Unique Planet Pty Ltd

The Aquadam Project

Hydrological & Yield Assessment Report

Issue 1
19 May 2006

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reference: S:\JOBCORRO\2005\076-100\05-091 Aquadam Project - Unique Planet PtyLtd\WBFeasibilty 05-091.doc

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DOCUMENT CONTROL RECORD

Belleng VDM Pty Ltd ***Evandale Place, 142 Bundall Road*** ***Surfers Paradise Qld 4217***		**Job No:**	2005-091
Telephone:	07 5510 3655	**File reference:**	S:\JOBCORRO\2005\076-100\05-091 Aquadam Project - Unique Planet PtyLtd\WBFeasibilty 05-091.doc
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Report Details:

Title:	The Aquadam Project Hydrological and Yield Assessment Report
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Status:	Issue No. 1 - Final
Client:	Unique Planet Pty Ltd
Client Contact:	Mr John Dobozy
Synopsis:	This report investigates the potential yield and hydrological requirements for the Aquadam Project, a floating water reservoir proposed to be anchored at sea.

Revision History:

Issue No.	Date	Checked By & Date		Issued By & Date		Distributed to:	No. of Copies
1	19/5/06	JE	19/5/06	DD	19/5/06	Unique Planet Pty Ltd	1
						Belleng VDM Pty Ltd	1

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1. Introduction

1.1. Background

Belleng VDM Pty Ltd have been commissioned by Unique Planet Pty Ltd to undertake an hydrological and yield assessment for the Aquadam Project.

The Aquadam Project is an innovative proposal to construct a large scale freshwater collection and storage system offshore to conserve valuable land area yet provide a viable storage volume for potable water treatment and supply.

1.2. Objectives

The objectives of this report are to investigate the feasibility of the hydrology through:

1. Identification of Council drainage catchments suitable for potential stormwater capture.

2. Estimate the potential yield and storage requirements for the identified catchments and Aquadam storage.

3. Provide an estimate of preliminary sizing for the project and analyse conveyance methodology;

4. Discuss conceptual details for the capture and delivery system.

5. Evaluate the feasibility of the adopted system.

2. Catchment Hydrology

For the Aquadam storage to operate effectively, it will be necessary to collect sufficient stormwater runoff from catchments close to the proposed storage location. For this report, the coastal catchments of the Gold Coast were studied to evaluate possible collection points and catchment areas necessary.

2.1. Viability

Recent experience with the proposed desalination plant for Tugun has indicated that it needs to provide a yield of approximately 20% of the daily demand to be considered viable by the local Council and State government. The current daily demand for the Gold Coast City is around 175 ML, resulting in an annual demand of approximately 63,875 ML.

Using this as a guide for the potential supply necessary from the Aquadam, it is estimated that the daily demand would be approximately 35 ML and the annual demand that could be expected would need to be 12,775 ML.

2.2. Rainfall

Average Annual Rainfall for the Gold Coast is naturally variable depending upon the measuring location. The Bureau of Meteorology station at the Coolangatta Airport has a recorded average annual rainfall of 1,509.9mm and the Southport station

40190 has an average of 1,462 mm/yr. To aid in the identification of appropriate catchments and contributing areas, we have selected the lower annual rainfall from Southport as a conservative approach.

2.3. Catchments

In estimating and identifying suitable catchment areas, the required annual demand of 12,775 ML has been divided by half of the average annual rainfall to allow for infiltration and loss of major storm events exceeding the capacity of the network. From this calculation it is estimated that a total catchment area of approximately 1,800 hectares will be necessary to provide the volume of runoff required to service the demand.

In the first instance, suitable catchments have been investigated based upon the average rainfall. These catchments have been identified and evaluated according to the following criteria;

1. Proximity to the coast;
2. Suitable area for runoff collection;
3. High percentage of impervious surfaces and therefore runoff;
4. Stormwater infrastructure presently in place.

Six catchments have been identified as potential possibilities for further investigation. These include; Main Beach (167.2 ha), Mermaid Beach (403.9ha), Surfers Paradise (292.6 ha), Nobby's Beach (119.1 ha), Miami (715.1 ha), and Palm Beach (246.9 ha).

Catchments of this size rarely drain to a single point for discharge, and final connection points would need to be identified during a detailed design stage. This may also influence the final catchment area draining to the connections, and would, therefore, need to be revised as the design process progressed.

3. RUSTIC

The computer program, Runoff Storage and Irrigation Calculator or RUSTIC, (DPI 1993) was used in this investigation.

