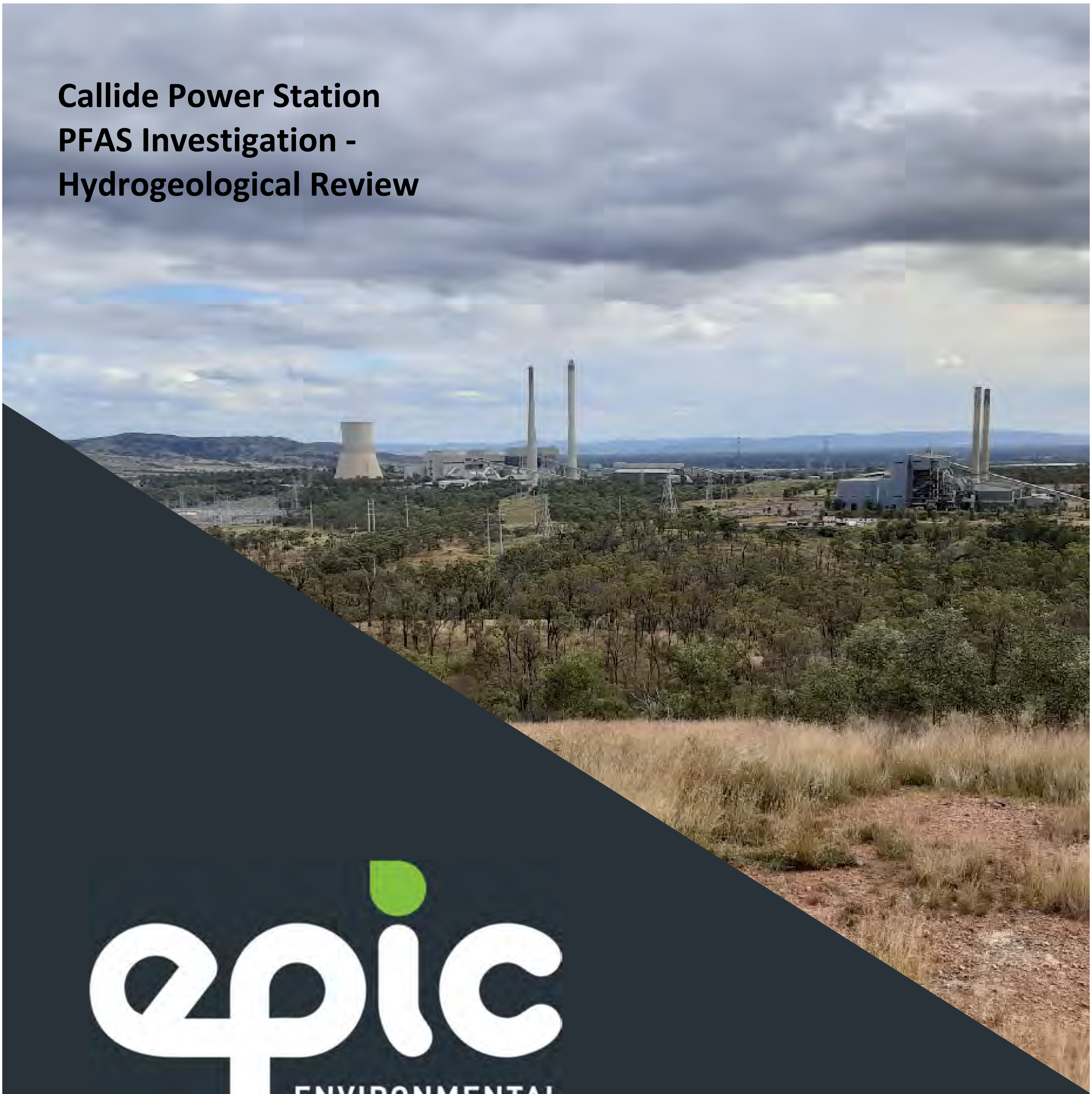
Callide Power Station PFAS Investigation - Hydrogeological Review



ENVIRONMENTAL

CS Energy Limited
PFAS Investigation - Hydrogeological Review
Callide Power Station
BC200153.04
4 April 2022

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DOCUMENT CONTROL

Revision	Revision date	Revision details	Author	Editorial review	Technical review	Approver
A	18/03/2022	Draft for Client Review	LA	DH	DH	LA
B	30/03/2022	Draft for Client Review	LA	DH	DH	LA
0	4/04/2022	Final for Issue	LA	DH	DH	LA

DISTRIBUTION

Revision	Revision date	Issued to
A	18/03/2022	CS Energy
B	30/03/2022	CS Energy
0	4/04/2022	CS Energy

DOCUMENT INFORMATION

Printed:	5 April 2022
Last saved:	5 April 2022 01:07 PM
File name:	BC200153.04-rpt-Callide_Hydro_Review-4Apr22_Rev0
Author:	Luke Amies
Project manager:	Luke Amies
Client:	CS Energy Limited
Document title:	Callide Power Station PFAS Investigation - Hydrogeological Review
Project number:	BC200153.04

EXECUTIVE SUMMARY

In order to assess PFAS migration at the Callide Power Station site, and in areas downstream, a hydrogeological review has been completed utilising results from onsite and offsite investigations completed up to December 2021. Hydrogeological reviews have been completed by Environmental Management Strategies (onsite hydrogeological review[1]) and RDM Hydro (offsite hydrogeological review[2]). This report provides a summary of the findings of the two hydrogeological reviews completed, and presents an updated conceptual site model (CSM) which incorporates key findings and information from the reports.

The primary objective of the hydrogeological review was to undertake a detailed review of the onsite (EMS 2022) and offsite (RDM Hydro 2022) technical reports to inform updates to the current CSM and provide a concise conceptualisation of PFAS migration at the site (Callide Power Station), and in areas downstream of the site.

Based upon the findings of the hydrogeological review and PFAS investigations completed to date, the conceptual site model has been reviewed, with a summary of key CSM aspects relating to this hydrogeological investigation summarised in **Table 1**, and presented in **Figure 5** and **Figure 6** (refer **Section 3**).

Table 1. Conceptual Site Model Summary

CSM Aspect	Details
PFAS Sources	The two main sources of PFAS identified include: • Areas of historical AFFF use at Callide B and C Stations (including fuel oil tanks and fire training ground) • Surface water flows from the area of the mine located upgradient (north) of the site It is estimated that <1,000 L of AFFF concentrate has historically been used at Callide B and C Stations, with approximately 300 L of this volume (estimated PFAS mass of 16.2 kg) used in training activities, system tests and use/maintenance of extinguishers that may have resulted in the release of PFAS at the site. The remaining volume of AFFF was either captured and disposed offsite or passed though the power station boilers resulting in the likely destruction of PFAS compounds. The residual mass of PFAS at the fire training ground and fuel oil tanks at Callide B and C Stations is estimated to be approximately 4.8 kg (Epic 2022). Additional PFAS mass may be present at remaining onsite source areas, however the majority of AFFF releases occurred at these two locations, with mass at remaining source areas likely to be minor. Surface water entering the northern (upgradient) site boundary from the area of the mine, located north of the site was reported to contain elevated concentrations of PFAS, with concentrations of total PFAS reported up to 6.62 µg/L during sampling events completed on behalf of CS Energy between March 2021 and January 2022. The mass flux of PFAS from areas upgradient of the site is currently unknown. An Environmental Evaluation issued to Batchfire the operator of Callide Mine, located north of the site reports that approximately 7,122 L of AFFF was used at the mine between 2009 and 2015. PFAS has been detected in surface water at Callide A, however AFFF use is understood to have been limited to fire extinguishers, with fire deluge systems utilising water sprinklers. Available information indicates Callide A is likely to be a minor source of PFAS (compared to Callide B and C Stations and other offsite sources).

[1] Environmental Management Strategies (EMS 2022). Conceptual Site Model for PFAS Migration – Callide PS, February 2022. Final Rev 2.
[2] RDM Hydro (RDM Hydro 2022). Callide Power Station PFAS Investigations – Offsite Hydrogeological Conceptualisation, 8 March 2022. Final.

Migration Pathways – Callide B and C	The primary onsite pathways for migration of PFAS at Callide B and C is via surface water flows through onsite drainage and overland flow to the Drains Reclaim Dam (DRD) and ultimately to Ash Dam B (EMS 2022). Once within Ash Dam B, pathways for PFAS migration include: • Circulation within Ash Dam B via movement of surface water and operational water uses (i.e. dust suppression, ash watering) • Adsorb to ash, sediments and soils within Ash Dam B • Infiltration to groundwater and discharge via deep seepage (approximately 75% recovered and returned to Ash Dam B) • Discharge via shallow seepage (collected as surface water and returned to Ash Dam B) • Licenced stormwater discharges (occasional) The estimates of deeper seepage recovered and fugitive seepage from Ash Dam B to Callide Creek are 558 m^3/day and 188 m^3/day respectively (EMS 2022), equating to successful recovery of approximately 75% of deeper seepage. It is estimated that the mass of PFAS within water contained within Ash Dam B is between 0.15 kg to 0.6 kg, with the mass of PFAS in fugitive seepage (not recovered) currently estimated to be approximately 0.01 kg per year (EMS 2022). Surface water entering the site from the direction of the mine, located upgradient (north) of the site was reported to contain elevated concentrations of PFAS. Upgradient water is diverted around the northern and western boundaries of Ash Dam B via the Western Stormwater Diversion Channel. During large rainfall events, surface water diverted around the site will discharge directly to Callide Creek, with some water retained within the diversion channel. During smaller rainfall events, surface water may be retained within the diversion channel. Water retained within the diversion channel in the southwestern corner of the site is anticipated to infiltrate to groundwater through alluvial soils and eventually the Callide Creek alluvium (EMS 2022). A generalised CSM for Callide B and C is presented as **Figure 6** (refer **Section 3**).
Migration Pathways – Callide A	The primary onsite pathways for migration of PFAS at Callide A is via surface water flows which are directed to the eastern and northern stormwater ponds (located adjacent to Ash Dam 2 catchment). Release of water is authorised under CS Energy's Environmental Authority at Release Point R2, located at the toe of Ash Dam 2. Releases discharge directly into Dunn Creek. PFAS has been detected in surface water within the eastern and northern stormwater ponds (up to 0.0130 µg/L and 0.0561 µg/L total PFAS respectively), along with water at release point R2 (0.0053 – 0.2020 µg/L total PFAS). Surface water from areas upgradient (north) of Callide A are directed to a mine dam (Dunn Creek Dam) located adjacent to the north-eastern corner of the site. Dunn Creek Dam is an authorised mine affected water release location (Environmental authority EPML00720413 Callide Coal Mine). Concentrations of PFAS in Dunn Creek (upstream of Callide A) reported concentrations of total PFAS up to 0.244 µg/L. A generalised CSM for Callide A is presented as **Figure 5** (refer **Section 3**).
Migration Pathways – Offsite (Surface Water)	Offsite migration of PFAS via surface water flow is considered to occur as follows: • Regional surface water flows (including from Callide Power Station and southern portions of the mine) drain towards Callide Creek • Surface water within Callide Creek flows from east to west. When the aquifer is comparable to the level of Callide Creek (water level high), water will continue as surface water to downstream catchments (bypass flow). When the aquifer is below the level of Callide Creek, surface water will infiltrate into the aquifer • Callide Creek is generally considered to be losing (surface water infiltrating to groundwater), however in some sections groundwater may discharge to surface water when the underlying aquifer is full (gaining)

	The current and historical mass and flux of PFAS in surface water is considered to be highly variable, and influenced by release of PFAS from source areas (historical releases higher than current releases), rainfall within the catchment, water released from Callide Dam and the condition of the underlying aquifer. Key PFAS migration pathways for surface water are presented on **Figure 7** (refer **Section 3**).
Migration Pathways – Offsite (Groundwater)	Within the Callide Creek alluvium, concentrations of PFAS are variable, but present throughout the entire alluvium. Water movement within the Callide Creek Alluvium occurs at an estimated rate of 4.2 m/day, with water moving from east to west and expanding with the aquifer. Since the commissioning of Callide B Power Station, groundwater may have moved up to 17 km down the Callide Valley. Migration of PFAS is considered to mirror water movement, however migration of PFAS will occur at a slower rate. A number of mechanisms are considered to have influenced the current distribution of PFAS within the aquifer. These include: • Current and historical releases of PFAS from Callide Power Station and other potential PFAS sources. It is noted that the mass of PFAS entering the alluvium is considered to be lower than historically, and will continue to decrease with time following cessation of AFFF use • Recharging of the aquifer by surface water is likely to dilute PFAS within central areas of the alluvium (along the alignment of Callide Creek). The higher concentrations along the northern and southern margins of the aquifer are considered to represent the longer-term background concentrations prior to the commencement of surface water releases from Callide Dam which commenced in 2010 The current mass of PFAS within the Callide Creek Alluvium (between Callide Power Station and Jambin-Dakenba Road) is estimated to be 6.8 kg. Key PFAS migration pathways for surface water are presented on **Figure 8** (refer **Section 3**).
PFAS Mass Balance	Based on the findings of investigations completed to date, approximately 53% (8.65 kg) to 75% (12.2 kg) of the total mass of PFAS (16.2 kg) estimated to have been released at the Callide Power Station site has been accounted for as follows: • Soils and concrete at the fire training ground and fuel oil tanks – 4.8 kg • Water within Ash Dam B (including recovered seepage) – 0.15 kg to 0.6 kg • Callide Creek alluvial aquifer – 3.7 kg to 6.8 kg The estimate represents the current 2020/21 PFAS mass in groundwater storage and doesn't provide an estimate of mass that has passed outside the investigation area (i.e. beyond Jambin-Dakenba Rd) or has been extracted from groundwater. The estimate also excludes contribution of PFAS from other source sites.

