Benthic Communities and Habitat Mapping Report

Swan River Ferry Expansion – Perth to Applecross

Customer	Public Transport Authority via Department of Transport and Major Infrastructure
Project	003555.000
Deliverable	R-3555-3
Version	0
Date	7 July 2025

Document Control

Document Identification

Title	Benthic Communities and Habitat Mapping Report
Project No	003555.000
Deliverable No	R-3555-3
Version No	0
Version Date	7 July 2025
Customer	Public Transport Authority via Department of Transport and Major Infrastructure
Classification	OFFICIAL

Author	A Kempton, D Tuladhar
Reviewed By	L Synnot, Public Transport Authority
Project Manager	A Kempton

Amendment Record

The Amendment Record below records the history and issue status of this document.

Version	Version Date	Distribution	Record
A	06 June 2025	L Synnot	Editorial and Technical Review
B	11 June 2025	Public Transport Authority	Client Review
0	02 July 2025	Public Transport Authority	Final Client Issue

Acronyms and Measurement Units

Acronym/ Measurement unit	Description
BCH	Benthic Communities and Habitat
GPS	Global Positioning System
PTA	Public Transport Authority
RGB	Red/Green/Blue
SCE	Swan Canning Estuary
SCR	Swan Canning Riverpark
sp.	Species (singular)
spp.	Species (plural)
%	Percent
ha	Hectares
km/h	Kilometres per hour
m	Metres

Contents

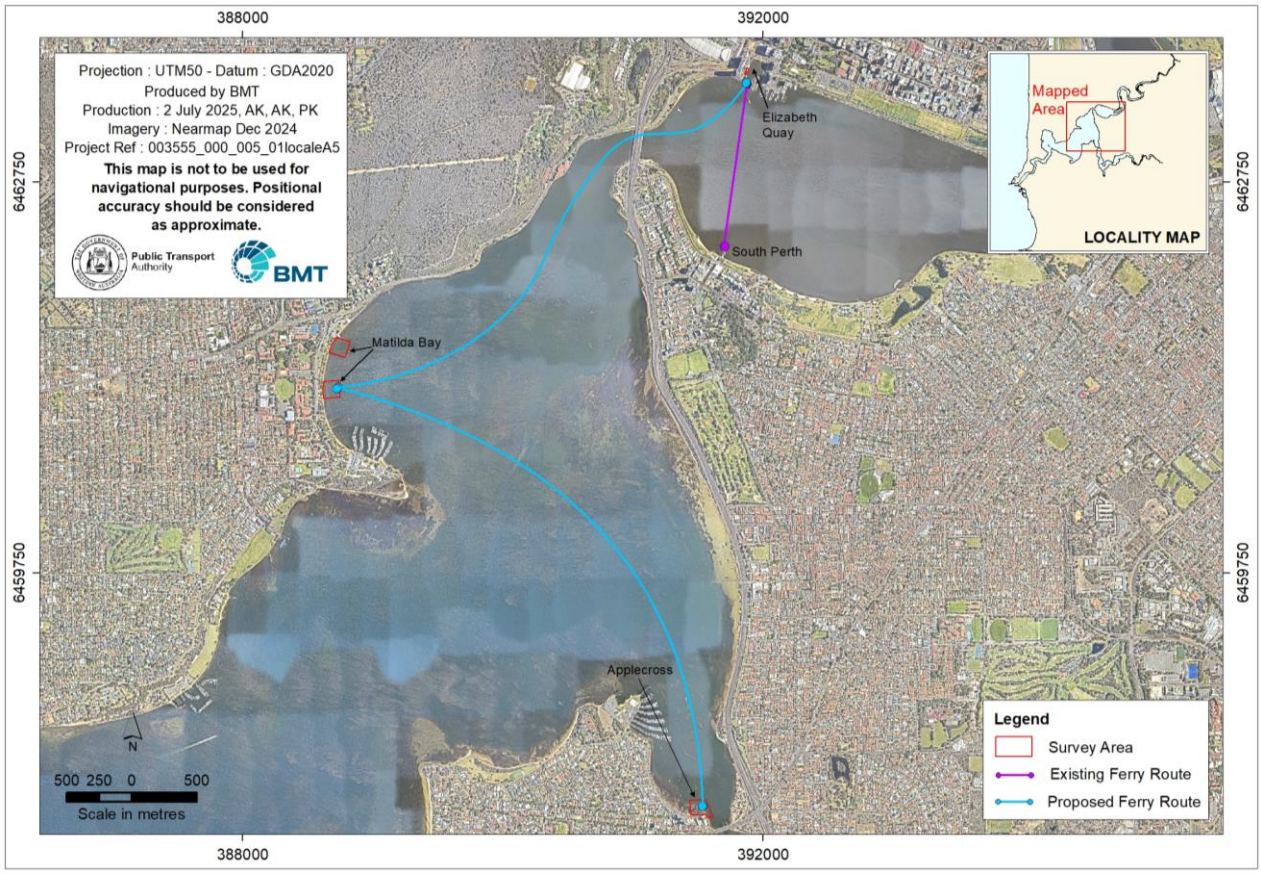
1 Introduction

1.1 Project description and background

The Public Transport Authority (PTA) proposes to expand the public ferry service network within the Swan River/ Derbal Yerrigan in metropolitan Perth, Western Australia. The proposed expansion involves linking the existing ferry route between Elizabeth Quay and South Perth, downstream to Matilda Bay and Applecross (Figure 1.1). The proposed expansion project will require an upgrade of existing ferry infrastructure at Elizabeth Quay and the development of ferry passenger terminals (hereafter; terminals) at Matilda Bay and Applecross.

