	37552.5
4	250.30	87664.6
5	250.70	154125.9
6	251.10	232872.2
7	251.50	322759.9
8	251.90	423309.8
9	252.30	533977.4
10	252.70	653147.1
11	253.10	782376.7
12	253.50	925204.5

Log Elev- Ho	Log Vol.
-1.097	2.764
-0.319	4.008
-0.056	4.575
0.107	4.943
0.225	5.188
0.318	5.367
0.394	5.509
0.459	5.627
0.516	5.728
0.566	5.815
0.611	5.893
0.651	5.966

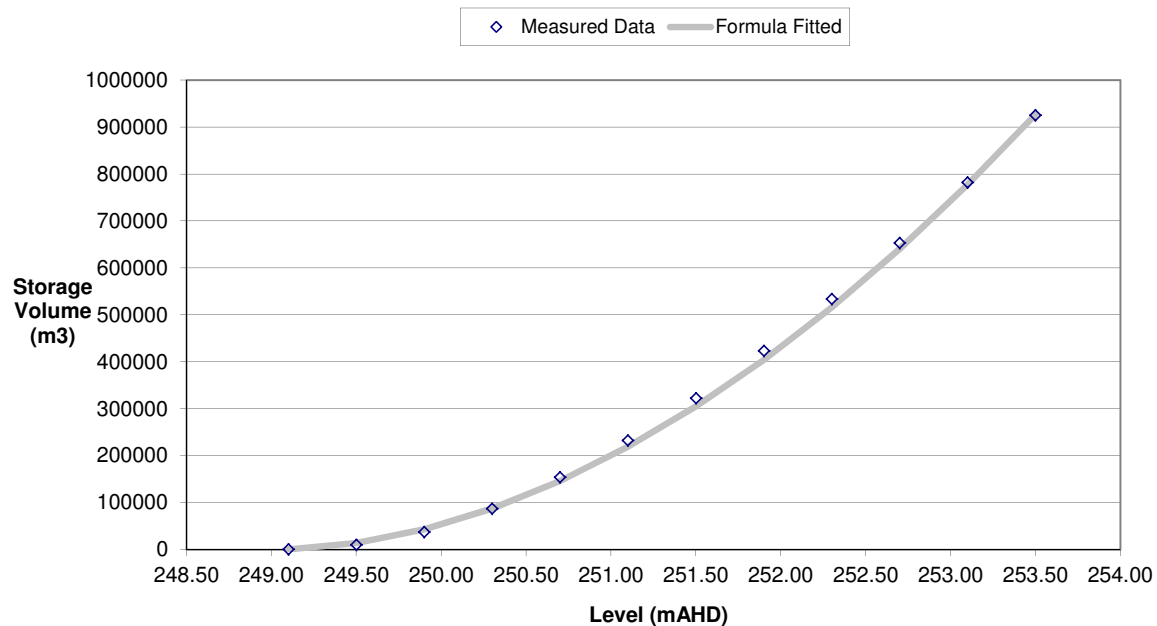
Formula Vol (m3)	Error (m3)	Error (%)
479	-102	17.5%
13917	3726	36.6%
43497	5945	15.8%
87982	318	0.4%
146699	-7427	4.8%
219185	-13688	5.9%
305087	-17673	5.5%
404125	-19185	4.5%
516064	-17914	3.4%
640703	-12444	1.9%
777869	-4508	0.6%
927406	2201	0.2%

### Volume formula

intercept	55314.098
slope	1.880

Max Error	36.6%
Mean Error	8.1%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S03**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	240.650	adjust Ho for best fit
<b>A=</b>	3924	
<b>B=</b>	2.404	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9997
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	241.00	387.4
2	241.55	2374.6
3	242.09	8102.4
4	242.64	19875.2
5	243.18	37549.0
6	243.73	60968.0
7	244.27	90761.9
8	244.82	126886.4
9	245.36	168633.9
10	245.91	216037.5
11	246.45	269649.2
12	247.00	330693.5

Log Elev- Ho	Log Vol.
-0.456	2.588
-0.048	3.376
0.158	3.909
0.298	4.298
0.403	4.575
0.488	4.785
0.559	4.958
0.620	5.103
0.673	5.227
0.721	5.335
0.764	5.431
0.803	5.519

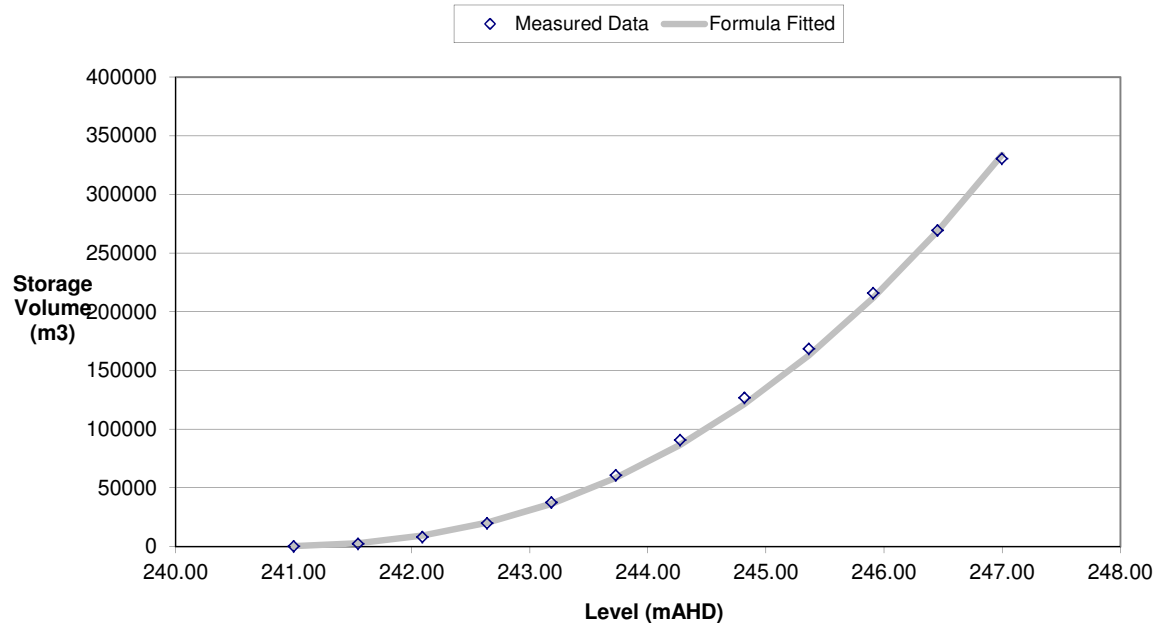
Formula Vol (m3)	Error (m3)	Error (%)
314	-73	18.8%
3006	632	26.6%
9434	1332	16.4%
20413	538	2.7%
36581	-968	2.6%
58476	-2492	4.1%
86571	-4191	4.6%
121290	-5596	4.4%
163020	-5614	3.3%
212120	-3917	1.8%
268923	-726	0.3%
333744	3051	0.9%

### Volume formula

intercept	3923.824
slope	2.404

Max Error	26.6%
Mean Error	7.2%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S04-1**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	242.400	adjust Ho for best fit
<b>A=</b>	2395	
<b>B=</b>	2.701	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	1.0000
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	243.00	668.7
2	243.42	2452.8
3	243.85	5899.6
4	244.27	12325.5
5	244.70	22424.5
6	245.12	35987.2
7	245.54	53693.1
8	245.97	75253.0
9	246.39	102234.6
10	246.81	134467.6
11	247.24	170460.0
12	247.66	215456.9

Log Elev- Ho	Log Vol.
-0.222	2.825
0.010	3.390
0.161	3.771
0.272	4.091
0.361	4.351
0.434	4.556
0.497	4.730
0.552	4.877
0.601	5.010
0.645	5.129
0.685	5.232
0.721	5.333

