Bathymetric Multibeam and Aerial Lidar Survey of Wemmershoek Dam: Accuracy Assessment, Volume Analyses and Heritage Insights

James PARKES and Jonathan DINGLE, South Africa

Key words: Bathymetry, Multibeam Sonar, Lidar, Survey, Dam Volume Analyses, Heritage

1. SUMMARY

In June 2025, Tritan Survey conducted a multibeam sonar survey of Wemmershoek Dam, Western Cape, South Africa. The survey was complemented by an aerial lidar survey of the above water area. The primary objective was to accurately determine the current storage capacity of the dam. However, the survey also revealed several unexpected opportunities for further study.

The bathymetric survey was conducted while the dam was at 85% capacity. The aerial and terrestrial lidar data was collected at a lower dam level of 50% resulting in overlapping areas of coverage. This provided a rare opportunity to assess the accuracy and noise levels of the multibeam bathymetry data.
Additionally, the survey revealed a preserved historic valley landscape submerged following the completion of the dam in 1957, including evidence of construction earthworks, farm terraces, roads, and former riverbeds.

Key questions arising from this work included:

- What is the achievable accuracy of these types of multibeam surveys?
- What is the impact of improved technology on volume calculation and understanding dam sedimentation processes?
- What heritage information can be gleaned from this survey of the preserved pre-dam landscape?

To address these questions, the following analyses were undertaken:

- Comparison of overlapping aerial lidar and terrestrial laser scan data with bathymetric data to evaluate accuracy and precision.
- Comparison with previous single-beam bathymetric surveys to quantify changes in volume calculations, resulting from technological improvements.
- Investigation of sedimentation patterns visible in the bathymetric data.
- Overlaying of historic maps with the bathymetric survey and identification of points of historic interest.

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2. Introduction

The Wemmershoek Dam is located 9km north of the town of Franshoek, Western Cape, and it supplies the greater Cape Town area. It is recorded by the City of Cape Town (COCT) to be a 58 644 megalitre dam (COCT, 2026). It is accessed from R301 road and is not open to the public.

The dam wall itself is an earthen embankment style dam, conceived in the early parts of the 20th century with the final construction taking place between 1953 and 1957 (Morris, 1959). Its catchment area is 84.2 km^2 with a reported 99% assurance of supply (Vuuren, 2010) making it a small but important part of the Cape Town's water supply.

Tritan Survey was contracted to survey the dam, for the purpose of generating a digital terrain model, volume report and capacity curve. In addition, Tritan Survey was to supply a contour plan of the dam area. This was completed through the combination of GNSS control, aerial lidar, multibeam bathymetry and terrestrial laser Scanning (TLS). The bathymetric survey was conducted over two visits, the last of which was at a higher water level. The aerial and terrestrial lidar data were collected at lower dam levels resulting in useful overlaps. The combination of equipment provided a unique opportunity to study and compare the different technologies that infrequently overlap.

Areas of study include: The assessment of the accuracy and noise levels of the multibeam bathymetry data; The impact of improved technology on volume calculation and understanding dam sedimentation processes; and the nature of the historic valley landscape submerged after the dam construction.

3. The Survey

3.1. Control

A strong network of ground control points for lidar, imagery and terrestrial scanning were established using RTK GNSS. The GNSS base station was positioned at a temporary location giving the best vantage point over the dam. Eight existing control points were observed and a mean shift calculated onto the existing network. GNSS data was logged at the base station for later post processing. This network would establish a strong reference for connecting the various data sources. Residuals of the control final shift were no higher than 10mm in any axis, defining the limit of absolute accuracy.

3.2. Terrestrial Scan

A terrestrial scan survey was conducted around the spillway infrastructure when the water level was low and the structure was exposed. Twenty-five scans were completed using the Z+F Imager 5016 laser scanner. The scans were linked to four of the GNSS control points with the largest residual being 12mm. The high-resolution scans enabled accurate modelling of the dam spillway. Critically, it also allowed for a precise determination of the spillway level, as well as confirmation of the full supply level. Figure 1 depicts the scan data of the spillway. The area includes a large, flat concrete pad, which provided a very precise comparison platform captured by all three survey technologies used on site.