The Swan Canning Estuary (SCE) is downstream of the Swan and Canning Rivers and is a salt-wedge urban estuary which receives ocean flushing from the Indian Ocean and river flow from the Avon and Swan coastal catchments (Kilminster 2010). These catchments contain urban, agricultural and industrial land uses. The SCE supports commercial, recreational and tourism activities, as well as diverse ecosystems. These ecosystems include perennial and ephemeral benthic communities and habitats (BCH) including rocky reef, oyster beds, algal mats, and seagrass, amongst large extents of sand (Forbes & Kilminster 2014, RPS 2021).

The proposed ferry routes are in the Swan Canning Riverpark (SCR) which is managed by Department of Biodiversity, Conservation and Attractions Swan River Trust in accordance with the *Swan and Canning Rivers Management Act 2006*. The SCR comprises of the Swan and Canning river reserve and adjoining public land reserved as parks and recreation under the Metropolitan Region Scheme. The proposed terminals comprise a fixed jetty, a suspended access gangway to enable queuing for the ferry and a floating pontoon that enables ferry berthing. Although the proposed ferry expansion is at concept stage with further detailed design underway, potential impact to BCH within the Swan Canning River may occur as a result of construction of the terminals. To support environmental approvals associated with the ferry expansion BMT was engaged by the PTA to complete BCH mapping within the terminal concept footprints proposed at Elizabeth Quay, Matilda Bay and Applecross (Figure 1.1).



Note: Ferry routes are indicative only and do not show the exact proposed routes

Figure 1.1 Location of existing and proposed ferry route expansion and benthic communities and habitat survey areas for proposed ferry passenger terminals

1.2 Purpose of document

A BCH survey to classify estuarine habitats in the Swan River within the proposed terminal concept design footprints was completed in March 2025. This report presents the BCH survey design, ground truth and mapping methods, habitat classification and final mapping products.

The specific objectives of the report are to:

- Understand the spatial extent and BCH assemblages in the terminal concept design footprints (hereafter; survey areas) at Elizabeth Quay, Matilda Bay[1] and Applecross.
- Quantitatively characterise the extent of BCH within the survey areas and develop a mapping product for future environmental approvals to support assessment of BCH biodiversity and ecological function and development of the ferry expansion project.

[1] The Matilda Bay survey area is comprised of two discrete areas of interest; however, the proposed ferry passenger terminal development is positioned within the southern area. The methods and results described herein for the Matilda Bay survey area are referring to the two areas of interest collectively.

2 Scope of Work

The scope of work for the field survey and BCH mapping is detailed below:

- Review of existing accessible datasets including BCH, bathymetry and satellite/aerial imagery in the area to identify gaps in coverage and the most appropriate method(s) to derive a current habitat map relevant for the project area (Section 3.1.1).
- Execute a field survey in late summer/early autumn to collect ground truth towed video data during the peak growth/ biomass period of BCH (Section 3.1.2).
- Classify ground truth towed video data into BCH categories and merge with the vessel position log to produce a shapefile of classified ground truth transects (Section 3.1.3; Section 4.1).
- Further explore sources aerial or satellite image appropriate for BCH mapping in the area and complete supervised classification of the survey areas (Section 3.2.1), validated with the classified ground truth data (Section 3.2.2) to produce a BCH map product which identifies BCH types and distribution (Section 4.2).

3 Methods

3.1 Ground truthing survey

3.1.1 Survey design

A preliminary desktop assessment of aerial imagery, existing habitat data and reports, and bathymetry datasets was completed to identify potential areas of interest and distribution of BCH in the survey areas (Figure 1.1). These include:

- High-resolution imagery sources:
  - Worldview 2 & 3 imagery
  - Geo Eye 1 imagery
  - Legion image 3 & 4 imagery
  - Nearmap image series
- Historical maps and reports (Forbes & Kilminster 2014)
- Bathymetry datasets (Surrich 2024a, b).

The proposed survey areas for the terminals were provided by PTA and were based on the terminal concept designs and surrounding area to provide additional context on nearby BCH.

The review of available high-resolution satellite imagery determined that classification of seabed features via remote sensing techniques was not suitable for deeper proportions of the survey areas (Figure 1.1). The available high–resolution bathymetric and imagery sources (i.e., GeoEye 1, World View 2 and 3, Legion image 3 and 4, Nearmap) within proportions of the survey areas were not appropriate image quality for remote mapping of riverbed features due to turbidity, water clarity (tannins) and water depth. However, the nearshore area of the Matilda Bay and majority of Applecross survey areas had suitable image quality for detection of riverbed features for habitat mapping. Nearmap imagery with good water clarity in nearshore/intertidal areas were used as primary data sources to support the nearshore mapping of features and substrates within the survey areas (Figure 1.1). Due to poor through-water clarity in imagery for detection of riverbed features around the Elizabeth Quay, BCH extent in this area was informed from ground truth data and field observations during the sediment sampling survey in April 2025 (BMT 2025b).

Given high-resolution imagery was not able to be utilised for riverbed feature detection in proportions of the survey areas to generate complete mapping products and the requirement for validation of BCH features where detected in imagery, a ground truth BCH survey was executed. A total of seven transects were located to spatially represent the Matilda Bay (four transects) and Applecross (three transects) survey areas to allow for spatial interpolation of benthic habitats (BMT 2025b). Given the close proximity of existing ferry terminal infrastructure in the Elizabeth Quay survey area towed video footage transects could not be collected, and imagery was captured via drop-cameras (BMT 2025b).

