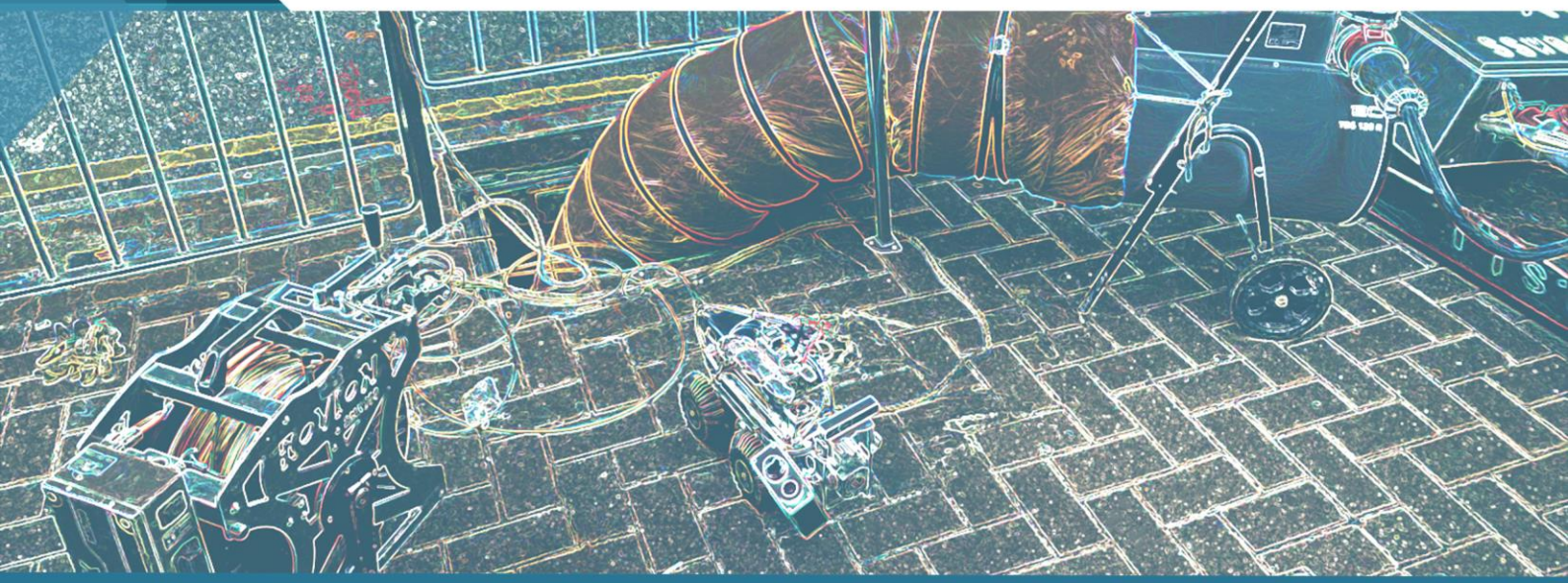
SPECIFICATIONS FOR NONDESTRUCTIVE TESTING, SURVEYING, IMAGING AND DIAGNOSIS FOR UNDERGROUND UTILITIES

2,1 VISUAL INSPECTION (VERSION.1)

[NDTSID-UU-2,1]



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SPECIFICATIONS FOR NONDESTRUCTIVE TESTING, SURVEYING, IMAGING AND DIAGNOSIS FOR UNDERGROUND UTILITIES

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Foreword

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DISCLAIMER

VISUAL INSPECTION

Table of Content

A – Acknowledgement to Steering, Technical Workgroup 2,1

This document (2,1) is one of the six specifications prepared for accrediting laboratories/survey companies conducting underground utility surveys. The project team expresses the greatest appreciation and gratitude to the following parties for providing support during the drafting and implementation of this specification.

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B – Background

B1 – History

In recent years, the inspection of pipe condition has become an important feature of the management of sewage and drainage systems, as well as other utilities such as relined water and gas pipes. Such surveys generate large amounts of data that require careful analysis when used as a health monitoring tool and as a basis for making decisions about the replacement or rehabilitation of buried pipes. In 1980, the first edition of The Manual of Sewer Condition Classification (MSCC) (2013) was published in order to provide a UK standard system for defect coding, and the latest 5th edition was published in 2013. This manual has been extensively updated over the past decades to describe the use of what has become the equivalent coding system listed in BS EN 13508-2:2003+A1:2011.

