



BENNETT RESOURCES

Human Health Risk Assessment Valhalla Gas Exploration and Appraisal Program

BNR_HSE_MP_017

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Acronym / abbreviation

Terms / acronym	Definition / expansion
BNR	Bennett Resources Pty Ltd
CoPC	Constituent of potential concern
DoH	Department of Health
EP Act	<i>Environmental Protection Act 1986</i>
EPA	Environmental Protection Authority
ERD	Environmental Review Document
ESD	Environmental Scoping Document
Ha	hectares
HFS	Hydraulic fracture stimulation
HHRA	Human Health Risk Assessment
km	kilometres
m	meter
PM	Particulate matter
Proposal	Valhalla Gas Exploration and Appraisal Program
TO	Traditional Owner
VOC	Volatile Organic Compounds
µg	micrograms

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1 Overview

Bennett Resources (BNR) has prepared a site-specific Human Health Risk Assessment (HHRA) for the Valhalla Gas Exploration and Appraisal Program (the Proposal). The requirement to undertake a HHRA risk assessment was specified by the Environmental Protection Authority (EPA) in the Environmental Scoping Document (ESD), ESD requirement #52 for the environmental factor Social Surroundings:

Provide a peer-reviewed, site-specific human health risk assessment, addressing potential short and long-term health impacts of the proposal that addresses health risks from:

- a. airborne chemicals;
- b. chemicals proposed to be used in drilling and hydraulic fracture stimulation;
- c. fluids and those expected to be present in produced or flowback water;
- d. storage and handling of drilling and hydraulic fracture fluids; and
- e. storage and disposal of drilling and hydraulic fracturing flowback fluids (including wastewater).

Note: peer-reviewed, site-specific human health risk assessments will be provided to the Department of Health for comment.

The interest and scrutiny arise from the development of a new unconventional project following the lifting of the HFS (hydraulic fracture stimulation) moratorium and the lack of public knowledge relating to impacts and risks associated with the project in region of the West Kimberley. Prior to undertaking the Proposal, the scope of potential impacts to the public that may emerge needs to be understood, verified and shared with stakeholders, as well as with the public during the Section 38 referral under the *Environmental Protection Act 1986* (EP Act). This HHRA will define the scope of impacts to public health in a site-specific context for the Proposal, based on a risk-based framework approach.

The closest relevant human receptor, an Indigenous Community, is aware and supportive of the Proposal. They are currently knowledgeable of the risks to the environment and of the chemical sources arising from the Proposal given in the past they have supported and worked for a similar unconventional project, now part of Bennett Resources' existing assets. Community members and associated workers such as pastoralists travelling within the Proposal's area understand that they are not considered susceptible or vulnerable populations likely to be exposed by the Proposal's activities.

With the extensive environmental awareness and the depth of hydrogeological knowledge of the local and regional setting, all transport mechanisms have been adequately considered. It must be highlighted that all potential pathways were explored during the preparation of this HHRA, and that the feasible and reasonable pathways and thus associated risks are the focus of this risk assessment. Where necessary, where other exposure media and pathways were not detailed, the HHRA has clarified why these were not feasible for detailed inclusion in the HHRA. This HHRA will be included in the Proposal's Environmental Review Document (ERD) for assessment by the EPA.

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2 Methodology

This HHRA has been prepared in accordance with the Health Risk Assessment (Scoping) Guidelines (DoH 2010). The guidelines provide a framework for the health risk assessment component for Environmental and Health Impact Assessment processes. Specifically, the guideline is used to determine if a detailed Health Impact Assessment is required.

BNR used this process to determine which (if any) Health Hazards and subsequent Health Impacts required further detailed assessment. Procedurally, this HHRA follows a standard risk assessment approach (Figure 2-1) being:

- the activity is detailed and key issues identified relevant to the risk assessment
- hazards associated with the activities are identified
- exposure pathways associated with the hazards are identified
- the adverse effects to human health (Impacts) arising from exposure are defined
- consequence mitigation identified

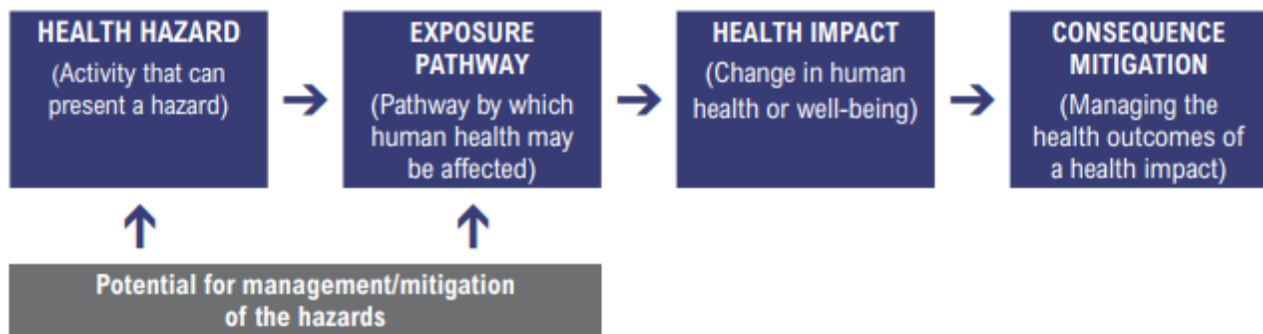


Figure 2-1: Links between health hazards and health impacts (DoH 2010)

All stages of the HHRA model are closely linked, and thus the outcomes of one stage of the assessment may affect the progression or outcomes of the subsequent assessment stage. As with all BNR risk assessments, a precautionary principle / approach has been considered applied to manage any uncertainty in the HHRA.

