HAZard IDentification (HAZID) Study for the Solids Removal and Treatment Facilities Upgrade at the Southern Waste Water Treatment Works, Merewent, KwaZulu-Natal

Second Draft

eThekwini Water and Sanitation

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February 2015 (updated June 2015)

ETHEKWINI MUNICIPALITY

Royal HaskoningDHV
Enhancing Society Together

DOCUMENT DESCRIPTION

Client:
eThekwini Municipality - Water and Sanitation

Project Name:
HAZard IDentification (HAZID) Study for the Solids Removal and Treatment Facilities Upgrade at the Southern Waste Water Treatment Works, Merewent, KwaZulu-Natal

Royal HaskoningDHV Reference Number:
T01.DUR.000274

Authority Reference:
DM/WML/0050/2014
DM/0032/2014

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Date:
21 February 2015 (updated June 2015)

Location:
Durban

Review & Approval: Siva Chetty

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Signature

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Abbreviations and Acronyms

AD	Anaerobic Digestion
EWS	eThekwini Water and Sanitation
HAZID	Hazard Identification Study
HAZOP	Hazard and Operability Study
HSE	Health, Safety and Environment
MHI	Major Hazard Installation
O&M	Operations and Maintenance
PFDs	Process Flow Diagrams
PST	Primary Settling Tank
QA	Quality Assurance
QC	Quality Control
RHDHV	Royal HaskoningDHV
SWWTW	Southern Wastewater Treatment Works
UPS	Uninterrupted Power Supply

1 INTRODUCTION

A HAZard IDentifcation study (HAZID) was performed for the proposed solids removal and treatment facilities upgrade at the Southern Wastewater Treatment Works (SWWTW), KwaZulu-Natal, South Africa on 6th February 2015. The purpose of which was to identify process related risks or hazards associated with the upgrade works in support of the Environmental Impact Assessment (EIA) and Waste Management License application.

A HAZID study may be used as a tool with which to identify process related hazards on a high level based on the process flow diagrams (developed by consultant AECOM) for the proposed works. The aim of the HAZID study is to identify, assess, propose mitigation measures and/or recommendations for hazards identified early on in the project. The focus of the HAZID study was specifically on the process related hazards associated with the upgrade and installation of the new facilities and systems at the Southern Wastewater Treatment Works.

The identified process hazards may require further study with respect to health and safety for personnel and the environment in subsequent phases and/or dealt with under separate specialist studies e.g. major hazard installation (MHI) risk assessment for preconstruction notifications by consultant ISHECON, dated February 2015. The conclusions and recommendations of the HAZID report have been made on the basis of the HAZID study results and may be used to develop an inventory for future HAZOP studies relating to the proposed works.

2 BACKGROUND

The Southern Waste Water Treatment Works (SWWTW) is located in South Durban, Merewent on the north-eastern bank of the Umlaas Canal. The SWWTW is surrounded by a mixed development of both residential and industrial developments. The eThekwini Water and Sanitation (EWS) is responsible for the treatment of all municipal sewage in the greater eThekwini area. The bulk of the wastewater from the SWWTW site is discharged through the marine outfalls that serve the Central Works and the Southern Works wastewater treatment facilities, which are owned and operated by the eThekwini Municipality. The SWWTW discharges to a sea outfall of 4.2 km in length with 34 diffusers discharging at a depth of 54 – 64 m.

The Southern Wastewater Treatment Works processes wastewater consisting of a combination of both domestic and industrial effluent. The SWWTW receives the majority of its raw sewage effluent through three large (1500 mm diameter) trunk sewers. Other industrial effluent streams entering the SWWTW include those from Mondi, SAPREF, various road tankers, as well as from the Jacobs trunk sewer (discharging close to the head of works) and Illovo (discharging closer to the outlet of the works). The total average daily flow to the works is in the region of 130 million litres per day and all the treated flows leaving the works is discharged directly to sea (by gravity and by pumping) through the 4.2 km long sea outfall pipeline.

The SWWTW proposes to begin treating a portion of the raw industrial effluent instead of pumping it directly out to sea. A physical treatment process (through primary settling) will result in the organic load to sea being drastically

reduced. The settled solids (referred to as primary, or raw, sludge) will then be removed and stabilised through a process of anaerobic digestion, before being dewatered and disposed off-site. The biogas produced will be stored in biogas holders and typically utilised on site (for heating of digesters). SWWTW will refurbish and bring on-line a number of existing decommissioned processing equipment, as well as constructing new facilities.

In summary, the proposed upgrade entails refurbishing (and re-commissioning) of two existing primary settling tanks (PSTs), two anaerobic digesters (AD), installation and commissioning of six new PSTs, three thickeners feeding four AD trains (comprising of two digesters and biogas storage facilities per train). The upgrade facilities also include new sludge dewatering facilities and sludge storage silos for off-site disposal. The project shall be implemented in a phased approach. The existing works, new Phase 1 and Phase 2 of the facilities upgrade at the SWWTW is provided in Appendix 1 to 3.

FIGURE 1: SWWTW AND LAYOUT OF PROPOSED UPGRADE FACILITIES

3 HAZID PRINCIPLES

The purpose of a HAZID study is to assess the potential hazards to personnel (health and safety) and the environment. This was done in respect to regulatory requirements, standard operating practices at the SWWTW, hazardous events, operability and maintainability considerations.

