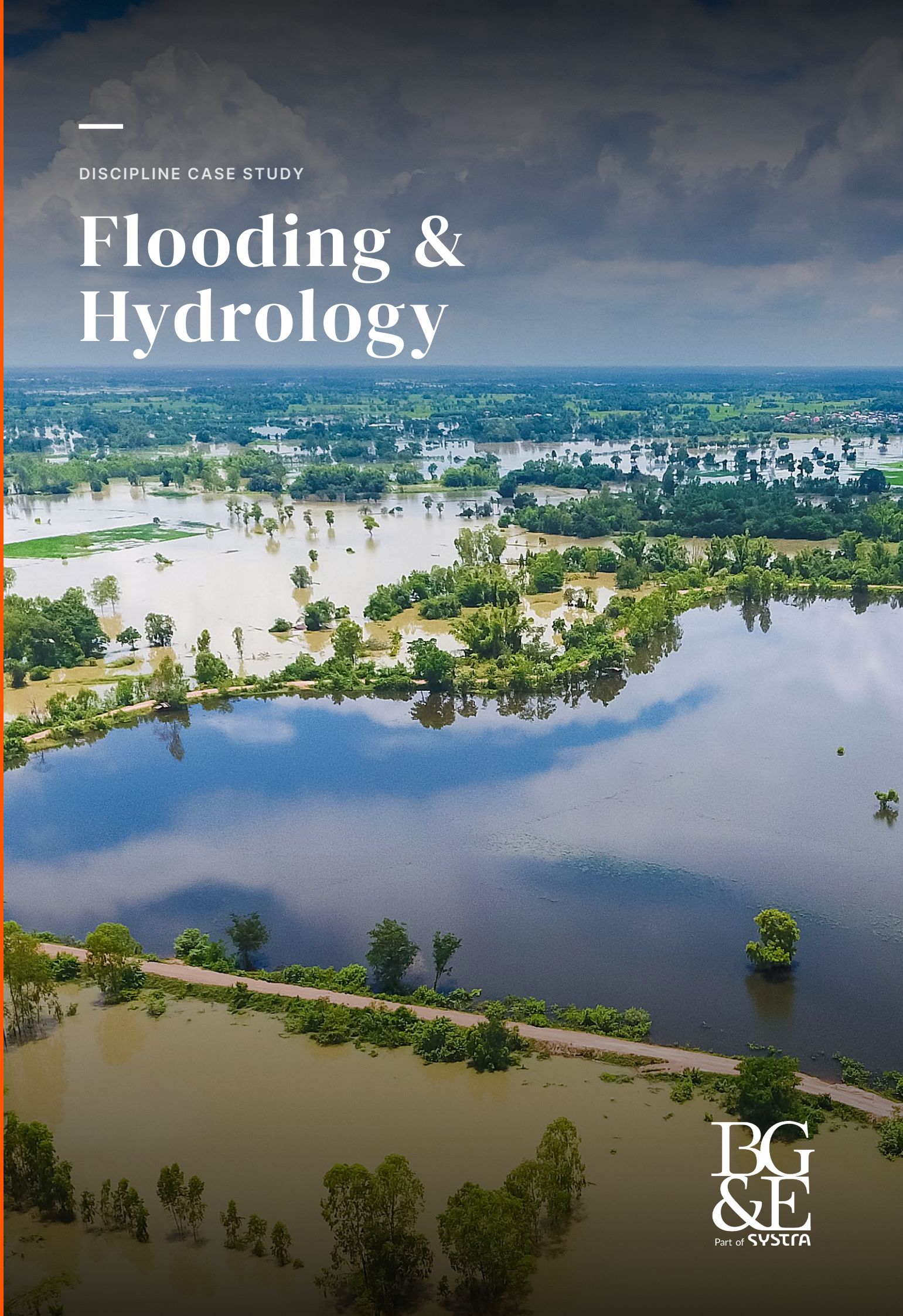
DISCIPLINE CASE STUDY

Flooding & Hydrology



BG&E
Part of SYSTRA

New Fitzroy River Bridge

ROADS & HIGHWAYS | BRIDGES | DETAILED DESIGN

KIMBERLY REGION, WA, AUSTRALIA
CLIENT: MAIN ROADS WA

Winner of the 2025 Flood Risk Management Project of the Year Award, the New Fitzroy River Bridge — delivered by the Fitzroy Bridge Alliance (Main Roads WA, Georgiou, BMD and BG&E) — officially opened to traffic in December 2023, more than six months ahead of schedule, reconnecting East and West Kimberley.

Flooding generated by ex-tropical Cyclone Ellie in December 2022 and January 2023 caused significant damage to the sections of Great Northern Highway at Willare Crossing and Fitzroy Crossing in the Kimberley.

At Fitzroy Crossing, the Fitzroy River Bridge was significantly damaged along with 500 metres of road, cutting access to Indigenous communities east of the Fitzroy River as well as the East Kimberley and Northern Territory. Main Roads WA (MRWA) determined that a new bridge was required at the same location, with repairs to the existing bridge not considered feasible.

New Fitzroy River Bridge —
Kimberly, WA, Australia.

Given the critical importance of this bridge to the State and National Road network, MRWA was looking to have a new bridge structure and access roads completed within the shortest practical timeframe and its elements that could be impacted by water flow completed before the next wet season.

BG&E provided flooding and hydrology, bridge, civil engineering, and sustainability services for the Fitzroy River Bridge replacement project.

The design aimed to ensure the bridge remained resilient to future flood events and minimise the disruption to local communities and freight connections during floods. Research was conducted to explore globally available techniques for scour protection. The selected approach needed to be practical, easy to implement, and resilient to environmental conditions.

To mitigate excessive riverbank erosion upstream of the future bridge location, groynes with rock protection surfaces were installed to redirect water flow away from the riverbank and designed to withstand events larger than the original event. The Alliance approach allowed for strong collaboration between the designer, contractor and client to achieve this.