3.1.2 Collection of towed video data

Three field personnel conducted the BCH field survey between 10–12 March 2025. Ground truth videos within the survey areas were collected topside from the vessel '*Assassin'* along seven predefined transects and at two drop camera locations (Figure 3.1). The BCH field survey was scheduled for late

summer during peak growth periods for seasonal and ephemeral benthic flora. Weather conditions during the BCH field survey were relatively calm with moderate winds (7–26 km/h), minimal wind swell and a high and low tide of ~1.1 m and 0.6 m respectively. Majority of the ground truth transects were within shallow water depths and targeted to high tide conditions to capture adequate footage. Visibility was generally limited across transects due to background turbidity experienced in the Swan River; however, BCH were able to be characterised in the footage collected.

High–definition towed video data was collected using Spot X Real–Time Underwater Video System. The video system was lowered topside from the vessel to ~0.5 m above the seabed to record seabed features. The height of the camera above the seabed was monitored by the field personnel to provide a field of view containing a 2–3 m wide band of the seabed. Video footage was recorded using the primary downward–facing camera while the secondary (~30–40 degree angle) camera was used to navigate the system (i.e., avoiding unnecessary damage to benthic habitat). Live footage was relayed to the vessel via an umbilical cord during deployment to navigate/fly the system and allow for semi qualitative analysis, as required. The vessel travelled at a speed of 1–5 knots to ensure the best quality footage was captured. A waypoint at the start and end of each transect was recorded using a handheld Global Positioning System (GPS), and a tracklog was recorded using an echomap with inbuilt GPS. The time was recorded by the camera at the start of each transect to provide an accurate definition of start and end time to match with the tracklog. The recorded tracklog contained date, time, latitude, longitude and heading information, which was updated every second. Side scan sonar was run and recorded for each transect. Video footage was backed up daily onto an external storage device.

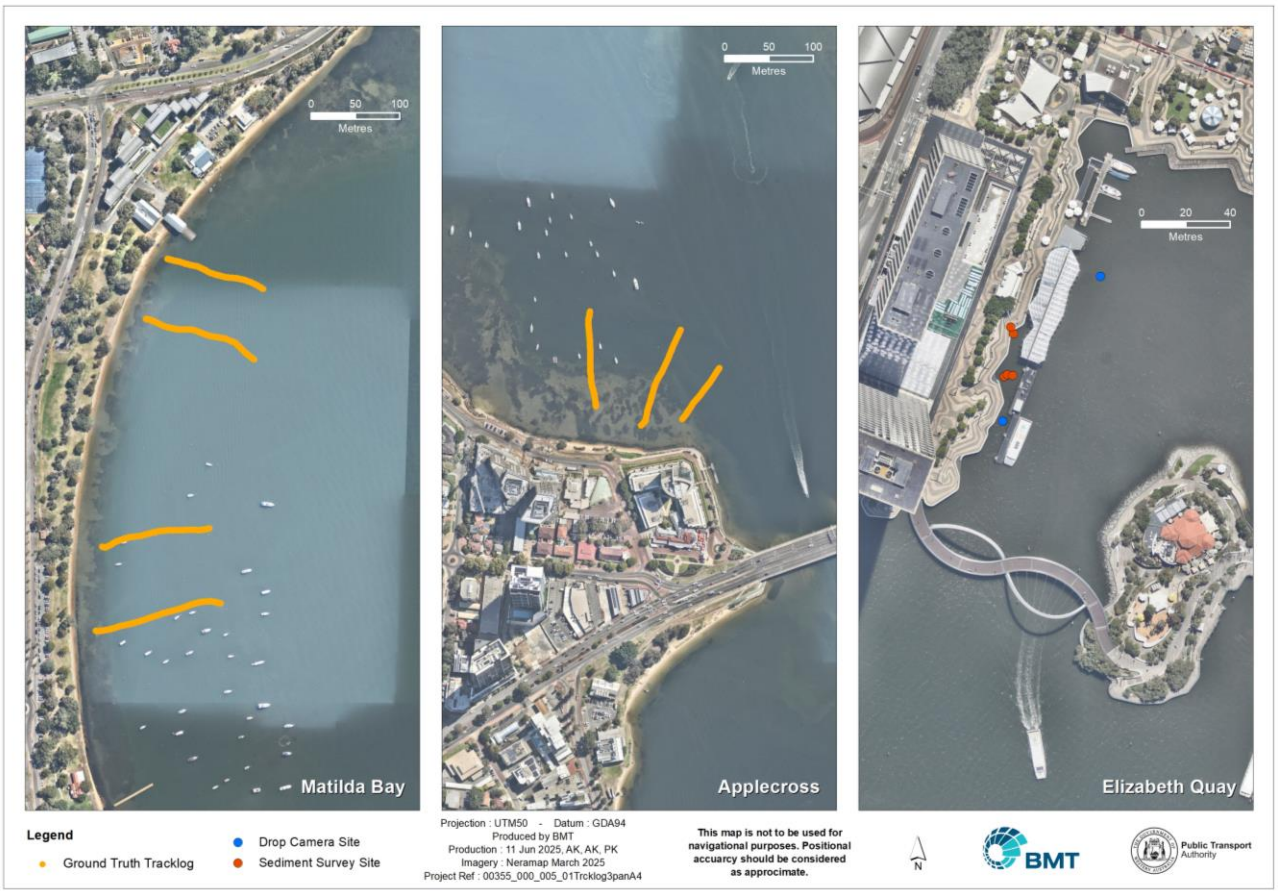


Figure 3.1 Vessel tracklog of benthic communities and habitat ground truth video transects and drop cameras surveyed within Matilda Bay, Applecross and Elizabeth Quay survey areas, March 2025

3.1.3 Classification of video footage

The video footage was analysed and classified according to the categories listed in Table 3.1 by a trained marine ecologist using Transect Measure (BMT 2025b, SeaGIS 2013). The software allows a single benthic habitat type to be assigned to each frame of video footage. The BCH was classified by identifying the dominant habitat category and minor categories, where possible (Table 3.1). A percent (%) cover category was also applied to each frame of the video where BCH was present (Table 3.1).