The HAZID approach was applied for the two phases of the SWWTW facilities upgrade. In this study, the HAZID guide words were identified and selected on the extent of their impact on the process and may be recommended for further study in subsequent phases, or referred to a HAZOP study.

With reference to the facilities upgrade at the SWWTW, the following has to be managed:
1) To identify the hazards of unwanted events early on;
2) To determine the effect and consequences for the health and safety of humans and the environment;
3) To assess the risks before risk reduction measures have been implemented;
4) To demonstrate how the hazards can be eliminated (by an inherently safe design) or to demonstrate that safety measures can control the hazards to a safe and acceptable situation;
5) To determine the remaining risk and demonstrate that the risk has been reduced to an acceptable level.

Purpose of the HAZID study

The objective of the HAZID study is to review an installation through a series of engagements and interactive sessions, during which the multidisciplinary team methodically 'brainstorms' the proposed installation to identify possible hazards, assess the likely effects, identify the causes and propose recommendations, or mitigation measures, for consideration. A HAZID is guided by a typical checklist (Appendix 4) and draws benefit from the HAZID team's experience.

Performing the HAZID at the earliest possible stage in the project enables fundamental decisions in the process design to be taken or confirmed. A HAZID does not preclude the need for further hazard assessment (unless deemed necessary by the HAZID team). Instead, it is a precursor to subsequent hazard analyses and risk assessments and is normally carried out during the earliest project phases. The HAZID should be implemented as soon as preliminary plot plans, environmental conditions, process flow diagrams and utility flow diagrams are available.

HAZID Team

HAZID team members should be selected for their knowledge of the technical and operational aspects of installations similar to the installation to be studied or of the existing installation in the case of extension / revamping / upgrade (as with the SWWTW).

The HAZID team should consist of a HAZID team leader with general experience of hazard identification, a technical secretary, engineering and operational personnel relevant to areas of the installation being studied.

Typically the HAZID team should include, but not be limited to:

- A Team Leader (or Facilitator);
- A Project representative (Client);
- A Process representative (Design engineer);
- A representative from Operations and Maintenance;
- A Technical Secretary (Scribe);
- Other Technical specialist(s) (depending on project requirements).

In order to keep manageable HAZID sessions, it is recommended to limit HAZID team composition to maximum 8 people around the table at any time.

4 METHODOLOGY

HAZID is a technique for (early) identification of potential hazards and threats. The focus of the HAZID for the SWWTW upgrade works has been specifically on identifying the process related risks or hazards. The HAZID should be applied at the early stages of a project or new installation. It is often likely to be the first formal Health, Safety and Environment (HSE) related study for any new project. The major benefit of a HAZID is that the early identification and assessment of the process hazards provides essential input to project development decisions. This will lead to safer and more cost-effective design options being adopted with a minimum cost of change penalty.

The HAZID has been executed in line with an internationally accepted approach. The new facilities (or systems) are divided into Nodes for the purposes of the HAZID study. The entire upgrade facilities was classified into two nodes: Node 1 comprised of the PSTs, raw sludge pump station and sludge thickeners, and Node 2 comprised of the primary and secondary digesters as well as the sludge dewatering plant (refer to Appendix 3). The checklist of potential guidewords is given in Appendix 4. The risk assessment (risk rating) of the individual hazards was carried out using the risk matrix presented in Appendix 5.

The Team Leader identifies a ‘Node’ to be studied (column 2 of the HAZID worksheets, provided in Appendix 6). The Node may be the whole facility, an area of it, individual process(es) or system(s). The process description of the selected node is discussed and agreed by the team, typically this is provided by the Process (or Design) engineer. The HAZID team then systematically goes through the relevant process guidewords as presented in Appendix 6. In each case the team analyses each guide word to determine if the guide word is relevant to the selected Node. The team identifies any causes leading towards the specific guide word situation (e.g. unignited gas release). A brainstorming exercise is used to identify all the potential causes which could result in the potential development towards a given consequence. The team analyses the appropriate controls (systems or practices) that are / could be in place to prevent each cause. The team then determines any controls (systems or practices) that may be recommended to be put in place to prevent each cause, or mitigate the effects thereof. During the study, the team uses a general qualitative system to give a simple priority rating (high, medium or low)

associated with the hazard identified based on the consequences and likelihood (probability). The risk matrix used for the HAZID study can be found in Appendix 5. The risk rating is then recorded in the HAZID worksheets (refer to Appendix 6).

5 PARTICIPANTS

The HAZID meeting was held on the 6th February 2015 at the AECOM offices in Westville, KwaZulu-Natal, South Africa. The HAZID team consisted of the following persons:

TABLE 1: TEAM MEMBERS OF HAZID STUDY

HAZID Team Member	Company	Function
Ashley Pillay	EWS	Project Engineer
Lalitha Moodley	EWS	Acting Senior Engineer – Central Coastal Area
Mohamed Abdelmegeed	AECOM	Scientist - Water
Samista Jugwanth	AECOM	Design Engineer/Project Manager
Ruth Cottingham	AECOM	Process Engineer
Kirshen Naidoo	RHDHV	Facilitator (Process Engineer)
Seun Oyebode	RHDHV	Scribe (Civil Engineer)
Norman Fortmann	EWS	Consultant
Reneshree Pillay	EWS	Chemical Technician (Southern Works)

The signed attendance register can be found in Appendix 1.