With wide media attention, the project has highlighted the need to quickly reconnect communities after flooding and improve the resilience of communities to flooding. The project allowed for community partnerships, working closely with the local community to ensure meaningful engagement and develop an understanding of flood risk management and flood resilience by providing a structure that can withstand extreme flood events for quicker recovery, contributing to stronger economic benefits for the Kimberly region.
The quick timeframe in which the project was designed and constructed (less than one year), demonstrates that flooding recovery management does not need to be a lengthy process and that recovery including inbuilt future resilience can be achieved with successful community outcomes.

The new eight span bridge is 100 metres longer than its predecessor, 270 metres long and twice as wide at 12.4 metres wide.

Blade wall piers with pile caps were installed and supported by 1200 millimetre diameter cased piles with concrete infill. The supporting piles of the bridge substructure were placed significantly deeper than the old piles to cater for scour in the riverbed during extreme flood events, reaching a maximum depth of 40 metres into the riverbed.

Avon River Bridge

RAIL | BRIDGES | DETAILED DESIGN

STRATFORD, VIC, AUSTRALIA
CLIENT: RAIL PROJECTS VICTORIA (RPV) & CPB CONTRACTORS

The existing rail bridge over the Avon River, built in 1988, underwent several lengthening works due to changing riverbed germorphology. Located north of the existing rail bridge in Stratford, its aging condition was impacting rail service efficiency, requiring the need for replacement.

BG&E delivered the detailed bridge design for CPB Contractors, engaged by Rail Projects Victoria under a D&C model. The project included the construction of a new 500 metre rail bridge crossing the Avon River, along with flood relief structures and culverts in the vast floodplain area.

BG&E's Flooding and Hydrology specialists reviewed the reference design flood modelling including the Flood Frequency Analysis, updating the hydrology and representation of existing bridges in the flood model to better represent current site flood conditions. Flood modelling of the proposed works was developed to assess the impact of the new bridge on flood behaviour and to assist in design of mitigation measures.

Using Tuflow for hydraulic modelling, methods of modelling bridges were investigated in detail. The adopted approach used a combination of setting appropriate form losses and blockages to the bridge layers to represent the hydraulic effect of the proposed bridge over the river and the floodplain. As the allowance for afflux was small (<5 millimetres), sensitivity was undertaken on bridge parameters to understand the confidence bounds of the flood modelling and provide certainty to approval authorities that flood impacts would not have a material impact on people or property.

The cause of afflux was complicated by the timing of the over topping of the river bank and the flooding to the north and south of the embankment, which resulted in equalising behaviour occurring through the flood relief culverts in the embankment.

Our Flooding and Hydrology team worked closely with our civil and structural disciplines to prepare the detailed designs for the new bridge and flood relief culverts.

Through detailed flood modelling results analysis, BG&E was able to map and present the flood behaviour, working towards an achievable and practicable design solution.

The project also required stakeholder engagement, including:

- Close consultation with the Catchment Management Authority — the approval authority for the flood report.
- Engagement with local landowners, completed through our client, to consult on potential flood behaviour implications of the proposed bridge and flood relief culverts.

Avon River Bridge — Stratford, VIC, Australia.

Brooking Channel Bridge Replacement

ROADS & HIGHWAYS | BRIDGES | DETAILED DESIGN

KIMBERLY REGION, WA, AUSTRALIA
CLIENT: MAIN ROADS WA

BG&E was engaged by Main Roads WA to design a new two lane bridge to replace the existing Brooking Channel Bridge, with the project brought forward following the completion of the new two-lane Fitzroy River Bridge.

The Brooking Channel Bridge is located approximately one kilometre north of the Fitzroy River Bridge where the Great Northern Highway crosses the Brooking Channel near the Fitzroy Crossing township.

The new $100 million bridge is 127 metres long and 12.4 metres wide, providing two lanes for vehicles and a 1.8 metre pedestrian walkway.

To support the design and ensure the safety and flood resilience of the new bridge, two-dimensional hydraulic modelling was carried out for the upstream catchment and a 10 kilometre stretch of Fitzroy Crossing. This modelling informed the structural design and scour protection measures and ensured that the new bridge does not create adverse flooding impacts for Fitzroy Crossing township.

Mandurah Estuary Bridge Duplication

ROADS & HIGHWAYS | BRIDGES | DETAILED DESIGN

MANDURAH, WA, AUSTRALIA
CLIENT: GEORGIOU GROUP (FOR MAIN ROADS WA & CITY OF MANDURAH)

The $148 million Mandurah Estuary Bridge Duplication project involved constructing a new 380 metre long, two lane bridge to provide additional traffic lanes and a new four metre wide shared path to help the local community better access recreational activities.

Originally constructed in the 1980s, the Mandurah Estuary Bridge was designed with future duplication in mind. The bridge was designed with capacity for three lanes, initially opening with two active lanes in each direction and a third lane available for future expansion, ensuring it meets the region's future traffic demands.

BG&E provided bridge design, civil and structural engineering, and flood modelling and hydrology services for the project.

Key flooding and hydrology services included:

- Two-dimensional hydraulic modelling was undertaken to inform the scour assessment for the new bridge, considering tidal flows and catchment flooding.
- Detailed hydrological modelling was carried out for an adjacent urban area to estimate overland flows that are conveyed to an existing drainage channel that runs parallel to the western approach.
- Hydraulic modelling was conducted to ensure potential adverse flood impacts associated with the new bridge and modifications to the existing drainage channel were mitigated.

M1 Pacific Motorway Extension to Raymond Terrace: Black Hill to Tomago

ROADS & HIGHWAYS | BRIDGES | DETAILED DESIGN

NEWCASTLE, NSW, AUSTRALIA
CLIENT: JOHN HOLLAND & GAMUDA JV

The M1 Pacific Motorway extension to Raymond Terrace project includes a 15 kilometre extension of the existing M1 Pacific Motorway (M1) at Black Hill to the existing Pacific Highway at Raymond Terrace. This extension will provide a critical link between Sydney and Brisbane and includes a 2.5 kilometre viaduct over the Hunter River floodplain.

BG&E, alongside JV partner, Jacobs, provided the detailed design for the Southern Package — which achieved multiple 10/10 review scores from Transport for NSW (TfNSW), met an ambitious eight month delivery design schedule, and optimised key design elements — significantly reducing quantities in the detailed design phase.

