STAPYLTON RECLAIMED WATER STORAGE : ENVIRONMENTAL CONSTRAINTS ON THE DAM AND DIFFUSER DESIGN

M. Barker¹, T. Burt², K. McCallum-Gaul³, Dr M. Barry⁴

ABSTRACT

The disused Stapylton quarry is located in the suburbs of the Queensland Gold Coast. Gold Coast City Council, as part of the Northern Wastewater Strategy, has included the use of the quarry for storage and re-distribution of reclaimed water from the Beenleigh Water Reclamation Facility (WRF) to the downstream cane farmlands. A comprehensive EIS has been produced, which has strict water quality requirements for the quarry environs as well as the reservoir and outflow. This paper presents the background to the Northern Wastewater Strategy, the requirements for the Stapylton reservoir and the analysis performed for the detailed design of the embankment dam and the inlet bubble plume destratification system. The modelling of the destratification system was undertaken using the programme DYnamic REservoir Simulation Model (DYRESM) coupled with Computational Aquatic Ecosystems DYnamics Model (CAEDYM). The outcomes and implications of the modelling for the design and system operation including environmental monitoring are discussed.

Key Words: Destratification, Water Quality, Environmental, Monitoring, Reclaimed water

1. INTRODUCTION

1.1 Northern Wastewater Strategy

Background

Gold Coast City is one of the fastest growing areas in Australia. Population in the northern part of the City is expected to grow significantly from an approximate population of 70,000 to over 350,000 by the Year 2050.

In anticipation of this significant growth, Gold Coast City Council developed the Northern Wastewater Strategy (NWS). Development of the NWS involved significant community input through an advisory committee process. A further stakeholder committee known as the Northern Wastewater Effluent Reuse Advisory Committee (NWERAC) subsequently developed the Reclaimed Water Scheme (RWS) and incorporated reuse components into the Scheme, which will be completed in a number of stages.

The intention of the RWS is to recognise the valuable resource potential of reclaimed water, maximise social, economic and ecological benefits through maximising its reuse, and to release reclaimed water to waterways only when available reclaimed water is in excess of requirements for practical reuse. The reclaimed water is to be re-used in Stage 1A for irrigating sugar cane, cooling and power generation for the Rocky Point Cogeneration Plant and other option such as rehabilitating degraded wetlands, open space irrigation, and industrial use. Stage 1A of the RWS is shown on Figure 1.

The RWS requires a storage facility for reclaimed water in the Alberton-Stapylton area to balance the difference between the relatively constant supply of reclaimed water from Beenleigh Water Reclamation Facility (WRF) and the future Stapylton WRF (Stage 1B) and the time-varying demand for reclaimed water reuse, particularly in dry weather periods of high cane irrigation demand.

Site Selection Consultation and the Alberton Storage Siting Group

The initial site selection process considered 18 sites and ranked the sites by scoring against the selection criteria predominantly based on technical feasibility and limited social and amenity aspects.

The Alberton Storage Siting Group (ASSG) was then established to assist Gold Coast City Council to review the selection criteria and reassess potential storage sites. The ASSG was supported by Council consultants URS, GHD and The Rowlands Group to provide technical input and consultation logistics.

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A total of twenty five selection criteria covering social, technical, economic and environmental categories were used to shortlist five sites from which a disused quarry site had the highest ranking and was the preferred site for the Alberton reclaimed water storage. The particular advantages of this site included, an existing pit of approximately 300ML capacity, the location is in an industrial precinct, existing buffers between the site and the few surrounding residences, low visual amenity implications, and significant potential to enhance the degraded flora and fauna values of the site.

**Description of the Proposed Site**

The existing quarry pit, shown on Photo 1, has considerable volume below the lip of the pit and is in relatively low permeability rock. Three options were investigated for the design, which was based on the following requirements:

- An embankment at the eastern and western ends of the pit to RL 35m AHD;
- A spillway for rainfall events in excess of the 1 in 200 AEP event;
- Excavation of blast rock between the two voids in the pit to be used as the embankment shoulder material;
- Slope stability works for the pit walls;
- Inlet and outlet pipework;
- Air diffuser system for management of vertical variations of temperature and dissolved oxygen concentrations.

**Figure 1** Northern Wastewater Strategy Reclaimed Water Scheme Arrangement (Draft EIS)
1.2 Environmental Constraints

Environmental Management Documentation and Strategy

A schematic relationship of the various documents produced for the RWS is provided in Figure 2. A total of ten documents were prepared to assess the environmental impact and then define the environmental protection needs and constraints for the RWS system.

