SREBA FRAMEWORK
Consultation Draft

A guide to undertaking a Strategic Regional Environmental and Baseline Assessment in the Northern Territory

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This document has been published on the Department of Environment and Natural Resources consultation website www.denr.nt.gov.au/consultation for the purposes of seeking feedback from the public. Submissions can be made by emailing sreba@nt.gov.au. The consultation draft of the SREBA Framework is open to public comment until 14 February 2020.

Acknowledgement:

This draft SREBA Framework was developed with significant input from CSIRO, and input from many different subject matter experts who contributed to workshops, discussion papers, draft Guidance Notes, and the overall Framework. A draft Framework was reviewed by a US consultant (Ambient Technologies, LLC) and informed by his work as Director of Marcellus Center for Outreach and Research at Pennsylnania State University .

The result is a Framework which includes a set of technical Guidance Notes that are have drawn from best practice and tailored to the NT's circumstances. The Framework includes the flexibility to further refine baseline studies to reflect regional differences within the NT. The approach will be reviewed on a regular basis to ensure that lessons learnt are incorporated and the approach remains fit for purpose in the NT.

Contents

Overview

The Framework was developed in response to the Northern Territory Government's acceptance in April 2018 of all recommendations of the *Scientific Inquiry into Hydraulic Fracturing in the Northern Territory*. The Inquiry noted the importance of undertaking pre-development baseline studies of regions with onshore unconventional petroleum resources before production approvals were granted. These baseline studies were grouped under the umbrella term of Strategic Regional Environmental and Baseline Assessment, or SREBA. Chapter 15 of the Final Report describes the components the Inquiry Panel felt should be included in a SREBA in order to provide government, regulators, communities and industry with an improved information base to assess and plan the development of a future industry.

Whilst the Final Report describes the requirements and components of a SREBA in general terms, this Framework seeks to translate the intent of the Final Report into detailed technical guidance on how to undertake these baseline studies, whilst also allowing for flexibility, innovation and participation of communities in the regions where the studies will take place. This consultation draft of the SREBA Framework explains the roles and responsibilities of those involved in these baseline studies, and technical guidance around how these studies should be designed and delivered. The requirements have been translated into seven elements:

- Context and delivery responsibilities - an explanation of where and when a SREBA is required, the role of Government, industry and the community, how the series of studies will be designed, managed and reported, and how the information generated will be managed to protect privacy and commercial confidentiality, whilst still allowing the information to be published as a valuable public resource.
- A Guidance Note for studies of water quality and quantity.
- A Guidance Note for studies of aquatic dependent ecosystems.
- A Guidance Note for studies of terrestrial ecosystems.
- A Guidance Note for studies of greenhouse gases –focused heavily on methane because this is the gas most likely to be affected by development of onshore petroleum resources.
- A Guidance Note for environmental health studies – because these are most relevant to a regional scale health assessment.
- A Guidance Note for social, cultural and economic studies, and a strategic regional assessment of how the development of an onshore unconventional gas industry may affect communities within the region.

The design and delivery of this series of studies needs to be carefully coordinated and this is addressed in Section 2.

It is important to note that these pre-deveopment baseline studies precede, and in no way replace, studies required for planning or authorisation of individual projects that may be undertaken in a region. Project-level analysis and assessment are separate activities and are tailored to the particular characteristics and requirements of those projects. The regional level baseline studies addressed by this consultation draft will provide a broader view of the region where projects may operate, and the information collected will be valuable to both communities and industry as they assess the likely outcomes of those projects.

A SREBA will initially be undertaken for the Beetaloo Sub-basin as it is currently the only proven onshore unconventional gas reservoir in the Northern Territory. The requirement for a SREBA in other unconventional reservoirs will be revisted once there is more certainty around their potential.

Introduction

The purpose of this framework is to define the objectives and content of a Strategic Regional and Environmental Baseline Assessment (SREBA). The framework provides information on:

- Scope and content
- Purpose and application
- Gathering and managing baseline data
- Analysis, synthesis and reporting
- When SREBAs are required
- Development and implementation, including timeframes
- Governance arrangements and stakeholder engagement

Section 1 describes the background to and content of a SREBA. Section 2 describes how a SREBA will be developed and delivered for a specific region. Sections 3 to 8 provide technical guidance for undertaking each of the baseline studies that make up a SREBA.

1. Context and content

1.1. Background

In December 2016, the Northern Territory Government established the *Scientific Inquiry into Hydraulic Fracturing in the Northern Territory*[1] (Scientific Inquiry, 2018), which found that:

> "…..it is the Panel's opinion that, provided all of the recommendations made in this Report are adopted and implemented in their entirety, not only should the risks associated with an onshore shale gas industry be minimised to an acceptable level, in some cases they can be avoided altogether."

In April 2018, the Northern Territory Government announced it had accepted all recommendations of the Inquiry's Final Report and commenced their implementation. This includes Recommendation 15.1 – "*That a strategic regional environmental and baseline assessment (SREBA) be undertaken prior to the granting of any further production approvals*". In the context of the Inquiry, this applies to onshore unconventional gas reservoirs.

The Final Report envisaged the purpose of a SREBA was "*to provide the information necessary for appropriate decisions to be made about the development of any onshore shale gas industry in the NT, including assessment of water and biodiversity resources, to inform land-use planning, and the collection of baseline data to provide a reference point for ongoing monitoring*".

The Final Report noted that the lack of adequate pre-development assessment and environmental baseline data was one of the biggest environmental regulation and management-related issues associated with the

[1] The full report is available at https://frackinginquiry.nt.gov.au/inquiry-reports/final-report

development of the gas industry in the US and Queensland. The Inquiry considered adequate pre-development baseline information was important to:

- predict the magnitude of any post-development change and assess its impact
- underpin modelling of the possible impacts of any new industry
- inform site-specific quantitative risk assessments by industry and regulators
- strategically plan for the rollout of any onshore shale gas industry, by industry, government, community and affected stakeholders
- identify key sensitivities in a regional context, and openly and constructively investigate and resolve issues that may arise as a result.

Additionally, an integrated, strategic and coordinated approach to data collection over large regions with multiple industry players would help ensure consistency between datasets, and maximise their value for region-wide assessment and management.

The Final Report also noted that there is generally poor spatial coverage of data on surface and groundwater characteristics and of both aquatic and terrestrial biodiversity in the regions of the Northern Territory most likely to be affected by any onshore shale gas industry. Limited information on biodiversity assets and their location impedes the ability to properly assess the risks of any shale gas development (especially cumulative risks over large areas) and reduces the ability to plan the location of infrastructure to minimise the risk of unacceptable impacts to aquatic and terrestrial biota.

Consequently, the Final Report considered it essential that the key knowledge gaps identified in the Final Report are addressed prior to the granting of any further production approvals for onshore gas development.

The Final Report made three specific recommendations to address the issues described above:

- **Recommendation 15.1** - *That a strategic regional environmental and baseline assessment (SREBA) be undertaken prior to the granting of any further production approvals*
- **Recommendation 15.2** - *That the regulator oversees the auditing and the data-collection processes and provides a central repository for all data informing any SREBA*
- **Recommendation 15.3** - *That a SREBA should be completed within five years from the first grant of exploration approvals; and must be completed prior to the grant of any production approvals.*

Chapter 15 of the Final Report describes the elements of a SREBA that would meet these recommendations. Other chapters and recommendations throughout the Final Report also refer to SREBA, and a full list of recommendations relevant to the development of a SREBA is included at the end of this document.

The Final Report also paid particular attention to the potential social and cultural impacts associated with onshore gas development. While the development of a regional social and economic baseline, and an assessment of Aboriginal cultural impact, are described as part of a SREBA in Chapter 15 of the Report, they are also considered more fully in Chapters 11 and 12. In particular, Chapter 12 of the Report provides specific recommendations in relation to the requirements for, and content of, strategic social impact assessment (SIA), including:

- **Recommendation 12.1** - *That a strategic SIA [Social Impact Assessment], separate from an EIS [Environmental Impact Statement], must be conducted for any onshore shale gas development prior to any production approvals being granted.*
- **Recommendation 12.6** – *That a strategic SIA be conducted as part of any SREBA to obtain essential baseline data.*
- **Recommendation 12.7** - *That in order to operationalise an SIA framework in the NT, the Government must:*
  - *give the regulator power to request information from, and to facilitate the collaboration between, individual gas companies, government agencies (including local government), Land Councils, communities and potentially affected landholders;*
  - *establish a long-term participatory regional monitoring framework, overseen by the regulator, with secure funding from the gas industry and able to endure multiple election cycles; and*
  - *establish periodic and standardised reporting to communities on the social, cultural, economic and environmental performance of the industry through either the regulator or a specialised research institution. This includes information from the monitoring of key indicators, and an industry-wide complaints and escalation process.*

The terms '*Baseline Study*' and '*Strategic Regional Assessment'* are used for the purposes of the Social, Cultural and Economic Guidance Note, to ensure there is a clear differentiation between the type of assessment described in the Final Report and a project-level Social Impact Assessment (SIA). While developing the Social, Cultural and Economic Guidance Note, initial consultations and workshops showed the terms 'Strategic SIA,' 'SIA' and 'Strategic Assessment' - which are used interchangeably in the Final Report - were a cause for confusion, as the features of project-level SIA and Strategic Regional Assessment are different in nature and require different levels of information regarding project-specific activities.

The objective of these Baseline Studies and the Strategic Regional Assessment is to develop an understanding of the social, cultural and economic environments across a region, to identify aspects that may be sensitive to development and to consider the potential cumulative impacts of multiple projects.

1.2. Purpose and Application of a SREBA

The primary purpose of a SREBA is to provide adequate pre-development baseline data to inform strategic land-use planning and resource management, regional and project-level assessment, effective regulation, and monitoring associated with the development of an onshore gas industry in that region. Good management of our resources, the environment and the services they provide requires accurate and reliable information and a clear understanding of biophysical and socio-economic interactions. Improving our understanding of the environment of the Northern Territory is central to the objective of providing a robust evidence base to inform management and regulatory decisions.

Baseline studies include the collection and analysis of data within the broad domains described in Section 1.3 and Table 1.1. When these studies are consolidated as a baseline report they will provide a region-wide perspective of the pre-development environment and the communities that work and live in the region; describe and map important values within that domain; and identify potential sensitivities to onshore gas development. This baseline information and sensitivity analyses will be valuable to regulators, industry and the community, and a common understanding of the baseline will be promoted through open access to SREBA outputs.

The baseline data secured through the SREBA may be applied in a variety of mechanisms for informed decision-making during the development of the onshore gas industry in that region. This Framework does not provide detailed guidance about such application (for example, quantitative risk assessment), except where specifically addressed in individual Guidance Notes in response to Final Report recommendations or legislative drivers, most notably for social impact assessment. Links between the SREBA process and management application are illustrated in Figure 1, and potential application of key information outputs from each SREBA domain are tabulated in Table 1. Some aspects of the application of SREBA outputs are described below.

1.2.1. Area-based assessment

A critical value of the SREBA will be to enable the assessment of regional and cumulative effects of likely development scenarios for onshore gas development, rather than effects to be considered on a well-by-well, or project-by-project basis. Such regional effects will include the establishment of infrastructure to service entire gas fields, processing facilities, transport requirements, etc. There are several existing models for regional or area-based assessment which are discussed in the Final Report (section 14.8.2), including in Alberta and British Columbia. Strategic assessment may be undertaken under Part 10 of the Commonwealth *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) to address the cumulative impacts, on matters of national environmental significance, of a class of actions at a regional scale. Provision for strategic assessment is also contained in the new *Northern Territory Environment Protection Act 2019*, which the Northern Territory Government may consider in the future. In addition to better accommodating consideration of cumulative impacts, area-based or strategic assessment may improve regulatory efficiency and reduce the need for repetitive environmental impact assessment of individual, but similar, gas projects.

The application of area-based or strategic assessment is a future decision for the Northern Territory government and industry regulator, but the design of studies to collect SREBA baseline information should be mindful of the potential requirements of the EPBC Act.

Other initiatives such as the Commonwealth Geological and Bioregional Assessment (GBA) program may provide a model for the use of regional-scale data to assess the potential impacts of onshore gas development scenarios on water resources and other identified matters of environmental significance. There should be alignment between in the SREBA program and such initiatives where appropriate.

1.2.2. Project-level assessment

The requirements for project-level assessment and approvals for onshore petroleum activities in the Northern Territory are prescribed in the *Petroleum Act 1984*, associated regulations, and the *Environmental Assessment Act 1982*. A SREBA does not replace project-level impact assessment and approval processes, or the need for proponents to prepare an Environmental Impact Statement under either Northern Territory or Commonwealth legislation (such as the *Environment Protection and Biodiversity Conservation Act 1999)* if required by the regulator.

Nonetheless, the completion and publication of SREBA baseline information and regional strategic social impact analysis will improve the environmental assessment of individual projects through:

- assisting the proponent to design the project to maximise local and regional social, cultural and economic benefits
- identifying features that are potentially sensitive to the effects of industry development, allowing proponents to more easily avoid or mitigate potential negative impacts during the project design phase
- providing contextual regional data to assist the Northern Territory Environment Protection Agency (NT EPA) in determining whether assessment under the *Environment Assessment Act 1989* is required
- streamlining project-level environmental assessment by improving data availability for local and regional context and informing assessment in focusing on identified significant issues
- facilitating the robust assessment of potential cumulative impacts through providing a regional baseline and identifying spatially explicit environmental values
- where relevant, assisting in the identification of appropriate environmental offsets.

1.2.3. Strategic regional planning (land-use and infrastructure)

Baseline information collected during the SREBA can inform the strategic allocation of land to infrastructure associated with gas field development (e.g. pipeline, roads, processing plants) and help resolve potential land use conflicts. This may be done, for example, by the identification and delineation of areas of high conservation value (using the objective criteria described in the aquatic and terrestrial ecosystems guidance notes), so that these areas may be proactively avoided during infrastructure planning. The delineation of such areas may also inform the land release process for further gas exploration, or contribute to the declaration or refinement of reserved blocks ('no go zones'), as described in section 14.5 of the Final Report.