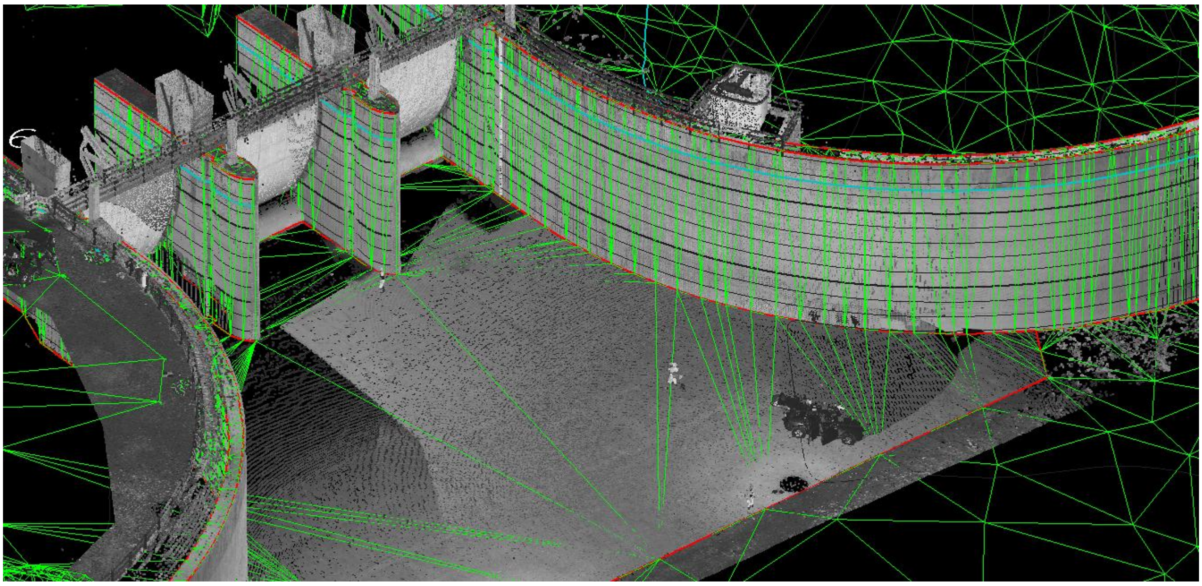


Figure 1. Terrestrial Scan Data

Figure 2 shows the difference in dam levels between the two site visits. The full supply level is also visible as a dark stain on the spillway wall.

Figure 2. left TLS Scan at 50% capacity; right second MBES survey at 85% capacity

3.3.Lidar and Aerial Imagery

The lidar survey was conducted by a South African Civil Aviation Authority (SACAA) approved operator, capturing lidar and imagery with a DJI Zenmuse L2 lidar aboard a DJI Matice 300 drone. The service provider delivered a processed lidar point cloud and orthophoto. This data was captured at a low water level allowing for overlap with the terrestrial scan and bathymetric data, over a variety of terrains, including hard surfaces, rocky slopes, and sandy surfaces. The orthophoto and lidar were linked to the other data sets via the network of GNSS derived GCP's with vertical residuals spread over a 100mm range, which is within the expected precision for this lidar system.

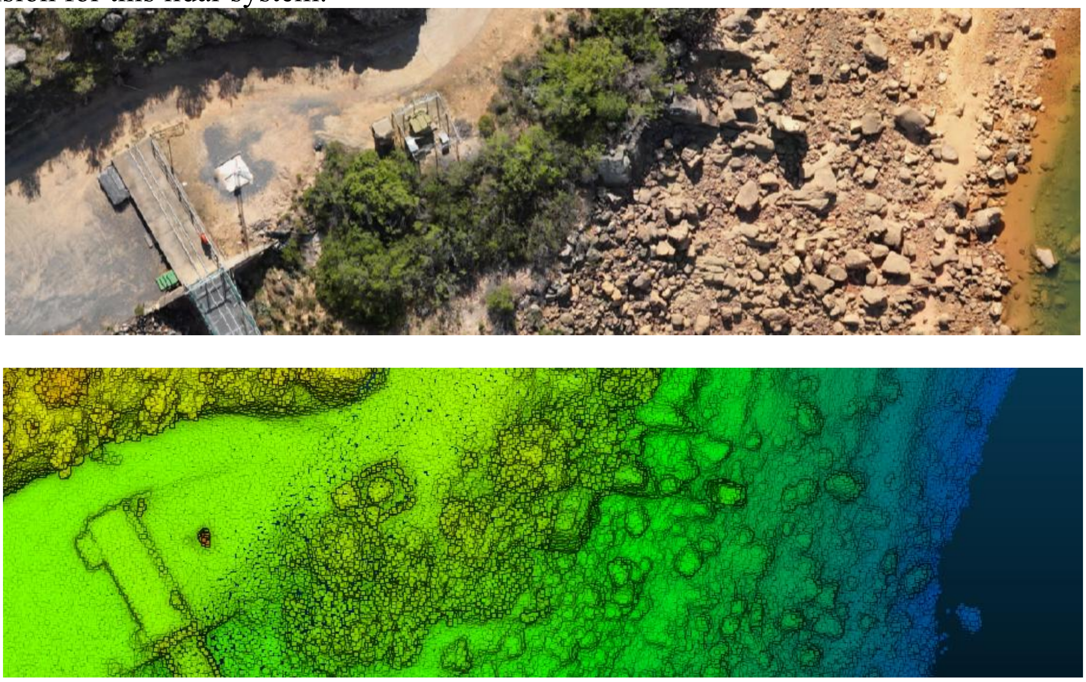


Figure 3. Orthophoto and lidar data

3.4.Bathymetric Survey

The bathymetric survey was conducted over two visits corresponding to the changes in water levels. The survey was done from the vessel “Tritan Surveyor”, a 5.5m RIB equipped with a Norbit WMBS multibeam, SBG Systems Ekinox inertial navigation system and custom made over the side pole mount for the Multibeam Echo Sounder (MBES). Sound velocity profiles were measured with a Valeport Swift SVP. A patch test was done to determine the roll pitch and yaw mounting angles of the MBES. The before and after patch calibration are depicted below.