As shown on Figure 2, the Critical Issues Paper documented key environmental and social issues identified through a stakeholder workshop process and assessed using a risk-based procedure while the Review of Environmental Factors (REF) was the umbrella environmental assessment document which assessed the regional impacts of the overall scheme to 2050 and provided the framework for identifying areas where ongoing research and investigation are required, as well as management and regional environmental monitoring needs.

The REF was supported by four Environmental Impact Statements that dealt with specific wetland sites and the following Environmental Management Plans (EMP) that provided the framework for the development and operation of the RWS:

- The Operations Management Plan (OMP)
- The Construction Management Plan (CMP)
- The Wetlands Management Plan (WMP)
- The Irrigation Management Plan (IMP)

Figure 2 Gold Coast City Council - Northern Waste Water Strategy Functional Relationships
The Site-Based Environmental Management Plan (SBMP) for the Alberton storage included the following aspects relevant to water quality and dam design.

- Performance and operation of aeration and mixing equipment and monitoring of depth variation of dissolved oxygen and temperature.
- Management of algal growth and potential blue-green algae, control and variation of water storage level, monitoring and control of quality of reclaimed water supplied from the WRF, and monitoring of algal cell counts and nutrient and chlorophyll-a concentrations.

- Storage to be operated to maintain adequate free board to allow for wet season surcharge to ensure that the storage does not overflow (excepting for design extreme events). This will include monitoring of storage water level, supply and off-take flow metering, and climatic data (rainfall and evaporation) to contribute to refinement of the water balance analyses and seepage estimates.

- Groundwater level and quality monitoring to identify potential impacts arising from seepage losses from the storage.

2. WATER QUALITY

2.1 Hydrodynamic and Water Quality Modelling

The two main processes that have the potential to adversely influence the water quality in the storage are:

- The continual receipt of nutrient laden water from Beenleigh WRF in conjunction with summertime heating of the surface waters, which may promote enhanced phytoplankton growth in the storage.

- The potential development of a vertical summertime thermal stratification in the storage, which could result in the isolation of water at depth (referred to as hypolimnetic water), with a consequent reduction in local dissolved oxygen (DO) concentrations and a corresponding deterioration of water quality. This deep water then has the potential to mix with surface waters following natural dismantling of the thermal stratification in Autumn and Winter. This vertical mixing may also have the potential to encourage enhanced phytoplankton activity in the storage.

Simulation of the hydrodynamics and water quality of Stapylton storage utilised the following one-dimensional models developed by the Centre for Water Research (CWR) at the University of Western Australia.

DYRESM (DYnamic REservoir Simulation Model).

DYRESM is used for predicting the vertical distribution of temperature, salinity and density in lakes and reservoirs subjected to meteorological forcing, inflows, outflows and the action of artificial destratification systems.

Model inputs include bathymetric data, meteorological data (short wave radiation, cloud cover, air temperature, vapour pressure, wind speed and rainfall) inflow, outflow and initial temperature and salinity profiles.

CAEDYM (Computational Aquatic Ecosystem DYnamics Model).

CAEDYM is an aquatic ecological model that was coupled with DYRESM in this study, and consists of a series of mathematical equations representing the major biogeochemical processes influencing water quality.

CAEDYM has the capability to model the evolution of a large range of water quality parameters, ranging from metals to zooplankton and jellyfish. Of this range, the following subset was modelled in this study:

- Dissolved Oxygen (DO);
- Total Phosphorus (TP);
- Phosphate (PO₄);
- Total Nitrogen (TN);
- Ammonium (NH₄);
- Nitrate (NO₃);
- Biological Oxygen Demand (BOD);
- Total Suspended Solids (TSS);
- pH;
- Silica (SiO₂);
- Microcystis aeruginosa;
- Freshwater Diatoms; and
- Cylindrospermopsis raciborskii.

Model inputs include the inflow water quality, initial state condition and the
ecological and pollutant state parameters that describe rates, temperature coefficients and preference factors for a range of ecological and pollutant transport processes.

The limitations of CAEDYM (when linked with DYRESM, as in this study) were as follows.

- The inability to model horizontal variations in water quality parameters;
- The use of a simple sediment dissolved oxygen (DO) demand model, called the “static” model. This was used due to lack of site specific data describing the relationship between carbon accumulation and sediment DO demand for Stapylton storage;
- The processes involving invertebrate dynamics and grazing of phytoplankton by zooplankton were not simulated due to a lack of site specific data describing these processes;
- At the time of this study, CAEDYM did not model nitrogen fixation by phytoplankton and so this process was absent from the nitrogen budget.

