

Paving the way for effective mapping and planning of the underground: Singapore's Digital Underground experience

Prof. Dr. Martin Raubal
Principal Investigator Digital Underground
Institute of Cartography and Geoinformation, ETH Zurich
mraubal@ethz.ch

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UNDERGROUND

Digital Underground CH, Workshop @ ETH Zürich, 6.9.2022



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CENTRE**

ETH zürich

- ETH Zürich's only major institute outside Switzerland
- Research on urbanization-related matters in Singapore since 2010

Team

Scientific leadership



Prof. Dr. Martin RAUBAL
Principal Investigator
Singapore-ETH Centre
ETH Zürich
Institute of Cartography and
Geoinformation



Prof. Dr. Andreas WIESER
Co-Principal Investigator
ETH Zürich
Institute of Geodesy and
Photogrammetry

Research team



Dr. Jonas JOERIN
Project Coordinator



Dr. JAW Siow Wei
Researcher
Data Capture



Michelle CHAN
UX/UI Specialist
Use cases



WU Hao
Senior Software Engineer
Data Management Platform



LI Meng Chan (Lawrence)
Geospatial Software Developer
Data Management Platform



Dr. Lasse Hedegaard HANSEN
Visiting Researcher
Survey & mapping solutions

Advisors



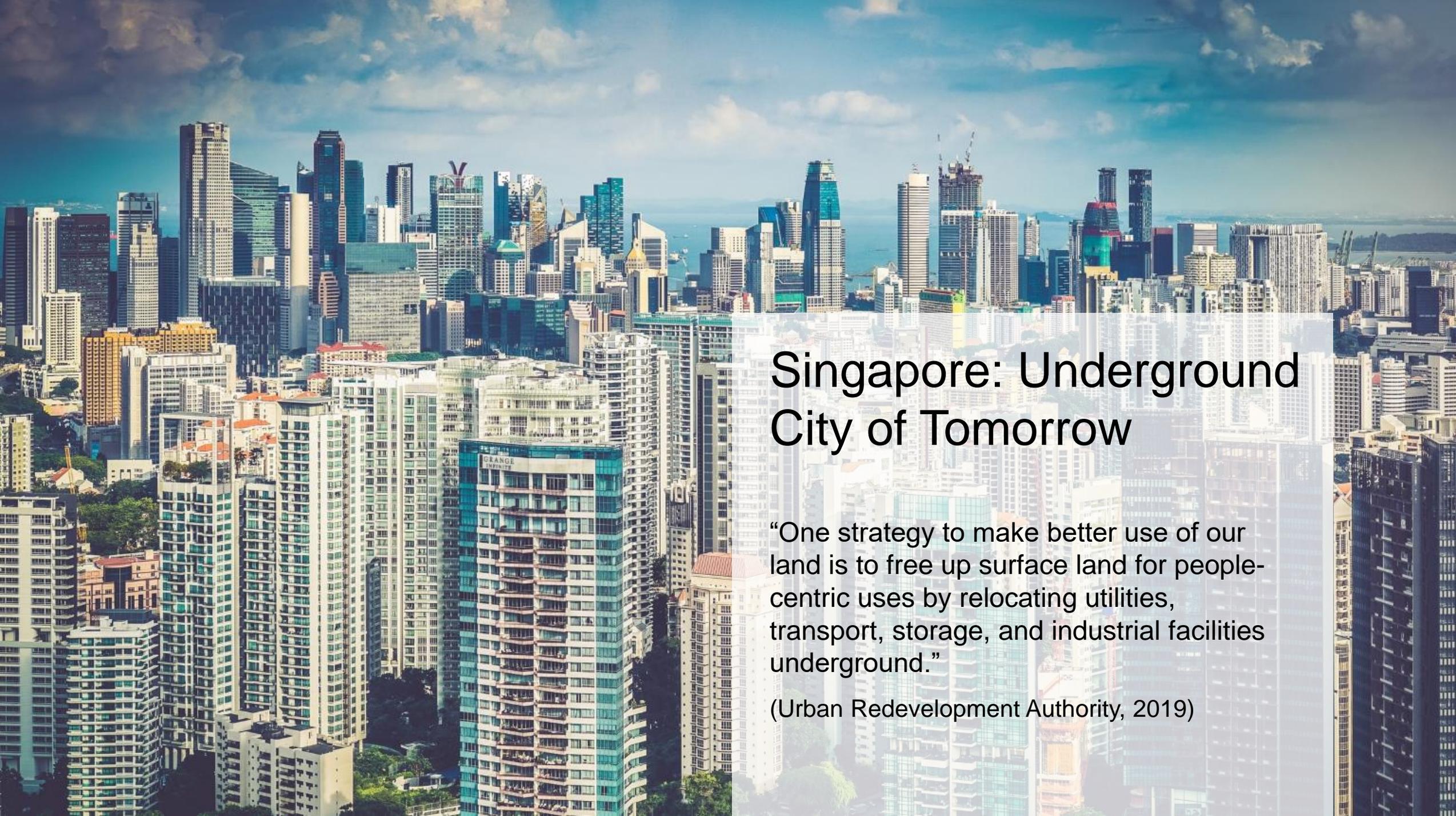
Dr. Gerhard SCHROTTER
Advisor
Stadt Zürich
Geomatics and Surveying