BG&E's flood assessment of Glenrowan Creek demonstrated that the reference design five span bridge could be constructed as a single span bridge without adversely impacting flood behaviour. Extensive analysis confirmed that flood velocities were low enough to eliminate the need for scour protection of piers in the river and floodplain.

The flood impact of the viaduct on communities during and after construction was a key driver for the design. A key issue was balancing the height of the maintenance access track across the floodplain to the bridge to minimise future flood impacts upstream.

Various iteration scenarios were modelled to determine the optimal height of the track, supported by rigorous geotechnical analysis and a greater level of onsite investigation and testing. Modelling of varying lengths of temporary access platforms on each side of the river for construction in the river was undertaken to determine the maximum platform length without impacting flood levels upstream during construction.

Potential flood risk due to the construction methodology was a major concern for stakeholders and affected landowners, where the potential for change in the duration of inundation would affect cropping and agricultural practices.

BG&E, working closely with its construction partners and TfNSW, prepared documentation for community engagement and engaged directly with affected landholders at community information sessions.

For the final design, the Flooding and Hydrology and Structures teams developed a custom precast pile cap with curved ends, significantly reducing afflux and improving constructability, shortening construction time in the river.

Additionally, we optimised the shape and size of bridge piers to achieve the most hydrodynamically efficient design. This minimised flow obstruction during flooding while maximising pier spacing and maintaining the structural integrity of the viaduct across the floodplain and the Hunter River.

BG&E led the hydrology and flooding design for the project, collaborating closely with the contractor and TfNSW. The team upgraded the Tuflow flood model to exploit important developments and benefits, such as sub-grid sampling and variable grid sampling to finesse proposed structures, earthworks, and to minimise flood storage loss.

M1 Pacific Motorway Extension to Raymond Terrace: Black Hill to Tomago — Newcastle, NSW, Australia.

Tonkin Gap Project

ROADS & HIGHWAYS | BRIDGES | DETAILED DESIGN

PERTH, WA, AUSTRALIA
CLIENT: MAIN ROADS WA

BG&E provided structural, civil, and flooding and hydrology services for the $400 million Tonkin Gap Project — designed to relieve congestion where the Great Eastern Highway narrowed from three lanes to two in Bayswater and Redcliffe.

The upgrade connects two major infrastructure projects, Gateway WA and NorthLink WA, significantly improving travel times and road safety.

Delivered by the Tonkin Gap Alliance comprising Main Roads WA, Public Transport Authority, Georgiou, BMD, WA Limestone, GHD, and BG&E, the project included the duplication of the existing Redcliffe Bridge over the Swan River.

Key flooding and hydrology services included:

- Conducting a waterways assessment for the duplication of the Redcliff Bridge, which involved two-dimensional hydraulic modelling to confirm design flood levels and identify any potential impacts to flood behaviour.
- Engaging with key stakeholders, including DWER and MRWA Waterways Section, to obtain support in-principal for the design.
- Carrying out hydraulic modelling to inform the design of temporary works associated with the construction of the bridge.

Hallam North & Heatherton Road Upgrade

ROADS & HIGHWAYS | DETAILED DESIGN

HALLAM, VIC, AUSTRALIA
CLIENT: MAJOR ROAD PROJECTS VICTORIA & SYMAL GROUP

BG&E provided flood modelling and drainage design for the detailed design of the Hallam North and Heatherton Road upgrade, part of Victoria's Big Build.

Flood impact management was a key constraint, as the project was located in a highly developed urban area and required close attention to mitigate flood impacts to neighbouring residential properties.

Detailed design of drainage infrastructure, including culverts and drains, was carried out to minimise impacts to existing flood behaviour based on strict requirements from the approving authority, Melbourne Water. Various design options were considered to achieve a practical approach to managing flood impacts.

The works consisted of:

- The duplication of Hallam North Road from two lanes to four lanes (two lanes in each direction) with a central median.
- Intersection upgrade and signalisation of the Hallam North and Heatherton Road intersection to replace the existing roundabout.
- Upgraded signalised intersection with Thomas Mitchell Drive to improve access and safety.
- Provision of a new signalised intersection with Heatherton Village Shopping Centre and Heatherton Road.
- Dedicated turn lanes and U-turn facilities.
- New and upgraded SUPs along both sides of Hallam North Road and Heatherton Road for project length.
- Stormwater and sub-surface drainage design and flood modelling.
- Road works, earthworks, retaining wall design, street lighting, safety barriers, new shared paths, traffic signals, and associated works.
- Relocation and protection of utility services.
- Landscaping, urban design, and associated works.

The upgrade has improved traffic flow and eased congestion at the Heatherton Road intersection, improved accessibility to the freeway network, made it easier for the local community to walk or cycle in the local area, and lowered the risk and severity of crashes by adding safety barriers.

Bunbury Outer Ring Road Planning Study

ROADS & HIGHWAYS | BRIDGES | DETAILED DESIGN

BUNBURY, WA, AUSTRALIA
CLIENT: MAIN ROADS WA

The $852 million Bunbury Outer Ring Road (BORR) provides a 27 kilometre transport corridor linking Forrest Highway to Bussell Highway in WA — enabling drivers to avoid 13 sets of traffic lights while improving freight efficiency and road safety.

BG&E adopted the role of Service Delivery Manager for the single largest regional planning and development project by Main Roads WA, undertaking project development with JV partner GHD and leading the Integrated Project Team (IPT).

BG&E obtained in-principal approval from key stakeholders for the transverse drainage concept design to enable the project to proceed to the delivery phase.

BG&E led the hydrology and flood modelling scope for the project, which involved:

- Major waterways analysis for bridges over the Collie, Ferguson, and Preston Rivers.
- Hydrologic analysis to establish design flows for ungauged, rural catchments.
- Two-dimensional hydraulic modelling to establish concept culvert sizes across the project.
- Impact assessment throughout project area.
- Concept bridge and culvert sizing for transverse drainage concept.

EastLink WA Planning Study

ROADS & HIGHWAYS | CONCEPT DESIGN

PERTH, WA, AUSTRALIA
CLIENT: MAIN ROADS WA

EastLink WA is WA's largest road network planning study that forms the start of the Perth Adelaide National Highway (PANH) to link Perth to the eastern states via Adelaide.