6 STUDIED DOCUMENTS

During the meeting the following engineering documents were available and consulted when necessary:

- PFDs:
  - Final PFD (Appendix 2)
  - Existing Phase (Appendix 3A)
  - Phase 1 PFD (Appendix 3B)
  - Phase 2 PFD (Appendix 3C)
- List of Applicable Guidewords (Appendix 4)
- Risk Matrix (Appendix 5)
- HAZID worksheets (Appendix 6)

Other supporting documents:

- Final Environmental Scoping Report by Royal HaskoningDHV (September 2014)
- Southern Wastewater Treatment Works VOC Assessment by Ecoserv (January 2008)

- Major Hazard Installation Risk Assessment for Preconstruction Notifications by ISHECON (February 2015)

7 SUMMARY OF HAZID RESULTS/FINDINGS

The results of the HAZID study are presented in tabulated form, reflecting the discussions with regard to the facilities upgrade hazards. Refer to Appendix 6 for summary of HAZID results.

The results are presented in tabulated form giving the following information:

- Part of the facility upgrade (referred to as NODE) under discussion;
- Guidewords (Hazardous events);
- Probability of occurrence (Yes or No);
- Cause of Hazardous Event;
- Potential Consequences (without taking regard of the safeguards in place);
- Controls and safeguards, preventing the scenario (if available);
- Risk ranking;
- Recommendations/Actions;
- Team Remarks.

The remarks from the HAZID are addressed in Table 2 below.

TABLE 2: SUMMARY OF HAZID REMARKS

Remarks Number	Remarks	Responsible
1	Proper maintenance schedule, regular inspections	Guidelines to be provided by contractor and implemented by EWS
2	Immediate clean-up of spillage and safe disposal, put alarms in place for visual, audible and mobile.	Guidelines to be provided by contractor and implemented by EWS
3	Review existing Uninterrupted Power Supply (UPS) and include in scope of work, Review O&M in a possible HAZOP phase	AECOM
4	Consider additional lighting and security	AECOM
5	Consider potable water top up in equipment design	AECOM
6	Consider alternative fuel source for heat exchangers during start-up or in supplementing biogas	AECOM and EWS
7	EWS to consider alternatives for backup sludge removal	EWS
8	Adequate upstream screening and maintenance of overflows	EWS
9	Consider upstream monitoring for contaminants and control of tanker discharges	EWS
10	Review safeguarding in a possible HAZOP phase	AECOM/EWS

11	Implement procedures for safe handling of sludge	EWS
12	Consider additional eye wash stations, safety showers and first aid stations	EWS
13	Consider automated shutdown and startup procedures for digester and biogas handling; Review startup/shutdown procedures with operations and maintenance in a possible HAZOP phase	AECOM/EWS
14	Review of QA/QC procedure for suppliers	AECOM

8 CONCLUSIONS

The HAZard Identification (HAZID) study for the proposed upgrade of the Southern Wastewater Treatment Works has been undertaken within the context of the latest environmental legislation in South Africa. The legislative underpinnings and key management strategies relate to pollution prevention, waste minimisation, adoption of the precautionary principle, hazard identification in relation to its causes and probability of occurrence, as well as adoption of mitigation measures to such inherent hazards. The proposed development has adopted a precautionary approach of ensuring opportunity for the upgrade of facilities in a phased approach: Phase 1 and Phase 2.

In this study, most of the hazards identified are of low to medium risk for health and safety of personnel and the environment, resulting in a conservative classification from the risk matrix. However, the need for the adoption of recommendations and actions (in subsequent phases) is of critical importance as the occurrence of the identified hazards is deemed probable.

9 APPENDICES

APPENDIX 1: ATTENDANCE REGISTER

Southern Wastewater Treatment Works - HAZID Study

Title : Hazid Identification Study
Date : 6/02/2015

List of Participants

Name	Organization	Function	Signature Date: 06/02/2015
Ashley Pillay	EWS	Project Engineer	
Lalitha Moodley	EWS	Act Snr. Eng - Central Coastal Area.	
Mohamed Abdelmegeed ~~Hugh Abatz~~	AECOM	Scientist - Water	
Samista Jugwanth	AECOM	Design Engineer/Project Manager	
Ruth Cottingham	AECOM	Process Engineer	
Kirshen Naidoo	RHDHV	Facilitator	
Seun Oyebode	RHDHV	Atom Consultant / Scribe	
Siva Chetty			
Sharleen Moodley			
NORMAN FORTMANN	EWS	CONSULTANT (DESIGN) BR	
Reneshree Pillay	EWS	Chemical Technician (Southern Works)	
KEITH BRACKENBURY	EWS	WORKS PROJECT ENGINEER	