2.1 Project Context

2.1.1 Location and existing land use

The Proposal is located on the active Blina and Noonkanbah pastoral stations, on the Warlangurru and Noonkanbah Native Title Areas, respectively. Yungngora People of the Yungngora Community are employed by Noonkanbah Station and regularly travel on the station to verify cattle presence, feedstock, groundwater pastoral bore operation and associated watering troughs. Blina Station workers occasionally travel to the southern border of Blina Station which intersects the northern section of the Development Envelope to verify their cattle and station equipment. Cattle are free roaming, and pastoralists use existing station and BNR tracks to access specific areas of the station all throughout the Development Envelope

In addition to pastoral activities, the Traditional Owners (TOs) of the land and members of the Yungngora Community, including some Warlangurru People residing at the Jimbalakudunj Community, use the land within and surrounding the Development Envelope for cultural practices, such as hunting and gathering of traditional foods, initiations and education. The land in this region is also used for recreational purposes such as swimming and fishing. The TOs are made aware of all BNR presence and activities on the permit, with sufficient notice and engagement prior to undertaking any activities and visits to the sites.

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2.1.2 Receptor Analysis

Receptors relevant to the scope of this HHRA have been grouped into two categories:

- Fixed
- Non-fixed
- Out of scope.

Fixed

BNR has defined fixed receptors as locations where humans are known to reside or be present for long periods of time. For the purpose of this assessment these include:

- the Jimbalakudunj Community – located ~20 km from the nearest proposed well site and the general Development Envelope
- the Yungngora Community – located ~28 km from the nearest proposed well site and ~20 km from the general Development Envelope

The Jimbalakudunj Community, although located closer to proposed well sites than the Yungngora Community, was not identified as a receptor of the identified potential health hazards. However, the members of the Jimbalakudunj Community travel along the permit road to access the Yungngora Community and attend meetings, particularly as Warlangurru People reside in both communities, however do not often use the land itself for other reasons. Given the distance to the proposed activities and to any of the hazards, with separation from the Great Northern Highway, no exposure pathways have been associated with the Jimbalakudunj Community as a fixed receptor.

No other tourist or public access locations are present within the Development Envelope, thus no other locations are known where humans have the potential to reside or be present for a long period of time.

Non-Fixed

The existing land use throughout the Development Envelope is pastoral use. Consequently, any pastoral station worker conducting activities throughout the station has the potential to be non-fixed receptor. For context Blina Station comprises a total area of 254,600 ha. Noonkanbah Station covering the majority of the Development Envelope comprises a total area of 172,400 ha and employs less than 10 people, with the number of workers generally doubling during the mustering season. Approximately four Yungngora locals are employed by the station. Given that the disturbance footprint of this Proposal is limited to 109 ha, the potential direct impact is limited to <0.03% of the total pastoral stations.

To further define the non-fixed receptors, pastoralists verifying the operation of pastoral bores, which may include touching the bore equipment and bore water, have been identified as those closest to the exposure pathway for non-fixed receptors. In addition to pastoral use, as stated in Section 2.1.1, TOs use the land within and surrounding the Development Envelope for cultural practices and recreational purposes. TOs utilising the land for such reasons may be defined as non-fixed receptors. Specific cultural locations where TOs may occasionally frequent are not located in close proximity of the Proposal's disturbance footprint. Consultation with the TOs has shown that BNR is aware of these areas of cultural importance to the community members.

As the Calwinyardah-Noonkanbah Road runs through the Development Envelope, this has been considered another non-fixed receptor as users of the Calwinyardah-Noonkanbah Road do not reside in this specific area nor are located along the road for a long period of time. As direct exposure to any road user is not expected, this receptor has not been considered further.

Out of scope

As detailed in Section 5.4.3.6 of the Environmental Review Document (BNR_HSE_MP_013) there are no permanent water bodies within the Development Envelope. The Mount Hardman Creek is a non-perennial water body and only flows during the wet season. As there is no vulnerable shallow aquifer in communication with seasonal creeks the use of such waterbodies will not result in any exposure, thus it has not been considered further.

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2.2 Step 1 – Hazard

As defined by DoH, a Health Hazard is defined as:

The elements of an organisation’s activities that present a hazard or source of risk to health or well-being and may be an event, incident or circumstances. They are activities or elements of a proposal that can interact with human health to represent a risk to health or well-being. Examples are air or water emissions, noise and displacement or relocation of people (DoH 2010).

To understand the potential health hazards associated with the Proposal, BNR developed a conceptual model which is presented in Figure 2-2. This model identifies the Health Hazards for the Proposal as being limited to:

- air emissions
- groundwater emissions
- soil contamination.