1.2.4. Water planning and licencing

Baseline information for ground and surface water collected during the SREBA will address many of the requirements under the *Water Act 1992* for the development of regional Water Allocation Plans (WAPs). Recommendation 7.7 effectively requires that a WAP is in place to enable the allocation of groundwater resources to the onshore gas industry and inform the assessment and grant of individual water extraction licences.

1.2.5. Regional and compliance monitoring

The Final Report considered that the collection of baseline data during the SREBA provided a reference point for ongoing monitoring. Monitoring may be at project scale, for example as a condition of approval in order to demonstrate that potential impacts have been successfully mitigated; or at regional scale, where monitoring may be implemented to quantify cumulative impacts, or allay community concerns about longer-term effects on human or environmental health. In both cases, regional baseline data collected during the SREBA will be important for the development of appropriate and cost-effective monitoring methods with adequate power to determine effects above an agreed threshold.

1.2.6. Strategic Regional Assessment

Baseline social, cultural and economic information collected during the SREBA will form the knowledge base to examine the potential social impacts of onshore gas industry development in the regional context.

Social, cultural and economic baseline studies will:

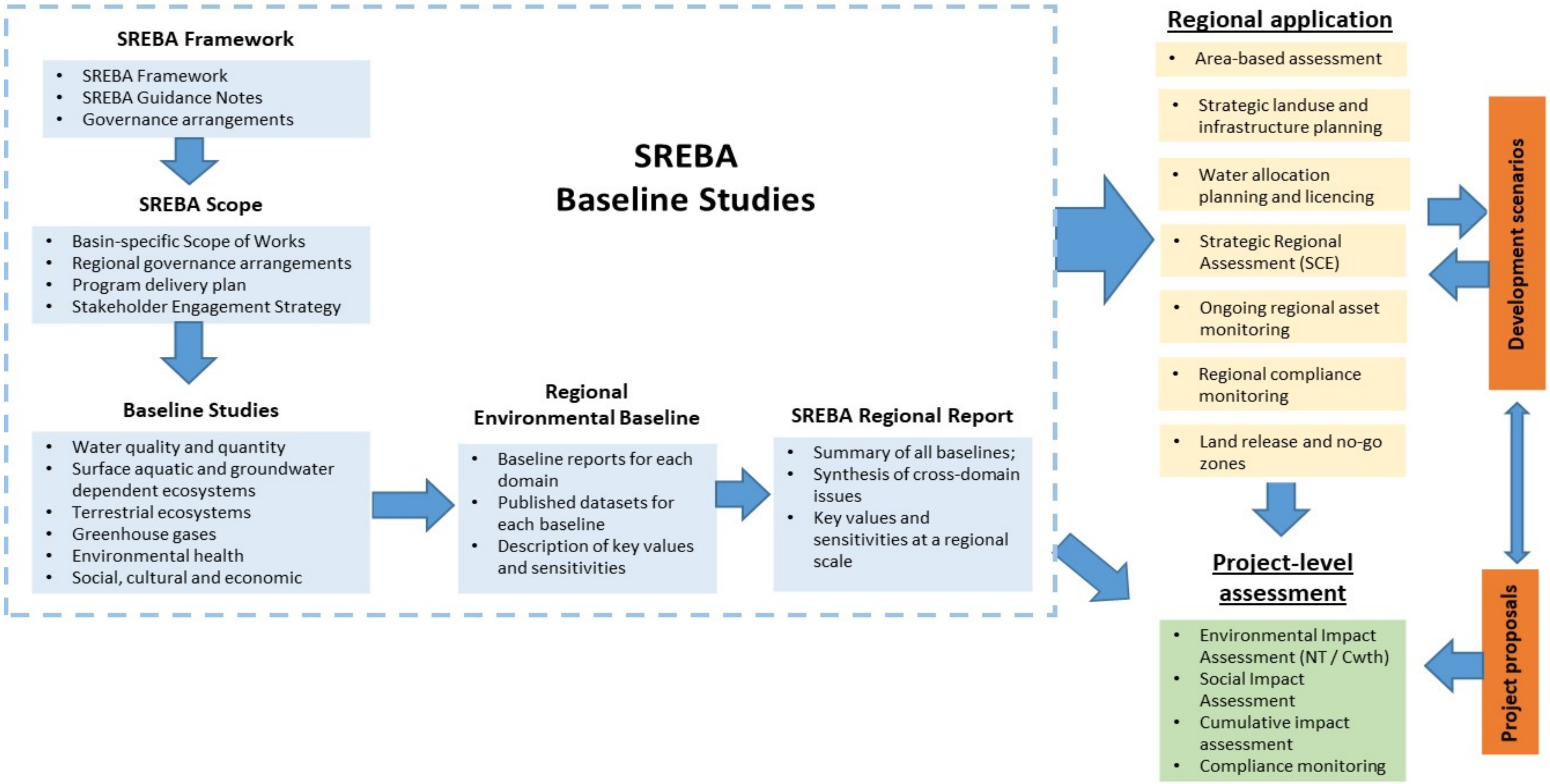
- establish baseline data, around identified themes, inclusive of qualitative information such as values, beliefs, goals, aspirations, perceptions, attitudes and capital across a region
- determine and correlate locally agreed indicators from baseline data and information for future monitoring of impacts and outcomes.

The Strategic Regional Assessment aims to deliver an independent and valuable resource for proponents, government, and the NT EPA in their role of assessing project-specific SIAs. It will do this through identifying, mapping and comprehensively assessing the social, cultural and economic environments of a region, as well as provide a mechanism for cumulative impact assessment, monitoring and evaluation.

The Strategic Regional Assessment brings together information regarding potential industry development together with information from the Baseline Studies to:

- assess potential cumulative impacts of industry development in the region
- determine regional development aspirations and potential outcomes
- design and establish a regional monitoring framework.

Figure 1.1 Diagrammatic representation of the key elements of the SREBA process and application to regional and project-level planning, assessment, regulation and monitoring.



1.3. Content of a SREBA

The Final Report (Chapter 15) provides substantial, but not entirely prescriptive, guidance about the content of a SREBA. Based on this guidance, the baseline studies in the SREBA are grouped within six domains:

- Water Quality and Quantity
- Aquatic Ecosystems
- Terrestrial Ecosystems
- Methane and Greenhouse Gas
- Environmental Health
- Social, Cultural and Economic

In addition to the guidance provided in the Final Report, it is important that the baseline data collected during a SREBA assists in implementing other relevant recommendations of the Inquiry, and contributes to other legislative, regulatory and planning requirements of the Northern Territory Government relevant to the potential development of an onshore gas industry. All of these factors were considered in the development of detailed Guidance Notes for each of the six domains, which are included in Section 3 of this Framework.

For each domain, the Guidance Note considers and describes:

- information requirements (as outlined in the Inquiry and for additional factors described above)
- the assessment approach (the array of baseline studies required)
- appropriate methods for data collection
- analysis and synthesis (to develop the required information products)
- reporting and data management.

The key information products from each domain are summarised in Table 1 on the following page. Each domain will produce a Baseline Report containing a detailed description of the methods, results, analyses and synthesis products, as well as cataloguing the data collated and collected during the SREBA, with appropriate metadata.

Table 1. Key information outputs from each domain of the SREBA, and potential application of this information.

Domain	Key SREBA Information and Data Outputs	Regional Application
Water quality and quantity	• Description and mapping of regional hydrostratigraphy, including characterisation of all aquifer systems • Recharge rates, recharge zones and sustainable yield for potentially affected aquifer systems • Description and mapping of surface water resources • Mapping and characterisation of water dependent ecosystems • Integrated regional groundwater/surface water model • A natural water balance for each identified water resource. • Regional water balance which shows the connection between each water resource. • Baseline regional water quality for potentially affected aquifers and surface waters	• Development and refinement of regional Water Allocation Plan • Assessment of water licence allocation • Strategic infrastructure planning • Area-based environmental assessment (e.g. strategic assessment under EPBC or NT EP Acts) • Project-level environmental impact assessment • Refinement of conceptualisation of regional hydrogeology • Refinement of ecological conceptual models for water-dependent systems • Project-scale water monitoring requirements • Regional scale ground and surface water monitoring
Aquatic ecosystems	• Mapping and classification of all aquatic ecosystems within the SREBA boundary • Description of assemblages of aquatic biota and evaluation of environmental determinants, including predictive spatial models • Spatial distribution models for significant aquatic species • Identification of high ecological value aquatic ecosystems • Identification of dry season refugia	• Development and refinement of regional Water Allocation Plan • Strategic infrastructure planning • Area-based environmental assessment (e.g. strategic assessment under EPBC or NT EP Acts) • Project-level environmental impact assessment • Identification or refinement of “no-go zones” • Refinement of ecological conceptual models • Regional scale monitoring

Domain	Key SREBA Information and Data Outputs	Regional Application
	• Evaluation of the sensitivity of HEVAEs and significant species to onshore gas-related development • Description of indicators and methods for regional monitoring	
Terrestrial ecosystems	• Regional ecosystem mapping • Description of regional assemblages of plants and selected vertebrate and invertebrate groups, and regional biogeographic patterns • Spatial distribution models for significant species • Identification and mapping of high conservation value areas • Evaluation of sensitivity of significant species to onshore gas-related development • Description of indicators and methods for regional monitoring	• Strategic infrastructure planning • Area-based environmental assessment (e.g. strategic assessment under EPBC or NT EP Acts) • Project-level environmental impact assessment • Identification or refinement of "no-go zones" • Refinement of ecological conceptual models • Regional scale monitoring
Greenhouse gas emissions	• Regional methane baseline assessment • Identification of areas with, and sources or, elevated emissions pre-development	• Project-level environmental impact assessment • Development of project-level compliance monitoring • Regional scale, post-development monitoring
Human health	• Baseline studies of human health conditions (medical, well-being and mental health) that may be affected by exposure or proximity to development of an onshore gas industry • Baseline studies of environmental health parameters (water, air, soil, food sources) that may be affected by exposure or proximity to development of an onshore gas industry	• Identification or refinement of setback distances or buffer areas, and "no-go zones" • Regional scale monitoring for cumulative impacts over time • Strategic infrastructure planning to mitigate potential stresses on communities within the region • Community engagement strategies between industry, Government and communities within the region

Domain	Key SREBA Information and Data Outputs	Regional Application
	• A human health risk assessment undertaken at regional scale, describing potential risks, threshold values, impacts, and potential to mitigate adverse effects of development of an onshore gas industry	• Project-level social impact assessments and management plans • Regular reporting to communities within the region of the public/environmental health impacts and risks associated with industry development
Social, cultural and economic	• Baseline assessment report identifying at a regional scale the social, cultural and economic characteristics of the region • A regional social assessment report describing the social, cultural and economic environment of a region, identifying and assessing the potential cumulative impacts of multiple projects over time, and recommending a monitoring and evaluation program to be implemented if industry progresses to the development phase.	• Identification or refinement of setback distances or buffer areas, and “no-go zones” • Regional scale monitoring for cumulative impacts over time • Strategic infrastructure planning to mitigate potential stresses on communities within the region • Community engagement strategies between industry, Government and communities within the region • Project-level social impact assessments and management plans • Potential training, upskilling and business development programs for the region • Regular reporting to communities within the region of the social, cultural and economic impacts and risks associated with industry development

The final SREBA Report will provide a summary of the domain Baseline Reports, as well as examining the interconnection and dependencies between the different elements of the SREBA in order to provide an overview of values of the region, sensitivities to potential development, opportunities to maximise social, cultural and economic benefits, and management and regulatory implications. It is anticipated that development of the final Report would include a workshop of authors of the various domain baseline reports, as well as industry and community representatives such as a regional reference group (see Section 2).

The collation of the technical baselines will also facilitate the development of recommendations in the Regional Social Impact Assessment on community aspirations and any competing land uses of a region; the resilience of a community and ability to absorb change; the recommended pace, scale and type of development that is sustainable; policy and regulatory implications and ongoing governance structures and community involvement.

The technical Guidance Notes describe the general approach and methods for pre-development baseline studies undertaken in a SREBA in any region of the Northern Territory. However, some of the detail of the approach and appropriate methods will depend on the environmental and social attributes of the particular region in which each SREBA is undertaken. The process for 'operationalising' this Framework and Guidance Notes for an individual SREBA is described in Section 2.

1.4. References

Scientific Inquiry (2018). *Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory*. Darwin, 2018. https://frackinginquiry.nt.gov.au/inquiry-reports?a=494286

2. Development and delivery of regional baselines

2.1. Initiation and timeframes

Recommendation 15.1 states that a SREBA should be undertaken prior to the granting of production approvals for extraction of unconventional onshore gas. That is, a SREBA is not required for approval of exploration activities (which may include the drilling and fracking of a number of exploration wells) but is required to enable approvals once development of an onshore shale gas play moves into the production phase. As stated in the Final Report (section 16.3.2), this refers to the approvals for production activities (including clearing, drilling and fracturing), rather than the grant of a production licence.

As of late 2019, the Beetaloo Sub-basin is the only proven unconventional petroleum reservoir in the Northern Territory and is considered the most prospective onshore petroleum opportunity. The Northern Territory Government has agreed that a SREBA is required for the Beetaloo Sub-basin in order to support the potential development of this resource and to meet industry projections of production-level activity by 2022-23. Other sedimentary basins in the Northern Territory have the potential to contain unconventional reservoirs but the prospective source rock formations have not been tested to the extent that they could be classified as known unconventional reservoirs. Uncertainty about the potential of these other basins means that similar regional baseline studies are not currently warranted. A SREBA will not be required for conventional onshore petroleum development, noting that this may involve hydraulic fracturing of some wells.

