Inspection Guidelines for Condition Assessment of Concrete and Steel Structures Using Unmanned Aerial Vehicles (UAV’s)

(Business Rules)
Inspection Guidelines for Condition Assessment of Concrete and Steel Structures Using Unmanned Aerial Vehicles (UAV’s)
I. FOREWORD

Inspection guidelines are prepared to ensure that the Water Corporation staff, consultants and contractors are informed as to the Corporation’s requirement on the methodical approach to asset condition assessment. The Corporation’s ultimate objective of this Guideline is to contribute toward ensuring the provision of safe and functional plant and equipment at minimum whole-of-life cost.

In the Corporation, high risk/specialist inspections are carried out by Inspection Service Providers (ISP’s) by means of Scaffolds, Rope Access, Ladder Climbing Systems (LCS), and Elevated Work Platforms (EWP’s). These activities carry inherent safety risk to the inspectors.

In order to minimise the risk and maximise efficiency, the use of Unmanned Aerial Vehicles (UAV’s) for asset inspection was trialled in 2015 by Asset Management Branch. It is envisaged the benefits of UAV inspection are as follows:

- aligned with Corporation’s achieving Zero Harm safety policy;
- less labour intensity process;
- the collection of higher-quality data in real time;
- inspection data can be analysed faster and remedial actions can be planned and carried out proactively to maintain the integrity of the asset; and
- as part of the on-going Corporation’s Renewals Planning practice, learnings from UAV’s inspections will be shared amongst other Australian water utilities for on-going asset management.

Suggestions and reviews to this document by Aroona Alliance and other stakeholders are gratefully acknowledged and referenced in this document. Experience and qualification documents requirement provided by consultants, inspection equipment manufacturers and suppliers are gratefully acknowledged.

The ISP’s shall familiarise themselves with the Corporations “Safety Essentials” which are mandatory rules for our high risk activities that came into effect in January 2015 and can be found on the [http://www.watercorporation.com.au](http://www.watercorporation.com.au) webpage. All safety and environmental hazards shall be reported in Sentinel [Refer: http://sentinel/Cintellate/jsf/main.jsp]. The ISP’s shall adhere to Corporation’s privacy policy PCY252 at all times.

Users are invited to forward recommendations for continuous improvement to the Supervising Engineer or Manager, Renewals Planning, Water Corporation who will consider these for incorporation into future revisions.

Samuel Lee Mohan
Supervising Engineer
Asset Management Branch
II. DISCLAIMER

This Guideline is intended solely for inspection of Water and Wastewater infrastructure in operating areas in Western Australia where the Water Corporation has been licensed to provide water services subject to the terms and conditions of its Operating License.

This Guideline is provided for use only by a suitably qualified professional inspector, engineer or technician who shall apply the skill, knowledge and experience necessary to understand the risks involved and undertake all infrastructure condition assessment work.

Any interpretation of content in this Guideline that deviates from the requirements specified in the project design drawings and construction specifications shall be resolved by reference to and determination by the Design Engineer.

The Corporation accepts no liability for any loss or damage that arises from anything in the Guideline, including loss or damage that may arise due to the errors and omissions of any person.

This document is prepared without the assumption of a duty of care by the Water Corporation. The document is not intended to be nor should it be relied on as a substitute for professional engineering design expertise or any other professional advice.

Users should use and reference the current version of this document.

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## V. AMENDMENT REGISTER

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<th>Section</th>
<th>Version/Revision</th>
<th>Date</th>
<th>Description of Amendment</th>
<th>Authoriser</th>
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<td>All</td>
<td>1.0/0</td>
<td>24.03.15</td>
<td>New Version/Revision</td>
<td>SM</td>
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<td>4.0</td>
<td>1.0/0</td>
<td>20.04.15</td>
<td>Western Australian Surveillance Devices Act 1998.</td>
<td>SM</td>
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</tbody>
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**WARNING**: DOCUMENT UNCONTROLLED WHEN PRINTED
VI. GLOSSARY OF TERMS & ABBREVIATIONS