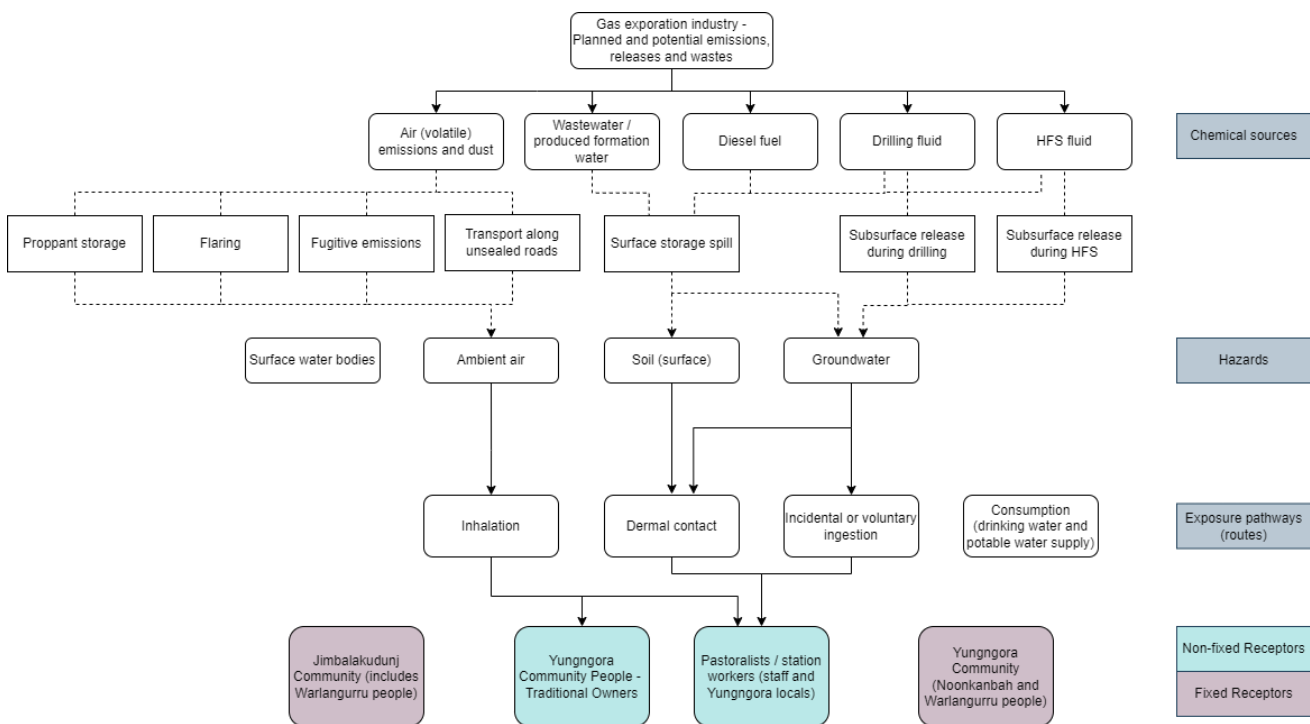


Figure 2-2: Site-specific conceptual site model illustrating the source – pathway – receptor analysis undertaken for the HHRA

2.3 Risk Assessment Process

The risk assessment process undertaken for the Proposal was completed following four steps:

- Step 1 the identification of the hazards
- Step 2 defines the feasible pathways from each of the hazards
- Step 3 determines the potential health impacts from the hazards through the identified exposure pathways
- Step 4 consists of the risk assessment itself.

The consequence of the described health impact is defined, whereby the magnitude of the impact is detailed, in qualitative or quantitative terms. Once the consequence defined, the likelihood of the consequence is determined, where the frequency and probability of the consequence occurring is evaluated, in qualitative or quantitative terms. The combination of the consequence and the likelihood of that particular consequence occurring results in the inherent health risk level for the specific hazard. The risk level is considered as an

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indication of the significant of a health or well-being impact. If required, depending on this risk level, risk management criteria (management of mitigation measures required to reduce negative impact of enhance positive impact) may be applied in order to reduce the risk to human health.

2.3.1 Step 2 – Exposure

An exposure assessment was initially undertaken for each of the hazards in accordance with the DoH Health Risk Assessment (Scoping) Guidelines (DoH 2010) and in consideration with the principles set out in the DoH environmental health risk assessment process (enHealth 2012).

As defined by DoH, an exposure is defined as:

The Pathway by which human health may be affected (DoH 2010).

Given that the sources of hazards are clearly understood (refer to Section 3.1, Section 3.2 and Section 3.3), assessment of exposure to these sources was completed by considering the receptors with the potential to be exposed and consideration as to the magnitude, frequency, and duration of potential exposure (WHO 2004).

2.3.2 Step 3 – Health Impact

An impact (or risk) assessment was undertaken for each of the hazards in accordance with the DoH Health Risk Assessment (Scoping) Guidelines (DoH 2010) and in consideration with the principles set out in the DoH environmental health risk assessment process (enHealth 2012).

As defined by DoH, health impacts are defined as:

the overall effects, direct or indirect, of activities on the health of a population. The variation and vulnerability among sectors of the population need to be considered (DoH 2010).

2.3.3 Step 4 – Risk Assessment

Consistent with DoH guidelines (DoH 2010), BNR assessed the:

- Consequences, in accordance with the definitions provided in Table 2-1
- Likelihood, in accordance with the definitions provided in Table 2-2
- Risk Level, in accordance with the definitions provided in Table 2-3
- Risk Management Criteria, in accordance with the definitions provided in Table 2-4.

Table 2-1: Categories for Health Consequences (source (DoH 2010))

Category	Acute Health Consequences (per Hazard or outbreak)	Chronic Health Consequences(per Project Lifecycle)
Catastrophic 1	>1 fatality OR >5 permanent disabilities OR Non-permanent injuries requiring hospitalisation for 5–10% of population at risk OR Acute health effect requiring hospitalisation for >5-10% of population at risk	Chronic health effect requiring medical treatment for 10–15% of population at-risk*
Massive 2	1 fatality OR 2–5 permanent disabilities OR Non-permanent injuries requiring hospitalisation for 2–5% of population at risk OR Acute health effect requiring hospitalisation for	Chronic health effect requiring medical treatment for 5–10% of population at-risk*