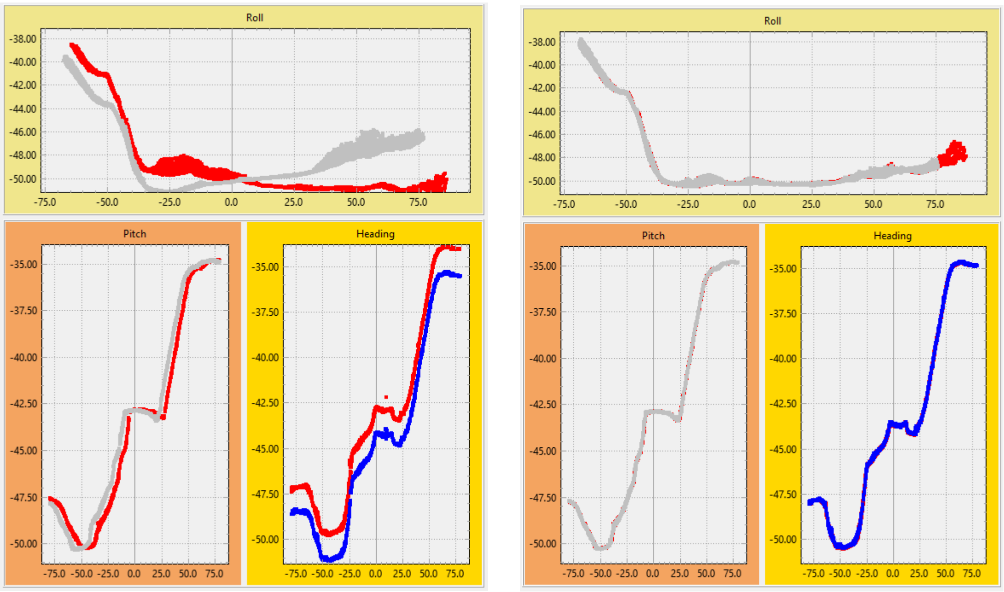


Figure 4. MBES Calibration

Figure 5. Tritan Surveyor

The GNSS base data along with the logged 200kHz INS data was post processed and a tightly coupled solution computed. The exported trajectory was applied to the multibeam data. The resulting dataset was filtered and cleaned.

4. Results and Discussion

4.1.Multibeam Performance

A comparison of the 2025 multibeam bathymetry data with the single beam echosounder survey (SBES) captured in 2000 demonstrates a clear improvement in resolution. By computing height differences between the two datasets, these improvements can be clearly illustrated. Figure 6 presents the resulting height differences, where red indicates berms captured by the MBES, and blue highlights gullies and depressions that were not detected by the SBES.

While a well-executed SBES survey can define the general shape of a dam, MBES data captures fine-scale detail. Berms, gullies, and break lines are clearly visible in the MBES dataset that were previously invisible. The lower image has the SBES digital terrain model visible to depict the resolution of the SBES (only the red Berms are therefore visible).

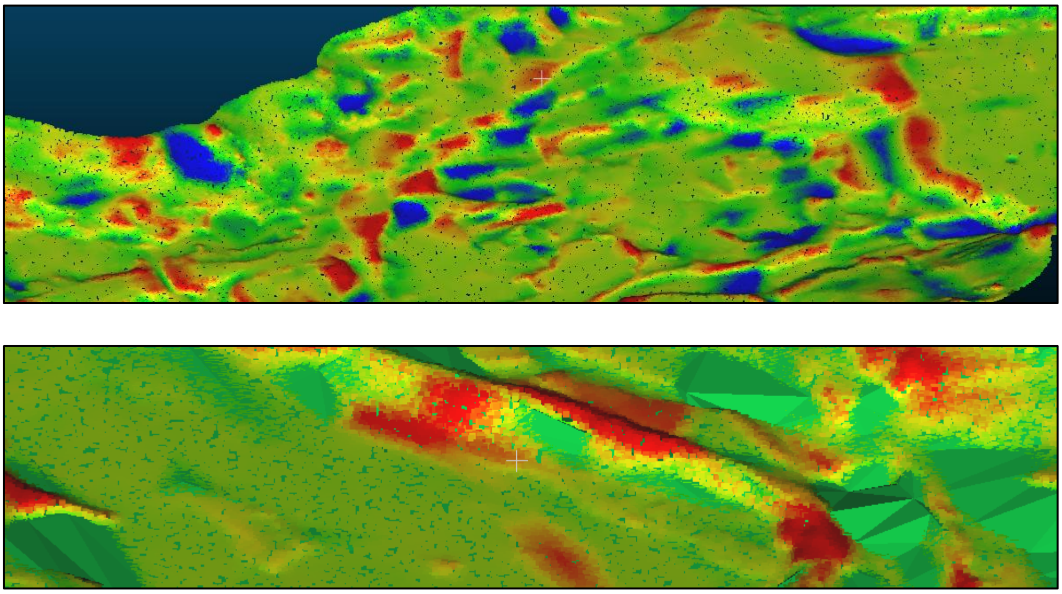


Figure 6. MBES versus SBES

A second point of interest to demonstration the value of having higher resolution is the ability to observe movement of sediment. Figure 7, depicts sand waves moving slowly in from the head of the two main valleys.