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tr>
<td>ACA</td>
<td>Asset Condition Assessment.</td>
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<td>ACS</td>
<td>Asset Class Strategy – Specific to an asset class.</td>
</tr>
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<td>AMB</td>
<td>Asset Management Branch.</td>
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<tr>
<td>ARA</td>
<td>Asset Risk Assessment.</td>
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<tr>
<td>Authorised Operation</td>
<td>An operation which is authorised to conduct Aerial Photography, Aerial Spotting and Aerial Surveying.</td>
</tr>
<tr>
<td>Authorised UAV</td>
<td>An operation using Multi Rotor and Fixed Wing type with restricted size and of smaller category.</td>
</tr>
<tr>
<td>CASA</td>
<td>Civil Aviation Safety Authority.</td>
</tr>
<tr>
<td>Chief Controller</td>
<td>The person appointed by the Certificate Holder as its Chief UAV Controller and whose appointment has been approved in writing by CASA.</td>
</tr>
<tr>
<td>Corporation</td>
<td>Water Corporation, Western Australia.</td>
</tr>
<tr>
<td>DST</td>
<td>Decision Support Tools.</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographic Information System.</td>
</tr>
<tr>
<td>IPWEA</td>
<td>Institute of Public Works Engineering Australia.</td>
</tr>
<tr>
<td>ISP</td>
<td>Inspection Service Provider.</td>
</tr>
<tr>
<td>OH &amp; S</td>
<td>Occupational Health and Safety.</td>
</tr>
<tr>
<td>Operator</td>
<td>The holder of UAV Operator’s Certificate.</td>
</tr>
<tr>
<td>O &amp; M</td>
<td>Operational and Maintenance Group.</td>
</tr>
<tr>
<td>RSL</td>
<td>Remaining Service Life</td>
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<tr>
<td>UAV</td>
<td>Unmanned aerial vehicle.</td>
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<tr>
<td>UAS</td>
<td>Unmanned Aerial Systems.</td>
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1.0 PURPOSE AND SCOPE

The purpose of this document is to provide guidance for Level 1 inspections as part of the hierarchy of Condition Assessment (CA) guidelines of high risk assets e.g. Egg Shaped Digester, Flue Stacks in Wastewater Treatment Plants, High Level Tanks, Reservoirs, Intake Towers in Dams, etc. using UAV’s.

This guideline will assist Inspection Service Providers (ISP’s), Operational Asset Managers (OAM)/Region/Alliance to conduct objective, consistent and reproducible Level 1 asset inspections in a cost effective and safe manner.

This document is also intended to assist ISP’s in the scoping of appropriate testing and investigation works such that the output received will be of a high standard and be a positive contribution to the management of Corporation assets.

The guideline clarifies the qualification(s), responsibilities, accountabilities, inspection data capturing techniques and interpretation for ISP’s.

The guideline will also aid the ISP’s to prepare and deliver the inspection findings to an appropriate format so that Asset Management Branch (AMB) can, where possible, determine the Remaining Service Life (RSL) of the asset and subsequently prioritise the renewal of the asset on the informed Asset Risk Assessment (ARA) and Decision Support Tools (DST’s).

For more details on the steel and concrete structures condition assessment guidelines, references shall be made to Aqua Docs 11051170 and 11963553 [1, 2].

This document should be in read in conjunction with S151 Prevention of Falls [3].

2.0 CAUTION

It is important to define the Scope of Work and inspection location as it dictates flight path and safety/privacy of the general public.

Weather plays a major role during the UAV inspections. The stability of the UAV hovering on the tightly spaced areas i.e. under the bridge, high level tanks will pose major problems. If the weather is cloudy, dark with gusty winds, then the imagery obtained will not be clear and the asset details may not be captured which will render the quality to poor.
3.0 BACKGROUND

Asset Condition Assessment (ACA) is vital as infrastructure ages [4]. ACA’s are used to determine the condition of assets and RSL to enable the Corporation to prevent premature asset failures that result in service interruptions and significant damage. Assets should be regularly inspected to detect any issues as early as possible.

Renewals Planning proactively identifies assets for inspection by means of Asset Risk Assessment (ARA) and various DST’s thereby calculating RSL. It is well known that inspecting assets manually is a time-consuming and labor intensive process. It also comprises a significant percentage of a utility’s operating costs each year. In some cases, manual inspection such as use of EWP’s, Rope Access, and Cherry Pickers etc. of certain assets can also be high risk resulting in injuries and fatality.