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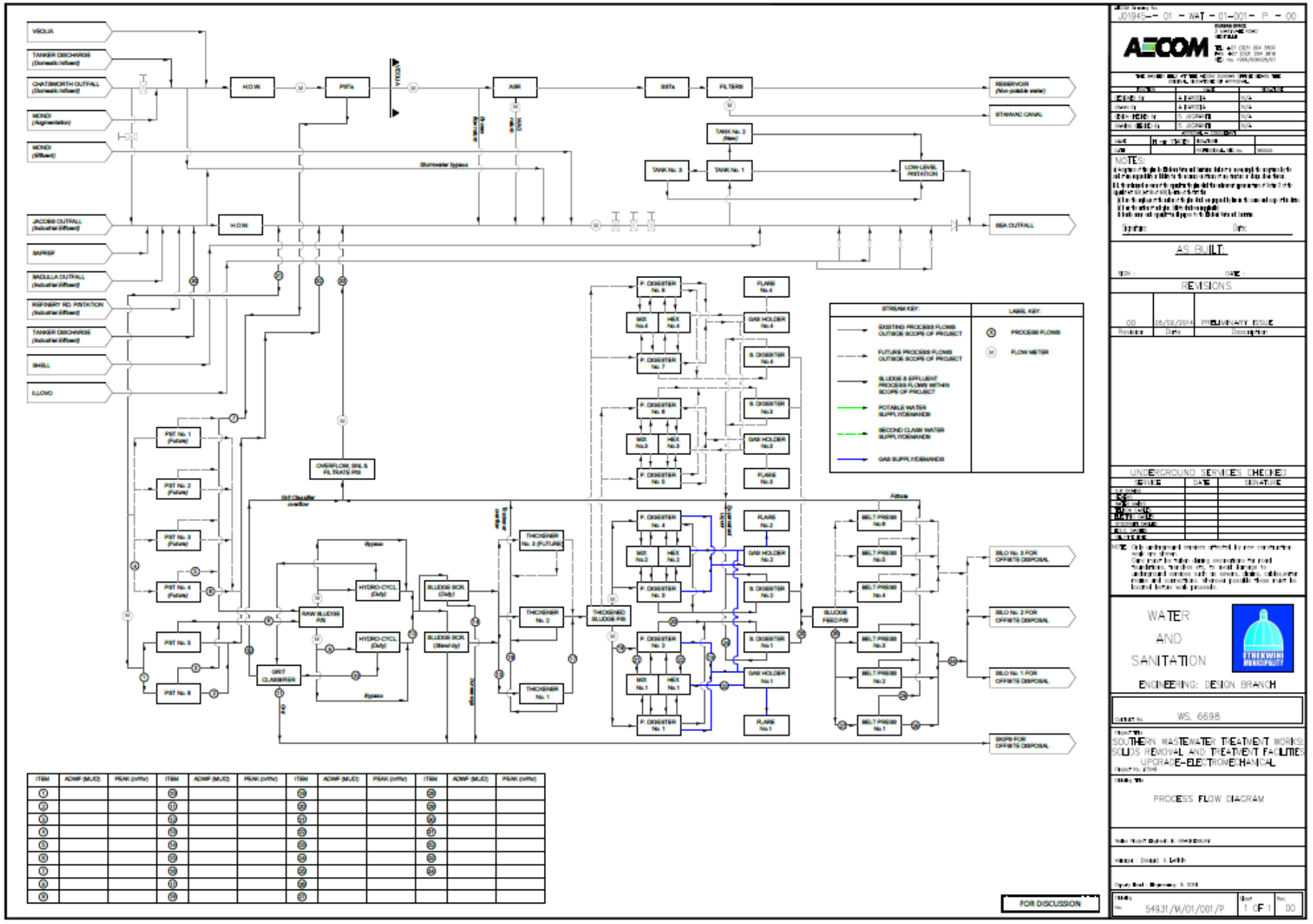