Receptors	Identified human health and ecological receptors include: • Human health including: - Extraction and use of groundwater from the Callide Creek alluvium for irrigation, farm supply, stock water and industrial use - Extraction and use of groundwater for human consumption (drinking water) ○ It is noted that where extraction and use of groundwater has been identified, alternate drinking water supply has been provided to affected landowners - Use of surface water from Callide Dam and groundwater as town water for Biloela ○ Concentrations of PFAS in Callide Dam and groundwater supply bores have been reported below the Drinking Water Criteria (refer **Sections 2.4.1** and **2.4.2**) - Exposure to surface water and groundwater (i.e. swimming, boating, showering, cooking) - Human consumption of stock, produce and aquatic biota which is watered by or sourced from PFAS impacted water - Ingestion, dermal contact and inhalation pathways for workers and visitors to the site associated with impacted media at the site (soil, sediment, surface water and groundwater) and the use of potentially impacted water for dust suppression and operational processes • The main exposure pathways associated with human health are considered to be ingestion, associated with primary surface water and groundwater pathways (including drinking water) and secondary pathways through the consumption of produce and biota (which is watered by or sourced from PFAS impacted water). Ingestion of impacted media and to a lesser extent dermal contact and inhalation pathways are considered to be limited • Aquatic Ecosystems of Callide Dam and Callide Creek - Potential impacts to aquatic ecosystems will be influenced by environmental factors including surface water inflows (rainfall and dam releases) and conditions in the underlying aquifer. Surface water inputs may result in increases or decreases of PFAS concentrations • Terrestrial ecosystems including potential terrestrial and wetland groundwater dependent ecosystems and terrestrial biota (including avian) - When full, aquifer water levels are maintained at the approximate level of Callide Creek

1 INTRODUCTION

CS Energy Limited (CS Energy) currently operate the Callide Power Station site, located approximately 9 km north-east of Biloela, Queensland. Following release of the Queensland Department of Environmental Sciences' (DES's) Operational Policy for the management of firefighting foam in 2016, CS Energy undertook a review of site operations and identified historical use of Per- and poly-fluoroalkyl substances (PFAS) which identified former storage and use of non-compliant and persistent Aqueous film forming foams (AFFF) at the site. Removal of all non-compliant AFFF commenced in late 2018, with all non-compliant AFFF removed from service and disposed to a licensed disposal facility in accordance with the requirements of DES's Operational Policy.

Following removal of non-compliant AFFF, CS Energy committed to DES to undertake a voluntary PFAS Environmental Investigation, to assess potential impacts associated with the former use of PFAS containing products at the site. Epic Environmental (Epic) was engaged by CS Energy as their Suitably Qualified Person (SQP) to undertake assessment of PFAS at Callide Power Station as part of the voluntary PFAS Environmental Investigation.

Initial investigations completed at the site in 2019 targeted existing onsite and offsite environmental monitoring locations, with the investigation expanded during 2020 and 2021 to include sampling of private groundwater supply wells up to 10 km downstream of the site. Results from monitoring completed to date have reported concentrations of PFOS + PFHxS above the Australian Drinking Water Guideline in groundwater and surface water at some locations downstream of the site.

In order to assess PFAS migration at the site, and in areas downstream, a hydrogeological review has been completed utilising results from onsite and offsite investigations completed up to December 2021. Hydrogeological reviews have been completed by Environmental Management Strategies (onsite hydrogeological review[3]) and RDM Hydro (offsite hydrogeological review[4]).

This report provides a summary of the findings of the two hydrogeological reviews completed, and presents an updated conceptual site model (CSM) which incorporates key findings and information from the reports.

1.1 Background

The hydrogeological review was completed based on site investigation and monitoring data completed up to December 2021. Analytical data has been sourced from PFAS soil and water investigations completed at the site between November 2020 and December 2021 (refer **Section 2.3.2** and **Section 2.4**) and supplemented with relevant environmental monitoring previously completed at the site, including the Callide Power Station Receiving Environment Monitoring Plan (REMP) and review of publicly available geological and hydrogeological information for the investigation area. Data was then assessed in the context of known and suspected PFAS sources to identify preferential migration pathways and establish linkages between these sources and PFAS results.

The hydrogeological review was completed as two separate but concurrent reviews for onsite and offsite areas, with a summary of each review presented in **Section 2.1** and **Section 2.2** respectively.

1.2 Objective

The primary objective of the hydrogeological review was to undertake a detailed review of the onsite (EMS 2022) and offsite (RDM Hydro 2022) technical reports to inform updates to the current CSM and provide a concise conceptualisation of PFAS migration at the site (Callide Power Station), and in areas downstream of the site.

Table 2 summarises key requirements of a CSM, and sections of this report which address these requirements.

[3] Environmental Management Strategies (EMS 2022). Conceptual Site Model for PFAS Migration – Callide PS, February 2022. Final Rev 2.
[4] RDM Hydro (RDM Hydro 2022). Callide Power Station PFAS Investigations – Offsite Hydrogeological Conceptualisation, 8 March 2022. Final.

Table 2. Summary of CSM Requirements

From NEPM 2013[5] Schedules B2 and B4

CSM Elements	Relevant Report Section/References
Source (S) Known and potential sources of contamination and contaminants of concern including: - mechanism(s) of contamination (e.g. 'top down' spill or sub-surface release from corroded tank or pipe) - typical and maximum concentrations - vertical and horizonal distribution - physical and chemical properties of the contaminants and their likely mobility in the environment	A summary of relevant information on PFAS sources is presented in **Table 5**, with additional information presented in **Sections 2.1.1, 2.2.2, 2.3.1, 2.3.2** and **2.3.3** and **Appendix A**. Detailed information on PFAS sources, including mechanisms, concentrations, known distribution and properties is presented in previous investigation reports (refer **Section 0**).
Pathway (P) Potentially affected media (soil, sediment, groundwater, surface water), including: - physical properties associated with the geology and hydrogeology - the potential presence of subsurface geology or structures that may act as a preferential pathway for migration of contamination	A summary of key migration pathways is presented in **Table 5**, with additional information presented in **Appendix A**.
Receptor (R) Human and ecological receptors including - the means by which exposure could occur - the duration of exposure	A summary of human and ecological receptors is presented in **Table 5**, with additional information presented in **Appendix A**.
S-P-R Linkages Potential and complete exposure pathways	Details on exposure pathways and linkages are presented in **Table 5** and **Appendix A**.

[5] National Environmental Protection Council (NEPC), 2013, National Environment Protection (Assessment of Site Contamination) Amendment Measure (NEPM) (No 1)

2 HYDROGEOLOGICAL REVIEW

A review of the hydrogeological conditions for the site and areas downstream of the site were completed as part of two independent investigations. Each review was completed utilising environmental monitoring data and information collected up to December 2021. A summary of these are provided in the sections below.

2.1 Onsite Hydrogeological Review (EMS)

A summary of the key onsite geo-environmental aspects governing the occurrence and movement of water at the site is presented in **Table 3.** A further discussion of each environmental aspect is provided in the following sections. The area included within the onsite hydrogeological review and key site features are presented on **Figure 1.**

Table 3. Onsite Environmental Conditions Summary

Information sourced from EMS (2022)

Geo-environmental Aspect	Key Findings (EMS, 2022)
Drainage	**Callide A:** Site drainage is collected within the northern and eastern stormwater ponds, with overflow from these ponds draining into the Callide A Wetlands, then to Dunn Creek. Prior to the construction of Callide B, blowdown water from Callide A would discharge down Suicide Gully into Callide Creek (beneath the current footprint of Ash Dam B). Current release of surface water and seepage from Callide A is permitted at EA Release Point R2, located at the decommissioned Ash Dam 2. **Callide B and C:** Site drainage is captured in the stormwater system which discharges to the Drains Reclaim Dam (DRD). Overflow from the DRD will discharge into Ash Dam B. Processing water and captured seepage is discharged into Ash Dam B. Surface water entering the site through the northern boundary is diverted around the site through the Western Stormwater Diversion Channel.
Geology	The site is underlain by the Youlambie Conglomerates (formally known as the Rainbow Creek Beds), the Biloela Formation and the Lochenbar Formation (formally known as the Kroombit Creek Beds) comprised predominantly of andesitic rocks. The Youlambie Conglomerate also underlays Callide A, which is then underlain by the Lochenbar Formation which extends under the current Callide B and C stations including Ash Dam B. The Youlambie Conglomerates, the Biloela Formation, and the Lochenbar Formation are all overlain by Tertiary sediments in the southwest portion of the site grading into the Quaternary alluvium floodplain clays, silts, sands and gravels associated with Callide Creek. The Lochenbar Formation is highly fractured beneath the site, with a potential fault running north-south in line with the Callide Dam spillway along the western boundary. Dioritic dykes, likely associated with the faulting have been found running co-linear with the suspected fault, with the width being more than 50m and have been noted as being deeply weathered (in excess of 22 m in MW27).
Aquifers	The principal aquifers identified onsite comprise: • Tertiary and Quaternary alluvial sediments • Weathered/fractured bedrock of the Lochenbar Formation under Callide A, B and C • The Youlambie Conglomerate under the northeast corner of Callide A. A former alluvial channel of Suicide Gully is suspected to be present at the southwestern portion of Ash Dam B, which will likely facilitate surface water infiltration in the area immediately southwest (down gradient) of the dam wall.
Surface Water Bodies	Onsite surface water bodies include: • Ash Dam B • Ash Dam 4 • The remaining evaporation ponds (progressively being filled in with ash)

	• The Western Stormwater Diversion Channel • The Western Seepage Collection Trench and Pond (WSCT and WSCP) • The Eastern Seepage Collection Trench and Pond (ESCT and ESCP) • The Drains Reclaim Dam (DRD)
Groundwater Flow	Groundwater flow across the site is typically consistent with topography, with groundwater generally flowing from the northeast boundary down to the southwestern boundary of the site. The hydraulic conductivities for various geological materials have been adopted based on previous investigation by Aurecon (2011): • Coal Ash: 0.0864 m/day • Tertiary sediments: 2.2 m/day • Fresh bedrock (bulk mass): 0.05 m/day • Fractured bedrock: 10.25 m/day
Groundwater Chemistry	Groundwater beneath the site is characterised by high salinity and chloride dominant. Seepage from the onsite evaporation ponds and Ash Dam B result in elevated sulfate in surrounding groundwaters with the sulfate to chloride ratio key in identifying seepage impacts.
Seepage Pathways	Historically seepage from the westernmost evaporation ponds discharged into the Western Stormwater Diversion Channel and Ash Dam B, however subsequent filling of the evaporation ponds with dense phase ash has significantly reduced this pathway. Shallow seepage has been reported along the western and southern boundaries of Ash Dam B, with seepage intercepted by the western and eastern seepage collection trenches. Deeper seepage has been observed in areas south (southern seepage), southeast (eastern seepage) and west (western seepage) of Ash Dam B, with a network of seepage recovery bores installed to intercept deeper seepage and return it to Ash Dam B. When fully operational, the seepage recovery groundwater bores installed within the bedrock aquifer result in radial drawdown of the water table reducing offsite groundwater migration locally. All shallow seepage is considered to be intercepted and recovered (i.e. 100% recapture) by the seepage collection trenches and returned to Ash Dam B. It is noted that shallow seepage has the potential to be released should the seepage collection ponds overflow (i.e. during significant rainfall events). Limited seepage has potentially occurred along the western boundary evidenced by the slightly elevated sulfate to chloride ratios in MW27 along the western site boundary, possibly indicating limited infiltration from the western seepage collection trench or Ash Dam B. A longer groundwater seepage pathway has also been identified southeast of the eastern seepage recovery area, with the inferred pathway connecting the area of ADB spillway with monitoring wells MW32 and MW43 and ultimately Callide Creek. This longer seepage pathway is estimated to be up to 600 m length and 300 m in width at the widest point. Based on monitoring data, groundwater velocity via this longer seepage pathway is estimated to be approximately 75 m/year, with water movement anticipated to take approximately 15.2 years to reach Callide Creek. The estimates of deeper seepage recovered and fugitive seepage to Callide Creek are 558 m^3/day and 188 m^3/day respectively, equating to successful recovery of approximately 75% of deeper seepage.