Recently, UAV’s are employed for asset inspection by a growing number of utilities throughout the world. Using UAV’s for asset inspection provides a number of substantial improvements over traditional inspection methods, including safety, efficiency and data quality [4]. However, developments in Unmanned Aerial Systems (UAS) and UAV look set to streamline and enhance the asset inspection process. As a result, UAV inspections are being trialed and adopted by a growing number of utilities [5].

Employing a UAV to inspect assets means that staff can stay at a safe distance removing the need for working at heights, thus reducing the likelihood of injury. Also, UAV inspections offer higher quality, more accurate and usable data, as well as improving safety efficiency and reducing costs.

It is also important that all images captured and anomalies recorded by the UAV’s may be spatially tagged and therefore incorporated readily into the Corporation’s Geographic Information System (GIS). The ability to record the size and dimension of anomalies also means that they can be compared after each subsequent inspection to detect and measure any changes that may have occurred.

Renewals Planning in Asset Management Branch undertook trials in highly trafficable areas and demonstrated that staffs were not in direct contact with operational hazards such as working at heights, working with or near high voltage assets, biological hazards and large bodies of water.

Appendix A, illustrates in photographs 1- 6 some of the high risk assets in the Corporation’s water and wastewater environment and the traditional techniques used by the ISP’s to undertake asset condition inspections.
4.0 QUALIFICATIONS

The UAV operator shall possess valid certificate issued by Civil Aviation Safety Authority (CASA) under Civil Aviation Act 1988 [6]. The operator shall produce valid certificate upon Corporation’s request.

The UAV operator should be able to recognise basic understanding in identifying various types of structural failures.

UAV will be piloted by individuals who are properly trained and competent to operate the vehicle or its systems.

UAV flights shall be conducted only after a thorough assessment of risks associated with the activity is completed. Also, Water Corporation’s Job Safety Environment Analysis (JSEA) forms shall be filled and endorsed by the relevant Operational & Maintenance Group (O&M) [7].

The UAV operator shall fully understand the Safety Essentials, Mandatroy Rules for our High Risk Assets, published by Water Corporation [8].

The UAV operator shall fully understand the Water Corporation’s Privacy Policy PCY 252 [9], and also Commonwealth Privacy Act, 1988 [10].

5.0 CONDITION RATING INTERPRETATION

5.1 Condition Rating System

The main purpose of rating the asset is to evaluate the condition in an objective approach and determine its effective RSL. By means of rating, appropriate level 2 condition assessments can be prioritised and/or remedial measures. For example, if the rating is 7 then 70% physical life is consumed, then the asset should be remediated within 1 year to achieve the required Level of Service (LOS).

For the condition assessment of Steel and Concrete assets, AMB utilises DST model [Refer: Figure 1]. The condition rating is based on 1 to 10 rating systems and the outcome is summarised as below [12].

☑ Excellent Physical condition - Observable deterioration is none. Less than 10% physical life is consumed.

☑ Very Good Physical condition - Observable deterioration is insignificant. No adverse service reports. 30% physical life is consumed.

☑ Acceptable Physical condition - Observation and/or testing indicate that the asset is meeting all service requirements. Sound Physical condition. Minor deterioration/minor defects observed. 50% physical life is consumed.

☑ Bad Physical condition - Moderate deterioration evident. Minor components or isolated sections of the asset need replacement or repair now but not affecting short term structural integrity. 70% physical life is consumed.

☑ Poor Physical condition - Serious/Significant deterioration evident and affecting structural integrity. Asset is now moving into zone of failure. 90% physical life is consumed.

☑ Very Poor Physical condition - Failed or failure imminent. Immediate need to replace most or the entire asset. 100% physical life is consumed.
Figure 1 – Asset Condition Rating based on DST model.
6.0 OVERVIEW OF LEVEL 1 ASSET CONDITION INSPECTION

AMB propose on all the Water Corporation assets that the condition assessment is undertaken at three levels:

6.1 Level 1 – Routine Operation and Maintenance Inspection

Level 1 inspection is carried out as part of routine operational budgets and activities. Level 1 inspection will assist in assessment of the overall safety and performance of the asset. **UAV inspection is classified as Level 1 inspection and shall be carried out only by Authorised Operation.** Relevant inspection data is captured as part of the on-going operation and maintenance process.

If corrosion defects are a threat to the structural integrity of the asset, then an Asset Deficiency Report (ADR) must be created by the asset inspector for remedial works.