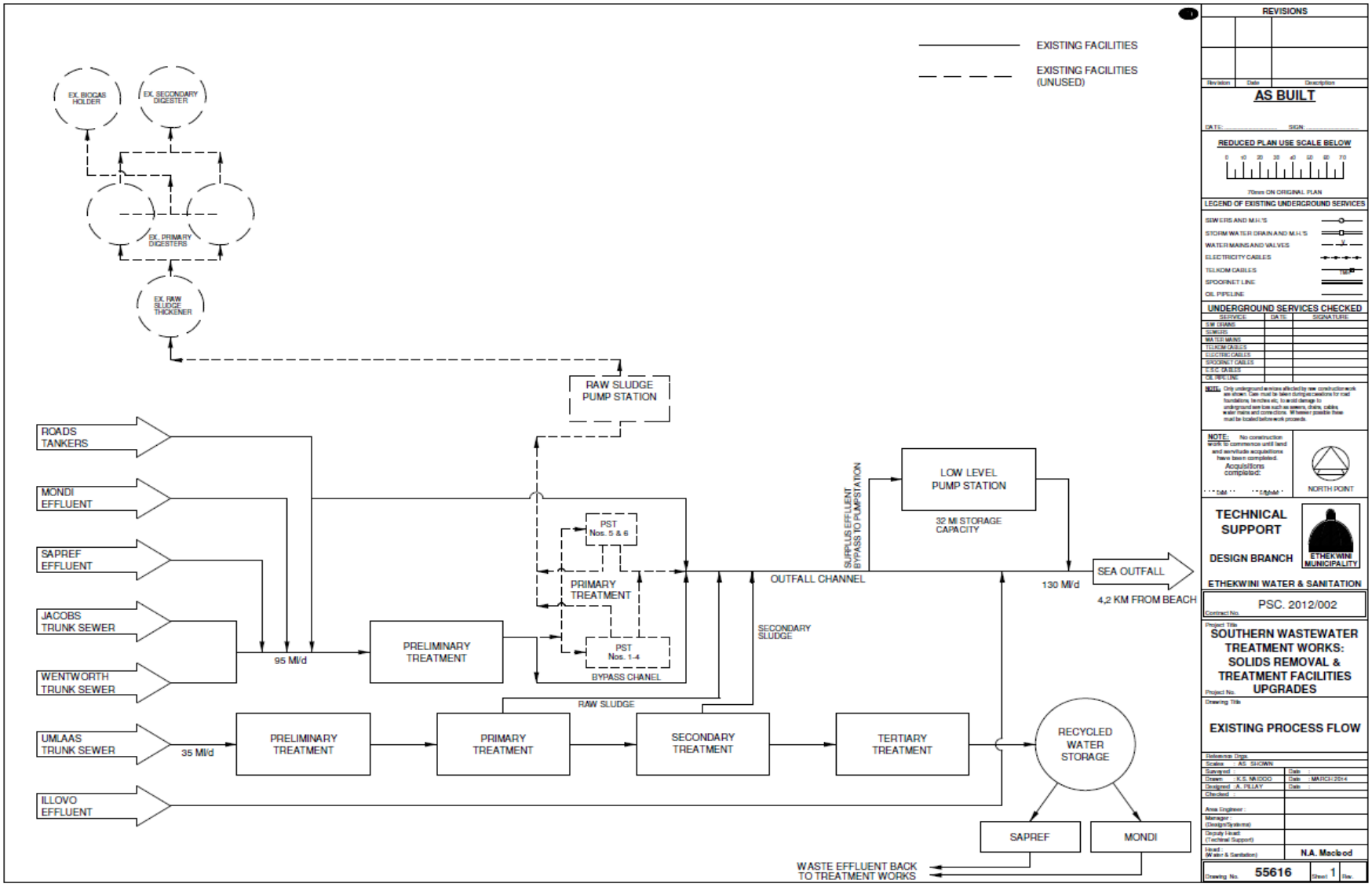
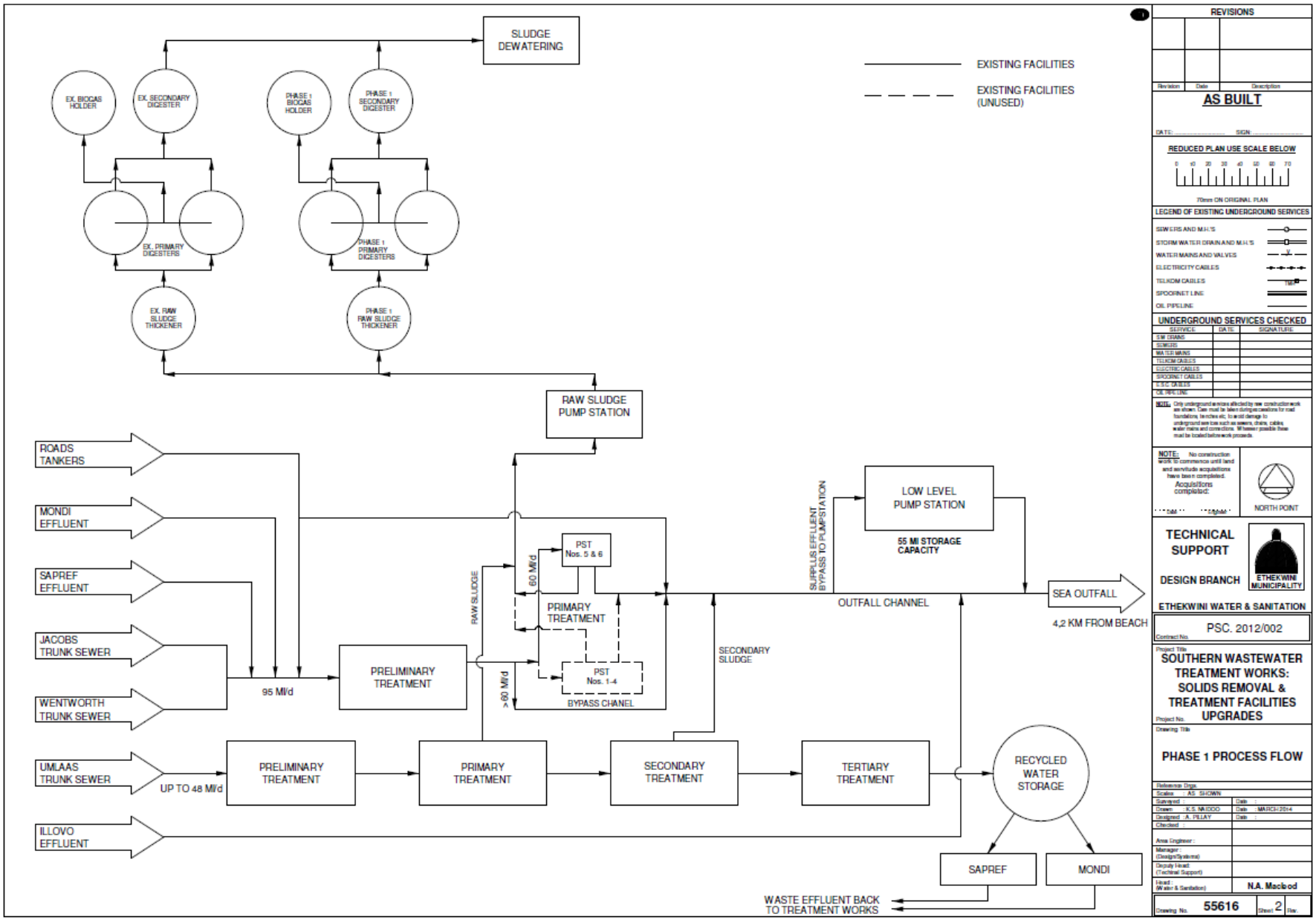
APPENDIX 2: OVERALL PFD (BY AECOM)