Dr. Geoff ZEISS
Advisor
Between The Poles
Open Geospatial Consortium



Rob VAN SON
Consultant

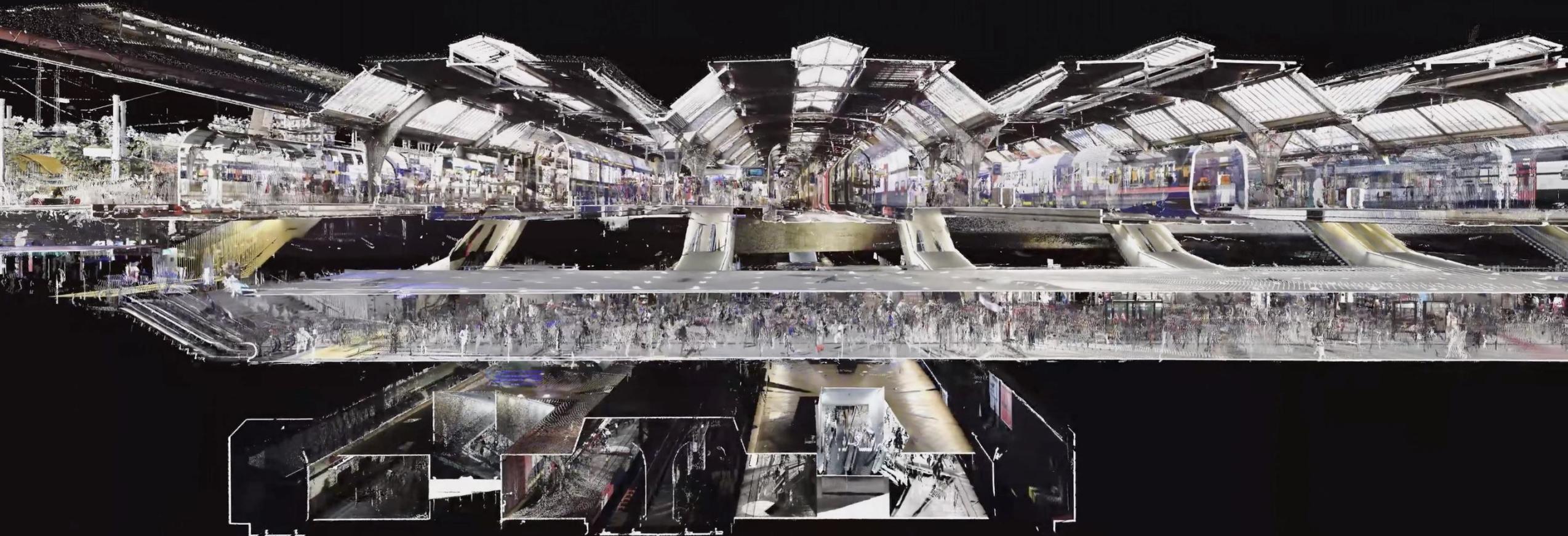


Singapore: Underground City of Tomorrow

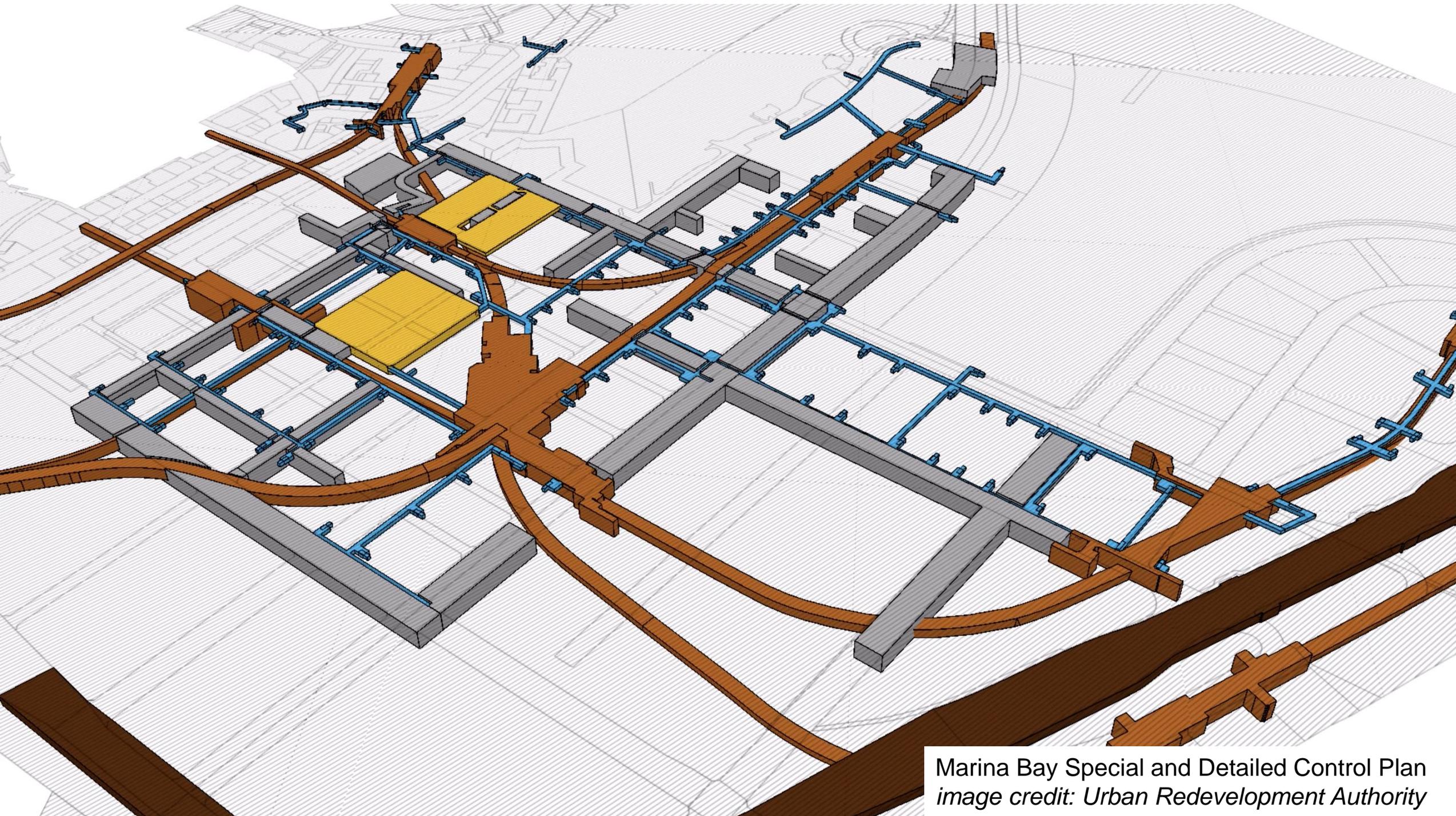
“One strategy to make better use of our land is to free up surface land for people-centric uses by relocating utilities, transport, storage, and industrial facilities underground.”

