

OPERATIONS DUE DILIGENCE

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R2A Due Diligence Engineers

Summary:

With limited resources available for organisations to deliver sustained prosperity and safety there is a need to ensure assets and processes are being utilised efficiently and effectively. To meet the expectations of shareholders, boards, customers and regulators, this needs to be demonstrated in a diligent, transparent and robust manner.

The *Operations Due Diligence* process for a site, plant or process, addresses issues from a strategic viewpoint by determining the actual plant efficiency in the context of all of the credible risk issues and system characteristics to which the site is exposed. It highlights the areas of greatest concern. Precious resources can then be targeted to optimise existing assets and processes to get maximum net outputs from the plant.

A case study of the Operations Due Diligence process as applied to the Gladstone Area Water Board for critical infrastructure is presented. The Queensland Competition Regulator¹ has published the full report.

Keywords:

Due Diligence, Risk Management, Operations, Reliability

1 INTRODUCTION

Transparency in decision-making in complex technological enterprises is often difficult. Requests for greater system, plant or network reliability is often seen as 'gold plating' by financial markets and shareholders, and yet the failure to have sufficient redundancy can result in the catastrophic loss of shareholder funds and community devastation.

The sorts of questions often asked include:

- We know that there are offsite issues that can seriously affect our product delivery processes. We do not have direct control over these offsite resources. How can we communicate our concerns to those responsible in a way that motivates action?
- Our engineers have recommended new plant upgrades. We recognise that their arguments are based on good engineering practice but we can't see a robust connection to future profitability. How can these recommendations be transparently assessed?
- How do we include offsite threats in a meaningful way in our overall plant availability model?
- We have had reliability studies completed on our plant. But there are some credible, critical issues that are considered to be so unlikely they don't seem to rate any attention. We know that if one happens, the business will be critically exposed. How do we demonstrate the importance of these to the board in a constructive way?
- We have spent a great deal of time and effort on reliability studies. But we don't feel they are contextually sound and have no process to test this. Is there a way this can be addressed?

The top-down Operations Due Diligence process specifically addresses these questions and enables a persuasive argument to be presented for proposed upgrades. It also ensures that the outcomes are aligned with the values and goals of the organisation.

¹ <http://www.qca.org.au/files/W-GAWB2010-PriceInvest-Sub2-App16-1209.pdf>. Viewed on 15Nov2012.

2 THE LIMITATIONS OF CONVENTIONAL RELIABILITY ANALYSIS

Conventional asset availability management has been traditionally done 'stair-wise' (bottom-up) outside the context of the enterprise risk framework, enabling high level critical issues to be overlooked. Analysis is focused almost exclusively on the physical characteristics of the system.

Bottom-up analysis has a number of shortcomings from the decision makers' viewpoint. From an organisational viewpoint, all causes of system failure are important, including factors such as external effects (for example, materials supply interruptions, power failures, bushfires, floods, staff epidemics) and accidents (for example, building fires, materials handling, vehicle collisions, operator errors). In addition, common mode failures are influenced by physical co-location and will only be identified if different systems are analysed together, rather than in isolation. And there are often functional relationships that aren't clear from a low-level hardware description. These factors are external to the traditional scope of availability / reliability analyses but can have a disproportionate effect, as the damage caused can be severe, leading to much longer downtimes than simple failures.

Further, in large organisations, analyses tend to follow the organisational structure, with separate models produced for each department then being combined to produce the overall model. This can have the effect of lower levels focusing on what is important to the department, rather than the organisation as a whole, and omission of issues that fall outside individual departments – particularly common cause vulnerabilities. This is depicted in the figure below.