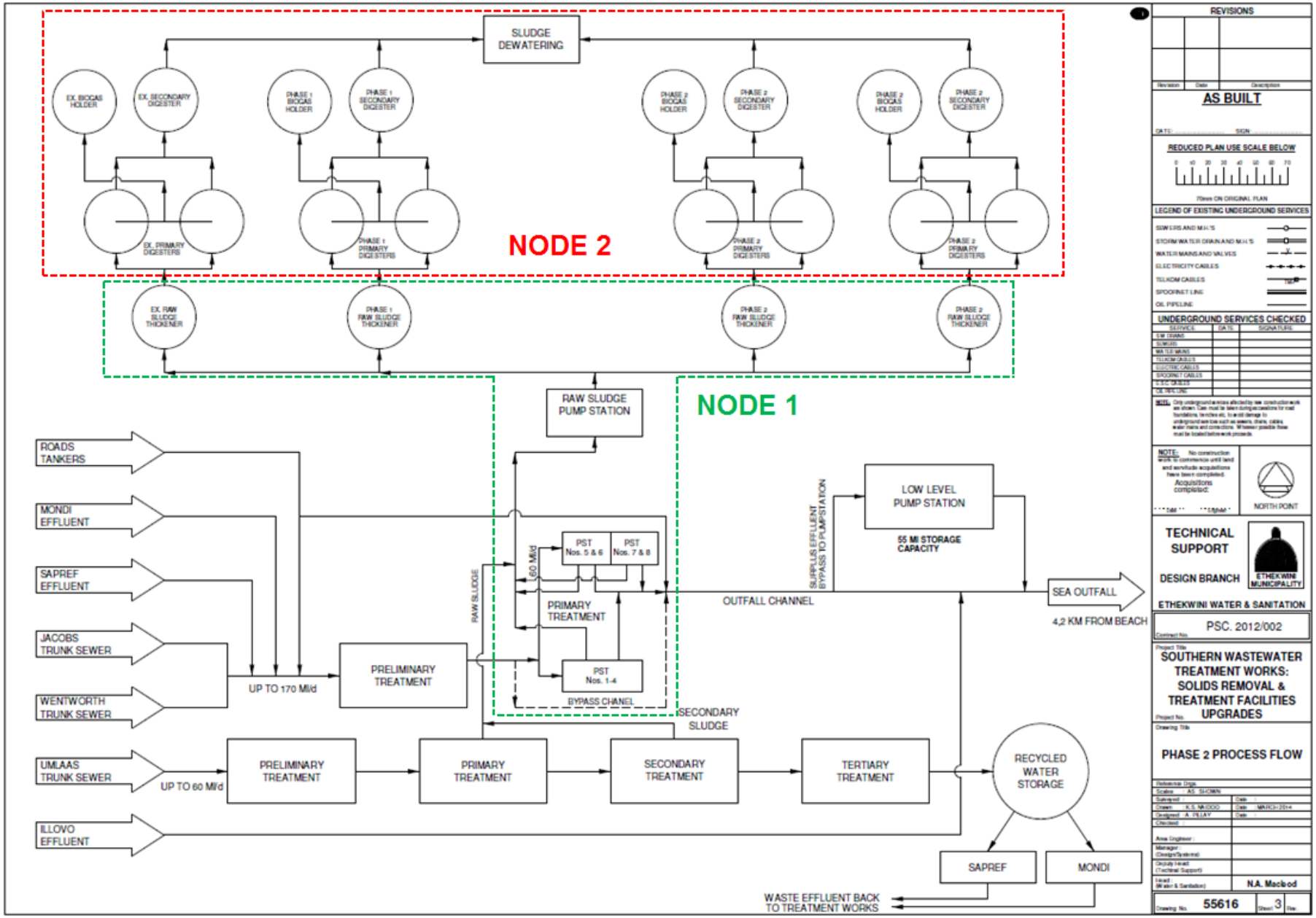
APPENDIX 3A: PRELIMINARY PFD – EXISTING PHASE