Recommendation 15.3 of the Final Report states that a SREBA should be completed within five years from the first grant of exploration approvals, referring to approvals granted after the moratorium was lifted. Some of the guidance in Chapter 15 of the Report suggested that two to five years of baseline data may be required for adequate coverage of inter-annual variability of aquatic ecosystems, and potentially even longer in drier areas. While multi-year sampling is clearly essential for some elements of a SREBA, the approaches and methods outlined in the Guidance Notes (Section 3) suggest that, if undertaken efficiently and with adequate resources, a SREBA can be completed within three years of commencement. In some cases, a pragmatic approach is required to balance the tension between sampling across the full range of inter-annual environmental variability and providing reasonable certainty to industry and investors. Careful sampling design, modelling, and the use of conservative assumptions during risk assessment can also reduce problems associated with large environmental variability.

It is expected that, where required, a SREBA would commence after early exploration success but well before production approvals are expected to be applied for, likely during the appraisal phase of industry development.

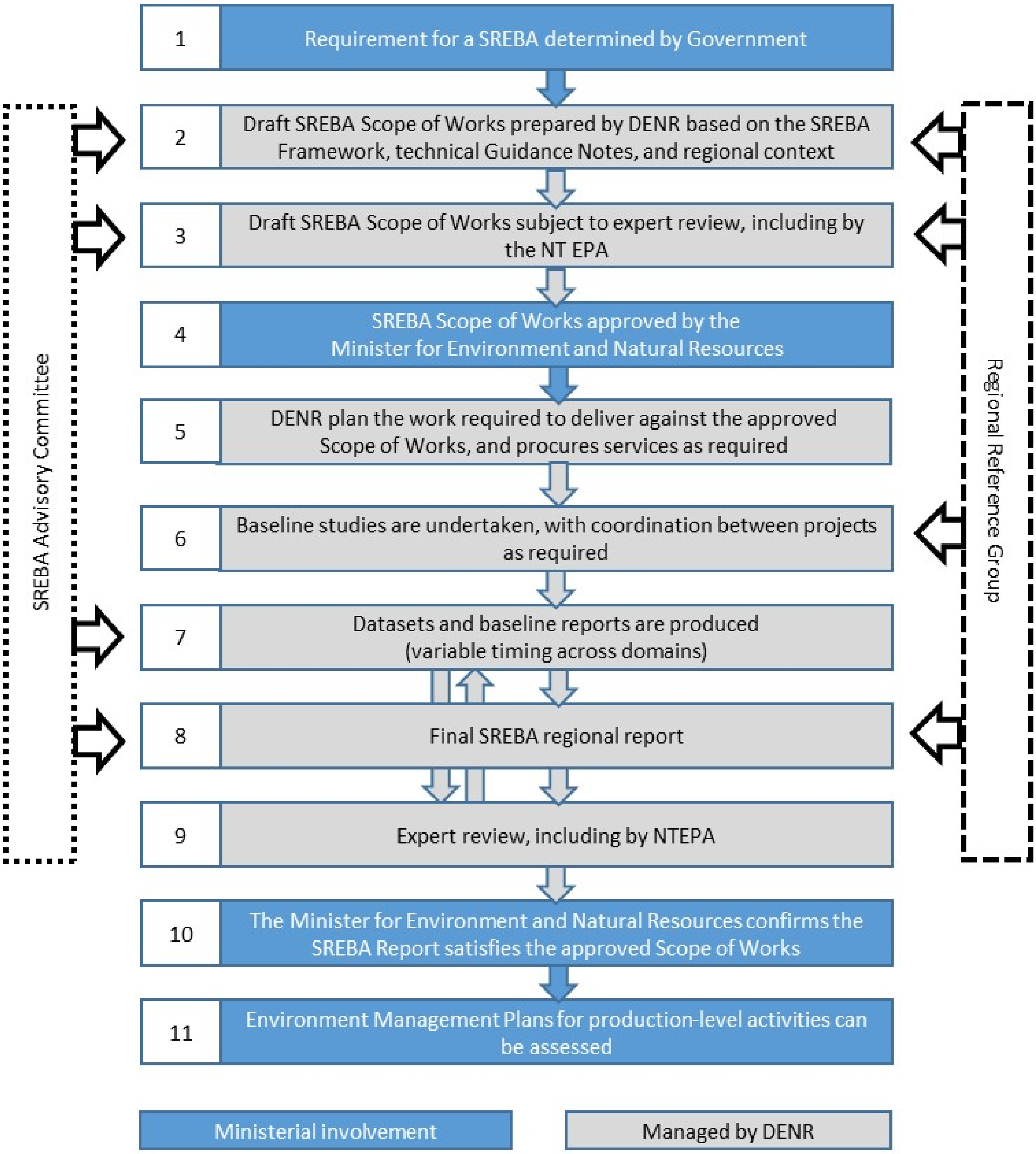
2.2. Governance arrangements

The key elements of the governance of the SREBA process are summarised in the table below, and the flow diagram (Figure 2.1) that follows:

	Role
Minister	- The Minister for the Environment and Natural Resources will approve the Scope of Works for a SREBA. This Scope of Works will describe in detail the regional studies that must be completed within each domain of the SREBA. The Minister may choose to seek advice from the NTEPA on the draft Scope of Works before it is finalised - After submission of the SREBA final report, the Minister for the Environment and Natural Resources will determine if the requirements of the Scope of Works have been met, and the SREBA is completed. This will then allow the Minister to consider applications for environmental approval for production activities in the SREBA region
Department of Environment and Natural Resources	- Project management of the SREBA, including coordinating and overseeing the delivery of all required studies, data management and publication, and developing and implementing the stakeholder engagement and communications strategy - Will prepare the Scope of Works for a SREBA for consideration by the Minister for Environment and Natural Resources, following the guidance within the SREBA Framework - Will coordinate the program of work and the various studies required to deliver the approved Scope for the SREBA. This is likely to involve procurement of external parties to deliver various components of the SREBA. - The Department will utilise their own expertise, and draw on support from other departments and/or procure services from external service providers as appropriate
SREBA Advisory Committee	- The Department may establish one or more technical advisory committees to provide expert input into the design of different baseline studies
Regional Reference group	- The Department may establish a regional reference group comprising stakeholders who live or have interests within the SREBA region to ensure there is appropriate local and regional engagement in baseline studies and SREBA outcomes
Other Northern Territory Government Agencies	- Other Northern Territory agencies such as the Department of Health and the Department of the Chief Minister may provide input on studies of environmental health, or social, cultural and economic studies. This will be coordinated by the Department of Environment and Natural Resources

	Role
Other contributors	- There may be opportunities for other Northern Territory organisations to advise on and/or deliver baseline studies for the SREBA. This will be facilitated by the Department of Environment and Natural Resources in their role as SREBA Project Manager

Figure 2.1 The development, delivery and approval process for a SREBA.



2.3. Scope of Works

The Scope of Works is the detailed, region-specific description of the baseline studies, synthesis and reporting required for the SREBA, based on this Framework and the technical Guidance Notes for each domain. The Scope of Works will be developed by DENR with input from technical advisory committees, industry, regional stakeholders and external subject matter experts as required. The draft Scope of Works will be reviewed by the NT EPA prior to consideration and approval by the Minister for Environment and Natural Resources.

The Scope of Works will include:

- a stakeholder engagement strategy that identifies regional stakeholders and their interests, including a Regional Reference Group if appropriate
- a draft timeframe to deliver all elements required under the Scope of Works, identifying independencies between elements, critical constraints, risks and progress review points
- for each baseline domain:
  - the spatial and temporal boundaries of the domain
  - detailed information requirements and data collection methods
  - a project plan, indicating timeframes, resources required and risks
  - reporting and data management requirements
- the approach to collating and synthesis information from each domain into a regional report.

In addition to being consistent with this Framework and the technical Guidance Notes, the Scope of Works (and subsequent delivery of the SREBA) should be informed by the general principles described below (Table 2.2).

Delivery of the multiple components of the SREBA will require complex program planning, and the Department of the Environment and Natural Resources will be responsible for this role. SREBA studies may be contracted to suitably qualified service providers, research agencies, or delivered by NT Government experts.

2.3.1 Boundaries and timeframes

Whilst it may be possible to define an overall, indicative spatial boundary for a SREBA within the Scope of Works, the spatial boundary for individual domains will be addressed in the design of individual studies, informed by the guidance notes for each domain.

In general, the spatial boundary should encompass the elements of the environment on which onshore gas development could feasibly have an impact, including predictable indirect and cumulative impacts; as well as sufficient regional extent to provide adequate context to assess the significance of any potential impact. While boundaries may differ between domains, these will be standardised to the extent possible in development of the Scope of Works. Determination of appropriate SREBA boundaries will also consider feedback from community, industry and regulators.

A SREBA baseline will reflect the pre-disturbance nature of a region. The temporal scope of the SREBA is relevant in ensuring that baselines adequately encompass inter- and intra-annual variation in regional attributes and values. The Scope of Works should consider what time horizons are appropriate for each baseline domain.

SREBA development principles

Overarching principles to inform the design and execution of a SREBA are described below. These will be applied when developing the Scope of Works and at each subsequent stage of delivering the studies required.

Principle	Expectation:
Fit for purpose, flexible, adaptive and tailored to local and NT needs	We will adopt an approach that is proportionate, flexible and adaptable to regional and Northern Territory circumstances. The SREBA will take a number of years so governance should be sufficiently dynamic to respond over time.
Scientifically robust	The baseline studies and indicators will utilise science-based methodologies to ensure the studies are as objective and as free from bias as possible, and any uncertainty around data, information and conclusions will be disclosed. Appropriate expertise is fundamental to this.
Privacy and confidentiality will be respected	Practices will be adopted to ensure that information on communities will be collected in a respectful and ethical way, individuals or organisations will not be identified in publicly available SREBA databases or reports, and confidentiality restrictions will apply if a regulator needs to access sensitive data to make informed decisions.
Transparency	Information collected from baseline studies and from ongoing monitoring and compliance programs will be publicly available, provided it does not breach privacy and confidentiality requirements or compromise commercial or regulatory activities.
Respect for and Inclusion of local people	Whenever possible local residents and organisations people will be offered the opportunities to participate in the design and execution of baseline studies and ongoing monitoring.
Inclusion of local organisations	Whenever possible local organisations will be offered the opportunity to undertake baseline studies and ongoing monitoring and the Northern Territory Buy Local Plan will apply to SREBA baseline studies.
Efficient and effective	Baseline methods will be selected based on their ability to achieve desired outcomes cost-effectively

2.4 Stakeholder engagement

A stakeholder engagement strategy is a critical component of a SREBA and will be addressed in the Scope of Works. The Strategy should identify regional stakeholders and their interests and comprehensively map out how they will be engaged. This overarching strategy will be adhered for all of the baseline study domains, to ensure messaging is coordinated and consistent and avoid community consultation fatigue. Engagement with industry, community and other stakeholders will continue throughout the life of a SREBA.

2.4.1 Community engagement planning

Meaningful participation requires that people are given timely, relevant, jargon-free and impartial information so they are aware of the implications of proposals and can make an objective assessment of how they might be affected. A variety of tools such as maps and visual aids will be adopted to provide information and context in a form that is appropriate to an audience. People will get feedback on how their input influenced decisions where they provide formal feedback on the studies or work program undertaken as part of a SREBA. The stakeholder engagement strategy will use the principles reflected in the IAP2's Quality Assurance Framework (2015) and IFC Performance Standards (2012) as a guide.

2.4.2 Engaging with Aboriginal people in the Northern Territory

Recommendation 11.5 of the Inquiry requires that interpreters are used when consulting Aboriginal people for whom English is a second language. The stakeholder engagement strategy will ensure this happens for specific pieces of work that require discussion or engagement of Aboriginal people within the region where SREBA studies will take place. The stakeholder engagement strategy will recognize that the demography of the Northern Territory requires a tailored approach to engaging different stakeholders and will ensure that people undertaking studies have appropriate cross-cultural training and competence, seek advice and work with appropriate leaders in specific communities.

2.4.3 Regional Reference Group

A Regional Reference Group may be established, including stakeholders who live within the region where a SREBA is undertaken. The Regional Reference Group will operate in an advisory capacity to the Department of the Environment and Natural Resources in its role as project manager responsible for delivering all required SREBA studies. The Regional Reference Group will not be a decision-making body.

2.5 Data and information management

Baseline studies undertaken for the SREBA will use a range of information from different sources, drawing upon existing information when it is available, as well as generating new data and information. The information will be used by different stakeholders for different purposes, and all stakeholders need to be confident that the data is reliable, and the scope and limitations of the information clearly explained. An information protocol will be developed to ensure that SREBA-related information maintains integrity as it is collated, summarized, analysed, and then reported.

In general, all data should be open-access, however access may be restricted to some data according to the policy included in the Scope of Works on managing and publishing information that is culturally sensitive or commercial in confidence. Where it is available, the SREBA may be able to draw upon work undertaken in the same region under other initiatives such as the Commonwealth's Geological and Bioregional Assessment Program (GBA), or studies and data produced by research bodies such as universities or the CSIRO. Any data sourced from or provided by third parties will be identified.

Data standards for all data collected during the regional baseline assessments will be specified in the Scope of Works. Data will be stored in the information management system developed for the SREBA and curated under data management plan developed for each domain. The data management plan for each domain will identify data owners and custodians for all datasets, and any data restrictions.

3. Guidance Note for studies of water quality and quantity

3.1. Introduction

This Guidance Note describes the general approach and methods for water resource baseline assessment, as part of a broader Strategic Regional Environmental Baseline Assessment (SREBA).

This guidance applies to a SREBA undertaken in any region of the Northern Territory. The guidance will inform the development of a Scope of Works for resource assessment in any region subject to a SREBA, where the detailed methods will be tailored to the hydrology, geology and hydrogeology, regional water quality, and environmental attributes of that region.