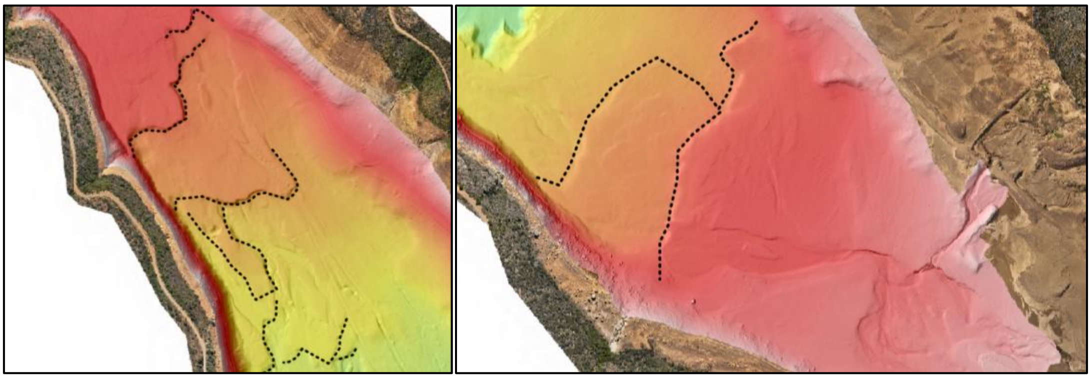


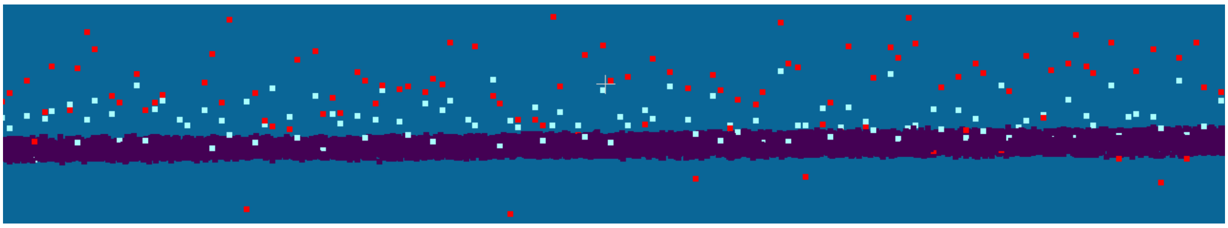
Figure 7. Leading edge of waves of sediment ingress at the head of the two main valleys.

The final datasets were overlaid, with both the lidar and MBES data gridded at 0.25 m and compared against the terrestrial data. The terrestrial data acting as the baseline was grided to 0.1m and triangulated enabling distances from it to be calculated. The gridding enables a more direct and consistent comparison.

As previously mentioned, the opportunity to compare these three technologies is not frequent. This comparison is especially unique, as the spillway consists of a large, flat concrete pad, allowing for a clean comparison without additional compounding factors. The distances between the terrestrial data and both the MBES and lidar were computed. A histogram of these distances was derived. The results of this are recorded in Table 1, where noise is represented by the standard deviation of the differences and accuracy by the mean of the differences. The accuracy assessment is indicative rather than rigorous as the test is conducted over a single area, and results may vary elsewhere.

Data Acquisition	Noise	Accuracy
Lidar (0.25 Grid)	29mm	41mm
MBES (0.25 Grid)	13mm	8mm
Terrestrial Scan (unfiltered)	<5mm	Reference
* Accuracy measured against the terrestrial scan data * Noise measured as Std dev		

Table 1. Accuracy and Noise lidar & MBES



*Lidar is shown in red, terrestrial scan in purple, and MBES in blue.

Figure 8. Cross Section Concrete Pad

The MBES is comparable to the terrestrial scan data in this instance. Although favourable conditions, shallow depths, and the slow speed of the bathymetric survey made this possible, it is nonetheless impressive to see how far sonar technology has progressed in terms of resolution and precision.

With increased depth and poorer conditions, one would expect the MBES to be of lesser quality. Nonetheless, it is remarkable that such resolutions are achievable under optimal conditions.

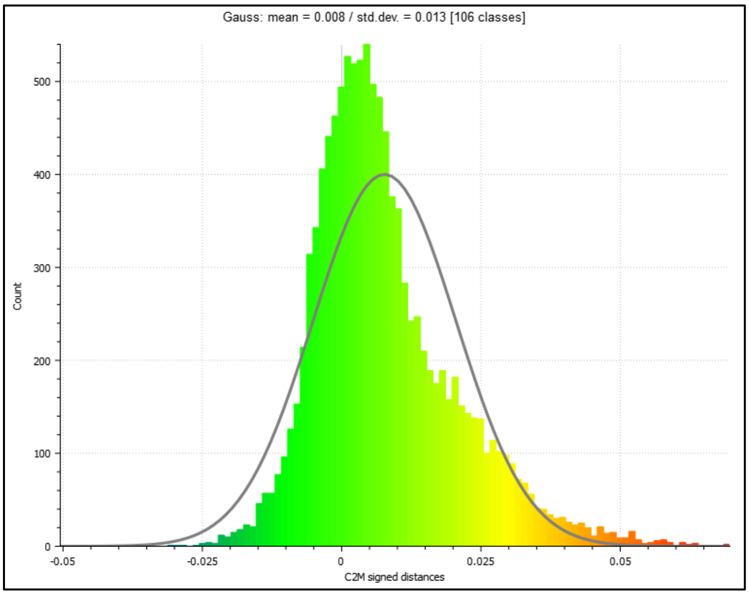


Figure 9. MBES distances to terrestrial scan

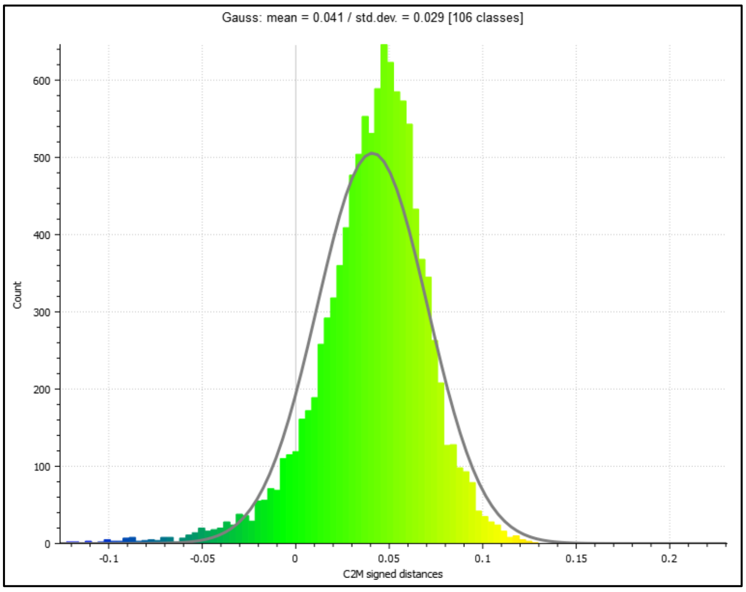


Figure 10. Lidar distances to terrestrial scan

4.2. Capacity Calculation

The commercial aim of such a survey is the determination of the capacity of the dam. Dam capacities are of importance to the managers of water resources, as they assist in understanding the total volume available, the rate of depletion, as well as evaporation rates. All this data is expressed in the capacity curve and the surface area chart (not presented here). A higher precision survey and the resulting precise capacity calculation benefits stakeholders.