2.1.1 Onsite Distribution of PFAS

PFAS distribution onsite is primarily driven by surface water migration, with groundwater flow infiltration and migration of PFAS impacted waters (excluding seepage) likely having minimal impact on the PFAS concentrations. The highest PFAS concentrations within surface water onsite have been observed at SW34 along the northern site boundary (total PFAS 6.62 µg/L, 7 July 2021) . This surface water channel collects water from southern portions of the mine and areas north of the site before it enters the site. All waters from this pathway are diverted around the site within the Western Stormwater Diversion Channel which discharges directly into Callide Creek.

The Drains Reclaim Dam, collecting stormwater and process water from the site, has reported total PFAS concentrations ranging from 0.0286 to 0.151 µg/L, while the Eastern Dirty Drain reported concentrations of total PFAS of 0.0495 µg/L in August 2021. The PFAS concentrations within saturated ash (MW76), has reported concentrations of only PFBA, representing a different signature of PFAS relative to other groundwater bores onsite.

PFAS concentrations have been detected in areas surrounding the former evaporation ponds, including MW46, MW75, MW76 and MW77, with the lowest PFAS concentrations reported at MW75. The former borrow areas and the western seepage collection trench have reported the highest PFAS concentrations along the western margin, with groundwater reporting concentrations nearly an order of magnitude lower. This suggests that the collection of seepage along the western margin is effective, with minimal seepage passing mitigation measures. As such, PFAS distribution in this area is primarily driven by surface water migration. As surface waters drain towards the southwestern corner of the site, the seepage collection trench drains into the western seepage collection pond.

The southern end of the collection trench, the associated collection pond in addition to the southern end of the Western Stormwater Diversion Channel are located within the former alignment of Suicide Gully and the associated alluvium. This alluvium would enable the infiltration of surface waters into the water table, combining with the southern seepage coming from Ash Dam B. Groundwater bores within the vicinity of the Western Seepage Collection Pond have reported concentrations significantly higher than the western seepage collection trench in eight bores (0.22 to 3.77 µg/L for total PFAS). The concentrations of total PFAS in this area are also within the same order of magnitude as SW35 (with the exception of MW49), which is located at the outlet of the Western Stormwater Diversion Channel and within the former alluvial stream channel of Suicide Gully. Concentrations at SW35 have consistently reported higher concentrations of Total PFAS and a different composition (>86% PCA compounds) than those in Ash Dam B (>75.4% PSA compounds). The seepage recovery bores installed in 2014 have possibly been capturing PFAS impacted groundwaters and transferring it into Ash Dam B.

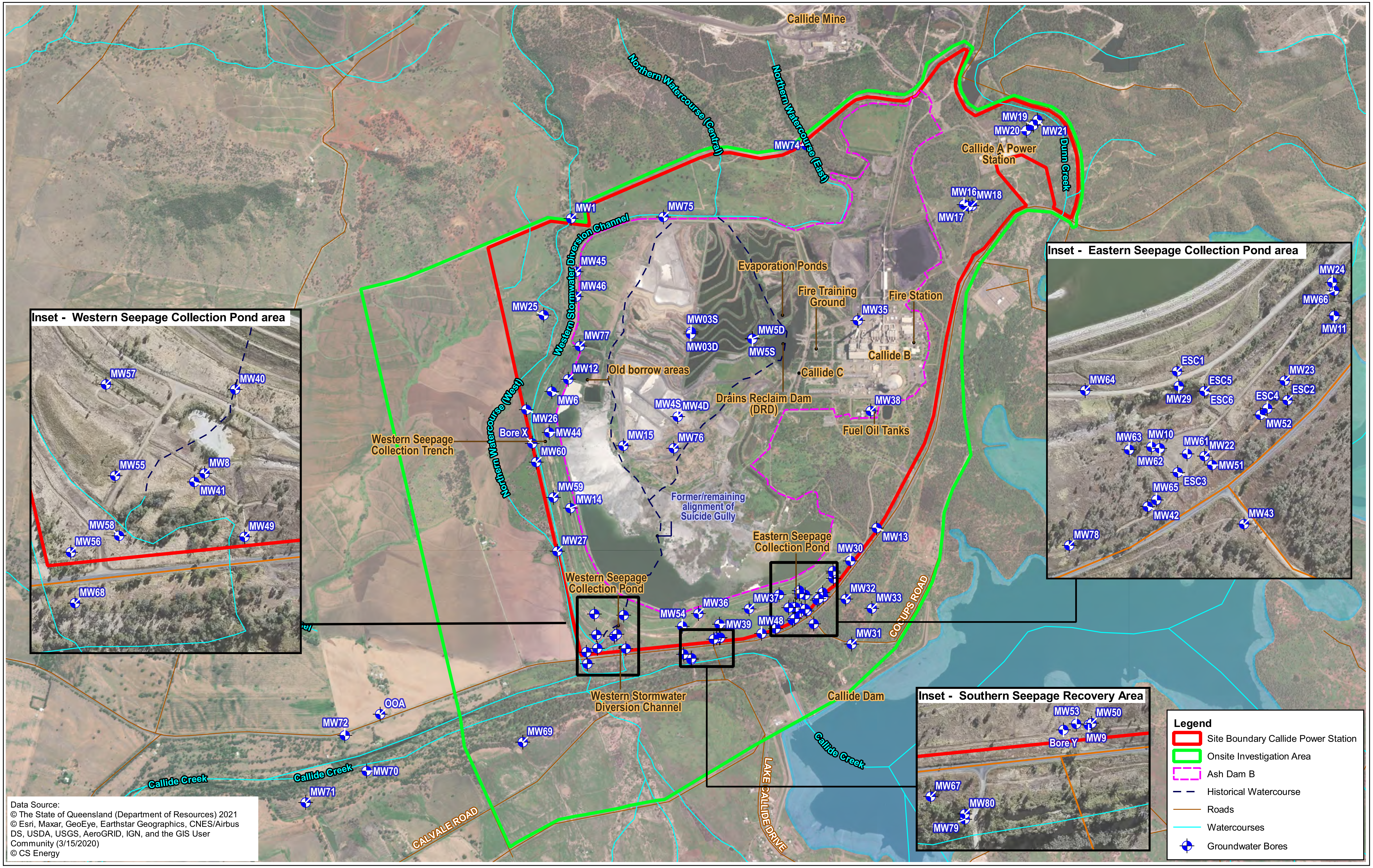
The higher concentrations in MW49 (relative to the surrounding groundwater bores) are likely influenced by the hydraulic conductivity, which is noted as being an order of magnitude slower relative to the surrounding bores. This could result in the localised accumulation of PFAS within the fractured rock over time from the infiltrating waters from the Western Seepage Collection Pond, Western Stormwater Diversion Channel in addition to the infiltration of licenced discharge waters from the Western Seepage Collection Pond.

The signature of PFAS compounds within MW40 and MW68 in close proximity to the western seepage collection pond may be the result of the diffusion of seepage from the Western Seepage Collection Pond or direct very slow seepage from Ash Dam B. However, as the signature reported concentrations of PFOS > PFHxS, this may be an indicator of historic PFAS impacts which may not be associated with the seepage from the Western Seepage Collection Pond, groundwater recovery and seepage from Ash Dam B. These impacts may be the result of historic Callide A blowdown water flowing in Suicide Gully, localised infiltration of PFAS from dust suppression of roads/tracks and/or localised firefighting operations.

Concentrations of PFAS in the eastern seepage recovery area were reported to be higher immediately southeast of the area (at monitoring wells MW43 and MW32) relative to the concentrations within the recovery area. This suggests that a potential migration pathway with elevated PFAS concentrations has historically existed, with the higher proportions of the more mobile PFHxS relative to PFOS indicating that the plume has been migrating potentially from Ash Dam B towards Callide Creek. This is consistent with the interpretation derived through the analysis of the sulfate to chloride ratios in monitoring wells. The flow time of PFAS to MW32 is estimated to be approximately 5 years, while PFAS travel times to MW43 and Callide Creek along the inferred migration pathway (Ash Dam B spillway → MW32 → MW43 → Callide Creek) are estimated at 9.0 and 15.2 years respectively. As such, it is possible that PFAS has not reached Callide Creek along this migration pathway, noting surface water results from SW12 and SW2 have reported relatively low concentrations of total PFAS compared to MW32 and MW43. Alternatively, concentrations of PFAS could be diluted by seepage from Callide Dam, with potential seepage from this pathway likely to have been diluted by release waters from Callide Dam during sustained releases which occurred between 2010 and 2020.

The southern seepage area reported concentrations of Total PFAS up to 0.114 µg/L, similar order of magnitude to the concentrations in Ash Dam B and the Eastern Seepage Recovery Area.

Immediately south of the site, total PFAS concentrations have been found to be higher in the overlying Callide Creek alluvium (0.0505 to 0.229 µg/L) in MW79 compared to the underlying bedrock aquifer (0.0218 to 0.0432 µg/L) in MW80. The surface waters immediately offsite at the base of the Callide Dam spill way (SW12) are mostly PSA (PFHxS dominant) with PCAs compounds detected only on three occasions in addition to no FSAs. PFOS has only been detected in surface water samples five times out of the eleven samples collected at these locations.



CS Energy
PFAS investigation (Callide Power Station)
Hydrogeological Summary Report

Figure F1
Onsite Investigation Area

BC200153.04 Rev 0 04/04/2022

2.2 Offsite Hydrogeological Review (RDM Hydro)

A summary of the offsite environmental conditions is presented in **Table 4.** Details relating to the findings of the review is detailed in the subsections below and are extracted from the report.

Table 4. Offsite Environmental Conditions Summary

Sourced from RMD Hydro (2022)

Environmental Aspect	Key Findings (RMD Hydro, 2022)
Drainage	The main watercourse within the study area is Callide Creek which commences at the base of Callide Dam, adjacent to the Callide Power Station site and continues in a westerly direction towards Biloela before trending north-west. Callide Creek joins with Kroombit Creek approximately 28 km downstream of the Callide Power Station site.
Geology	The geology within the study area was primarily Quaternary Alluvium associated with the Callide and Kroombit Creek Valleys, with Tertiary coalluvium at the margins of the valley. The alluvium is up to roughly 30 m thick and reaches a maximum width of 3.2 km upstream of Biloela and is comprised of silt, clay, sand and gravels. Alluvial deposits are underlain by the Lochenbar Formation. The extent of the alluvial aquifer was confirmed through the correlation of geological mapping and the radiometric imagery, which were found to be generally consistent.
Aquifers	There are two principal aquifers within the study area: • Tertiary and Quaternary alluvial sediments • Weathered/fractured bedrock of the Lochenbar Formation The alluvial aquifer composition is highly varied, however sands and gravels are found in a relatively continuous layer at the base of the alluvium to a maximum thickness of 12 m, with lower permeability sand, clay and silt mixtures above. The primary flow path is likely through the sandy gravel layer located at the base of the aquifer unit. Further details on the alluvial aquifer are presented in **Section 2.2.1.** The groundwater within the alluvial aquifer and the surface waters in the Callide Creek channel interact between each other. Surface water infiltrates into the aquifer when water levels are higher than the groundwater levels, while groundwater will discharge into the creek when groundwater levels are higher than the surface water levels. There is minimal information available on the bedrock aquifer, however available data indicates that groundwater levels within the bedrock have remained relatively stable over time. Groundwater gradients in the bedrock aquifer appear to generally follow the topography, with the levels suggesting that the bedrock groundwaters would discharge into the overlying alluvial aquifer when water levels are lower (in the overlying aquifer). The estimated flow velocities of the bedrock at the western site boundary are estimated to be between 0.02 m/day (unweathered) and 1.3 m/day (weathered).
Surface Water Bodies	Prominent surface water bodies within the study area and surrounding areas include: • Callide Dam • Callide Creek and associated weir • Kroombit Creek
Groundwater Flow	Groundwater typically flows east to west turning slightly northwest beyond Jambin-Dakenba Road (joining with alluvium along Kroombit Creek). The groundwater levels within the aquifer are observed to remain below ground level through the investigation area, indicating that the aquifer discharges at a lower elevation (outside the investigation area) and that groundwater flows down-valley towards this discharge point. The groundwater gradients area relatively consistent, despite variation in the topography, with groundwater flow estimated as 4.2 m/day in the Callide Creek alluvium and 1.8 m/day in the Callide Valley alluvium. Using these estimated flow rates, it would take approximately 7 years for groundwater to travel from the southwest of the Power Station

	to Jambin-Dakenba Road. Since the commissioning of Callide B Power Station, groundwater may have moved up to 17 km down the Callide Valley. Groundwater levels within the aquifer have fluctuated over time, with a difference of between 4.7 m to 10.8 m observed in individual groundwater wells between the 1950s and 2020. The effect of groundwater extraction (irrigation or domestic) is not evident in groundwater levels, suggesting that the aquifer is highly transmissive and hydraulically connected with surrounding aquifer lithologies and recharge by both rainfall and dam releases are equivalent to groundwater pumping. As such, any groundwater pumped out of the aquifer is quickly replaced by groundwaters from the surrounding aquifer. Groundwater bores installed within the alluvial aquifer in close proximity to the current creek channel show quick responses to water flow (including dam releases) within the creek relative to bores further away which show a subdued response. This indicates that there is a high degree of connectivity between the creek channel and the alluvial aquifer.
Groundwater Chemistry	Salinity within groundwater typically has an inverse relationship with groundwater levels (salinity decreases as water levels increase). Additionally, a notable spike in conductivities in groundwater was observed up to 500 m downstream following the commissioning of Ash Dam B, however no notable changes were noted in the general groundwater chemistry.
Summary of PFAS Pathways	The highest concentrations of total PFAS were identified on the margins of the alluvial aquifer. This is likely the result of long-term background concentrations prior to regular dam releases. The lowest concentrations of total PFAS were generally along the centre of the aquifer likely the result of dilution from infiltrating dam release waters.