The planning study was undertaken under a collaborative contractual model via an Integrated Project Team (IPT) — in 2021, the GHD and BG&E JV formed the EastLink WA IPT with Main Roads to undertake planning, design development, and project scoping works.

The project scope involved the development of 65 kilometres of urban and rural highway that traverses complex urban and peri-urban freeway-type operations along Reid Highway and Roe Highway, with eleven grade-separated interchanges connecting to lower-order arterial networks.

BG&E led the hydrology and flooding scope for the project, which involved:

- A regional hydrology assessment considering existing gauging data for Jane Brook, Susannah Brook, Gidgegannup Brook, Wooroloo Brook, and Clackline Brook catchments.
- Developing concept designs for transverse drainage infrastructure to inform the environmental referral for the project.
- Establishing one-dimensional and two-dimensional hydraulic models throughout the 80 kilometre length of proposed highway within metropolitan and rural areas.
- Developing a concept design that focused on minimising adverse impacts to the existing hydrologic regime.
- Consultation with key stakeholders — Main Roads WA, Water Corporation, LGA, and DWER.

Sydney Metro: City & Southwest — Tunnel Station Excavations (TSE)

METRO | DETAILED DESIGN

SYDNEY, NSW, AUSTRALIA
CLIENT: JOHN HOLLAND, CPB & GHELLA JV

The Sydney Metro City and Southwest (SMCSW) project extended the existing metro rail line between Chatswood and Marrickville and includes a new tunnel beneath Sydney Harbour.

The Tunnelling and Station Excavation (TSE) works include:

- Construction of 15.5 kilometres of twin railway tunnels, including a 750 metre section under Sydney Harbour, and entry and exit dive structures at Chatswood and Marrickville (north of Sydenham Station).
- Excavation of complex underground structures to accommodate six new metro railway stations at Crows Nest, Victoria Cross, Barangaroo, Martin Place, Pitt Street, and Waterloo.
- Excavation of multiple shafts for construction.

Sydney Metro — City & Southwest: Tunnel Station Excavations (TSE) — Sydney, NSW, Australia.

Arcadis and BG&E, in a JV (ABJV), were responsible for the TSE design, including civil and structural engineering, materials and durability services, and flooding and hydrology services, including a project-wide flood assessment led by BG&E.

The hydrologic and hydraulic modelling included Australian Rainfall and Runoff (ARR) assessment to assess:

- Pre-development and post-development flood behaviour.
- The impact of flood behaviour for project compliance.
- Flood immunity levels for the 12 station dive, shaft sites, and the Marrickville stabling yard.

The key challenge was preventing flood waters from entering the excavations for all events up to and including the Probable Maximum Flood (PMF), into any potential openings into the tunnels.

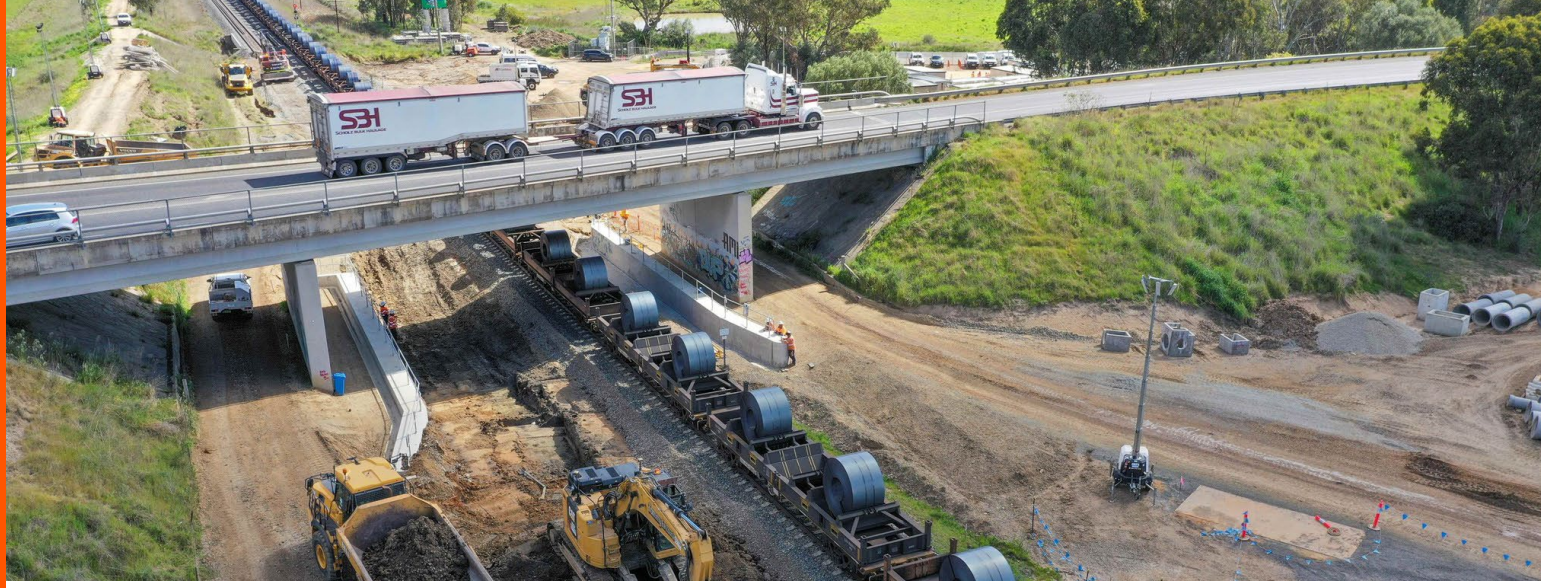
Interfaces with structure designers were important to determine flood immunity levels for critical infrastructure and flood mitigation measures which were achievable within the design.

Flood strategies were developed for each location to prevent inundation of excavations and shafts from PMF, typically with one or all of the below solutions:

- Raised capping beams.
- Amplifying the drainage and inlet system to capture additional flow to an upgraded stormwater system.
- Temporary realignment of the existing stormwater system to allow construction.