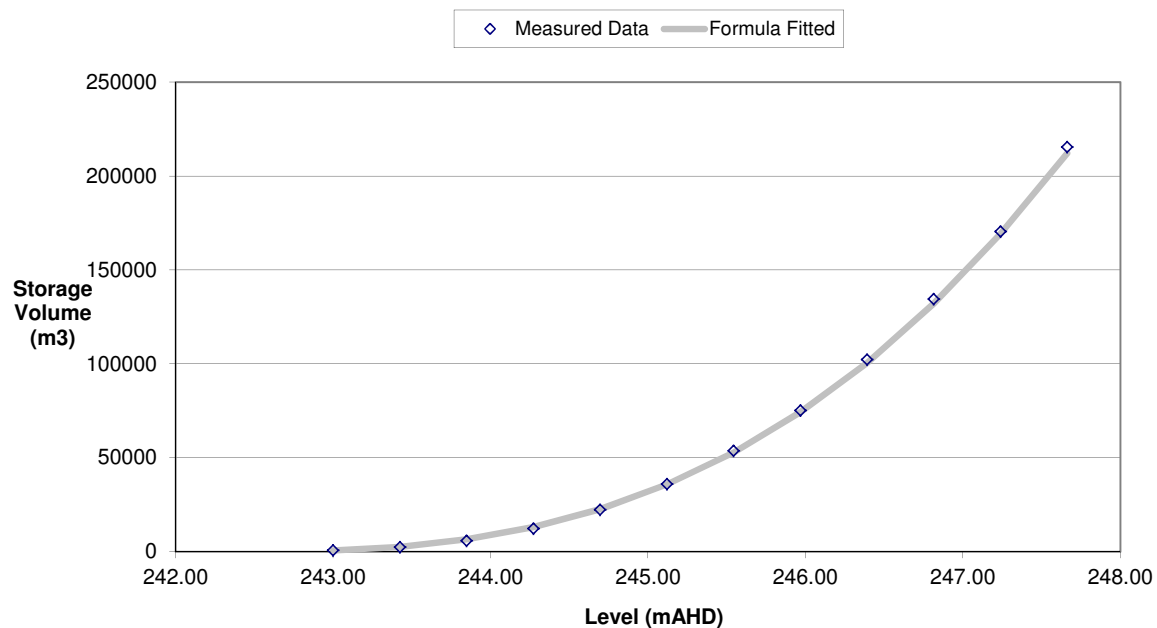
Formula Vol (m3)	Error (m3)	Error (%)
603	-66	9.9%
2552	99	4.1%
6504	605	10.3%
13013	688	5.6%
22585	160	0.7%
35691	-296	0.8%
52778	-916	1.7%
74271	-982	1.3%
100579	-1656	1.6%
132097	-2371	1.8%
169206	-1254	0.7%
212278	-3179	1.5%

### Volume formula

intercept	2394.808
slope	2.701

Max Error	10.3%
Mean Error	3.3%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting S04-2

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

Ho=	255.300	adjust Ho for best fit
A=	2188	
B=	2.881	
C=	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	1.0000
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	256.00	777.1
2	256.27	1975.6
3	256.54	4114.4
4	256.82	7454.3
5	257.09	11938.5
6	257.36	17791.6
7	257.63	25364.7
8	257.91	34650.5
9	258.18	45846.1
10	258.45	59238.1
11	258.72	75319.4
12	259.00	93758.2

Log Elev-Ho	Log Vol.
-0.155	2.891
-0.012	3.296
0.095	3.614
0.181	3.872
0.253	4.077
0.314	4.250
0.368	4.404
0.416	4.540
0.459	4.661
0.499	4.773
0.535	4.877
0.568	4.972

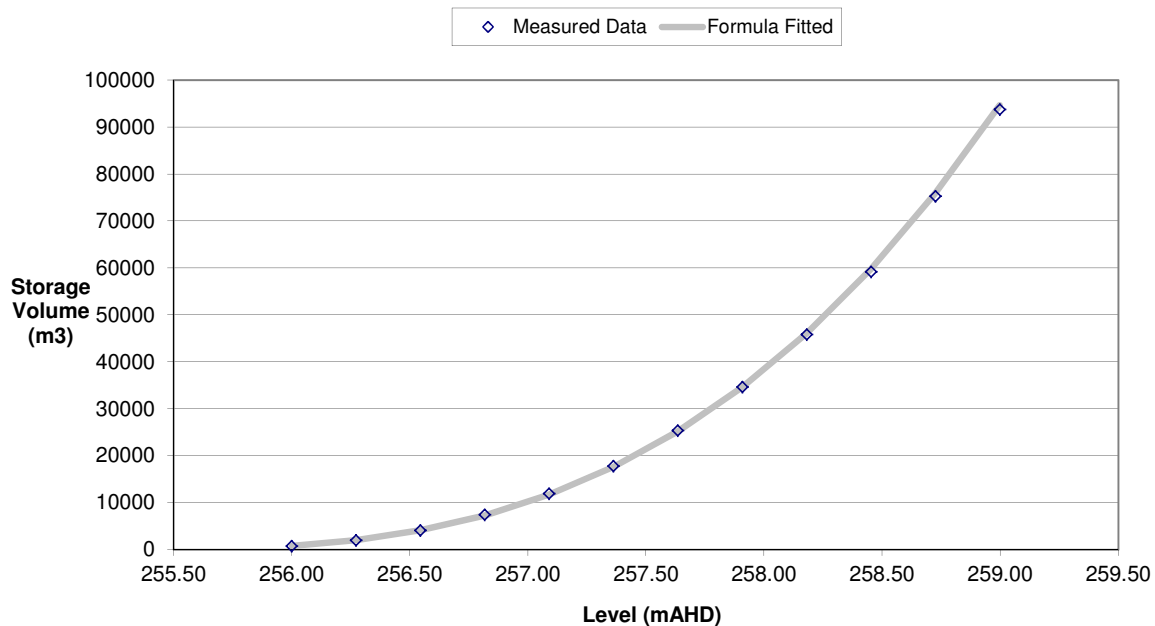
Formula Vol (m3)	Error (m3)	Error (%)
783	6	0.8%
2019	44	2.2%
4114	0	0.0%
7276	-178	2.4%
11710	-229	1.9%
17613	-178	1.0%
25183	-181	0.7%
34612	-39	0.1%
46088	242	0.5%
59801	563	0.9%
75935	615	0.8%
94673	915	1.0%

### Volume formula

intercept	2188.190
slope	2.881

Max Error	2.4%
Mean Error	1.0%

### Storage vs Elevation Plot





## Subsidence Pond Level-Storage Data and Curve Fitting

**S05-1**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	243.100	adjust Ho for best fit
<b>A=</b>	31	
<b>B=</b>	5.010	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9999
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	244.70	373.7
2	245.05	782.7
3	245.39	1724.0
4	245.74	3955.1
5	246.08	7790.9
6	246.43	13815.3
7	246.77	22213.2
8	247.12	33689.1
9	247.46	49813.0
10	247.81	71755.0
11	248.15	101307.8
12	248.50	143161.4

Log Elev- Ho	Log Vol.
0.204	2.573
0.289	2.894
0.360	3.237
0.421	3.597
0.474	3.892
0.522	4.140
0.565	4.347
0.604	4.527
0.639	4.697
0.673	4.856
0.703	5.006
0.732	5.156

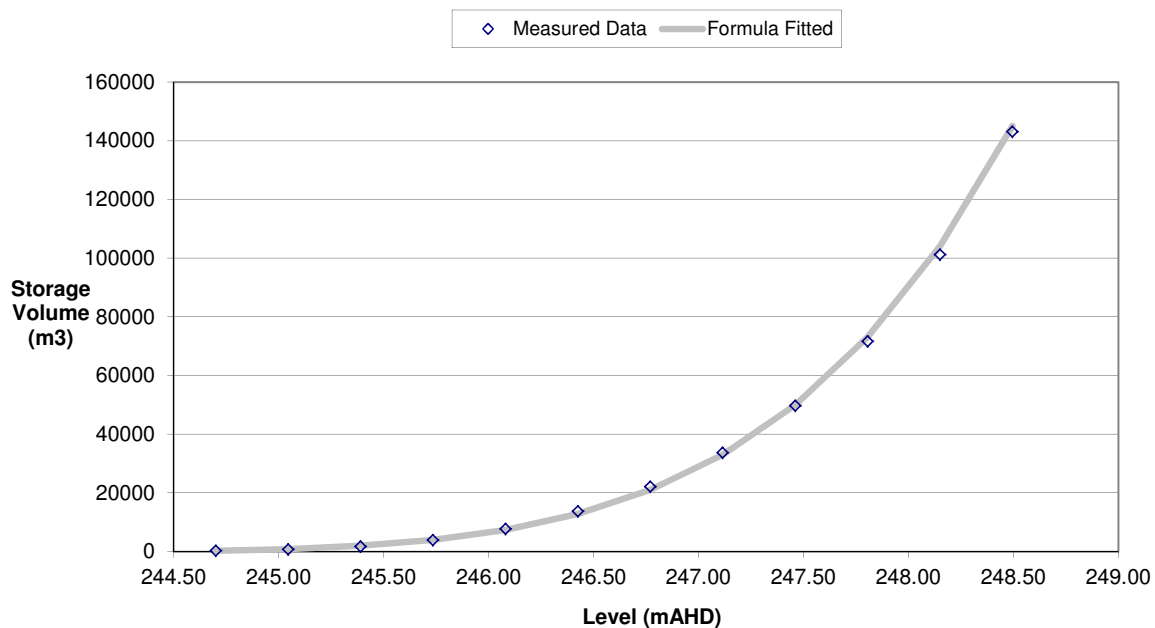
Formula Vol (m3)	Error (m3)	Error (%)
329	-45	12.0%
875	92	11.8%
1982	258	15.0%
4004	49	1.2%
7416	-375	4.8%
12838	-977	7.1%
21052	-1161	5.2%
33019	-670	2.0%
49901	88	0.2%
73079	1324	1.8%
104172	2864	2.8%
145053	1891	1.3%

### Volume formula

intercept	31.227
slope	5.010

Max Error	15.0%
Mean Error	5.4%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S05-2**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	240.500	adjust Ho for best fit
<b>A=</b>	293	
<b>B=</b>	3.033	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9999
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	241.50	263.2
2	242.00	1162.8
3	242.50	2622.4
4	243.00	4633.5
5	243.49	7563.8
6	243.99	12253.1
7	244.49	18810.6
8	244.99	27803.7
9	245.49	38911.9
10	245.99	52249.8
11	246.49	68160.5
12	246.98	86127.3