2.2 Simulation Periods

In order to capture the range of hydrodynamic and water quality behaviours expected in the storage, two five year periods were simulated, the first comprising the repetition of a characteristic “wet” year, and the second comprising the repetition of a characteristic “dry” year. This was intended to capture the “worst case scenarios” that might take place in the storage where the “wet” simulation was intended to capture the effect of increased residence times (due to reduced withdrawals for irrigation purposes) and the “dry” simulation was intended to capture the influence of increased atmospheric heating (and hence increased likelihood for the development of intense stratification).

The average annual rainfall for the area is about 1200 mm and representative wet and dry years were selected for the periods 1/7/1988 – 30/6/89 and 1/7/1992 – 30/6/1993 with total rainfalls of 1610 mm and 613 mm respectively. A simulation interval beginning in July and extending through to the following June was selected so that the simulations could be initiated during winter where, in the absence of monitoring data, the storage could be assumed to be devoid of thermal stratification.

2.3 Calibration and Analysis

Calibration and validation of hydrodynamic and water quality models typically requires the use of extensive field data sets. During calibration, these data sets are compared with model outputs and model parameters refined such that the model replicates the field data. Validation then involves testing the calibrated model over a different time period and reassessment of model output against alternative field data sets. This process was not possible in the case of this study, as no hydrodynamic or water quality field data was available. As such, the models were run with parameters based on previous experience of other, similar water bodies. Although this is not ideal, there was no alternative for this study, since the dam is a new infrastructure component, no field data obviously exists.

DYRESM

Calibration was achieved by comparing the hydrodynamic model performance over the five year periods with “accepted typical behaviours” that have been observed to characterise other water bodies in south-east Queensland as follows.

- Typical temperatures:
  - Surface layers should be in the range of 25°C to 29°C during summer, and 15°C to 20°C during winter;
  - The bottom layers should not vary as much as the surface layers and should be in the range of 15°C to 20°C all year round. The bottom temperatures could increase beyond this range if the water body becomes so shallow that wind induced mixing is able to penetrate to the sediments.
- Typical hydrodynamic behaviour:
  - The storage should be relatively well mixed during the winter months (June through August) with a uniform temperature profile with depth (approximately 15°C);
The storage should begin to develop a vertical thermal stratification in August to September;

- This stratification should intensify throughout the ensuing summer months (October through February) with peak surface temperatures reaching approximately 28ºC to 29ºC. If the water body becomes so shallow that wind induced mixing is able to penetrate to the sediments uniform temperature would occur across the entire water depth;

- The stratification should begin to weaken over February through March, and be completely dismantled by the end of April.

The wet and dry five year periods were run in the model and contour plots of temperature obtained, as shown on Figure 3 for the wet period simulation.

Figure 3 Contour Plot of Temperature Evolution in the Storage, Wet Period Simulation

A typical plot of the annual temperature cycle predicted by the model is shown in Figure 4. Figure 5 shows a time series of typical surface and bottom temperatures in the storage, and demonstrates the clear summertime vertical temperature stratification in the reservoir.

These temperature ranges and hydrodynamic behaviours were deemed to be consistent with those characterising other South East Queensland lakes and reservoirs and the DYRESM model was assessed to be adequately predicting the likely hydrodynamic evolution of the proposed storage.

Figure 4 Temperature Evolution During a 12 Month Wet period Simulation

Figure 5 Time Series Temperature Evolution During a 12 Month Wet Period

CAEDYM Model

Based on previous experience of modelling water quality in freshwater reservoirs the three phytoplankton species (Microcystis aeruginosa, Freshwater Diatoms and Cylindrospermopsis raciborskii) are generally sufficient to largely capture the overall phytoplankton dynamics in typical water bodies.

By choosing to model the evolution of these three species in the Stapylton storage, it was not intended to imply that only these species will ever be present in the water body or that these species would be present at all. Rather, these species were used as guides for likely algal behaviour. The simulation results were, therefore, interpreted as being representative of
the overall phytoplankton dynamics likely to characterise the storage, rather than of any particular species.

The water quality of reclaimed water entering the storage was based on the release limits documented within the Beenleigh WRF licence conditions. Many of the conditions were nominated in terms of an 85th percentile value and in these cases, a median, or 50th percentile value was estimated, as noted in Table 1.