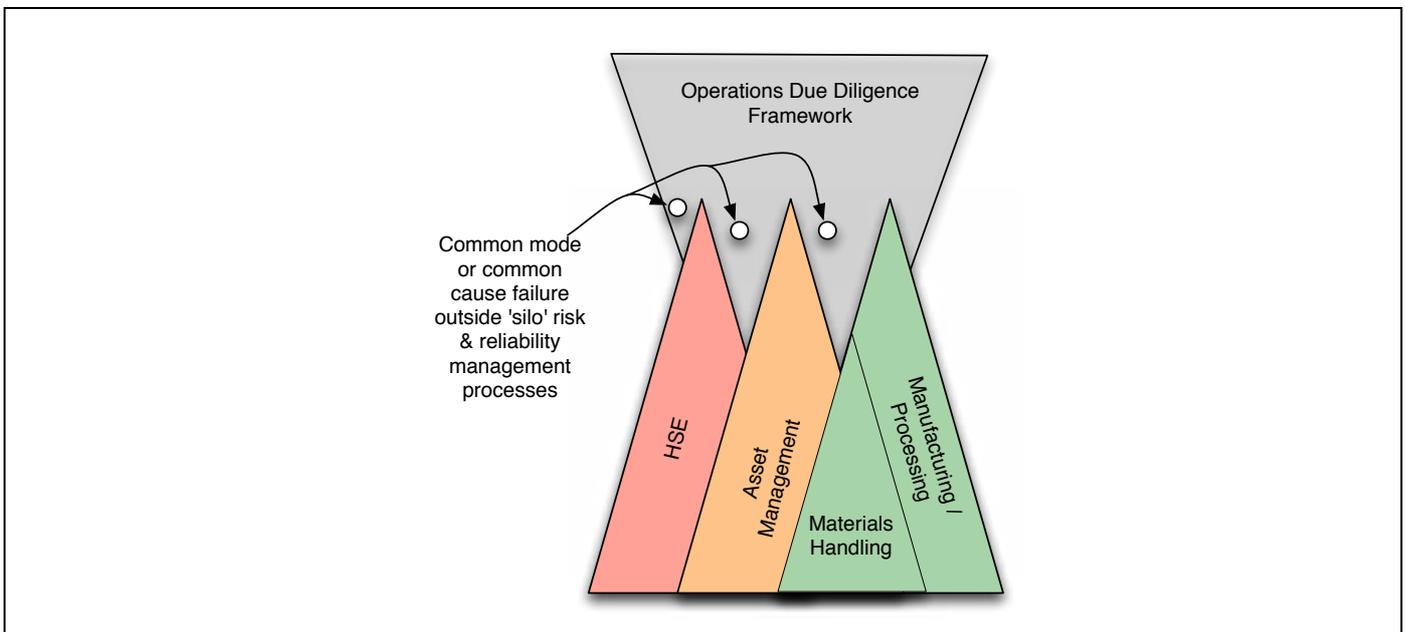


Figure 1: Operational Silos

A full bottom up analysis is voluminous – usually requiring significant further effort to identify issues of concern. The final conclusions are produced from what can appear to be an abstract collection of data, with direct connections between cause and effect difficult to see. Decision makers are required to trust the results of such an analysis, allocating resources without a clear, contextual understanding of the issues.

3 TOP DOWN OPERATIONS DUE DILIGENCE

Operations Due Diligence provides a completeness check to ensure that all credible external and on-site common mode threats are identified for large complex operations (including plants, mines, distribution/supply networks). From a criticality viewpoint, any credible event (usually rare) that can cause long outages will be of primary concern to senior decision makers. In addition, high-level availability modelling focuses on identifying the independent elements within the system so that senior decision makers are made aware of critical process bottlenecks that could constrain the business. The key outcome of the review is to ensure that there is a focus on credible critical issues so that all reasonable practicable precautions are in place for each. The analysis is aligned with the organisational values and goals using a transparent process that is easy to present.

Operations due diligence is a top-down approach consisting of 4-stages as represented below:

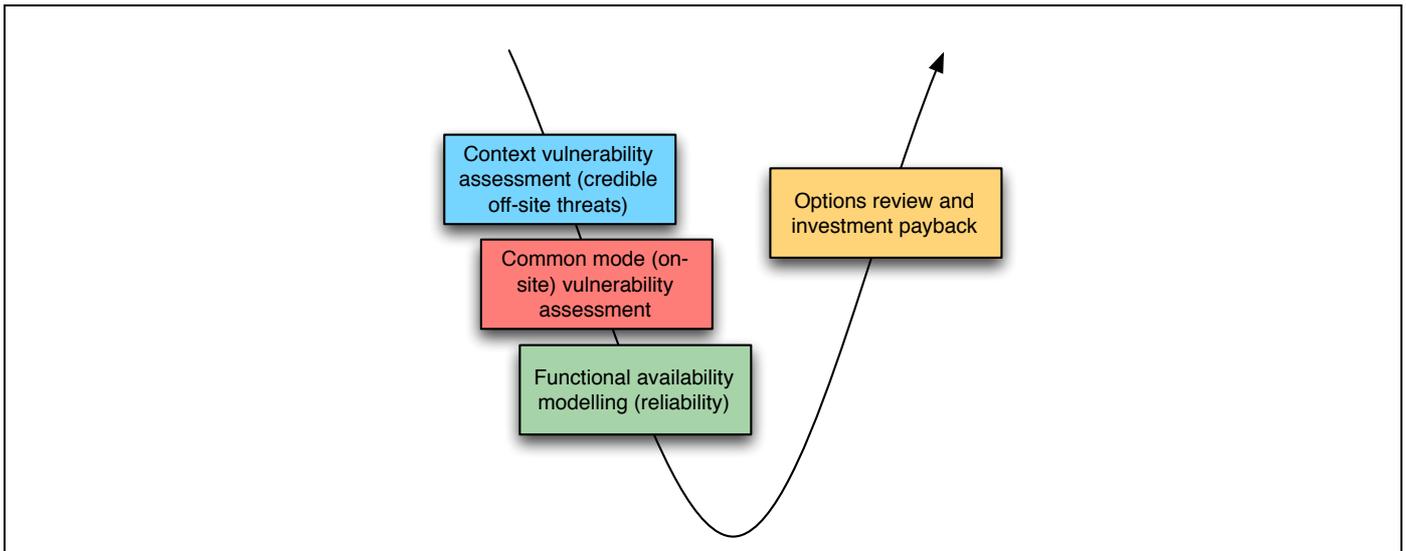


Figure 2: The four stage Operations Due Diligence Process

1. **Context Vulnerability Assessment:** This is a high-level context (boundary) analysis providing a strategic completeness check of potential vulnerabilities to determine the issues that can critically impact on the operations. This is an established process derived from the security / military intelligence community. It simply asks two questions: “What are we trying to achieve” (that is, what required outcomes need protection) and “what are the credible threats to these aims?”
2. **Common Mode (Zonal) Vulnerability Assessment:** This is a geographic or zonal risk ‘completeness’ assessment undertaken by examining each major element in its geographic, community and environmental context. It identifies site-specific issues such as critical common mode and common cause failures including fires/explosions, pipe failures and power failure. These are typical common mode failures for which organisations purchase insurance, especially fires and explosions. This process is long established in underwriting and Highly Protected Risk (HPR) industries. By focussing on failure modes that affect multiple sections of the plant or process, or which don’t fit into the silos defined by the organisation, risks are defined within the context of the boundary vulnerability analysis. This leads naturally to the preliminary segmentation of the plant or process into functional sections affected by different common mode failures, rather than accepting, without testing, the organisational silos defined prior to the study.
3. **Functional Availability Modelling:** The key concept here is to divide the system or process under consideration into sub-systems that are independent of each other and that all the interested parties can picture and agree represents the system as a whole. Block diagrams are a simple way of representing complex systems diagrammatically and can be used for both risk and availability studies.

Care must be taken when constructing models, as physical layout may not represent the functional arrangement. For instance, if two power feeds are physically in parallel but, alone, neither can supply enough power for the process, they are functionally in series. Critical process components show up as bottlenecks in the block diagram, as do any common mode failures identified in the previous step.

The following figure describes the integration of the first three steps of the process.