Log Elev- Ho	Log Vol.
0.000	2.420
0.176	3.065
0.300	3.419
0.397	3.666
0.476	3.879
0.543	4.088
0.601	4.274
0.652	4.444
0.698	4.590
0.739	4.718
0.777	4.834
0.812	4.935

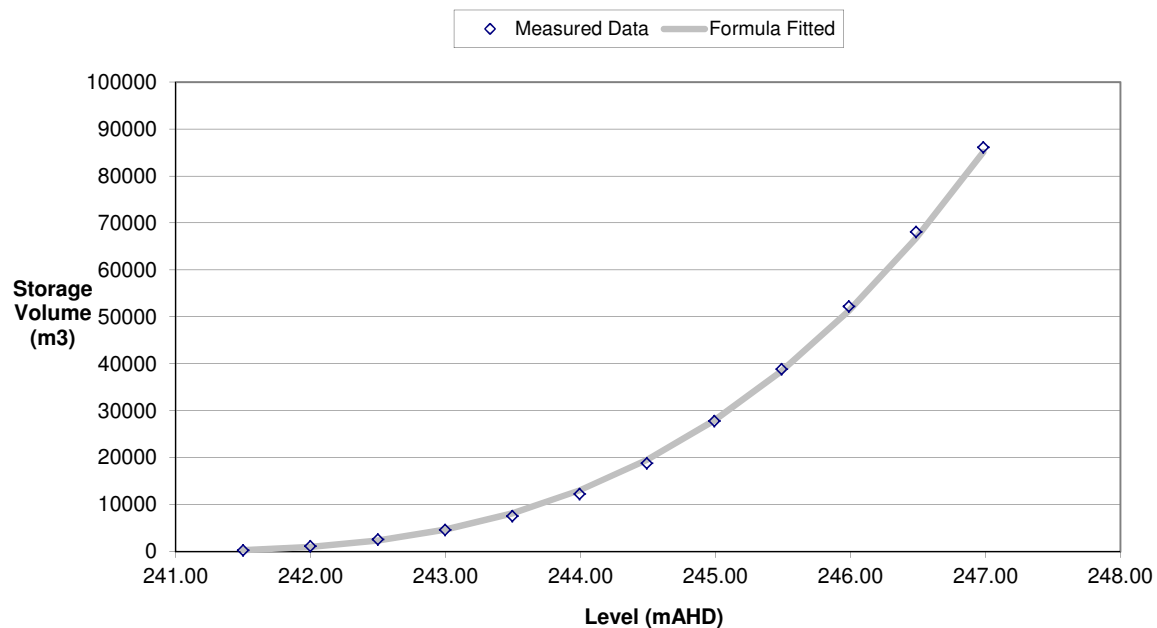
Formula Vol (m3)	Error (m3)	Error (%)
293	30	11.5%
1001	-162	13.9%
2392	-230	8.8%
4703	69	1.5%
8170	607	8.0%
13035	782	6.4%
19538	727	3.9%
27920	117	0.4%
38425	-486	1.3%
51297	-952	1.8%
66781	-1380	2.0%
85121	-1006	1.2%

### Volume formula

intercept	293.474
slope	3.033

Max Error	13.9%
Mean Error	5.1%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S06-1**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	251.500	adjust Ho for best fit
<b>A=</b>	5328	
<b>B=</b>	2.374	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9999
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	251.80	310.8
2	251.95	764.2
3	252.11	1620.6
4	252.26	2935.8
5	252.42	4549.2
6	252.57	6455.8
7	252.73	8722.8
8	252.88	11401.8
9	253.04	14545.2
10	253.19	18204.1
11	253.35	22592.7
12	253.50	27482.3

Log Elev- Ho	Log Vol.
-0.523	2.493
-0.342	2.883
-0.215	3.210
-0.117	3.468
-0.037	3.658
0.030	3.810
0.089	3.941
0.140	4.057
0.186	4.163
0.228	4.260
0.266	4.354
0.301	4.439

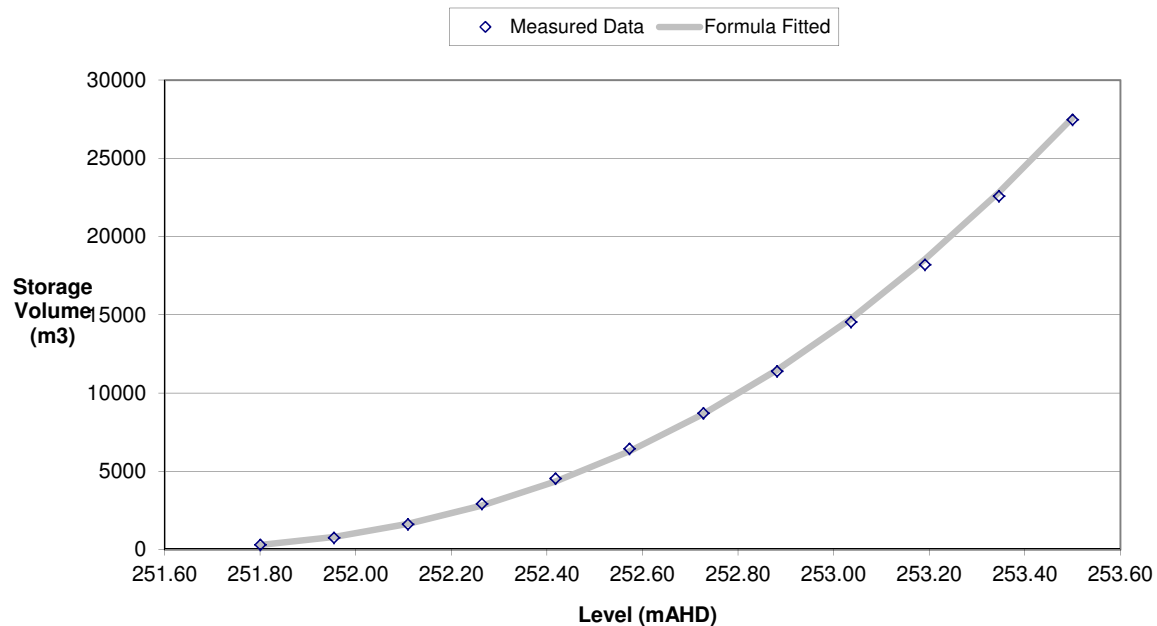
Formula Vol (m3)	Error (m3)	Error (%)
306	-5	1.7%
819	55	7.2%
1642	21	1.3%
2808	-127	4.3%
4350	-199	4.4%
6294	-162	2.5%
8664	-59	0.7%
11482	80	0.7%
14768	223	1.5%
18542	338	1.9%
22821	229	1.0%
27623	140	0.5%

### Volume formula

intercept	5327.579
slope	2.374

Max Error	7.2%
Mean Error	2.3%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S06-2**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	245.500	adjust Ho for best fit
<b>A=</b>	1288	
<b>B=</b>	3.569	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9998
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	246.30	537.6
2	246.64	2302.1
3	246.97	5479.7
4	247.31	10607.7
5	247.64	18635.2
6	247.98	30517.9
7	248.32	48784.1
8	248.65	76612.3
9	248.99	114263.0
10	249.33	159493.7
11	249.66	214882.2
12	250.00	281778.8

Log Elev- Ho	Log Vol.
-0.097	2.730
0.055	3.362
0.168	3.739
0.257	4.026
0.331	4.270
0.395	4.485
0.450	4.688
0.499	4.884
0.543	5.058
0.583	5.203
0.619	5.332
0.653	5.450

