Government of **Western Australia**
Department of **Water**

Millstream aquifer – determination of a long-term sustainable yield and long-term reliable allocation

Looking after all our water needs

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Contents

Summary v

1 Background information 1

- 1.1 The West Pilbara Supply Scheme....1
- 1.2 Current supply status....2
- 1.3 Current management criteria....3

2 Determination of sustainable yield....4

- 2.1 Modelling inputs and results....4
- 2.2 Review of current criteria....7
  - Derivation of criteria....7
  - Historical record....8
  - Chinderwarriner outflow criteria 8
  - Deep Reach Pool outflow criteria 10
  - Revised criteria used for sustainable yield estimate 11
- 2.3 Applying revised criteria to scenarios....11
  - Additional estimates of spring discharge 11
  - Determining yield based on 100-year scenarios....15
- 2.4 Conclusion – long-term reliable allocation 18
- 2.5 Comparison with historical abstraction and previous yield estimates....19
- 2.6 Assumptions and limitations....20

3 Next steps 21

Shortened forms....22

References 23

Figures

Figure 1 Chinderwarriner Pool discharge measured data compared to modelled and corrected modelled 5

Figure 2 Current Chinderwarriner Pool outflow criteria (12.96 ML/day) probability of exceedance for modelled 100-year scenarios 6

Figure 3 Current Deep Reach Pool outflow criteria (17.28 ML/day) probability of exceedance for modelled 100-year scenarios 6

Figure 4 Minimum aquifer level criteria (293.1 m AHD) probability of exceedance for 100-year scenarios....7

Figure 5 Probability of exceedance Chinderwarriner Pool outflows combined data set 1968–2008....10

Figure 6 Probability of exceedance for Deep Reach Pool outflows for recorded data 1968–1999 11

Figure 7 Chinderwarriner Pool outflow–aquifer level (exponential) relationship for Water Corporation provided data set 200 –2006....12

Figure 8 Chinderwarriner Pool outflow –aquifer level (polynomial) relationship for measured data set 1968 –2005....13

Figure 9 Chinderwarriner Pool outflow–aquifer level (polynomial) relationship for combined data set 1965–2005 13

Figure 10 Deep Reach Pool outflow–aquifer level relationship for measured data 1968 –1999 14
Figure 11 Comparison of measured, modelled and calculated data for Chinderwarriner Pool outflows....15
Figure 12 Probability of exceedance Chinderwarriner Pool outflows predicted by groundwater model and aquifer level spring discharge relationships ...16
Figure 13 Average Chinderwarriner Pool outflow exceedance for average annual abstractions....17

Tables

Table 1 Current criteria for relating to aquifer discharge and aquifer level 3
Table 2 Available Chinderwarriner Pool outflow data....9
Table 3 Deep Reach Pool available outflow data. 10
Table 4 Summarised Chinderwarriner outflow exceedances and reliability for possible mean annual abstractions 18
Table 5 Previous estimates of the potential yield from the Millstream aquifer. ..19

Summary

The Pilbara regional water plan identifies the need to review the sustainable yield for the Millstream aquifer. As part of meeting objective 2.1(12) of the regional plan, the Department of Water initiated a review of the sustainable yield and source management to improve the West Pilbara Water Supply Scheme operating strategy and to inform the Pilbara water allocation plan, scheduled for 2012.

The Water Corporation and the Department of State Development asked the department to bring forward the sustainable yield review to assist with interpretation of water supply agreements and inform future source planning.

The term sustainable yield is normally used to mean the amount of water that can be taken out of an aquifer each year, while leaving enough water to maintain the integrity of the resource and the water dependent values for the long term. The long-term sustainable yield for Millstream must take into account the highly variable cyclonic recharge to the aquifer.

A preliminary assessment of the long-term sustainable yield, adequate for current purposes, has been made using the recently completed numerical groundwater model of the resource and monitoring data, and is based essentially on existing management criteria. The work completed to date estimates the long-term sustainable yield of the Millstream aquifer at 5.2 GL/yr at 100 per cent reliability (after incorporating an acceptable level of exceedance of management criteria).

The long-term sustainable yield is relatively low due to the variability of recharge. Recharge for the aquifer is primarily derived from cyclones or cyclone related events. Periods of two to three years or more without recharge occur with sufficient frequency to mean that the long-term sustainable yield is low. This was recognised in the 1980s, when the Harding Dam was constructed to improve reliability of supply.

From this work the department has also set a long-term reliable allocation of 6.0 GL/yr for the Millstream aquifer. The long-term reliable allocation is used to guide planning to meet demand and for new source development for the West Pilbara Supply Scheme. The risk to the resource of an allocation greater than the sustainable yield will be managed through criteria on operation of the borefield.

Annual abstraction greater than 6.0 GL/yr will be possible when the aquifer level is high. However, there is some risk that when aquifer levels are low that the abstraction from the aquifer will need to be restricted.

Work undertaken in 1982 estimated a similar sustainable yield for the aquifer, and this has informed management of the Millstream borefield since then. The department's current work refines this earlier estimate, and provides a rationale for setting a long-term reliable allocation from the Millstream aquifer at 6.0 GL/yr.

A long-term reliable allocation of 6.0 GL/yr allows for discharge to the river pools within and downstream of the Millstream Chichester National Park to be met with approximately 80% reliability. Based on data from the previous 30 years, it is

expected that the ecosystems that depend on the discharge will survive with this level of risk.

With a long-term reliable allocation of 6.0 GL/yr from the Millstream aquifer, the reliable supply from the conjunctive Millstream Harding system is approximately 9.0 GL/yr. The Water Corporation estimate the reliable supply of the conjunctive scheme at 10.0 GL/yr based on a simpler groundwater model for the Millstream aquifer.

The current use from the conjunctive scheme is in excess of 10.0 GL/yr and for the 2009–2010 water year was approximately 14.0 GL. This demand could be met from the scheme because there has been sufficient recent recharge to maintain Harding Dam water levels and water quality, and Millstream aquifer water levels.

However, the existing water supplies for Karratha are at capacity due to increasing demand from residential and industrial growth and because the reliability of supply from current sources is highly variable. If there is no recharge for two to three years, water levels will decline to the point where the scheme cannot meet the current level of demand.

Over the next twelve months, the department will continue to review the management and monitoring criteria for the Millstream aquifer to inform the Pilbara water allocation plan.

This report confirms the need for a third source for the West Pilbara Supply Scheme and can be used in assessment of future source options.

1 Background information

1.1 The West Pilbara Supply Scheme

The Millstream aquifer provides water to the West Pilbara Water Supply Scheme operated by the Water Corporation. The borefield has been operating since 1969 with eight production bores currently providing water to ports and towns. An additional source, Harding Dam, was commissioned in 1985 after it was realised the Millstream resource could not sustain high rates of abstraction (> 6.0 GL/yr), particularly when recharge was low. Together, Harding Dam and the Millstream borefield are operated as the conjunctive West Pilbara Water Supply Scheme. Water from Harding Dam is used as the first preference. The Millstream borefield is operated when water is not available from Harding Dam, or more recently when demand is greater than can be provided to the scheme via the Harding Dam infrastructure alone.

As well as being a vital water source for the scheme, the Millstream aquifer supports the groundwater-dependent vegetation and biologically rich river pools and wetlands of the Millstream Chichester National Park. The park attracts approximately 20 000 visitors a year (DEC 2007). The river pools and wetlands are listed on the Register of the National Estate and in the Directory of Important Wetlands. Millstream is also of great cultural importance to the Yindjibarndi people, the traditional owners of Millstream. All the pools are important, and their significance increases moving upstream to Deep Reach Pool.

The Water Corporation's operation of the conjunctive scheme is licensed up to a maximum take of 15.0 GL/yr. The yield for the Millstream aquifer as a stand alone source is not specified in the current licence. However, until recently (2008) the operating strategy for the scheme included a long-term average annual abstraction of 6.0 GL/yr for the Millstream aquifer.

The Pilbara regional water plan identifies the need to review the sustainable yield for the Millstream aquifer and determine an allocation limit. This is an objective for the state's water resource manager, the Department of Water. Revising the yield and setting an allocation limit will improve the West Pilbara Water Supply Scheme operating strategy and inform the Pilbara water allocation plan, scheduled for 2012.

The Water Corporation and the Department of State Development have asked the Department of Water to bring forward the sustainable yield review to assist with interpretation of water supply agreements. The agreements were made in the 1960s and 1970s between the state government and Rio Tinto Ltd. Circumstances have changed significantly since then:

- throughput of iron ore has significantly increased
- towns have been normalised
- the aquifer is better understood
- environmental legislation has changed

- the state has supplemented the scheme with the Harding Dam.