**For Level 2 and Level 3 inspection references shall be made to relevant Steel and Concrete structures guidelines [1, 2].**

For example, an overview of the Corporation’s ACA process on steel tanks is shown in **Figure 2.**
Inspection Guidelines for Condition Assessment of Concrete and Steel Structures Using Unmanned Aerial Vehicles (UAV’s)

Figure 2 – Overview of Corporation’s steel tank ACA process.
7.0 ASSET INSPECTION PROCEDURE

Prior to conducting any inspection, the Authorised Operation must fully understand the condition assessment and data capture process. They must also be familiar with the criterion (condition rating & priority repair works) used to assess the asset condition. Relevant permits shall be obtained from the Asset Manager/Responsible Person prior to start of inspection.

Any inspector undertaking on-site condition assessments shall be appropriately qualified and competent for the task. The data collection and reports will provide valuable information not only on the asset RSL but also assists in understanding the risk and current performance of the asset.

The inspector should ensure that the assessment is complete with appropriate levels of detail for each relevant component of the asset with a rated condition. The corrosion assessments must be made with degree of reasonable accuracy. The data collected should adhere to the criteria provided to enable consistency between surveys.

All inspecting personnel shall hold appropriate site safety inductions both general and site specific. If the asset is deemed to be confined space and/or working at heights, then appropriate valid certification shall be possessed by the in-house personnel and ISP’s. The certificates shall be available to the Corporation for at least 10 working days prior to the inspection.

After completion of inspections, the report should be sent to the inspection initiator whom should then forward to the Asset Manager or Responsible Person and Renewals Planning. The inspection data must then be updated and analysed in the DST database. The inspection documents will be saved in Aqua and linked to ACA database.
7.1 Roles and Responsibilities

<table>
<thead>
<tr>
<th>Activities</th>
<th>Role(s)*</th>
<th>Responsible Branch*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1</td>
<td>Visual Inspection using UAV’s</td>
<td>Authorised Operation</td>
</tr>
<tr>
<td>Level 2</td>
<td>External &amp; Internal inspection</td>
<td>ISP†</td>
</tr>
<tr>
<td>Level 3</td>
<td>Detailed &amp; Laboratory Assessment</td>
<td>External Consultants*</td>
</tr>
<tr>
<td>ARA</td>
<td>Regional/Alliance Civil Asset Planners and Maintainers</td>
<td>Region/Alliance Partners/AMB</td>
</tr>
<tr>
<td>Inspection data review</td>
<td>Level 1 by OAM &amp; Region/Alliance Partners. Level 2 and 3 inspection data analysis by Renewals team.</td>
<td>AMB</td>
</tr>
<tr>
<td>Inspection data update in Database</td>
<td>Analyst in Renewals team</td>
<td>AMB</td>
</tr>
</tbody>
</table>

Table 1 – Roles and Responsibilities Matrix for UAV Inspection.

* Changes in Roles and Responsibilities matrix shall only be approved by Supervising Engineer, AMB.
† MESB and other External Contractors [13].
* Metallurgy/Materials/Corrosion Specialists.

7.2 Defects Notification

During Level 1 inspection, corrosion related failures may be identified by the Authorised Operation and/or ISP's that requires urgent attention shall be notified to the OAM/Region/Alliance. The defects recognised needs to be addressed as soon as practicable, so that the asset can be brought back to operation. Some of the common issues that may require immediate notification include:

1) Safety compliance issues.

2) Security issues.

3) A defect that will have detrimental effect on the asset if not rectified.

4) A defect that is adversely affecting the service being provided by the asset.
7.3 Inspection Data Interpretation

Persons responsible for identifying and recording defects, service conditions and construction features for preparing reports and operating equipment shall hold a suitable qualification for various levels of inspection and is discussed in Section 7.1.

AMB is responsible for analysing the asset inspection data (Level 2 & Level 3) provided by Authorised Operation and/or ISP’s and shall be competent in the following:

1) Interpreting information contained in the inspection reports.
2) Identifying and coding of defects and other features.
3) Verifying the inspection scoring/grading system.
4) Recording the inspection scoring/grading system in DST tools.
5) Recognising corrosion related defects and the likely parameter contributing to the defects.
6) Recognising poor quality inspection videos and camera inspection.
8.0 APPENDIX A - HIGH RISK ASSETS IN CORPORATION’S WATER AND WASTEWATER ENVIRONMENT
Photo 1 – Elevated steel tank.