Locally, in Hong Kong, as a reflection of the city's congested underground environment, the first edition of the Code of Practice (COP) was published by the government in 1996 and updated in 2006 by the former Environment, Transport and Works Bureau (ETWB, 2006). The COP gave guidance on monitoring and maintenance of water-carrying services that might affect slopes. It was prepared under the direction of the Standing Committee on Slope Safety chaired by the Works Branch (ETWB, 2006) in response to a recommendation made by Professor Morgenstern, an international geotechnical expert, in his report on the Kwun Lung Lau Landslide in 1994 (GEO, 1994). Later, in 2009, the Utility Training Institute (UTI) (2009a) published a standard Hong Kong Conduit Condition Evaluation Code (HKCCEC), which is similar to the several editions of WRC (1993/2004/2013) but includes survey and inspection covering a wider range of local contexts. In addition, two specifications for Conduit Condition Evaluation (CCTV & ME Survey) and Manhole Internal Condition Survey (MHICS) were also published by the Utility Training Institute (2009b, 2009c). These documents form the basis of this specification and the accreditation mechanism for service providers and labs.

B2 – Significance, Applications and Scope of Specification

B2,1 Significance and application

Underground utilities are the veins of any city. Damage to various types of pipes can be visually inspected and systematically recorded via a number of coding systems published by different agencies. The visual inspection method described in this specification covers the history, theories/principles, equipment, field procedures, interpretation of data, and methods for the non-destructive and near-surface visual inspection system. The approach suggested in this method for conducting visual inspection is the most commonly used, widely accepted, and well proven. However, other technically sound approaches or modifications to visual inspection may be substituted if technically verified, validated and documented.

The **inspection records** are the major deliverables of surveys aimed at assessing the five different categories of observations of manhole/pipe internal conditions: namely, structural/fabric, service/durability, construction details, re-liner defects and miscellaneous. However, the ways these records are produced based on proper test/survey/diagnostic procedures vary significantly between companies and individuals. Erroneous or incomplete information within the utilities map can mislead users, causing unnecessary damage and exposing the public and workers to danger. Experience and knowledge of the subject area greatly enhance the credibility of the utilities map and, most importantly, help clarify when the test/survey/diagnostic results are uncertain due to site, materials and equipment limitations rather than the Signatory/Survey Officers' abilities. The successful management of the above factors can be summarized in a **4M1E** framework: namely, **M**an/woman, **M**achine, **M**aterials, **M**ethods and **E**nvironment, which can be applied within an accreditation framework following 'ISO/IEC 17025 (2017) General requirements for the competence of testing and calibration laboratories'. In

view of the above needs, this document provides a unified specification and standard for visual inspection of underground utilities based on 4M1E, which aims to help utility companies, laboratories/survey companies, developers, estate managers, contractors and consultants to maintain consistent standards of UU testing, surveying, imaging and diagnosis.

Although visual inspection can reflect the true condition of utilities under the right conditions, consistent and reliable interpretation can only be performed by an experienced Signatory/Survey Officer). Such experience can be gained through use of the system and through training courses provided by recognized universities, institutions, various equipment manufacturers or consulting companies.

B2,2 Scope

1. This test method covers the history, theories/principles, equipment, field procedures, interpretation of data, and methods for the visual inspection of vertical shafts (e.g. manholes) and horizontal pipes (e.g. drains, sewers, water and gas pipes).
2. The approach suggested in this method for conducting visual inspection is the most commonly used, widely accepted, and well proven. However, other technically sound approaches or modifications may be substituted if technically verified, validated and documented.
3. This method does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this method to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.

Method A: Manhole survey of vertical shafts

The objective of manhole surveys is to check and verify the position of the manhole structure(s) against any existing records, to record all salient features such as reference number, cover and invert levels of each manhole, and the diameters, flow directions and shapes of all the connecting pipes. The survey should also assess the structural and surface condition of the manhole(s), and look for any evidence of leakage or infiltration.

Method B: CCTV inspection/survey of horizontal pipes (e.g. drains, sewers, water supplies, gas, etc.)