<table>
<thead>
<tr>
<th>Input</th>
<th>Value</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>DO</td>
<td>8.0 mg/L</td>
<td>Min. value of 4.0 specified. Selected value based on previous experience of DO concentrations in free flowing inflows.</td>
</tr>
<tr>
<td>TP</td>
<td>1.5 mg/L</td>
<td>85th percentile of 2.0 mg/L</td>
</tr>
<tr>
<td>TN</td>
<td>7.5 mg/L</td>
<td>Specified in Licence</td>
</tr>
<tr>
<td>NH₄</td>
<td>0.7 mg/L</td>
<td>85th percentile of 1.0 mg/L</td>
</tr>
<tr>
<td>NO₃</td>
<td>2.8 mg/L</td>
<td>85th percentile of combined NH₄ &amp; NO₃ of 5.0 mg/L and 85th percentile of NH₄ of 1.0 mg/L.</td>
</tr>
<tr>
<td>BOD</td>
<td>7 mg/L</td>
<td>85th percentile of 10 mg/L.</td>
</tr>
<tr>
<td>TSS</td>
<td>11 mg/L</td>
<td>85th percentile of 15 mg/L.</td>
</tr>
<tr>
<td>pH</td>
<td>7.5</td>
<td>Midway between max and min Licence values</td>
</tr>
</tbody>
</table>

Table 1 Median inflowing water quality concentrations derived from Beenleigh WRP Release Limits Table

The division of total phosphorus into particulate (organic) and dissolved (inorganic) fractions was an important consideration given that biological activity within the storage is likely to be limited by phosphorous availability – in particular the availability of dissolved phosphorous which is generally readily available for uptake by phytoplankton. It is generally accepted that the vast majority of phosphorus within reclaimed water from advanced BNR treatment plants tends to be in dissolved form, since the particulates are generally readily removed in the process. The 1.5 mg/L total phosphorus was, therefore, assumed to be in dissolved (Pas PO₄) form. It was also assumed that inflow concentrations of SiO₂, Microcystis aeruginosa, freshwater diatoms and Cylindrospermopsis raciborskii were zero. It was also assumed that phytoplankton growth and decay is largely dominated by in-storage processes, rather than by importation of phytoplankton-laden waters. The temperature of each inflow was computed as an average of the previous four days measured air temperatures.

The initial conditions for the model calibration were set to those of the inflow water given in Table 1 and the ecological and pollutant state parameters were extracted from a number of literature sources, including previous field investigation reports of other water bodies in South East Queensland. Some examples of the required parameters, and their corresponding values, were as follows:

- Maximum potential growth rate of Microcystis aeruginosa – 0.6/day;
- Static sediment exchange rate for DO – 2.6 g/m²/day.

As there was no monitoring data for calibration, the performance of the water quality model was assessed by examining:

- Typical DO behaviour:
  - The storage should experience oxygen depletion (to approximately 0 to 1 mg/L DO) at depth underneath the summertime thermal stratification;
- Typical phytoplankton behaviour
  - Elevated phytoplankton concentrations should be observed in the storage during the warmer summer months due to the abundance of light, warm water heated by solar radiation and.

The five year CAEDYM simulations were run and the results were assessed in terms of their adherence to these general trends.

Figures 6 and 7 show the evolution of dissolved oxygen concentrations during the dry period simulation. These figures shows that over summer, isolation of hypolimnetic waters can occur, with the possibility of severe reduction in bottom DO concentrations. In particular, the figures demonstrate that during mid to late September, DO concentrations at depth can begin to drop to almost zero, with intensification of this effect during November and December.

Figure 8 shows a timeseries of the typical annual Cylindrospermopsis raciborski evolution, (which dominates the simulated phytoplankton dynamics in the storage). This figure shows peak concentrations reaching over 100 µg chlorophyll-a/L.
As stated earlier, the results do not necessarily predict actual blooms of this particular species in the storage but suggests that overall, the storage is likely to experience elevated concentrations of some phytoplankton species during this time.

### 2.4 Destratification Design

A relatively common technique employed to prevent the evolution of stratified conditions and subsequent oxygen depletion at depth is the installation of a bubble plume destratification device. This involves pumping air down to the bottom of a water body through a pipe network and then out through a diffuser system of suitable diameter holes at regular spacings. This system does not directly deliver appreciable quantities of oxygen to the hypolimnion but the rising air forms a buoyant plume that generates a shear layer that entrains surrounding water. The ‘heavy’ bottom water is entrained, lifted and mixed with ‘lighter’ surface water in the water body. The ambient stratification is reduced and the water body is then capable of overturning under the influence of natural forcing such as wind. This overturning encourages the entire water column to remain well oxygenated, particularly at depth. This oxygenation at depth then minimises the release of nutrients and other pollutants from the water body’s sediments.