Up to date technology as well as careful processing will result in a high-quality calculation. The method involves creating a triangulated digital terrain model (DTM) of the dam area and then calculating 10mm volumetric slices through its entire height. The combination of mapping techniques in the appropriate areas can yield a high-fidelity model. Depicted in Figure 11 is the combined model.

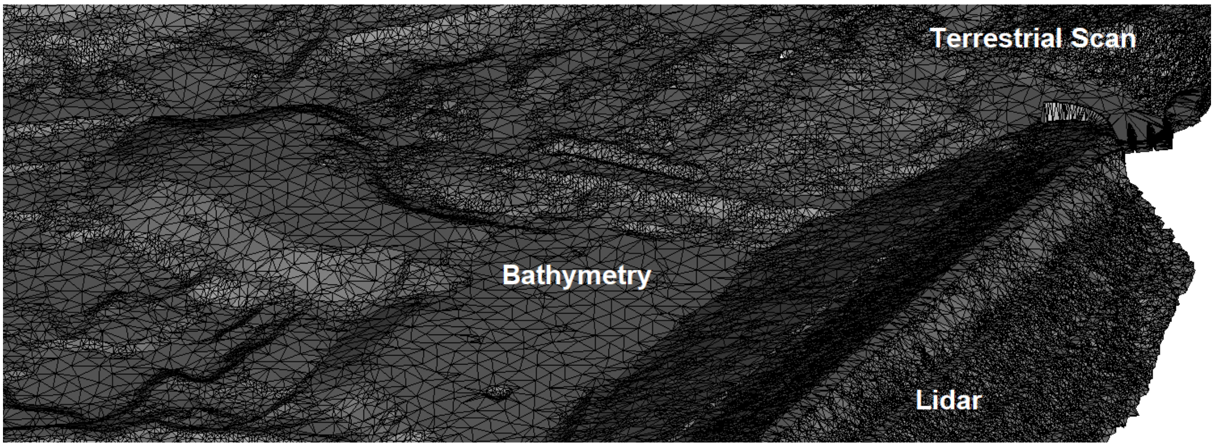


Figure 11. Triangulated DTM model.

The capacity calculation derived from the MBES survey is shown in Figure 12 alongside a single-beam calculation completed in 2000. The graph indicates a slight decrease in capacity, which may be attributed to improved data resolution or sedimentation. However, the capacity curves are remarkably similar. This suggests that a carefully conducted single beam survey, although of lower in resolution, can still produce capacity curve data that is comparable in overall accuracy to that derived from the MBES data.