Closed-circuit television (CCTV) survey using a robotic tractor is the most direct method for inspecting and systematically recording the structural, service, repair condition, as well as construction details and miscellaneous features of utilities that are not fully or partially filled with fluid. A CCTV inspection of the cleaned pipe shall be carried out for regular inspection, and prior to and after re-lining. Most importantly, the gradings determined from the CCTV survey coding results provide a decision-making tool for use in any rehabilitation scheme. For pipes with an internal diameter of 1500 mm or larger, man-entry inspection may be carried out if safety can be assured. However, it must be emphasized that working in a confined space can be hazardous, especially in foul sewers where lethal gas can be generated by septic sewage and sludge.

B3 – Glossary

The glossary can be found in the following three recognized specifications MSCC (WRC, 1993/2004/2013), HKCCEC (UTI, 2019a) and BS EN 13508-2, and is therefore not repeated here.

B4 – Theories and Principles

B4,1 Method A: Manhole survey of vertical shafts and Method B: CCTV inspection/survey of horizontal pipes

Visual Inspection is the oldest and most basic method of inspection dating back to the days before sensors exploiting a range of different physical principles and wavelengths were invented. Relying solely upon the naked eye, it is a process of examining a target object, utilities in this specification, and inspecting it for surface defects/flaws. It is simple, relatively cost effective and is always the first step of any inspection before sensors are deployed. One of the largest concerns is the personnel conducting the visual inspection, as their training, experience and biases are the biggest sources of variation in inspection results.

B4,2 Accuracy

Table 1 recommends the survey accuracies for different measurements according to Utility Training Institute (2009b). No accuracy level is suggested for Methods B.

Table 1 Recommended accuracies for different measurements

Survey method	Measurement	Tolerances
Method A: Manhole survey	Depths (linear measurement)	± 25 mm
	Relative depths of pipe inverts within the chamber (linear measurement)	± 20 mm
	Pipe sizes (linear measurement)	± 20 mm
	Box culverts/nullah (linear measurement)	± 50 mm
	All other dimensions (linear measurement)	± 50 mm

If required, all reported coordinates and levels should be represented in HK 1980 Grid coordinates based on HK80 Datum. (The coordinates for N,E are presented as 8*****.***, 8*****.***, relative to the HK80 Datum. Normally, “All levels are referred to HKPD” must be present).

C – Qualified Personnel

C1 – Personnel

The Signatories and Survey Officers for visual inspection shall meet the personal requirements in Sections C2 and C3 below, respectively.

C2 – Signatory

C2,1 A **Signatory** of a report for both Method A and B shall either have:

(i) a Bachelor of Science (e.g. Geomatics/Land Surveying and Geo-informatics) or Engineering (e.g. Civil/Electrical/Materials/Mechanical/Gas/Industrial) degree with specialization in underground-utility (UU) survey or a Bachelor of Science (e.g. Geomatics/Land Surveying) degree with not at less than 200 contact hours of BSc/BEng’s UU training plus final year project, provided by a recognized tertiary institution plus at least ***three*** years of technical and managerial experience of underground utilities, within which a period of two years is substantially[1] related to the subject matter in this specification, or

(ii) a valid certificate or diploma[2] of specialization in visual inspection of utilities issued by a recognized organization operating under international standards or qualifications framework level 4 plus at least ***five*** years of technical and managerial experience of

underground utilities, within which three years are substantially[1] related to the subject matter in this specification, or

(iii) at least a higher certificate or diploma issued by a recognized technical institute or an equivalent qualification in a relevant discipline, with at least ***seven*** years of direct technical and managerial experience, within which five years are directly related to the subject matter in this specification, plus relevant training courses[2] covering the content in this specification.

[1] Direct technical and managerial involvement in 10 test/survey reports in different contracts/works orders.
[2] A typical certificate/diploma shall include all aspects covered in this specification.