It should be noted that bubble plume destratification devices:

(a) cannot improve ambient water quality by any other means than maintaining a well mixed water body with elevated dissolved oxygen concentrations at depth; and

(b) cannot prevent the onset of water quality deterioration that might be caused in a water body by mechanisms (such as the perpetual inflow of nutrient or pollutant rich water) other than sediment nutrient or pollutant release. As these sediment releases are typically associated with low ambient dissolved oxygen concentrations, a bubble plume destratification device can only be of use in the improvement of water quality in a water body if persistent and prolonged reduced dissolved oxygen concentrations are observed at depth without the action of artificial mixing devices.
A similar design of entrainment was also provided for the inlet pipes to minimise the requirement to operate the bubble plume destratification system, thereby reducing the operational cost. The DYRESM and CAEDYM models were not able to model the inlet diffuser operation and only the bubble plume diffuser was modelled using the following system parameters:

- 350 metres in length;
- located at the base of the storage;
- contains 25 diffuser outlets;
- supports an airflow rate at depth of 20 L/s when the storage is full; and
- is operated from 1st July to 1st February each year.

The results of the wet simulation periods are presented on Figures 9 to 11, which show that the model predicts that the diffuser system:

- acts to adequately prevent thermal stratification of the storage;
- improves DO concentrations at depth to a typical minimum of approximately 5 mg/L; and
- reduces maximum *Cylindrospermopsis raciborskii* concentrations to approximately one third of that predicted by the simulations without the action of a bubble plume destratification device. This reduction is only indicative, as it is species dependent.

The simulations also predict that, in the absence of sediment nutrient release, the nutrient concentrations across the depth of the storage are typically uniform.

The water quality analyses have shown that the simulated diffuser generally improves the hydrodynamics and water quality in the storage during both wet and dry periods. However, the residual phytoplankton concentrations of 30-40 µg chl-a/L in the surface water, even when the diffuser is in operation, still point to a potential issue with phytoplankton growth in the water body over time. The following options were, therefore, considered to manage this potential outcome.

### 2.5 Phytoplankton Management

The water quality analyses have shown that the simulated diffuser generally improves the hydrodynamics and water quality in the storage during both wet and dry periods. However, the residual phytoplankton concentrations of 30-40 µg chl-a/L in the surface water, even when the diffuser is in operation, still point to a potential issue with phytoplankton growth in the water body over time. The following options were, therefore, considered to manage this potential outcome.

**Reduction of inflowing phosphorous loads**

Further simulations at approximately 10% and 5% of the original inflow bioavailable...
phosphorous concentration of 1.5 mg/L were run to assess the sensitivity of the storage phytoplankton dynamics to changes in phosphorous loading.

Chlorophyll-a time series information, and associated temporal statistics, were extracted from the model at 2 m below the water surface for these additional simulations. The mean, median, maximum and minimum chlorophyll-a concentrations are shown in Table 2, where the bracketed quantities show the percentage reduction of each statistic from the 100% (1.5 mg/L) inflow concentration scenario.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>100%</th>
<th>10%</th>
<th>5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>32.4</td>
<td>29.0 (10.5)</td>
<td>20.9 (35.5)</td>
</tr>
<tr>
<td>Median</td>
<td>31.8</td>
<td>29.3 (7.9)</td>
<td>21.5 (32.4)</td>
</tr>
<tr>
<td>Max.</td>
<td>41.1</td>
<td>35.0 (14.8)</td>
<td>25.1 (38.9)</td>
</tr>
<tr>
<td>Min.</td>
<td>25.8</td>
<td>23.2 (10.1)</td>
<td>15.6 (39.5)</td>
</tr>
</tbody>
</table>

Table 2 Chlorophyll-a Statistics of Reduced Phosphorous Inflow Concentration Simulations. Statistics in units of µg chl-a/L.

The benefit of reducing inflowing phosphorous concentrations to 10% of their original value is, whilst detectable, not as significant as for the reduction to 5% of orginal inflow nutrient concentrations. Assuming that *Cylindrospermopsis raciborskii* concentrations are representative of total chlorophyll-a concentrations in the storage (regardless of species), then a mean of approximately 20 µg chl-a/L in the 5% inflowing phosphorous concentrations scenario is not dissimilar to typical maximum total chlorophyll-a concentrations observed in other water supply reservoirs in South East Queensland.