2.2.1 Offsite Groundwater Aquifers

A geological model was produced for the subsurface distribution of lithologies. This model was constructed from a total of 805 groundwater bore logs, with 470 located directly within the study area. The developed model lithologies categorised as follows: topsoil, silt, clay (including silty clay), clay bound sands and gravel, clayey sands and gravels, sandy clay and sand/clay mixtures, sand (including silty sand) and sand and gravel. These lithological units are consistent with those previously employed by KBR (2004) for aquifer modelling. A fence diagram extracted from the model is presented in **Figure 3**, with geological cross-sections along the alignment of Muirs Road and the Dawson Highway presented in **Figure 4.** Due to quality of the input data, the overall reliability of the model is to be considered relatively low. However, the following conclusions were developed from the model with respect to the aquifer:

- Sands and gravels, which form a relatively continuous layer at the base of the aquifer, are likely to form the primary aquifer lithology and their higher permeability and conductivity would allow for higher groundwater production
- There appears to be a sandy sequence above the primary aquifer lithology upstream of Linkes Road that could provide a direct pathway for infiltration of rainfall/runoff into the aquifer
- The layer of sands and gravels extend upstream to the edge of the Callide Power Station and Ash Dam B, and thin to approximately 4 m along the alignment of Muirs Road. They were found to be the thickest upstream of the Dawson Highway (generally 8 to 10 m) and thinning again to 4 to 8 m downstream of the highway
  - There is a choke at the confluence of the Callide Creek alluvium and the Callide Valley alluvium, where the sands and gravels thin to less than 3 m in thickness
- Within the Callide Valley alluvium, the thickest aquifer appears to the east of the Burnett Highway, in the vicinity of the current Callide Creek Channel
- Upstream and downstream of Jambin-Dakenba Road, there is a very thin (less than 1 m) aquifer thickness between the Callide Creek channel where it flows up against the valley edge
- The top of the aquifer is at a maximum depth of 20 m below ground
- The top of the sands and gravels are deepest along the southern margin of the Callide Creek alluvium crossing to the northern side west of the Dawson Highway and then follows the current channel of Callide Creek
- The top of the aquifer is shallowest beneath Callide Creek, except for the Valley edge

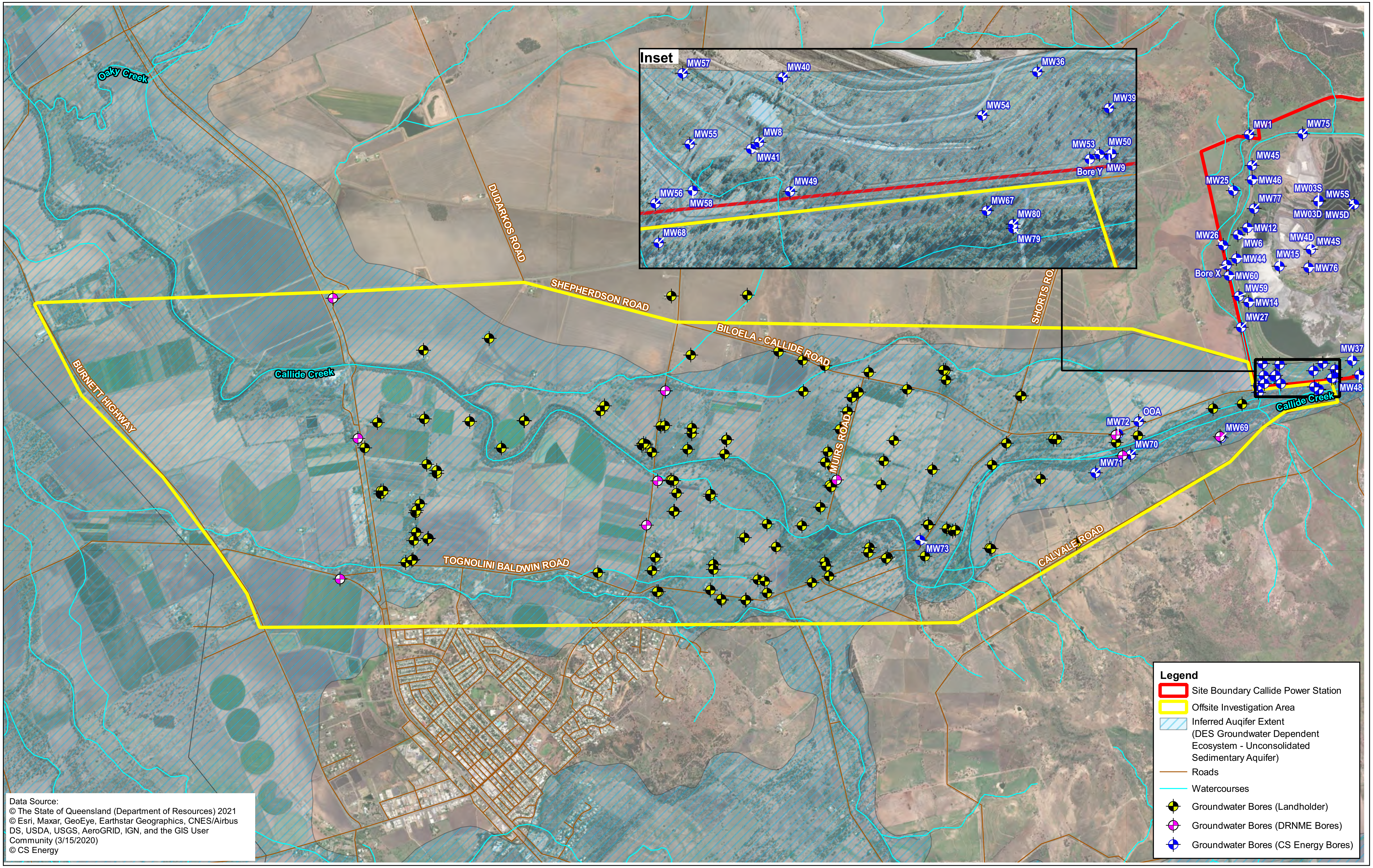
2.2.2 Offsite Distribution of PFAS

PFAS has been reported to be effectively ubiquitously present throughout the alluvial aquifer within the investigation area. Samples collected from groundwater monitoring wells installed within underlying bedrock did not report detectible concentrations of PFAS. PFAS within the alluvial aquifer is reported to be dominated by PSAs (including PFOS and PFHxS), with detections of PCA and FSA compounds generally limited to areas upstream of the Dawson Highway. Surface water in Callide Creek is reported to be dominated by PSAs.

Concentrations of PFAS in groundwater were observed to be greatest along the margins of the alluvium; in the south up to Linkes Road, and in the north to west of the Dawson Highway. Lowest concentrations were observed through the central portion of the alluvium to Muirs Road, then extending south to southwest towards Calvale Road. A low (south) to high (north) concentration gradient of PFAS is observed in the aquifer west of Linkes Road, with the trend observed along the alignments of Muirs Road and the Dawson Highway. Groundwater results reported a high degree of variability in terms of concentration and speciation, with limited trends observed in the data up to December 2021. An increasing trend was observed in groundwater monitoring wells located along the northern margin of the aquifer up to Muirs Road.

The current distribution of PFAS in the alluvial aquifer is considered to have been influenced by a number of mechanisms which include:

- Variability in the source of PFAS (concentrations/mass and composition) based on historical activities, products used and environmental influences. It is noted that the mass of PFAS entering the alluvium is considered to be lower than historically, and will continue to decrease with time
- Recharging of the aquifer by surface water is likely to dilute PFAS within central areas of the alluvium (along the alignment of Callide Creek). The higher concentrations along the northern and southern margins of the aquifer are considered to represent the longer-term background concentrations prior to the commencement of surface water releases from Callide Dam which commenced in 2010



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Scale: 1: 38,000@ A3

Datum: GDA94 Projection: MGA zone 56

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PFAS investigation (Callide Power Station)

Hydrogeological Summary Report

Figure F2

Offsite Investigation Area

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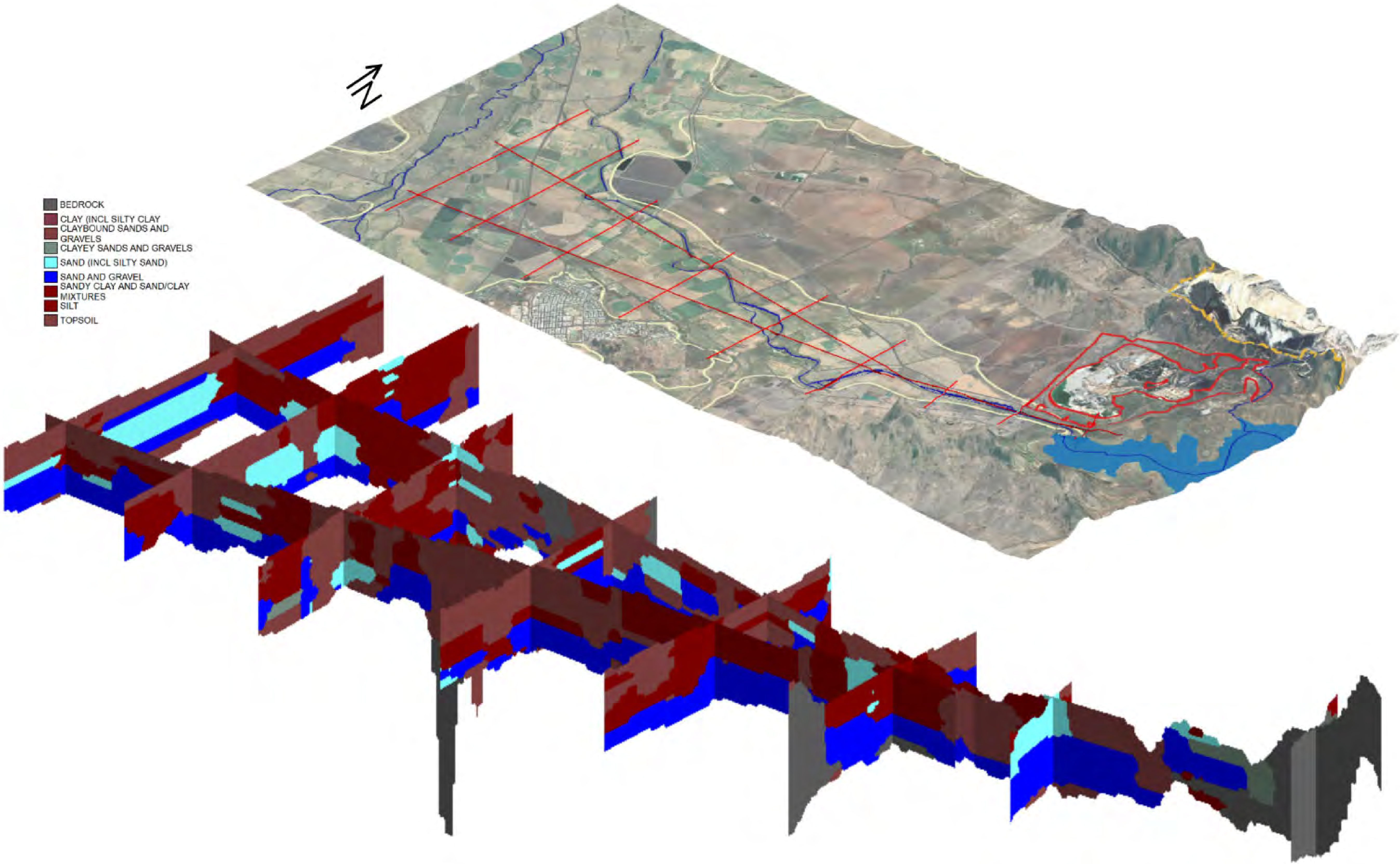
Figure 3. Geological Fence-Diagram of Callide Creek Alluvium (from RDM Hydro 2022)