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	>2–5% of population at risk	
Major 3	No fatality AND (1 permanent disability OR Non-permanent injuries requiring hospitalisation for >1–2% of population at risk OR Acute health effect requiring hospitalisation for >1–2% of population at risk OR Evacuation is necessary)	Chronic health effect requiring medical treatment for 2–5% of population at-risk*
Moderate/ Significant 4	No fatality AND No permanent disability AND (Non-permanent injuries requiring hospitalisation for 1–2% of population at risk OR Acute health effect requiring hospitalisation for 1–2% of population at risk AND No evacuation	Chronic health effect requiring medical treatment for 1–2% of population at-risk*
Minor 5	No fatality AND No permanent disability AND (Non-permanent injuries requiring hospitalisation for 1–5 persons OR no acute health effect requiring hospitalisation) AND No evacuation	Chronic health effect requiring medical treatment for about 0–1% of population at-risk*
Negligible/slight 6	No fatality AND No permanent disability AND No non-permanent injuries requiring hospitalisation AND No acute health effect requiring hospitalisation AND No evacuation	No chronic health effect requiring medical treatment

Table 2-2: Likelihood Categories for Health Impact Assessments (source (DoH 2010))

Likelihood Descriptor		Frequency of Incident or outbreak with Non-Chronic Health Effect	% Chance of Chronic Health Effect during life of project
1	Rare/remote	Once in more than 10 years	Up to 5%
2	Unlikely	Once in 5 – 10 years	6 – 30%
3	Possible/ occasionally	Once in 3 – 5 years	31% – 60%
4	Likely	Once in 1 to 3 years	61% – 90%
5	Almost certain	More than once a year	Over 90%

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Table 2-3: Qualitative Risk Matrix for Health Impact Assessments (source (DoH 2010))

Likelihood	Consequences					
	Slight/negligible	Minor	Moderate	Major	Massive	Catastrophic
Almost Certain	Low	Medium	High	Extreme	Extreme	Extreme
Likely	Low	Low	Medium	High	Extreme	Extreme
Possible	Very Low	Low	Low	Medium	High	Extreme
Unlikely	Very Low	Very Low	Low	Low	Medium	High
Rare/remote	Very Low	Very Low	Very Low	Low	Low	Medium

Table 2-4: Risk management criteria according to risk rating at scoping stage (source (DoH 2010))

Risk Rating	Risk Mitigation/Management Criteria
Extreme	Potentially unacceptable: modification of proposal required
High	Major mitigation/management (including offsets) may be required – Assessment required of health hazards
Medium	Substantial mitigation/management required – Assessment required of health hazards
Low	Some mitigation/management may be required – No detailed assessment of health hazards required but addressed with routine controls
Very Low	No further assessment required

2.4 Peer Review

BNR engaged Geosyntech consultants (Geosyntech) to complete a review of this HHRA. BNR sent through Revision 0 to Geosyntech to which a response was provided (included as Appendix A). In summary Geosyntech provided the following recommendations (Summarised):

- BNR consider Surface Water Resources, and describing these even if no exposure pathway existed
- To include more information on Constituents of Potential Concern (COPC)
- To discuss surface release and exposure to groundwater systems

In summary, Geosyntech stated:

Overall, the study is very close to complete, is well ordered, easy to follow, and consistent with relevant administrative authority guidelines. Excepting additional discussion regarding the projected nature and extent of proposal CoPCs, and in recognition of the very low potential for exposure to populations outside Valhalla Gas workers, it is unlikely that a more detailed and comprehensive HHRA will be required.

BNR addressed the recommendations from Geosyntech in Revision 1 of this HHRA.

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3 Health Risk Assessment

3.1 Air

3.1.1 Hazard

Exposure to air emissions is limited to dust emissions and volatile organic compounds (VOCs).

The health hazards (activities that can present a hazard and interact with human health) from air include:

- VOCs and dust from transport along unsealed roads / tracks
- Dust from proppant (fine sand) storage on site
- VOCs and products of incomplete combustion (PICs) from flaring during well testing activities on site
- VOCs as fugitive emissions from the well following completion of HFS activities.

These health hazards will be limited to the duration of the activities at each well site and transport along the roads and tracks during mobilisation and demobilisation of the Proposal equipment.

3.1.2 Exposure

Monitoring from other programs have demonstrated that VOCs rapidly dissipate upon release with no ground level exposures above human health criteria/screening levels (Ramboll 2019). As such, no further consideration of human health impacts from VOCs have been considered given there is no potential exposure to Fixed or Non-fixed receptors.

As such, health impacts associated with changes to ambient air are associated with the following pathway:

- Inhalation (respiratory system) associated with dust from sand storage onsite.

BNR reviewed the Proposal’s Chemical Inventory (Appendix A of the Valhalla Environmental Review Document [BNR_HSE_MP_013]) to identify products that contained:

- suspected carcinogens
- mutagens,
- developmental toxicants and endocrine disruptors.

These were then further refined to understand those products that pose a human health risk via inhalation. Specifically for the water-based drilling fluid, cementing system and HFS fluid, the following Constituents of Potential Concern (CoPC) were identified as posing a human health risk:

- Silica.

Silica can be measured onsite through monitoring of particulate matter (PM). Baseline studies identified a range of environmental concentrations for PM_{2.5} and PM₁₀ onsite dependant on various environmental conditions. The Valhalla Monitoring Plan (Appendix C of the Valhalla Environmental Review Document [BNR_HSE_MP_016]) details 24-hour average – Health indicators for PM_{2.5} and PM₁₀. BNR will monitor for these over the course of the Proposal.

As detailed in Section 5.5.3.1 of the ERD, the closest public communities (Aboriginal communities) are located 20 km and 28 km from the closest proposed well sites within the Development Envelope. No other fixed sensitive human receptors are known to occur within the Development Envelope.

Consequently, no exposure to fixed receptors is expected to arise from dust emissions associated with the Proposal.

As stated in Section 2.1.2, pastoral workers and travelling Yungngora Community TOs have the potential to be present within the Development Envelope over the course of the Proposal. These workers and people using the land for traditional purposes are considered Non-fixed receptors and exposure would only occur in the event they were located within proximity of the well site during HFS activities. As dust from the proppant storage is

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expected to be influenced by the weather and wind conditions, and as baseline monitoring has indicated existing PM levels within the Development Envelope fluctuate due to the weather conditions, the change to ambient air quality levels is not expected to be significant.