Photo 2 – Elevated steel tank.

Photo 3 – Elevated Concrete Tank.

Photo 4 – Pipeline under the bridge.

Photo 5 – Inspection of Intake tower in the Dam by conventional inspection approach.

Photo 6 – Sacrificial Anode inspection on the intake tower.
9.0 APPENDIX B - ASSET CONDITION RATING
9.1 ASSET CONDITION RATING 1 - EXCELLENT

☑ General Comment: Excellent Physical condition. Observable deterioration is none.

Photo 7 – Tek Screw in Condition Rating 1 – Excellent.

Photo 8 – Elevated tank air vent & hand rail in Condition Rating 1 – Excellent.

Photo 9 – Reservoir roof vent & tek screws in Condition Rating 1 – Excellent.

Photo 10 – Hold down bolt & beam in Condition Rating 1 – Excellent.

Photo 11 – Outlet concrete valve pit in Condition Rating 1 – Excellent.

Photo 12 – Tank security fence in Condition Rating 1 – Excellent.
9.2 ASSET CONDITION RATING 3 – VERY GOOD

☑️ General Comment: Very Good Physical condition. Observable deterioration is insignificant. No adverse service reports.

Photo 13 – Tek Screw in Condition Rating 3 – Very Good.

Photo 14 – Elevated tank platform supports are in Condition Rating 3 – Very Good.

Photo 15 – Roof Sheeting in Condition Rating 3 – Very Good.


Photo 17 – Chlorination plant cubicle in Condition Rating 3 – Very Good.

Photo 18 – Tank compound fence in Condition Rating 3 – Very Good.
9.3 ASSET CONDITION RATING 5 - ACCEPTABLE

☑ General Comment: Observation and/or testing indicate that the asset is meeting all service requirements. Sound Physical condition. Minor deterioration/minor defects observed.

Photo 19 – Tek Screw in Condition Rating 5 – Acceptable.

Photo 20 – Timber platform in Condition Rating 5 – Acceptable.

Photo 21 – Purlins in Condition Rating 5 – Acceptable.

Photo 22 – Timber platform and handrail are in Condition Rating 5 – Acceptable.

Photo 23 – Pipework in Condition Rating 5 – Acceptable.

Photo 24 – Minor water seepage from tank in Condition Rating 5 – Acceptable.
9.4 ASSET CONDITION RATING 7 - BAD

☑ General Comment: Moderate deterioration evident. Minor components or isolated sections of the asset need replacement or repair now but not affecting short term structural integrity.

Photo 25 – Tek Screw in Condition Rating 7 – Bad.

Photo 26 – Concrete spalling in Condition Rating 7 – Bad.

Photo 27 – Loose timber platform in Condition Rating 7 – Bad.

Photo 28 – Holes on the tank roof sheeting in Condition Rating 7 – Bad.

Photo 29 – Cracks on the concrete wall in Condition Rating 7 – Bad.

Photo 30 – Cracks on the concrete floor in Condition Rating 7 – Bad.
9.5 ASSET CONDITION RATING 9 - POOR

✔ General Comment: Serious/Significant deterioration evident and affecting structural integrity. Asset is now moving into zone of failure.

Photo 31 – Tek Screw in Condition Rating 9 – Poor

Photo 32 – Corroded roof in Condition Rating 9 – Poor.

Photo 33 – Decayed timber platform of elevated steel tank in Condition Rating 9 – Poor.

Photo 34 – Crack on the concrete wall in Condition Rating 10 – Poor.

Photo 35 – Corroded purlin of steel tank in Condition Rating 9 – Poor.

Photo 36 – Corroded weir plate in Condition Rating 10 – Poor.
9.6 ASSET CONDITION RATING 10 – VERY POOR

☐ **General Comment:** Failed or failure imminent. Immediate need to replace most or all of the asset.

- **Photo 37** – Tek Screw in Condition Rating 10 – Very Poor.
- **Photo 38** – Access hatch in Condition Rating 10 – Very Poor.
- **Photo 39** – Broken Pipe in Condition Rating 10 – Very Poor.
- **Photo 40** – Loose nails on timber deck – trip hazard in Condition Rating 10 – Very Poor.
- **Photo 41** – Roof sheet and wall panel in Condition Rating 10 – Very Poor.
- **Photo 42** – Corroded & Leaking Pipe in Condition Rating 10 – Very Poor.