The BCH classifications were cumulative of all categories present within the frame of video footage including mixed assemblage (i.e., there was no single dominant habitat; Table 3.1). Following classification, the time/classification log was merged with the time/position log to provide a single file with a classification of every position where valid footage was obtained, resulting in a shapefile of classified ground truth transects (Section 4.1).

Table 3.1 Benthic communities and habitat classes and percent cover classifications

Major class	Minor class	Cover
Seagrass	*Halophila decipiens* *Halophila ovalis* Mixed *Halophila* spp. Other sp.	Very sparse (<5%) Sparse (5-35%) Moderate (35-70%) Dense (70-100%)
Mixed	Mixed seagrass and macroalgae	
Macroalgae	Macroalgae	
Filter feeders	Sponges/hydroids/other	
Sand	Bare sand Shell debris, rocky rubble	
Wrack	Seagrass/Macroalgae wrack	
Rock substrate	Bare rock reef/rubble	None

3.2 Supervised classification – benthic communities and habitat mapping

3.2.1 Classification and mapping procedures

Available satellite and aerial image archives were reviewed to identify the best reference for mapping the coverage of BCH in the survey areas. Results of video tracklog classification suggested that most of the seagrass habitat were dominated by ephemeral species, therefore the BCH coverage mapped in the survey areas can partially depend on the date of the imagery and how the timing corresponds to peak growth periods of ephemeral species. Considering the quality of the available imagery and date of capture with relevance to March 2025 field survey, Nearmap images captured on 1 February 2025 and 29 October 2024 were selected as primary image source for Applecross and Matilda Bay respectively. Nearmap red/green/blue (RGB) images resampled to 0.5 m resolution were classified using supervised classification method based on Maximum likelihood rule in ERDAS Imagine (Hexagon 2022) to derive the BCH coverage in the Matilda Bay and Applecross survey areas. General information on the distribution of BCH types highlighted by classified ground truth video tracklog results were used as the reference to categorise the vegetated areas in further detail (e.g. seagrass, macroalgae and mixed). The results were post-processed in ArcGIS version 10.8 (ESRI 2020) to filter falsely classified pixels (e.g. overestimation of vegetated areas in deeper areas).

3.2.2 Validation of the benthic communities and habitat interpolation results

BCH mapping results were validated against the classified ground truth video dataset by cross checking the actual classification of the video transect data with the final habitat layer. Accuracy assessment results are presented as user's accuracy, producer's accuracy and overall accuracy. User's accuracy indicates the probability that image pixel classified in the habitat layer is representative of classifications from the ground truth data, therefore indicating the reliability of the map from a user's point of view. Producer's accuracy is the proportion of validation points that are classified into the correct classifications in the mapped layer. Overall accuracy reports the proportion of correctly classified points by the total points used for validation.

User's accuracy of the final dataset is calculated by dividing the total number of correct pixels in a classification by the total number of pixels that were classified. The commission error, which represents the overestimation of a BCH class, is derived by subtracting the user's accuracy from 100 and indicates the proportion of validation points assigned to incorrect class. Producer's accuracy is calculated by dividing total number of correctly classified validation points by total number of points in the validation type. Omission error, representing underestimation of a BCH class, is derived by subtracting producer's accuracy from 100 and indicates proportion of validation points left out by the map classes.

User's accuracy for seagrass, seagrass and macroalgae and sand were 84.9% or above suggesting high reliability of the BCH habitat map produced (Table 3.1). The producer's accuracy for seagrass and macroalgae are 61.2% and 60.0%, respectively due to the fact that some of the areas with sparse habitat identified in ground truth video are not visible in the Nearmap image and have not been mapped in the final map dataset. The overall accuracy of the final map is not presented in Table 3.2, however was calculated as 85.9%.

Table 3.2 Accuracy assessment summary of mapped benthic communities and habitats

	Mapped categories					
Ground truth categories	Benthic communities and habitats	Seagrass	Seagrass and macroalgae	Sand	Total	Producer's accuracy (%)
	Seagrass	85	0	54	139	61.2
	Macroalgae	0	3	2	5	60.0
	Mixed[1]	10	32	14	56	75.0
	Sand	11	5	395	411	96.1
	Total	106	40	465	611	–
	User's accuracy (%)	89.6	87.5	84.9	–	–

Notes:

1. **"Mixed" = Mixed seagrass and macroalgae, see Table 3.1 for further detail.**
2. **Non-percentage values in the table represent number of ground truth tracklog points overlapping the mapped areas.**
3. **"–" = no data**

3.2.3 Mapping limitations

Ground truth video transects were targeted to high tide conditions (Section 3.1.2); however, water depths in areas of transects immediately adjacent to the shoreline were too shallow for vessel access and subsequent ground truthing. Available Nearmap images from multiple dates in previous years of comparable seasonality (late summer, early autumn) were used to validate BCH coverage in these shallow areas. Due to the dominance of ephemeral species in these survey areas, and the typical seasonal changes in biomass and extent of ephemeral species the mapped BCH coverage may not represent extent of the coverage of BCH in other seasons and years. The mapped BCH coverage is considered a representative "snap-shot" in temporal scale.

4 Results

4.1 Ground truthing benthic communities and habitat

Towed video transects were not collected within the Elizabeth Quay survey area due to the location adjacent to existing ferry infrastructure. Alternatively, camera drops of still images were captured during the BCH field survey where vessel access was possible to collect ground truth data to support classification (Figure 3.1). Drop camera footage combined with images of sediment samples collected in April 2025 (BMT 2025b, Figure 3.1 [right]) were utilised to inform BCH within Elizabeth Quay that showed predominantly bare sand (Figure 4.1).