**Surface impellers (mechanical mixing).**

The sole employment of surface impellers in Stapylton Storage was not modelled in this study. The operation of two surface impeller devices operating in conjunction with the bubble plume diffuser was simulated using 5 m diameter impellers with draft tube lengths of 13 m delivering 1 m$^3$/s of water to the bottom of the storage. At the time of the study, it was not possible to model draft tube length changes in DYRESM-CAEDYM. Consequently an artificial 5 year period was simulated using the dry year with altered storage inflows and outflows to maintain an approximately constant water depth.

The analysis results presented in Table 3 show that there appears to be little reduction in the *Cylindrospermopsis raciborskii* concentrations when the surface impellers are employed in addition to the bubble plume. The bracketed quantities show the percentage reduction from the bubble plume only scenario.

<table>
<thead>
<tr>
<th>Statistic</th>
<th>Simulation</th>
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<tbody>
<tr>
<td></td>
<td>Bubble plume</td>
</tr>
<tr>
<td>Mean</td>
<td>17.8 (2.8)</td>
</tr>
<tr>
<td>Median</td>
<td>17.5 (2.9)</td>
</tr>
<tr>
<td>Max.</td>
<td>24.9 (3.2)</td>
</tr>
<tr>
<td>Min.</td>
<td>11.6 (-4.3)</td>
</tr>
</tbody>
</table>

Table 3 Chlorophyll-a Statistics of Artificial Bubble Plume and Surface Impeller Simulations. Statistics in units of µg chl-a/L.

**Ongoing Operation of the Storage**

The simulation results are only indicative of the overall phytoplankton dynamics that are likely to characterise the storage. Without monitoring data of any kind, the recommendation for managing the potential phytoplankton issue in the storage was to move forward to the operational phase of the facility and commence monitoring of the situation over time.

The management of phytoplankton in the storage will be an iterative process and is likely to be related to the meteorological conditions, storage water levels and rate of drawdown or filling of the storage.

### 3. STORAGE MONITORING

Monitoring of the storage will be carried out in three phases: an initial short-term intensive phase of one year; a less intensive mid-term phase of 3 years; and low intensity long-term phase.

**Short Term Intensive Phase**

- Sampling Frequency of two weeks
- Sampling at a fixed location by means of a GPS.
– Measurements of temperature, dissolved oxygen and redox potential to be taken from at least 8 equi-spaced locations in the profile.
– Water quality samples at four positions measuring
  • Total suspended solids;
  • NO₃;
  • NO₂;
  • NH₃;
  • Total Nitrogen;
  • PO₄;
  • Total Phosphorous;
  • Total Carbon;
  • pH;
  • Conductivity;
  • Algal Species including;
    – Total Chlorophyll-a concentrations;
    – Total algal cell counts per mL;
    – Whether or not cyanobacteria are present and if so cell counts per mL of each cyanobacteria species present.

Mid Term Less Intensive Phase

Locations and sampling the same as the short term phase but with reduced sampling frequency of monthly intervals.

Long Term Low Intensity Phase

Locations and sampling the same as the short term phase but with reduced sampling frequency of two monthly intervals used to continually assess the performance of the bubble plume device and to keep a check on the general health of the storage

Data Review

The monitoring data will be progressively reviewed as it is collected to allow efficient assimilation of the data and an overall appreciation of the storage water quality as early as possible in the storage operation. After sufficient monitoring data has been collected to permit an informed assessment of the trends in storage water quality, Council will be in a position to assess:

• What phytoplankton species, if any, dominate in the storage;
• If the phytoplankton concentrations are of concern; and if so,
• How best to manage these species (depending on typical concentrations and toxicity); and,
• What measures could be taken to reduce their growth.

4. GROUNDWATER

4.1 Geology

Rock at the quarry site is quartzite, chert, greywacke and argillite belonging to the Neranleigh-Fernvale Beds.

Weathering in the rock is variable and depends to some extent on the rock type. Moderately weathered or slightly weathered rock occurs within a few metres of the ground surface across most of the site. No large or extensive permeable zones which could allow excessive leakage through the rock mass were evident. As shown on Photo 1, some of the upper rock profiles are slightly open with tension cracks evident on the surface due to stress relief in the natural slopes, relaxation of the rock mass around the quarry and the effects of blasting during quarrying operations.

4.2 EIS Requirements

According to the EIS, the potential impacts of the limited seepage from the storage facility are as follows.