(Urban Redevelopment Authority, 2019)

Going underground requires a new perspective



Zürich Hauptbahnhof, Zürich, Switzerland
image credit: SCANVISION GmbH, 2019



Marina Bay Special and Detailed Control Plan
image credit: *Urban Redevelopment Authority*

Going underground demands quality data

- Mindset shift: From land to space
- Systematic and continuous management of underground space as asset is required
- Planning and land administration need to integrate space above and below the surface

Reliable 3D data on what lies beneath are essential

Finding space for the future

To use our space more efficiently, the Government is looking to launch its Underground Master Plan in 2019. Here are some subterranean ideas that are being explored.

Substations

Electrical substations, which are essential for providing electricity to estates, currently occupy small tracts of land at the ground level, even though they are connected to the underground cabling network. To save space, these can be housed underground, and can still be serviced through access points with a smaller footprint.

Bus interchange

The new Bidadari housing estate will be home to Singapore's first underground air-conditioned bus interchange below Housing Board flats. Slated for completion by 2019, it will sit below a carpark and a garden, and will likely cater to five bus services.

Road and rail networks

To enhance our living environments, future major road and rail networks, especially those that will cut through built-up areas, will be located underground. This reduces the impact of noise and dust on homes.

Deep Tunnel Sewerage System

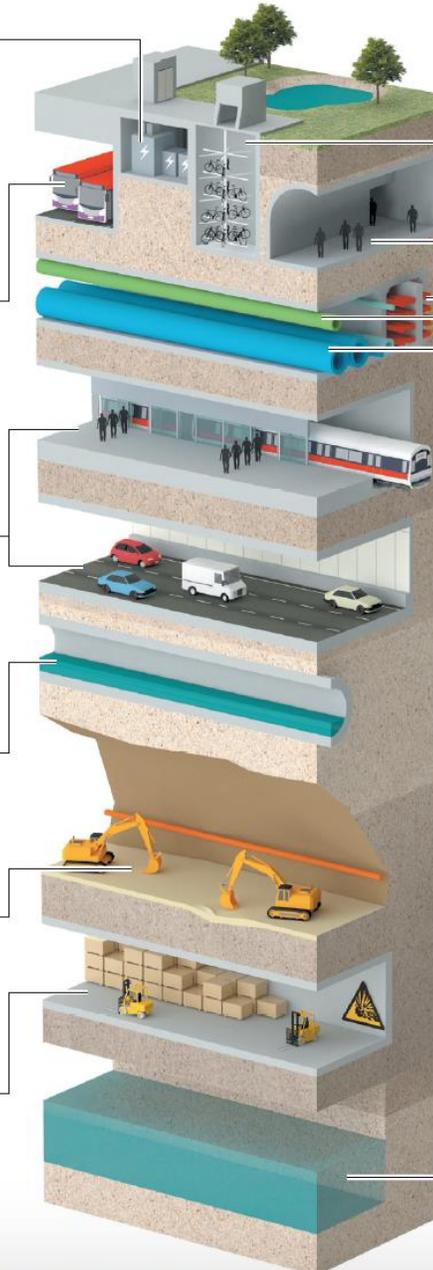
This is a network of tunnels that operates on gravity, and transports sewage and waste water across the island to two centralised water reclamation plants.

Jurong Rock Caverns

The Jurong Rock Caverns under Jurong Island is for petrochemical storage. In phase one, its five caverns are as high as nine storeys, saving approximately 60ha of land.

Ammunition facility

The underground ammunition facility built under a quarry in Mandai in 2008 stores ammunition and explosives. It frees up land about half the size of Pasir Ris town.



SecureMyBike

In Admiralty, the Land Transport Authority completed the first automated underground bicycle parking space, known as SecureMyBike. Users can leave their bikes at kiosks located above ground, which then houses them in storage cells extending up to 10m underground.

Pedestrian links

Underground pedestrian links make it easier to connect between buildings or cross busy streets. For a more extensive underground pedestrian network, the Urban Redevelopment Authority offers an incentive scheme to co-fund the construction of selected linkages in Orchard Road and the Central Business District.

Common Services Tunnel

More than just space-saving measures, underground pipes are less prone to external wear and tear. The Common Services Tunnel in Marina Bay is a creative way of housing all utilities together. This frees up land, with lesser maintenance disruptions on the roads.

Waste disposal

In housing estates, trash can be carried away to a centralised bin centre through a suction force via underground pipes, using pneumatic waste conveyance systems. Such a waste disposal network can be seen in an HDB estate in Yuhua, removing the need for refuse workers to manually collect waste from each block.

Air-conditioning pipes

Chilled water used for air-conditioning could be supplied centrally through an underground network of pipes, known as a district cooling system. This is already done in Marina Bay, and the authorities are looking to implement them in the Punggol Digital District.

Reservoirs

Water can be stored in underground reservoirs, with the national water agency PUB currently looking into an idea that can free up significant parcels of land for development. The 17 reservoirs currently occupy 3,700ha, or around 5 per cent of Singapore's total land.

Available information is unreliable

Data quality is insufficient

Data is often locationally inaccurate, not up to date, and incomplete.

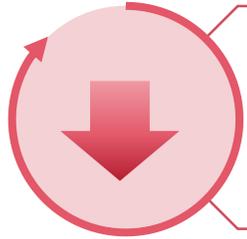
Data quality is undefined

Data quality is largely unknown and techniques of measurement undefined

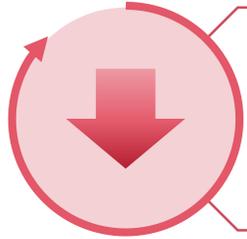
The underground – **opportunity or obstacle?**



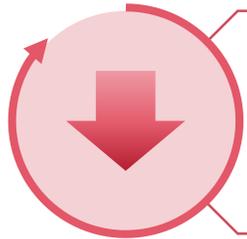
Unreliable information leads to repeated pains