3.1.3 Impact

It is well established that dust emissions can have adverse impacts (adverse changes) on human health. These health impacts can be both short-term (acute) and long-term (chronic). Dust particles (i.e. in the PM₁₀ and PM_{2.5} size ranges) including fine sand particles that are readily inhaled are associated with a range of chronic health effects. Both fine and coarse dust particles can cause acute health effects (e.g. eye or breathing irritation) and also deposit and remain on surfaces leading to soiling.

Further to this, a completed HHRA, in accordance with DoH guidelines (DoH 2010), is provided in Table 3-1.

Table 3-1: Human Health Risk Assessment – Air

	Description
Consequence	<p>The generation of dust on unsealed roads already occurs within the Development Envelope from community members travelling to and from the Yungngora and Jimbalakudunj Communities, and from pastoral activities along existing access tracks and transportation of cattle using road trains on the unsealed Calwinyardah-Noonkanbah Road. Current PM₁₀ dust levels along the road often exceed the daily health guideline levels of 50 µg/m³ most days of the week. Dust resulting from the Proposal will only increase the current dust concentrations along the Calwinyardah-Noonkanbah Road during transportation of equipment to and from the well sites, and specifically on parts of the road located at least >20 km away from the closest community.</p> <p>Proppant, or frac sand, is expected to be stored on each well site and protected from wind and equipment that may disturb the sand. The mechanical handling of sand for storage on site and during the preparation of HFS fluid may generate dust that can temporarily disperse to the exterior of the well site fences.</p> <p>Given the distance to potential Non-fixed human receptors in the Development Envelope, the temporal nature of their presence in the area, and as the Proposal has more separation than recommended in accordance with EPA Guidance (EPA 2005), the Proposal is not expected to result in any chronic health effects requiring medical treatment.</p>
Likelihood	In accordance with DoH guidelines, BNR does not believe that the Proposal would result in one event / incident of chronic health in more than 10 years and consequently the likelihood of exposure is considered rare / remote. The reason to this is that the public (including TOs from the Yungngora Community and pastoralists) is restricted from site access, and exposure will be limited to the duration of the activity which will be limited to months (at each well site). Consequently, the duration of exposure will be limited, the extent to which humans can be exposed is limited and the nature of the exposure (as detailed in Section 5.6.3 in the ERD) is limited.
Inherent Risk Level	Based upon the DoH qualitative Health Impact Assessment risk matrix, the level of risk is: Very Low .
Uncertainty	BNR has completed monitoring of existing dust and VOC air quality within the Development Envelope. Consequently, during the implementation of the Proposal, BNR will be able to monitor the changes to air quality associated with the Proposal. Given the robust amount of baseline data combined with the proposed monitoring program and actions in Appendix C of the ERD, there is limited uncertainty associated with the Proposal.
Health Risk management	Based upon the DoH risk management criteria, no further assessment is required.

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3.2 Groundwater

3.2.1 Hazard

Exposure to groundwater is limited to CoPCs that may reach Liveringa Aquifer groundwater used by pastoral station bores screened in the same aquifer. The health hazards (activities that can present a hazard and interact with human health) from groundwater include:

- surface release of drilling fluids and HFS fluids
- subsurface release of drilling fluids
- subsurface release of HFS fluids.

3.2.2 Exposure

Groundwater contamination is associated with unplanned events, specifically relating to drilling or HFS fluid systems. Groundwater exposure to humans is limited to those events that reach the Liveringa Aquifer groundwater used by pastoral station bores screened in the same aquifer. The closest utilised pastoral bores are located >1.5 km away from the closest proposed well site.

Although the release of subsurface HFS fluids was identified as a chemical source, HFS fluids will only have the potential to be released along the HFS zones between 2,000 m and 5,000 m below ground. As such, any release would be contained by the thick shale layers from the Laurel and Anderson formations as described in Section 5.4.5.4 of the ERD. With over 1.5 km separation between the targeted Laurel Formation during HFS activities and any Community bores used for potable water screened in the Poole and Grant aquifers, a subsurface release of HFS fluids was not considered to result in a feasible exposure pathway.

The release of drilling fluids to an aquifer is only a hazard whilst drilling through the Liveringa Aquifer. As detailed in Section 5.4.5.2 of the ERD, BNR are required to utilise low-toxicity water-based drilling fluids when installing the surface casing. Once the surface casing is installed, there is no risk of drilling fluid loss as the surface casing provides a barrier between the drilling fluids and the aquifer. Consequently, the health hazard from groundwater specifically includes:

- Lost circulation events causing contamination of groundwater during the installation of the surface casing (drilling activity).

As stated in Section 2.1.2, pastoral workers and community members traditionally using the land have the potential to be present within the Development Envelope over the course of the Proposal. These people are considered Non-fixed receptors and exposure would only occur if:

- an unplanned release of drilling fluids occurred during installation of the surface casing
- the pastoral bores are located down gradient of the well site
- pastoral bores were in operation and CoPCs were pumped to the surface

Consequently, exposure to contaminated groundwater is extremely unlikely. However, should this occur, health impacts associated with changes to groundwater are limited to the following pathways:

- dermal contact
- incidental and voluntary ingestion

Consumption (drinking water) has been differentiated from incidental or voluntary ingestion, and was not considered further given that the surficial Liveringa Aquifer is not used for potable water purposes or for Community water supplies. The pathway 'incidental or voluntary ingestion' was considered given that pastoral workers are known to drink raw bore water whilst working, and TOs may know the location of these pastoral bores and use the water if needed when hunting and roaming in the permit area.