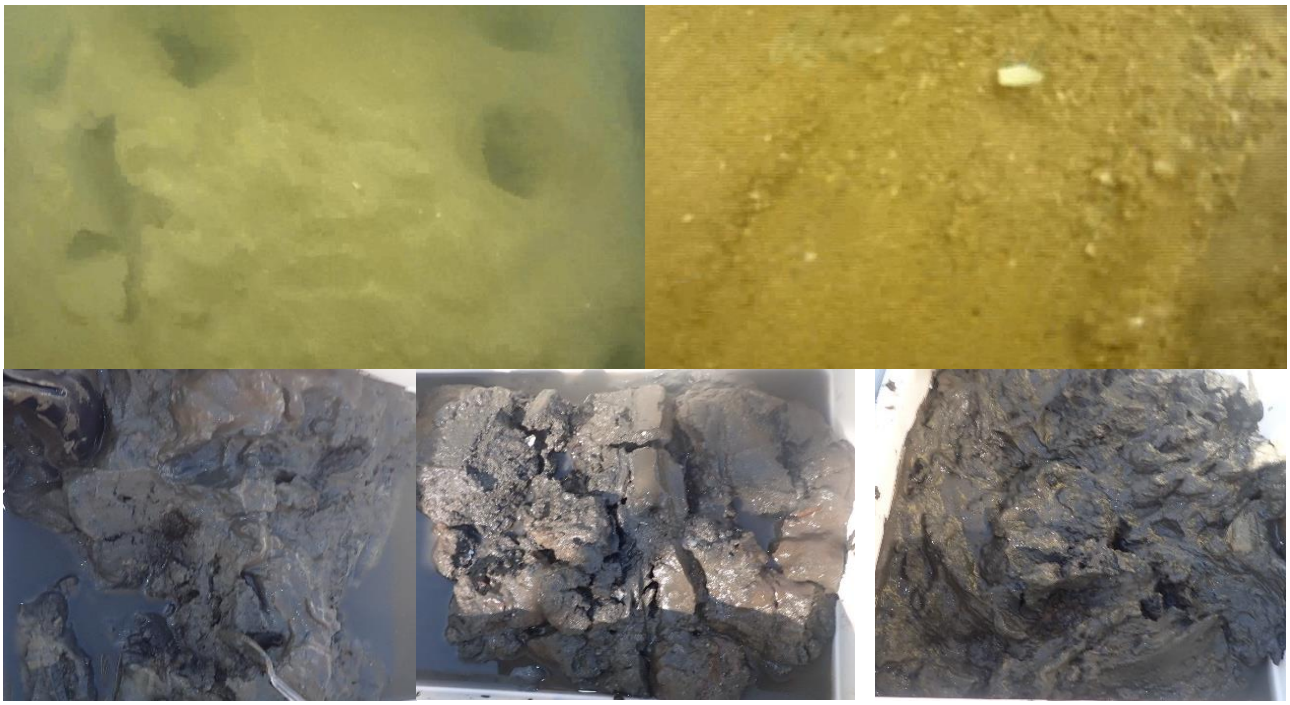


Figure 4.1 Drop camera video screenshots (top) and sediment sample photos (bottom) collected from Elizabeth Quay in March and April 2025

A total length of ~830 m of video footage collected in the Matilda Bay and Applecross survey areas was classified from the BCH ground truth field survey. The transects were classified and mapped to understand preliminary BCH assemblages, distribution and extent in the survey areas. Percent cover was also assessed during the video analysis classifications for each BCH category to assign an overall cover (Table 3.1). The BCH classifications assigned during the video analysis were detailed to the lowest taxonomic level, where possible, and majority of BCH transects included classification to seagrass genera or species level. However, for the purposes of mapping validation, seven major BCH categories were assigned to classification of the ground truth video analysis:

- seagrass
- macroalgae
- mixed (seagrass and macroalgae)
- sand

- filter feeders
- wrack; and
- rock substrate.

Classified ground truth video analysis of the Matilda Bay survey area identified predominantly bare sand interspersed with patches of seagrass (*Halophila* spp.) in the nearshore area, transitioning to bare sand habitat in areas further offshore (Figure 4.2). Classified ground truth video analysis of the Applecross survey area identified mixed BCH assemblages in nearshore areas comprised of bare sand with patches of seagrass, macroalgae and mixed seagrass and macroalgae (Figure 4.3). BCH habitats in areas outside of the Applecross survey area, further offshore, showed predominantly bare sand with some filter feeders present (Figure 4.3). Example images of the habitat classifications identified during the Transect Measure processing and analysis (Section 3.1.3) are provided in Annexure A.

Figure 4.2 Classified ground truth video transects at Matilda Bay, surveyed March 2025

Figure 4.3 Classified ground truth video transects at Applecross, surveyed March 2025

4.2 Mapped benthic communities and habitat

4.2.1 Matilda Bay

The nearshore area of Matilda Bay beyond the intertidal zone is dominated by a band of moderate to dense seagrass which extends between ~20–40 m offshore (Figure 4.2). Classified ground truth video analysis determined the seagrass assemblage is mixed species of *Halophlia decipiens* and *H. ovalis.* In the intertidal zone and areas further offshore bare sand is the dominant BCH category (Figure 4.2). Small-scale temporal variation in the seagrass extent is evident between ground truth data and Nearmap imagery capture likely attributed the seasonal timing between the BCH field survey and Nearmap imagery combined with highly seasonal productively and biomass of ephemeral seagrasses (Section 3.2). The combined Matilda Bay survey area is 3.17 ha, of which seagrass comprises 0.46 ha and sand representing the dominant BCH (Table 4.1).