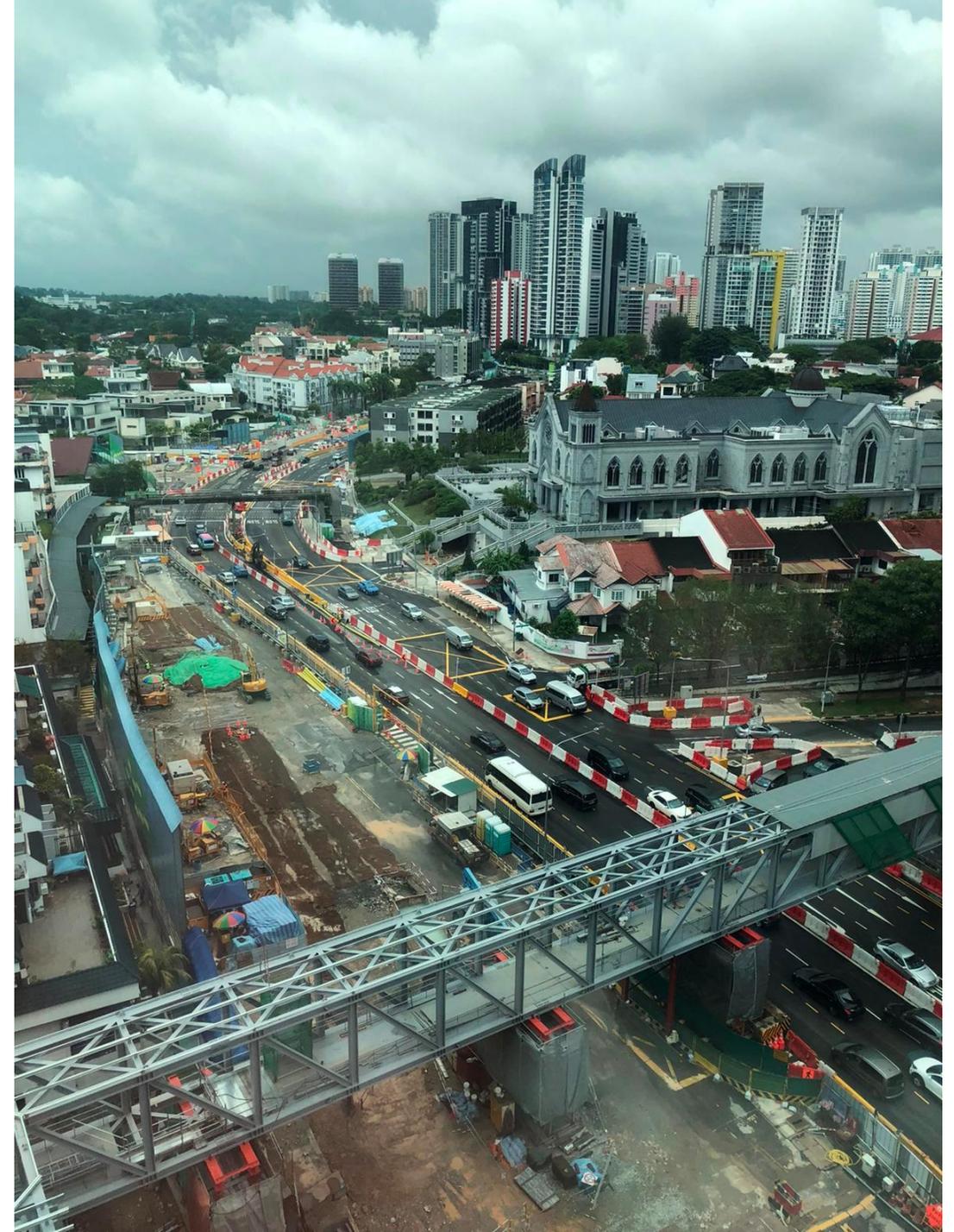
Sub-optimal use of underground space; loss of opportunity