The guidance should be read within the context provided by Sections 1 and 2 of the SREBA Framework. As water quality and quantity are key elements for many other aspects of the SREBA, other guidance notes should be referred to while scoping the water assessment, including those for aquatic and terrestrial ecosystems, and social, cultural and economic studies.

3.1.1. Requirements of the Final Report

Chapter 15 of the *Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory* describes the requirement for a SREBA and the scope of objectives within each of the major domains. In relation to water quality and quantity, the Final Report states the SREBA should address the following objectives:

- establish a baseline for groundwater and surface water hydrology over a period that is representative of the climatic cycles of the area and of the geological and geomorphological variation across the region
- characterise the hydrostratigraphy of the region sufficient to identify and characterise the aquifer systems and any interconnectivity that could be affected by the extraction of water for any onshore shale gas development
- quantify recharge rates (and where possible, recharge zones) and to establish the sustainable yield for potentially affected aquifer systems
- develop suitably calibrated groundwater-surface water flow models to quantify the connectivity between groundwater and surface water systems to predict the likely impacts of hydrological perturbation as the result of any potential onshore shale gas development and production
- establish a baseline for water quality, including measuring vertical profiles of water quality parameters through potentially affected aquifers and surface waters, noting that this will need to be done at a number of locations across a region to inform the lateral variations in quality. In semi-arid and arid regions, particular attention should be paid to the water quality of perennial to near-perennial water bodies that are likely to provide dry season refugia for aquatic biota and drinking water sources for wildlife
- define, using baseline water quality data, a staged operational regime (that is, response trigger levels) for remedial action in the event of upward trending key water quality indicators, such as dissolved methane and/or electrical conductivity.

These objectives are reflected in a number of Inquiry recommendations summarised in Table 3.1 (below). Table 7.5 of the Report (reproduced in Appendix 3.1 of this Guidance Note) also describes acceptability criteria adopted for the water-related risks.

Table 3.1. Recommendations of the Scientific Inquiry relevant to the water component of SREBA.

Recommendation	
7.5	*That before any further production approvals are granted, a regional water assessment be conducted as part of a SREBA for any prospective shale gas basin, commencing with the Beetaloo Sub-basin. The regional assessment should focus on surface and groundwater quality and quantity (recharge and flow), characterisation of surface and groundwater-dependent ecosystems, and the development of a regional groundwater model to assess the effects of proposed water extraction of the onshore shale gas industry on the dynamics and yield of the regional aquifer system.*
7.7	*That in relation to the Beetaloo Sub-basin:* • *the Daly-Roper Water Control District (WCD) be extended south to include all of the Beetaloo Sub-basin;* • *that Water Allocation Plans (WAPs) be developed for each of the northern and southern regions of the Beetaloo Sub-basin;* • *the new northern Sub-basin WAP provides for a water allocation rule that restricts the consumptive use to less than that which can be sustainably extracted without having adverse impacts on other users and the environment; and* • *the southern Sub-basin WAP prohibits water extraction for any onshore shale gas production until the nature and extent of the groundwater resource and recharge rates in that area are quantified.* *That in relation to other shale gas basins with similar or greater rainfall than the Beetaloo Sub-basin, WCDs be declared and WAPs be developed to specify sustainable groundwater extraction rates for shale gas production activities that will not have adverse impacts on existing users and the environment.* *That in relation to other potential shale gas basins in semi-arid and arid regions, all groundwater extraction for any shale gas production activities be prohibited until there is sufficient information to demonstrate that it will have no adverse impacts on existing users and the environment.*
7.8	*That the following measures be mandated to ensure that any onshore shale gas development does not cause unacceptable local drawdown of aquifers:* • *that prior to the grant of any further exploration approvals, the extraction of water from water bores to supply water for hydraulic fracturing be prohibited within at least 1 km of existing or proposed groundwater bores (that are used for domestic or stock use) unless hydrogeological investigations and groundwater modelling, including the SREBA, indicate that a different distance is appropriate, or if the landholder agrees to a variation of this distance;*

Recommendation	
	• *that relevant WAPs include provisions that adequately control both the rate and volume of water extraction by the gas companies;* • *that gas companies be required, at their expense, to monitor drawdown in local water supply bores; and* • *that gas companies be required to immediately 'make good' and rectify any problems if the drawdown is found to be excessive.*
7.9	*That prior to the grant of any further exploration approvals, the reinjection of wastewater into deep aquifers and conventional reservoirs and the reinjection of treated or untreated wastewaters (including brines) into aquifers be prohibited, unless full scientific investigations determine that all risks associated with these practices can be mitigated.*
7.11	*That prior to the grant of any further exploration approvals, in order to minimise the risk of groundwater contamination from leaky gas wells:* • *all wells subject to hydraulic fracturing must be constructed to at least Category 9 or equivalent*[2]*, and tested to ensure well integrity before and after hydraulic fracturing, with the integrity test results certified by the regulator and publicly disclosed online;* • *a minimum offset distance of at least 1 km between water supply bores and well pads must be adopted unless site-specific information of the kind described in Recommendation 7.8 is available to the contrary;* • *where a well is hydraulically fractured, monitoring of groundwater be undertaken around each well pad to detect any groundwater contamination using multilevel observation bores to ensure full coverage of the horizon, of any aquifer(s) containing water of sufficient quality to be of value for environmental or consumptive use;* • *all existing well pads are to be equipped with multilevel observation bores (as above);* • *as a minimum, electrical conductivity data from each level of the monitor bore array should be measured and results electronically transmitted from the well pad site to the regulator as soon as they are available. The utility of continuous monitoring for other parameters should be reviewed every five years or as soon as advances in monitoring technology become commercially available; and* • *other water quality indicators, as determined by the regulator, should be measured quarterly, with the results publicly disclosed online as soon as reasonably practical from the date of sampling. This monitoring regime should continue for three years and be reviewed for suitability by the regulator.*

[2] Refer Table 5.2 on page 62 of the Final Report

Recommendation	
7.13	*Upon a gas company undertaking any exploration activity or production activity, monitoring of the groundwater must be implemented around each well pad to detect any groundwater contamination, adopting the monitoring outlined in Recommendation 7.11. If contamination is detected, remediation must commence immediately.*
7.16	*That appropriate modelling of the local and regional groundwater system must be undertaken before any production approvals are granted to ensure that there are no unacceptable impacts on groundwater quality and quantity. This modelling should be undertaken as part of a SREBA.*
7.19	*That the SREBA undertaken for the Beetaloo Sub-basin must take into account groundwater-dependent ecosystems in the Roper River region, including identification and characterisation of aquatic ecosystems, and provide measures to ensure the protection of these ecosystems.*
7.20	*That the Beetaloo Sub-basin SREBA must identify and characterise all subterranean aquatic ecosystems, with particular emphasis on the Roper River region.*
8.12	*That directional drilling under stream crossings be used in preference to trenching unless geomorphic and hydrological investigations confirm that trenching will have no adverse impact on water flow patterns and waterhole water retention timing.*
15.2	*That the regulator oversees the auditing and the data-collection processes and provides a central repository for all data informing any SREBA.*
5.4 7.1 7.15 7.18 14.21 14.22	Other recommendations that mention water-related issues.

The Final Report also provides guidance around issues that must be addressed in designing a SREBA. For water, the key points are:

- The data collected for the regional assessment must be sufficient to inform the water supply, surface and groundwater interactions, and water quality components of the baseline assessment.
- The key groundwater parameters are recharge rate, recharge mechanism, sustainable yield and flow velocity.
- The regional assessment should identify locations where groundwater aquifers intersect with surface waters, and the extent and importance of any ecosystems dependent on, or influenced by, groundwater. In particular, the locations of groundwater-fed springs and dry season aquatic refugia must be identified and characterised, and the sensitivity of these assets to the extraction of groundwater should be assessed.

- For all relevant water resources and water dependent assets, a description of baseline conditions, and conceptual and numerical computer models of potential impacts of any onshore shale gas industry need to be developed. Numerical modelling should be undertaken to inform an understanding of potential impacts to a particular water resource. Such models should be constructed in accordance with the conceptual model, be calibrated and verified with appropriate baseline data, and should explore the probability of a range of possible outcomes based on uncertainty analysis.
- Adequate sampling of groundwater quality should take into account the following issues:
    1. aquifer systems can be vertically stratified, with overlying younger water flowing across the top of the aquifer profile and much older water residing below it. Therefore, measurements of groundwater age that do not specifically address this issue can yield estimates of recharge (and therefore sustainable yield) that are incorrect
    2. the concentrations of dissolved oxygen through the aquifer needs to be determined to inform the potential for degradation of fugitive methane in groundwater by aerobic or anaerobic microbial pathways, and the potential for the occurrence of stygofauna
    3. the baseline concentrations of major ions must be established through the aquifer profile to provide a reference condition against which leakage of flowback water from a well, or from a surface spill contaminating the groundwater, can be assessed.
- Addressing these issues will require the targeted installation of multilevel piezometer arrays screened across a number of discrete vertical intervals to permit sampling through time and conducted reliably and reproducibly at each horizon. In this context, the Panel has recommended that multilevel bores be used for performance monitoring of installed shale gas extraction wells (see Recommendation 7.11).
- Multiple entities are likely to collect water samples, but all data being collected for a SREBA must be collated into a single repository database. Ideally, this collation should be performed regularly to ensure that any identified issues are addressed as expeditiously as possible, including inconsistencies in analysis quality and achieved quantification limits.
- Ongoing attention to quality control for water sampling and analysis is critical, and there should be an annual field and laboratory evaluation component overseen by the regulator
- It is essential that any SREBA is designed to include multiple-year sampling of aquatic ecosystems (addressed further in the aquatic ecosystem guidance note).
- Bores developed for a regional assessment of groundwater quality can also be designed to be appropriate for stygofauna assessment.

3.1.2. Additional considerations

Onshore gas development in the Northern Territory is likely to be subject to authorisation and regulation under various legislation, including:

- *Petroleum Act 1984*, and Petroleum (Environment) Regulations 2016
- *Water Act 1992*

- *Environment Assessment Act 1989* (which will be replaced in 2020 by the *Environment Protection Act 2019*)
- *Environment Protection Act 2019*
- *Environment Protection and Biodiversity Conservation Act 1999* (Commonwealth)

Water Act 1992

Water Control District (WCD)

Recommendation 7.7 states that before exploration can occur a WCD should be declared. Section 22 of the *Water Act 1992* allows the Minister to declare a water control district, its purpose and name. It is noted that a WCD has already been declared over the Beetaloo Sub-basin, however SREBAs can assist in describing the nature and extent of the water resources where future WCDs may be required. The SREBA may help in defining the boundary and purpose of the WCD in relation to surface water, groundwater and their interconnectivity.

Water Allocation Plan (WAP)

Recommendation 7.7 also states that:

> *WAPs be developed to specify sustainable groundwater extraction rates for shale gas production activities that will not have adverse impacts on existing users and the environment.*

Under Section 22B of the *Water Act 1992*:

(1) The Minister may, by notice in the Gazette, declare a water allocation plan in respect of a water control district.

(2) The Minister must specify the period (not longer than 10 years) that a water allocation plan is to remain in force.

(3) The Minister must ensure that a review of a water allocation plan is conducted at intervals not longer than five years.

(4) Water resource management in a water control district is to be in accordance with the water allocation plan declared in respect of the district.

(5) A water allocation plan is to ensure in the water control district that:

   (a) water is allocated within the estimated sustainable yield to beneficial uses

   (b) the total water use for all beneficial uses (including those provided through rural stock and domestic use and licences granted under sections 45 and 60) is less than the sum of the allocations to each beneficial use

   (c) the right to take or use water under a licence granted under section 45 or 60 is able to be traded (in part or in full)

   (d) as far as possible – the full cost for water resources management is to be recovered through administrative charges to licensees and operational contributions from licensees.

(6) An allocation under subsection (5)(a) is to include an allocation to the environment.

The implication of Section 22B is that water resource management in a WCD is to be in accordance with the water allocation plan declared in respect of the district. The SREBA should provide much of the information required in meeting the requirements of section 22B of the *Water Act 1992*.

The SREBA can inform the water allocation planning process by:

- documenting and assessing the characteristics of different water resources
- determining the natural water balance
- providing conceptual models of ecosystem function
- developing an integrated surface water - groundwater model
- documenting the climate record for the water resource
- identifying water dependent ecosystems and determining their environmental significance
- quantifying environmental water requirements
- identifying cultural values associated with water
- quantifying cultural water requirements
- documenting current water use and entitlements
- assessing future water demand for petroleum activities and all other beneficial uses
- providing an optimal monitoring program (sites and methods) for surface water and groundwater

Useful outputs of the SREBA for water allocation planning include:

- characterisation of each water resource
- natural water balance for each water resource
- depth to groundwater maps
- recharge areas and recharge rates
- location and rates of groundwater discharge and discharge
- location and significance of interconnection sites between surface water, groundwater and aquifers
- location and significance of water dependent ecosystems
- location and significance of cultural values

Environment Protection and Biodiversity Conservation Act 1999 (EPBC Act)

Although the water trigger under the EPBC Act does not apply to Northern Territory onshore gas resources, the *Significant impact guidelines 1.3: Coal seam gas and large coal mining developments — impacts on water resources* (Australian Government 2013) provide a useful guide for the content of the SREBA Water Guideline. The information requirements for assessment, approval and auditing in relation to these authorisations, including those relating to water as described in the guidelines are:

Value of a water resource

- provisioning services (e.g. use by other industries and use as drinking water)
- regulating services (such as the climate regulation or the stabilisation of coastal systems)
- cultural services (including recreation and tourism, science and education)
- supporting services (e.g. maintenance of ecosystem function).