BNR reviewed the Chemical Inventory (Appendix A of the Valhalla Environmental Review Document [BNR_HSE_MP_013]) to identify products that contained:

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- suspected carcinogens
- mutagens,
- developmental toxicants and endocrine disruptors.

These were then further refined to understand those products that pose a human health risk via dermal contact or ingestion. Specifically for the water-based drilling fluid, cementing system and HFS fluid, the following COPC were identified:

- Nitrotriacetic acid, trisodium salt monohydrate
- Sulfuric acid

The outcomes of local groundwater characterisation is included as Appendix H of the Valhalla Environmental Review Document (BNR_HSE_MP_013). These studies identified a range of environmental concentrations for relevant CoPCs, including chloride and sulfate. These ranges indicate levels are relatively steady throughout the Development Envelope. Concentrations will continue to be monitored and management actions undertaken in accordance with the trigger and threshold criteria detailed in the Groundwater Management Plan (Appendix I of the Valhalla Environmental Review Document [BNR_HSE_MP_015]).

As detailed in Section 5.4.5.5 of the Environmental Review Document (BNR_HS_MP_013), based on the depth to groundwater, any surface release is expected to take 70–300 days to travel from the ground surface to the water table (Rockwater 2016). With the mitigations in place, BNR did not deem this a credible hazard, thus it has not been considered any further.

3.2.3 Impact

It is well established that the quality of groundwater, when used for drinking purposes, can have adverse impacts on human health. These health impacts can be both short-term (acute) and long-term (chronic) depending on the CoPCs, the concentration of CoPCs and the duration of consumption of water. Although Liveringa Aquifer groundwater is not extracted and drunk as potable water, or stored for potable water supplies for communities or residences, as discussed in Section 3.2.2, only dermal contact and incidental or voluntary ingestion of non-treated non-potable bore water have been identified as feasible exposure pathways for groundwater. Dermal contact with non-treated bore water with higher concentrations of CoPCs may potentially lead to skin irritations, including skin dryness. Incidental or voluntary ingestion of non-treated bore water, in general, may result in aesthetically displeasing tastes and potentially temporary upset stomachs, based upon the expectation that a limited amount of bore water is ingested occasionally.

Further to this, a completed HHRA, in accordance with DoH guidelines (DoH 2010), is provided in Table 3-2.

Table 3-2: Human Health Risk Assessment – Groundwater

	Description
Consequence	<p>A local and regional groundwater characterisation of the Liveringa Aquifer, including of the CoPCs identified as indicator constituents for drilling fluid, has shown that groundwater quality varies within the Development Envelope. Previous operational and surveillance monitoring on site during similar drilling operations in the Development Envelope showed no significant variation in CoPC data that was attributable to drilling activities. With the limited amount of drilling fluid potentially released at the subsurface, the dilution of CoPCs, and the migration of any CoPCs to the location of pastoral bores, the quality of the groundwater abstracted away from any of the well sites (>1.5 km) is not expected to differ from natural variations.</p> <p>Similar petroleum industry activities occur around the state, where low-toxicity drillings fluids are used. Low-toxicity drilling fluids are planned to be used by BNR that are not expected to result in environmental impacts, nor health impacts.</p> <p>Given the distance to the Non-fixed TO receptors using the whole permit area, and their infrequent presence around the pastoral bores, the Proposal is not expected to result in any chronic health effects to TOs using the land for cultural or recreational purposes, that would require medical treatment.</p>

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	Despite the more regular presence of station workers around the pastoral bores and frequency of contact with bore water, the Proposal is still not expected to result in any chronic health effects to station workers that would require medical treatment.
Likelihood	<p>In accordance with DoH guidelines, BNR does not believe that the Proposal would result in one event / incident of chronic health in more than 10 years and consequently the likelihood of exposure is considered rare / remote. The reason to this is that the community members are not expected to use or touch groundwater from pastoral bores unless needed in case of thirst, given their remote location within the bush in the Development Envelope away from the Community residences.</p> <p>Additionally, pastoralists are aware that the groundwater abstracted from their bores are for cattle watering purposes. Pastoralists will regularly clean and maintain the cattle troughs where bore water is run through. Voluntary drinking directly from the bore pump pipe is common during station activities.</p> <p>As such, the dermal and ingestion exposures are limited to if and when these Non-fixed receptors are purposefully visiting the pastoral bores. Consequently, the duration of exposure will be limited, the extent to which the public can be exposed is limited and the nature of the exposure (as detailed in the Consequence section above) is limited.</p>
Inherent Risk Level	Based upon the DoH qualitative Health Impact Assessment risk matrix, the level of risk is: Very Low.
Uncertainty	The previous operator of the permit completed groundwater monitoring on bores within existing well sites that underwent drilling and HFS activities, which showed no significant variation in CoPC data that was attributable to drilling activities. BNR has completed further groundwater monitoring, including baseline monitoring within the Development Envelope to further understand the existing groundwater quality of the Liveringa Aquifer (in which pastoral bores are screened and in which Proposal monitoring bores will be screened) within the Development Envelope. Consequently, during the implementation of the Proposal, BNR will be able to monitor if any changes to groundwater quality associated with the Proposal occur. Given the robust amount of baseline data combined with the proposed monitoring program and actions in Appendix C of the ERD, there is limited uncertainty associated with the Proposal.
Health Risk management	Based upon the DoH risk management criteria, no further assessment is required.

3.3 Soil

3.3.1 Hazard

Soil contamination has the potential to occur from an unplanned release (spill event) on site over the course of the Proposal. Specifically, the onsite surface spill events may include spills from:

- drilling fluids
- HFS fluids during pumping
- wastewater – produced formation water
- diesel fuel storage.