Long and costly planning, design, and development of infrastructure

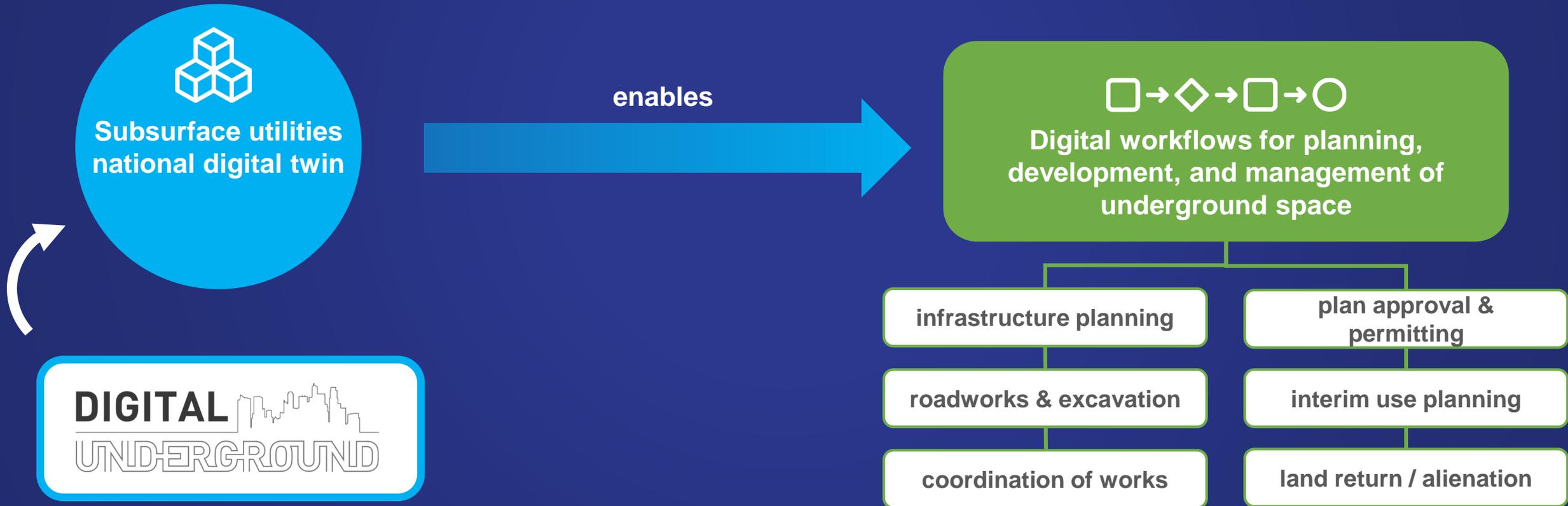


Nuisances, incidents, and disruptions

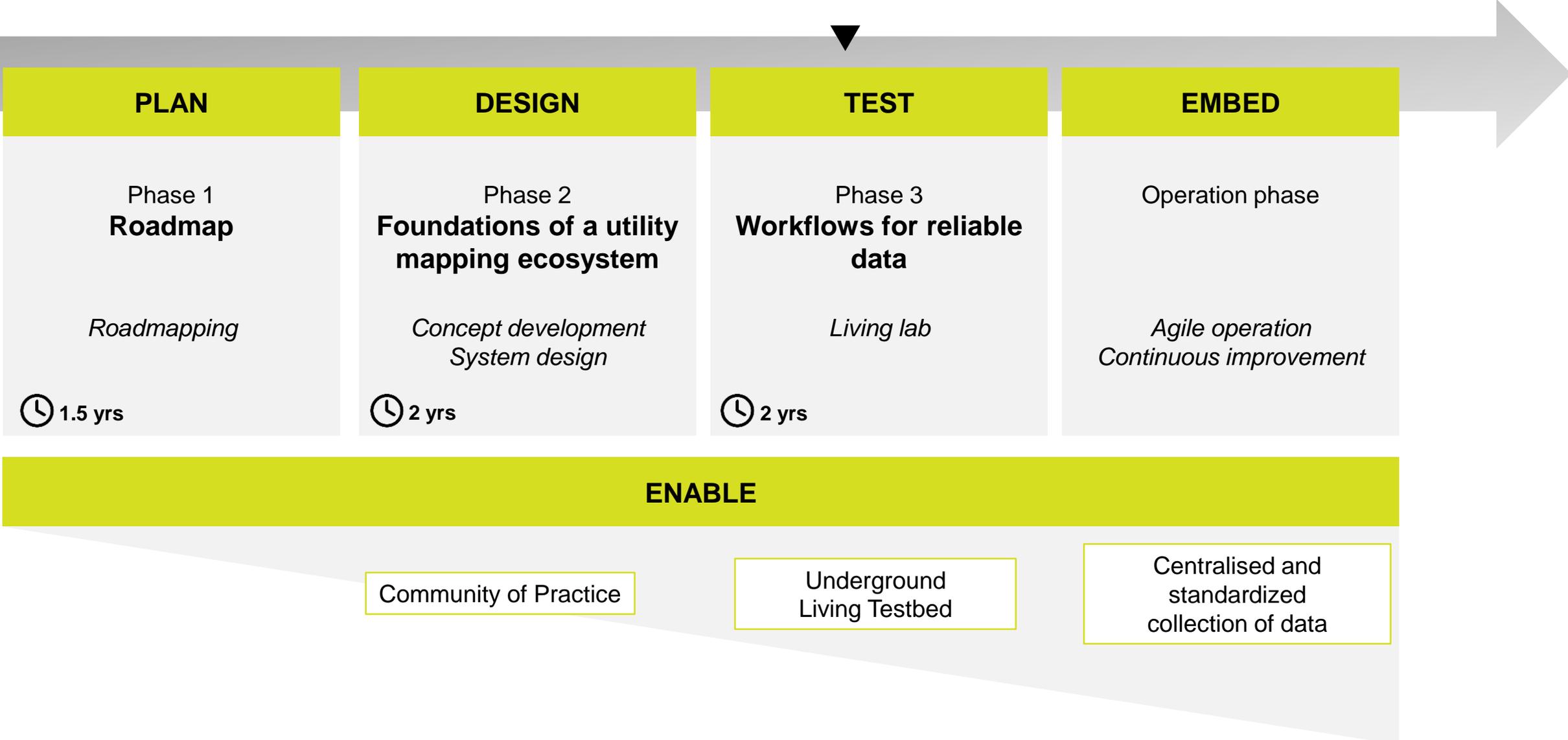


The Digital Underground project

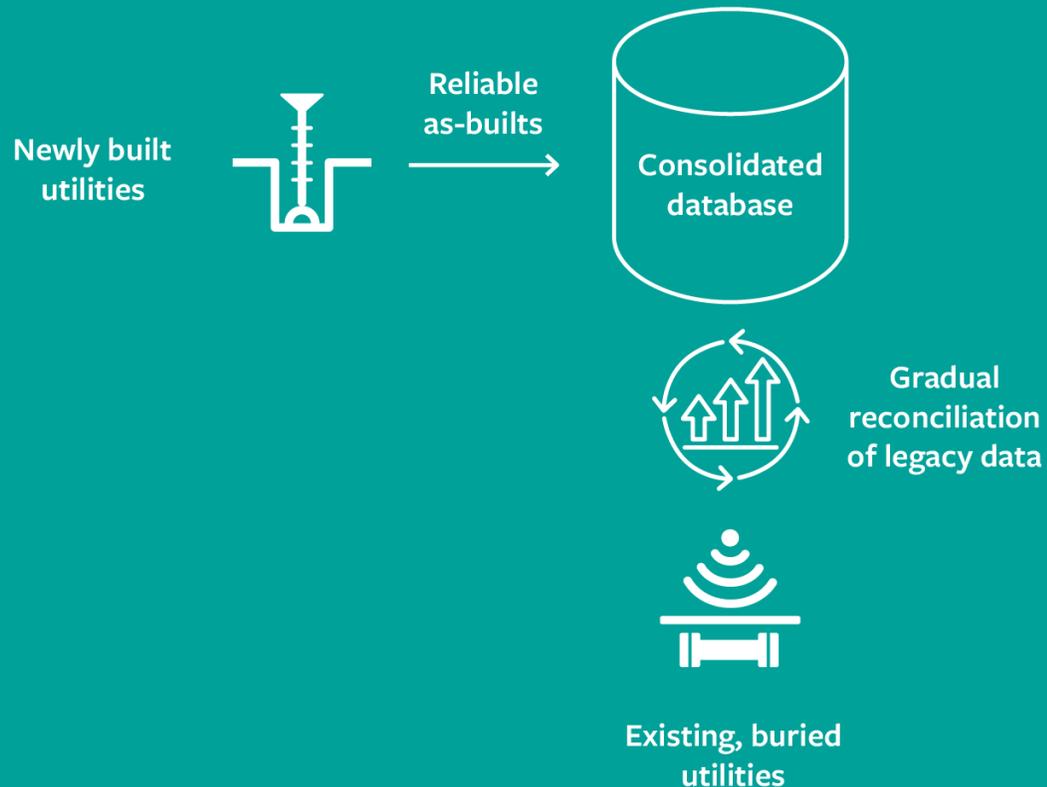
Towards developing a reliable digital twin of subsurface utilities in Singapore for land administration, urban planning and development