At Marrickville, a significant overland flow path was diverted across the dive via a bridge structure and into the existing open drainage channel. Alternative options for diverting the overland flow path around the dive structure were not feasible based on the natural surface grade, available space for the flow path and potential impacts on the adjoining rail corridor.

The full flood modelling package was completed within one year and included the design of flood mitigation measures and modelling of construction staging.



Inland Rail — A2P

RAIL | BRIDGES | DETAILED DESIGN

REGIONAL NSW (ALBURY TO PARKES), AUSTRALIA
CLIENT: MARTINUS & ARTC

The Albury to Parkes (A2P) project comprises 355 kilometres of brownfield sections between Albury and Illabo (A2I) and Stockinbingal to Parkes (S2P). The BG&E and Aurecon Design JV was engaged by Martinus to provide design services for the A2P package.

The detailed design included 29 D&C packages. This includes structure modifications, track reconfigurations, bridge replacements, track lowering and raising, track slews and level crossing updates, and bridge removal.

As part of these design works a flood assessment at each site was undertaken if there was a risk of flooding present. This was defined as within a known PMF extent or, if no studies were available, an assessment was undertaken to assess the risk. The assessments were undertaken to ensure that the packages complied with the Project Scope and Requirements, the CSSI Conditions of Approval, and the Updated Mitigation Measures.

The flood assessment for each site aimed at:

- Estimating the flood behaviour within each site's study area.
- Assessing potential flood impacts as a result of the design outside the project boundary.

As rail embankments are linear infrastructure, in flood affected areas they are the major hydraulic control across the catchment. Modifications to this infrastructure can have effects on nearby properties upstream or downstream of the rail. Mitigation measures were proposed and modelled in liaison with the design team and Martinus to provide the optimal design solution when non-compliance was present.

Nyidinghu Rail Baseline Hydrology & Concept Drainage Design

RAIL | BRIDGES | CONCEPT DESIGN

PILBARA REGION, WA, AUSTRALIA
CLIENT: FORTESCUE

BG&E was engaged by Fortescue to carry out a baseline hydrological study for several future railway alignment options associated with the Nyidinghu mine site. The study area includes the hydrologically complex Fortescue Marsh with large areas of overland sheet flow influenced by existing linear infrastructure.

The project involved developing several two-dimensional hydraulic models with the direct rainfall approach to establish baseline flood behaviour for each of the alignments to identify the location of major flow paths and future waterway crossings.

Following selection of a preferred alignment, preliminary sizing for cross drainage infrastructure, including culverts, bridges, and diversion drains, was carried out. A flood impact assessment was also conducted to identify and mitigate potential impacts to adjacent infrastructure and sensitive receptors.

The Flooding and Hydrology team worked collaboratively with bridge engineers to develop concept designs for eight major bridge crossings and associated scour protection.

Parkes Flood Mitigation & Surface Water Assessment

ASSET MANAGEMENT | DETAILED DESIGN

PARKES, NSW, AUSTRALIA
CLIENT: PARKES SHIRE COUNCIL

The township of Parkes has been impacted by several severe flash floods in recent years. This has resulted in significant economic losses and disruption of regular day-to-day activities. Additionally, Parkes is future proofing its water supply infrastructure by augmenting its storage and pumping capacity. BG&E's Flooding and Hydrology team provided technical support to Council for a number of projects in the area.

BG&E was engaged to assess several flood mitigation options within the township and other works associated with the Water Treatment Plant (WTP) infrastructure of Parkes Shire Council.

Parkes Flood Mitigation & Surface Water Assessment — Parkes, NSW, Australia.

BG&E's scope of works encompassed multiple projects:

- Design of drainage channel to provide Probable Maximum Flood protection to a raw water storage lagoon and extension of existing flood mitigation basins to mitigate downstream impacts.
- Flood impact assessment for a proposed levee and water storage lagoon adjacent to the Lachlan River.
- Incorporation of ten flood mitigation measures within the urban area to alleviate flood impacts across Parkes township.

These mitigation works included the design of a new detention basin at Crocker Park, augmentation of the stormwater system in various areas of town, increase of drainage pits to enhance the capture of stormwater runoff and changes to the road surface to aid in the conveyance of runoff towards inlet pits.

The flood model went through a thorough review process before incorporating flood mitigation measures. Several changes to the hydrological layout in the modelling were made to adequately assess the flood mitigation measures. Two Tuflow models were developed to design the drainage channel next to the raw water storage lagoon and a Tuflow model of the Lachlan River near the Tallawalla property was also prepared.

Upon completion of the preliminary flood modelling for Crocker Park detention basin, BG&E's Civil team embarked on the detailed design phase and further provided support to Parkes Shire Council during the tendering phase.

The works carried out by BG&E have supported Parkes Shire Council to bring forward those designs into Detailed D&C contracts meeting the Council's milestones successfully. As a result of BG&E's performance, we were engaged in further scopes of work including additional flood mitigation and detailed design in the area not directly related to the first engagement. Each scope of work has been delivered on time and within budget.

Country Rail Network Washaway Assessments

RAIL | ASSET MANAGEMENT | RISK ASSESSMENT

NSW, AUSTRALIA
CLIENT: JOHN HOLLAND & TRANSPORT FOR NSW

Following a number of washaways, silt deposition, blockage, and scour issues after several heavy rainfall events, BG&E's Flooding and Hydrology specialists undertook analysis for over 100 culverts at about 20 locations across the Country Rail Network (CRN) to assess the magnitude of the event and propose mitigation and management solutions to minimise future washouts and rail disruption.

At each location, gauged rainfall observations and RADAR data were used to establish the Annual Exceedance Probability of the rainfall event that caused the incident. Through site observations and photographs provided immediately after the events, blockage assessments and catchment potential for blockage were also undertaken to understand the likelihood of blockage being a key factor in rail overtopping.

Given the wide catchment spread across regional NSW (from Tamworth to Manildra to Orange), it was important to consider suitable parameters of catchments individually rather than adopt a one-size-fits-all approach. Design event flows were determined through rainfall-routing (XP-RAFTS and WBNM) modelling of the catchments using ARR2019 procedures, calibrated and validated against the rainfall-derived AEPs and alternative methods such as RFFE and rain-on-grid modelling.