The sustainable yield is the amount of water which can be taken out of the aquifer for consumptive use while leaving enough water in the aquifer to maintain the integrity of the resource and the dependent environmental, social and cultural values. The sustainable yield is calculated as an annual rate of abstraction that could be taken over the long term and is referred to as the 'long-term sustainable yield'.

The groundwater-dependent values associated with the Millstream aquifer are maintained by aquifer discharge through springs into the pools and wetlands and in some areas by a shallow depth to groundwater. The rate of discharge from the aquifer is directly linked to aquifer level and decreases as aquifer level decreases.

Recharge to the aquifer occurs mainly from flows in the Fortescue River after cyclonic or cyclone related events. Recharge is highly variable and periods of two to three years with little or no recharge are relatively common, with nine years the longest dry period since 1975. Because of the variable nature of recharge and the frequency of droughts, the long-term sustainable yield is low.

In some instances where the demand for the resource and cost of alternative supplies are high, and where it is possible to manage the risk to the resource and the dependent values, the department sets an allocation limit higher than the sustainable yield.

Because of the high variability of the Millstream resource and its recharge, a fixed or constant allocation limit is not suitable. Instead, in this instance the department has set a long-term reliable allocation. Rates of abstraction greater than the long-term reliable allocation are possible in years when the aquifer is full. Conversely, if the aquifer level is low, as occurs during the frequent drought periods, abstraction needs to be lower. However, for the purposes of long-term resource management, source planning and new supply planning the long-term reliable allocation should be used.

This report presents the long-term sustainable yield and long-term reliable allocation and the methodology used to derive these figures.

1.2 Current supply status

The West Pilbara Supply Scheme supplied approximately 14.0 GL for the 2009–10 water year. Current dam and aquifer levels are relatively high and water is primarily being supplied to the scheme from Harding Dam. Without additional recharge Harding Dam is likely to be usable until December 2010. Based on projected groundwater levels, if there is only minimal take (up to 2.0 GL/yr) from the Millstream aquifer over the intervening period, it would be able to provide 15.0 GL/yr until May 2012. Beyond this, discharge from the aquifer would decrease to levels predicted to cause environmental harm. Sustained abstraction at low aquifer levels may affect the stability of the resource and put dependent values at risk.

1.3 Current management criteria

Abstraction from the aquifer is currently managed through management criteria specified in the Water Corporation's operating strategy for the West Pilbara Water Supply Scheme (Water Corporation 2008). The criteria are designed to maintain the water requirements of groundwater-dependent in situ values. The criteria specify minimum discharge rates from groundwater fed pools, acceptable rates of decline of aquifer level and a minimum mean aquifer level (Table 1).

Table 1 Current criteria relating to aquifer discharge and aquifer level

Site	Criteria
Chinderwarriner Pool	Instantaneous flow rate of 0.15 kL/s and ≥ 0.2 kL/s during Nov and Dec.
Deep Reach Pool[1]	Minimum annual average discharge of 6.5 GL/a (0.20 kL/s) to the riverine system below Deep Reach. For Nov/Dec > 0.27 kL/s.
Crossing Pool	Instantaneous flow rate of 0.08 kL/s and ≥ 0.11 kL/s during Nov and Dec.
Minimum mean aquifer level (MAL)	Mean aquifer level (MAL) not to fall below what is considered to be the historical minimum of 293.10 m AHD.

Note: Criteria are from the West Pilbara Water Supply Scheme operating strategy

The existing pool outflow criteria are based on the measured, documented, relationship between aquifer level and spring discharge and estimates of the environmental water demand of ecosystems downstream of the springs. The springs discharge directly into pools and the criteria are applied as rates of outflow from the pools. The minimum pool discharges, as per the current operating strategy for the system, are represented as criteria to be maintained at all times (Table 1). A more detailed description, and the first phase of a review, of these criteria was recently completed by the department (Antao and Braimbridge 2009).

[1] The management criteria for Deep Reach Pool were replaced by criteria on outflows from Crossing Pool. However, for the purposes of determining a sustainable yield for the aquifer the Deep Reach Pool outflow criteria has been applied (see Section 2.2).

2 Determination of sustainable yield

The long-term sustainable yield for the Millstream aquifer was determined by an iterative process that made use of the recently completed numerical model of the aquifer and available monitoring data. It was intended that the yield would be determined by applying the existing management criteria, as contained in the current operating strategy for the scheme, to the modelling results. However, some revision of both the criteria and the model results was required following initial results. This revision considered available groundwater, surface water and other monitoring data.

The determination of a sustainable yield for Millstream has some inherent difficulties due to the natural variability of the system. Because there are frequent sustained droughts, when the aquifer naturally becomes depleted, and a very large variation in the magnitude of recharge events, defining a fixed sustainable yield to be available in all (or almost all) years is difficult. A probabilistic approach using a range of predicted outcomes was used and is detailed in the following sections.

2.1 Modelling inputs and results

The main tool used in determining the long-term sustainable yield estimate for the Millstream aquifer was the numerical groundwater model developed for the department by SKM. Full details of the model's conceptual hydrogeology, construction, calibration and scenario runs are provided in SKM (2009).

The model was constructed using (in part) groundwater and surface water data for the period 1968–2007. Calibration of the model was conducted for the entire period to check the predictive accuracy of the model. A series of predictive scenarios were also run over a synthetic 100-year climate series. The 100-year synthetic climate series was developed by DHI on request from the department using a 'bootstrapping' technique which created a 100-year time series by randomly sampling the available climate record (DHI 2009). The following abstraction scenarios were run with the 100-year climate series as an input:

- 0.0 GL/yr
- 2.0 GL/yr
- 4.0 GL/yr
- 6.0 GL/yr
- 8.0 GL/yr
- 15.0 GL/yr.

All abstraction scenarios applied a constant and continuous abstraction rate and were not constrained by management criteria. Initial modelling runs indicated that the model was under predicting spring discharge. A post hoc correction factor dependent on aquifer level was determined by the modellers and applied to improve the accuracy of spring discharge estimates (Figure 1).

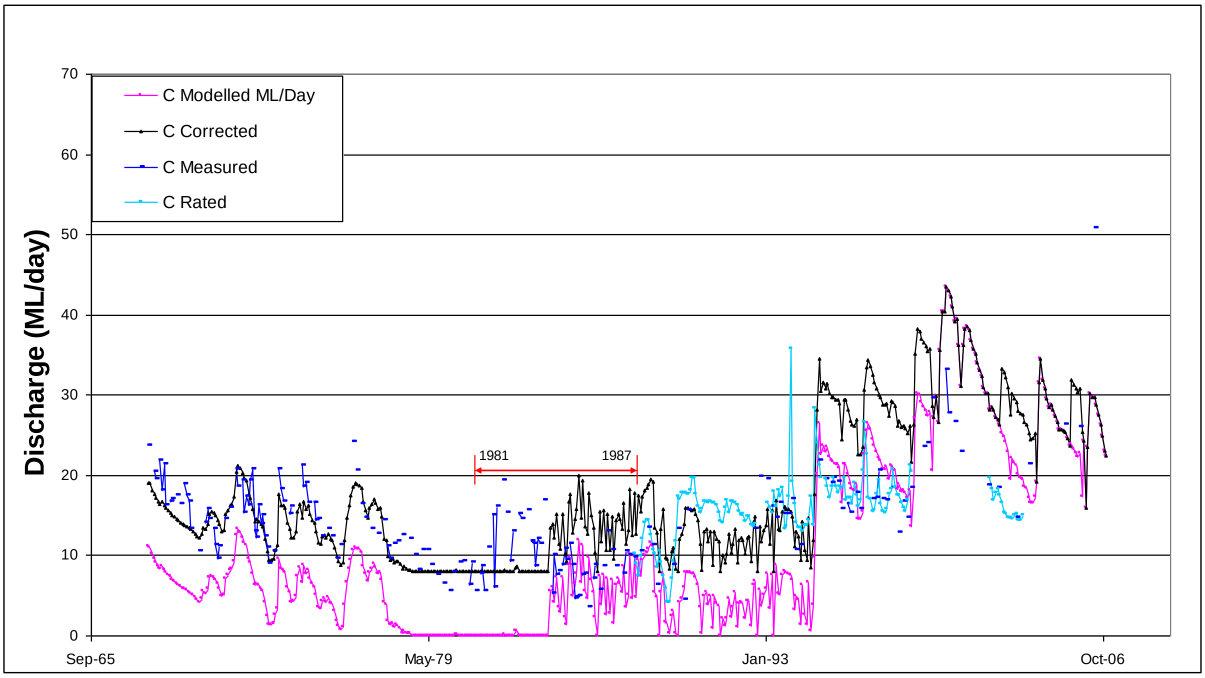

Figure 1 Chinderwarriner Pool discharge measured data compared to modelled and corrected modelled

The six 100-year scenarios were run and the correction factor applied to the spring outflows post hoc.