RUSTIC considers daily rainfall within a catchment and estimates the catchment's runoff based on catchment characteristics in accordance with the USDA method of Runoff Estimation (United States Department of Agriculture). Runoff is routed to storage and drafted to supply the water needs of a crop. The crop in this instance is 20% of the daily potable water demand for the city.

Other sources of water considered by RUSTIC include direct interception of rainfall, reliable allocation and inter catchment diversion.

Key outputs from RUSTIC include:

- Long term storage reliability;
- Water demand requirements; and
- The number of days that water supply is available.

Data required for a RUSTIC analysis includes but is not limited to:

- Daily historic rainfall data;
- Daily evaporation data;
- Soil characteristics;
- Demand characteristics (continuous in this instance);

- Storage parameters; and
- Allocation volumes and rates.

3.1. Daily Historical Rainfall Data

Several rainfall stations exist within a reasonable distance from the site. To maximise the period of rainfall data used in analysis a composite daily rainfall file was created from 2 nearby stations with suitable data. Rainfall stations and details used have been identified in previous sections.

The daily rainfall file station for Southport was adopted as the base daily rainfall file for the composite rainfall file as it demonstrated the longest period. Where data was missing or incomplete it was adopted from a nearby rainfall station with the most similar overlapping data.

The composite daily rainfall file extended over an 82 year period from 1915 to 1996. The degree of correlation between the adopted rainfall data set and those of the nearby stations was considered suitable for use in further analysis.

3.2. Site Runoff

Only runoff from the nominated catchments was considered.

Runoff was estimated using the USDA Method (USDA). The USDA Method requires that a catchment be classified on condition, land use and soil type to derive a KII value. In conjunction with antecedent moisture conditions the KII value determines at what depth of rainfall runoff commences.

3.2.1. KII Value

The KII value estimated for the fully developed site was 80. This value is high but reflects the development of the catchments.

The KII values were weighted with area to produce the adopted KII value of 80.

3.2.2. Catchment Yield

Runoff generated from the catchment, or yield, was estimated with the USDA method for the fully developed catchments. Catchment yield is typically expressed in terms of percentage of years that a runoff volume would be expected based on the period of analysis. Note that reliability is based on long term analysis. It is likely that in any record there are small periods of a few years where the reliability is very low. Such periods can be seen in Figure 1, showing annual total runoff.

Catchment yields for 90%, 75%, 50% and 25% of years for the catchments have been listed in Table 1 for the full 82 year period of analysis.

Table 1. Catchment Yield Reliability

Scenario	Reliability (%) of Catchment Yield (ML)			
	90% of Years	75% of Years	50% of Years	25% of Years
All catchments	1,322	2,651	4,659	7,145

Key points to note from Table 1 include:

- In 90% of years it could be expected that the catchments generate 1,322ML; and
- The overall yield from the catchments is lower than the necessary annual demand of 12,775ML.

Total annual runoff volumes for the fully developed and partially developed sites have been presented in Figure 1.

3.2.3. Limitations of the USDA Method

The USDA Method is a simple and widely accepted method for estimating runoff from rainfall.

As daily rainfall is used in analysis, the intensity of a particular event is not taken into account. The runoff generated from 50mm that falls over a 24 hour period will be significantly less than runoff generated from 50mm that falls in 2 hours.

Despite this, the former Water Resources Commission of the Department of Primary Industries collected data from 20 farm storages indicating that the “average“ performance of a catchment was reasonably well represented by the USDA Method although measured runoffs from individual storms varied considerably to either side of the predicted value.

FIGURE 1. TOTAL ANNUAL RUNOFF VOLUME FOR SELECTED CATCHMENTS

3.3. Evaporation Data

The Department of Natural Resources, Mines and Energy (NRME) supplied average recorded daily evaporation data for Southport. Monthly values listed in Table 2.2 were converted from daily evaporation and included in the RUSTIC model.

Table 2. Monthly Recorded Evaporation

Month	Ave Evaporation (mm)
January	245
February	188
March	180
April	135
May	109
June	90
July	96
August	127
Septembe r	174
October	198
November	201
December	236

3.4. Storage Parameters

Aquadam's preliminary surface areas were estimated based upon the annual demand volume. Assuming a conservative depth of 5m for the storage resulted in an available area of around 255 Ha.

3.5. Annual Total Water Requirement

The annual water requirement for the Aquadam was calculated using the parameters discussed in previous Sections. This has been set at 12,775 ML.

3.6. Storage Reliability

Storage reliability is the term used to express the reliability, as a percentage of years in the analysis, that the Aquadam can meet the water requirements of the potable water demand.

If the water requirements of the demand are not met in full on a given day a failure is recorded. Reliability is calculated based on daily requirements as shown below in Equation 1.

$$\text{Reliability (\%)} = \frac{\text{Daily Volume Required}}{\text{Daily Volume Supplied}} \times 100 \qquad \text{Equation 1}$$

If the golf course requirement is not met in full on a single day a failure is recorded for that day. Failure to supply the full requirement does not insinuate that zero water was delivered, just not 100% of the requirement.

A reliability of 75% indicates that the water needs of the golf course were met in 3 years out of every 4. Storage reliability refers to the long term reliability calculated over the entire period of analysis. It must be noted that within any long term reliability analysis there will be shorter periods of lower reliability. It is not uncommon for a scheme with a long term reliability of 75% to demonstrate periods of 4 or 5 consecutive failure years, during such periods the short term reliability is well below the long term reliability of 75%.

The reliability figure of 75% discussed would be an appropriate level if the Aquadam was utilised as a “reserve” water supply during the dry periods. It would indicate that enough water was available to supply potable demand 3 years out of 4.

A reliability exceeding 95% was adopted as the goal in this investigation to reflect the continuous demand of potable water supply.

This was determined utilising a daily water balance model developed by Belleng VDM to aid in the sizing of rainwater tanks for various industries.

3.7. Reliability Analysis

Several scenarios to supply water were investigated to determine the reliability with which they could meet the potable water demand. Scenarios investigated have been listed in Table 3.

Table 3. Scenarios Investigated

Volume (ML)	Reliability	Percentage of Town Demand
100	41%	8%
150	49%	10%
200	53%	11%
250	57%	11%
300	60%	12%
400	64%	13%
500	68%	14%
600	70%	14%
800	74%	15%
1000	76%	15%

Water supply reliabilities for Aquadam for each scenario investigated have been listed in Table 3. Recall that the full supply of the potable water requirements in 95% of years was the reliability target.

Key points to note from Table 3 include:

- Reasonable reliability is achieved with the use of a storage of around 800ML;
- Additional benefits for increased capacity diminish;
- The desired reliability of 95% does not seem achievable with the demand criteria imposed.

Figure 2 details the results from the water balance analyses demonstrating that the storage appears to reach an asymptote beyond which increased storage volume appears to make little difference. This is a factor of the limited catchment area draining to the storage and the volume of water demand.

Therefore, the catchment area required to improve the reliability has been investigated. As can be seen in Table 4, it is necessary to have a catchment area of approximately 2,800 Ha and storage volume of 1,000 ML to improve the reliability to the desired level.

Table 4. Alternate Catchment Areas for Improved Reliability

Volume (ML)	Reliability	Percentage of Town Demand
100	47%	9%
150	59%	12%
200	65%	13%
250	71%	14%
300	74%	15%
400	80%	16%
500	84%	17%
600	87%	17%
800	92%	18%
1,000	95%	19%

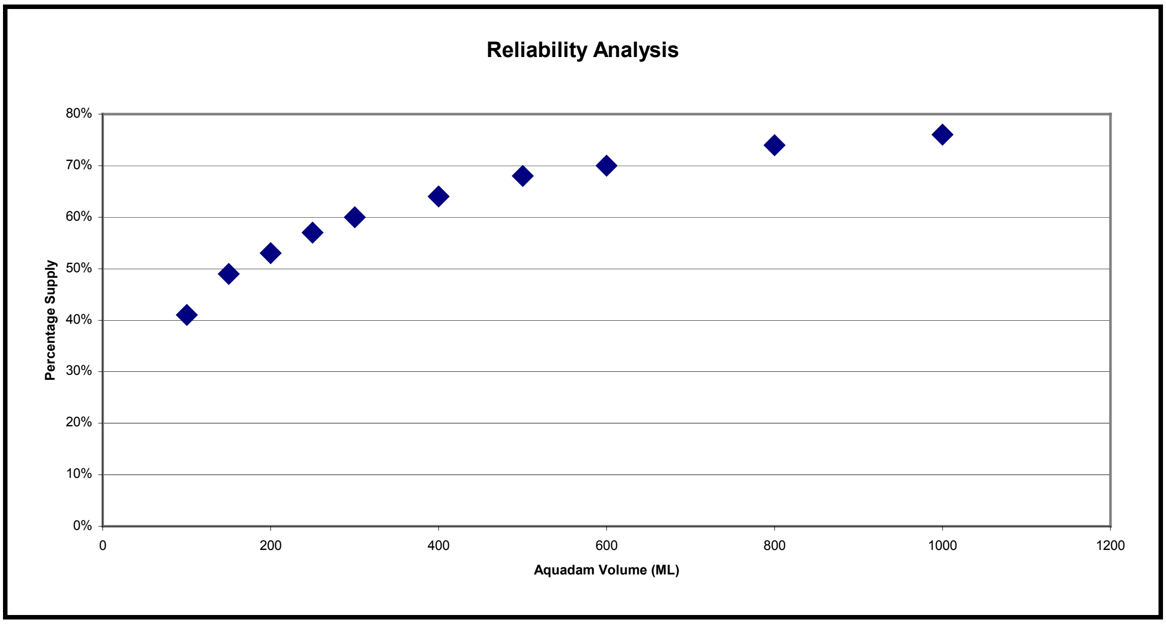

FIGURE 2. RELIABILITY ANALYSIS

4. Conveyance Methodology

Collection and transport of the runoff to the Aquadam is potentially the biggest challenge to its construction and acceptance by authorities and community. Connection to the outlet structures that exist presently, discharging to the beach and/or neighbouring waterways, would need to provide a hidden solution such that pipes were not seen crossing beaches. To facilitate this, it would be necessary to intercept the pipes prior to the beach, probably with a manhole or drop structure, and lower the invert below the level of the beach following recorded erosion events.

Construction of a submarine pipeline would then need to be undertaken with a watertight material and fully sealed to ensure infiltration is minimised. Similarly, as the pipeline will be below water level, it is unlikely that gravity will be able to drive the stormwater flow into the Aquadam, therefore, it is probable that it will be necessary to pump the stormwater into the storage. Alternately, it will be necessary to lower the storage bladders below the sea level to facilitate flow into the structure, transferring the energy costs from pumping to mechanical depth controls.

Whilst a detailed analysis of each sub-catchment has not been undertaken within the scope of this report, it will be necessary to identify each outlet structure. These may number in the hundreds to maintain the desired catchment area and will result in significant construction costs.

Additionally, assuming water treatment was provided aboard the Aquadam, a “treated supply” pipe would need to be installed to pump back into the network or land-based reservoir. If treatment was not provided onboard Aquadam, the untreated water would need to be pumped back to the nearest water treatment plant, presently located at Mudgeeraba. This would have significant costs associated with it.

If the intent of Aquadam was altered to be a storage maintained solely by desalinated water from an “onboard” desalination plant, then there would potentially be only one pipe connection back to the land and this could inject into the existing supply network or a land-based reservoir. In terms of risk assessment regarding potential failures in the network, it is considered that there would be less risk of both minor and catastrophic failure associated with this option.

It would appear that whichever option is selected, it will require pumping to facilitate the collection and supply of water back to the land.

5. Potential Constraints

The following constraints have been identified:

- A structure of the volume discussed above will have a significant footprint. This is likely to be clearly visible from many community members living in high-rise apartments, even if anchored kilometres from shore. This aesthetic outcome would need to be addressed through effective community consultation.
- The significant footprint, if constructed as a single structure, will likely affect ocean currents and wave set-up. Intensive studies will be necessary to satisfy the relevant authorities and community groups (eg. Surfriders) that the structure in any proposed location will not adversely affect the beach breaks and sand movement.

- The capture of untreated stormwater from urban areas for ultimate use as potable supply will possibly raise similar objections to those raised regarding indirect potable reuse of treated effluent.
- Urban stormwater runoff contains many contaminants that are potentially difficult and expensive to remove at high flow rates. Once removed from the runoff, the contaminants will constitute a hazardous waste that must then be disposed of to an appropriate waste management facility. (Refer Table 5)
- Anchoring the Aquadam, whether a flexible or rigid structure, will likely require a construction similar to an oil rig. This will require risk analysis for performance during extreme events.
- Both stormwater treatment and desalination will require significant amounts of energy to drive pumps and processes. However, the footprint should provide significant potential for utilisation of wave, solar and wind energy. This would need to be investigated in more detail as the scope refines.
- The coastal environment can be corrosive to electrical components and any power generation facilities would need to be designed to withstand the harsh conditions.
- Access arrangements for staff and/or visitors would need to be investigated and emergency evacuation plans prepared for extreme weather events.
- If desalination is selected, detail modelling will be necessary to evaluate any potential impacts associated with the discharge of brine byproduct back to the sea.
- Demand considerably influences the viability and reliability of supply when determining the capacity of the Aquadam and the catchments supplying it. If the demand were for smaller industries, communities or "townships" it is likely to improve in reliability than the criteria of supplying 20% of the current City's demand, but this would need to be balanced with a reduced catchment area.

Table 5. Urban Runoff Pollutants and Sources

(Mudgway et al. 1997; Camp Dresser & McKee 1993 and Makepeace et al. 1995)

Pollutant	Automobiles & roads	Atmospheric deposition	Residential activities	Industrial activities	Construction activities
Sediment	Pavement wear	Air-borne dust	Erosion		Erosion
Nutrients (N and P)	Roadside fertiliser		Organic matter, fertiliser, cleaners	Solvents, cleaners, waste	Waste
Bacteria & viruses			Organic matter, septic		
Oxygen demand	Street litter	Wet deposition	Organic matter		
Oil & grease	Lubricants & motor fluids (spills, leaks)		Paint, solvents	Oils, lubricants	
Heavy metals	Cr, Cu, Pb, Zn, Fe, Cd, Ni, Mn – emissions, lubricants, corrosion, wear of tyres (filler), bearings,		Cd, Cr, Cu, Pb, Zn, - corrosion, pesticides, herbicides, fertilisers, paint weathering, roofs	Cd, Cr, Cu, Fe, Ni – metal finishing, combustion products	

	brakes				
Toxic materials	Fuels, herbicides, pesticides, eg. fuel combustion	PCBs, herbicides, pesticides	Herbicides, pesticides (including As)	Fuels, pesticides, herbicides, eg. smelting	Herbicides, pesticides
Floatables	Litter		Litter	Litter	Litter, waste

Empty grey cells indicate that specific sources are not outlined in literature. Empty white cells imply that the source is not common.

6. Potential Benefits

The following benefits have been identified:

- Depending upon the final operation model for the Aquadam, it could provide a suitable "emergency reserve" for stormwater supply or an alternate supply through desalination for less than 20% of the daily potable water demand.
- It would not occupy vast areas of land for storage.
- Depending upon construction and design, the Aquadam could provide significant new fish habitat and commercial fishing & diving opportunities.
- It would harness renewable energy to reduce or eliminate requirements for land-based electricity supply.
- It would potentially create hundreds of jobs during construction and operation.
- The disposal of brine, typically a major constraint associated with desalination plants, will be direct to the ocean and subject to significant dilution and mixing actions far from terrestrial ecosystems.
- Depending upon the location and construction, the structure could provide dampening of wave effects during extreme events thereby protecting valuable beachfront properties from erosion.
- "Lost" urban stormwater runoff would be captured, treated and reused.
- Existing stormwater discharges to coastal beaches would be removed and relocated underground.

7. Legislative Requirements

The Aquadam project will likely require several approvals from Federal, State and Local governments to proceed. The following list of legislation, whilst not exhaustive, is an indication of those requirements to be addressed;

- Integrated Planning Act (Qld) 1998
- Environment Protection Act (Qld) 1994 and associated Environmental Protection Policies
- Coastal Protection and Management Act (Qld) 1995
- Water Act (Qld) 2000
- Environment Protection and Biodiversity Conservation Act (Aus) 2000

A project of this scale and nature will require the support of the local authority and in Queensland could be considered to be a "Project of State Significance" and therefore could be "called in" to be assessed by the State Government, if necessary. It will be subject to referral agencies and will likely be controlled by the State Government as a result of the number of Departments involved.

It would also need to address the “controlled actions” requirements of the EPBC Act and therefore be assessed by the Federal Environment Minister and Department of Environment and Heritage.

8. Summary

Evaluation of the hydrology and potential yield for the Aquadam has indicated the following:

- Reliability of supply, based upon providing 20% of the Gold Coast City's current potable water demand, varies between 41% and 76% using discharges from the coastal catchments from Main Beach to Palm Beach and storage volumes between 100ML and 1,000ML.
- Reliability improves through reducing daily demand and/or increasing catchment area.
- The feasibility of the capture, treatment and storage of urban stormwater runoff appears less than the feasibility of desalination and supply from the Aquadam.
- The construction of a storage suitable to provide 20% of the average daily demand for the Gold Coast will have environmental, economic and social impacts both positive and negative that would require further detailed investigation.
- The Aquadam, as a desalination storage for a smaller community or township appears to be a feasible solution to providing water storage without the construction of many hectares of dams.

9. References

The information presented herein has been prepared with reference to the following:

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