• a rise in local and regional groundwater levels, with the formation of a groundwater mound underneath the storage facility and lateral dissipation of this mound;
• lateral seepage, through the walls of the storage facility, emerging at the ground surface downslope of the storage; and
• deterioration of local and regional groundwater quality.

The main areas of risk in the immediate vicinity of the storage included:

– the domestic water supply bores located immediately to the east of the Quarry; (not usually used domestically)
– the residential areas to the north;
– the agricultural areas to the east of the quarry;
– local creeks which receive contribution from groundwater, such as the Sandy Creek to the south of the quarry;
– the wetlands associated with Sandy Creek and located approximately 2.5 km to the east of the quarry;
– the Albert River to the west.
– the rubbish dump/landfill to the south-west;
– a quarry to the south of this site.

Of these identified receptors, the most sensitive were the domestic bores, the agricultural areas, Sandy Creek to the south and associated wetlands to the east, the residential areas to the north of the quarry and the Albert River to the west.

The embankment and groundwater seepage assessment for the storage was, therefore, undertaken for the north ridge area and the main embankment.

4.3 Permeability Data
Permeability data for the site included packer testing and in situ falling head tests located within the blast affected rock zones and the basement rock. Permeability values shown on Table 4 were evaluated using the test data for the upper 3m of the foundation in the blast affected zone and for the lower foundation rock. Where permeability data was not available, the adopted values shown on Table 4 were based on data available from other projects.

Seepage modelling is not sensitive to the permeability of the rockfill shoulders or drains as these do not form the impervious barrier of this 15.5m high 150m long clay core embankment. Nevertheless, the permeability value adopted for the rock fill assumed that this material will have a significant quantity of fines when placed.

4.4 Seepage Analysis and Results
Steady state two dimensional seepage models were developed using SEEP/W as follows:

- Seepage under the main embankment at the eastern end of the storage;
- Seepage through the ridge to the northern side of the storage.

<table>
<thead>
<tr>
<th>Material</th>
<th>Location</th>
<th>Perm. (m/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Found. Rock</td>
<td>Inside pit in walls</td>
<td>$1 \times 10^{-7}$</td>
</tr>
<tr>
<td>Upper Found. Rock</td>
<td>Under embankment blast affected areas</td>
<td>$2 \times 10^{-6}$</td>
</tr>
<tr>
<td>Upper Found. Rock</td>
<td>Under embankment blast affected areas after grouting</td>
<td>$1 \times 10^{-7}$</td>
</tr>
<tr>
<td>Lower Found. Rock</td>
<td>Basement rock in pit</td>
<td>$1 \times 10^{-8}$</td>
</tr>
<tr>
<td>Lower Found. Rock</td>
<td>Basement rock under embankment</td>
<td>$1 \times 10^{-7}$</td>
</tr>
<tr>
<td>Lower Found. Rock</td>
<td>Basement rock under embankment after grouting</td>
<td>$1 \times 10^{-8}$</td>
</tr>
<tr>
<td>Soils</td>
<td>Soils near surface outside pit</td>
<td>$1 \times 10^{-7}$</td>
</tr>
<tr>
<td>Clay Core</td>
<td>Core of embankment</td>
<td>$1 \times 10^{-9}$</td>
</tr>
<tr>
<td>Filter Drains</td>
<td>Transition zone or drains either side of embankment core</td>
<td>$1 \times 10^{-5}$</td>
</tr>
<tr>
<td>Rockfill</td>
<td>Shoulders of embankment</td>
<td>$1 \times 10^{-4}$</td>
</tr>
</tbody>
</table>

Table 4  Stapylton Storage Permeability Values for Seepage Analysis

The seepage model for the main embankment using the model parameters for the grouted foundation is shown on Figure 12. The model shows seepage past boundaries within the area assessed in m$^3$/s per metre of foundation, which have been changed to litres/day/m in Table 5 which presents the seepage analysis results for the existing foundation with the reservoir level at the FSL and the grouted foundation with the reservoir level at the present water level and the FSL.