Initial results from the 100-year scenarios indicated that the Chinderwarriner outflow criteria was a major constraint on yield from the aquifer and suggested the criteria is unrealistic. Criteria were breaching 5% of the time at 0.0 GL/yr abstraction and 35% of time for the 4.0 GL/yr scenario (Figure 2). Criteria for Deep Reach pool and minimum aquifer level were not as constraining (Figure 3 and Figure 4).

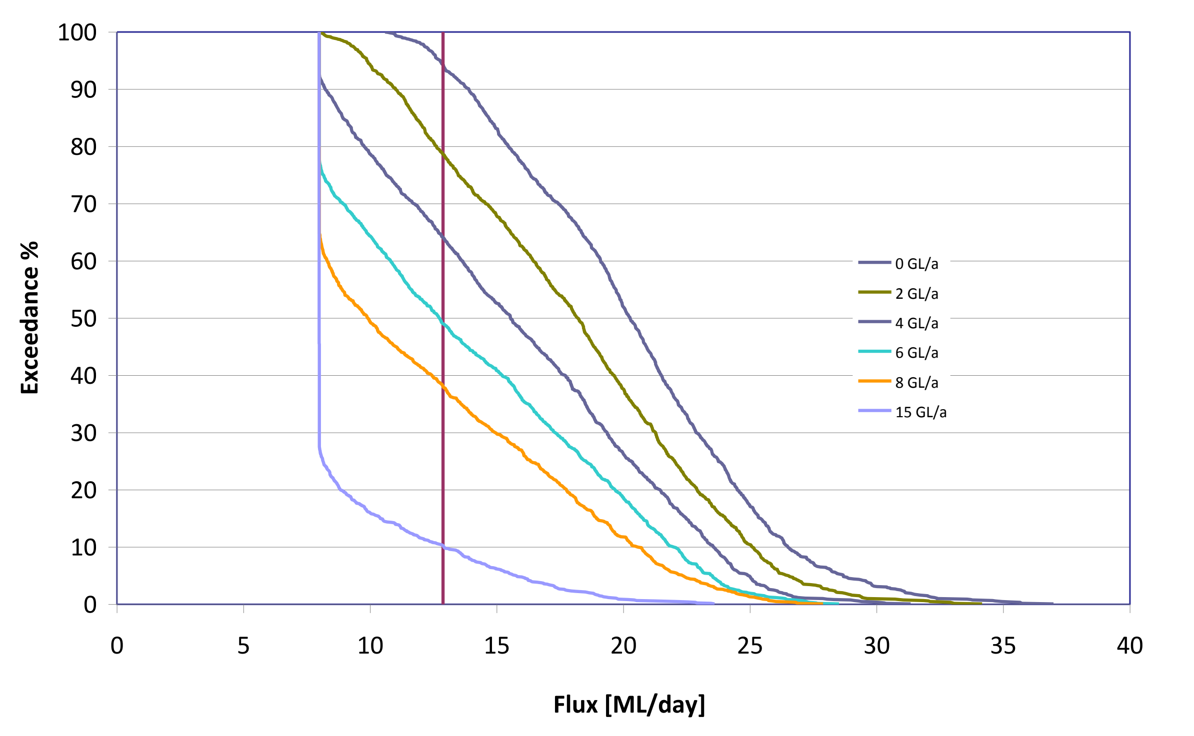

Figure 2 Current Chinderwarriner Pool outflow criteria (12.96 ML/day) probability of exceedance for modelled 100-year scenarios

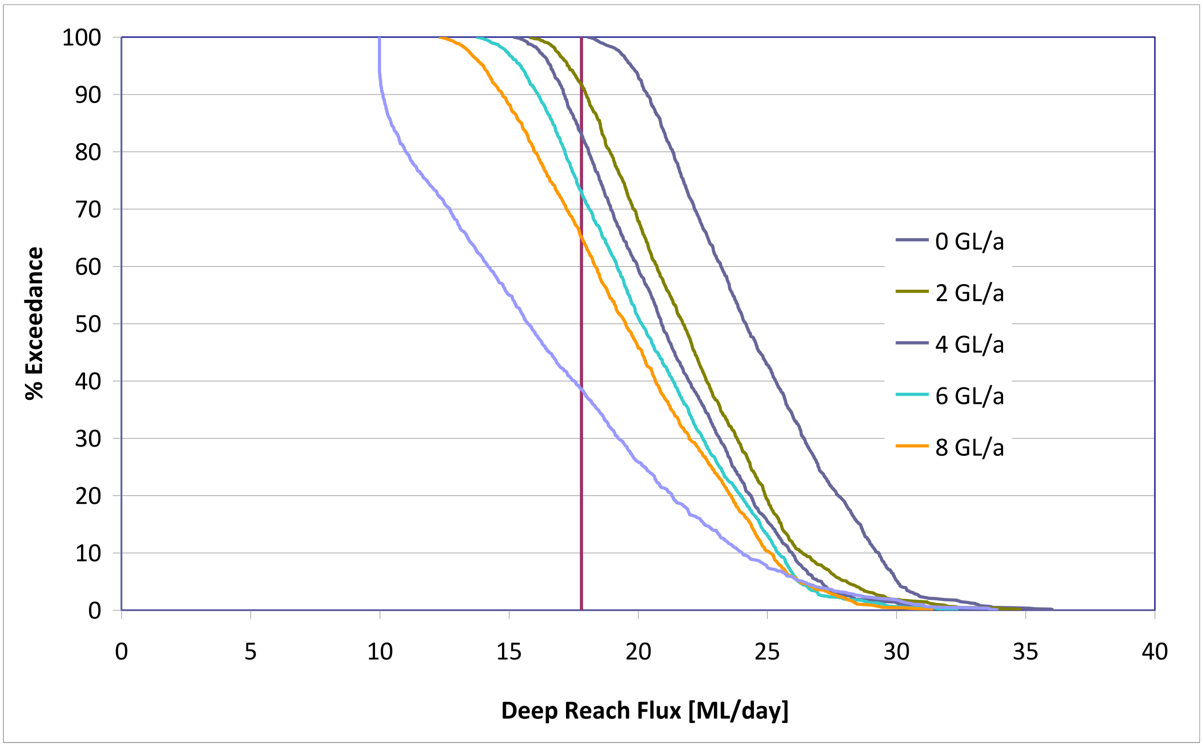

Figure 3 Current Deep Reach Pool outflow criteria (17.28 ML/day) probability of exceedance for modelled 100-year scenarios

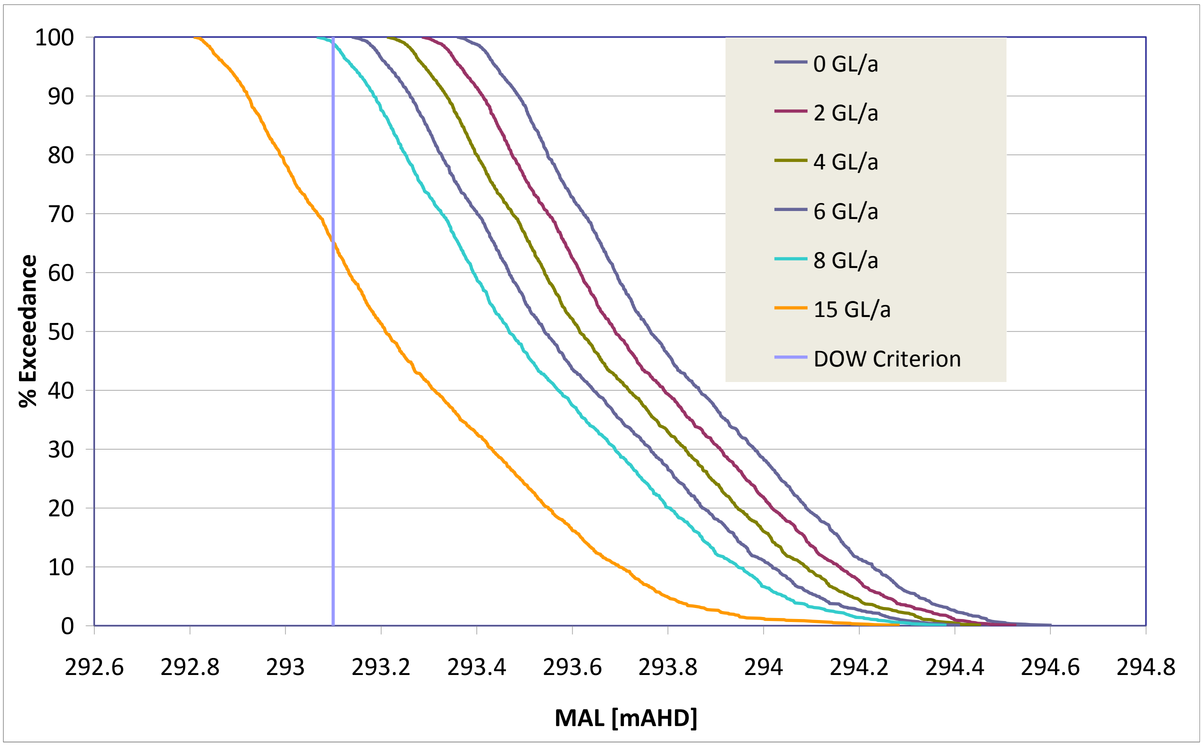

Figure 4 Minimum mean aquifer level criteria (293.1 m AHD) probability of exceedance for 100-year scenarios