C3 – Survey Officer

C3,1 A **Survey Officer** or coder for both Method A and B shall normally be supervised by a Signatory having the necessary qualifications, experience and technical knowledge, and shall either have:

(i) a Bachelor of Science (e.g. Geomatics/Land Surveying and Geo-informatics) or Engineering (e.g. Civil/Electrical/Materials/Mechanical/Gas/Industrial) degree with specialization in underground-utility (UU) survey or a Bachelor of Science (e.g. Geomatics/Land Surveying) with not at least 100 contact hours of BSc/BEng's UU training provided by a recognized tertiary institution, plus at least ***one*** year of substantial on-the-job experience[3] related to the subject matter in this specification, or

(ii) a valid certificate or diploma[4] of specialization in visual inspection of utilities issued by a recognized organization operating under international standards or qualifications framework level 3 plus at least ***two*** years of substantial on-the-job experience[3] related to the subject matter in this specification, or

(iii) at least a higher certificate or diploma issued by a recognized technical institute or an equivalent qualification in a relevant discipline, plus at least ***three*** years of substantial on-the-job experience[3] related to the subject matter in this specification, plus relevant training courses[4] covering the content in this specification, or

(iv) at least ***eight*** years of substantial on-the-job experience[3] related to the subject matter in this specification.

[3] On-the-job direct involvement in 10 test/survey reports in different contracts/works orders.
[4] A typical certificate/diploma shall include all hands-on aspects covered in this specification.

D – Instrumentation

D1 – General

The CCTV camera shall be capable of 360-degree pan, tilt and zoom, and be fitted with an inclinometer for measuring variations in gradient. A CCTV tractor shall contain a means of transporting the CCTV camera in a stable condition through the sewers or drains under inspection. Such equipment shall ensure that the CCTV camera's position is maintained on or near to the central axis of a cylindrical sewer or drain. Where the CCTV camera is towed by winch and bond through the sewers or drains, all winches shall be stable with either lockable or ratcheted drums. All bonds shall

be steel or of an equally non-elastic material to ensure the smooth and steady progress of the CCTV camera. All winches shall be inherently stable under loaded conditions.

A CCTV system, including the camera(s) and a tractor, shall carry sufficient numbers of guides and rollers such that, when surveying, all bonds are supported away from the sewer, drain or manhole structures, and all CCTV cables and/or lines used to measure the camera's location within the sewer/drain are maintained in a taut manner and set at right angles, where possible, to run through or over the measuring equipment.

A CCTV system, including the camera(s) and a tractor, shall carry a range of flow control equipment, as opposed to over-pumping equipment, for use in controlling the flow during the survey. In many locations, it is anticipated that access to slopes may be difficult for the normal type of vehicle-mounted CCTV survey equipment. The CCTV system shall be available to enable difficult locations such as steep pipes and steep slopes to be surveyed. The lab/survey company is required to control the water flow of the pipeline during CCTV survey, for example to keep the water level at below the required levels.

D2 – Equipment calibration

The requirements for equipment calibration/verification intervals are provided in Table 2 and 3.

Table 2 Camera's colour calibration

Shades of grey	The grey scale shall show equal changes in brightness ranging from black to white with a minimum of five clearly recognizable stages.
Colour	With the monitor control adjusted for correct saturation, the six colours plus black and white shall be clearly resolved with the primary and complementary colours in order of decreasing luminance. The grey scale shall appear in contrasting shades of grey with no tint.
Linearity	The background grid shall show squares of equal size, without convergence/divergence over the whole of the picture. The centre circle shall appear round and have the correct height/width relationship (+/-5%).
Resolution	The live picture must be clearly visible with no interference and be capable of registering a minimum number of TV lines/picture height lines. The resolution shall be checked with the monitor colour turned down. In the case of tube cameras this shall be 350 lines and in the case of CCD type cameras 250 lines.
Colour consistency	To ensure that the camera shall provide similar results when used with its own illumination source, the lighting shall be fixed in intensity prior to commencing the survey. In order to ensure colour constancy, generally no variation in illumination shall take place during the survey.
Focus/Iris/ Illumination	The adjustment of focus and iris shall allow optimum picture quality to be achieved and shall be remotely operated. The adjustment of focus and iris shall provide a minimum focal range from 150 mm in front of the camera's lens to infinity. The distance along the sewers or drains in focus from the initial point of observation shall be a minimum of twice the vertical height of the sewers or drains. The illumination shall allow an even distribution of the light around the sewer/drain's perimeter without the loss of contrast, flare out of picture or shadowing.