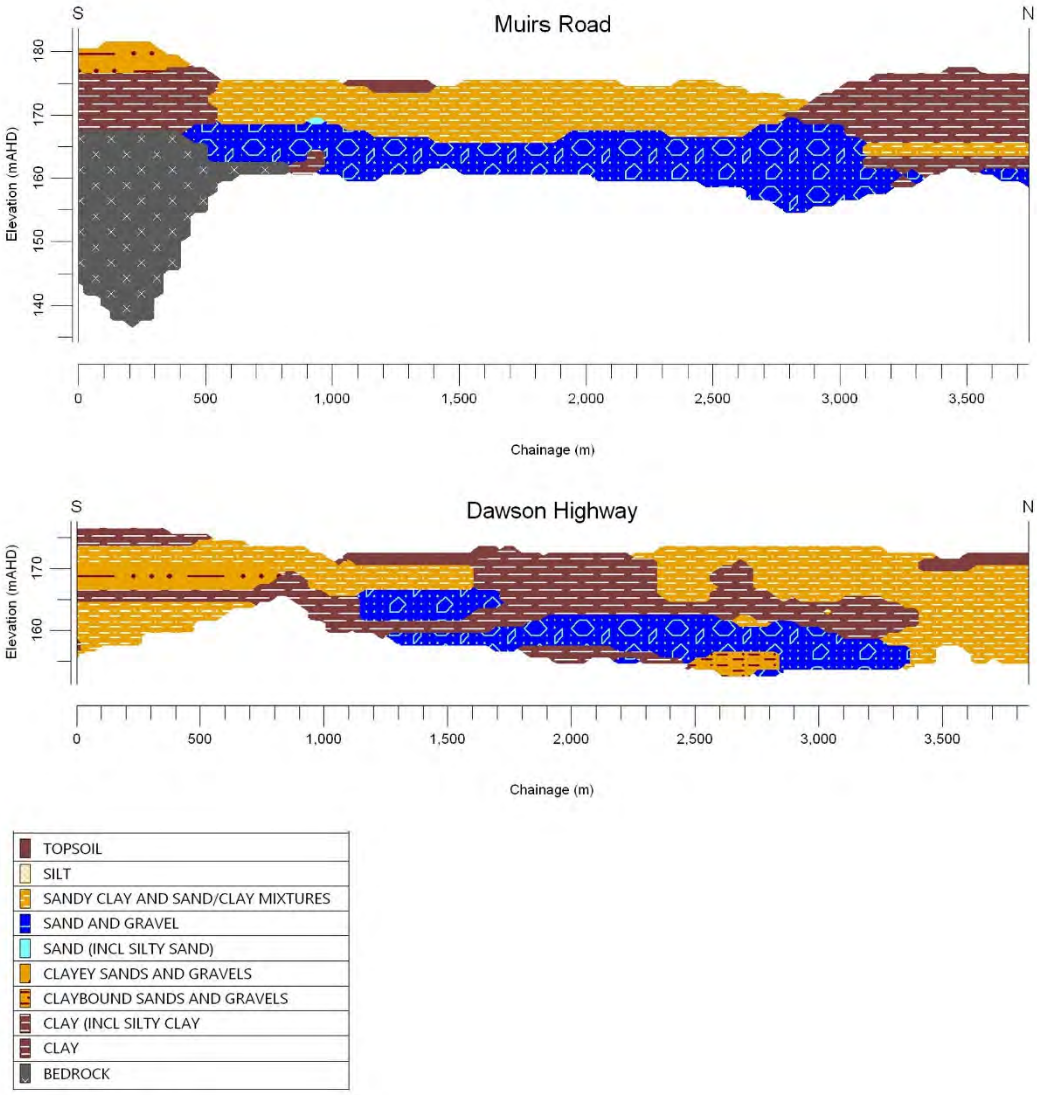


Figure 4. Geological Cross-sections[6] through Callide Creek Alluvium (from RDM Hydro 2022)

2.3 PFAS Investigations (Epic)

Investigations into potential PFAS sources have been completed by Epic Environmental to provide further clarity in the distribution of PFAS in addition to meeting regulatory obligations of CS Energy. The findings which are relevant to the hydrogeological conceptual site model are summarised in the sections below. Full details and results are available in each of the referenced reports.

2.3.1 Preliminary PFAS Environmental Investigation (Epic 2020)

A Preliminary PFAS Environmental Investigation (desktop based) was completed at the site to assess potential impacts associated with the historic use of PFAS containing products at the Callide Power Station site. This initial investigation identified a total of nine potential onsite primary source areas associated with Emergency

[6] Cross-sections shown at 25 times vertical exaggeration

Response Team training exercises and system tests (five areas), incident responses (three areas), and areas with limited information (one area). It was found that of the nine primary source areas, three were identified to have resulted in the release of AFFF to ground including the fire training ground, fuel oil tanks and Emergency Evacuation Area A.

Historical information available for the site identified that up to 300 L of AFFF concentrate (estimated PFAS mass of 16.2 kg) was used in training activities, system tests and use/maintenance of extinguishers. A further approximately 500 L of AFFF concentrate was reported to have been used in emergency response associated with coal fires at the Coal Plant, however the mass of PFAS was likely thermally destroyed as coal passed through the boiler.

In addition to the primary sources identified during the investigation, a number of potential secondary source areas were also identified. These secondary sources included onsite surface water bodies such as the Drains Reclaim Dam, ash dams and seepage recovery areas. This initial investigation identified that the most likely potential onsite pathway was the migration from primary and secondary source areas to offsite receptors including surface water (Callide Creek, Dunn Creek and Callide Dam) and fractured rock aquifers located beneath the site (connected to alluvial aquifers and surface water). These findings triggered the subsequent investigations into the potential sources and pathways (refer Epic 2021).

2.3.2 PFAS Environmental Investigations (Epic 2021)

Based on the findings of the Preliminary PFAS Environmental Investigation, an initial soil investigation was completed at the fire training grounds, fuel oil tanks and Emergency Evacuation Area A to confirm the presence of potential soil contamination at locations of known release of AFFF to ground. This investigation comprised the sampling of two locations at the fire training grounds to target the earthen stormwater drain draining the area, four locations at the fuel oil tanks to target adjacent areas of unsealed ground and four locations at Emergency Evacuation Area A.

Results reported concentrations of PFOS in soil above the NEMP ecological indirect exposure criteria of 0.01 mg/kg (PFOS + PFHxS) at the fire training grounds and fuel oil tanks, with the highest concentrations reported in sample BH01-0.4-0.4 (1.71 mg/kg PFOS + PFHxS) at the fuel oil tanks. Concentrations of PFAS in soils at the fire training grounds and fuel oil tanks were reported to be leachable at concentrations that may impact on ecological and human health receptors, with further investigation recommended to delineate the extent of PFAS contamination at these locations and assess potential impacts to surface water and groundwater receptors.

PFAS was detected in one of the four locations at Emergency Evacuation Area A, with concentrations of PFPeA (0.0014 mg/kg) reported above the laboratory's limit of reporting (0.0002 mg/kg) in sample BH06-0.0-0.1, with all samples from Evacuation Area A below the adopted assessment criteria. The findings of this investigation were used to design the soil investigation (refer Epic 2022).

2.3.3 Soil Investigation – Fire Training Ground and Fuel Oil Tanks (Epic 2022)

Following the findings of the PFAS Environmental Investigation (Epic, 2021), a targeted soil investigation was completed to delineate residual PFAS impacts reported at the fire training ground and fuel oil tanks.

A total of 51 locations were investigated at the fire training ground, with 15 of the 51 locations reporting concentration of PFOS above the ecological indirect exposure criteria of 0.01 mg/kg. Concentrations of PFOS were reported to be leachable in all soil samples analysed, with 28 of the 31 samples analysed leachable above the drinking water criteria of 0.07 µg/L. A total of approximately 800 m^3 of soil and concrete hardstand at the fire training ground was identified to have the potential to leach concentrations of PFAS which would result in exceedances of the NEMP Drinking Water criteria in surface water and groundwater. It is estimated that the residual mass of PFAS in soils at the fire training ground is approximately 0.3 kg, with an additional 0.1 kg of PFAS mass in concrete forming the fire training ground bund.

A total of 37 locations were investigated at the fuel oil tanks, with 25 of the 37 locations reported concentration of PFOS above the ecological indirect exposure criteria of 0.01 mg/kg. Concentrations of PFOS were reported to be leachable in all soil samples analysed, with 31 of the 33 samples analysed leachable above the drinking water criteria of 0.07 µg/L. A total of approximately 4,900 m^3 of soil at the fuel oil tanks was identified to have the potential to leach concentrations of PFAS which would result in exceedances of the NEMP Drinking Water criteria in surface water and groundwater. It is estimated that the residual mass of PFAS in soils at the fuel oil tanks is approximately 4.4 kg.

This information is currently being used to design a remediation program which will include the removal and/or immobilisation of residual PFAS impacts from each area.

2.3.4 Ongoing Investigations

As part of the PFAS assessment, CS Energy is currently completing a number of investigations which are currently in progress:

- **Landholder Sampling** – Sampling of private landholder bores commenced in 2021, with sampling completed at landholder properties within the investigation area located hydraulically downgradient of the site during 2021. The landholder sampling program included sampling of groundwater supply bores and locations of water use including kitchen taps, laundry taps, water tanks, stock troughs and surface waters used for recreation. Re-sampling of groundwater supply bores commenced in late 2021 and is currently ongoing.
- **Quarterly Technical Monitoring** – Quarterly monitoring is currently being completed at select groundwater and surface water locations across the site and within the study area to provide a temporal dataset to assess PFAS impacts including seasonal variation. Two quarterly monitoring events have been completed in October 2021 and January 2022. Additional quarterly monitoring events will be completed as part of the environmental evaluation (EE) scope detailed below.
- **DES Environmental Evaluation Notice** – A notice to conduct or commission an environmental evaluation (EE) was issued to CS Energy, on the 15 December 2021, with ongoing investigations and future investigations to be completed to address the requirements of the notice. This notice was issued to CS Energy in response to the findings of previous PFAS investigations described in the sections above. A sampling analysis and quality plan (SAQP) was submitted to DES on 28 February 2022, with sampling in accordance with the SAQP commencing prior to 7 March 2022.
- **Callide Dam Release Monitoring** – Monitoring of selected groundwater and surface water monitoring locations is being undertaken along Callide Creek to assess potential impacts associated with the release of water from Callide Dam. An initial sampling event was completed in May 2021 when Sunwater (the operator of Callide Dam) released a total of 245 ML of water from Callide Dam into Callide Creek between 19 May 2021 and 25 May 2021. Further release of water from Callide Dam commenced on 8 December 2021, with sampling completed between 9 to 16 December 2021. Release of surface water continued into January 2022, with sampling completed as part of the quarterly monitoring scopes of January 2022 and April 2022 to be used to inform conditions during and after the release event respectively.

Information collected during the ongoing investigations have been used (where applicable) in the assessment of the hydrogeological conditions within the study area. Anonymised landholder groundwater analytical results were utilised to generate the current understanding of PFAS distribution and impacts with finalised reports of each investigation due at the completion of the scopes.

2.4 Other Investigations

2.4.1 Sunwater Callide Dam Monitoring

Sunwater undertook sampling of surface water within Callide Dam during February 2021. A total of eight samples were collected from locations within and upstream of Callide Dam. All samples reported concentrations of PFAS below the laboratory's limit of detection for all analytes.

2.4.2 Banana Shire Council Monitoring

Banana Shire Council commenced monitoring of Biloela town water supply locations for PFAS in February 2021. Locations monitored include seven water supply bores (BIL05 to BIL11), the intake pipe from Callide Dam (BIL01) and the Biloela Town Pump (BIL13). Banana Shire Council have reported that all water supply locations have reported concentrations of PFAS below the Drinking Water Criteria.

2.4.3 Callide Coal Mine Environmental Evaluation

A notice to conduct or commission EE was issued to Batchfire Callide Pty Ltd and Batchfire Callide No. 2 Pty Ltd, the operators of Callide Coal Mine on 16 December 2021. The EE notice (STAT-E-100078550) reports that PFAS has been detected at the site, with the following information presented in the facts and circumstances section of the EE:

- Batchfire identified that between 2009 and 2015, approximately 7,122 litres of PFAS containing AFFF was used at Callide Coal Mine.
- Based on limited sampling at historical use of PFAS areas, in 2019 Batchfire removed 613.08 tonnes of PFAS contaminated soil from the former fire training area (FFTA).
- In April 2021, Batchfire conducted further onsite sampling, identifying that PFAS contamination remained at Callide Coal Mine.
- On 26 August 2021, Batchfire notified the department of preliminary PFAS sampling results for the Dunn Creek Mining Area, indicating varying levels of PFAS contamination in soil and sediment and surface water samples.
- On 13 September 2021, Batchfire provided a report which identified surface water and groundwater sample results with concentrations of PFOS exceeding PFAS NEMP freshwater values and PFAS NEMP drinking water values including:
  - Surface water sample taken at warehouse/workshop area
  - Groundwater sample taken north of the warehouse/workshop
- Dunn Creek Dam (within the Dunn Creek Mining Area), located approximately 880m south-east downgradient to FFTA (PFAS historical use area), is a valley-fill catch dam situated in the main channel of Dunn Creek and passively overflows to Callide Creek. Sample results submitted on 13 September 2021 for Dunn Creek Dam identified PFOS concentrations of 0.0176µg/L. However, the sample was dominated by PCAs (75%), which may indicate significant biotransformation has occurred from the original source (FFTA).
- PFAS contamination has been detected in a drainage channel, downstream and offsite to Callide Coal Mine's warehouse/workshop area through samples taken as part of a regional investigation into PFAS, including a sample taken on 7 July 2021 which reported a total PFAS concentration of 6.62 µg/L.