2.2 Review of current criteria

The initial results indicated that the pool outflow criteria in their current state were overly conservative and required review as detailed below. This was not the case for the mean aquifer level (MAL) criteria and no review was required.

Derivation of criteria

As a result of the initial modelling runs, an interim review of the existing pool outflow criteria was undertaken to avoid an unrealistic long-term sustainable yield estimate. The review of the current criteria looked at the derivation of the environmental demand estimates and the frequency with which the criteria had been breached historically.

The Chinderwarriner outflow criteria is based on an initial estimate of environmental requirements of 0.11 kL/s by Welker (1995). The initial estimate was scaled up to the current criteria level of 0.15 kL/s to allow for losses due to weeds and distribution through the delta wetland area. Since the mid 1990s there has been large scale removal of date palms and other weeds within the delta area.

For the purposes of determining a long-term sustainable yield the criteria has been reduced to 0.11 kL/s (9.5 ML/day). This reduction was done on the basis that additional flows to account for losses due to weeds are no longer required. The seasonal increase to 0.2 kL/s for the months of November and December has also been removed. An increase in water stress on vegetation due to seasonal conditions at this time of year is a natural occurrence and does not need to be incorporated into the aquifer management criteria.

In 1997 criteria for Deep Reach Pool were replaced with criteria for Crossing Pool due to difficulties in establishing and maintaining a stage height–discharge rating curve at the downstream end of Deep Reach Pool. However, Crossing Pool is located off the modelling domain and therefore its outflows were not available as an output from the numerical groundwater model. For the purpose of determining a sustainable yield, the Deep Reach Pool we applied the criteria of 0.2 kL/s (equivalent to 17.28 ML/day).

Historical record

Historical data sets were used to examine the frequency of past breaches of criteria flow levels.

We have measured monthly mean aquifer level (averaged from nine bores) from 1968 to 2005.

We have a varied record of measured spring discharge from Millstream. For Chinderwarriner Pool we have:

- instantaneous measured discharge roughly every two months from 1965 to 2008 ('measured' data set)
- continuous flow data from 1987 to 2003 with a few gaps ('continuous' data set).

We have also combined the measured and continuous data sets to create a more comprehensive data set ('combined' data set).

We have excluded flows greater then 30.0 ML/day as these are considered likely to contain at least some surface water inputs, and they are also considered beyond the accurate range of the rating curve for Chinderwarriner Pool outflows.

Chinderwarriner outflow criteria

Over the period of historical record, there have been a number of times when pool outflow discharge criteria (0.11 kL/s) were not met (Table 3).

During the period 1968–2008, with the exception of the period 1981–1987, the downstream ecosystems have remained in good condition. During the 1981–1987 period, levels of abstraction were high and aquifer levels were low. Damage to downstream ecosystems resulted and supplementation of pool outflows was required. There is also anecdotal evidence which suggests that over-abstraction exacerbated erosion at the toes of Deep Reach and Crossing pools. There is potential for further erosion of these areas to reduce the storage of the aquifer.

Water quality issues, such as increased salinities in Chinderwarriner Pool and groundwater from production bores near the pool, also occurred during these periods of high abstraction.

Table 2 Available Chinderwarriner Pool outflow data

Data set	Period	Percentage of time criteria not met
Measured discharge	1965–2008	20
Measured discharge	1988–2008	10
Continuous discharge	1988–2003	10
Continuous discharge (< 30.0 ML/day)	1988–2003	8
Combined	1965–2008	25
Combined	1988–2008	15
Combined (< 30.0 ML/day)	1965–2008	30
Combined (< 30.0 ML/day)	1988-2008	15
Combined (< 30.0 ML/day)	1965–1980 and 1988-2008	17
Combined (< 30.0 ML/day)	1981–1987	70

Using this historical evidence, it is reasonable to set a level of non-detrimental breach of the spring discharge criteria. Using the most robust data set available (the combined data set) and excluding the period 1981–1987, the level of non-detrimental breach or acceptable level of exceedence has been set at 17% of the time (Figure 5).

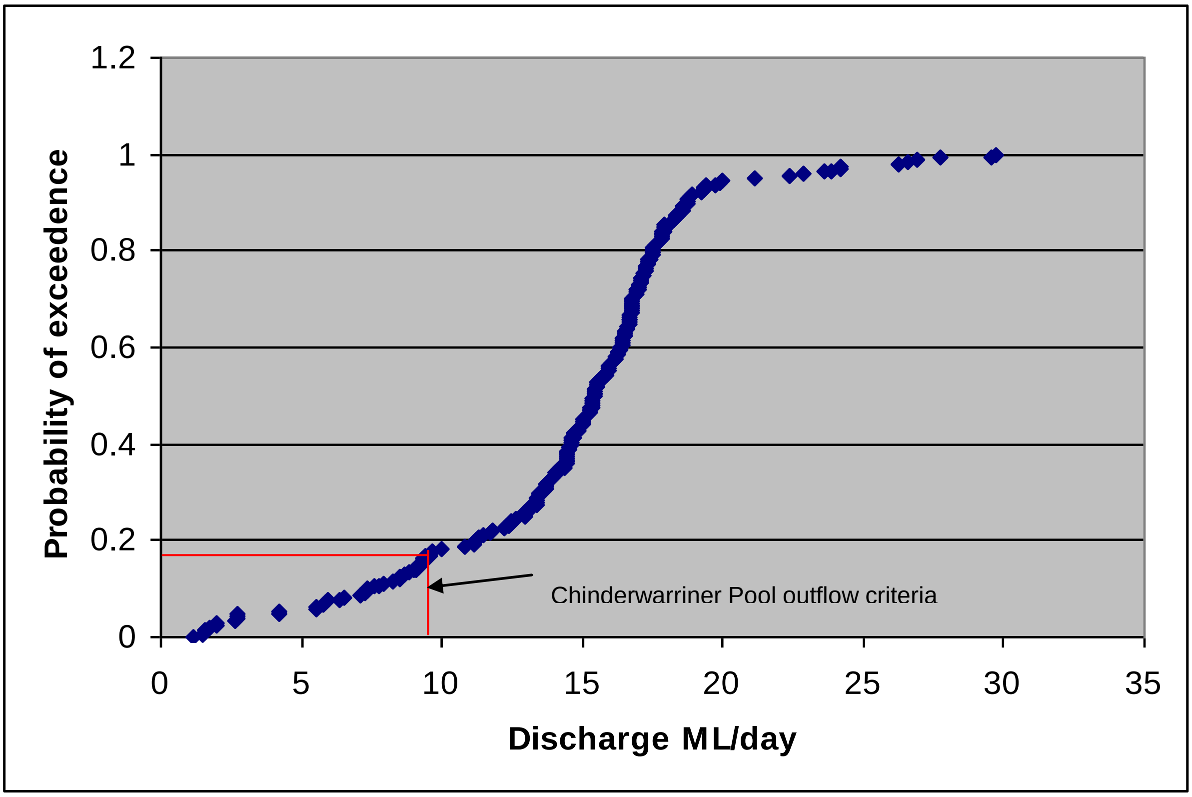

Figure 5 *Probability of exceedance for Chinderwarriner Pool outflows for combined data set 1968–2008, excluding 1981–1987 and flows greater than 30.0 ML/day*

Deep Reach Pool outflow criteria

There is less data available for Deep Reach Pool than for Chinderwarriner Pool, and during the period we have outflow data for there has been no supplementation. Based on this data, criteria for Deep Reach pool discharge have been exceeded 15% of the time (Table 3 and Figure 6).