Hydraulic analysis was undertaken using either Hy-8, HEC-RAS, or Tuflow to:

- Determine the design capacity of the current culverts.
- Undertake blockage sensitivity analysis.
- Assess rail over-topping.
- Identify options to improve culvert capacity or drainage where required to meet Country Rail Network Standards.

While the client originally requested a 1D hydraulic analysis, upon review of LiDAR data and site inspection, BG&E recommended a 2D analysis for some areas. This delivered key benefits:

- Enabled better definition of overland flows, taking into account catchment storage and poorly defined catchments with cross-catchment flows, where water flows along the rail corridor.
- Prevented underestimation of existing culvert capacities, which could have potentially led to unnecessary culvert and drainage upgrades to meet flood immunity and culvert capacity standards.

The advantage of the 2D approach mean that existing culvert capacities were not significantly underestimated which could have potentially led to unnecessary culvert and drainage upgrades to meet flood immunity and culvert capacity standards.

Through the modelling, BG&E made recommendations including culvert upgrades, scour protection, and improved drainage measures to improve rail immunity to flooding and reduce the risk of further washaway.

As a result of this work, BG&E was subsequently appointed to deliver the detailed design of some of the culvert and drainage upgrades at some locations.

Country Rail Network Washaway Assessments — NSW, Australia.

Dampier Salt Surface Water Management Study

ASSET MANAGEMENT

PILBARA REGION, WA, AUSTRALIA
CLIENT: RIO TINTO (DAMPIER SALT)

Dampier Salt engaged BG&E to conduct a Surface Water Management Order of Magnitude Study (OoM) to identify controls to reduce risks associated with rainfall and cyclone events as much as reasonably practicable.

In the study, BG&E carried out hydrologic and two-dimensional hydraulic modelling for the Port Hedland and Dampier sites to identify high-level risks to operation and corresponding risk mitigation options. A risk assessment was also carried out for the Lake MacLeod site based on existing design water levels and newly collected LiDAR data. Options had to consider potential impacts to nearby infrastructure such as BHPB's railway.

The project involved:

- Site visits to identify problem areas.
- LiDAR collection.
- Development of rainfall-runoff models and regional peak flow estimation.
- Two-dimensional hydraulic modelling for the existing scenario and design options for each site.
- Flood impact assessment.
- Stakeholder and risk workshops.

Bonalbo Flood Study & Floodplain Risk Management Plan

COMMUNITY RESILIENCE | FLOOD PLANNING & POLICY

BONALBO, NSW, AUSTRALIA
CLIENT: KYGOLE COUNCIL

The town of Bonalbo, NSW, is affected by flooding from both overland flows and from Peacock Creek. BG&E prepared the town's first ever Flood Study to help Kyogle Council understand the risk and assist in future planning decisions, as well as emergency response planning.

BG&E developed detailed hydrologic and hydraulic models for Bonalbo using XP-RAFTS, ICM, and Tuflow. The models were calibrated against three significant historical flood events — 1967, 2008, and 2022 — to ensure accuracy and reliability.

Using a water level gauge at Peacock Creek and historic rainfall, the hydrograph at the gauge was recreated, validating the hydrologic model setup. Further validation of the hydraulic model was achieved through comparison with community-sourced flood observations and other historical flood data, that provided valuable insight into local flood behaviour.

Throughout the Flood Study and FRMS&P, BG&E undertook community consultation, including questionnaires, personations, attendance at community days, and talking with individuals. These interactions were essential not only for model validation but also for ensuring that the study reflected local knowledge and concerns.

Flood Planning Areas and Flood Planning Levels (FPLs) were established to guide future development in Bonalbo. Given the combination of mainstream and local overland flow flooding, FPLs were tailored to reflect the specific flood source, flood hazard, and flood depths. It was important to define practicable FPLs that suitably managed the flood risk without preventing any future development in the areas.

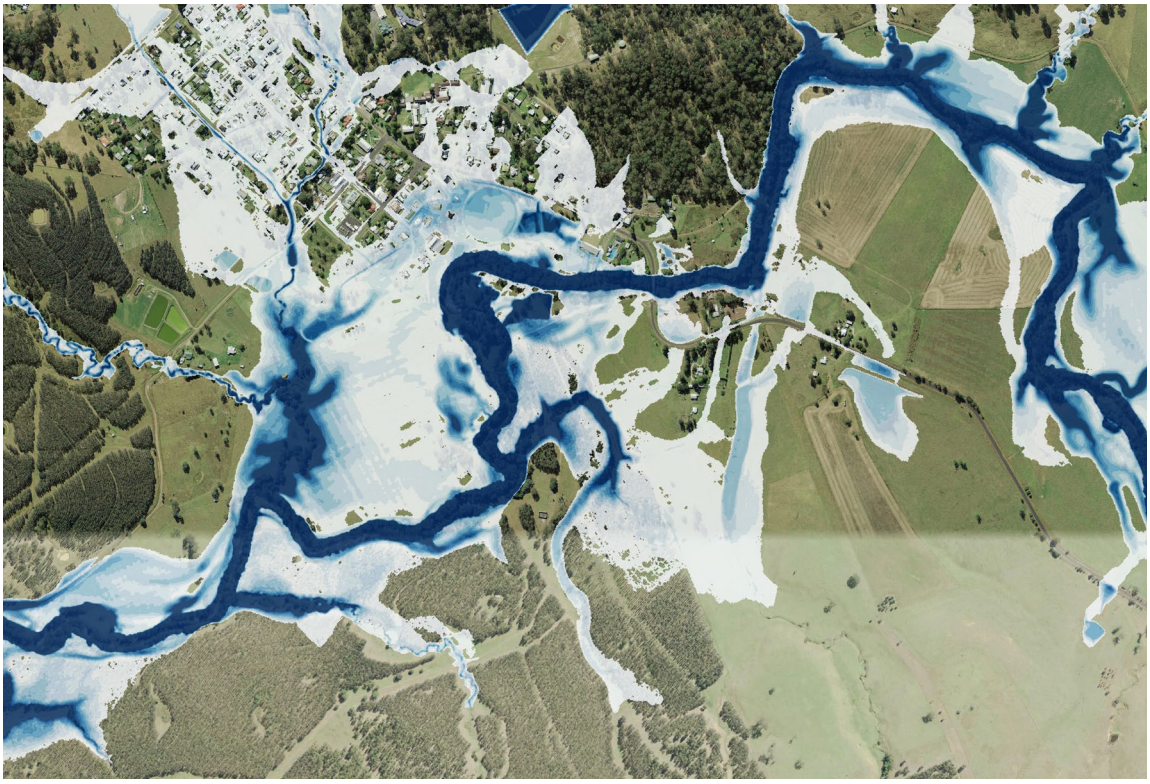
BG&E undertook a review of current land use zoning and made recommendations in regard to rezoning of currently undeveloped residential zone land subject to high hazard flood prone land to recreation or environmental uses to prevent future population intensification in areas where flood risk is considered unacceptable.