Table 3 Specific Calibration/Verification Requirements

Type of equipment	Maximum period between successive calibration/ verification	Calibration/verification procedure or guidance documents and equipment requirements
CCTV camera	Before each test	The requirements in Table 2 shall be fulfilled by using Marconi Chart, or equivalent. A test device for the CCTV equipment shall be available on site enabling the tests specified below to be conducted. The test card shall be the Marconi Resolution Chart No. 1 or its derivatives with a colour bar, clearly defined with no tinting to show the colours: white, yellow, cyan, green, magenta, red, blue, and black. At the start of every working shift, the camera shall be positioned centrally and at right-angles to the test card at a distance where the full test card just fills the monitor screen. The card shall be illuminated evenly and uniformly without any reflection. The electronic systems, television camera and monitor shall be of sufficiently good quality. The CCTV camera shall have suitable illumination and shall be capable of providing an accurate and clear record of the sewer's or drain's internal condition. A system check shall be carried out on-site and before site work.
CCTV tractor (support/host of the CCTV camera)	1 year	Verify the wheel/odometer in a length not less than 10m and at least five distinct distances with an increment of 10m. All measurements shall be within ±1% of the length or ±0.3m, whichever is greater.
	Before each test	(1) Measure the cable length at one point with a minimum length 10m, and accurate to ±1% of the length or ±0.3m, whichever is greater. (2) Measure the height of the camera's vertical position appeared on the monitor at half of the pipe. All measurements shall be ±10% of the vertical pipe dimension. This process can be done on the ground.
Other equipment related to this visual inspection survey (e.g. total station, digital level, tape measure, cable calibration device)	1 year (calibration)	Accuracy requirement provided by the manufacturer shall be observed.

E – General Testing and Survey Procedure

The testing, survey and coding procedure of **one** of the following three recognized specifications shall be followed in general, while some key points as a general rule of thumb in Table 4 shall be followed.

1. Water Research Council (WRC), Manual of Sewer Condition Classification (MSCC) 3rd Ed. or above, or
2. Utility Training Institute (UTI) (2009a), Hong Kong Conduit Condition Evaluation Codes 4th Ed and/or Utility Training Institute (2009b) Specification for Conduit Condition Evaluation (CCTV & ME Survey) and/or Utility Training Institute (2009c) Specification for Manhole Internal Condition Survey (MHICS), or
3. Investigation and assessment of drain and sewer systems outside buildings – part 2 Visual inspection BS EN 13508-2:2003+A1:2011, or equivalent.

Table 4 Key points of testing and survey procedures

	CCTV survey
Maximum Allowable Water Level	< 30% for pipe diameters above 600mm. < 25% for pipe diameters between 300mm to 600mm. < 20% for pipe diameters less than 300mm.
Camera's Height	In the case of circular or regular shaped pipes, the camera lens shall be positioned centrally within the sewers or drains to minimize photo distortion. In the case of egg-shaped sewers and drains, the camera lens shall be positioned vertically above the invert at a height two-thirds of the vertical dimension of the pipe. In all circumstances, the camera lens shall be positioned looking forward along the axis of the pipeline. The system check requirement on the camera height before each test refers to Table 3.
Images	The CCTV camera shall have suitable illumination and be capable of providing an accurate and clear record of the drain's internal condition. Pipes shall be cleansed prior to the survey. The advancement of the camera shall be stop to ensure that an accurate and clear record is taken whenever defects are being noted on the coding sheet.
Camera Tractor Speed	The speed of the CCTV tractor shall be limited to 0.1 m/s for pipes of diameters less than or equal to 225 mm, 0.15 m/s for diameters exceeding or equal to 225 mm but less than or equal to 300mm, and 0.2m/s for diameters larger than 300 mm. The system check requirement on the camera wheel/odometer before each test refers to Table 3.
Monitor Display	A data generator shall electronically generate and clearly display on the viewing monitor and video recording a continuous record and real-time display of the following information: (a) CCTV camera's meter position from "adjusted zero. (b) Location (street name/slope reference). (c) Pipeline dimensions. (d) Manhole or sewer/drain length reference numbers. (e) Date of survey. (f) Direction of survey. (g) Time of start of survey. (h) Pipeline classification (sewers or drains). (i) Name of company and operator.
Image checking	The CCTV camera shall have suitable illumination and shall be capable of providing an accurate and clear record of the sewer's or drain's internal condition. A system check shall be carried out on-site and before site work.