Changes to hydrological characteristics

- changes in the water quantity, including the timing of variations in water quantity
- changes in the integrity of hydrological or hydrogeological connections, including substantial structural damage (e.g. large-scale subsidence)
- changes in the area or extent of a water resource

The following aspects may need to be considered when assessing changes in hydrological characteristics:

- flow regimes (volume, timing, duration and frequency of surface water flows)
- recharge rates to groundwater
- aquifer pressure or pressure relationships between aquifers
- groundwater table and potentiometric surface levels
- groundwater-surface water interactions
- river-floodplain connectivity
- inter-aquifer connectivity
- coastal processes including changes to sediment movement or accretion, water circulation patterns, permanent alterations in tidal patterns, or substantial changes to water flows or water quality in estuaries.

Information requirements

Information required for assessment of the impact should include:

- the characteristics of the potentially impacted water resource(s)
- known baseline conditions of the water resource(s), including existing third party uses, including environmental and other public benefit outcomes
- reasonably foreseeable future use of the water resource(s)
- the likely impact of the action on the water resource(s), including consideration of impacts in the context of existing impacts
- proposed avoidance and mitigation measures
- the alignment of the action with any relevant water resource and/or water quality plans.

While the SREBA does not aim to provide all the data required for local-scale, project-level water assessment, it should provide sufficient regional-scale context to ensure that:

- the required scope of project-level water assessment can be reliably and precisely defined
- the regional significance of water-dependent environmental and cultural values identified at local scale can be determined
- the contribution of local-scale impacts to regional-scale cumulative impacts can be assessed

Consequently, these water-related information requirements have been considered in informing the scope of the SREBA, in addition to those detailed in the Final Report.

Water assessment products

For the SREBA to meet the requirements of the recommendations of the Final Report and, where possible, meet complimentary requirements of water allocation planning and environmental management the following products should be delivered:

- A description of the hydrological and hydrogeological character of each groundwater and surface water resource including a description of the connection between water resources, if they exist. This information will assist delineating the boundary of the water resources, a water control district, a water allocation plan and management zones.
- A regional integrated groundwater/surface water model.
- A natural water balance for each resource.
- A regional water balance which shows the connection between each water resource.

3.2. Baseline information requirements

The baseline data for water quality and quantity that should be provided through the SREBA, based on the requirements described above, are listed below with further detail provided in Section 3.4.

- Climate, including rainfall and evaporation
- Catchment-based surface water resources
- Water quality in key river systems
- Hydrogeological system-based groundwater resources
- Aquifer-based water quality, including profile (stratified) water quality if applicable
- Water quality at key groundwater discharge sites (e.g. springs)

The information products that should be derived through analysis of these baseline data are listed below, with further detail provided in Sections 3.4 and 3.5.

- Surface water assessment and mapping
- Hydrogeological assessment and mapping
- Identification and mapping of water dependent ecosystems

- Mapping of water-reliant land development options
- Water quality response “trigger” values appropriate to the region.

3.3. Assessment approach

The water resource assessments for the SREBA require the following steps. The key elements of each step and appropriate methods are described in Section 3.4, noting that some aspects will be determined for each SREBA during the development of a Scope of Works.

1. Define the study areas and boundaries
2. Data collation and literature review
3. Ground-based surveys to confirm existing data and acquire additional data
4. Develop conceptual model of water resources that may be affected by onshore gas development
5. Targeted survey to locate groundwater discharge sites and sites of shallow groundwater levels
6. Reporting of surface water and groundwater resource assessments
7. Data management
8. Development of a targeted monitoring strategy

3.4. Methods

3.4.1. Boundary

The boundary of each SREBA will be determined during the development of the Scope of Works for that region following expert advice from DENR (or an expert advisory group established to assist with this). It will be desirable to align the boundary of the SREBA, the surface water and groundwater resources and the Water Management areas as closely as possible. For the water-related domains of the SREBA, considerations in defining the boundary are to include:

- the surface water catchment area that encompasses the geological (sub)basin with the gas resource
- sufficient hydrogeological extent to provide adequate context to assess the significance of any potential impact.
- vertical limits that define each aquifer that will be encountered by gas drilling activities and that could feasibly be impacted, focusing on systems that may have some beneficial use
- aquifer boundaries focusing on systems that are considered to have value in terms of declared beneficial use

In general, the boundary should correspond to the surface water catchment or hydrogeological unit mapping – whichever is of greatest extent. However, additional consideration should be given to:

- where it is clear that gas development can feasibly only occur in one part of a large hydrogeological system or surface water catchment, sub-regional boundaries may be appropriate

- where only a small portion of a mapped water resource overlaps the edge of a gas (sub)basin, that entire region cannot be cost-effectively be incorporated in the SREBA, so only a portion of that resource should be included
- where there is potential for a material impact of extraction from development (notably on the quality or quantity of groundwater or surface water, iconic locations or water-associated ecological values), the boundary may extend out of the catchment area where the development will occur, likely following (sub) catchment boundaries.

3.4.2. Data collation, literature review and gap analysis

Collation and review of existing data and information at the commencement of the water studies are essential to establishing the current level and extent of resource knowledge and mapping; identifying key data/information gaps for reliable regional water quantity and quality assessments; identifying potential sources of additional data; and developing strategies and preliminary plans to undertake targeted ground surveys.

Information sources include (but are not limited to):

- climate surfaces
- geological and hydrogeological mapping
- bore test and aquifer hydraulic analyses
- groundwater level data
- groundwater Assessments
- mapping of surface water systems
- river and/or streamflow data
- surface water assessments
- topographic mapping and DEM
- NR Maps and bore reports
- water quality data from streams, springs, and groundwater systems and bores

Existing data, with relevant metadata, should be collated within the data management system established for the SREBA. It is important that the quality and reliability of the data is assessed, and relevant quality assurance reported, particularly where water data is to be used for modelling and the development of reference values (see Appendix 3.2).

3.4.3. Regional ground-based surveys

This work aims to verify key data sources to confirm existing data held in the DENR Water Resources database across the surface water catchment and hydrogeological extent of the SREBA region. The surveys may also present opportunities to acquire additional data. The detailed approach and method for each survey should be determined for a SREBA region following the initial data collation and review, following advice from the expert reference group.

Verification of historic stream gauge locations and status, and water quality update

The Northern Territory has a considerable amount of historic streamflow and gauged data that were acquired prior to the 1990s and before the use of GPS for precise location information. Such data will be invaluable in surface water assessment and to develop hydrologic models. The change in climatic conditions will affect the current flow regime (in relation to the historical) and therefore measurement of current flow data at the same location will assist in placing the historical dataset within the temporal context.

An updated water quality assessment at the locations of interest will indicate any deviation from baseline data which could be associated with changing land usage, hydrologic changes or other landscape changes over the intervening period.

Verification of bore locations, status reporting and bore water sampling

In the majority of cases, bore data and analysis of other data originating from the bore will provide the fundamental basis for the development of hydrogeological conceptualisation. Locational inaccuracy, often a legacy of driller-sourced data up to the early to mid-2000's, has the potential to corrupt or create uncertainty in hydrogeological assessment.

The field work required to locate old bores creates the opportunity to update the status information for each bore in the DENR database. Additionally, bore water quality analyses that may be found on individual bore files are often undertaken soon after the bore was drilled (and therefore are unlikely to be useful as "baseline" reference values) and do not provide analyses for a comprehensive range of constituents including stable isotopes. These data are often useful in establishing the source aquifer and correlation across the hydrogeological system.

Regional reconnaissance to confirm outcropping geology and current mapping

Geological mapping in some regions of the NT can be up to 50 years old. The outcrop geology mapping serves the basis for hydrogeological conceptualisation and mapping of groundwater resource extent. This field activity serves to check or update current mapping and, in some cases, to enable bore strata correlation to be made on a regional scale. This work should be undertaken across the SREBA region to confirm the hydrogeological limits.

Ground-based survey of bores that are available and suitable for geophysical logging

This activity could be undertaken concurrently with the survey of existing bores across the region. Accessing bores for the acquisition of additional geophysical logging data may prove invaluable in correlating hydrostratigraphy across the region, but will depend on the bore's status.

Surveys of groundwater discharge sites

Surveys may need to be undertaken to locate groundwater discharge sites and measure discharge as well as confirming the nature of environments that are speculated to be related to shallow groundwater levels (groundwater dependent ecosystems). This field-based activity will assist in understanding the spring or shallow groundwater discharge mechanisms as well as the mapping of water dependent ecosystems. Water quality data from springs is useful to associate them with the groundwater source.

Collection, collation, and analysis of surface and groundwater quality data

In many regions there will be inadequate reliable surface and groundwater quality data for physical and chemical toxicants (e.g. nutrients, metals, organics, and radionuclides) at suitable spatial and temporal scales for the development of water quality response "trigger" values. Additional targeted water sampling will be needed to provide baseline data (following the *Code of Practice for Petroleum Activities in the Northern Territory*) for development of reliable "trigger" values for investigation and management actions designed to protect the water quality and environmental values of the region.

3.4.4. Surface water and groundwater resource assessments

This work culminates in the analysis and/or update of existing knowledge, acquisition and synthesis of further data, and identification of knowledge gaps. The assessments should provide detailed description of the baseline water resources, including critical water-dependent values of concern that are supported by those resources. The detail of each assessment may vary between SREBA regions but should include the information listed below.

Surface Water Assessment

- A description of the surface water resources of the site and region, including maps of all surface water resources relevant to the project
- Presentation of the understanding of surface hydrology, including hydrographs, raw data and any records of seasonal and historic variations in flow to demonstrate rainfall-runoff response and behaviour of the catchment
- Quantified flow relationships between key sub-catchment areas
- Statistical analysis of flow and flood frequency for key sub-catchments
- Inundation mapping
- Assessment of the extent of hydrological interactions between water sources including surface water / groundwater connectivity, and connectivity with marine and estuarine environments

Groundwater Assessment

- Descriptions of geology and hydrogeology at an appropriate level of spatial and vertical resolution (i.e. at both site and regional scale) with contextual information (e.g. surface geology and cross sections) that provide a plausible conceptualisation of the natural processes of recharge, discharge and flow via aquifer systems.
- Descriptions of hydraulic characteristics (for example, hydraulic conductivity and storage characteristics) for each aquifer, and presentation of key geological information (e.g. structures and boundaries) that will influence groundwater flow, recharge, connectivity/continuity and resource extent.
- Presentation of data to demonstrate the varying depths to the aquifers and associated standing water levels or potentiometric heads and hydraulic characteristics.

- Definition of the likely recharge sources for each aquifer, details of discharge from the aquifers, direction of groundwater flow and contours of groundwater elevations for all aquifers likely to be impacted by development.
- Quantification of recharge, discharge and groundwater flow such that a water balance for the groundwater system is suitably demonstrated to support its conceptualisation.
- Presentation of water quality data that provides evidence of groundwater resource extent
- Location of springs and potential groundwater dependent ecosystems;
- Identification of the aquifer to which springs and groundwater dependent ecosystems are connected
- Estimation of the ecological water requirements of identified springs and groundwater dependent ecosystems

3.4.5. Baseline water quality

Background (or reference condition) surface water and groundwater quality data (physical and chemical) will be used together with guidelines and approaches recommended by the Australian and New Zealand water quality guidelines (ANZG 2018, ANZECC & ARMCANZ 2000) to develop response "trigger" values appropriate to the region. Once developed and approved by the appropriate regulator, these response values can be used as formal benchmarks against which to assess the results of monitoring programs and as triggers for investigations and management actions designed to protect the environmental values of the region.

The response "trigger" values can be structured as a comparison between background (or reference) and monitoring data or as a comparison with a single ANZG (2018) guideline "trigger" values for ecosystem protection (see Appendix 3.1).

In general, the greater the amount of background (spatial and temporal) data gathered, the smaller will be the error associated with detecting change in toxicant concentrations in the field. Adequate regional water quality baseline data could result in a refinement of the ANZG (2018) guideline "trigger" values for ecosystem protection to suit regional or local water quality parameters and other conditions.

Note that the aquatic ecosystem guidance note provides a framework for establishing some of the surface water quality baseline.

3.5. Synthesis

The primary objective of the SREBA is to provide adequate baseline data, in this case for water resources, to inform the assessment of potential impacts of development at project and regional scales. Many of the information products provided through the undertaking of the resource assessment work are described in Section 3.4 above.

Outputs from the water assessment component of the SREBA will help inform studies undertaken in some of the other SREBA domains, and some of the information requirements described in the Final Report are addressed in other Guidance notes. In particular, the aquatic ecosystem domain will:

- Define geographic extent of aquatic ecosystems systems, including maximal wet season extent of floodplains and seasonal extents of semi-permanent waterbodies.

- Ground truth the extent of coverage, and determine abundance and diversity of species associated with these systems.
- Undertake a regional survey for stygofauna
- Map and describe the ecological characteristics of groundwater dependent ecosystems Undertake a survey of GDEs
- Investigate the relationship between aquatic ecological values and water quality.

3.5.1. Strategy for addressing knowledge gaps

While the SREBA will provide the baseline information on water quality and quantity required for regional water allocation planning, issue of water licences and the assessment of the potential impacts of onshore gas developments, longer-term management of the water resources will inevitably benefit from continual improvement of the knowledge base.

A strategy for further investigation, monitoring and research opportunities required to clarify or seek additional data should be developed. This work will build on the baseline inventory and address areas identified in the resource assessment phase as being knowledge-poor or having significant uncertainty.

- The baseline data should relate to the areas outlined in 3.4 and further monitoring may be required to complete this.
- The further investigation work required will be identified as a result of the assessments conducted in Section 3.4 and will relate to providing clarity or evidence to support the hydrogeological conceptualisation.
- Research opportunities may be identified where water investigation results may imply the occurrence of processes (e.g. groundwater recharge, vegetation water use). Further work may be required to validate or quantify these processes.