Digital Underground long-term approach



A national mapping strategy for subsurface utilities



1. MEASURE TO UNDERSTAND

- A central repository to assess and understand data quality, identify issues and potential interventions, and support data use

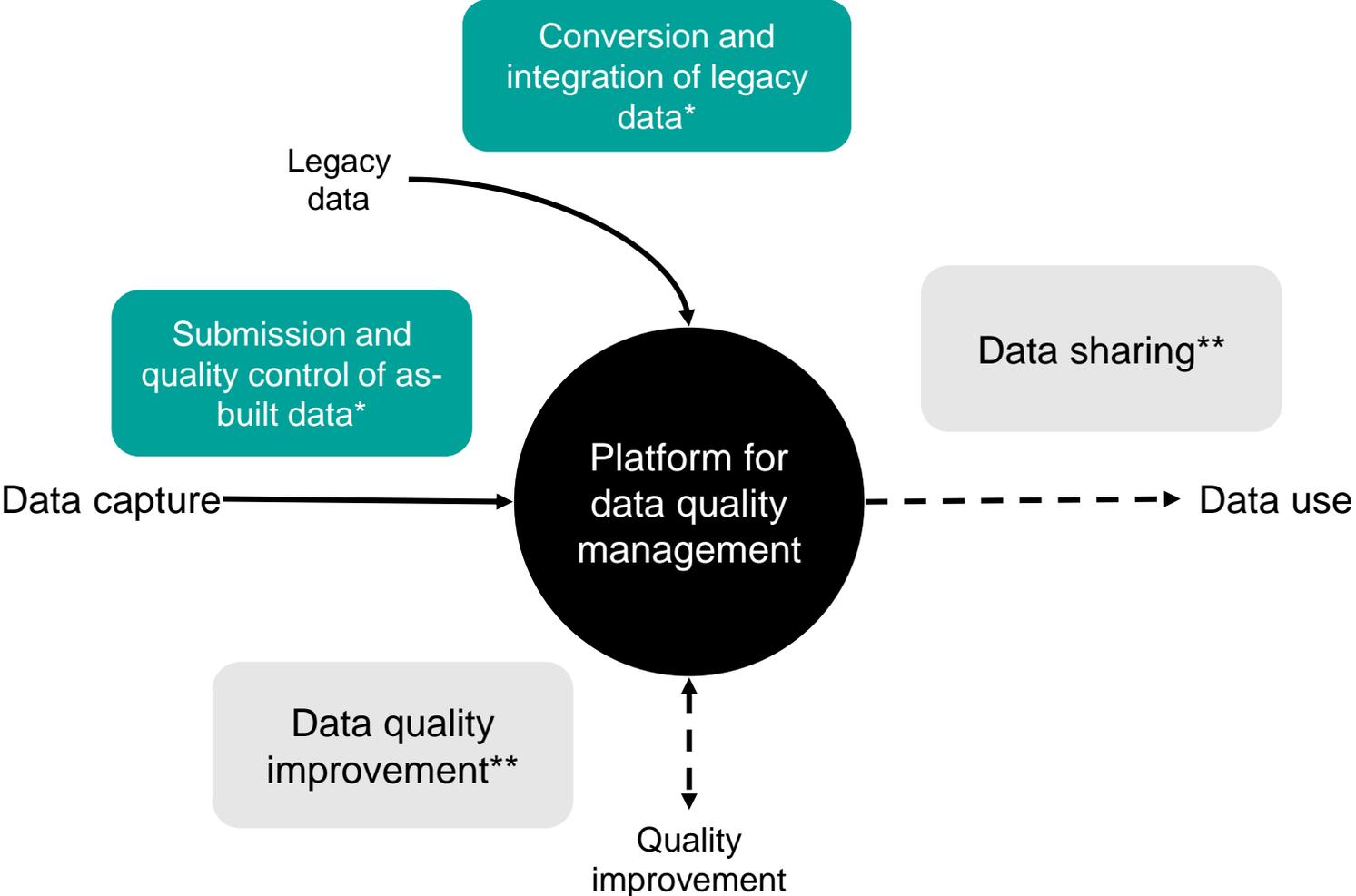
2. ENSURE QUALITY OF NEW DATA

- Ensure reliable as-builts for newly built utilities and accurate as-is for existing utilities
- Establish strong quality controls at the front-end of the information supply chain

3. RECONCILE LEGACY DATA

- Capitalize on opportunities to assess and reconcile quality of legacy data

Development of a prototype platform for subsurface utility data quality management



Key features

- Integration of legacy data in a harmonized format
- Submission of as-built data in a standardized, digital, machine readable format
- Modules for data quality control
- Integration and consolidation of all data

Schematic overview of platform workflows

* covered by DU phase 2

** currently not implemented yet

Platform impressions

As-built submission creation

Hello, Surveyor

DIGITAL UNDERGROUND

My Projects > Project 01 > Create Submission

Submission Package*

Surveyor Name: Mr Boh Kwan Kun
 Surveyor ID: BLK288752Z
 Submission Name: Submission 01
 Submission ID: P07-S01
 Creation Date: 28/05/21 | 00:00:00
 Latest Update: xx/07/21 | 00:00:00
 Survey Tech: Total Station, 3DLaser

Surveyed Utility Structures*

Telco Manhole (PI): Proj7SPTEL_Whitley Road_661_Manhole1
 Telco Pipe (Lx): Proj7SPTEL_Whitley Road_661_Pipe2312

Supporting Documents*

Calibration Certificate: WHITLEYRD661_CALIBRATION TOTAL
 Observation Data: Proj7SPTEL_Whitley Road_661_IMG01, Proj7SPTEL_Whitley Road_661_IMG02, Proj7SPTEL_Whitley Road_661_IMG03, Proj7SPTEL_Whitley Road_661_VIDEO01
 Point Cloud Data
 Connectivity Information Template: [Click to download \(.csv\)](#)
 Connectivity Info