Following the completion of the Flood Study, BG&E developed the Bonalbo Floodplain Risk Management Study and Plan. We identified a range of flood mitigation options, including:

- Physical flood modification.
- Response modification.
- Property modification measures.

Each option was evaluated through a multi-criteria assessment process, which included a damages assessment and benefit-cost ratio analysis. The outcomes of this assessment were used to rank the options and present them to Council and other stakeholders for consideration and potential implementation.

Bonalbo Flood Study & Floodplain Risk Management Plan — Bonalbo, NSW, Australia.



Urbenville & Woodenbong Flood Study

COMMUNITY RESILIENCE | FLOOD PLANNING & POLICY

URBENVILLE & WOODENBONG, NSW, AUSTRALIA
CLIENT: TENTERFIELD SHIRE COUNCIL & KYOGLE COUNCIL

Urbenville and Woodenbong, located along Tooloom Creek, are prone to flooding from both the creek and local catchments. Frequent road inundation often isolates these communities. BG&E was engaged to prepare flood risk mapping to better understand and manage these risks.

BG&E developed hydrologic and hydraulic models and presented flood mapping for a range of Annual Exceedance Probability flood events and future climate change scenarios.

This helped Council and other decision makers in understanding risk to existing populations and inform decisions for flood risk management and mitigation.

Due to limited river gauges, sub-daily rainfall gauges, and suitably recorded flood markers, a model validation approach was used instead of detailed calibration. For historic flood events, daily rainfall for gauges was aligned with patterns of sub-daily gauges to inform model outputs. Where available, RADAR data was also used to validate rainfall patterns.

BG&E led a community consultation program that included:

- Distribution of newsletters and questionnaires.
- A presentation to the Progress Association and community members.
- Development and hosting of dedicated websites for each flood study.
- An online platform for the community to provide recollections of flooding and perceived priority areas for flood mitigation.

The outcomes of the flood studies considered the flood risk to people, considering potential isolation of the populations, and managing future development. High risk areas were mapped by defining the floodways, and an assessment of appropriate freeboard was also undertaken. An assessment of road crossing, frequency, and duration of flooding and alternative routes was undertaken to inform the NSW SES and Council and allow for improved flood response.

Urbenville & Woodenbong Flood Study — Urbenville & Woodenbong, NSW, Australia.

Parramatta Square

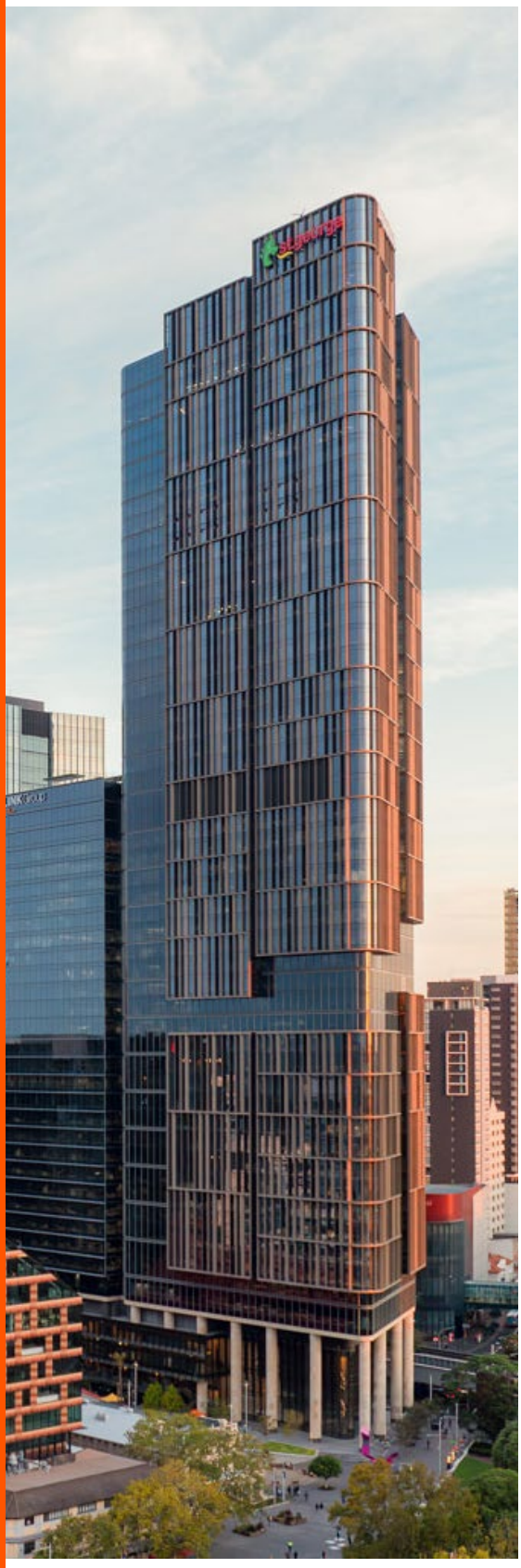
URBAN DEVELOPMENT | MIXED-USE | EVACUATION PLANNING

PARRAMATTA, NSW, AUSTRALIA
CLIENT: WALKER CORPORATION

BG&E provided civil, flooding and drainage, and structural engineering services for Parramatta Square, a project of significant scale and importance to the community. Located in the heart of the city, this development has firmly established Paramatta as a modern destination and one of Greater Sydney's three CBDs.