Table 4.1 Benthic communities and habitat coverage in the Matilda Bay survey area

Habitat	Matilda Bay north (ha)	Matilda Bay south (ha)	Matilda Bay survey area[1] (ha)
Moderate/Dense Seagrass[3]	0.20	0.26	0.46
Sand	1.38	1.33	2.71
Total	1.58	1.59	3.17

Notes:
1. Represents the combined areas of BCH within Matilda Bay north and south, collectively referred to as the Matilda Bay survey area.
2. "ha" = hectare.
3. Sparse seagrass was present in Matilda Bay south, however represented a total of 0.0015 ha so it was not reported separately from Moderate/Dense Seagrass.

4.2.2 Applecross

The BCH within the Applecross survey area is partitioned into three main categories: nearshore was predominantly bare sand habitat with isolated patches of mixed seagrass and macroalgae, in the transition from nearshore to offshore bare sand with connected patches of predominantly moderate to dense seagrass (*Halophila* spp.) was observed, and further offshore was predominantly bare sand (Figure 4.5). These BCH categories are reflected in the coverage of the total survey area (1.70 ha), with sand comprising 1.19 ha, moderate/dense seagrass comprising 0.26 ha, sparse seagrass comprising 0.01 ha, moderate/dense seagrass and macroalgae comprising 0.21 ha, and sparse seagrass and macroalgae comprising 0.02 ha (Table 4.2).

Table 4.2 Benthic communities and habitat coverage in the Applecross survey area

Habitat	Applecross survey area (ha)
Moderate/Dense Seagrass	0.26
Sparse Seagrass	0.01
Moderate/Dense Seagrass and Macroalgae	0.21
Sparse Seagrass and Macroalgae	0.02
Sand	1.19
Total	1.70

Note:
1. "ha" = hectare

4.2.3 Elizabeth Quay

The Elizabeth Quay survey area was mapped using ground truth data (i.e. drop-camera imagery) as there was no suitable high-resolution imagery of the riverbed (Section 3.2). The Elizabeth Quay survey area is 0.07 ha and comprised of bare sand (Figure 4.6).

Figure 4.4 Mapped benthic communities and habitat within the Matilda Bay survey area

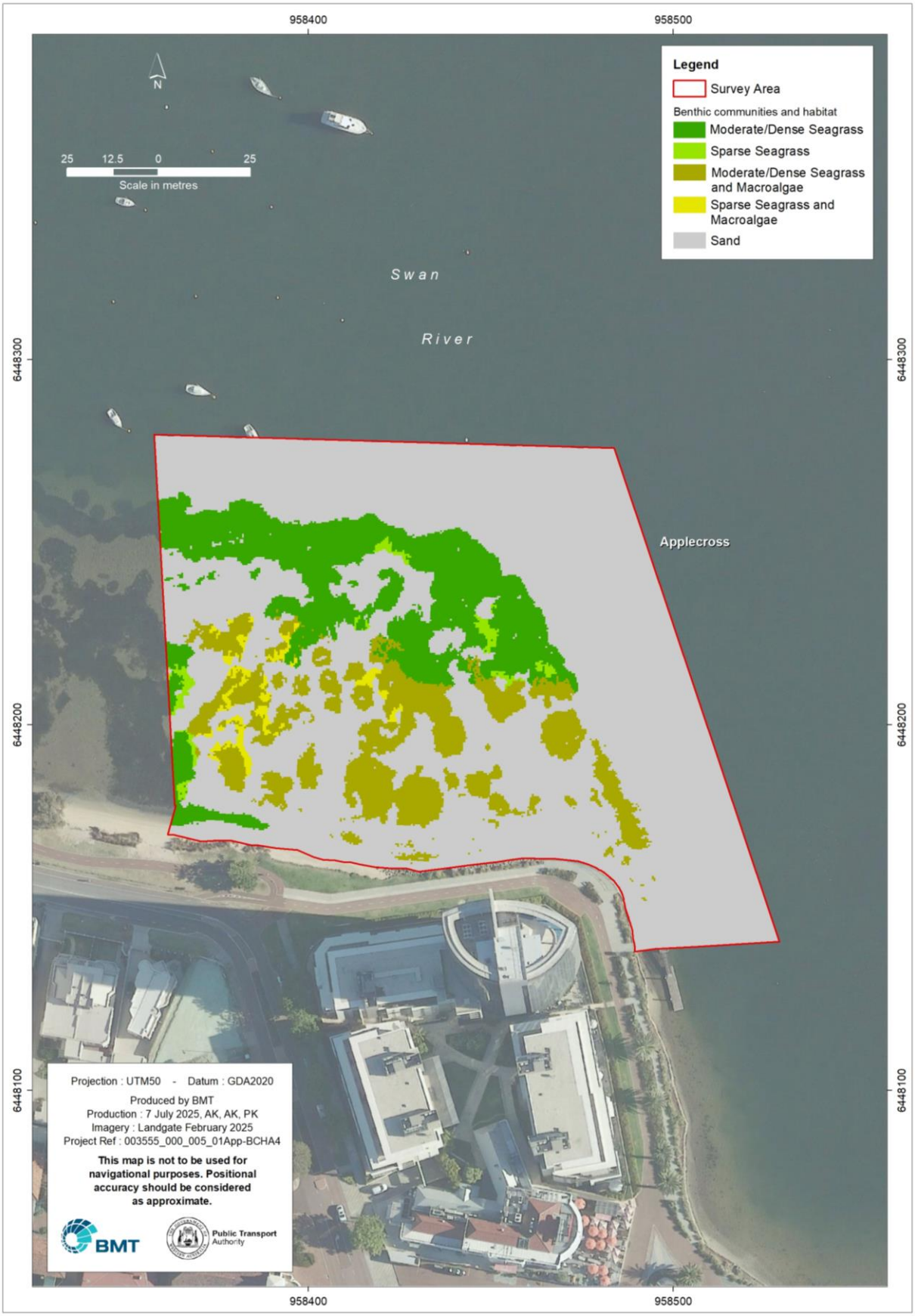


Figure 4.5 Mapped benthic communities and habitat within the Applecross survey area