Table 3 *Deep Reach Pool available outflow data.*

Data set	Period	Percentage of time criteria not met
Measured	1968–1999	15
Measured (< 30.0 ML/day)	1968–1981, 1988–1999	15

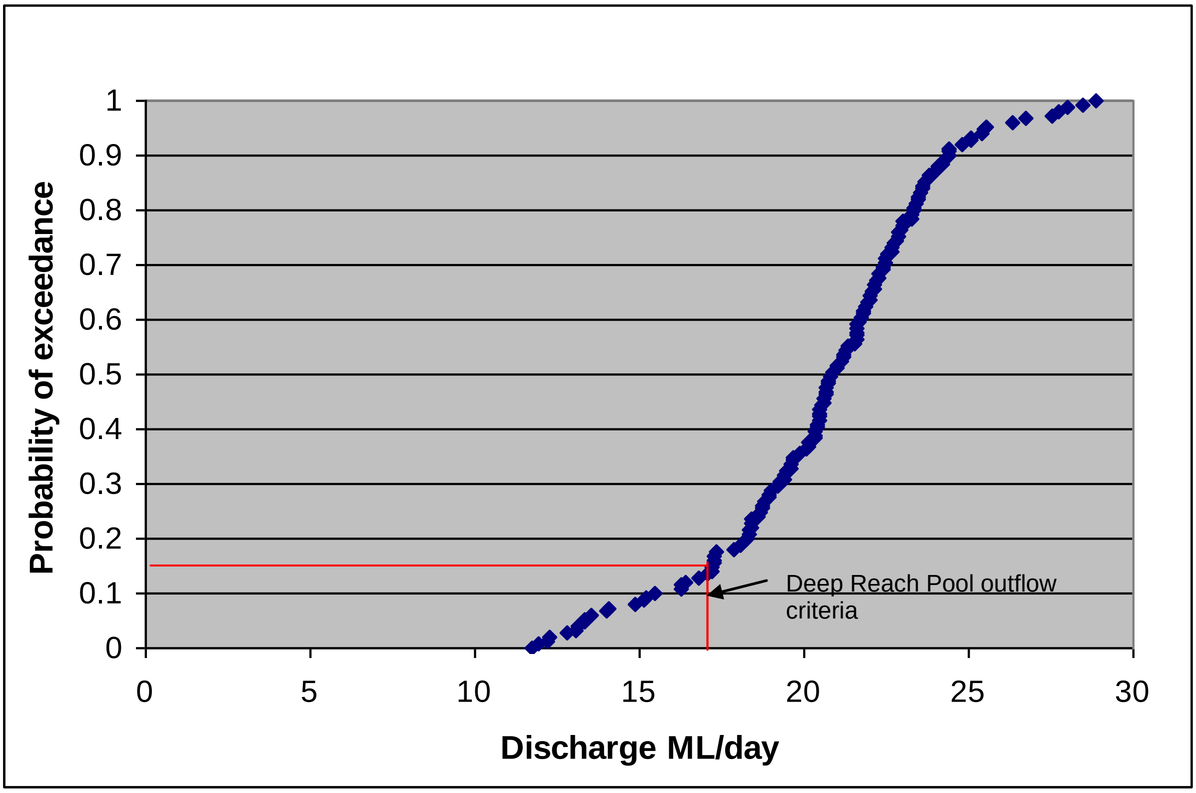

Figure 6 *Probability of exceedance for Deep Reach Pool outflows for recorded data 1968–1999, excluding 1981–1987 and flows greater than 30.0 ML/day*

Revised criteria used for sustainable yield estimate

The determination of sustainable yield therefore proceeded with the following criteria:

- a revised minimum spring discharge from Chinderwarriner Pool of 0.11 kL/s (9.5 ML/day)
- the previous criteria of 0.2 kL/s (17.28 ML/day) for Deep Reach Pool
- an acceptable exceedance of 17% for both discharge criteria
- the existing minimum mean aquifer level criteria of 293.1 m AHD.

The acceptable level of exceedance means that in determining the long-term sustainable yield for the aquifer we have incorporated or allowed the pool outflow criteria to be breached up to 17% of the time. This is based on evidence that this frequency of criteria breach in the past has not had a lasting detrimental effect on the dependent ecosystems.

2.3 Applying revised criteria to scenarios

Additional estimates of spring discharge

To supplement the model outputs, mainly due to concerns that the model may be underestimating spring outflows, spring outflows were also estimated using calculated relationships between MAL and discharge. These relationships were derived via regression analysis using monitoring data sets.

Three relationships were derived for Chinderwarriner Pool and two for Deep Reach Pool outflows based on different data set combinations available. Linear, exponential and polynomial regressions were fitted for the alternative data sets and the relationships with the strongest correlation (highest R^2) value selected for each data set combination.

The data sets used to develop aquifer level discharge relationships for Chinderwarriner Pool outflows were:

- Water Corporation supplied pool outflows and MAL for 2002–2007 (Figure 7)
- Measured data set and MAL for 1968–2005 (Figure 8)
- A combined data set and MAL for 1968–2006 (Figure 9).

For polynomial relationships it was necessary to adjust MAL by a constant for calculation purposes. This did not affect the strength of the relationship between aquifer level and discharge.

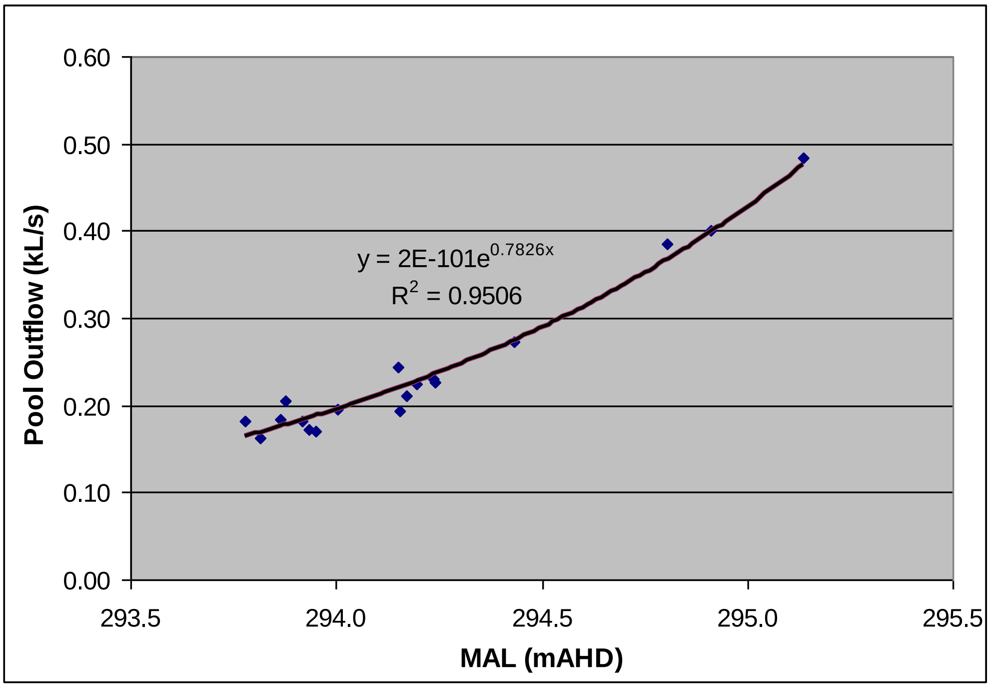

Figure 7 Chinderwarriner Pool outflow–aquifer level (exponential) relationship for Water Corporation provided data set 2002 –2006