F – Reporting

F1 – Findings, Grades of Severity and Survey Drawings

The investigation results (layout plan only) shall be plotted at 1:100 scale or another scale to be confirmed in A1/A3 (paper size) drawings on the specified grid and datum. The findings shall be reported in accordance with the coding systems in **one** of the following standards:

1. Water Research Council (WRC), Manual of Sewer Condition Classification (MSCC) 3rd Edition or above, or
2. Utility Training Institute (UTI) (2009a), Hong Kong Conduit Condition Evaluation Codes 4th Ed, or
3. Investigation and assessment of drain and sewer systems outside buildings – part 2 Visual inspection BS EN 13508-2:2003+A1:2011, or equivalent.

The coding systems for pipes comprise of a series of codes that shall be used to describe the defects and features found in the pipe. A separate inspection report shall be prepared for the full length of each inspected utility. If an additional node is found during the inspection, then separate inspection reports shall be prepared for each of the two pipeline lengths. Where a survey is declared abandoned, either in the same direction or from the other direction, then one or more than one of the reasons given in Section G shall be clearly reported. In particular,

a. In the drawing, the location(s) of suspected defect(s), if any, shall be connected to the identified utility alignment, ground features like valves, roads and buildings contained in the location plan. If required, all reported coordinates and levels should be represented in HK 1980 Grid coordinates based on HK80 Datum. (The coordinates for N,E are presented as 8*****.***, 8*****.***, relative to the HK80 Datum. Normally, “All levels are referred to HKPD” and must be present in the survey plan).
b. For all defects, for continuous or repeated structural or service conditions, photos shall be taken at the beginning of the defect and at not less than 5 m intervals thereafter.
c. For all junctions, connections, defects or other appropriate features, a photo shall be taken during the CCTV survey to illustrate the degree of mortar loss, size of a crack or fracture, size of a void or any other quantifiable defect, and a suitable metric scale shall be included in the clearly focused photograph. When a photo is taken to illustrate mortar loss, the scale shall be inserted in the joint between the bricks. Where a photo is taken to illustrate a specific defect, it shall occupy the central part of the photograph and be clearly in focus and accurately reflect the defect.
d. For submission in CAD and GIS format, requirements in Computer-Aided-Drafting Standard for Works Projects (CSWP) Version 1.03.00 (2007) and Geographic Information System (GIS) Specifications for Engineering Surveys of Highway Department (2015) shall be followed, respectively.

F2 – Test Report

The report shall include, but not be limited to the following sections:

- Introduction and background
- Site areas, boundary and conditions
- Record drawings of utilities within the site area
- General test/survey procedures (Section E) and site-specific procedures
- Instrumentation (Section D)
- Summary of findings
- Survey drawings in CAD/GIS/BIM/point-cloud formats (Section F1)

- Limitations (Section G)
- Conclusions
- Site photos in an appendix
- Record drawing (reference utility plans provided by utility companies and clients)

G – Limitations

When the survey cannot be completed or completed with limitations, the following statuses shall be declared: SA (survey abandoned), UTR (unable to raise), UTL (unable to locate), UTGA (unable to get access), and UTS (unable to survey), according to the examples given below in Table 5. The lab/survey company shall expand the list as an in-house procedure, if necessary.

Table 5 Limitations of visual inspection

Type of survey	Limitations	Examples
Method A: Manhole survey of vertical shafts	Record drawings	Utility information is not available or incomplete or is in general inaccurate.
	UTR (unable to raise)	Underneath a car, keyhole damaged or no keyhole found, pit/manhole cover tightly closed, oil in pit/manhole, pit/manhole on carriageway and no temporary traffic arrangement (TTA), work in progress, pit/manhole cover corroded, obstructed, harmful pest (e.g. bees).
	UTL (unable to locate)	The pit/manhole is shown in record plan but could not be found on site.
	UTGA (unable to get access)	Private area, pump room, construction site inside the survey area, access points are far away from the survey area but the alignment is believed to enter the survey area, thus the alignment may be missed.
	UTS (unable to survey)	Full of silt/water, abandoned pit/manhole.
CCTV survey of horizontal pipes	Record drawings	Utility information is not available or incomplete or is in general inaccurate.
	SA (survey abandoned)	Pipe obstruction, pipe blocked/collapsed, high water flow rate within the pit/manhole, vermin.