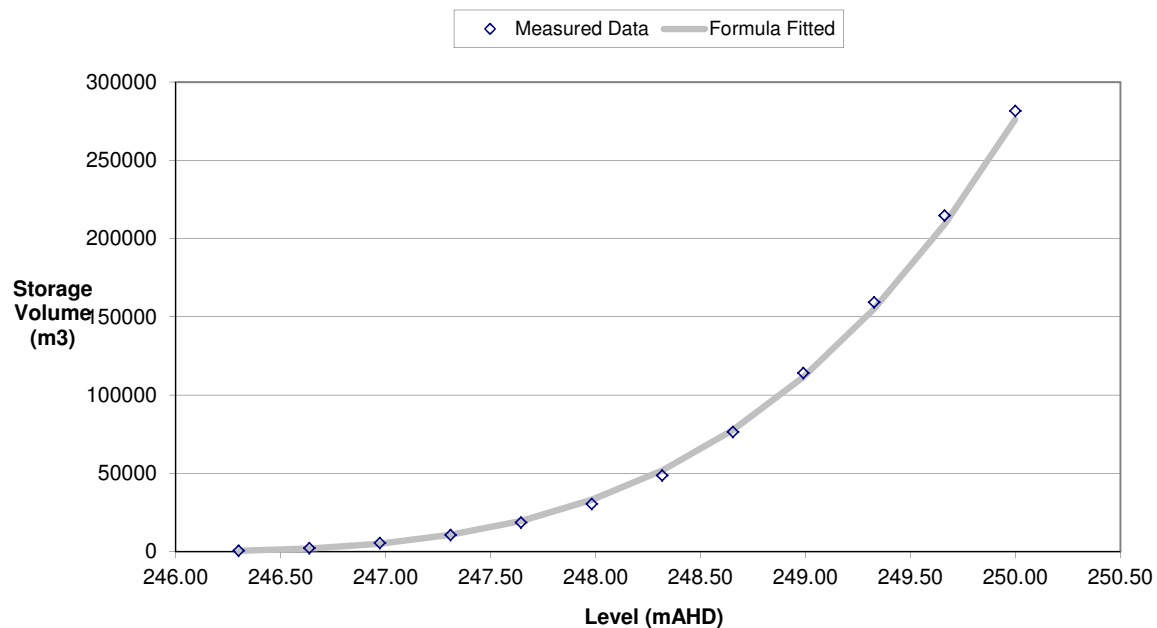
Formula Vol (m3)	Error (m3)	Error (%)
581	43	8.0%
2032	-270	11.7%
5126	-354	6.5%
10681	73	0.7%
19630	994	5.3%
33011	2493	8.2%
51959	3175	6.5%
77703	1090	1.4%
111554	-2709	2.4%
154909	-4585	2.9%
209243	-5639	2.6%
276106	-5673	2.0%

### Volume formula

intercept	1287.972
slope	3.569

Max Error	11.7%
Mean Error	4.9%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S06-3**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	241.700	adjust Ho for best fit
<b>A=</b>	413	
<b>B=</b>	2.928	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9999
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	242.80	499.5
2	243.23	1484.9
3	243.65	3119.2
4	244.08	5433.6
5	244.51	8637.2
6	244.93	12964.1
7	245.36	18255.6
8	245.79	25014.4
9	246.21	33573.5
10	246.64	43790.2
11	247.07	56151.3
12	247.49	70852.7

Log Elev- Ho	Log Vol.
0.041	2.699
0.184	3.172
0.291	3.494
0.377	3.735
0.448	3.936
0.510	4.113
0.564	4.261
0.611	4.398
0.655	4.526
0.694	4.641
0.730	4.749
0.763	4.850

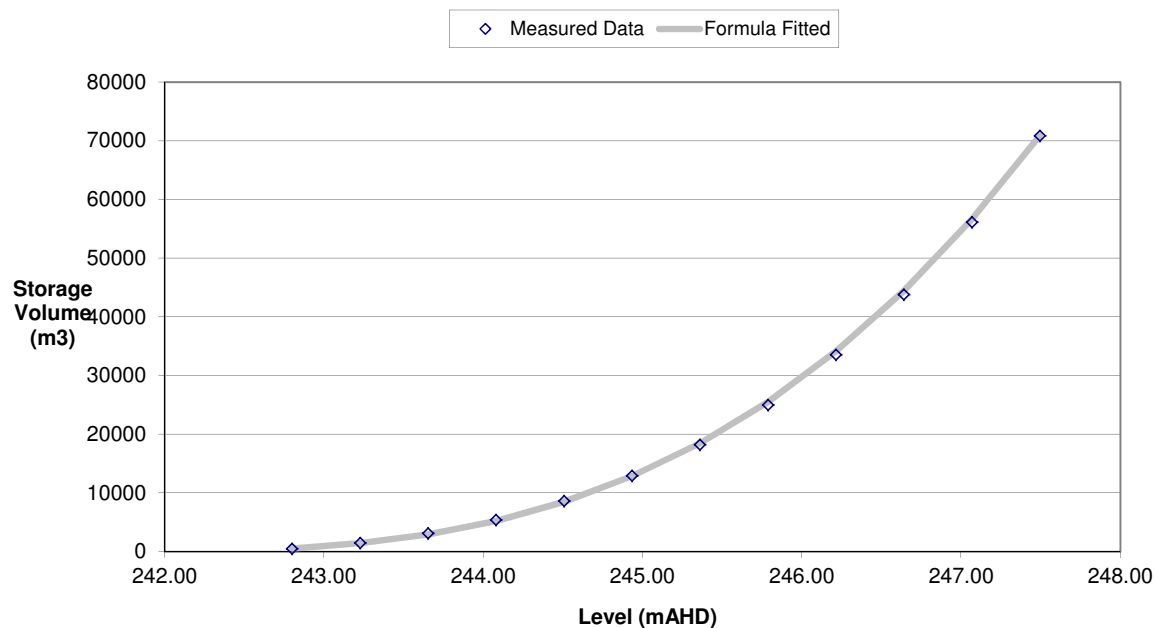
Formula Vol (m3)	Error (m3)	Error (%)
546	47	9.4%
1427	-58	3.9%
2937	-182	5.8%
5238	-195	3.6%
8490	-147	1.7%
12850	-114	0.9%
18473	218	1.2%
25514	500	2.0%
34126	552	1.6%
44460	670	1.5%
56667	515	0.9%
70896	43	0.1%

### Volume formula

intercept	413.321
slope	2.928

Max Error	9.4%
Mean Error	2.7%

### Storage vs Elevation Plot





## Subsidence Pond Level-Storage Data and Curve Fitting

**S06-4**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	243.500	adjust Ho for best fit
<b>A=</b>	350	
<b>B=</b>	3.381	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	1.0000
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	244.50	367.9
2	244.82	865.8
3	245.14	1817.8
4	245.45	3390.7
5	245.77	5564.2
6	246.09	8557.6
7	246.41	12648.1
8	246.73	18451.8
9	247.04	25543.4
10	247.36	34262.1
11	247.68	44785.2
12	248.00	57151.4

Log Elev- Ho	Log Vol.
0.000	2.566
0.120	2.937
0.214	3.260
0.291	3.530
0.356	3.745
0.413	3.932
0.464	4.102
0.509	4.266
0.550	4.407
0.587	4.535
0.621	4.651
0.653	4.757

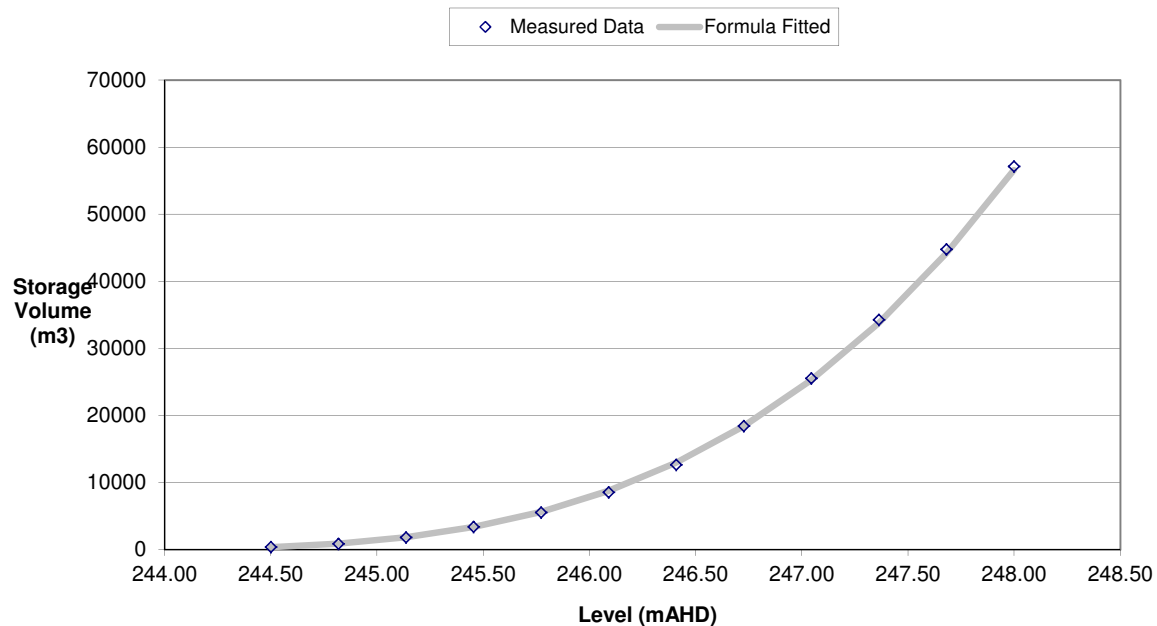
Formula Vol (m3)	Error (m3)	Error (%)
350	-18	4.8%
891	26	3.0%
1851	34	1.8%
3376	-15	0.4%
5621	57	1.0%
8754	196	2.3%
12950	302	2.4%
18395	-57	0.3%
25279	-264	1.0%
33803	-459	1.3%
44173	-612	1.4%
56603	-548	1.0%

### Volume formula

intercept	350.345
slope	3.381

Max Error	4.8%
Mean Error	1.7%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S07-1**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	247.800	adjust Ho for best fit
<b>A=</b>	32132	
<b>B=</b>	2.488	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9997
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	248.20	3606.3
2	248.45	10673.5
3	248.71	23271.9
4	248.96	44620.3
5	249.22	75784.3
6	249.47	118231.8
7	249.73	169049.9
8	249.98	230311.1
9	250.24	301938.1
10	250.49	382482.4
11	250.75	471300.7
12	251.00	571607.0