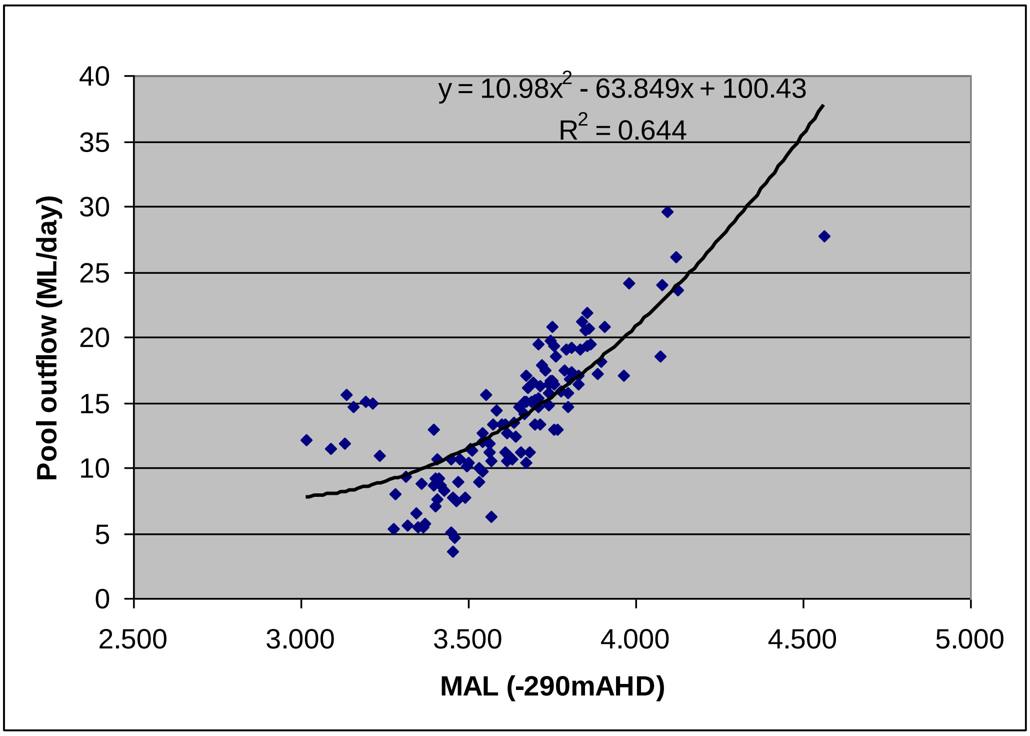

Figure 8 Chinderwarriner Pool outflow –aquifer level (polynomial) relationship for measured data set 1968 –2005

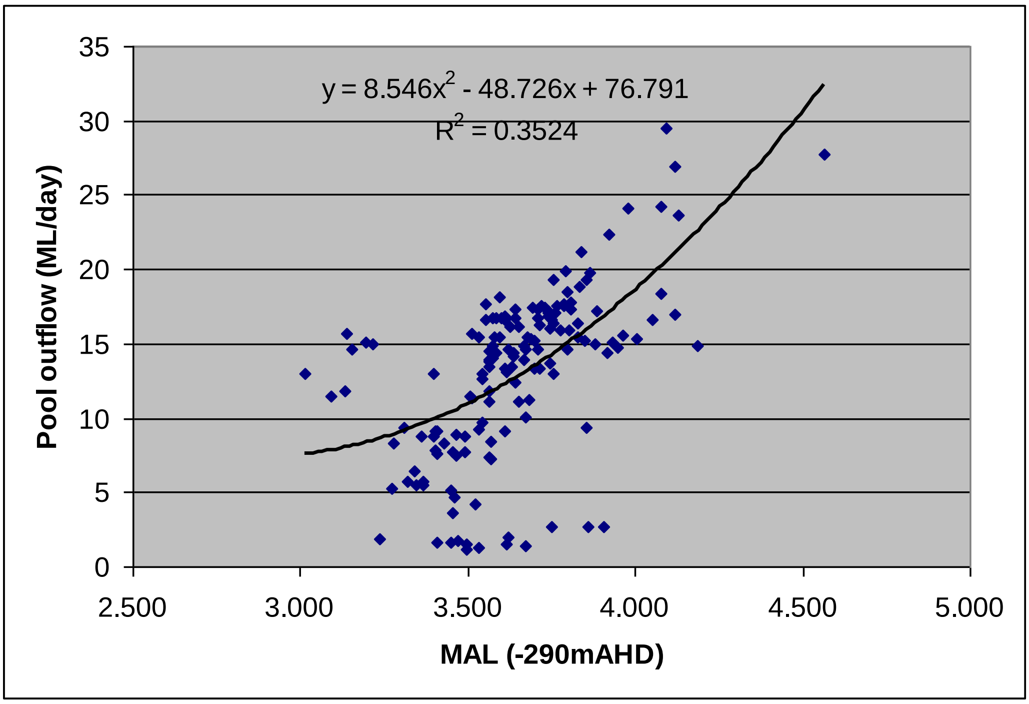

Figure 9 Chinderwarriner Pool outflow–aquifer level (polynomial) relationship for combined data set 1965–2005

For Deep Reach Pool relationships were determined using:

- available measured pool outflow data from 1968 to 1999 and MAL (Figure 10).
- an existing relationship determined by Dames and Moore (1984).

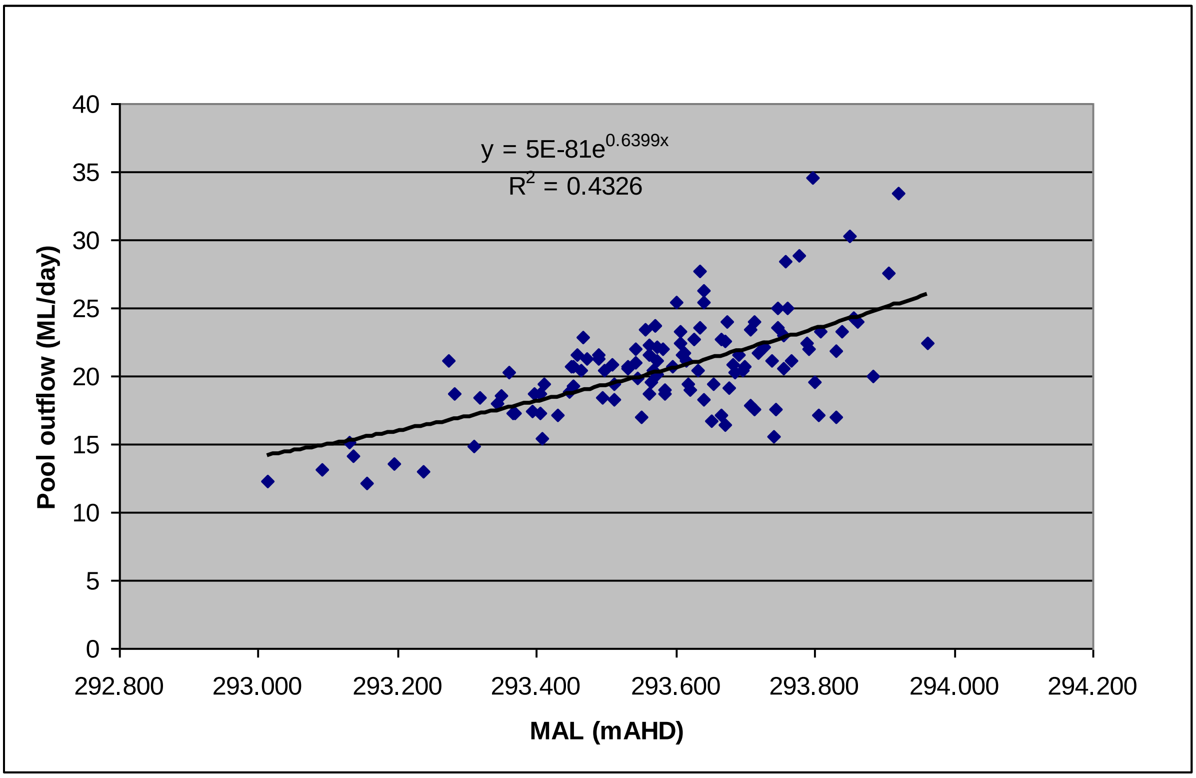

Figure 10 Deep Reach Pool outflow–aquifer level relationship for measured data 1968 –1999

The accuracy of the modelled spring outflows was compared with those predicted using the 'post hoc' relationships described above and the measured data (Figure 11).