In accordance with the requirements of the EE, Batchfire are currently investigating the nature and extent of PFAS impacts to soil, groundwater, surface water and sediment at the Callide Mine site. Investigations are proposed to be completed through 2022 and 2023, with a final investigation report due on 28 July 2023.

3 CONCEPTUAL SITE MODEL

Based upon the findings of the hydrogeological review and PFAS investigations completed to date (refer **Section 2**), the conceptual site model has been reviewed, with a summary of key CSM aspects relating to this hydrogeological investigation summarised in **Table 5**, and presented in **Figure 5** and **Figure 6**. A detailed CSM has been included in **Appendix A** for reference.

Table 5. Conceptual Site Model Summary

CSM Aspect	Details
PFAS Sources	The two main sources of PFAS identified include: • Areas of historical AFFF use at Callide B and C Stations (including fuel oil tanks and fire training ground) • Surface water flows from the area of the mine located upgradient (north) of the site It is estimated that <1,000 L of AFFF concentrate has historically been used at Callide B and C Stations, with approximately 300 L of this volume (estimated PFAS mass of 16.2 kg) used in training activities, system tests and use/maintenance of extinguishers that may have resulted in the release of PFAS at the site. The remaining volume of AFFF was either captured and disposed offsite or passed though the power station boilers resulting in the likely destruction of PFAS compounds. The residual mass of PFAS at the fire training ground and fuel oil tanks at Callide B and C Stations is estimated to be approximately 4.8 kg (Epic 2022). Additional PFAS mass may be present at remaining primary source areas, however the majority of AFFF releases occurred at these locations, with mass at remaining source areas likely to be minor. Surface water entering the northern (upgradient) site boundary from the area of the mine, located north of the site was reported to contain elevated concentrations of PFAS, with concentrations of total PFAS reported up to 6.62 µg/L during sampling events completed on behalf of CS Energy between March 2021 and January 2022. The mass flux of PFAS from areas upgradient of the site is currently unknown. An Environmental Evaluation issued to Batchfire the operator of Callide Mine, located north of the site reports that approximately 7,122 L of AFFF was used at the mine between 2009 and 2015. PFAS has been detected in surface water at Callide A, however AFFF use is understood to have been limited to fire extinguishers, with fire deluge systems utilising water sprinklers. Available information indicates Callide A is likely to be a minor source of PFAS (compared to Callide B and C Stations and other offsite sources).
Migration Pathways – Callide B and C	The primary onsite pathways for migration of PFAS at Callide B and C is via surface water flows through onsite drainage and overland flow to the DRD and ultimately to Ash Dam B (EMS 2022). Once within Ash Dam B, pathways for PFAS migration include: • Circulation within Ash Dam B via movement of surface water and operational water uses (i.e. dust suppression, ash watering) • Adsorb to ash, sediments and soils within Ash Dam B • Infiltrate to groundwater and discharge via deep seepage (approximately 75% recovered and returned to Ash Dam B) • Discharge via shallow seepage (collected as surface water and returned to Ash Dam B) • Licenced stormwater discharges (occasional) The estimates of deeper seepage recovered and fugitive seepage from Ash Dam B to Callide Creek are 558 m^3/day and 188 m^3/day respectively (EMS 2022), equating to successful recovery of approximately 75% of deeper seepage. It is estimated that the mass of PFAS within water contained within Ash Dam B is between 0.15 kg to 0.6 kg, with the mass of PFAS in fugitive seepage (not recovered) currently estimated to be approximately 0.01 kg per year (EMS 2022). Surface water entering the site from the direction of the mine, located upgradient (north) of the site was reported to contain elevated concentrations of PFAS. Upgradient water is diverted around the northern and western boundaries of Ash Dam B via the Western

	Stormwater Diversion Channel. During large rainfall events, surface water diverted around the site will discharge directly to Callide Creek, with some water retained within the diversion channel. During smaller rainfall events, surface water may be retained within the diversion channel. Water retained within the diversion channel in the southwestern corner of the site is anticipated to infiltrate to groundwater through alluvial soils and eventually the Callide Creek alluvium (EMS 2022). **Figure 6** presents a generalised CSM for Callide B and C. A detailed CSM has been included in **Appendix A**.
Migration Pathways – Callide A	The primary onsite pathways for migration of PFAS at Callide A is via surface water flows which are directed to the eastern and northern stormwater ponds (located adjacent to Ash Dam 2 catchment). Release of water is authorised under CS Energy's Environmental Authority at Release Point R2, located at the toe of Ash Dam 2. Releases discharge directly into Dunn Creek. PFAS has been detected in surface water within the eastern and northern stormwater ponds (up to 0.0130 µg/L and 0.0561 µg/L total PFAS respectively), along with water at release point R2 (0.0053 – 0.2020 µg/L total PFAS). Surface water from areas upgradient (north) of Callide A are directed to a mine dam (Dunn Creek Dam) located adjacent to the north-eastern corner of the site. Dunn Creek Dam is an authorised mine affected water release location (Environmental authority EPML00720413 Callide Coal Mine). Concentrations of PFAS in Dunn Creek (upstream of Callide A) reported concentrations of total PFAS up to 0.244 µg/L. **Figure 5** presents a generalised CSM for Callide A. A detailed CSM has been included in **Appendix A**.
Migration Pathways – Offsite (Surface Water)	Offsite migration of PFAS via surface water flow is considered to occur as follows: • Regional surface water flows (including from Callide Power Station and southern portions of the mine) drain towards Callide Creek • Surface water within Callide Creek flows from east to west. When the aquifer is comparable to the level of Callide Creek (water level high), water will continue as surface water to downstream catchments (bypass flow). When the aquifer is below the level of Callide Creek, surface water will infiltrate into the aquifer • Callide Creek is generally considered to be losing (surface water infiltrating to groundwater), however in some sections groundwater may discharge to surface water when the underlying aquifer is full (gaining) The current and historical mass and flux of PFAS in surface water is considered to be highly variable, and influenced by release of PFAS from source areas (historical releases higher than current releases), rainfall within the catchment, water released from Callide Dam and the condition of the underlying aquifer. **Figure 7** summarises key PFAS migration pathways for surface water.
Migration Pathways – Offsite (Groundwater)	Within the Callide Creek alluvium, concentrations of PFAS are variable, but present throughout the entire alluvium. Water movement within the Callide Creek Alluvium occurs at a rate of 4.2 m/day, with water moving from east to west and expanding with the aquifer. Since the commissioning of Callide B Power Station, groundwater may have moved up to 17 km down the Callide Valley. Migration of PFAS is considered to mirror water movement, however migration of PFAS will occur at a slower rate. A number of mechanisms are considered to have influenced the current distribution of PFAS within the aquifer. These include: • Current and historical releases of PFAS from Callide Power Station, and other potential PFAS sources. It is noted that the mass of PFAS entering the alluvium is considered to be lower than historically, and will continue to decrease with time following cessation of AFFF use • Recharging of the aquifer by surface water is likely to dilute PFAS within central areas of the alluvium (along the alignment of Callide Creek). The higher concentrations along the northern and southern margins of the aquifer are considered to represent the longer-term background concentrations prior to the commencement of surface water releases from Callide Dam which commenced in 2010

	The current mass of PFAS within the Callide Creek Alluvium (between Callide Power Station and Jambin-Dakenba Road) is estimated to be 6.8 kg. **Figure 8** summarises key PFAS migration pathways for surface water.
PFAS Mass Balance	Based on the findings of investigations completed to date, approximately 53% (8.65 kg) to 75% (12.2 kg) of the total mass of PFAS (16.2 kg) estimated to have been released at the Callide Power Station site has been accounted for as follows: • Soils and concrete at the fire training ground and fuel oil tanks – 4.8 kg • Water within Ash Dam B (including recovered seepage) – 0.15 kg to 0.6 kg • Callide Creek alluvial aquifer – 3.7 kg to 6.8 kg The estimate represents the current 2020/21 PFAS mass in groundwater storage and doesn't provide an estimate of mass that has passed outside the investigation area (i.e. beyond Jambin-Dakenba Rd) or has been extracted from groundwater. The estimate also excludes contribution of PFAS from other source sites.

Receptors	Identified human health and ecological receptors include:
	• Human health including:
	  - Extraction and use of groundwater from the Callide Creek alluvium for irrigation, farm supply, stock water and industrial use
	  - Extraction and use of groundwater for human consumption (drinking water)
	    ○ It is noted that where extraction and use of groundwater has been identified, alternate drinking water supply has been provided to affected landowners
	  - Use of surface water from Callide Dam and groundwater as town water for Biloela
	    ○ Concentrations of PFAS in Callide Dam and groundwater supply bores have been reported below the Drinking Water Criteria (refer **Sections 2.4.1** and **2.4.2**)
	  - Exposure to surface water and groundwater (i.e. swimming, boating, showering, cooking)
	  - Human consumption of stock, produce and aquatic biota which is watered by or sourced from PFAS impacted water
	  - Ingestion, dermal contact and inhalation pathways for workers and visitors to the site associated with impacted media at the site (soil, sediment, surface water and groundwater) and the use of potentially impacted water for dust suppression and operational processes
	• The main exposure pathways associated with human health are considered to be ingestion, associated with primary surface water and groundwater pathways (including drinking water) and secondary pathways through the consumption of produce and biota (which is watered by or sourced from PFAS impacted water). Ingestion of impacted media and to a lesser extent dermal contact and inhalation pathways are considered to be limited
	• Aquatic Ecosystems of Callide Dam and Callide Creek
	  - Potential impacts to aquatic ecosystems will be influenced by environmental factors including surface water inflows (rainfall and dam releases) and conditions in the underlying aquifer. Surface water inputs may result in increases or decreases of PFAS concentrations
	• Terrestrial ecosystems including potential terrestrial and wetland groundwater dependent ecosystems and terrestrial biota (including avian)
	  - When full, aquifer water levels are maintained at the approximate level of Callide Creek