3.5.2. Monitoring

Detailed guidance on indicators and monitoring programs are not provided here as they are dependent on the outcomes from data collection and analyses described in sections above, and the requirements for each SREBA region should be scoped once this information is available. However, general considerations would include:

- clear understanding and description of purpose and objectives for monitoring
- financial resources to support and maintain monitoring over time
- access to appropriate expertise and capability
- robust sampling design including appropriate spatial and temporal scales
- the choice of simple and meaningful indicators.
- appropriate review and assessment of program, including feedbacks into decision making
- role in regulatory compliance at a project level (e.g. what will trigger investigation and management action, the level of safeguard built into the decision-making process, and the risks of expense or environmental impact arising from errors in the assessment and monitoring process).

- well designed and appropriately focused monitoring programs would assess the effectiveness of control and management plans.
- monitoring programs should be maintained during and after implementation of management responses, to evaluate their performance in achieving the water quality objectives and hence the management goals. This process should be iterative and on-going to ensure the environmental values continue to be sustained.

3.6. Reporting and data management

The Water Baseline Report for a SREBA will contain detailed descriptions of the methods, results, analyses and synthesis products, as well as cataloguing the data collated and collected during the project with appropriate metadata.

Summary outputs from the assessment should be in formats that are readily available, and comprehensible, to a broad audience (such as web-enabled, interactive maps). Effective public communication of results will be informed by a SREBA-wide communication plan.

Data standards for all data collected during the regional baseline assessment will be specified in the Scope of Works. Data should be stored in the information management system developed for the SREBA and curated under a data management plan developed for the Water Resources component. The data management plan should identify owners and data custodians for all datasets, and any data restrictions.

In general, all data should be open-access, however access may be restricted to some data according to the sensitive data policy of the SREBA. For Water Resources data, this should apply only in very limited cases where open access to locality data may genuinely increase threats to a species, or where data may identify culturally sensitive sites.

3.7. References

ANZG 2018. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia. Available at www.waterquality.gov.au/anz-guidelines

ANZECC & ARMCANZ 2000. *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*. Australian and New Zealand Environment and Conservation Council, and Agriculture and Resource Management Council of Australia and New Zealand, Canberra.

Appendix 3.1 - Criteria adopted during the Inquiry identifying acceptable water-related risks

Drawn from Table 7.5 in the Final Report.

Environmental value		Environmental objectives	Acceptability criteria
Water quantity	Surface water	To ensure surface water resources are used sustainably.	Low likelihood that water use will exceed 20% of flow at any time.(1)
	Groundwater - regional	To ensure ground water resources are used sustainably.	Low likelihood that water use will exceed 20% of the 'sustainable yield' at any time.(1)
	Groundwater - local	To ensure ground water resources are used sustainably.	Low likelihood that drawdown of water supply bores within 1 km of shale gas development will be greater than 1 m.
Water quality	Surface water	To maintain acceptable quality of surface water resources.	Low likelihood that any toxicant will exceed the NHMRC drinking water guidelines (human health) or ANZECC water quality guidelines (stock drinking, agriculture).(2)
	Groundwater	To maintain acceptable quality of groundwater resources.	Low likelihood that any toxicant will exceed the NHMRC drinking water guidelines (human health) or ANZECC water quality guidelines (stock drinking, agriculture) in water supply bores.(2)
Aquatic ecosystems	Surface water - use	To protect surface water dependent ecosystems.	Low likelihood that water use will exceed 20% of flow at any time.(1)
	Surface water - quality	To protect surface water dependent ecosystems.	Low likelihood that any toxicant will exceed the applicable ANZECC water quality guidelines for protection of aquatic life.(2)
	Groundwater - quality	To protect groundwater dependent ecosystems.	Low likelihood that any toxicant will exceed the applicable ANZECC water quality guidelines for protection of aquatic life.(2)
Aquatic biodiversity	Surface and groundwater resources	To protect surface water and groundwater aquatic biodiversity.	No significant long-term change in aquatic biodiversity.

(1). DENR water allocation rules (DENR submission 230, Appendix A and B).

(2). Note: some toxicity of some chemicals in shale gas wastewater to human health, stock or aquatic ecosystems are not yet known.

Appendix 3.2 - Draft sampling standards for groundwater

Sampling of groundwater should be undertaken in accordance with the Australian Standard (AS/NZS 5667) using a National Association of Testing Authorities (NATA) registered laboratory to undertake chemical analyses using NATA-accredited analysis methods. If a NATA registered laboratory is not available, evidence to support data quality should be presented in the report.

The method of pumping groundwater to obtain a sample (e.g. bailing, high flow pumping or low-flow purge pumping) is determined by the water quality parameters of interest (Sundaram et al. 2009). Water levels and pressures should be measured within aquifers at the same time as water samples are collected. A flow cell should be used to measure field analysis parameters (i.e. with no air contact) at the time that samples are collected during the baseline monitoring program. A list of **parameters for analysis in the field** is below.

The basic field parameters are (as per WA guidelines: GWA 2016):

- Water level (m AHD) – water levels/pressures should be measured within aquifers, surface water systems and groundwater-dependent ecosystems at the same time as water samples are collected. It may be appropriate, or easier in some cases, to install continuous recording data loggers.
- Temperature (°C)
- Conductivity – compensated to 25°C, or if uncompensated – report the value measured and the temperature; report complete units (e.g. mS/cm, not mS)
- pH
- Redox potential (Eh)
- Dissolved oxygen (mg/L and %DO)
- Bicarbonate (HCO3–)

The list of **water quality parameters for laboratory analysis** presented in this Guideline is generic (list below). It is not mandatory to sample all parameters. The parameters selected for a groundwater monitoring program should be determined on a case-by-case basis using the results from a risk assessment. Results of the risk assessment (undertaken via an environmental plan) should also provide information about which parameters are related to the current shale gas and oil activities and can pose a risk to the environment or human health. This information can help to determine specific parameters that should be included in the monitoring program. Sampling/measurement should be directed to understanding regional groundwater dynamics. Measurement accuracy should be stated for each variable measured and recorded.

Laboratory analysis parameters (as per WA guidelines):

Physico-chemical

- Total dissolved solids – determined gravimetrically @ 180°C
- Turbidity
- Total hardness (as $CaCO_3$)
- Total alkalinity (as $CaCO_3$)
- Hydroxide (as CaCO3)
- Total Nitrogen (mg/L)
- Total Kjeldahl Nitrogen (TKN) (mg/L)
- Total Phosphorus (TP)

Ions

- Calcium (Ca2+)
- Magnesium (Mg2+)
- Sodium (Na+)
- Potassium (K+)
- Ammonia (NH4+)
- Phosphate (PO43–)
- Carbonate (CO32–)
- Bicarbonate (HCO3–)
- Chloride (Cl–)
- Sulphate (SO42–)
- Nitrite (NO2–)
- Nitrate (NO3–)
- Silica (SiO2)

Hydrocarbons

- Methane
- Ethane
- Propane
- Total Recoverable Hydrocarbons (TRH)
- Benzene
- Toluene
- Ethylbenzene
- Xylene
- Phenol
- Polycyclic Aromatic Hydrocarbons (PAH)
- Volatile Organic Compounds (VOC)

Metals

- Aluminium
- Arsenic
- Barium
- Beryllium
- Boron
- Cadmium
- Chromium
- Cobalt
- Iron
- Lead
- Manganese
- Mercury
- Molybdenum
- Nickel
- Selenium
- Vanadium
- Zinc

Other parameters as appropriate:

- Arsenic (As^{3+}, As^{5+})
- Bromide (Br^{-})
- Chromium (Cr^{3+}, Cr^{6+})
- Iron (Fe^{2+})
- Fluoride (F^{-})
- Lithium (Li^{+})
- Naturally Occurring Radioactive Material (NORM)
- Pesticides – organochlorines / organophosphates
- Radon (Rn)
- Selenium (Se^{4+}, Se^{6+})
- Stable isotopes of carbon (C) and hydrogen (H) within methane (CH_4) – undertaken to determine origin or source of the hydrocarbon
- Age dating – to provide information on the relative age of groundwater (e.g.^{13}C / ^{14}C – Carbon 14 dating, Tritium ^{3}H / ^{3}He, noble gases, CFC's, Strontium isotope ratios ($^{87}Sr/^{86}Sr$), Sulfur hexafluoride).
- Measurement of oxygen 18 and deuterium (^{18}O / ^{2}H) – to provide an indication of the connection of groundwater within the saturated unit (aquifer) with rainfall recharge.
- Uranium

Monitoring timeframes

Monitoring needs to continue following completion of the baseline study to detect changes in baseline characteristics or metrics over time.

The number and location of groundwater bores used for baseline and surveillance monitoring is determined on a case-by-case basis but will primarily depend on the level of risk associated with the proposed onshore hydrocarbon activities and the sensitivity and values of the surrounding environment and groundwater. Potential risks will require documentation in development proposals.

Baseline monitoring technically ends once drilling starts or a facility becomes operational (i.e. storing or processing hydrocarbons). Cessation of the baseline monitoring program does not mean the groundwater monitoring program should be discontinued. Monitoring at the same bores (or a subset as appropriate) should continue but in the form of 'surveillance' monitoring to detect any change compared to the baseline condition or relevant standard over time.

Surveillance groundwater monitoring should continue for at least the duration of the onshore shale gas and oil activities. Monitoring can cease following well decommissioning for shale gas and oil wells (either exploration or production) where there have been no external well failures or serious spill incidents. Monitoring should continue for two years after well decommissioning for shale gas and oil wells (either exploration or production) where there has been an external well barrier failure or a serious spill incident prior to decommissioning to account for any potential lag in groundwater movement from the well to the monitoring bore.

Surveillance monitoring should continue for two years at a quarterly frequency and then the frequency may be reduced in consultation with the regulator.

The scope of proposed activities (e.g. processing plants, multiple wells, or field development programs) may also influence the number and location of groundwater monitoring bores. For example, more rigorous sampling will be required in an aquifer that supplies public drinking water than a saline aquifer that has no beneficial use.

References

GWA (2016). *Guideline for groundwater monitoring in the onshore petroleum and geothermal industry.* Government of Western Australia, Department of Mines and Petroleum, Department of Water. https://www.dmp.wa.gov.au/Documents/Environment/ENV-PEB-040.pdf

Sundaram B, Feitz A, Caritat P de, Plazinska A, Brodie R, Coram J and Ransley T 2009. *Groundwater Sampling and Analysis – A Field Guide.* Geosciences Australia, Record 2009/27. Available from: http://www.cffet.net/env/uploads/gsa/BOOK-Groundwater-sampling-%26-analysis-A-field-guide.pdf

4. Guidance Note for studies of aquatic ecosystems

4.1. Introduction

This guidance note describes the general approach and methods for aquatic ecosystem baseline assessment, as part of a broader Strategic Regional and Environmental Baseline Assessment (SREBA).

This guidance applies to a SREBA undertaken in any region of the Northern Territory. The guidance will inform the development of a Scope of Works for aquatic ecosystem assessment in a region subject to a SREBA, where the detailed methods will be tailored to the environmental characteristics of that region.

The guidance should be read within the context provided by Sections 1 and 2 of the SREBA Framework. There is a significant relationship between aquatic ecosystems and some of the issues addressed in the guidance for water quality and quantity, as well as an overlap between aquatic and terrestrial ecosystems. Therefore, those guidance notes should also be referred to while scoping the aquatic ecosystem assessment.

4.1.1. Requirements of the Final Report

The *Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory* (Chapter 15) describes the requirement for a SREBA and the scope of objectives within each of the major domains. In relation to aquatic ecosystems, including groundwater dependent ecosystems (GDE), the Final Report states the SREBA should address the following objectives:

- determine locations of ecologically important perennial and temporary waterbodies and dry season aquatic refugia
- characterise the wet season surface water flow regime (including overland flow)
- characterise the dependency or degree of influence on ecosystems by groundwater, and their likely sensitivity to shale gas-related water extraction
- characterise inter-annual and seasonal water quality variability, with particular focus on dry season aquatic refugia (see above).

The fourth objective refers to a related one for water quality and quantity:

- In semi-arid and arid regions, particular attention should be paid to the water quality of perennial to near-perennial water bodies that are likely to provide dry season refugia for aquatic biota and drinking water sources for wildlife

These objectives are also reflected in several recommendations in the Final Report (Table 4.1) noting that, while some of these are specific to a SREBA for the Beetaloo Sub-basin, they reflect the type of information required in a SREBA more generally.

Table 4.1. Recommendations in the Final Report relevant to the aquatic ecosystems component of a SREBA

Recommendation:	
7.5	*That before any further production approvals are granted, a regional water assessment be conducted as part of a SREBA for any prospective shale gas basin, commencing with the Beetaloo Sub-basin. The regional assessment should focus on surface and groundwater quality and quantity (recharge and flow), characterisation of surface and groundwater-dependent ecosystems, and the development of a regional groundwater model to assess the effects of proposed water extraction of the onshore shale gas industry on the dynamics and yield of the regional aquifer system*
7.19	*That the SREBA undertaken for the Beetaloo Sub-basin must take into account groundwater dependent ecosystems in the Roper River region, including identification and characterisation of aquatic ecosystems, and provide measures to ensure the protection of these ecosystems.*
7.20	*That the Beetaloo Sub-basin SREBA must identify and characterise all subterranean aquatic ecosystems, with particular emphasis on the Roper River region.*
8.6	*That as part of a SREBA, a study be undertaken to determine if any threatened species are likely to be affected by the cumulative effects of vegetation and habitat loss, and if so, that there be ongoing monitoring of the populations of these species. If monitoring reveals a decline in populations (compared with pre-development baselines), management plans aimed at mitigating these declines must be developed and implemented.*

The Final Report also provides guidance around issues that must be addressed in designing a SREBA. For aquatic ecosystems, the key points are:

- For a SREBA a broad range of taxonomic groups should be considered, including fish and other vertebrates, macroinvertebrates, macrophytes, algae, and microcrustaceans that can play dominant roles in the aquatic biodiversity of some NT waters.
- It is essential that any SREBA is designed to include multiple-year sampling of aquatic ecosystems. As a general rule, in the Top End two to five years of baseline data will be required to achieve adequate coverage of inter-annual variability, while in drier zones a longer timeframe is required.
- The timing of sampling will be dependent on the hydrological cycle of the water bodies of interest. In systems with different inundation patterns and durations, the timing of sampling in each inundation cycle will need to be adapted, and optimal timing may differ for different taxonomic groups.
- Timing may be less critical for the assessment of surface GDEs than for non-groundwater dependent surface water ecosystems. Again, for these systems, a broad range of taxonomic groups should be considered.