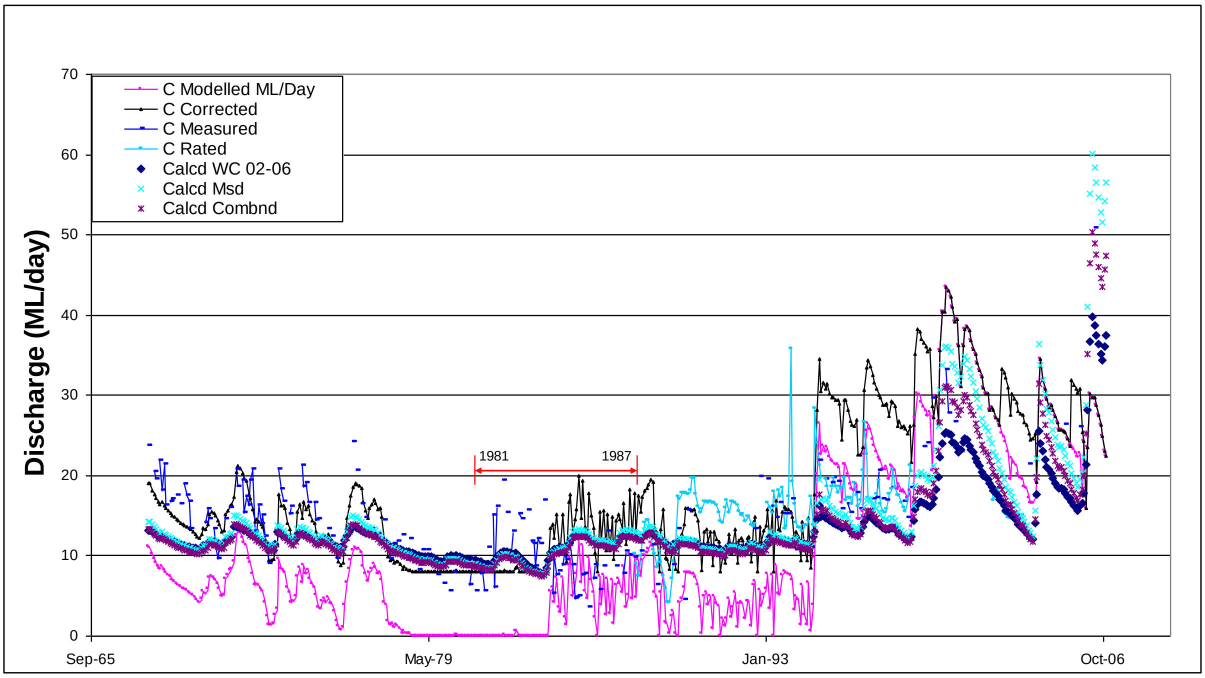

Figure 11 Comparison of measured, modelled and calculated data for Chinderwarriner Pool outflows

Determining yield based on 100-year scenarios

The post hoc relationships were used to predict spring outflows for the six alternate 100-year abstraction scenarios using the modelled MAL from the scenarios as an input. This together with the model outputs gave a range of exceedances for pool outflow criteria for each of the abstraction scenarios (Figure 12).

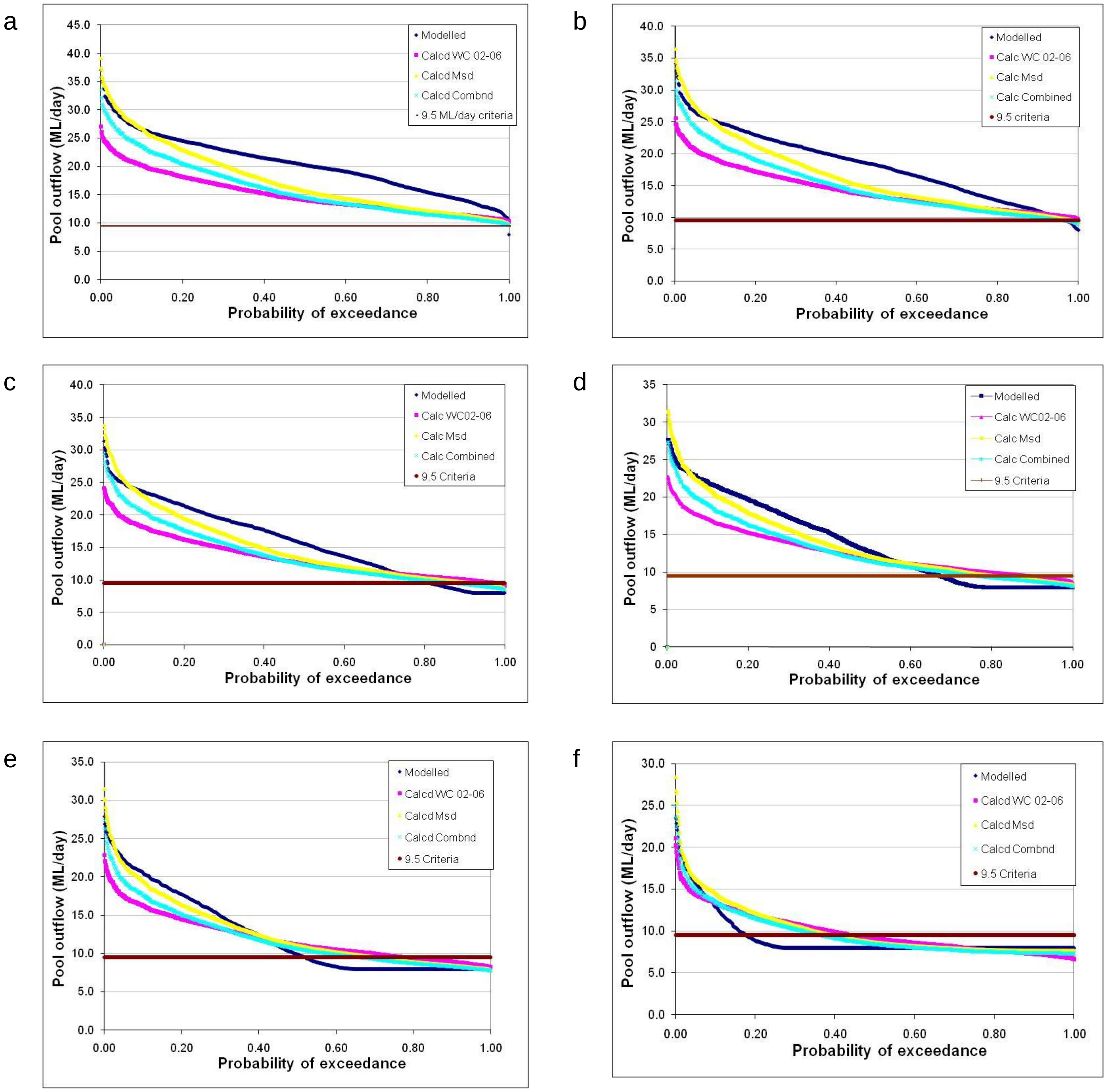

Figure 12 Probability of exceedance for Chinderwarriner Pool outflows as predicted by groundwater model and post hoc aquifer level spring discharge relationships for a) 0.0 GL/yr b) 2.0 GL/yr c) 4.0 GL/yr d) 6.0 GL/yr e) 8.0 GL/yr and f) 15.0 GL/yr scenarios

The modelled spring discharge is the most sensitive (of the estimates) to abstraction but due to the correction factor applied (see Section 2.1) there is a false minimum of 8.0 ML/day (because a correction factor was applied to the modelled spring discharges post modelling, spring outflows originally estimated to be zero now do not fall below 8.0 ML/day).

A combined average exceedance was calculated from the individual scenario outputs (Figure 13). This gives an average probability of pool outflow criteria being met for annual abstraction ranging from 0.0 to 15.0 GL/yr.

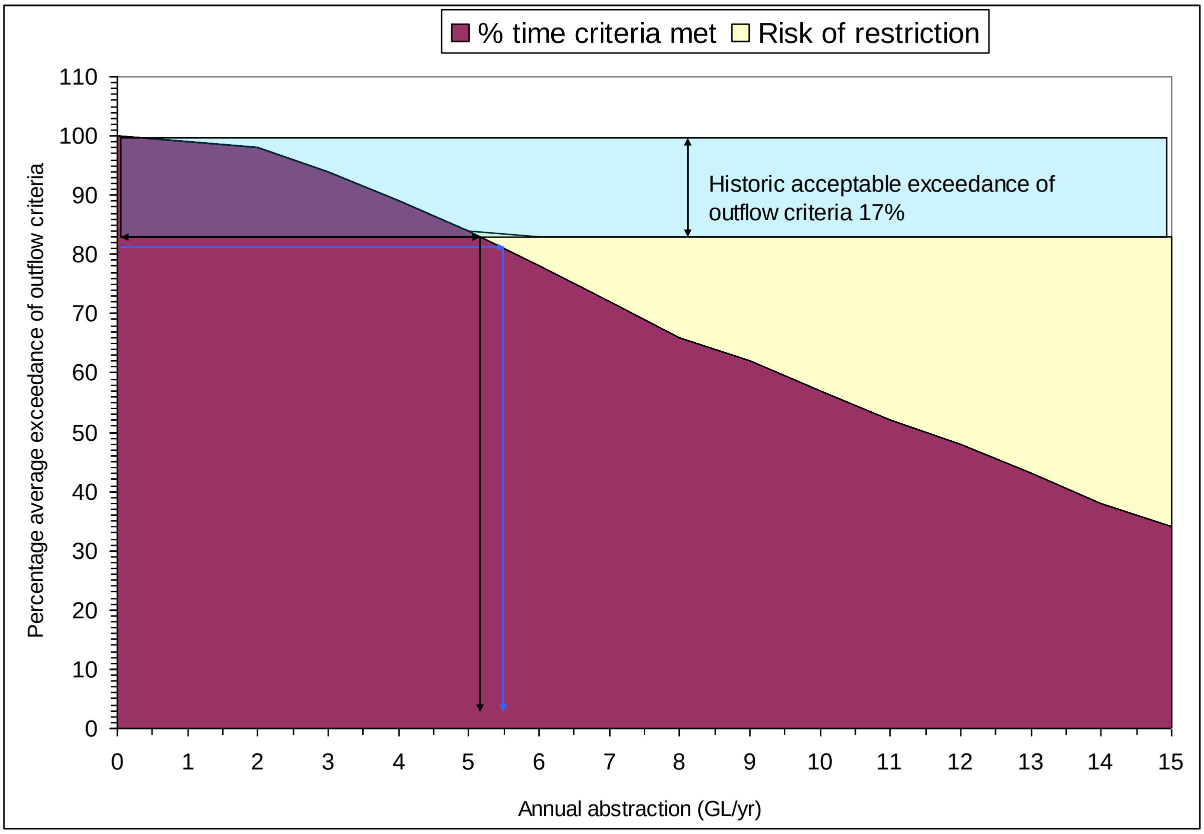

Figure 13 Average Chinderwarriner Pool outflow exceedance for average annual abstractions