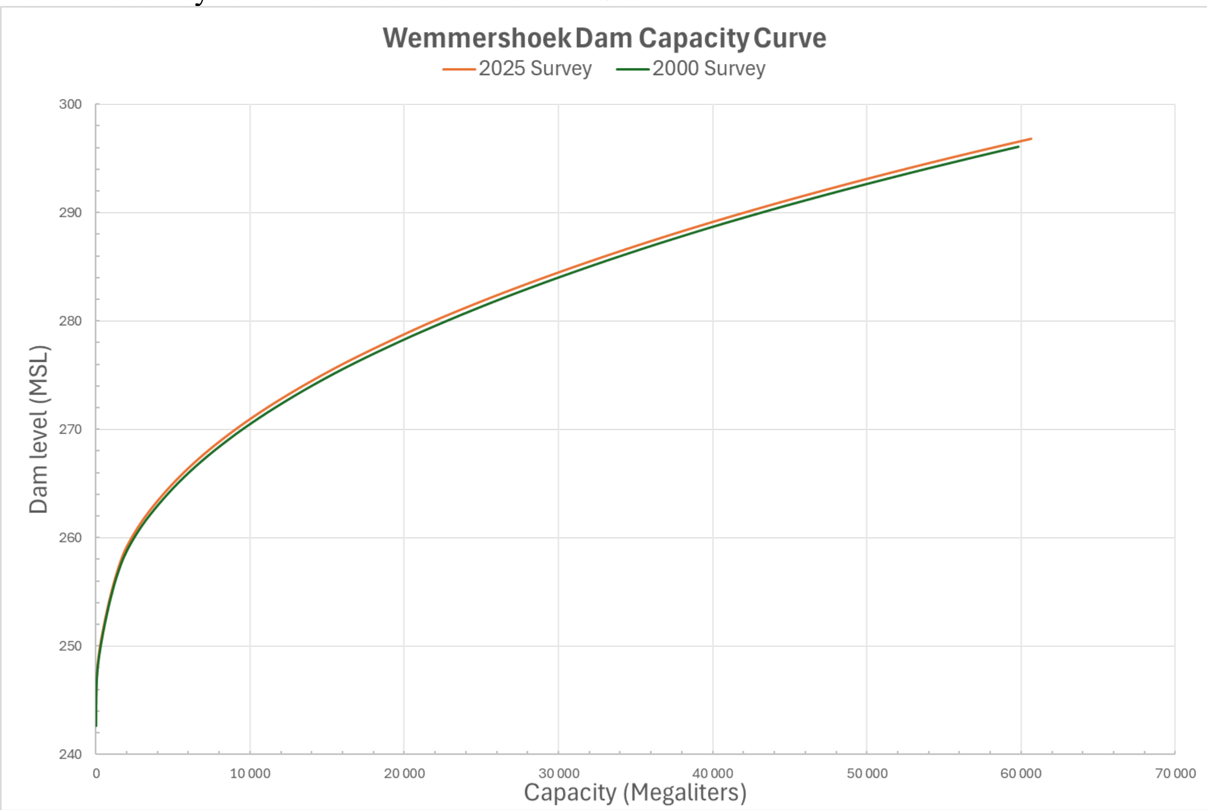


Figure 12. Capacity curves.

In summary of this section, a well-conducted MBES survey results in substantial improvements in resolution, result confidence and point accuracy. However, if similar due diligence is applied to a lower resolution survey such as one derived from SBES, similar results can be achieved.

5. Historic assessment

5.1. Heritage documentation

A collection of freely available historic documents where sourced and reviewed. Those of interest that could be checked against the current data set were isolated and a historical investigation conducted. The area of study may not have substantial historic notoriety; however dams have been submerging towns and communities for thousands of years, and it is conceivable that the ability to peel back the water over such areas around the world may open a time capsule to a preserved landscape, community and history. They are ultimately submerged ghost towns.

The earliest document obtained for the area that is of interest is the 1896 diagram for Farm 870 (R.J.Moll, 1896) and the 1901 cadastral diagram for Farm 873 (Pritchard, 1901). These diagrams show wooded areas, farmed fields, housing positions, and a notable fountain. The fountain suggests a spring being present, no doubt still contributing to the water supply. The 1901 diagram is a 'redline' diagram indicating that survey errors can be expected, however it can be used as guide to the identification of features.

Figure 13 depicts the remains of the long field and house visible in both the diagrams. The 1896 diagram for this area indicates it was "Garden Ground Free Hold". Once pointed out the feature is obvious, though it demonstrates how hidden a historical object can be.

Figure 13. Garden Ground Free Hold (Pritchard, 1901)

The next important historical data source was the National Geo spatial Information directorates (NGI) aerial photography. The earliest imagery providing meaningful insight is from the 1949 series, in which early farm layouts—now submerged below the water level—are clearly visible. Large features such as farm boundaries, roads, bridges, and tree lines can be identified.

When this imagery is compared with the MBES data, it becomes possible to observe how such large-scale features can be expected to appear in high-quality multibeam datasets. In addition, smaller individual planting furrows and drainage features are clearly visible, at a level of detail comparable to that seen in mid-20th-century aerial imagery. This is illustrated in Figure 14.

Furthermore, the position of the homestead can be inferred from the 1903 diagram, and this is supported by the historic photography showing that the area is heavily wooded and adjacent to a road. It is therefore highly likely that this location corresponds to the homestead. We can speculate from this what a ruined structure may look like in MBES data.

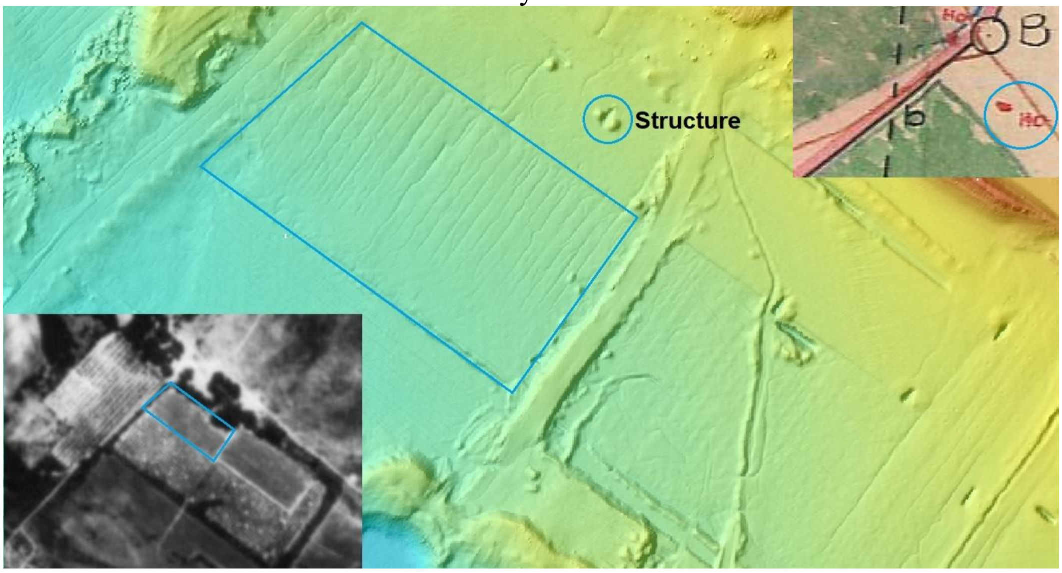


Figure 14. Historic Farms *Aerial image (Chief Directorate: National Geo-spatial Information, 1949)

The MBES data itself is the most revealing in terms of the historic landscape. In undisturbed areas, the farm field layouts and irrigation networks are clearly visible. In some cases, the resolution is of sufficient detail to distinguish orchard from farm field. It is truly remarkable that sonar derived imagery has advanced to point at which it can be captured in higher resolution than that of Aerial photograph of the 50's.