Log Elev- Ho	Log Vol.
-0.398	3.557
-0.184	4.028
-0.041	4.367
0.066	4.650
0.152	4.880
0.223	5.073
0.285	5.228
0.339	5.362
0.387	5.480
0.430	5.583
0.469	5.673
0.505	5.757

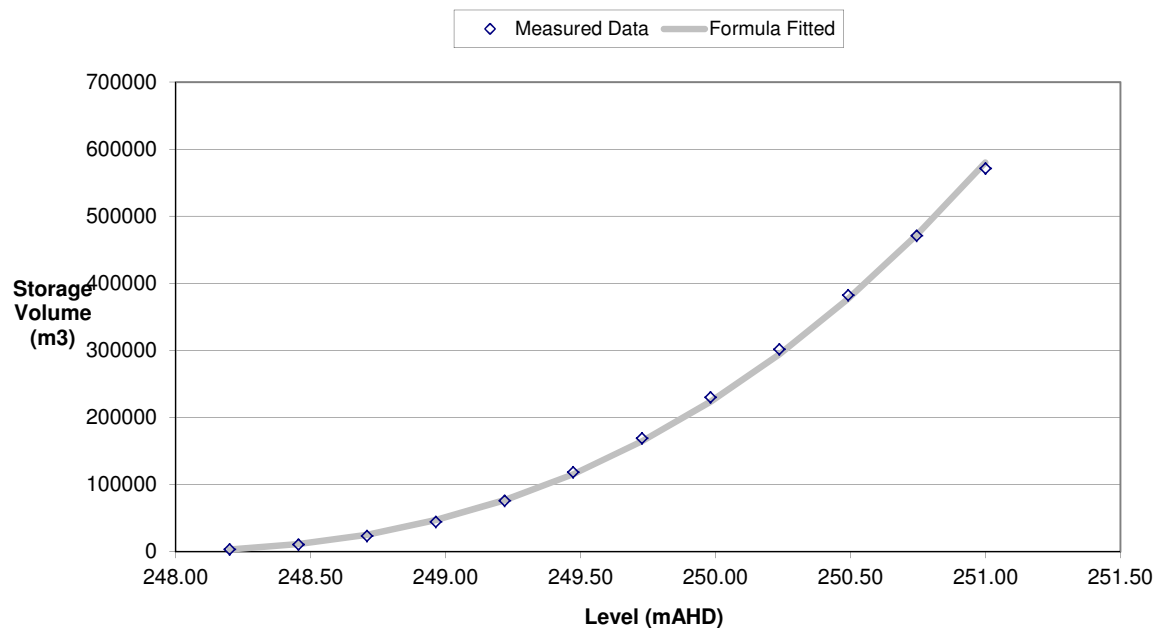
Formula Vol (m3)	Error (m3)	Error (%)
3287	-319	8.8%
11194	520	4.9%
25348	2076	8.9%
46848	2228	5.0%
76640	855	1.1%
115567	-2665	2.3%
164397	-4653	2.8%
223842	-6470	2.8%
294563	-7375	2.4%
377187	-5296	1.4%
472304	1003	0.2%
580479	8872	1.6%

### Volume formula

intercept	32131.611
slope	2.488

Max Error	8.9%
Mean Error	3.5%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S07-2**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	246.600	adjust Ho for best fit
<b>A=</b>	813	
<b>B=</b>	3.165	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	1.0000
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	247.40	346.2
2	247.77	1501.0
3	248.15	3525.4
4	248.52	6638.6
5	248.89	11130.9
6	249.26	17831.4
7	249.64	26988.9
8	250.01	39164.6
9	250.38	54447.2
10	250.75	73003.1
11	251.13	95211.2
12	251.50	122327.5

Log Elev-Ho	Log Vol.
-0.097	2.539
0.069	3.176
0.189	3.547
0.283	3.822
0.360	4.047
0.425	4.251
0.482	4.431
0.533	4.593
0.578	4.736
0.619	4.863
0.656	4.979
0.690	5.088

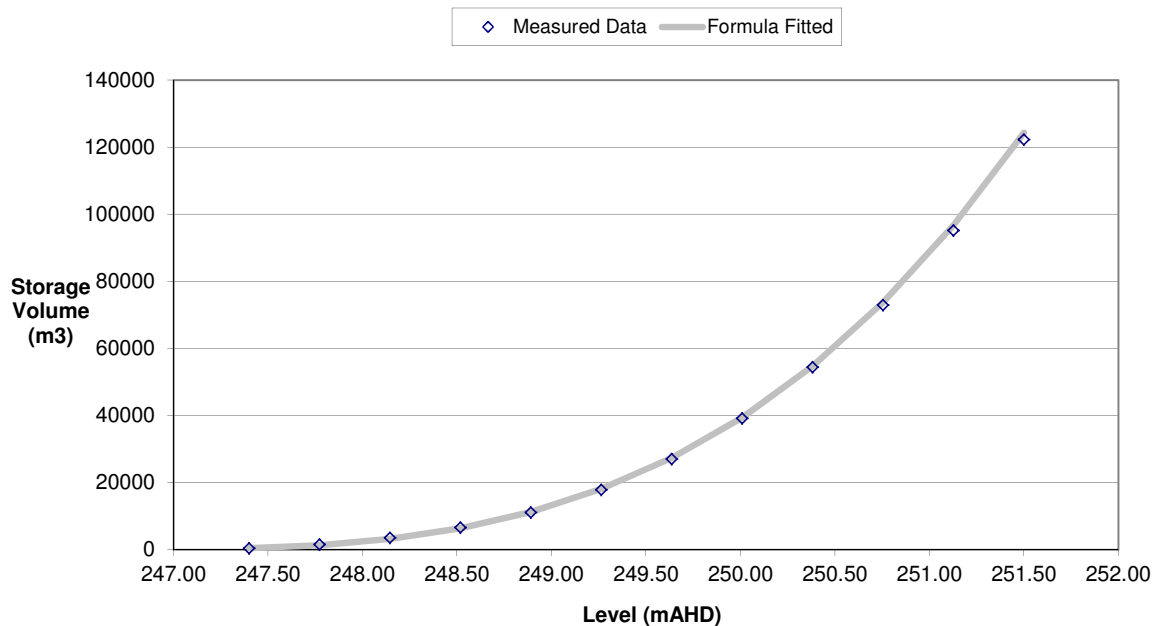
Formula Vol (m3)	Error (m3)	Error (%)
401	55	15.9%
1346	-155	10.3%
3225	-300	8.5%
6390	-249	3.7%
11209	78	0.7%
18062	230	1.3%
27338	349	1.3%
39438	273	0.7%
54768	321	0.6%
73744	741	1.0%
96787	1576	1.7%
124326	1999	1.6%

### Volume formula

intercept	813.180
slope	3.165

Max Error	15.9%
Mean Error	3.9%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S08**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	249.130	adjust Ho for best fit
<b>A=</b>	61686	
<b>B=</b>	2.003	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9998
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	249.20	323.0
2	249.55	9662.6
3	249.89	33996.9
4	250.24	73051.6
5	250.58	128656.3
6	250.93	201560.4
7	251.27	291236.5
8	251.62	394868.8
9	251.96	510111.7
10	252.31	636966.5
11	252.65	774734.3
12	253.00	922362.3

Log Elev-Ho	Log Vol.
-1.155	2.509
-0.381	3.985
-0.119	4.531
0.044	4.864
0.162	5.109
0.255	5.304
0.331	5.464
0.396	5.596
0.452	5.708
0.502	5.804
0.547	5.889
0.588	5.965

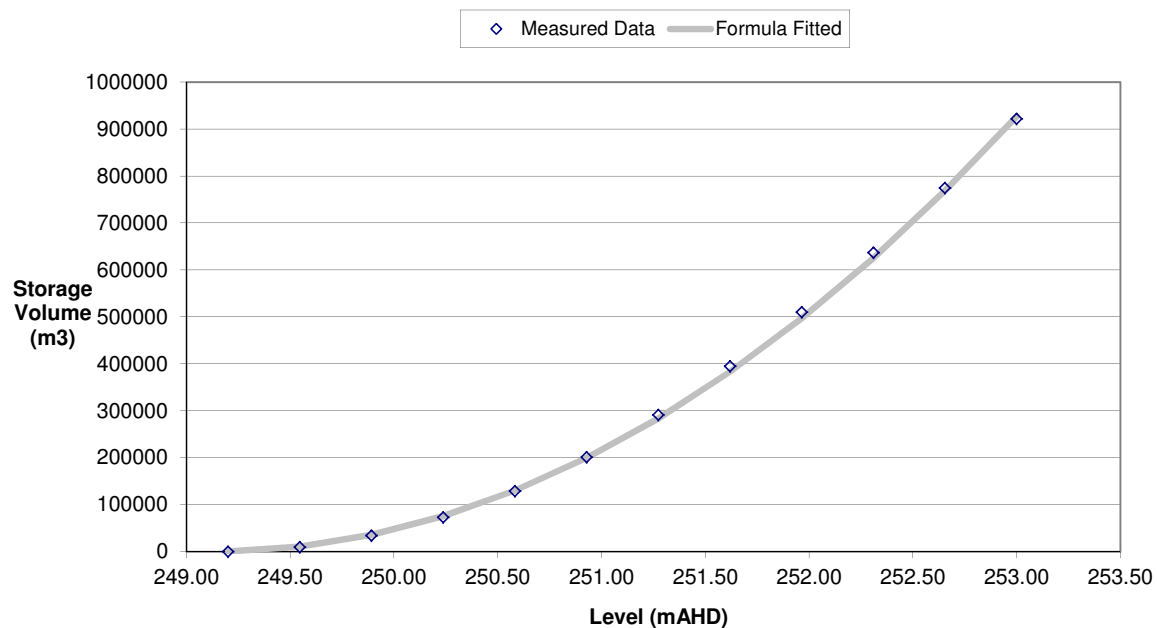
Formula Vol (m3)	Error (m3)	Error (%)
300	-23	7.1%
10623	961	9.9%
35690	1693	5.0%
75526	2475	3.4%
130145	1489	1.2%
199558	-2002	1.0%
283773	-7464	2.6%
382796	-12073	3.1%
496633	-13478	2.6%
625290	-11676	1.8%
768770	-5964	0.8%
927078	4716	0.5%