Submit Creation



Survey project overview

Hello, Surveyor

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My Projects > Project 01

Project Information

Today: 20/05/21 | 00:00:00

Name: Project 06
 ID: Toa Payoh_661
 Creation Date: 12/03/21 | 16:38:06
 Latest Update: xx/07/21 | 00:00:00
 Project Status: Open
 Utility Type: Water
 Utility Owner: Public Utilities Board (PUB)

Submissions

Submission 28: Submitted (11:03/21 | 14:00:00)

Submission 27: Response Required (06/03/21 | 19:36:07)

Submission 26: Approved (26/02/21 | 13:21:09)

Submission 25: Approved (26/02/21 | 13:21:09)



Quality control

Hello, Surveyor

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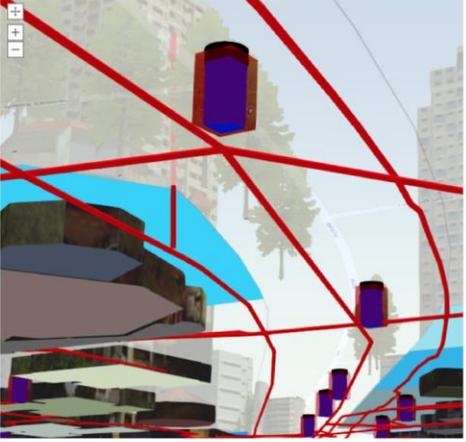
My Projects > Project 01 > Submission 28

Submission 28 Summary

- 1 Pass
- 2 In-progress
- 2 Attention (Check Comments)
- 2 Fail (Check Report)

Submission 28 Log - Submitted

ID Rule	Time	Status	Action
S28_RC100010	10/02/2021	In-progress	Comments Check Report
S28_RC100009	02/02/2021	In-progress	Comments Check Report
S28_RC100008	01/01/2021	Pass	Comments Check Report
S28_RC100007	13/09/2020	Attention	Comments Check Report
S28_RC100006	18/04/2020	Attention	Comments Check Report
S28_RC100005	18/01/2020	Fail	Comments Check Report
S28_RC100004	18/01/2020	Fail	Comments Check Report



Data consolidation

Hello, Approver

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My Tools > Submissions

Task Summary

2 Archived 4 Ready 0 Sent Back

Submissions	Time	Status	Comments	Action
Submission 29_RC100010	10/03/2021	Ready	Submission Chat	Review
Submission 33_RL100897	23/02/2021	Ready	Submission Chat	Review
Submission 62_TJ364868	20/02/2021	Ready	Submission Chat	Review
Submission 30_TP122837	03/10/2020	Ready	Submission Chat	Review

Pre-Existing with Database

Feature ID	Struct. Type	Status
S30_TP122837_MH#1	Manhole	Pre-Existing
S30_TP122837_PE#1	Pipe	New
S30_TP122837_MH#2	Manhole	New
S30_TP122837_PE#2	Pipe	New
S30_TP122837_MH#3	Manhole	Pre-Existing

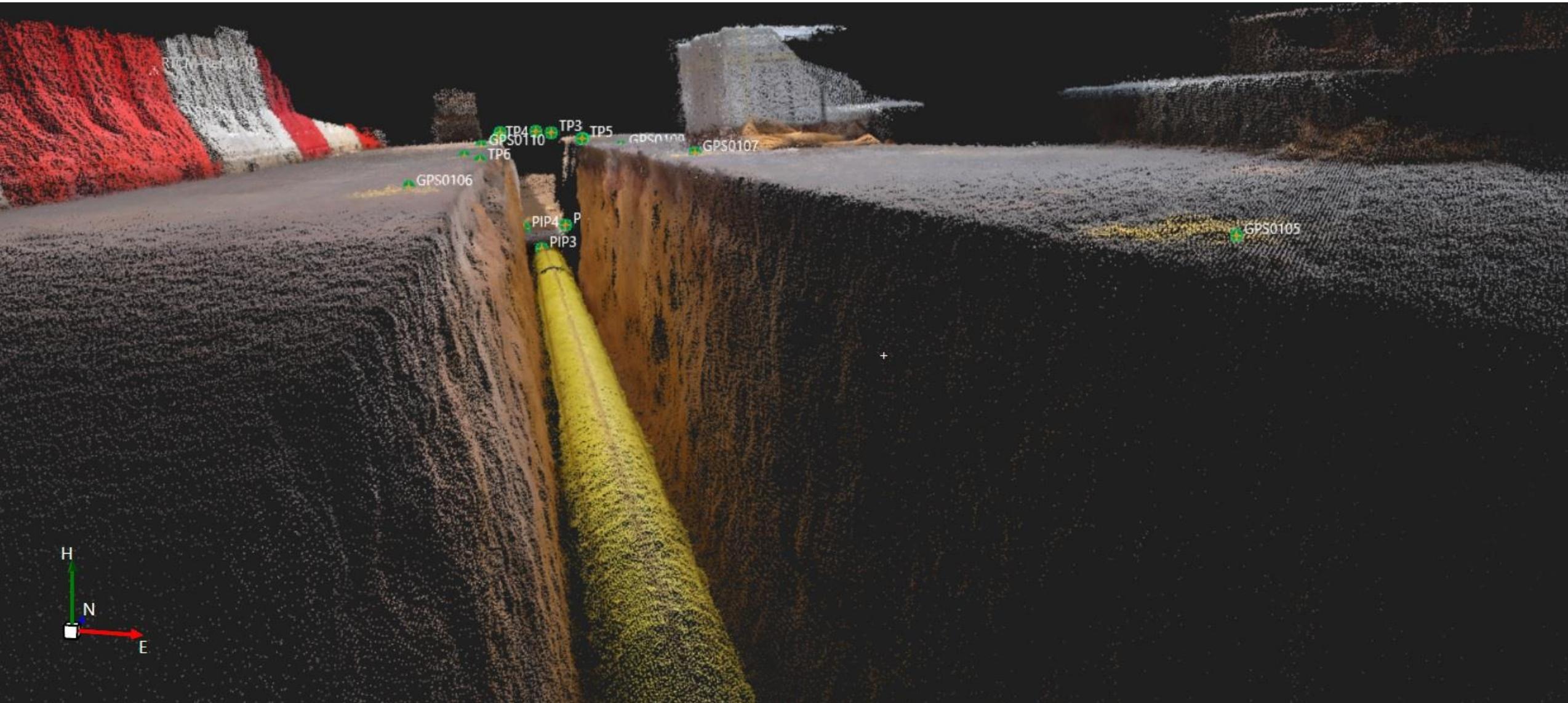
Approver Decision:





Exploring new workflows for newly built utilities and trial trenches





Proposed solution: The Digital Trial Trench

A digital representation of the trial trench and any exposed utilities inside that is:

1. In a **standardized** format
to establish clarity and consistency for data producers and users
2. Structured and **machine-readable in a GIS vector** or potentially a BIM model **format**
to support digital data-driven use cases (e.g., planning, BIM)
3. **2.5D or 3D geometry** in absolute geographic coordinates
for accuracy; can be produced with all endorsed surveying techniques
4. Collected and managed in a **single repository with proper metadata** along with other data on the location of subsurface utilities by an independent public sector agency
for simplicity, to serve the general interest, and to improve data quality
5. Securely and responsibly **shared in appropriate formats** (true 3D, 2.5D vector data, topographic drawings) to all public and private sector beneficiaries
to establish a cycle of reciprocal benefits (everyone contributes and benefits)

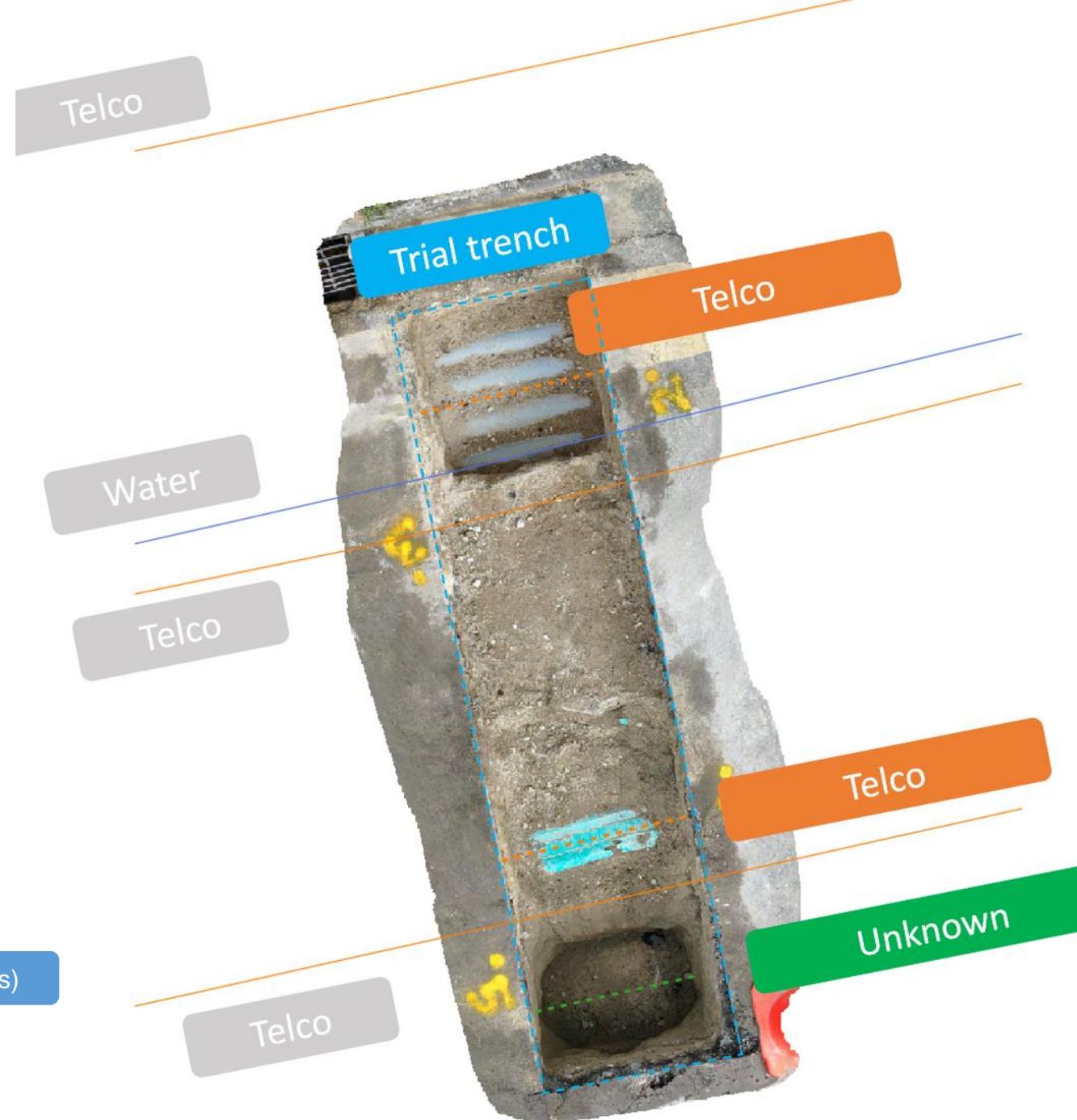


Image: Screenshot of a GIS displaying 2.5D geo-referenced digital trial trench data (dotted lines) overlaid with site photo and legacy data (labelled in grey boxes) in 2D

Digital Underground Phase 3: Workflows for reliable data quality

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Duration

26 months (1 November 2021 to 31 December 2023)

Objectives

- Develop a ready-for-implementation workflow for the capture of digital and reliable subsurface utility data together with a network of engaged stakeholders
- Investigate the tools and strategies necessary for Singapore to manage and improve subsurface utility data quality

TOWARDS IMPLEMENTATION OF A DATA CAPTURE WORKFLOW

WP DATA CAPTURE AND CONSOLIDATION

Pilot, evaluate and refine workflow for capture and collection of as-built data

WP INDUSTRY ENGAGEMENT

Continuation of Community of Practice

Establish a sustainable industry engagement platform

NEW WORKFLOWS OF THE FUTURE

WP DATA QUALITY IMPROVEMENT

Development of data quality improvement strategies

WP DATA QUALITY MANAGEMENT

Development of a data quality management and visualization framework



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With gratitude to our partners and advisors:

