Data Capture for Underground BIM

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SUMMARY

The Avon River is the cultural backbone of Christchurch's CBD, it also turns out it's the backbone of Christchurch's underground services.

The opportunity to redirect the focus of the CBD to the Avon River arose after the 2010 and 2011 earthquakes and an amazing redevelopment of Cambridge and Oxford terraces adjacent to the Avon commenced.

Physical works confirmed the presence of a dense network of underground services which required accurate mapping to optimise the progress of this unique scheme. Beca engineers along with Coffey and CERA designed a network of 238 service potholes (slot trenches) to identify conflicts between existing infrastructure and new construction.

Such a dense network of trenches over a large area provided a unique opportunity to effectively create a 3D model - an underground BIM - of the underground services throughout the project and see conflicts directly in relation to the 3D design.

High definition laser scanning and modelling of these services was the chosen methodology and was the first use of laser scanning to capture services information on such a large scale. The urgency of the project meant 620 individual scans containing 2739 individually modelled objects were completed over more than 3km in 10 weeks.

Such a model would be a powerful legacy item for the client and so several potential end users were identified. This variety of end users led to every service being allocated 15 attributes, in addition to 3D position...that's a little over 41 thousand attributes captured, compiled, and delivered in 6 different formats. The valuable photo-realistic point cloud data showing all the surrounding detail provides additional benefit for the client.

This paper presents the methodology by which this data was captured, processed and delivered, and reveals some of the important elements required for a successful underground BIM project.

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1. BACKGROUND

The Canterbury earthquake sequence had a vast impact on Christchurch. Much has been said and written about the resulting damage but this is a story about opportunity.

When the city turned its focus to recovery and rebuilding, the public was called upon for ideas. An overwhelming theme that came to the forefront was to redirect the attention of the city to the River Avon.

Adjacent to the Avon, Cambridge and Oxford Terraces were for years largely underutilized by pedestrians; the Avon River corridor would be reimagined as the backbone of the new CBD. Unlike the *Health Precinct* or the *Justice and Emergency Services Precinct*, where the aim was to bring like services together, The NZ$90m *Avon River Precinct* encircles the city framing two sides of the CBD connecting the *Health Precinct* with the *East Frame* and everything in-between.

2. THE PROBLEM

Oxford and Cambridge Terraces were already the backbone of the CBD in one very significant way. These roads were a main arterial for a large proportion of the city's underground services. Bundles of existing ducts were already present in the ground where tree pits, rain gardens and new services had been designed.

The Canterbury Earthquake Recovery Authority (CERA) together with their project managers, Coffey and Beca engineers established that the works required to achieve the original vision would require significant additional investment and that re-design would have a very high benefit-cost ratio.

The quality and format of existing records of the underground services varied greatly. New services may have accurate 3-dimensional records, but paper based plans and diagrams were also common. In several cases, diagrams showed measurements of physical features that had since been demolished.

To ensure successful advancement of the project we needed asbuilt locations of the existing underground services to be shown in 3-dimensions next to the design to form a clear picture of where clashes were going to occur. In many cases there was no guarantee that records of existing services represented their actual location. The shallow surface movement of the earthquake sequence had a significant effect on services all over the city.

It was all falling into place; it all needed to be asbuilt.

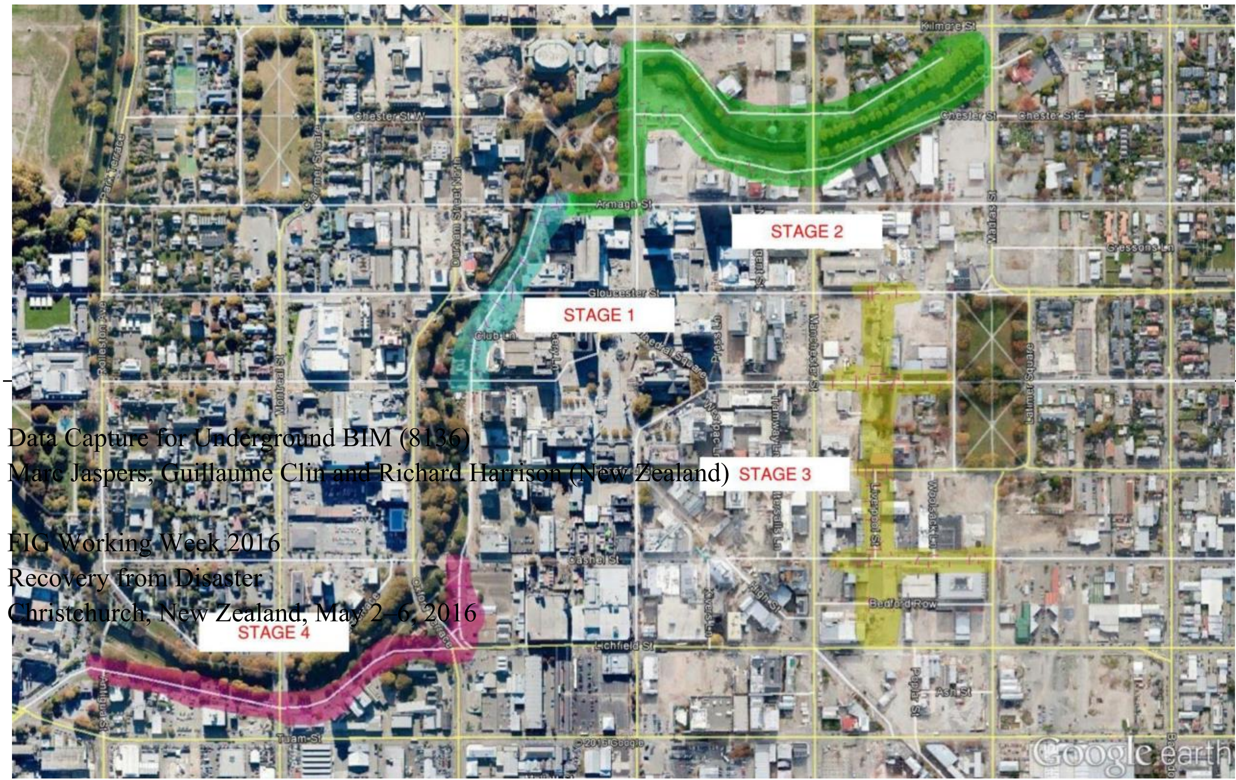
3. THE SOLUTION

The need that became evident was to create a fully attributed 3D model elements– an underground BIM – of the services throughout the project. This would not only be able to feed into the 3D design for the new precinct, but would also leave a powerful tool for the city going forward.

To leave a successful legacy there must be a lot of thought put into who will use the information in the future. Even just the parties involved up to this point used a variety of different software. Six different deliverables were required. Some (IFC, e57, Truview web viewer, annotated images) chosen for their broad range of use. Others (dwg, 12da) chosen for immediate use in the current systems.

This is where the real benefit of laser scanning for underground BIM is realized. Once a service is covered you lose any ability to visually inspect or verify what has been recorded without re-excavating. It therefore makes sense to capture as much useful data as possible at the time of survey. Fifteen separate attributes (unique ID, Service pothole ID, service type, diameter, modeled colour, physical colour, date of scan, photo ID, material type, survey firm, surveyors job number, surveyors initials, data release date, origin mark name, vertical datum) were identified as either necessary for the current project or potentially useful in the future.

In parallel to the survey planning, our engineers were working on where the measurements needed to be taken. They identified 238 half-metre wide trenches, ranging from 1m to 20m in length. Each one was designed to expose potential clashes with the new landscape and civil design. They also mandated a timeframe of 10 weeks, placing real pressure on the survey teams.



Although the original concept was based around laser scanning it was deemed prudent to complete a comparison between laser scanning and more conventional techniques, namely total station and GPS. We felt it was important to ensure any additional cost using laser scanning was warranted.

We compiled the table below for consideration.

Factor	Laser Scanning (full deliverables)	Total Station (no point cloud deliverables)
Field Data Collection		
Health and Safety	Requires the surveyor to maintain a position away from the pothole (remote measurement)	Requires the surveyor to be in the pothole, and/or lean over the pothole (direct measurement)
Speed of acquisition	Generally 0.5 - 2 hours per pothole,	Generally 0.5 - 2.0 hours per pothole
Data Processing		
Comprehensive data	Creates a comprehensive 3d 'picture' of the entire scene, including surrounding detail and many points on each service	Captures two individual points at either end of each service
Comprehensive data	High number of points means services are modeled in their real position	Services are modeled in the position of the two survey measurements (open to inaccuracy)
Comprehensive data	Actual service diameters determined in the office	Service diameters have to be measured in the field
Data confidence and QA	Point cloud data provides millions of points in the scene, ensuring a high degree of reliability	Survey data is limited to only the points that were measured
Capture of surrounding data for context	All surrounding data including surface markings is captured	No surrounding data is captured
Deliverable: DWG	Yes, from point cloud	Yes, from 2 points
Deliverable: IFC	Yes, from point cloud	Yes, from 2 points

Factor	Laser Scanning (full deliverables)	Total Station (no point cloud deliverables)
Deliverable: 12da	Yes, from point cloud	Yes, from 2 points
Deliverable: e57 point cloud for cross-platform support	Yes	No
Deliverable: point cloud web viewer	Yes	No
Other Factors		
Risk of incorrect service identification/survey	Reduced through capture of very complete dataset	Risk of incorrectly identified services increases, requiring contingency
Capture of contextual information	Ability to visually inspect surrounding GPR markings	Additional features or ground markings need to be picked up with additional survey time.
Program delays	Pothole can be backfilled as soon as the point cloud data has been downloaded and checked.	Pothole remains open until all survey processing is completed
Ability to extract additional data	Revisit the site in a 'virtual' 3d environment. Extract further measurements without specialist software or specialist survey capability Look at the site again in the light of changes to the program without having to physically go to site.	The data captured by the surveyor is the only data available. No further information can be extracted from the field data.
Interpretation	Point cloud data is highly visual and easy to understand	Survey data requires interpretation of survey plans
Responsive to 'scope creep'	Point cloud data can be utilized for multiple different applications, with different data extracted to suit the requirements	Survey data is fundamentally limited to 'only' the points that were measured.
Cost		
Relative costs	Cost of laser scanning is approximately 15% greater than conventional, offset by benefits from additional deliverables	

Factor	Laser Scanning (full deliverables)	Total Station (no point cloud deliverables)
	and applications.	

Both techniques had their distinctive benefits but scanning was chosen as the preferred option. Some of deciding factors were;

- Health and safety – able to survey from a remote position
- The ability to verify information – the point cloud enables us to re-inspect the actual service and/or the Ground Penetrating Radar (GPR) paint marks surrounding the trench.
- Full suite of deliverables – the point cloud data enables a full range of highly visual deliverables and offers the best future-proofing of the data.

4. FIELD ACQUISITION

A lot of effort was put into field logistics and after a methodical first few days, the field surveying soon became business as usual. A number of practical issues were identified early and worked around successfully throughout the project. Ongoing progress meetings between the client, contractor and Beca were also essential to the smooth running of the project.

The hydro-excavation and traffic contractor, City Care Ltd, and CERA were concerned with the safety issues of leaving trenches open for any longer than was necessary. It was desirable for Beca to give the go-ahead to backfill trenches by midday following the day of the measurements. This driver dictated much of the field and office processing cycle.

Scan locations utilized a control network consisting of survey ground marks and black and white paper targets. Target scans were completed in the field, enabling subsequent scan setups to be coordinated using ‘resection’ techniques. This was useful in allowing the field team to verify the precision of their control observations before returning to the office, removing the need for repeat visits to confirm control ties.

To ensure public safety and minimum disruption to the project multiple sites across the city, including complete sections of road were closed or individual trenches were fenced. 1.8m chain link sectional fencing was a significant challenge for the scanning team, who were working rapidly enough to require one person full time managing fences to maintain visibility to targets and surrounding features.

Visibility to the services dictated the number of setups needed for each trench. An unanticipated obstruction was the concrete kerb and channel sections that were left in place across most trenches (hydro-excavated underneath) which obstructed visibility to the complete trench. This obstruction often doubled the number of setups required for each trench and created the need for inverted scan setups, or very low setups to gain visibility into deep or tight trenches.

Some trenches had over 30 services within them. The team completing the modeling back in the office had a need to be able to clearly identify services in the point cloud data. To assist with this field sheets were designed to capture the required information for the team to put together the complete the model. With many services being 20mm cables, the field sheets provided a valuable resource for this process.

To effectively model the diameter of each service, at minimum 40% of the circumference of the service needs to be captured. It was identified early that the services needed to be washed clean of dirt and debris, and must be allowed to dry prior to scanning; otherwise inaccurate diameters could be modeled.

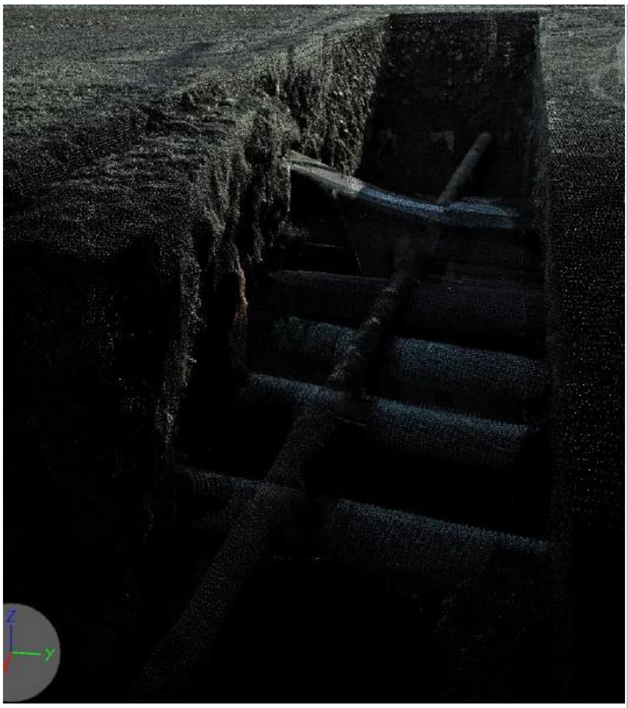
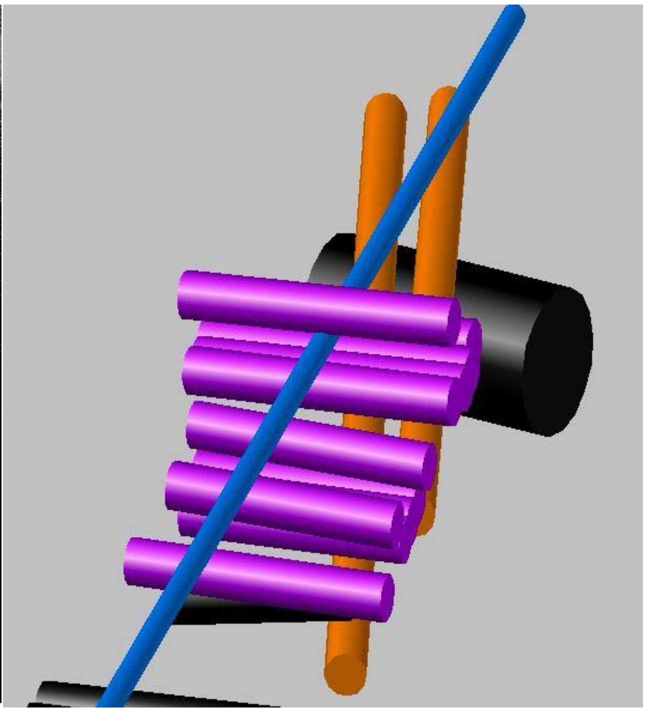
While hydro excavation and jet washing was taking place, high levels of noise as well as mud and debris were present. The survey team worked more efficiently when adequate time was allowed for the hydro-excavation teams to vacate each location, removing the risk of damage or injury from proximity to these trucks.