At 0.0 GL/yr the revised outflow criteria for Chinderwarriner Pool (Section 2.2) are met 100% of the time. At 15.0 GL/yr the criteria are met 34% of the time and therefore exceeded 66% of the time.

Based on the review of historical monitoring data for pool outflows we have identified a long-term sustainable yield by applying an acceptable level of exceedance for the criteria (Table 4).

Table 4 Summarised Chinderwarriner outflow exceedances and reliability for possible mean annual abstractions

Annual Abstraction GL/yr	% time criteria met	% time additional restrictions required	Reliability (incorporating 17% acceptable exceedance) %
0.0	100	0	100
2.0	98	0	100
4.0	89	0	100
5.0	84	0	100
5.2	83	0	100
5.5	81	2	98
6.0	78	6	94
8.0	66	17	83
10.0	57	26	74
12.0	48	35	65
15.0	34	49	51

Allowing for the estimated non-detrimental level of breach of the Chinderwarriner Pool outflow criteria (17% of the time) the long-term sustainable yield is 5.2 GL/yr.

Any level of breach greater than 17% of the time is considered to be a detrimental level of breach.

Results for Deep Reach Pool outflow provide a similar sustainable yield of approximately 5.5 GL/yr for the same frequency of acceptable exceedance.

Based on the results from the estimated spring discharges for both Chinderwarriner and Deep Reach pools the department has set the long-term sustainable yield for the Millstream aquifer at 5.2 GL/yr.

2.4 Long-term reliable allocation

Given the economic importance of the water supply, the Department considers that a higher risk of restrictions can be managed. The department has set the long-term reliable allocation as 6.0 GL/yr. This allocation incorporates an acceptable exceedance of 17% of the time for the management criteria and an additional risk of restrictions 6% of the time.

This figure has not been set as an allocation limit for the Millstream resource because the actual abstraction from the aquifer can exceed 6.0 GL/yr if the aquifer levels are sufficiently high. Conversely, when aquifer levels are low, the abstraction from the aquifer will need to be restricted.

With the current management criteria in place to manage the risk to dependent values, 6.0 GL/yr is the amount that can be taken over the long term. It is therefore the figure that should be used in resource management and supply and new source planning.

2.5 Comparison with historical abstraction and previous yield estimates

The mean annual abstraction for the entire period 1968 to 2008 is 6.2 GL/yr. If we exclude 1981–1987 when abstraction reached record high levels and caused environmental damage an average of 5.1 GL/yr has been abstracted. Thus for the same time period when there has been a level of non-detrimental breaches of the spring discharge criteria of 17%, abstraction has averaged 5.1 GL/yr.

Average annual abstraction since 1987, when the system has been part of a conjunctive scheme, is 4.5 GL/yr.

The potential yield of the aquifer has also been estimated previously (Table 5). Previous estimates that incorporate consideration of the environmental demands of the dependent values are in the vicinity of 6.0 – 6.5 GL/yr.

Table 5 Previous estimates of the potential yield from the Millstream aquifer.

Year	Yield GL/yr	Context	Reference
1982	6.4[1]	Aquifer yield such that 100% of the environmental demand is meet. Aquifer yield is defined as that constant draw which gives a maximum depletion volume of 200 x 10^6 m^3 below the long-term average aquifer level of 293.6 m AHD.	SMEC 1982
1992	6.4	Aquifer yield such that 100% of the environmental demand is meet. Aquifer yield is defined as that constant draw which gives a maximum depletion volume of 200 x 10^6 m^3 below the long-term average aquifer level of 293.6m AHD (taken from 1982 source)	WAWA 1992
1998	6.4	The sustainable yield of the Millstream aquifer is estimated at 6.4 GL (referencing the 1992 source).	Welker 1998
1998	6.0	The long-term average abstraction from the Millstream borefield is 6 GL/yr.	Water Corporation 1998
2001	6.0	The long-term average abstraction from the Millstream borefield is no more than 6 GL.	Water Corporation 2001

[1]SMEC acknowledges that this yield would result in an aquifer depletion rate of around 2.0 GL/year and most of the environment's needs would eventually need to be met through supplementation.

2.6 Assumptions and limitations

The following modifications have been made to avoid overly conservative long-term sustainable yield and long-term reliable allocation estimates:

- The minimum discharge criteria for Chinderwarriner Pool has been lowered from 0.15 kL/s to 0.11 kL/s a 26% reduction.
- Discharge criteria have been simplified and higher November and December discharge levels removed (0.2 kL/s to a flat 0.15 kL/s).
- We have accepted the risk that by including years when measured discharge was artificially high due to supplementation we are likely to be over estimating spring discharge especially at critical low aquifer levels.
- Based on historical data and anecdotal evidence of environmental condition we have assumed an acceptable level of exceedance for spring discharge criteria of 17% of the time and incorporated this into the long-term sustainable yield.

It is also important to note that whilst the brief review conducted to facilitate the determination of yield and allocation figures has incorporated an acceptable level of exceedance of criteria in terms of time of breach, an acceptable magnitude of breach has not been investigated. This will be completed as part of a revision of the ecological water requirements and management criteria for the system.

The assessment of long-term sustainable yield and long-term reliable allocation has not incorporated an assessment of the potential impact of abstraction on water quality in the aquifer and its discharges. As previous periods of sustained high abstraction have coincided with localised increases in salinity this will be considered as part of the revision of ecological water requirements and management criteria for the system.

In setting an acceptable level of exceedance for the aquifer we have also considered that the modelling scenarios have been run on the basis of a constant abstraction from the aquifer regardless of aquifer level and/or spring discharge. That is, even when aquifer levels and/or spring discharges have been below the minimum criteria levels, modelled abstraction has continued. This artificial scenario will over estimate the impact of abstraction on the aquifer.

3 Next steps

With a long-term reliable allocation of 6.0 GL/yr from Millstream, the reliable supply from the conjunctive Millstream Harding system is approximately 9.0 GL/yr. The Water Corporation estimate the reliable supply of the conjunctive scheme at 10.0 GL/yr based on a simpler groundwater model for the Millstream aquifer.

The current use from the conjunctive scheme is in excess of 10.0 GL/yr and supply for the 2009–2010 water year which ended in March 2010 was approximately 14.0 GL. This was met from the scheme because of the significant recharge event which occurred in February 2009. This event filled Harding Dam and resulted in very high aquifer levels at Millstream.

However, the existing water supplies for Karratha are at capacity due to increasing demand from residential development associated with industrial growth and because the reliability of supply from current sources is highly variable. If there is no recharge for two to three years water levels will decline to the point where the scheme cannot meet supply under the current level of demand. Given the likelihood of this, the operating rules for the West Pilbara Scheme need to be updated to specify the restriction approach that will be applied through the *Rights in Water and Irrigation Act 1914* licence.

Demand is now considerably more than the long-term reliable supply from the conjunctive scheme, and risk of restrictions is greater than ever before.

Over the next 12 months, the department will continue to review the management and monitoring criteria as input into the Pilbara water allocation plan scheduled to be completed in 2012.

This report confirms the need for a third source for the West Pilbara Supply Scheme and can be used in assessment of future source options. A third source, independent of rainfall (or at least in a different cyclone path), would deliver a more robust conjunctive scheme.

Shortened forms

AHD	Australian height datum
MAL	Mean aquifer level
SKM	Sinclair Knight Mertz
SMEC	Snowy Mountains Engineering Corporation
WAWA	Water Authority of Western Australia

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