4.1.2. Additional considerations

Onshore gas development in the Northern Territory is likely to be subject to authorisation and regulation under various legislation, including:

- *Petroleum Act 1984* and Petroleum (Environmental) Regulations 2016
- *Water Act 1992*
- *Environment Assessment Act 1989* (which will be replaced in 2020 by the Environment Protection Act 2019)
- *Environment Protection Act 2019*
- *Environmental Protection and Biodiversity Conservation Act 1999* (EPBC Act)

The information requirements for assessment, approval and auditing in relation to these authorisations, including those relating to aquatic ecosystems are described in:

- *Code of Practice: Onshore Petroleum Activities in the Northern Territory* (DENR 2019)
- *Land Clearing Guidelines* (DENR 2019)
- *Guidelines for Assessment of Impacts on Terrestrial Biodiversity* (NT EPA 2013)
- *NT EPA Environmental Factors and Objectives* (NT EPA 2018)
- *Significant Impact Guidelines 1.1 - Matters of National Environmental Significance* (CoA 2013)
- *Northern Territory Water Allocation Planning Framework* (DENR)

While the SREBA does not aim to provide all the data required for local-scale, project-level environmental assessment, it should provide enough regional-scale context to ensure that when such assessments are undertaken:

- the required scope of project-level assessment of aquatic ecosystems can be reliably and precisely defined
- the regional significance of aquatic ecosystems present at local scale can be determined
- the contribution of local-scale impacts to regional-scale cumulative impacts can be evaluated.

Additionally, the potential impacts of water extraction on ecosystems dependent on surface water or groundwater are key considerations during the development of Water Allocation Plans under the *Water Act 1992*.

Consequently, these information requirements inform the scope of the SREBA in addition to those detailed in the Final Report.

4.2. Baseline information requirements

Baseline assessments for aquatic ecosystems that should be provided through the SREBA are listed below, with further detail provided in Section 4.4.

- Aquatic ecosystem types
- Aquatic plants, including algae

- Aquatic vertebrate species
- Aquatic invertebrate species
- Threatened and other significant species
- Significant sites

The information products that should be derived through analysis of this baseline data are listed below, with further detail provided in Sections 4.4 and 4.5.

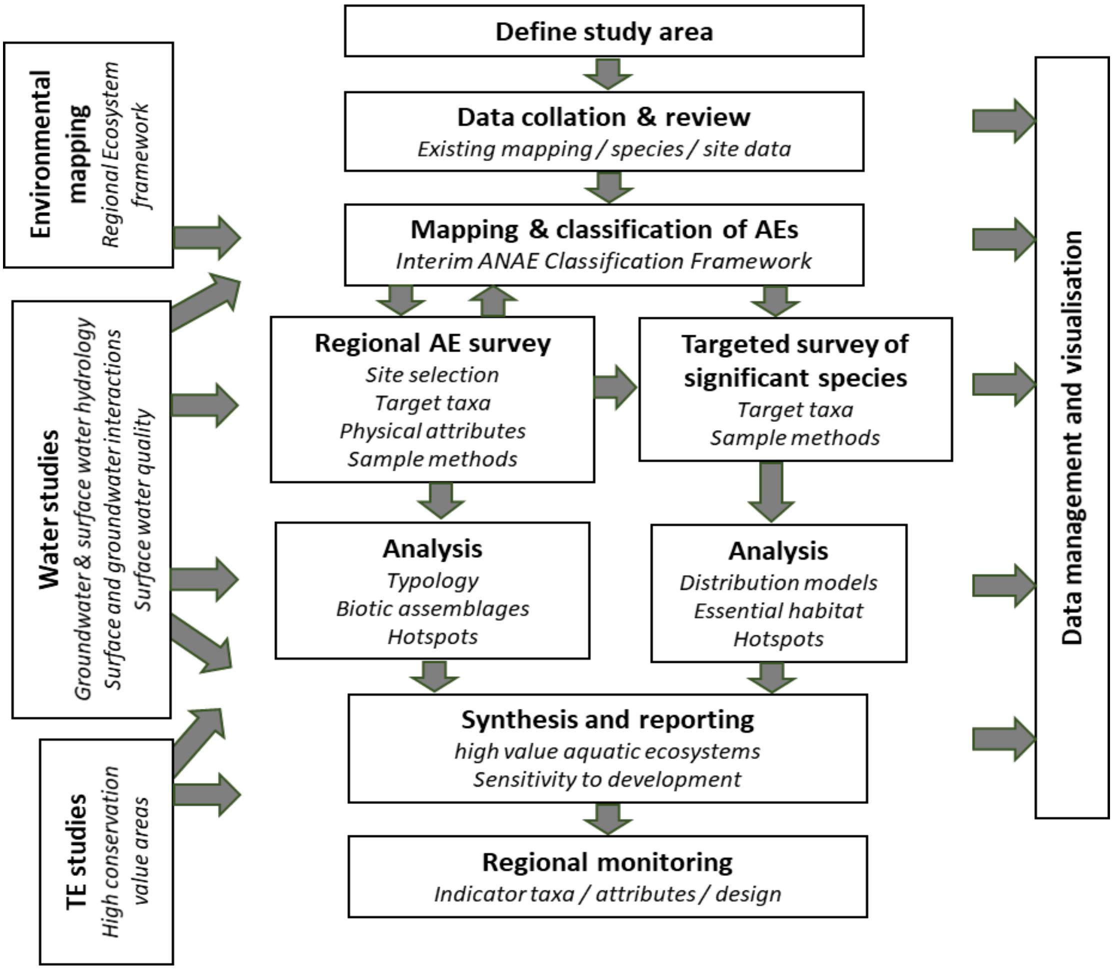
- Mapping and classification of aquatic ecosystems within the SREBA boundary
- Description of assemblages of aquatic biota and evaluation of environmental determinants, including predictive spatial models
- Identification of high ecological value aquatic ecosystems (HEVAEs)
- Identification of dry season refugia
- Spatial distribution models for significant aquatic species
- Evaluation of the sensitivity of HEVAEs and significant species to onshore gas-related development
- Description of indicators and methods for regional monitoring.

4.3. Assessment approach

The major components and general approach to aquatic ecosystem assessment in a SREBA are illustrated in Figure 4.1. The key elements of each step and appropriate methods are described in Section 6, noting that some region-specific aspects will be determined during the development of a Scope of Works. The Figure also highlights that inputs from, and collaboration with, other domains are important, notably surface and groundwater hydrology from the water baseline studies.

The Aquatic Ecosystems Toolkit (AETG 2012a) is a nationally agreed framework that provides a set of good practice tools for mapping, classifying and assessing the condition of aquatic ecosystems, and provides guidance to identify high ecological value aquatic ecosystems. In general, this framework and tools will be used in the SREBA, except where there is a well-documented benefit of an alternative method to meet requirements of the SREBA, or modifications necessary to meet specific regional characteristics.

Figure 4.1. Diagrammatic representation of the key elements of the aquatic ecosystem (AE) baseline study



4.4. Methods

4.4.1. Boundary

The boundary of each SREBA will be determined during the development of the Scope of Works for that region following expert advice from DENR (or an expert advisory group established to assist with this). For the aquatic ecosystem domain of the SREBA, the boundary should:

- encompass the geological (sub)basin with the gas resource
- encompass all aquatic ecosystems on which gas development in that region could feasibly have an impact, including predictable indirect impacts
- include sufficient extent to provide adequate regional context to assess the significance of any potential impact
- be based on catchment or sub-catchment boundaries, and the extent of underlying aquifers that support ground-water dependent ecosystems.

Considerations in defining the boundary include:

- the biogeographically-based boundaries adopted for terrestrial ecosystems should be used to the extent appropriate, so that similar boundaries are used for regional ecosystem mapping
- where only a small portion of a bioregion or catchment overlaps the edge of an identified gas resource, that entire region cannot be cost-effectively be incorporated in the SREBA, so only a portion of that subregion (within the zone of potential downstream impact) should be included.

4.4.2. Data collation and review

Collation and review of existing data and information at the start of the ecological studies is essential to informing environmental mapping, identifying the likely occurrence of significant species for targeted survey, informing the selection of target groups for regional biodiversity survey, and preliminary planning for these surveys. Information sources include (but are not limited to):

- Climate surfaces (e.g. SILO)
- Land resource and vegetation mapping
- Topographic mapping (GeoFabric) and digital elevation models (DEM)
- Remotely sensed data (Landsat, Sentinel, Water Observations from Space)
- Groundwater dependent ecosystems, e.g. Atlas of groundwater dependent ecosystems
- Northern Territory NR Maps
- Atlas of Living Australia
- Site data for vegetation and wildlife survey held by DENR
- Predictive distribution models for significant species developed by Environmental Resources Information Network (ERIN), National Environmental Science Program (NESP; Pintor et al., 2018)
- Existing wetland mapping and descriptions (e.g. Directory of Important Wetlands in Australia; Duguid et al. 2005; Kennard 2010).

Existing data, with relevant metadata, should be collated within the data management system established for the SREBA.

4.4.3. Mapping and classification of Aquatic Ecosystems

Accurate and relatively fine-scale mapping of aquatic ecosystems is essential to:

- provides the environmental stratification for regionally representative, site-based sampling of aquatic biota
- delineate the location and extent of high ecological value aquatic ecosystems
- predict the distribution of threatened or significant aquatic taxa
- allow aquatic ecosystems or habitats described at a local (project) scale to be placed in a regional context.

Aquatic ecosystems (AE) will be delineated during preliminary mapping of regional ecosystems in the SREBA study area as described in the Terrestrial Ecosystem Guidance Note (Section 5.4.3). As many aquatic ecosystems will have a very small area, these features must be mapped at a finer scale than the default resolution for regional ecosystems, and this requirement must be described in the SREBA Scope of Works. If the aquatic ecosystem SREBA boundary extends beyond that used for the terrestrial ecosystem domain, the regional ecosystem mapping methodology should be applied in the greater area for the landscape classes of interest.

Mapping of aquatic ecosystems by regional ecosystem mapping should be verified and refined by reference to:

- existing datasets on wetlands (e.g. Directory of Important Wetlands Australia, Duguid et al. 2005)
- datasets showing water presence over time (e.g. Water Observations from Space, Geosciences Australia)
- appropriate indices of water persistence and vegetation greenness from remotely sensed imagery (Landsat, or Sentinel for finer scale resolution)

Time series imagery from the datasets above can also be used to derive some aquatic ecosystem attributes, such as perenniality and water regime.

Once delineated, a preliminary classification for aquatic ecosystems within the SREBA boundary should be developed using the Interim ANAE Classification Framework (AETG 2012b), based on available information including geophysical mapping, remotely sensed imagery and existing site data. Key attributes for determining preliminary ecosystem classes are likely to include landform, substrate, dominant vegetation, and water regime. Where available, data and models from the water domain of the SREBA should be used at this stage to attribute the water source sustaining the aquatic ecosystem (surface and/or groundwater).

4.4.4. Regional characterisation of aquatic ecosystems

This element aims to provide a comprehensive description of the physical and biological attributes of a representative sample of aquatic ecosystems throughout the SREBA region.

Site selection

Sites should be sampled within a carefully stratified design based on the preliminary mapping and classification of aquatic ecosystems within the SREBA boundary. In general, all AE types should be represented by multiple sites that also encompass the spatial distribution of each type (particularly across any significant climate gradient). Other considerations in developing a stratified survey design include:

- A single wetland may need to be sampled by multiple sites according to extent and habitat complexity, and these sites should also be carefully selected to represent environmental variation within the wetland.
- With the exception of extremely spatially restricted cases, there should be multiple survey sites in each aquatic ecosystem type and the number of sites should be representative of the heterogeneity and spatial extent of each ecosystem (with a logarithmic rather than linear increase with area).

- Access considerations will inevitably bias the location of sites. Care must be taken to avoid unwanted consequences, such as underrepresentation of certain aquatic ecosystem types. Helicopter access to some remote sites is likely to be required to ensure adequate stratification.
- In addition to 'natural' environmental variation, the occurrence of many species will also be influenced by landscape condition at each site, particularly as affected by fire, weeds, grazing pressure (stock and feral animals), habitat modification and alteration of hydrological regimes.

  Where possible, sites should be selected in aquatic ecosystems in relatively 'good' condition, as determined by reference to relevant spatial information (e.g. fire scar mapping, distribution of stock water points, distance from settlement) and validated by field inspection, to enable the establishment of reference baseline conditions. For some areas or aquatic ecosystem types, availability of 'good' condition sites may be limited, and sites in poorer condition may be required to meet the necessary replication. Where there is evidence that there is a gradient in condition across particular aquatic ecosystem types, this should be explicitly considered within the sampling design and accounted for. In all cases, condition attributes should be scored for each site (as described below), so this can be included in analysis as a covariate.