### Volume formula

intercept	61686.326
slope	2.003

Max Error	9.9%
Mean Error	3.2%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S09-1**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	258.850	adjust Ho for best fit
<b>A=</b>	7268	
<b>B=</b>	2.607	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9999
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	259.20	501.2
2	259.36	1237.8
3	259.53	2478.6
4	259.69	4512.2
5	259.85	7350.0
6	260.02	11046.5
7	260.18	15614.9
8	260.35	21091.9
9	260.51	27477.0
10	260.67	34889.4
11	260.84	43410.8
12	261.00	53306.6

Log Elev- Ho	Log Vol.
-0.456	2.700
-0.289	3.093
-0.169	3.394
-0.075	3.654
0.002	3.866
0.068	4.043
0.124	4.194
0.175	4.324
0.220	4.439
0.261	4.543
0.298	4.638
0.332	4.727

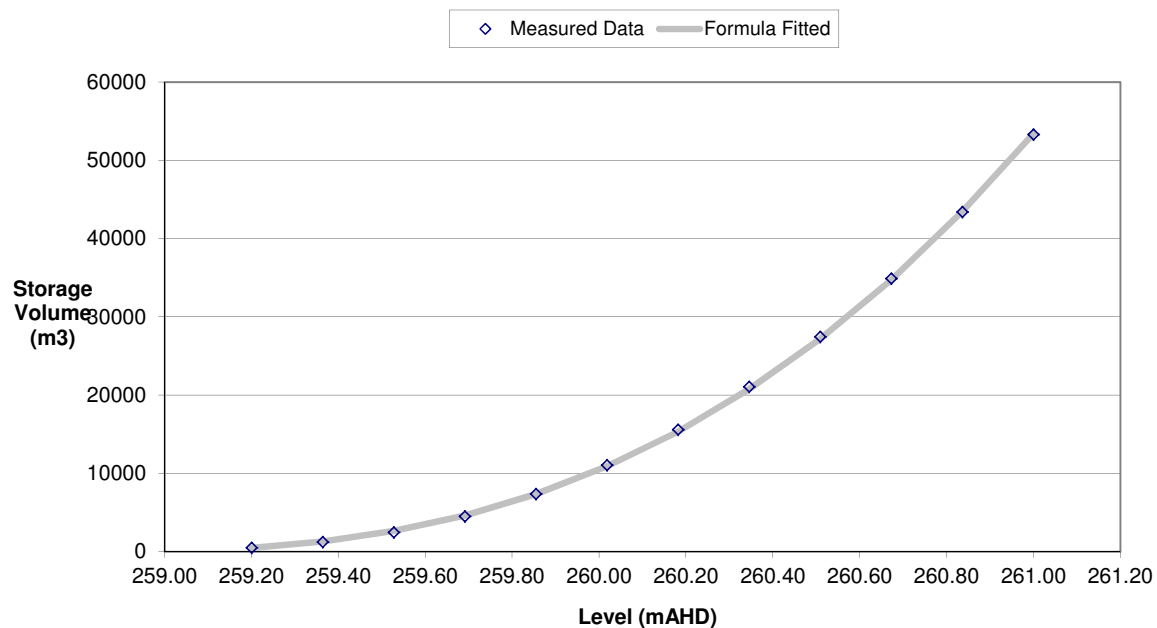
Formula Vol (m3)	Error (m3)	Error (%)
471	-31	6.1%
1279	42	3.4%
2631	152	6.2%
4626	114	2.5%
7354	4	0.1%
10900	-147	1.3%
15342	-273	1.7%
20754	-338	1.6%
27207	-270	1.0%
34770	-120	0.3%
43506	95	0.2%
53480	173	0.3%

### Volume formula

intercept	7267.737
slope	2.607

Max Error	6.2%
Mean Error	2.1%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S09-2**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	253.030	adjust Ho for best fit
<b>A=</b>	13853	
<b>B=</b>	2.389	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9995
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	253.20	225.6
2	253.59	3227.7
3	253.98	11188.9
4	254.37	25450.3
5	254.76	49065.4
6	255.15	85296.4
7	255.55	131819.9
8	255.94	187487.5
9	256.33	251162.0
10	256.72	322789.0
11	257.11	402642.2
12	257.50	491124.1

Log Elev- Ho	Log Vol.
-0.770	2.353
-0.251	3.509
-0.021	4.049
0.128	4.406
0.239	4.691
0.327	4.931
0.401	5.120
0.463	5.273
0.518	5.400
0.567	5.509
0.611	5.605
0.650	5.691

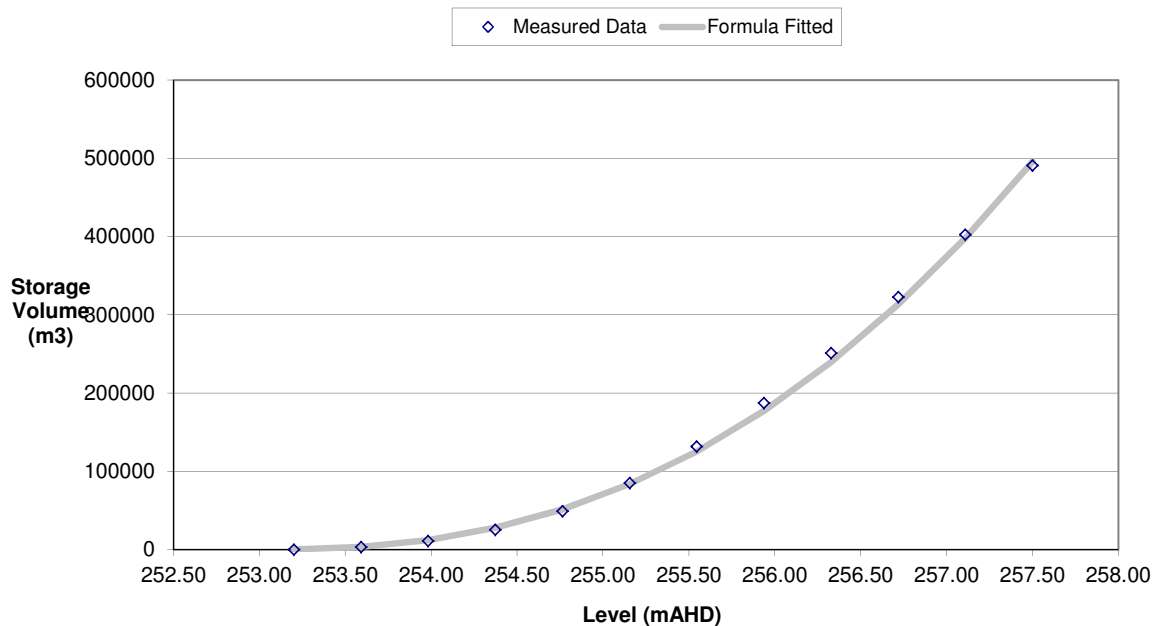
Formula Vol (m3)	Error (m3)	Error (%)
201	-25	11.0%
3480	252	7.8%
12311	1122	10.0%
28012	2561	10.1%
51580	2514	5.1%
83844	-1452	1.7%
125525	-6295	4.8%
177264	-10224	5.5%
239643	-11519	4.6%
313200	-9589	3.0%
398434	-4208	1.0%
495812	4688	1.0%

Volume formula

intercept	13852.816
slope	2.389

Max Error	11.0%
Mean Error	5.5%

### Storage vs Elevation Plot





## Subsidence Pond Level-Storage Data and Curve Fitting

**S09-3**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	256.670	adjust Ho for best fit
<b>A=</b>	9444	
<b>B=</b>	2.065	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9997
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	256.80	158.1
2	256.91	452.8
3	257.02	964.5
4	257.13	1790.0
5	257.24	2898.7
6	257.35	4272.9
7	257.45	5914.5
8	257.56	7732.4
9	257.67	9762.0
10	257.78	11944.6
11	257.89	14304.4
12	258.00	16836.1