3.3.2 Exposure

Exposure to humans is limited to those events that result in contamination outside of the well site. With the exception of well site access tracks (that are likely to be used for pastoral access once installed), the closest Non-fixed receptors (pastoral workers) who would be regularly visiting the area surrounding the well sites would be located ~1.5 km away given this is the distance to the closest pastoral bore.

This health hazard will be limited to each well site and the immediate perimeter (i.e. the firebreaks) during operation of the Proposal. The current pastoral activity within the Development Envelope around all proposed well sites is limited to cattle grazing. The land is not used for other agricultural reasons and is not used from crop growth for human consumption.

These station workers are considered Non-fixed receptors and exposure would only occur if:

- an unplanned release occurred that resulted in contamination outside of the well site

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- the station workers were on-site at the time of release.

Consequently, exposure is extremely unlikely. However, should this occur, health impacts associated with changes to soil are limited to the following pathways:

- dermal contact.

3.3.3 Impact

Dermal contact of contaminated soil with higher concentrations of CoPCs may lead to skin irritations, including skin dryness. Dermal contact may also lead to dermal absorption of CoPCs from soil. Impacts would be expected to be acute (short-term), and dependant by a variety of physical and chemical factors, including the type of CoPCs, the soil-chemical contact time, the degree of chemical saturation of the CoPCs in soil, the area of exposed skin, continuity/duration of soil-skin contact (exposure time), the amount of soil adhering to the skin and the amount of contaminant absorbed through the skin (NEPC 1999).

The substances for which dermal contact from soil and associated impacts are most likely to be significant are lipophilic compounds that are relatively long lived in the environment, accumulate in the body, and present a chronic (e.g., carcinogenic) risk (Spalt, et al. 2009).

Further to this, a completed HHRA, in accordance with DoH guidelines (DoH 2010), is provided in Table 3-3.

Table 3-3: Human Health Risk Assessment – Soil

	Description
Consequence	<p>As detailed in the ERD in Section 5.2.3.2 and in the human health hazard for soil in this HHRA, spills from drilling fluids, produced formation water and diesel fuel have the potential to contaminate soil and affect Non-fixed receptors. On this basis, the analytes considered both as indicators of spill events and as CoPCs for human health are Total Recoverable Hydrocarbons from diesel, Barium, Chloride, Cadmium and Chromium III from drilling fluids, HFS fluids and produced formation water. Similar petroleum industry activities occur around the state, where low-toxicity drillings fluids are used. Low-toxicity drilling fluids are planned to be used by BNR that are not expected to result in environmental impacts, nor health impacts.</p> <p>Regional baseline soil quality sampling, including for the above CoPCs, have shown that soil quality varies throughout the Development Envelope. Should a spill event occur on site during operations and contamination occur outside of the well site, this would result in the presence and/or increase of these specific CoPCs in soil prior to BNR immediately implementing management measures and remediation of the contaminated soil. Dermal contact with the CoPCs characteristic of the chemical sources is not expected to result in significant health impacts, primarily due to the nature of the exposure pathway and the very temporal nature of the exposure. Contact with these CoPCs will result in irritation and sensitization only if the skin contact is prolonged.</p> <p>Given the predicted distance to Non-fixed sensitive receptors at least 1.5 km away, the frequency of their presence in the surrounding area (approximately once a week), and the unlikely long-term skin exposure should a spill event occur, the Proposal is not expected to result in any chronic health effects requiring medical treatment.</p>
Likelihood	In accordance with DoH guidelines, BNR does not believe that the Proposal would result in one event / incident of chronic health in more than 10 years and consequently the likelihood of exposure is considered rare / remote. The reason to this is that the public is restricted from site access, the hazards are unlikely to go beyond the delimitation of the well sites, and remediation of any hazard is planned to occur as soon as possible to limit impacts to the environment in the first instance. Consequently, the duration of exposure will be limited, the extent to which the public can be exposed is limited and the nature of the exposure is limited.
Inherent Risk Level	Based upon the DoH qualitative Health Impact Assessment risk matrix, the level of risk is: Very Low .
Uncertainty	BNR has undertaken baseline soil monitoring within the Development Envelope to understand the existing soil quality of the different soils within region. Consequently, during the implementation of the Proposal, BNR will be able to monitor if any changes to soil quality associated with the Proposal occur. Given the robust amount of baseline data combined with the proposed monitoring program and actions in Appendix C of the ERD, there is limited uncertainty associated with the Proposal.

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Health Risk management	Based upon the DoH risk management criteria, no further assessment is required.
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4 Conclusions

This HHRA has presented plausible evidence of the exposure pathways linking the source of contamination and the exposed receptors. With the exception of air emissions (associated with dust generation), all exposure mechanisms are based upon unplanned events that are well understood in the industry with suitable management and consequence mitigation measures in place.

All risks were deemed to be very low according to characterisation in accordance with the DoH risk matrix, which determined that no further risk characterisation is required.

No specific human health risk management or the implementation of mitigation measures are necessary and this is consistent with advice from the Department of Health that indicate that detailed Human Health Risk Assessment is required when the source of the risk is located within close proximity of sensitive receptors.

This Human Health Risk Assessment demonstrates that the Proposal is not expected to have an impact on public health at the Yungngora and Jimbalakudunj Communities, nor on the associated pastoral station workers and Traditional Owners travelling on the land within the Development Envelope.