Parramatta Square is a three hectare mixed-use precinct developed by Walker Corporation, constructed in six stages and accommodating a mix of commercial, education and retail developments. 3PS, 4PS, and 6PS/8PS are Class A commercial office towers with a 5 Star rating, directly adjacent to the Parramatta Train Station and the main western train line.

BG&E undertook a detailed flood assessment of the site to consider local overland and mainstream flooding from the Parramatta River and identify risks and flooding management measures.



Parramatta Square — Parramatta, NSW, Australia.

Our Flooding and Hydrology specialists:

- Developed a 2D hydraulic model (Tuflow) for the entire Parramatta CBD to understand the local overland flood and to provide the best flood protection measures. Innovative approaches such as considering wind-driven rainfall on tall buildings and worst-case scenarios such as blocked stormwater drainage networks were investigated.
- Developed scenarios to determine the new building floor levels, basement carpark entries, and the redeveloped pedestrian walkway entry to the Parramatta Train Station. The results were used to inform automatic and manual flood barrier and flood door designs to provide the most effective flood mitigation strategies.
- Prepared flood maps and reports, working with the architects and project design team to determine the flood planning levels throughout the site based on the design criteria provided by the City of Parramatta Council.
- Diverting large trunk stormwater drainage infrastructure through the site to accommodate the development of the site.

One of the key challenges was minimising water egress into the buildings, in particular the connected basement areas, during a Probable Maximum Flood. This was achieved by raising thresholds to the basement access as high as reasonably practicable and providing automatic flood barriers up to the Probable Maximum Flood level.

An Evacuation Plan was developed, including a shelter-in-place approach during flooding. BG&E collaborated with the developers and the City of Parramatta Council to reach agreeable solutions and minimise risk to occupants of the buildings.

Paraburdoo Hospital Development

URBAN DEVELOPMENT | HEALTH | RISK MANAGEMENT

PARABURDOO, WA, AUSTRALIA
CLIENT: DEPARTMENT OF FINANCE

BG&E undertook a detailed flood assessment including hydraulic modelling, as well as civil and structural engineering services, to inform the design of the new facility.

The existing 50 year old Paraburdoo Hospital no longer meets modern standards in terms of space, functionality, and service delivery. This prompted the Department of Finance to replace it with a new facility designed to meet contemporary clinical service requirements and support the long-term health and well-being needs of the community.

The flood risk assessment involved a combination of rainfall-runoff modelling and direct rainfall modelling to estimate design flows under the current climate and future climate scenarios.

Two-dimensional hydraulic modelling was carried out for the existing and design scenarios to understand flood risk for the proposed development and ensure any potential adverse impacts to existing flood behaviour were mitigated.

Flood risk at the Paraburdoo Hospital site needed to be considered from the following sources:

- Bellary Creek — a major waterway to the north of Paraburdoo with a contributing area of 1,016 square kilometres.
- Bellary Creek tributary — a smaller waterway to the south of Paraburdoo, which has a contributing area of 34 square kilometres.
- Local catchment flooding — overland flow from within the Paraburdoo townsite, primarily extending to the north-east of the hospital site, with an estimated contributing area of 0.9 square kilometres.

Tom Price Hospital Development

URBAN DEVELOPMENT | HEALTH | RISK MANAGEMENT

TOM PRICE, WA, AUSTRALIA
CLIENT: DEPARTMENT OF FINANCE

BG&E was engaged by the Department of Finance to undertake a detailed flood assessment to inform the forward works package associated with the proposed Tom Price Health Service Redevelopment. The forward works package involves bulk earthworks associated with the building pad, access roads, and flood mitigation works.

The existing Tom Price Hospital, built in the late 1960s, does not meet the guidelines in terms of space and optimal functional arrangements. The Department of Finance decided to replace the facility with a new one to meet the clinical service delivery standards. The new facility aims at developing an asset that meets the health and related needs of the community in the long term.

A detailed hydrology assessment and two-dimensional hydraulic modelling were carried out to estimate flood behaviour for the existing site, which is located on land subject to flooding.

BG&E led several workshops with the design team to communicate flood risk, determine suitable flood immunity criteria for the hospital, and understand the implications of recently updated guidance relating to climate change.

Several mitigation measures were considered to achieve the flood immunity criteria, with an in-situ concrete retaining levee being the preferred option. BG&E carried out a flood impact assessment and a levee breach assessment to inform the flood hazard workshop.

Fortitude Valley Secondary College

URBAN DEVELOPMENT | EDUCATION | DETAILED DESIGN

BRISBANE, QLD, AUSTRALIA
CLIENT: QLD DEPARTMENT OF EDUCATION

BG&E provided comprehensive flooding and hydrology, civil, structural and traffic engineering services to Fortitude Valley State Secondary College — the first school to open in Brisbane's inner city in over 50 years.

The early works, valued at $81 million, facilitated the integration of flood modelling with civil and structural designs, ensuring a seamless approach to the project. Constructed by Hutchinson Builders, the project was completed ahead of the initial schedule, showcasing exceptional project management and execution.

Located in a flood prone area, a detailed understanding of flood behavior was key to suitably managing flood risk for the school.

BG&E's Flooding and Hydrology team undertook flood modelling to confirm that the design met relevant flooding criteria and was feasible for construction.

To manage flood risk to the school, as well as minimise flood level impacts to the adjoining rail corridor, our Flooding and Hydrology specialists worked with the design team to devise a floodable under-croft area to minimise loss of flood storage. A diversion channel was created to concentrate high-hazard overland flows away from the school building.

To provide further compensation for the loss of flood storage on the site, a below ground tank was sized and placed under the school playing fields. The tank was designed with a pump system to empty the stormwater network once flooding in the area had subsided.

At BG&E, we are united by a common purpose — we believe that truly great engineering takes curiosity, bravery and trust, and is the key to creating extraordinary built environments.

Our team of more than 800 highly skilled people, in offices across Australia, New Zealand, Singapore, the United Kingdom and Middle East, design and deliver engineering solutions for clients in the Property, Transport, Ports and Marine, Water, Defence, Energy and Resources sectors.

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