APPENDIX 3B: PRELIMINARY PFD – PHASE 1



APPENDIX 3C: PRELIMINARY PFD – PHASE 2



APPENDIX 4: LIST OF APPLICABLE GUIDEWORDS

HAZID GUIDEWORDS	
Process-based Hazardous Events	**Expanders (Examples of Guideword Application, not exclusive)**
Change in mode of operation	Abnormal operations or maintenance.
Chemical/Toxic release	Discharges to air, land and water (e.g. flares, emissions; effluent-stormwater mixture, effluent to sea etc.); Soil contamination via land application of sludge; emergency/upset discharges (e.g. overflow).
Climate Extremes	Temperature (air or water); Wind; Current; Salinity (water, air); Pressure change; Flooding; Drought; Sandstorm; Dust; Lightning.
Emergency Responses	All associated activities to set up and implement emergency response plan in the event of an incident; Communication system
Explosion	Improper handling of gases; Impact; High temperature; Gas migration.
Fire Outbreak	Short circuits; Overload; Operator error; Sparks from exposed cables/conductors; Stored flammables; High temperature; Control failure; Heat due to poor ventilation.
Health Hazards	Endemic diseases; Infection; Asphyxiating atmospheres; Failure to use appropriate PPE; Vessel entry; Use of Chemicals; Odour; Shift Patterns; Electric Shock; Extreme weather conditions; Journey management; Shift Patterns.
Human Error of Personnel	Lack of procedures (not known, not available, not communicated, not followed); Lack of information (data sheets, operating manuals, maintenance manuals, etc.); Lack of supervision; Lack of competence; Lack of training; Insufficient manpower; Fatigue; Unsafe behaviour; Incorrect modification; Use of outside design specification; Failure to respond to alarms
Noise/Vibrations	Poor maintenance culture on facilities such as degritters, movable or rotating devices (e.g. pumps).
Operational & Maintenance Philosophy	Concurrent operations; Appropriate Technology; On-line/Isolation maintenance; Inspection programmes; Test frequencies; Defect left after maintenance; Spare part procurement; Poor record keeping.
Procurement Hazards	Chemicals; Controls fluid; Combustibles; Spare parts; Alternative means of supply.
Proximity to adjacent industrial installations	Fire; Explosion; Dispersion of toxic or corrosive material; Odour.
Proximity to Valued ecosystems	Surface water ecosystems; Deepwater and marine environments.
Safety Hazards	Firefighting equipment; Emergency services
Security Hazards	Internal and external security threats such as theft, riots, civil unrest, attack on installation, etc.
Start-up / Shutdown	Poor status of valves, cables and electrical panels; Power outage; Load shedding.
Subsidence	Ground structure; Foundations
Unignited gas release	Corrosion; Over-pressure/temperature, Overfill of storage vessels; Control failure.

Utility systems hazards	Loss/Shortage of water supply; Power Outage; Load shedding; Shortage of fuel to run generator; Sludge pump failure due to power outage.
Vessel Rupture/Collapse	Impact, excessive process stress; Process control failure; Falling objects due to wear and tear; Corrosion due to toxic substances.

APPENDIX 5: RISK MATRIX

Risk Matrix (RAM)									
Severity	Consequences				Increasing likelihood				
	People	Assets	Environment	Reputation	A Never heard of in the industry	B Heard of in industry	C Has happened in the organisation or more than once per year in the industry	D Has happened at the location or more than once per year in the Organisation	E Has happened more than once per year at the Location
0	No injury or health effect	No damage	No effect	No impact	L	L	L	L	L
1	Slight injury or health effect	Slight damage	Slight effect	Slight impact	L	L	L	L	L
2	Minor injury or health effect	Minor damage	Minor effect	Minor impact	L	L	L	M	M
3	Major injury or health effect	Moderate damage	Moderate effect	Moderate impact	L	L	M	M	H
4	PTD or up to 2 fatalities	Major damage	Major effect	Major impact	L	M	M	H	H
5	More than 3 fatalities	Massive damage	Massive effect	Massive impact	M	M	H	H	H