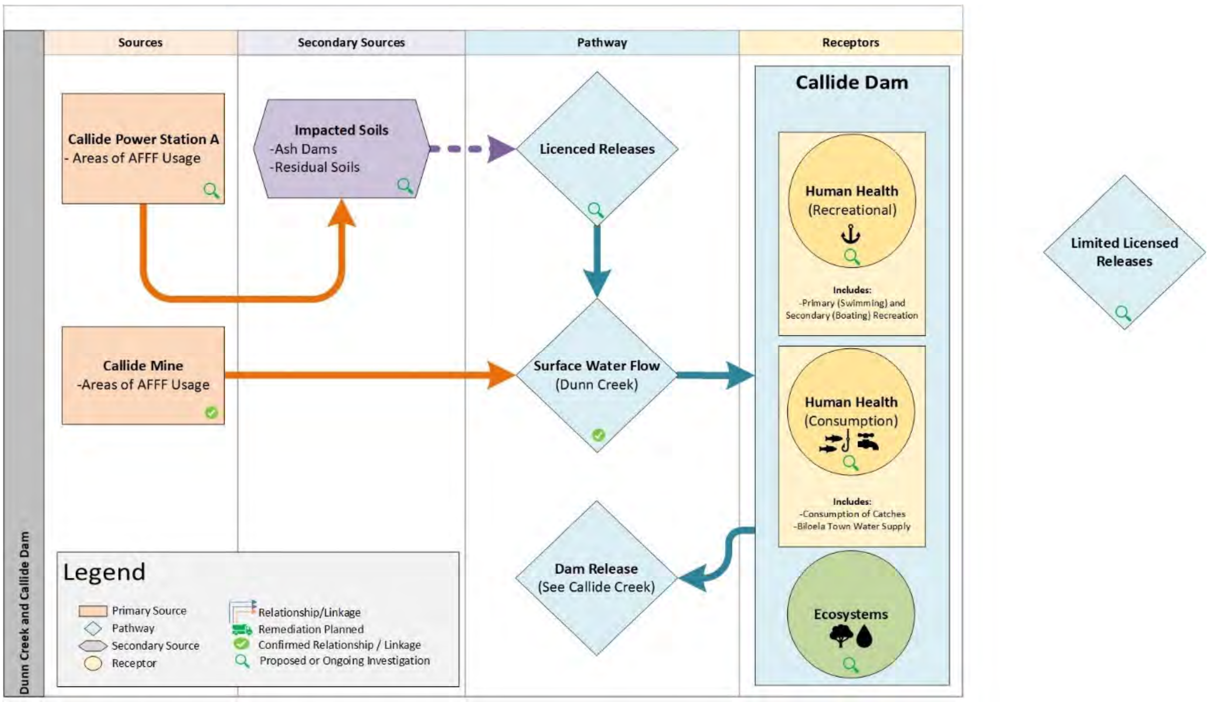


Figure 5. Conceptual Site Model Summary – Callide A

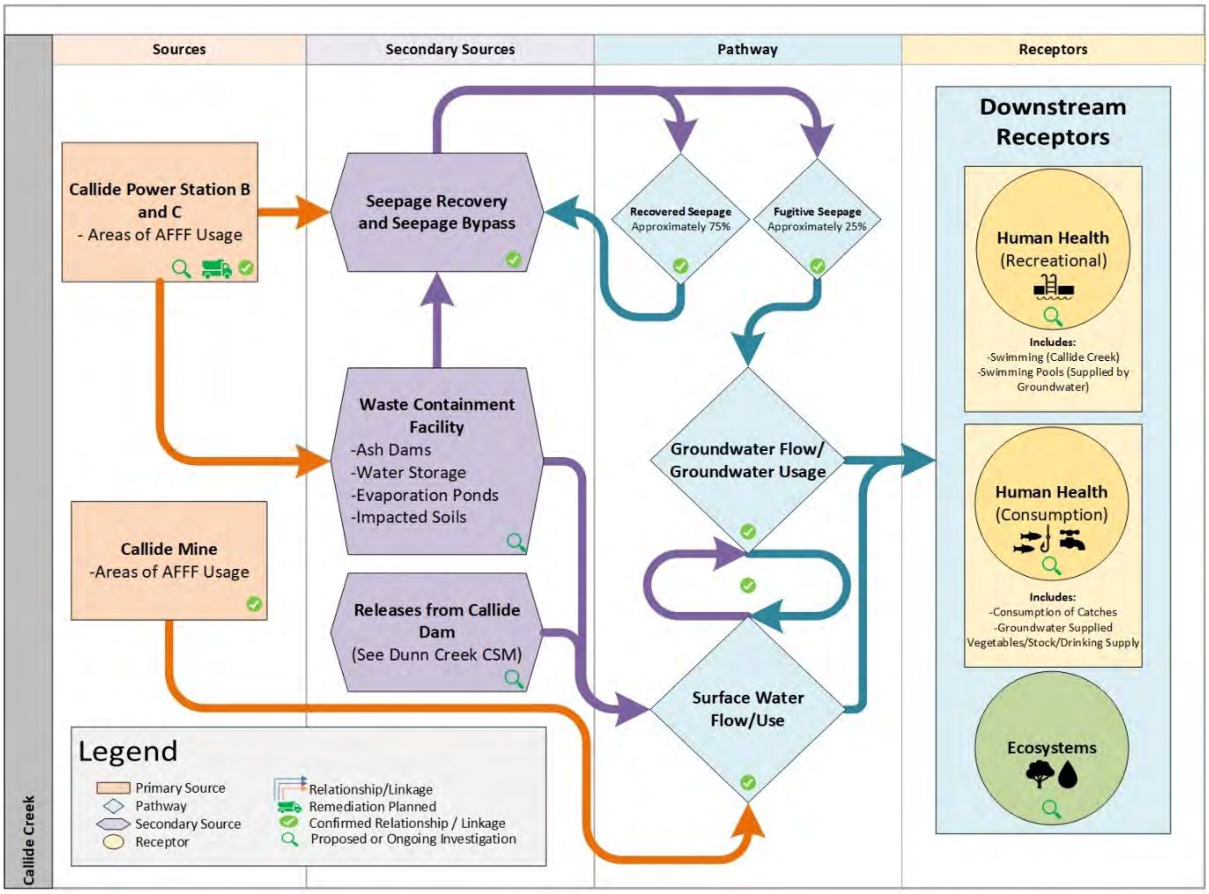


Figure 6. Conceptual Site Model Summary – Callide B and C

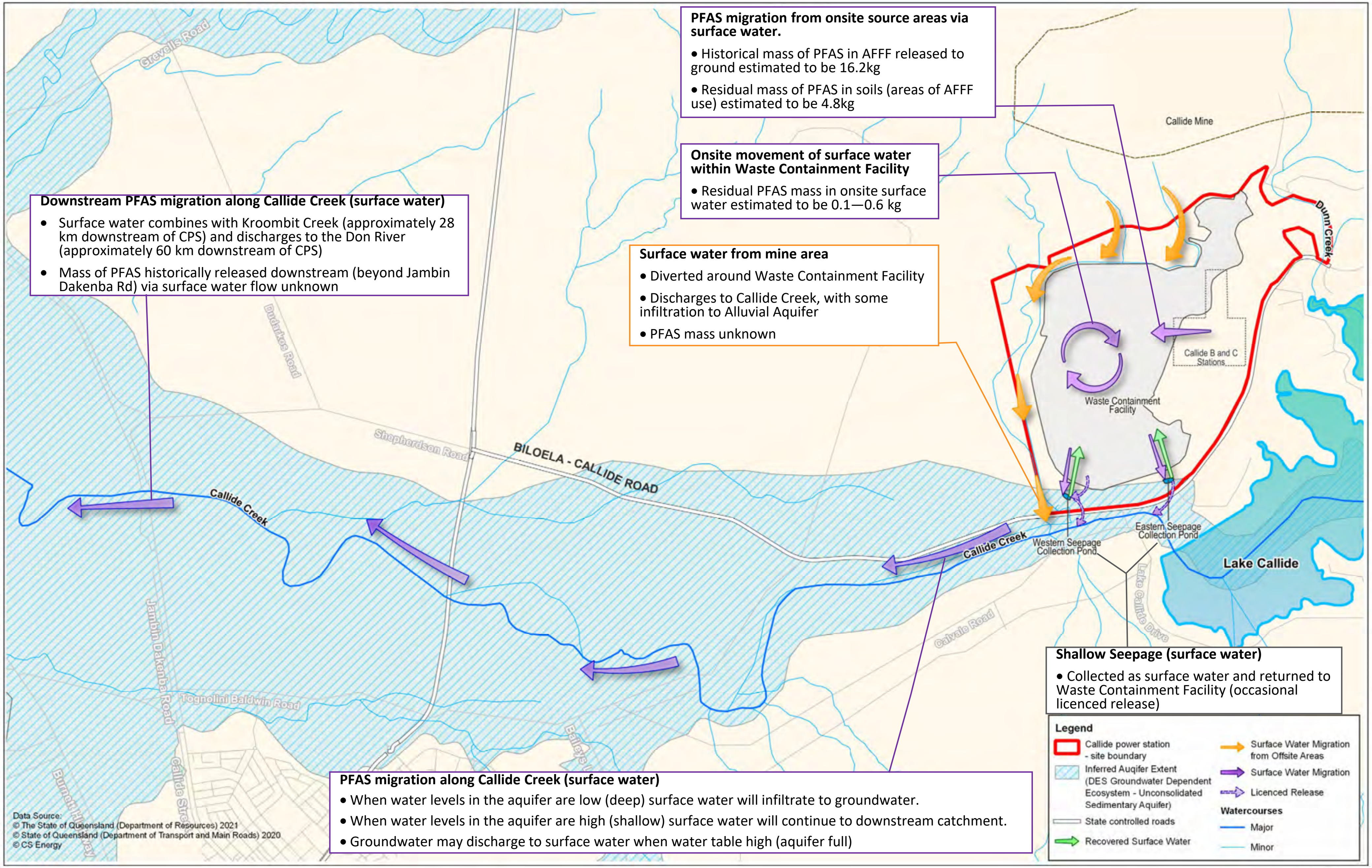


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Figure F7

PFAS Migration in Surface Water

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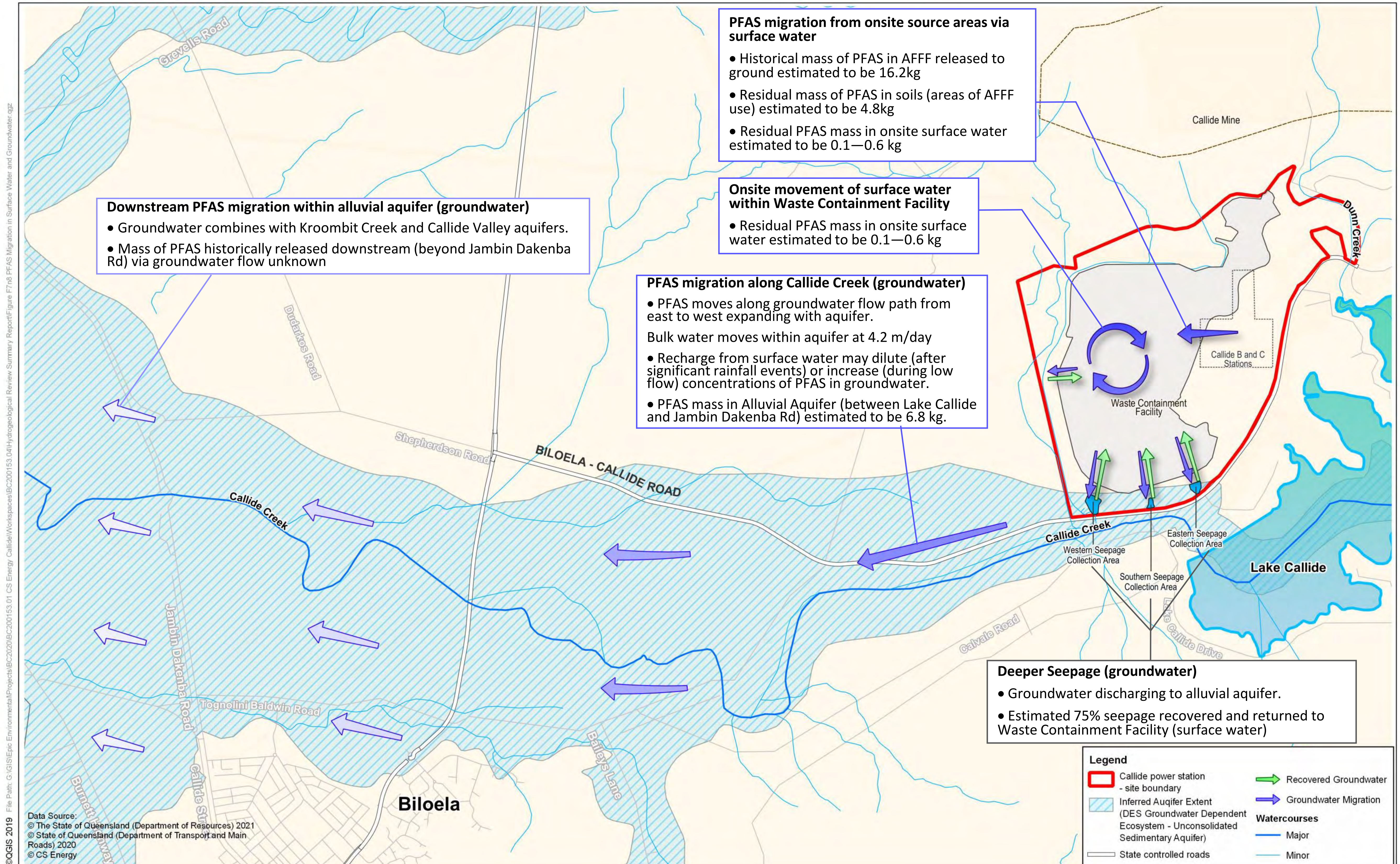

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Figure F8
PFAS Migration in Groundwater

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4 DATA AND INFORMATION GAPS

Based on the findings of the onsite and offsite hydrogeological reviews and updates to the CSM a number of data and information gaps have been identified. These are summarised in **Table 6.**

It is noted that investigation into the nature and extent of PFAS impacts at the site is required to be completed under the EE Notice issued by DES (refer **Section 2.3.4**). Works required to be completed under the EE are considered suitable to inform the data and information gaps identified.