To further enhance the point cloud data, and ensure it is useful for later visual inspection, trenches must be fully illuminated by direct sunlight, or illuminated using spot lights or High Dynamic Range (HDR) photography employed. The best option was direct sunlight, but the HDR imagery function of the scanner also produced acceptable results in a wider range of light conditions.

5. OFFICE PROCESSING

Each evening the data captured from that day was downloaded and imported into Cyclone processing software.

The following morning the new data was inspected and registered together. Beca's Laser Scanning lead, Guillaume Clin, created a macro that analysed the long and repetitive registration report and consolidated it in a simple graph format that enabled us to very quickly see if the data was acceptable for modeling. Once this report was signed off the contractor was notified and the trenches in question could be backfilled.

Even though the full processing steps hadn’t been completed, once the registration was complete we knew we could revisit each trench whenever we needed and see it as it actually was without the interpretation inherent in normal survey practices.

Processing proceeded along a well-defined path in order to complete a set of deliverables in the most efficient way, utilizing customized macros and map files to minimize the steps required.

- Cyclone
  - Download data
  - Import data to project
  - Visual inspection against field sheet
  - Register scans together
  - Assign unique ID to each service
  - Model services
  - Export Truview web viewer deliverable
  - Export e57 point cloud file deliverable
- Attribute database
  - Populate database from field sheets, modeled dimensions and position
- AutoCAD
  - Apply a custom script, creating modeled objects from data in the attribute spreadsheet
  - Export DWG deliverable

- 12d model
    - Apply a custom 12d map file to create modeled, attributed pipes from data in the attribute spreadsheet
    - Export 12da deliverable
    - Export IFC deliverable

6. DELIVERY

The final hurdle was delivering the data. The point cloud (e57) and Truview data were by far the largest components. The more advanced formats (12da, IFC) not only have the benefit of data attribution but they also use minimum data space. Even with these concessions, the final deliverable bundles were too large to send easily over the internet. In the end the best way was to burn the data to a hard drive and hand deliver to the client.

7. CONCLUSION

It has been an amazing enlightening project to be involved with. The earthquakes had caused significant damage and we were very pleased to have the opportunity to work on something so positive. This project was also a rare opportunity to develop new processes and procedures beyond what is generally required. The success of the project hinged on leveraging every efficiency that could be realized along the entire length of the process, including planning, personnel, field and office work.

BIOGRAPHICAL NOTES

Marc JASPERS has over 14 years of professional experience in topographic, engineering surveying and project management. His primary areas of expertise are undertaking and managing large-scale topographic surveys, Master Plans and Construction Surveying. Marc has worked on a variety of projects from as far afield as Yap in Micronesia and Belize in Central America to high-rise construction in London and is currently bringing the lessons he's leant from that experience to the Canterbury Rebuild.

Richard HARRISON is a professional land surveyor with deep technical knowledge of GNSS, optical and laser-based measurement and positioning technologies, as they relate to Surveying, Monitoring, Civil Construction, Architecture and GIS. Richard has applied his knowledge and experience to a cross-section of practical surveying applications around the world, delivery of technical support and professional training to surveyors and sales agents, management of surveyors & geospatial experts, and direct sales of equipment and software.

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