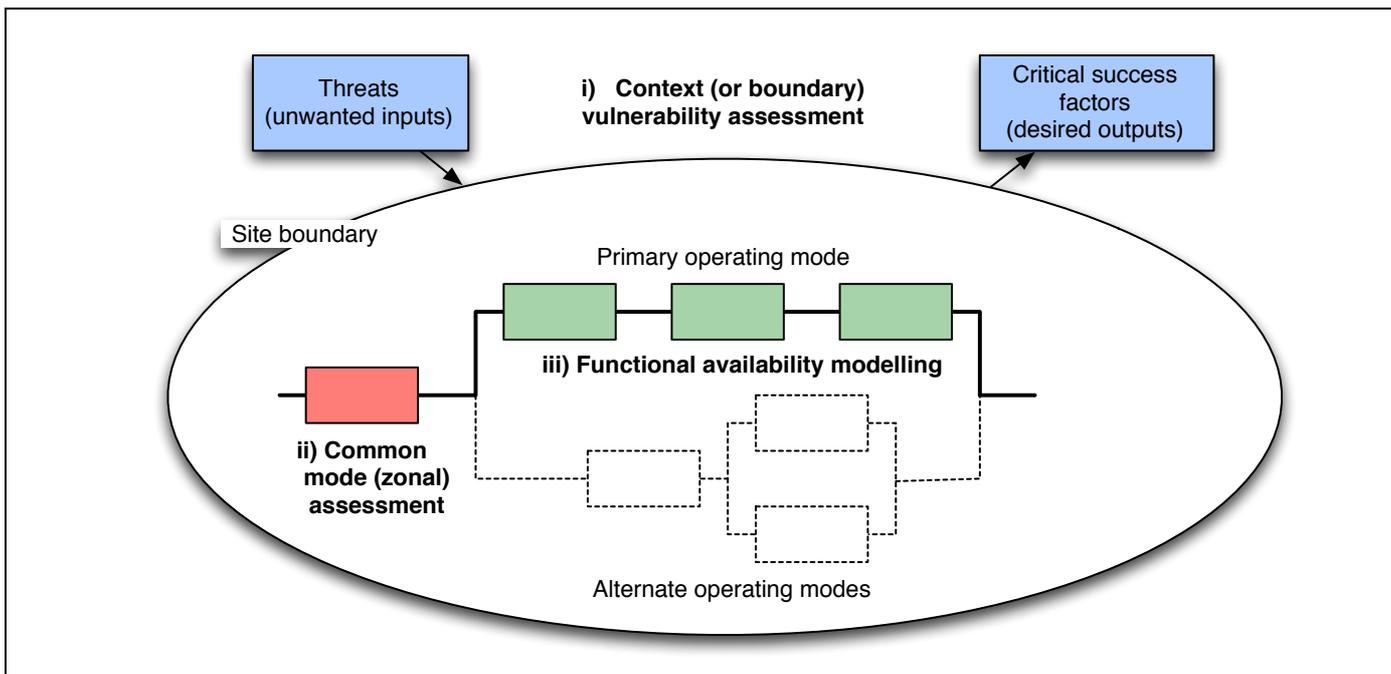


Figure 3: Interaction of the Operations Due Diligence tasks

4. *Options review, investment payback and recommendations:* Options to address the identified concerns are developed in consultation with stakeholders. Where different options are available, further modelling is conducted to determine which options should be recommended to management.

The key to all this work is the way in which results are presented to decision makers. There is no single 'right' way. It depends on the organisation and the services provided. The diagram below shows a demonstration model in a format that has often proved effective.

External and off-site Common Mode Failures				Site				Distribution																																																																															
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Figure 4: Summary functional availability model

To the left are the external off site threats that constrain the entire business. Senior decision makers usually assess these items by 'days out'. This is a measure of criticality, which is related to the type of business under consideration. If more than a week would be catastrophic, then all the credible issues that can cause more than a seven-day outage must be (seen to be) addressed.

Each of the primary onsite elements is considered further by delving into each individually. Again, the common mode failures for that process are identified and again, from a criticality viewpoint, any credible event that can cause long outages will be of primary concern to senior decision makers.

4 CASE STUDY – GLADSTONE AREA WATER BOARD CRITICAL INFRASTRUCTURE REVIEW

Gladstone Area Water Board (GAWB) commissioned R2A to undertake a critical infrastructure due diligence review to ensure that all sensible practicable precautions were in place to provide adequate water supplies to GAWB bulk customers².

Gladstone Area Water Board (GAWB) owns and operates bulk treated (potable) and raw (non- potable) water storage and supply system throughout the Gladstone region of Central Queensland. Assets include:

- Awoonga Dam on the Boyne River and raw water pumping station
- Gladstone and Yarwun Water Treatment Plants
- Raw water reservoirs at Gladstone (Fitzsimmons Street – 50MI and 16MI) and Toolooa (50MI)
- Treated water reservoirs at Boyne Island, East End, Golegumma, South Gladstone, Mt Miller, Gladstone Clearwater and Yarwun Clearwater
- Delivery pipelines (121km of raw water pipelines and 90km of treated water pipelines).

The network arrangements require water to be pumped from Awoonga Dam to Toolooa Reservoir nightly. The water is then distributed throughout the network the following day. Given this arrangement there is limited time available for preventive or corrective maintenance to the system without causing significant interruption to supply.

4.1 Functional Boundary Analysis & Common Mode Vulnerability Assessment

In order to determine the actual effective availability of the network in the context of all the credible risk issues for each of the critical customers identified, the following boundary analysis was completed. The context boundary was defined from the Awoonga pumping station to the meter of each critical customer as shown schematically in the diagram below.

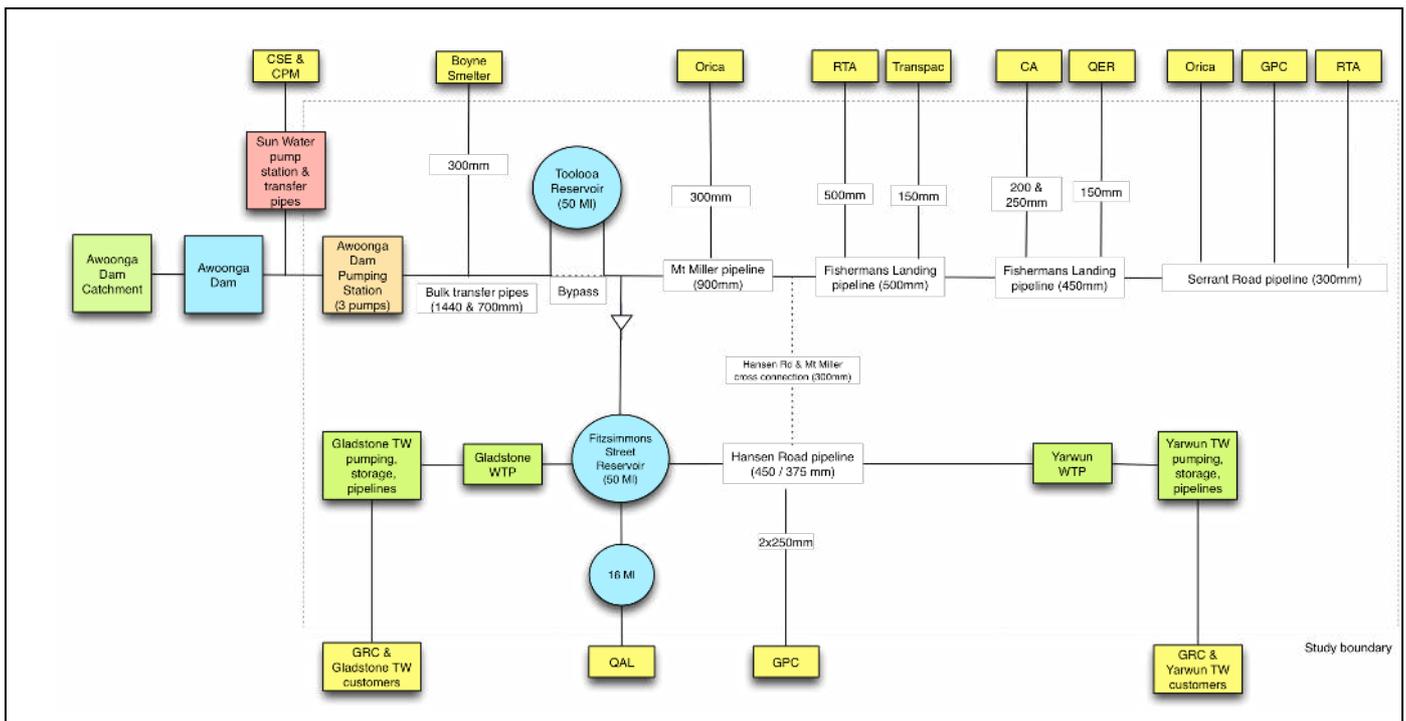


Figure 5: Bulk Water Transfer Functional Schematic

² <http://www.qca.org.au/files/W-GAWB2010-PriceInvest-Sub2-App16-1209.pdf>. Viewed on 15Nov2012.

The following vulnerability assessment was then completed identifying the critical success factors (defined as the requirements of GAWB's bulk customers) and the external (boundary) credible threats.

		GAWB Delivery Critical Success Factors									
		Boyne Smelter 650 Treated water (ML pa) 80	Cement Australia 230 40	Gladstone Port Corp. 580 -	Orica 1,120 570	QAL 10,775 6	QER 10 -	RTA 3,700 515	Transpacific 25 -	GRC - 9,000	CSE & CPM - -
Credible Threats											
1	Dam failure (earthquake, flood)	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2	Bushfire (catchment)	x	x	x	x	x	x	x	x	x	x
3	Power failure (cyclone/storm, supply failure, switchyard failure)	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
4	Regulatory changes incl. reduced allocation	x	x	x	x	x	x	x	x	x	x
5	Inundation / flood (tailwater)	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
6	Industrial issues incl. contractors esp treated water	xxx	xxx	-	xxx	xxx	-	xxx	-	xxx	-
7	External comms failure eg backup comms, telephone, modems	x	x	x	x	x	x	x	x	x	x
8	Drought	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
9	Contamination	x	x	x	x	x	x	x	x	x	x
10	Sabotage / Terrorism	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
11	Sun Water infrastructure failure	xx	xx	xx	xx	xx	xx	xx	xx	xx	xxx

Figure 6: Boundary Vulnerability Assessment

Where:

- xxx Credible critical potential vulnerability that must be (seen to be) addressed.
- xx Moderate potential vulnerability.
- x Minor potential vulnerability.
- No noticeable vulnerability.

4.2 Availability Modelling

The following schematic represents the key elements for the delivery of bulk water to GAWB customers.

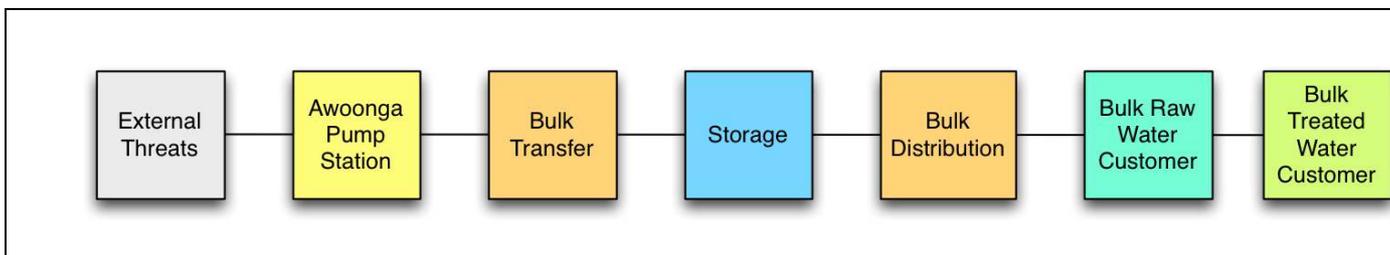


Figure 7: Delivery Block Diagram

Availability estimates for the model were based on GAWB and general industry experience.

4.2.1 External threats

This describes incidents that can affect the whole GAWB water supply chain. These were identified during the context vulnerability assessment and include drought, dam failure and power supply failure.

4.2.2 Awoonga pump station threats

The pump station at Awoonga has three pumps (duty, standby and backup) all capable of pumping the full bulk water requirement. However, a number of common mode failures were identified that take out all of the pumps at the same time, including: wooden power pole failure; storm or cyclone resulting in power supply impact; grouped cable fire; fire / explosion in pumpwell, VFD building or HV switch room; and pump well flood. It was also noted that there is a single point failure associated with the underground pipeline from the pump station to the bulk transfer pipes on the other side of the spillway.

4.2.3 Bulk water transfer

From the pump station the water can be transferred to the storage reservoirs either via the 1440mm underground or 700mm above ground pipeline. The two pipes run parallel along the road and three common mode failures were identified that could affect both pipes including transfer SCADA failure; washaway (one pipe washes out the other); and malicious damage.

4.2.4 Storage

Effectively bulk water is transferred to the two 50ML storage reservoirs at Toolooa and Fitzsimmons St. before being distributed to the bulk water customers. Either of the reservoirs can feed all bulk water customers, therefore making the storage system redundant.

4.2.5 Distribution system

The distribution system delivers bulk water to customers from the two storage reservoirs and is made up of various length underground pipes. An average fault rate per kilometre per year based on GAWB experience of unplanned failures, which was then used to estimate the failure rate for each delivery pipeline. It was noted during the review that pipes are not usually expected to fail catastrophically and minor failures can usually be repaired without significant interruptions to water delivery.

4.2.6 Water treatment

In addition to providing bulk raw water, GAWB is also responsible for the provision of some bulk treated water. GAWB have two water treatment plants, one at Gladstone and the other at Yarwun which are operated by the Gladstone Regional Council.

Two availability models were developed for the treated water, one each for Gladstone and Yarwun. Elements modelled included common mode failures to the water treatment plant, the treatment process, pumping, storage and customer delivery system.

The following table summarises the modelling results for bulk customers in days unavailable for each of the high-level functional elements.

Table 1: Bulk Customers – days unavailable

Customer	External threats	Awoonga PS	Bulk transfer	Storage	Bulk distribution	Raw water unavailability	Treated water unavailability
Boyne Smelter	4.65	1.0908	0.019	0.0127	0.0075	5.78	6.17
Cement Aust., Boat Creek	4.65	1.0908	0.019	0.0127	0.2205	6.02	6.77
Cement Aust., East End	4.65	1.0908	0.019	0.0127	0.2205	6.02	7.28
Gladstone Port Corp., Hansen Rd	4.65	1.0908	0.019	0.0127	0.0375	5.81	
Gladstone Port Corp., Serrant Rd	4.65	1.0908	0.019	0.0127	0.2206	6.03	
Gladstone Water Treatment Plant	4.65	1.0908	0.019	0.0127	0.0125	5.76	
Orica (Mt Miller)	4.65	1.0908	0.019	0.0127	0.2203	6.00	6.73
Orica, Serrant Rd	4.65	1.0908	0.019	0.0127	0.2206	6.03	
Queensland Aluminium	4.65	1.0908	0.019	0.0127	0.0025	5.77	6.17
Queensland Energy Resources	4.65	1.0908	0.019	0.0127	0.2205	6.02	
Rio Tinto Aust., Refinery	4.65	1.0908	0.019	0.0127	0.2204	6.01	6.73
Rio Tinto Aust., RMA	4.65	1.0908	0.019	0.0127	0.2206	6.03	6.85
Transpacific	4.65	1.0908	0.019	0.0127	0.2204	6.01	
Yarwun Water Treatment Plant	4.65	1.0908	0.019	0.0127	0.0375	5.81	

As can be seen in the table, the majority of the total days unavailable for bulk raw water is related to external threats and the common mode failures at the Awoonga pump station. Most of these items are characterised as unlikely but have significant downtime consequences. In turn the unavailability numbers for treated water is driven by the unavailability of bulk raw water to the treatment plants.

For example, based on the modelling Queensland Aluminium Ltd, on average will not have raw water available 5.77 days per annum. 4.65 of these days are a result of the external threats identified and 1.09 days associated with the threats identified at Awoonga Pump Station.

4.3 Precautionary Review

From a criticality viewpoint, there are a number of external threats and common mode failures that will interrupt supply for an extended period of time. These are shown in the table below.

Table 2: Credible Critical Threats

External threat / common mode failure	Criticality (days duration)
Sabotage / terrorism	1000
Dam failure	1000
Drought (single catchment)	36
Sunwater infrastructure failure	14
Inundation (tail water)	14
Fire / explosion in HV switch room	14
Pump well flood (broken pipe)	14
Fire / explosion in VFD building	14
Fire / explosion in pump well	14
Loss of surge tank	14
Corrosion / erosion of spillway pipe	14
Fire / explosion at Gladstone Water Treatment Plant	14
Sabotage / terrorism at Gladstone Water Treatment Plant	14
Fire / explosion at Yarwun Water Treatment Plant	14
Sabotage / terrorism at Yarwun Water Treatment Plant	14
Rail bridge failure (over Calliope River)	10
Power supply failure (grid loss)	7
Wash away of main transfer pipe to storage	7
Malicious damage of main transfer pipe	7
Group cable fire	5
Wooden pole failure at Awoonga	3
Storm or cyclone (power supply interruption)	3
Pole collapse into cutting	3
Lightning strike (control system)	3

During discussions with the GAWB stakeholders, a number of generic precautions emerged to address these concerns. The provision of an alternate independent water supply such as the Gladstone - Fitzroy pipeline or a desalination plant will address all of these identified long-term threat scenarios such as drought, dam break and the like.

The provision of a 2 week + off-line storage facility and associated pumping station will address supply interruptions associated with failures of 14 days and less. Such failures include Sunwater infrastructure failure, inundation of the Awoonga Pump Station, fire / explosion in various key buildings including the pump well, HV switch room, VFD building and water treatment plants. This significantly reduces the network's current criticality for all lesser critical threats and improves the average availability of bulk water to GAWB customers by approximately 2 days per annum (see table below).

Table 3: Bulk Customers – improvement in days unavailable with 2 week + off-line storage

Customer	External threats	Awoonga PS	Bulk transfer	Storage	Bulk distribution	Raw water unavailability	Treated water unavailability
Boyne Smelter	3.71	0	0	0.0127	0.0075	3.74	4.13
Cement Aust., Boat Creek	3.71	1.0908	0.019	0.0127	0.2205	3.98	4.74
Cement Aust., East End	3.71	1.0908	0.019	0.0127	0.2205	3.98	5.25
Gladstone Port Corp., Hansen Rd	3.71	1.0908	0.019	0.0127	0.0375	3.77	
Gladstone Port Corp., Serrant Rd	3.71	1.0908	0.019	0.0127	0.2206	3.99	
Gladstone Water Treatment Plant	3.71	1.0908	0.019	0.0127	0.0125	3.72	
Orica (Mt Miller)	3.71	1.0908	0.019	0.0127	0.2203	3.97	4.70
Orica, Serrant Rd	3.71	1.0908	0.019	0.0127	0.2206	4.00	
Queensland Aluminium	3.71	1.0908	0.019	0.0127	0.0025	3.74	4.13
Queensland Energy Resources	3.71	1.0908	0.019	0.0127	0.2205	3.98	
Rio Tinto Aust., Refinery	3.71	1.0908	0.019	0.0127	0.2204	3.98	4.70
Rio Tinto Aust., RMA	3.71	1.0908	0.019	0.0127	0.2206	3.99	4.74
Transpacific	3.71	1.0908	0.019	0.0127	0.2204	3.98	
Yarwun Water Treatment Plant	3.71	1.0908	0.019	0.0127	0.0375	3.77	

5 CONCLUSION

Organisations seek to achieve optimum efficiency and productivity in the operation of their plants and networks. They also aim to eliminate incidents that put the organisation's operations at risk. For operational vulnerabilities to be truly understood, they need to be analysed top-down in the context of organisational goals.

The Operations Due Diligence model does this and also provides a complete picture of the plants or process for Boards and senior decision makers. Transparency in decision making is achieved.

6 REFERENCE

- [1] R. M. Robinson, G. E. Francis, P. J. Hurley, *Risk and Reliability: Engineering Due Diligence*, 9th ed., Melbourne, R2A Pty Ltd., 2013.

- [2] Queensland Competition Authority, Gladstone Area Water Board 2010 Investigation of Pricing Practices Appendix 16 Critical Assets Due Diligence Review R2A Pty Ltd. <http://www.qca.org.au/files/W-GAWB2010-PriceInvest-Sub2-App16-1209.pdf>. Viewed on 15Nov2012