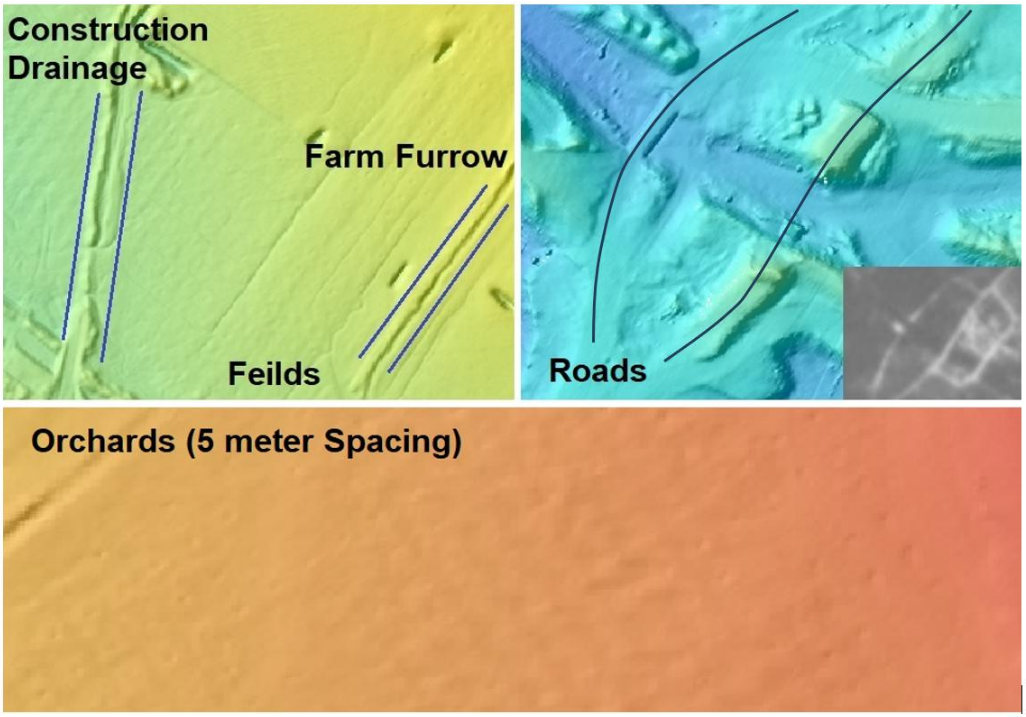


Figure 15. Farm and road detail.

Other areas of the dam clearly highlight the substantial earthworks undertaken during construction of the dam wall. As depicted in Figure 16, earthworks, stockpiles and water channels are evident.

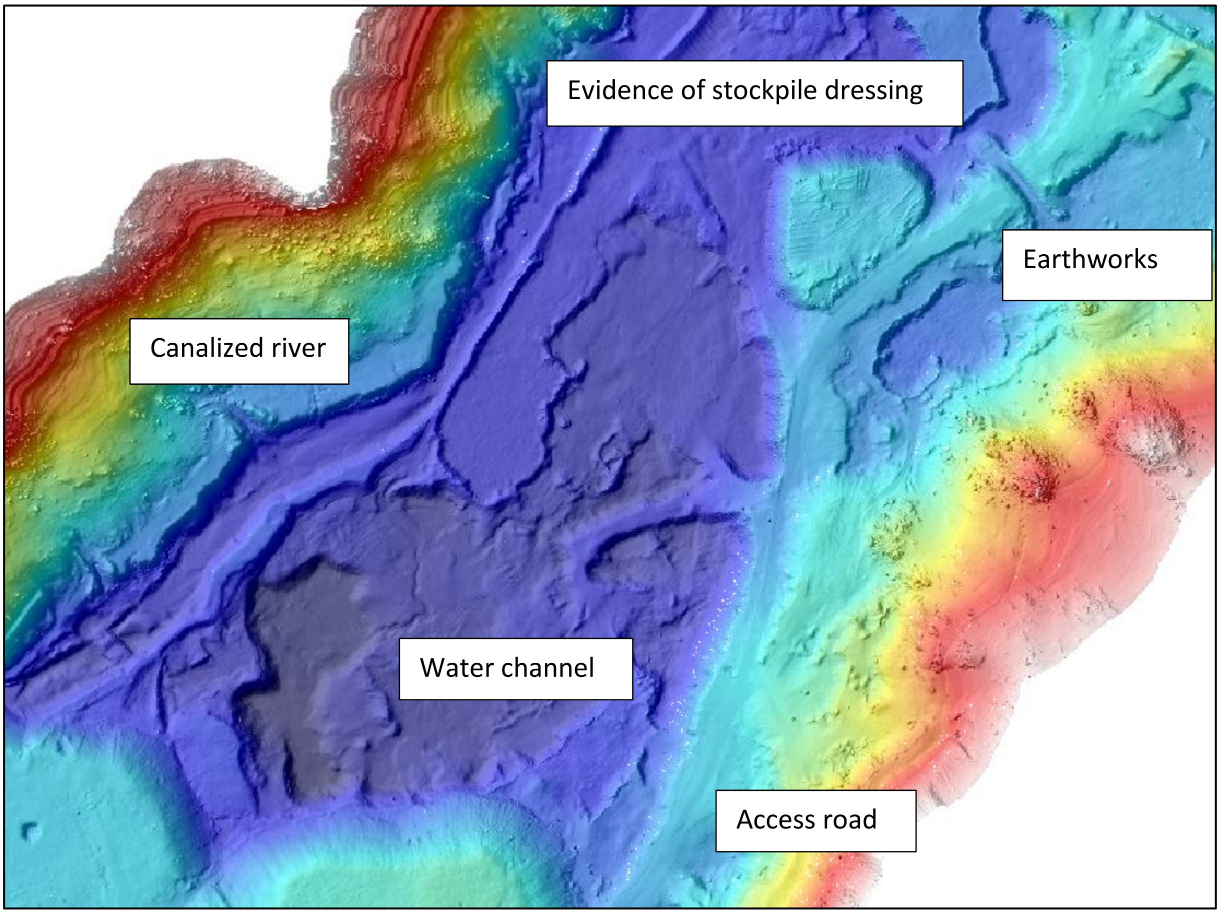


Figure 16. MBES extract of dam Earthworks.