Log Elev- Ho	Log Vol.
-0.886	2.199
-0.621	2.656
-0.458	2.984
-0.340	3.253
-0.247	3.462
-0.170	3.631
-0.105	3.772
-0.049	3.888
0.001	3.990
0.046	4.077
0.087	4.155
0.124	4.226

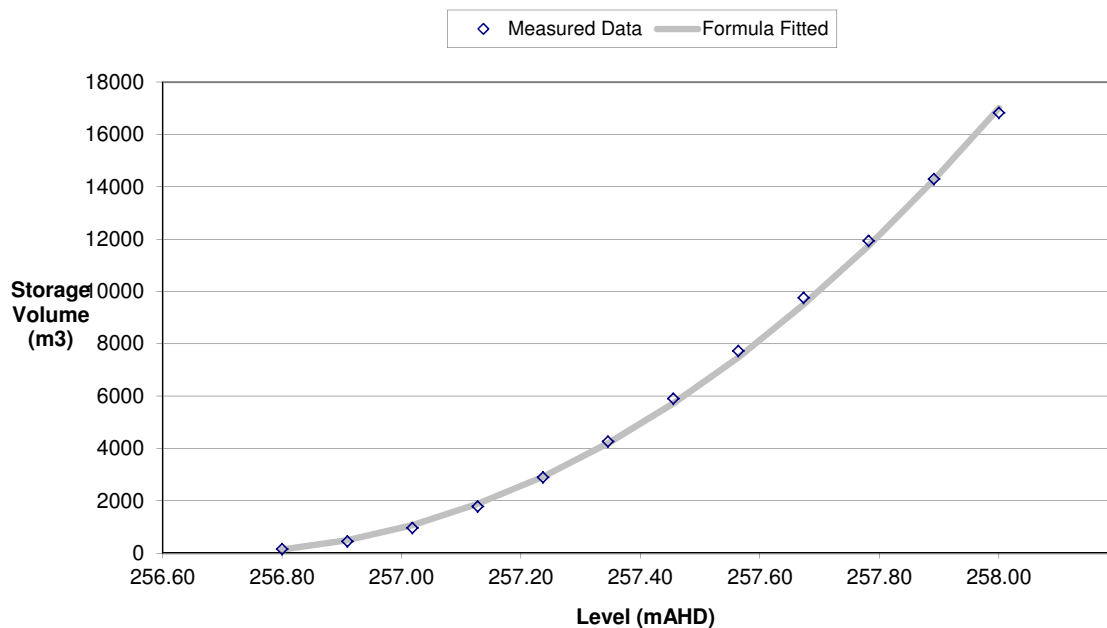
Formula Vol (m3)	Error (m3)	Error (%)
140	-18	11.5%
492	39	8.7%
1069	105	10.9%
1877	87	4.9%
2920	21	0.7%
4201	-72	1.7%
5722	-192	3.3%
7487	-246	3.2%
9497	-265	2.7%
11754	-191	1.6%
14260	-45	0.3%
17016	180	1.1%

### Volume formula

intercept	9443.675
slope	2.065

Max Error	11.5%
Mean Error	4.2%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S09-4**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	258.380	adjust Ho for best fit
<b>A=</b>	15580	
<b>B=</b>	2.090	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9999
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	258.50	190.9
2	258.59	576.2
3	258.68	1227.5
4	258.77	2235.3
5	258.86	3495.6
6	258.95	4986.7
7	259.05	6738.1
8	259.14	8748.9
9	259.23	11025.3
10	259.32	13571.4
11	259.41	16388.3
12	259.50	19514.6

Log Elev- Ho	Log Vol.
-0.921	2.281
-0.676	2.761
-0.520	3.089
-0.406	3.349
-0.315	3.544
-0.241	3.698
-0.177	3.829
-0.121	3.942
-0.072	4.042
-0.028	4.133
0.012	4.215
0.049	4.290

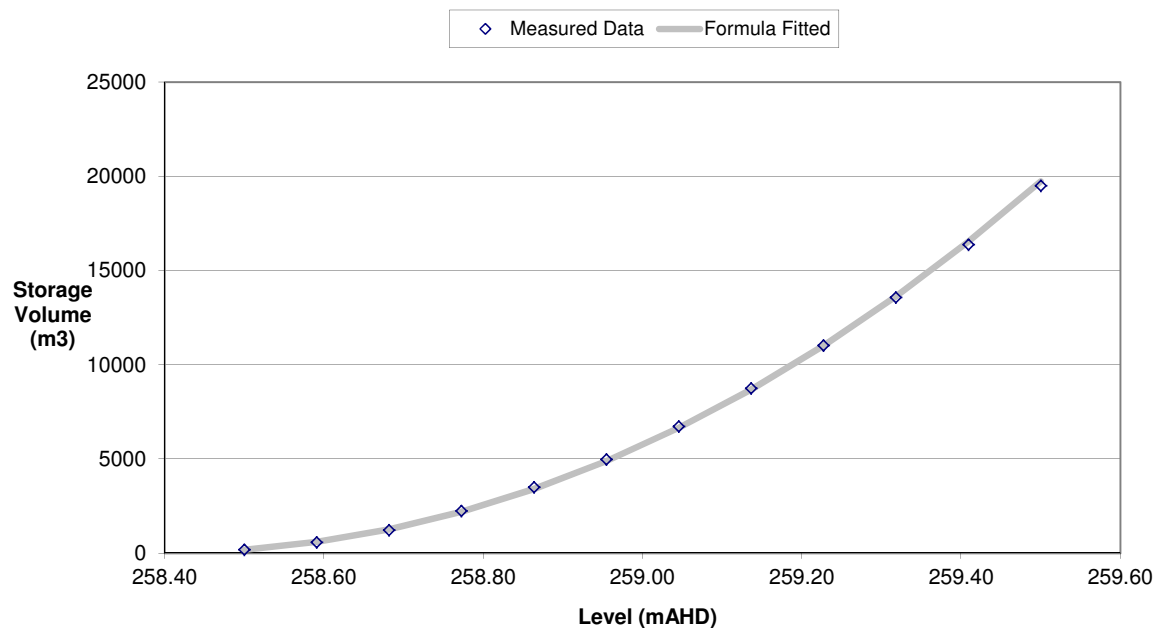
Formula Vol (m3)	Error (m3)	Error (%)
185	-6	3.0%
602	26	4.5%
1273	46	3.7%
2208	-27	1.2%
3412	-83	2.4%
4891	-95	1.9%
6650	-88	1.3%
8691	-58	0.7%
11018	-7	0.1%
13634	63	0.5%
16543	154	0.9%
19745	230	1.2%

### Volume formula

intercept	15579.991
slope	2.090

Max Error	4.5%
Mean Error	1.8%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S09-5**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	254.020	adjust Ho for best fit
<b>A=</b>	14105	
<b>B=</b>	2.240	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	1.0000
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	254.20	299.4
2	254.64	4796.0
3	255.07	15868.2
4	255.51	34866.9
5	255.95	61740.1
6	256.38	97036.9
7	256.82	141651.9
8	257.25	194922.7
9	257.69	258257.9
10	258.13	332583.9
11	258.56	416360.2
12	259.00	510085.3

Log Elev- Ho	Log Vol.
-0.745	2.476
-0.210	3.681
0.022	4.201
0.173	4.542
0.285	4.791
0.373	4.987
0.447	5.151
0.510	5.290
0.565	5.412
0.614	5.522
0.657	5.619
0.697	5.708

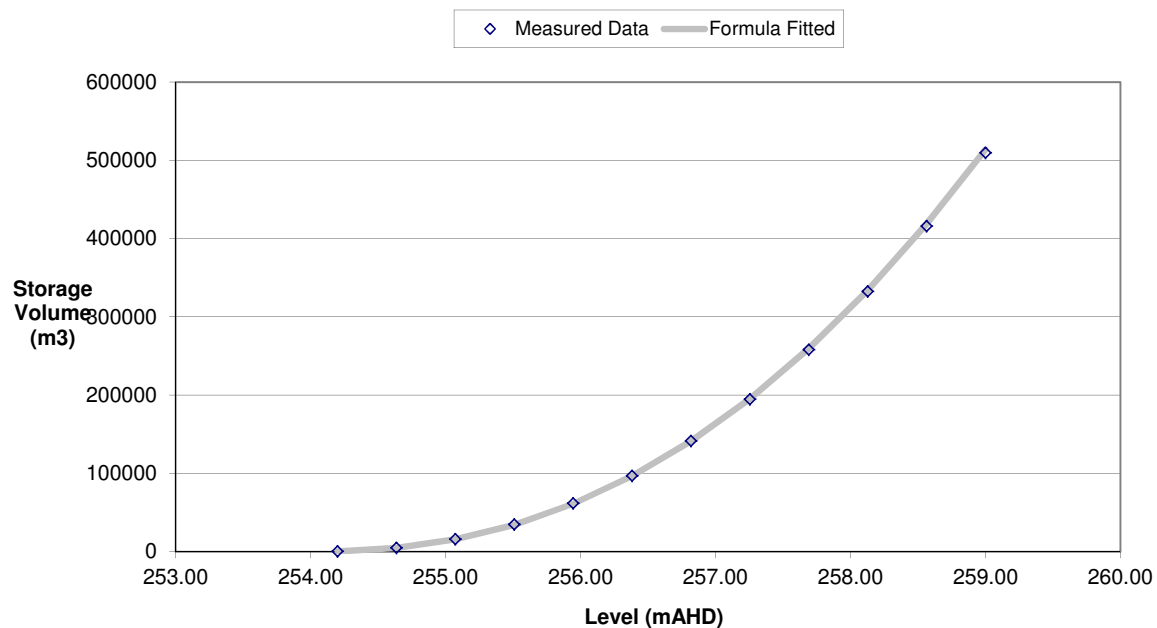
Formula Vol (m3)	Error (m3)	Error (%)
303	4	1.2%
4772	-24	0.5%
15825	-43	0.3%
34407	-460	1.3%
61181	-559	0.9%
96672	-365	0.4%
141319	-333	0.2%
195504	581	0.3%
259564	1306	0.5%
333805	1221	0.4%
418504	2144	0.5%
513917	3832	0.8%

### Volume formula

intercept	14105.077
slope	2.240

Max Error	1.3%
Mean Error	0.6%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S10-1**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	261.650	adjust Ho for best fit
<b>A=</b>	12537	
<b>B=</b>	2.543	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	1.0000
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	261.80	92.2
2	261.91	417.3
3	262.02	1040.8
4	262.13	1999.3
5	262.24	3338.3
6	262.35	5076.7
7	262.45	7230.8
8	262.56	9869.0
9	262.67	13007.7
10	262.78	16769.8
11	262.89	21192.2
12	263.00	26376.4

Log Elev- Ho	Log Vol.
-0.824	1.965
-0.587	2.620
-0.434	3.017
-0.321	3.301
-0.232	3.524
-0.158	3.706
-0.094	3.859
-0.039	3.994
0.010	4.114
0.054	4.225
0.094	4.326
0.130	4.421

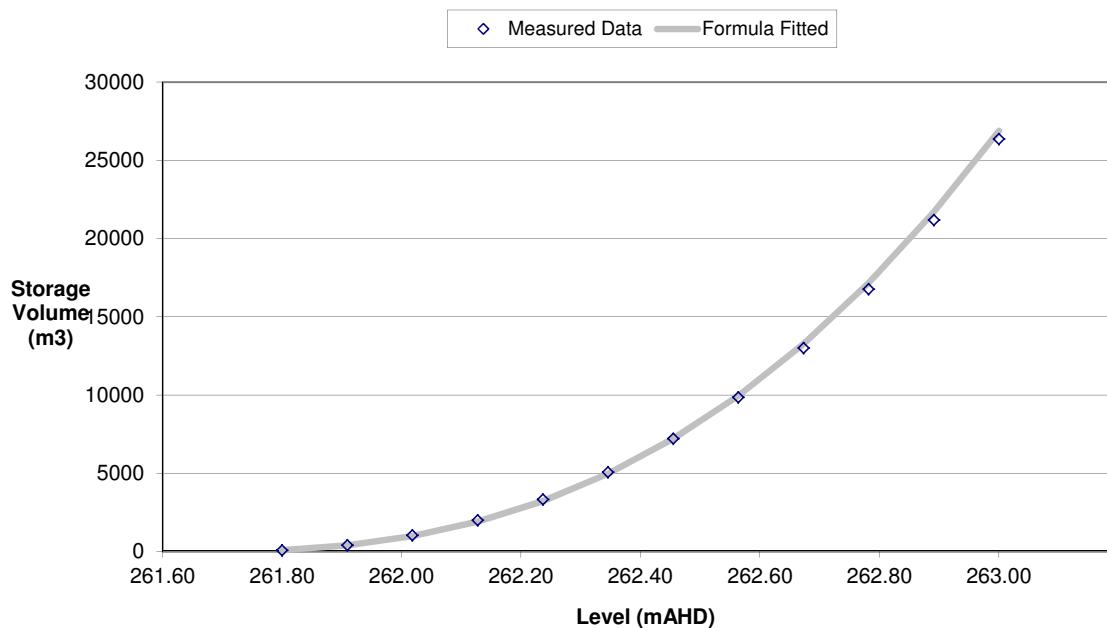
Formula Vol (m3)	Error (m3)	Error (%)
101	9	9.3%
404	-13	3.1%
988	-53	5.1%
1911	-88	4.4%
3226	-112	3.4%
4978	-98	1.9%
7211	-20	0.3%
9964	95	1.0%
13274	266	2.0%
17176	407	2.4%
21705	513	2.4%
26891	515	2.0%

### Volume formula

intercept	12536.725
slope	2.543

Max Error	9.3%
Mean Error	3.1%

### Storage vs Elevation Plot



## Subsidence Pond Level-Storage Data and Curve Fitting

**S10-2**

Derived Formula Parameters

$$Volume = A (H - H_o)^B + C$$

<b>Ho=</b>	257.060	adjust Ho for best fit
<b>A=</b>	14205	
<b>B=</b>	2.110	
<b>C=</b>	0	C value usually zero

$$Area = B * A (H - H_o)^{B-1}$$

Area equation derived by differentiation of Volume Equation

### Formulae Derivation

### Formula Check

Correlation ( $r^2$ )=	0.9998
------------------------	--------

### 12 point summary Storage Data

Point No.	Level (mAHD)	Vol (m3)
1	257.20	268.8
2	257.55	2534.2
3	257.89	8392.2
4	258.24	18910.9
5	258.58	34474.6
6	258.93	55038.8
7	259.27	79527.5
8	259.62	107780.7
9	259.96	139531.3
10	260.31	174918.1
11	260.65	214426.1
12	261.00	258115.5

Log Elev-Ho	Log Vol.
-0.854	2.429
-0.314	3.404
-0.080	3.924
0.071	4.277
0.182	4.537
0.271	4.741
0.345	4.901
0.408	5.033
0.463	5.145
0.512	5.243
0.556	5.331
0.595	5.412

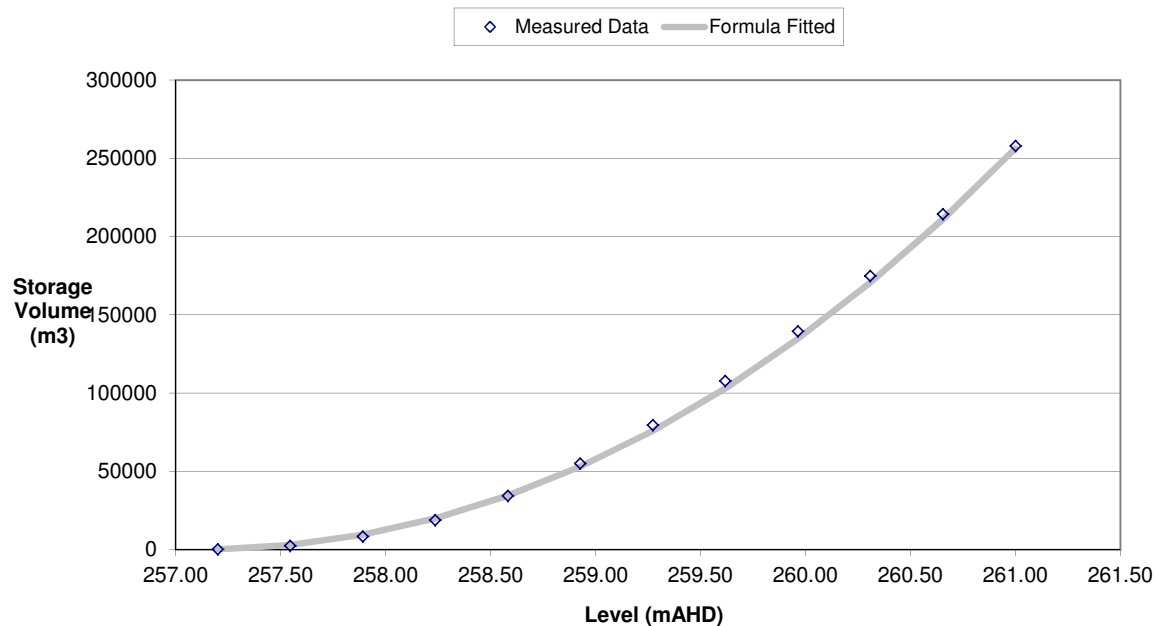
Formula Vol (m3)	Error (m3)	Error (%)
224	-45	16.6%
3092	558	22.0%
9610	1218	14.5%
20012	1101	5.8%
34454	-21	0.1%
53052	-1987	3.6%
75901	-3626	4.6%
103083	-4698	4.4%
134666	-4865	3.5%
170713	-4205	2.4%
211280	-3146	1.5%
256416	-1699	0.7%

### Volume formula

intercept	14205.453
slope	2.110

Max Error	22.0%
Mean Error	6.6%

### Storage vs Elevation Plot





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