The results of the analyses clearly show the beneficial effect of foundation grouting where the seepage is reduced from 31 ML/yr to 2.07ML/yr, with 1.99ML/yr (3.9 l/min) intercepted in the embankment drains leaving 0.08ML/yr (0.15 l/min) downstream of the embankment. Furthermore, the analyses assume that the storage is maintained at the full supply level of RL 34.5m throughout the year, which is very conservative as the storage level is likely to fluctuate from nearly empty to full on an annual basis. The estimates of seepage are, therefore, likely to be about one half of those found from the analysis.
4.3381e-007
4.3398e-007
1.7738e-008

Horizontal Distance (m)

-30
-20
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200

Elevation AHD (m)

-30
-20
-10
0
10
20
30
40
50
60

Figure 12  Stapylton Dam Seepage Analysis Results for Main Embankment with Grouted Rock Foundations and Reservoir at FSL of RL 34.5m

<table>
<thead>
<tr>
<th>Location of Seepage</th>
<th>Existing Foundation Reservoir at RL 34.5m</th>
<th>Grouted Foundation Reservoir at Existing Water Level ±RL 19m</th>
<th>Grouted Foundation Reservoir at RL 34.5m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>L/day/ m</td>
<td>Total ML/yr</td>
<td>L/day/ m</td>
</tr>
<tr>
<td>Under embankment axis</td>
<td>562</td>
<td>31</td>
<td>1.9</td>
</tr>
<tr>
<td>Downstream of embankment</td>
<td>53</td>
<td>3</td>
<td>1.9</td>
</tr>
<tr>
<td>Surface seepage at embankment drain outlet</td>
<td>509</td>
<td>28</td>
<td>No emb.</td>
</tr>
<tr>
<td>At property boundary</td>
<td>18</td>
<td>1</td>
<td>1.7</td>
</tr>
<tr>
<td>Surface leakage downstream of embankment to boundary</td>
<td>35</td>
<td>2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Table 5  Stapylton Storage Seepage under Main Embankment (150m length)

4.5 Surface and Groundwater Monitoring

A “v” notch weir will be located downstream of the embankment, which will facilitate seepage and surface run-off monitoring from the main embankment downstream slope and the foundation. In accordance with the Operations Management Plan, the following monitoring timing and parameters will be implemented:

- Monthly monitoring in the field for six months following construction for pH, SS, DO, Salinity, Oil and Grease, Iron Floc and Scum.
- Monthly laboratory analysis at a NATA registered laboratory for turbidity, dissolved oxygen, pH, aluminium and iron.
- Six monthly laboratory analysis at a NATA registered laboratory for pH, Total N, Total P, SS, Faecal Coliforms and chlorophyll-a.

Any changes in ecosystem will also be documented using bioindicators.

If the quality of the water fails to meet the EIS requirements or if the quantity is excessive and may affect the overall yield of the system, a sump will be provided downstream from the weir to pump the water back into the storage at regular intervals determined by the sizing of the sump.
An existing environmental monitoring program including groundwater monitoring is being used by GCCC to collect baseline data and information on groundwater levels and water quality in the vicinity of the storage. These monitoring bores will be maintained and monitored on a monthly and quarterly basis in accordance with the requirements of the Operations Management Plan and the EIS for which the following performance objectives will be evaluated:

- No significant change in seasonal groundwater quality.
- Maintain background groundwater quality.
- No significant change in the average seasonal groundwater level.
- No acid sulfate impacts resulting from the RWS.

5. CONCLUSIONS

Gold Coast City is one of the fastest growing areas in Australia. In anticipation of this significant growth, Gold Coast City Council developed the Northern Wastewater Strategy (NWS). The NWS siting studies resulted in the selection of a disused quarry site.

A bubble plume destratification device has been modelled for use in the reclaimed water storage. Although this modelling was not formally calibrated (due to a lack of monitoring data) it provided information on the sizing, installation and operation of a destratification device.

This work has shown that the use of this device will prevent the onset of stratified conditions and will subsequently result in more elevated dissolved oxygen conditions at depth. The outcome of preventing stratification is likely to be improvement in water quality and a reduction in phytoplankton activity. Destratification alone cannot entirely prevent elevated phytoplankton growth.

The recommendation for managing the potential phytoplankton issue in the storage was to move forward to the operational phase of the facility and commence monitoring of the situation over time. The management of the water quality during the operation phase is likely to be related to the meteorological conditions, storage water levels, rate of drawdown or filling of the storage and incoming water quality. The proposed monitoring program for the storage will be carried out in phases so that the evolution of its hydrodynamics and water quality can be followed and managed as an iterative process.

Alternative additional management tools have been investigated that could be used to improve the water quality in the storage if deemed necessary.

The seepage analyses performed for evaluating the effect on the groundwater have shown that seepage out of the storage will be of little consequence, with the majority of the seepage occurring under the embankment and collected using the sand drains which can then, if necessary, be controlled by pumping back into the reservoir.

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REFERENCES


2 WBM 2002, Water Quality Modelling of Stapylton Reclaimed Water Storage and Design of Destratification Infrastructure