Figure 4.6 Mapped benthic communities and habitat within the Elizabeth Quay survey area

5 Conclusions

Habitat mapping was completed utilising ground truth data collected in March 2025 and Nearmap imagery captured in October 2024 and February 2025 within the proposed ferry passenger terminal survey areas to quantitatively characterise and map the BCH extent to inform future environmental approvals. Within the three survey areas bare sand was the dominant BCH category, especially in the intertidal and offshore areas within Matilda Bay and Applecross, and entirely in Elizabeth Quay. The Matilda Bay and Applecross survey areas BCH displayed similar spatial distribution; bare sand with patches of seagrass, macroalgae or mixed seagrass and macroalgae in the nearshore of the survey areas transitioning to bare sand further offshore as the banks deepen, however vegetated BCH composition differed between the two areas. Vegetated BCH within the Matilda Bay survey area was predominantly moderate to dense seagrass, however in the Applecross survey area a mixed assemblage of seagrass and macroalgae of differing densities were generally present closer to shore, with moderate to dense seagrass predominant as into the transition from nearshore to offshore.

6 References

BMT (2025a) Sampling and Analysis Plan Implementation Report, Swan River Ferry Expansion – Perth to Applecross. Prepared for the Public Transport Authority by BMT Commercial Australia, Report No. R-3555-2_DRAFT, Perth, Western Australia, June 2025

BMT (2025b) Public Transport Authority Ferry Expansion – Sampling and Analysis Plan. Prepared for the Public Transport Authority by BMT Commercial Australia, Report No. R-3555-1, Perth, Western Australia, May 2025

ESRI (2020) ArcGIS Desktop: Release 10.8. CA: Environmental Systems Research Institute, Redlands, California. Available from https://www.esri.com/en-us/arcgis/products/arcgis-desktop/overview [Accessed 6 June 2025]

Forbes V, Kilminster KL (2014) Monitoring seagrass extent and distribution in the Swan-Canning estuary, Water Science Technical Series, Report no. 70, Department of Water, Perth, Western Australia, January 2014

Hexagon (2022) ERDAS Imagine. Hexagon AB, Stockholm, Sweden. Available at https://hexagon.com/products/erdas-imagine?accordId=FF39398BE2A34526BD929E68C3A4676B [Accessed 6 June 2025]

Kilminster (2010) Sediment quality in three south-western Australian estuaries, Water Science technical series, Report no. 18, Department of Water, Perth, Western Australia, January 2010

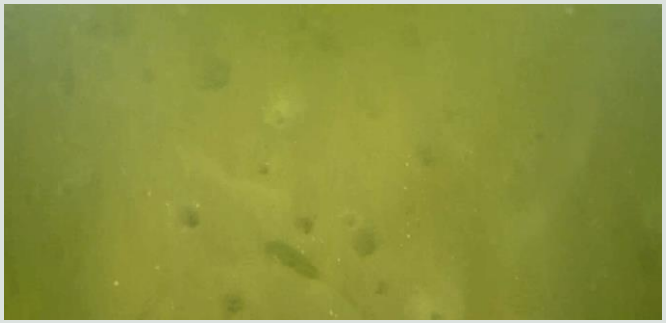
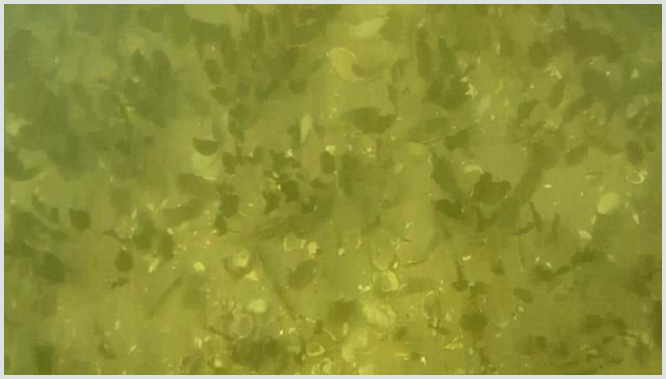
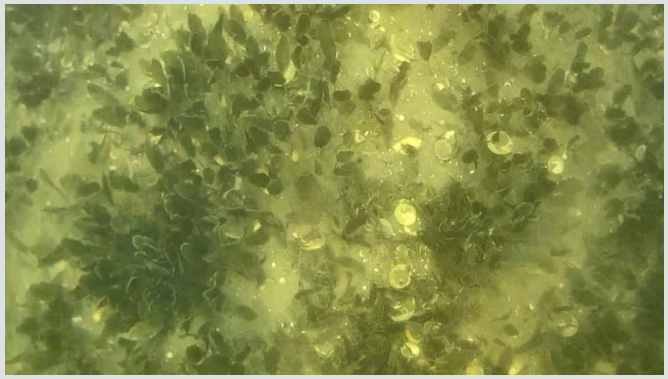
RPS (2021) Benthic Habitat Report, Swan River Crossings, Fremantle. Prepared by RPS for Arup, Report No. EEC20078.003, Perth, Western Australia, February 2021

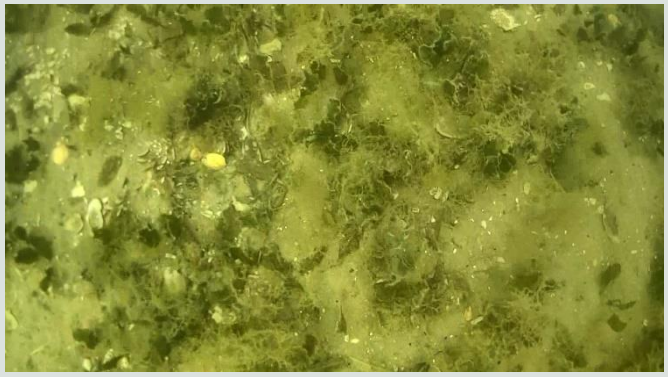
SeaGIS (2013) TransectMeasure – single camera biological analysis tool. SeaGIS Pty Ltd, Melbourne, Victoria. Available at < http://www.seagis.com.au/transect.html> [Accessed 6 June 2025]

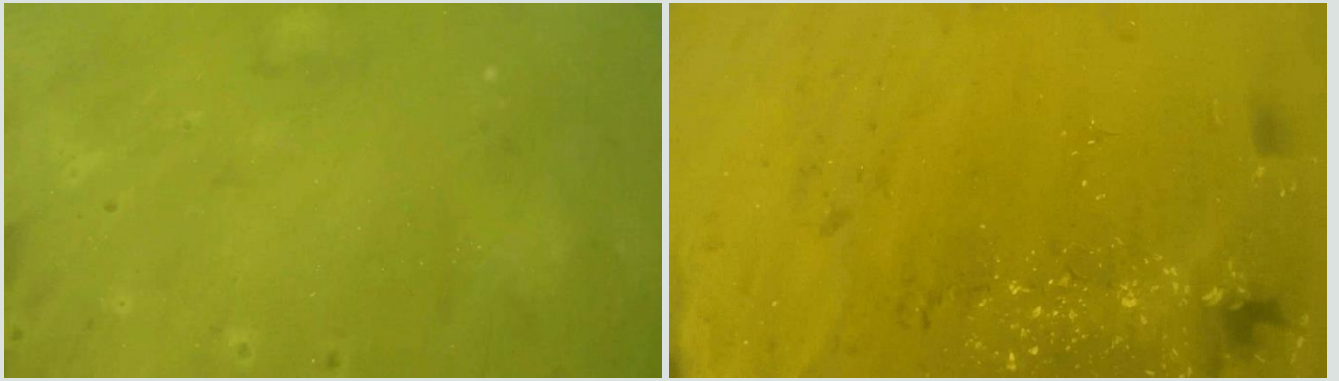
Surrich (2024a) Bathymetric Survey Factual Report. Prepared by Surrich Hydrographics Pty Ltd for PTG Consulting of behalf of the Public Transport Authority, Report No. PTA1024_Oct24_Perth_Ferry_Bathymetric_Survey_Report, Perth, Western Australia, October 2024

Surrich (2024b) Geophysical Survey Report. Prepared by Surrich Hydrographics Pty Ltd for PTG Consulting of behalf of the Public Transport Authority, Report No. PTA1024 Oct24 Perth Ferry Geophysical Survey Report, Perth, Western Australia, October 2024

Annexure A Habitat classification images from the towed video ground truth survey, March 2025

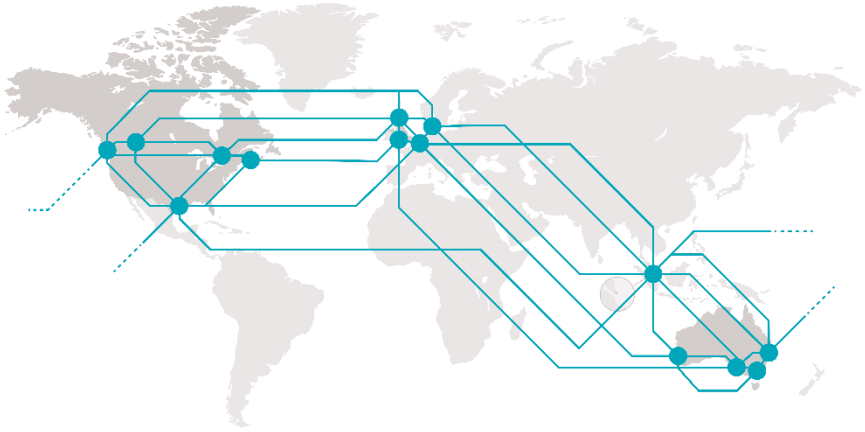
Major and minor habitat classes	Example images
Seagrass – *Halophila decipiens*	
Seagrass – *Halophila ovalis*	 

Major and minor habitat classes	Example images
Seagrass – Mixed *Halophila* spp.	
Mixed – Mixed seagrass and macroalgae	 
Macroalgae – Macroalgae	 

Major and minor habitat classes	Example images
Bare Sand – Bare sand (left) and shell debris / rocky rubble (right)	

Note:

1. Wrack and rock were not identified in towed video transect analysis; therefore, no images are available for these habitat classes. Filter feeder images were very unclear with low viability, so example images have not been provided.



BMT is a leading design, engineering, science and management consultancy with a reputation for engineering excellence. We are driven by a belief that things can always be better, safer, faster and more efficient. BMT is an independent organisation held in trust for its employees.

Level 2
150 St Georges Tce
Perth
WA 6000
Australia
+61 8 6163 4900

Registered in Australia
Registered no. 010 830 421
Registered office
Level 5, 348 Edward Street,
Brisbane QLD 4000 Australia

For your local BMT office visit www.bmt.org

Contact us

enquiries@bmtglobal.com

www.bmt.org

Follow us

www.bmt.org/linkedin

www.bmt.org/youtube

www.bmt.org/twitter

www.bmt.org/facebook