Table 6. Data and Information Gaps

Data/Information Gap	Details
PFAS Extent and Mass	Limited information is available on presence, distribution and mass of PFAS at the following locations: • Callide A, including Ash Dams 1 and 2 • Ash deposits within Ash Dam 4 and Ash Dam B • Potential stratification of deeper surface water, including the southern impoundment areas within Ash Dam B • Accumulated sediments within the eastern seepage collection trench and pond (ESCT and ESCP) • Accumulated sediments within the western seepage collection trench and pond (WSCT and WSCP) • Fugitive seepage observed at MW32/MW43
Western Stormwater Diversion Channel (WSDC)	Elevated concentrations of PFAS have been reported to enter the site along the northern site boundary, with surface water diverted around the northern and western boundaries of the site along the Western Stormwater Diversion Channel. Sampling completed within the Western Stormwater Diversion Channel to date has been limited to opportunistic sampling in northern areas (SW33 and SW34) and southern areas (SW28 and SW35) during rainfall events. Data gaps identified include: • Quantification of stormwater flows, including volume entering site, volume exiting site, extent of flow and potential areas of retention of surface water onsite • PFAS mass flux • Nature and extent of PFAS impacts in sediments along the Western Stormwater Diversion Channel, including sediments within the former alluvial channel

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7 ACRONYMS

- AFFF Aqueous Film-Forming Foams
- AHD Australian Height Datum
- CSM Conceptual Site Model
- CPS Callide Power Station
- DES Department of Environmental Science
- DRNME Department of Natural Resources, Mines and Energy
- DRD Drains Reclaim Dam
- EA Environmental Authority
- ESCP Eastern Seepage Collection Pond
- ESCT Eastern Seepage Collection Trench
- EE Environmental Evaluation
- FFTA Former fire training area (Callide Mine)
- FSA Fluorotelomer Sulfonic Acid
- ERA Environmentally Relevant Activities
- GDE Groundwater Dependent Ecosystem
- NEMP PFAS National Environmental Management Plan
- PCA Perfluoroalkyl Carboxylic Acid
- PFAS Per- and poly-fluoroalkyl substances
- PFHxS Perfluorohexanesulfonate
- PFOA Perfluorooctanoic acid
- PFOS Perfluorooctanesulfonic acid
- PSA Perfluoroalkyl Sulfonic Acid
- REMP Receiving Environmental Monitoring Program
- SAQP Sampling Analysis and Quality Plan
- SQP Suitably Qualified Person
- TOP Total Oxidation Precursor
- WCF Waste Containment Facility
- WSCP Western Seepage Collection Pond
- WSCT Western Seepage Collection Trench
- WSDC Western Stormwater Diversion Channel

APPENDIX A – CONCEPTUAL SITE MODEL

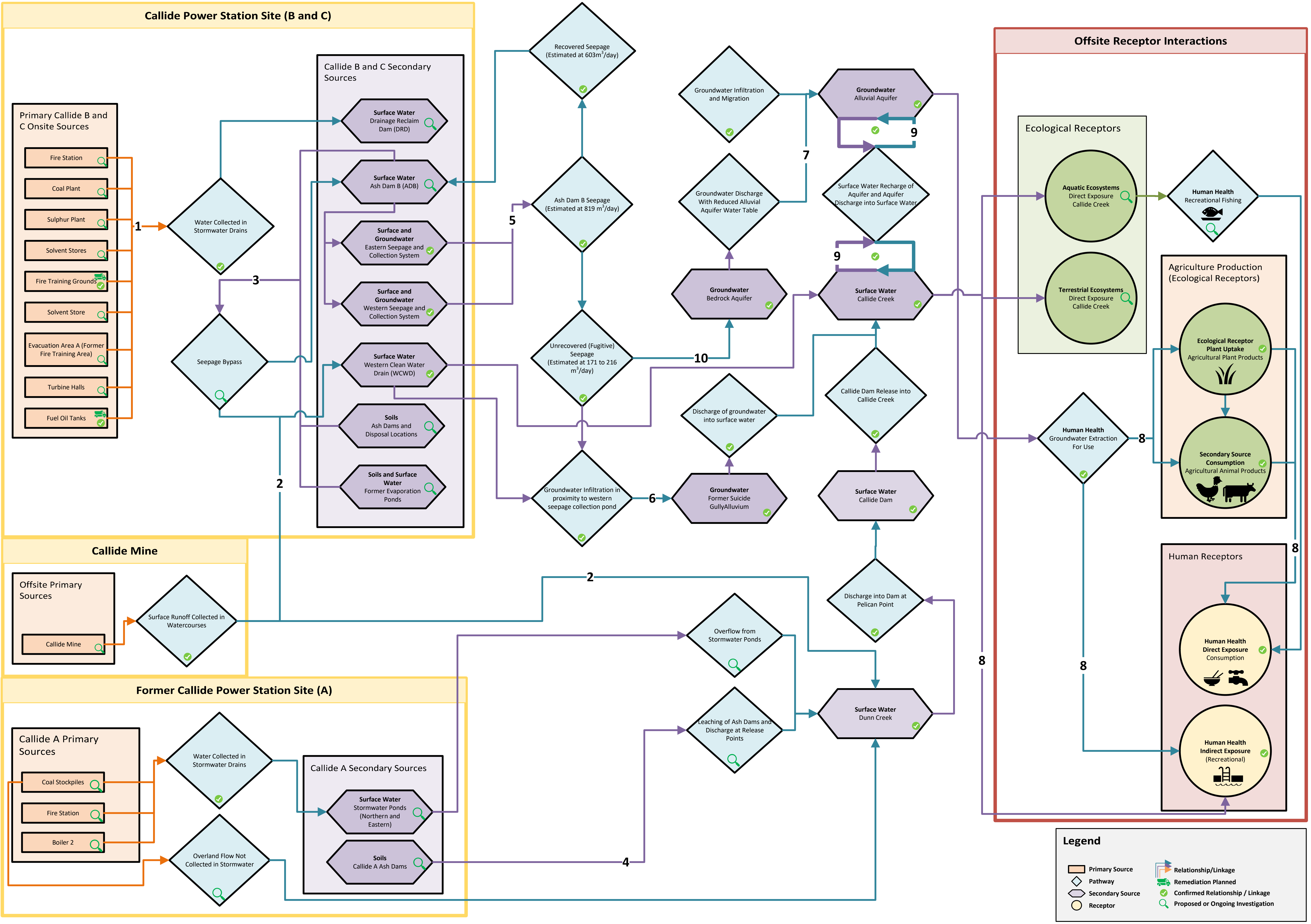
Table A1. Summary of Key Relationships of Conceptual Site Model (February 2022)

Item	Description	Rationale	Relative Contribution (Certainty)
1.	Onsite Primary Sources (Callide B and C) linkage to the Drains Reclaims Dam and Ash Dam B	Primary Sources have been identified within the fire training grounds and the fuel oil tanks with leachable concentrations of PFAS. As such it is considered likely that the areas contribute to concentrations in the DRD and eventually Ash Dam B via the Eastern Dirty Drain. No evidence significant groundwater infiltration has been found.	**High (Moderate)** A high level of certainty surrounds the fire training grounds and fuel oil tanks. However, additional investigation will be required of other identified potential sources (noting that due to ongoing operation of the power station, investigations may not be completed until decommissioning and closure).
2.	Offsite Primary Source of Callide Mine linkage to Callide Creek via the Western Clean Water Drain in addition to runoff entering Dunn Creek	Callide Mine has reported the use of PFAS products in areas upstream of the site, with surface water (SW34), at the northern boundary draining from the mine reporting the highest surface water concentrations for Total PFAS during the investigation. The detection of PFAS in MW74 indicate that some infiltration of impacted waters may be occurring upgradient of the site. Mine operation areas exist upstream of Dunn Creek	**High (High)** Consistent data exists on the upstream boundary with Callide mine indicating that surface runoff entering the site contains PFAS. Surface water impacts entering the northern boundary of the site travel through the Northern and Western Stormwater Diversion Channels, discharging to Callide Creek from the south-western corner of the site.
3.	Onsite secondary sources likely to have linkage to the Clean Water Drain and thus a pathway to the alluvial aquifer (See point 6)	Historic seepage from evaporation ponds, former borrow pits and Ash Dam B has potentially discharged into the western clean water drain, with limited fugitive seepage potentially migration further west (MW27). Northern ash dams (including BS3) potentially contribute to both surface runoff and groundwater to this pathway.	**Moderate (Low)** Historical data indicates some seepage has occurred, with salt impacts reported west of the site. No information available on potential PFAS impacts.
4.	Secondary sources associated with Callide A ash dams linkage with Dunn Creek	Concentrations of PFAS has been found at the licensed discharge point R2 associated with the ash dams on the eastern boundary of the site. This location discharges into Dunn Creek when flow is sufficient.	**Moderate (Low)** Limited information available to inform potential PFAS impacts at Callide A, with sampling completed to date indicate some PFAS impacts are present within Ash Dam 2 (represented by samples from R2) and onsite stormwater ponds (Callide A NSP and ESP). Limited surface water flows reported from Ash Dams 1 and 2, and along Dunn Creek. It is noted that upstream impacts from Callide Mine reported within Dunn Creek (See point 2).

5.	Secondary sources in the form of Ash Dam B recovered seepage recovery areas transferring PFAS impacted waters into Ash Dam B.	Seepage recovery areas and the waters captured in the associated infrastructure (recovery bores, collection trenches and collection ponds) have reported concentrations of PFAS. These impacted recovered waters are fed into Ash Dam B. These waters subsequently contribute to the seepage from Ash Dam B.	**High (High)** Consistent data exists on impacts in groundwater and surface water from fugitive seepage in the eastern, southern and western seepage areas. High concentrations of PFAS reported in the eastern and western seepage areas. Review of seepage pathways indicates that >70% of seepage is recovered by the current seepage recovery systems, with recovered seepage returned to Ash Dam B.
6.	Former Suicide Gully associated alluvium representing a secondary source and providing a pathway to groundwaters	Prior to the commissioning of Callide B, Callide A blowdown waters and discharge were discharged into Suicide Gully within infiltration into the associated alluvium likely to have contributed to historic PFAS concentrations (MW40). Since the establishment of Ash Dam B, the remnant alluvial channel is likely to provide a preferential pathway for waters collected in the seepage collection ponds and the western clean water drain to infiltrate into groundwater. These groundwaters will likely migrate to the Callide Creek alluvial aquifer.	**Moderate (Low)** Limited information available to inform potential PFAS impacts associated with residual areas of alluvial soils in the southwestern corner of the site. Surface water within the Western Stormwater Diversion Channel along with retained water in the Western Seepage Collection Pond may migrate to groundwater via alluvial soils in this area of the site. Elevated concentrations of PFAS has been reported in groundwater monitoring wells downgradient of alluvial soils.
7.	The groundwater in the bedrock aquifer discharges into the overlying alluvial aquifer	Salinity changes during years where the alluvial aquifer water table was significantly lower indicate an interaction between the bedrock and alluvial aquifer exists. The potential exists for PFAS impacted groundwaters within the Suicide Gully alluvium and bedrock to interact with the Callide Creek aquifer.	**Low (Low)** Limited information available to inform potential PFAS impacts from bedrock aquifer, however contribution to the Callide Creek alluvium via direct discharge is anticipated to be low.
8.	Human receptors exposed to PFAS through groundwater extraction and use.	PFAS impacted groundwaters are likely to have a complete pathway to human receptors based upon the high level of use of the alluvial aquifer for agricultural and domestic purposes.	**High (High)** Sampling of private bores downstream of the site have reported concentrations exceeding the Drinking Water Guideline Values. It is noted that where a potential risk to human health via the drinking water pathway has been identified, CS Energy has been working with the landowner to provide an alternative water supply solution, eliminating this exposure pathway.

9.	Groundwater interaction with surface results in the infiltration (into groundwater) and discharge (into surface water) waters at various points within Callide Creek and the associated alluvial aquifer.	Groundwater discharge into the creek of PFAS impacted groundwaters could result in the migration of impacted waters downstream where they would infiltrate back into the alluvial aquifer. This would accelerate the distribution of PFAS down valley. However, Callide Dam releases have are likely to have diluted PFAS concentrations as evidenced by the depressed concentrations of PFAS close to the creek channel, while the margins of the aquifer contain elevated concentrations (historic impacts).	**High (Moderate)** Further investigation is required to understand interaction between groundwater and surface water along Callide Creek, however there is potential for water loss from the creek to the aquifer, and vice versa. Surface water flows in Callide Creek may also provide a mechanism to bypass sections of the aquifer or may recharge the aquifer at different times depending on flows and whether the aquifer is full or not.
10.	Seepage bypass and licensed releases in the three seepage areas has likely linkage to the offsite alluvial aquifer and Callide Creek	The eastern seepage area, although having an established groundwater capture area, likely has historic or current fugitive seepage and associate PFAS impacts that migrated offsite. The salt plume identified in MW32/43 is similar to the possible PFAS plume recently identified. Additionally, offsite PFAS impacts have been identified in areas south of the western seepage area, with groundwater bores indicating a similar PFAS concentrations as the western seepage collection pond suggesting a possible linkage exists between surface waters and groundwaters in this area. Low yielding recovery bores in the southern seepage area indicate that fugitive seepage would likely be minimal.	**High (High)** Consistent data exists on impacts in groundwater and surface water from fugitive seepage in the eastern, southern and western seepage areas. High concentrations of PFAS reported in the eastern and western seepage areas. Review of seepage pathways indicates that >70% of seepage is recovered by the current seepage recovery systems, with recovered seepage returned to Ash Dam B. Unrecovered seepage is considered to discharge to alluvial aquifers and Callide Creek.

Figure A1: Conceptual Site Model (February 2022)



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