H – References

1. BS EN 13508-2:2003+A1 (2011). Investigation and assessment of drain and sewer systems outside buildings – Part 2: Visual inspection coding system.
2. Development Bureau of The Government of the Hong Kong Special Administrative Region (2007) Computer-Aided-Drafting Standard for Works Projects (CSWP) Version 1.03.00. (https://www.devb.gov.hk/en/construction_sector_matters/electronic_services/cad_standard/computer_aided_drafting/cad/index.html)
3. Environment, Transport and Works Bureau (ETWB) (2006) Code of Practice on Monitoring and Maintenance of Water-Carrying Services Affecting Slopes, Environment, Transport and Works Bureau.
4. ISO ISO/IEC 17025 (2017) - General requirements for the competence of testing and calibration laboratories - Third edition. *ISO copyright office, www.iso.org*
5. Geotechnical Engineering Office (1994) GEO Report No.103, The Government of the Hong Kong Special Administrative Region.
6. Highways Department of The Government of the Hong Kong Special Administrative Region (2015) Geographic Information System (GIS) Specifications for Engineering Surveys of Highway Department. (https://www.hyd.gov.hk/en/publications_and_publicity/publications/technical_document/GIS_Specifications/GIS_Specifications_of_HyD_version_2.pdf
7. Water Research Council (1993/2004/2013) Manual of Sewer Condition Classification (MSCC) 3rd/4th/5th Ed.
8. Utility Training Institute (2009a) Hong Kong Conduit Condition Evaluation Codes (HKCCEC), 4th Ed.
9. Utility Training Institute (2009b) Specification for Conduit Condition Evaluation (CCTV & ME Survey).
10. Utility Training Institute (2009c) Specification for Manhole Internal Condition Survey (MHICS).

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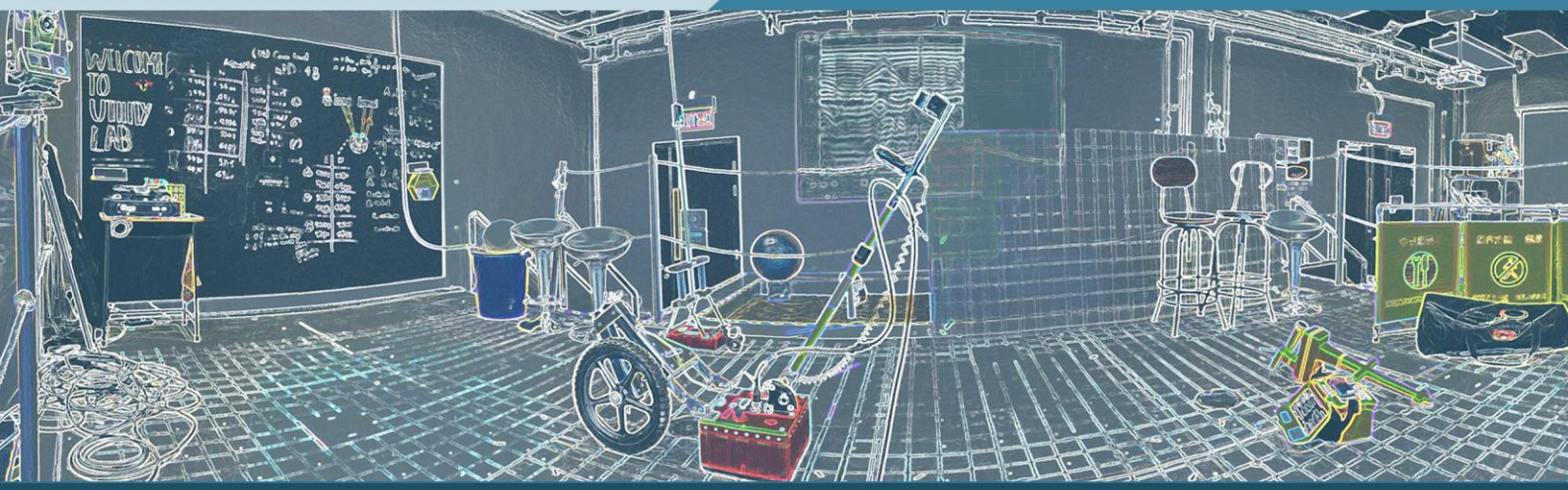

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