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Appendix A. Peer Review of Human Health Risk Assessment, Valhalla Gas Exploration and Appraisal Program

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TECHNICAL MEMORANDUM

Date: January 7, 2022

To: Samantha Richardson
Black Mountain Energy, Perth, WA

From: Travis Kline, MEM, BCES,
Geosyntec Consultants, Inc., Washington DC
David Reynolds, Ph.D., CEnvP (SC), Sydney, NSW

Subject: Peer Review of *Human Health Risk Assessment*, Valhalla Gas
Exploration and Appraisal Program, Bennett Resources, December 14,
2021

1. INTRODUCTION

Overall, the document is well-organized and conforms to the recommendations and structure as outlined in *Health Risk Assessment (Scoping) Guidelines* (DoH 2010). These guidelines provide a framework for the health risk assessment component for the Environmental and Health Impact Assessment processes, and incorporate, by reference, Department of Health (DoH) and Ageing and enHealth Council (2002, 2012) environmental health risk assessment guidelines as well as DoH human health risk and hazard guidelines issues for Western Australia (DoH 2006).

2. Recommendations

- a. **Surface Water Resources:** There is no discussion of surface water bodies (e.g., creeks, ponds) within the proposal area, although Section 2.1.1 lists swimming and fishing as relevant recreational activities in consideration of local communities. It is understood that there are no permanent water bodies within the development envelope, with Mt. Hardman Creek, a seasonal water body, the closest for consideration. Given that there is no vulnerable shallow aquifer in communication with even seasonal creeks, the predominant release mechanism associated with potential environmental exposure is the catastrophic failure and release of hydraulic fracturing fluid from container trucks or the lined retention ponds. The document could benefit from a discussion surrounding the low potential for surface water impacts and clarification of how flowback water will be managed on-site (e.g., impoundment construction, lining, secondary containment, if any). Surface water, as a receiving medium, should be added to Figure 2-2, if only to designate the absence of a complete exposure pathway under foreseeable future conditions.
- b. **Constituents of Potential Concern (CoPCs):** The document could benefit from a discussion of the CoPCs at issue. Section 3, Health Risk Assessment, notes volatile

organic compounds (VOCs) and dust in ambient air and drilling fluids and HFS fluids in groundwater. Table 3-3 lists the potential presence of diesel range hydrocarbons, barium, cadmium, and chromium in soil, resulting from drilling fluids, but there is no discussion of surfactants, algicides, lubricants, etc., associated with hydraulic fracturing fluids. It is understood that indirect inhalation of off-gassing VOCs or dust by populations other than Valhalla Gas employees is likely to be very minimal, given the large ambient air mixing zone. Direct contact with soil, impacted by localized spills at well heads during development, by non-Valhalla Gas employees is not anticipated, except as a component of trespassing. The pastoral bores do not supply residential drinking water, but they do supply water for cattle and, as noted by Bennett, periodic ingestion by station workers or transients. I will defer to Valhalla in regard to specific CoPCs in light of the need to protect business confidential/proprietary mixtures, but in the absence of more detail with regard to type of chemical and anticipated concentration in environmental media, it is impossible to judge the accuracy or defensibility of generalized, qualitative assessment and elicited outcomes, such as “potentially temporary upset stomachs.” In addition, Section 3.3 notes that some CoPCs could be associated with bioaccumulation. In light of cattle watering (Liveringa aquifer, low susceptibility from well development) and biotrophic transfer, the document could benefit from additional clarification. I am in agreement that there is low potential for chronic exposure (even if carcinogenic constituents are present) and very low potential for negative acute exposures; however, additional detail regarding specific CoPCs and anticipated ranges of environmental concentrations (perhaps in comparison to relevant health-based screening criteria) would significantly support the document as a defensible decision management tool and obviate the need for a detailed HHRA in the eyes of EPA and DoH.

- c. **Soil to Groundwater Leaching:** There is limited to no discussion of surficial releases and their potential impact to groundwater. I am unsure of the depth to the Liveringa (or the screen depth of pastoral bores completed in the Liveringa), but if it is within 30 mbgs, leaching and transfer to groundwater (and anticipated dilution/attenuation) is worth mentioning. Figure 2-2 can be updated to show surface soil to subsurface soil to groundwater as a contributing pathway (unless the depth to the Liveringa is too extreme). It is also worth mentioning that surficial releases will attenuate with depth and that there are no anticipated complete exposure pathways associated with subsurface soil for populations other than Valhalla Gas workers. Figure 2-2 should also be updated to include incidental ingestion of soil in any complete exposure pathway identifying dermal contact with soil.
- d. **Minor Clarifications:** The HHRA was not reviewed from a purely editorial perspective, although the following minor corrections are noted:
 - i. **Section 3.1.1, Hazard:** VOCs should be defined as volatile organic compounds (not carbons).
 - ii. **Section 3.1.1, Hazard:** The third bullet in this list should be revised to reflect: “VOCs and products of incomplete combustion (PICs) from flaring during well testing activities on site.”
 - iii. **Ramboll 2019.** Geosyntec did not conduct a thorough review of Ramboll 2019 but notes that this study reflects one specific operation. Geosyntec has not judged whether this operation is sufficiently similar in scope and nature to the Valhalla proposal, but is in general agreement that the low-level emissions associated with these activities will readily dissipate in the ambient air breathing zone, given the huge mixing zone available under proposed operations. Geosyntec does note that the only identified human health concern in the Ramboll 2019 study was predicated on dust and driven by background conditions (i.e., PM2.5, Caversham monitoring station), not specific to the study area.

3. SUMMARY & CONCLUSION

Overall, the study is very close to complete, is well ordered, easy to follow, and consistent with relevant administrative authority guidelines. Excepting additional discussion regarding the projected nature and extent of proposal CoPCs, and in recognition of the very low potential for exposure to populations outside Valhalla Gas workers, it is unlikely that a more detailed and comprehensive HHRA will be required.

Sincerely,



Travis Kline, MEM BCES
Senior Principal



David Reynolds
Senior Principal

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