5.2.Sedimentation

Insite can be gleaned into the sedimentation processes in the area, because of the high resolution of the modern data set and the temporal range of the surveys. As an example of this we can observe in Figure 16, the massive earthworks from the dam's construction. Where stockpiles remain above the current dam bed, it can be inferred that no significant sedimentation has occurred. Similarly, areas showing evidence of vehicle movement suggest an absence of sediment accumulation.

Little sedimentation is observed along road alignments and previously worked areas. Areas where streams are visible suggest that these features have experienced minimal sedimentation since their formation during open-air construction. Based on the sedimentation evident at the heads of the inflowing rivers, it can be concluded that most of the sediment deposition over the past 70 years has occurred in these upstream areas. The catchment does lie in the upper reaches of the river system. It is therefore conceivable that the large-scale sedimentation commonly observed in other dams is likely avoided.

The sand wave at the head of the inflowing river to the north can be observed in the 2000 SBES survey. It is visible only because, during the SBES survey, a single survey line was run directly over the sand wave. Figure 17 depicts a cross-section through the sand wave, comparing the 2025 survey (purple) with the 2000 survey (blue). In this instance, the sand wave has migrated approximately 40 metres downstream.

The limitation of SBES data is that it captures only isolated instances of sediment movement, often coincidentally, rather than providing the complete spatial picture achievable with MBES data.

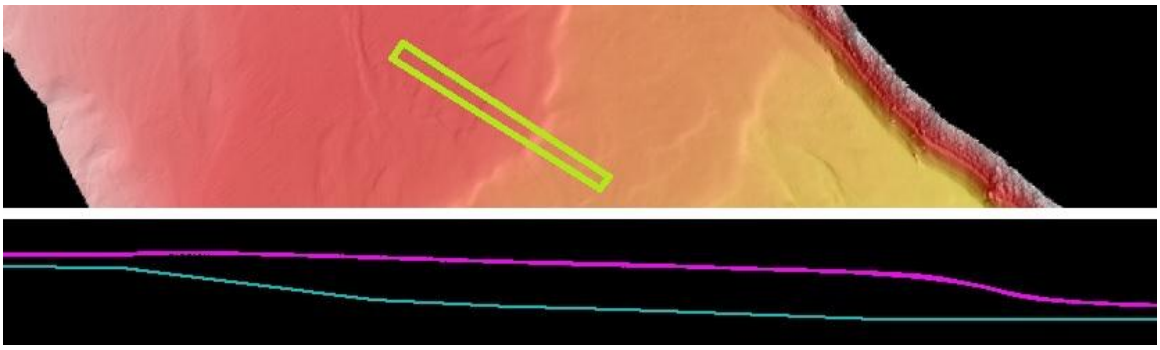


Figure 17. Sand wave SBES versus MBES

While the authors' ability to make detailed observations about sedimentation is limited, MBES data reveals the sedimentation process in remarkable detail.

6. Conclusion

It is clear from this investigation that MBES data offers significant superiority in terms of resolution and visual representation of the dam floor. However, provided that sufficient diligence is applied during acquisition and processing, it is entirely achievable to reach parity between MBES and SBES in terms of capacity calculation.

We can also make the general observation that carefully acquired MBES data can, in some cases, be of comparable quality and resolution to airborne lidar, although the specific characteristics may vary depending on conditions and survey parameters.

It is further evident that the resolution achievable with MBES at depths of approximately 50 meters can be sufficiently high to allow for historical or forensic assessments. While the potential use cases for such analyses may be limited, the capability clearly exists. It is truly remarkable that sonar imagery at depths of 50 m has advanced in resolution to be in parity with, or even surpass, aerial imagery of the mid-20th century

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BIOGRAPHICAL NOTES

James Parkes, holds a BSc in Geomatics (University of Cape Town, 2007), is a registered Professional Land Surveyor in South Africa (GPrLS 1225) and Director of Tritan Survey since 2014. Tritan Survey is based in Cape Town, South Africa and operate in most of sub-Saharan Africa. James specializes in precise engineering, deformation monitoring, hydrographic, photogrammetry, terrestrial and aerial lidar surveys.

Jonathan Dingle, holds a BSc in Geomatics (University of Cape Town, 2010) and an MSc in Engineering (University of Cape Town, 2013), and is a registered Professional Land Surveyor in South Africa (GPrLS 1475). Jonathan has been actively working in the surveying industry since 2013, with extensive experience gained in and around Cape Town, as well as in other regions of South Africa.

CONTACTS

James Parkes
Tritan Survey
Unit 11, River Park, 77 De Waal Rd

Cape Town
South Africa
Tel +27 21 797 2081
Email: jamesp@tritan.co.za
Web site: www.tritan.co.za/

Jonathan Dingle
Tritan Survey
Unit 11, River Park, 77 De Waal Rd
Cape Town
South Africa
Tel +27 21 797 2081
Email:jonathand@tritan.co.za
Web site: www.tritan.co.za/