APPENDIX 6: SUMMARY OF HAZID RESULTS

No.	Unit / Location / Node	Guideword	Possible Y/N	Cause	Potential Consequences	Safeguards: Mitigation & Protection measures	Priority / Risk rating	Recommendations / Actions	Responsibility	Hazid Team Comments
1	1	Change in mode of operation	Y	Maintenance or equipment failure, Peak flows	No sludge feeding into digesters, overflows, bypasses,	Standby Equipment, Bypasses, automated devices incorporated into the design.	L	Proper maintenance schedule, regular inspections	Guidelines to be provided by contractor and implemented by EWS	N/A
2	1	Chemical/Toxic release	Y	Sludge spillages, odour from spilled sludge	Potential for ground contamination, odour, potential health hazard	Mechanical ventilation for odours.	L	Immediate cleanup of spillage and safe disposal, put alarms in place for visual, audible and mobile.	Guidelines to be provided by contractor and implemented by EWS	N/A
3	1	Climate Extremes	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
4	1	Emergency Responses	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
5	1	Health Hazards	Y	Contact with Sludge, confined space entry	Sickness as a result of long exposure, exposure to gas at designated confined spaces	Proper PPE, health monitoring in place, potable gas detectors	L	Existing procedures in place	EWS	N/A
6	1	Human Error of Personnel	Y	Fatigue, lack of competence, lack of training or information, unsafe behaviour	possible process upset,	Existing procedures in place: Proper training, manual overrides, password protected	L	Existing procedures in place	EWS	N/A
7	1	Noise/Vibrations	N							
8	1	Operational & Maintenance Philosophy	Y	Operational failure mode	Incorrect operations, unnecessary overflows	Fail safe mode for process units, UPS	L	Review existing UPS and include in scope of work. Review O & M in HAZOP phase	AECOM	Review of risky O & M procedures in the HAZOP phase
9	1	Procurement Hazards	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
10	1	Proximity to adjacent industrial installations	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
11	1	Proximity to adjacent residential areas	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
12	1	Proximity to Valued ecosystems	Y	Possible waste going into overflow	Contamination of surf zone	Low level sump	L	Consider an increase in storage capacity; Put in place proper monitoring and strategic system management	AECOM and EWS	N/A
13	1	Safety Hazards	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
14	1	Security Hazards	Y	Theft, unauthorized personnel	N/A	Existing security	L	Consider additional lighting and security		
15	1	Start-up / Shutdown	N	No major hazards identified	N/A	N/A	N/A	N/A	N/A	N/A
16	1	Subsidence	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
17	1	Unignited gas release	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
18	1	Utility systems hazards	Y	No second class water for equipment demands	Shutdown of equipment	Alternative potable water supply in place	L	Consider potable water top up in equipment design	AECOM	N/A
19	1	Vessel Rupture/Collapse	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
20										
21										
22	2	Change in mode of operation	Y	Insufficient biogas generation;	Reduced heating of digesters and reduced performance	None	L	Consider alternative fuel source for heat exchangers during start-up or in supplementing biogas	AECOM and EWS	N/A
23	2	Change in mode of operation	Y	Potential bottleneck in sludge removal	Excess sludge on site	None		EWS to consider alternatives for backup sludge removal	EWS	N/A
24	2	Chemical/Toxic release	Y	Biogas release from gas holders (corrosion of gas holder roof)	Potential for biogas leakage (see unignited gas release)	Flares for excess biogas, interconnection between gas holders, water seal,	L	See unignited gas release	EWS	N/A
25	2	Chemical/Toxic release	Y	Potential overfilling of digesters due to blocked overflows	Spillage, Overflow		L	Adequate upstream screening and maintenance of overflows	EWS	N/A
26	2	Chemical/Toxic release	Y	Chemical contamination from HoW (industrial waste)	Poisoning of digesters	Regular sampling	M	Consider upstream monitoring for contaminants and control of tanker discharges.	EWS	N/A
27	2	Climate Extremes	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
28	2	Emergency Responses	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
29	2	Explosion	Y	Biogas and explosive mixture	Explosion of gas feedline	Low pressure return valve, flame arrestors	M	Reiew safeguarding in HAZOP phase	AECOM/EWS	N/A
30	2	Fire Outbreak	Y	Dry sludge catching fire	Potential damage to equipment and personnel		L	Implement procedures for safe handling of sludge	EWS	N/A
31	2	Health Hazards	N	See chemical/toxic release	See chemical/toxic release	See chemical/toxic release	See chemical/toxic release	See chemical/toxic release	See chemical/toxic release	See chemical/toxic release
32	2	Human Error of Personnel	N	Same as in Node 1	Same as in Node 1	Same as in Node 1	Same as in Node 1	Same as in Node 1	Same as in Node 1	Same as in Node 1
33	2	Noise/Vibrations	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
34	2	Operational & Maintenance Philosophy	Y	See Node 1 and MHI study	See Node 1 and MHI study	See Node 1 and MHI study	See Node 1 and MHI study	See Node 1 and MHI study	See Node 1 and MHI study	See Node 1 and MHI study
35	2	Procurement Hazards	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36	2	Proximity to adjacent industrial installations	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
37	2	Proximity to adjacent residential areas	Y	Biogas release from gas holder, poor maintenance culture	Odour due to wastewater treatment processes, spilled sludge, chemical or toxic emissions/explosions, fire outbreak, potential health hazad	Installation of potable gas detectors and flame arrestor, Flares for excess biogas, interconnection between gas holders, regular maintainence and monitoring	L	Reiew safeguarding in HAZOP phase	AECOM and EWS	N/A
38	2	Proximity to Valued ecosystems	Y	See Node 1 above	See Node 1 above	See Node 1 above	See Node 1 above	See Node 1 above	See Node 1 above	See Node 1 above
39	2	Safety Hazards	Y	Biogas generation, storage, flaring and burner room	Impact on personnel	Appropriate signage, PPE and controlled access, permit to work	L	Consider additional eye wash stations, safety showers and first aid stations	EWS	N/A
40	2			Slipping hazard into wet areas	Impact on personnel	Non-slip epoxy floors, demarcate areas, PPE, proper drainage	L		EWS/AECOM	N/A
41	2	Security Hazards	Y	Same as in Node 1	Same as in Node 1	Same as in Node 1	Same as in Node 1	Same as in Node 1	Same as in Node 1	Same as in Node 1
42	2	Start-up / Shutdown	Y	Incorrect startup/shutdown procedures	Negative pressures in gas holders; incorrect functioning of digester (large volume of undigested sludge to dispose off)	Standard operating procedures	L	Consider automated shutdown and startup procedures for digester and biogas handling; Review startup/shutdown procedures with operations and maintenance in HAZOP phase .	AECOM/EWS	N/A
43	2	Subsidence	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A
44	2	Unignited gas release	Y	Same as in Chemical/Toxic release	Same as in Chemical/Toxic release	Same as in Chemical/Toxic release	Same as in Chemical/Toxic release	Same as in Chemical/Toxic release	Same as in Chemical/Toxic release	Same as in Chemical/Toxic release
45	2	Utility systems hazards	Y	Same as Node 1	Same as Node 1	Same as Node 1	Same as Node 1	Same as Node 1	Same as Node 1	Same as Node 1
46	2	Vessel Rupture/Collapse	Y	Structural failure of equipment: Silos and gas holders	See chemical/toxic release	QA testing procedures for construction contractor	L	Review of QA/QC procedure for suppliers	AECOM	N/A