Biodiversity attributes

The Final Report emphasises that a broad range of taxonomic groups should be considered during assessment of aquatic ecosystems. However, it is not feasible to sample all elements of aquatic biodiversity, so the taxonomic groups included in regional aquatic ecosystems surveys need to be carefully selected, using the following criteria:

1. There must be established sampling methods for that group, that provide robust, repeatable data on composition and, where relevant, relative abundance
2. Sampling methods must not have access or resource constraints (cost, personnel or time) that prevent them being effectively applied over a large number of sites within the scope of a SREBA
3. Groups must be taxonomically tractable, and/or taxonomic expertise must be available to resolve taxa to a level that is useful for describing biogeographic patterns or detecting change due to disturbance
4. The group should not be subject to high stochastic variability in distribution and abundance
5. Taxa within the group are likely to be sensitive to environmental change potentially arising from the development of an onshore gas industry in the study region
6. The group is likely to be a useful indicator for distribution patterns and temporal trends of other taxonomic groups.

Additional considerations include:

- The range of aquatic biota present in different aquatic ecosystem types (e.g. springs vs. intermittent creeks vs. perennial lakes) will vary substantially, even at higher taxonomic levels. Consequently, the groups sampled may not be consistent across all aquatic ecosystem types, but must be consistent within categories of aquatic ecosystem types

- Similarly, there are significant differences between biomes in aquatic biota (e.g. aquatic reptiles are not present in arid systems), so that a single universal approach cannot be applied across all regions subject to a SREBA.

Consequently, the set of biota to be included in regional surveys of aquatic ecosystems must be determined based on the ecological characteristics of that region, and specified in the Scope of Works for each SREBA, following expert advice from DENR (or an expert panel established to provide this advice). An indicative set of biota that is likely to meet all or most of these criteria is shown in Table 4.2, noting that only a taxonomic subset may be selected from these broader groups.

Table 4.2. Components of biodiversity that should be sampled in regional aquatic ecosystem surveys

Group	Considerations
Plants	Terrestrial vegetation dependent on surface and/or groundwater should be sampled as part of the terrestrial ecosystem surveys Aquatic vascular plants and macroalgae should be included in aquatic ecosystem surveys
Fish	May be limited to taxa that can be reliably sampled through specified methods, but should be as comprehensive as possible
Other aquatic vertebrates	May be limited to taxa that can be reliably sampled through specified methods, but should be as comprehensive as possible
Waterbirds	Birds that are generally dependent on aquatic ecosystems for feeding and/or breeding (e.g. Anatidae, Ardeidae, Rallidae, Charadriidae, Scolopacidae)
Aquatic macroinvertebrates	May be limited to orders or families that are taxonomically tractable and/or with high information content
Stygofauna	See Section 4.4.7

Sampling methods

Methods must be tailored to the taxonomic groups chosen and the environmental conditions in a region, and a detailed sampling method for each group must be described in the Scope of Works for each SREBA following appropriate expert advice and review, and approval from DENR. Key aspects of the sampling methods for the groups most likely to be included are described below. Due to the wide range of techniques available and the limited knowledge about aquatic biota in many regions of the NT, it may be necessary to test selected techniques at pilot study sites during the first year of a SREBA to confirm or refine the suitability of sampling methods.

The Inquiry notes the high inter-annual variability in aquatic systems in the Northern Territory, as well as additional unpredictability in wetting-drying cycles in arid and semi-arid regions, and therefore that multi-year sampling is important. The primary aim of this regional characterisation survey is adequate spatial and environmental coverage, but temporal coverage should also be incorporated where feasible, particularly where water regimes have high intra- and/or inter-annual variation, and where the target taxa are known to have high seasonal variation in presence, abundance and/or detectability.

For aquatic ecosystems with high seasonality, sites should generally be sampled after filling, late in the filled phase, and during the drying phase. Where repeat sampling is not possible due to logistical or access constraints, sampling should be during the period where biodiversity in the target group is likely to be at a maximum, based on expert advice (such as during recessional flows in the wet: dry transition for macroinvertebrates, or towards the end of the dry season when aquatic biota are concentrated in dry-season refugia.

Within the time and resource constraints of a SREBA, multi-year sampling (in addition to sampling to capture major variation in the drying/wetting cycle, which may occur across 2 or more years) is likely to be limited to a subset of target taxa and sites. These would generally be taxa suitable as indicators for long-term regional monitoring programs, and multi-year baseline sampling may continue after the completion of the SREBA.

Vegetation

Terrestrial vegetation dependent on surface or groundwater (floodplains, riparian woodlands, wet rainforest, etc.) will be sampled during regional surveys described in the guidance for Terrestrial Ecosystems, and selection of survey sites should be coordinated between these two domains. Aquatic vegetation should be sampled using a systematic plot- or transect-based approach, depending on access.

Vertebrates

Appropriate survey techniques for fish will depend on the characteristics of aquatic ecosystems in the SREBA region and include electrofishing, netting and visual census. Systematic surveys may be limited to guilds, taxa and/or size classes that can be robustly sampled by cost-effective techniques.

Freshwater turtles may be sampled by baited traps and crocodiles and semi-aquatic monitors by systematic visual census.

Terrestrial birds frequenting water-dependent vegetation will be sampled during regional surveys described in the guidance for Terrestrial Ecosystems. Surveys for birds under the aquatic ecosystem domain should focus on waterbirds, and particularly the importance of aquatic ecosystems for supporting aggregations of waterbirds for feeding and/or breeding. In addition to site-based methods, this may require broader scale aerial survey of wetlands at appropriate times of year or, in arid and semi-arid regions, in appropriate years (Jaensch 1994, Kingsford and Porter 2009).

Aquatic invertebrates

Sampling for macroinvertebrates should generally follow the protocols for AUSRIVAS (Lloyd and Cook 2001), with area- or time-based sweeps using a dip net in different habitats present at the site (e.g. riffle and edge habitats). Under the AUSRIVAS protocols, identification of macroinvertebrates is generally only to family level, but resolution to genus or species may be required to adequately describe patterns of richness and endemism at the regional scale, and provide sufficient power to detect changes due to potential impacts form development. As this is impractical for all macroinvertebrate families, sampling and sorting major taxonomic groups should occur (e.g. Ephemeroptera, Plecoptera, Trichoptera - EPT Taxa), or be determined by availability of identification resources, taxonomic expertise, or expert opinion with reference to existing data.

Environmental DNA

Techniques for identifying the presence of aquatic organisms through the presence of their DNA in water samples (eDNA) are rapidly being developed and refined (e.g. Harper et al. 2019). These methods may use either specific-specific probes or a metabarcoding approach. The use of eDNA for sampling some target taxa should be considered in scoping the SREBA, where this method is sufficiently proven to provide timely, cost-effective and robust measures of presence or absence of target taxa.

Physical attributes and condition

A carefully selected set of environmental attributes should be scored for each survey site, which will contribute to refining the mapping and classification of aquatic ecosystems, and which may be used as covariates in analyses of the environmental determinants of biogeographic patterns, as well as predictive modelling of species' distribution. Suitable physical attributes are described by AUSRIVAS (Lloyd & Cook 2001), AquaBAMM (Clayton et al 2001) and IECA (DoEE 2017), and an attribute set that is appropriate to the aquatic ecosystem types present in the SREBA region should be defined in the scope of works, following expert advice and approval by DENR.

Sampling of water quality at each site should be coordinated with surface water sampling protocols undertaken for the Water domain of the SREBA (see Section 3) and should characterise seasonal and interannual variability in water quality.

Environmental attributes scored at each site should also be informative about ecosystem condition at the site, and these attributes should be applicable within the Integrated Ecosystem Condition Assessment Framework (IECA) (DoEE, 2017) .

Analysis

Analyses and outputs from the regional aquatic ecosystem survey will include:

- Refinement of the classification and mapping of aquatic ecosystem in the SREBA, including a detailed typology based on biological and physical attributes
- Identification of aquatic flora and fauna assemblages
- Evaluation of the distribution of these assemblages in relation to aquatic ecosystem type and to environmental covariates measured and derived at a site scale, including development of predictive spatial models
- Identification of aquatic ecosystem types and sites with significant biodiversity values (e.g. high richness or diversity, large number of endemic or spatially restricted species) and, where possible, development of predictive spatial models for these values

4.4.5. Targeted survey of significant species

Regional surveys that aim to characterise aquatic ecosystems across the SREBA region may identify ecosystems that have high richness or endemism, or contain distinct or rare assemblages. However, regional surveys are generally not effective in providing detailed information about the distribution of species that are rare, have highly restricted distribution, or are poorly detectable by the survey methods used. For species that are considered significant, targeted survey that is tailored to the ecology of each species is required.

Target taxa

In the context of the SREBA, significant species include:

- Matters of National Environmental Significance (MNES) under the EPBC Act, i.e. species listed as threatened; migratory species listed under international agreements
- Species listed as threatened under the *NT Territory Parks and Wildlife Conservation Act 2000*
- Species listed as data-deficient or near-threatened under the *NT Territory Parks and Wildlife Conservation Act 2000*, where available ecological information indicates that additional data is likely to confirm that they are threatened, or are short-range endemics
- Species that are short-range endemics according to the criteria adopted by DENR
- Species that may form significant aggregations (such as important breeding sites for waterbirds).

In some cases, social impact assessment undertaking during SREBA may indicate species of particularly high cultural significance that could be included in the ecology program. Where these are common or widespread species they may also be adequately detected during regional surveys.

A list of species for targeted survey within the SREBA should be developed through analysis of existing data and information for the region (section 4.4.2), including existing predictive modelling of distribution of threatened and migratory species (EPBC Protected Matters Search Tool (PMST), Species Profiles and Threats database (SPRAT), National Environmental Science Program (NESP; Pintor et al. 2018). In developing this list, consideration should be given to:

- Predictive species models for threatened species (e.g. EPBC Protected Matters tool) may have low precision and in some cases choice of target species should be supported by higher precision modelling (e.g. Pintor et al. 2018) and appropriate expert opinion.
- The number of species that can be feasibly subject to targeted survey within a SREBA will have limitations due to time and resource constraints. If necessary, priority should be given to species:
    - that are legislatively listed, and particularly those species that have a more severe threat category
    - that have the largest proportion of their currently known distribution within the region
    - that have higher predicted likelihood of occurrence within the region
    - for which the region contains significant areas of habitat known to be essential to the life history of the species (e.g. breeding sites) for which survey protocols that maximise detectability are known and can be cost-effectively applied within the SREBA region.

The list of species for targeted survey for a SREBA and the survey method for each (see below) should be subject to expert review, and approval by DENR.

Regional surveys may indicate the presence of significant species that were not identified in the initial selection process. In this case, a similar process should be applied to determine if additional targeted survey is required for these species.

Sample methods

Sample methods for significant species should followed published guidelines where available (e.g. DSEWPC 2011) and established methods supported by scientific literature, with modification for environmental characteristics of the SREBA region as required. Methods should provide sufficiently high detection probabilities and spatial sampling intensity to allow the development of robust spatial distribution models for the target taxa, and sampling should incorporate seasonal and inter-annual variation where this significantly influences the presence, abundance and/or detectability of the target taxa. Sample locations for a species may be informed by preliminary spatial distribution modelling, or by expert knowledge of habitat requirements. In all cases, targeted species surveys should have a quantified survey effort and environmental attributes should be collected for both presence and absence locations to assist analysis and interpretation.

4.4.5.1. Analysis

Analysis of targeted survey data will generally aim to develop a spatial distribution model for each species within the SREBA boundary. The appropriate analytical technique will depend on the nature of the species data and the spatial data used as environmental predictors and include occupancy modelling (MacKenzie et al. 2002) or presence-based approaches such as MaxEnt (Elith et al. 2011). In all cases modelling should quantify the uncertainty associated with the predicted distribution.

The significance of the occurrence and predicted distribution of significant species should be evaluated in the context of the species broader distribution, occurrence and habitat requirements. Where possible, analyses should delineate the extent of aquatic ecosystems within the SREBA boundary that are likely to be important for the persistence of the species in the region.

Data and models for each significant species may be overlaid to delineate areas (‘hotspots’) with relatively high concentrations of significant species.

4.4.6. Targeted survey of significant aquatic ecosystems

In addition to ensuring that significant species are adequately surveyed, consideration should be given to ensuring that aquatic ecosystems of special interest are adequately sampled. These are likely to be ecosystems that meet the criteria for High Ecological Value Aquatic Ecosystems (HEVAEs; Section 4.5) but may also be aquatic systems of public interest due to high social or cultural values, and/or concern about the potential impacts of onshore gas development.

An indicative list of significant aquatic ecosystems should be developed during initial data collation and review, including consideration of previous classifications (e.g. wetlands of national significance in the Directory of Important Wetlands Australia), existing data and the HEVAE criteria. These aquatic ecosystems should be sampled during the regional surveys described in Section 4.4.4 to ensure that there is adequate data for them to be included in the regional assessment of HEVAEs.

4.4.7. Stygofauna

The Final Report recommended that stygofauna should be included in the assessment of aquatic ecosystems during a SREBA, with this recommendation particularly being informed by the likely occurrence of stygofauna in the Cambrian Limestone Aquifer in the Beetaloo sub-basin.

Stygofauna are fauna that live in groundwater systems or aquifers and includes epigean fauna in shallow groundwater under streams, fauna in caves below the water table, and fauna in pore spaces in deeper aquifers. Stygofauna in the Northern Territory are extremely poorly known, but in similar habitats in northern Australia they have attracted attention due to high levels of endemism, phylogenetic novelty and biodiversity.

Sample methods for stygofauna have been developed for Western Australia and Queensland and are detailed in DSITI (2015) and WA EPA (2016). Based on these guidelines, an approach to sampling stygofauna during a SREBA would likely include:

- a desktop assessment of the hydrogeological conditions in the SREBA to identify aquifers that have attributes likely to make them favourable for stygofauna
- mapping the locations of existing bores likely to be screened in favourable aquifers, and the locations of other aquatic subterranean ecosystems (e.g. saturated karst systems, alluvial sediments where rivers are fed by groundwater, springs and sinkholes)
- sampling of stygofauna species diversity and relative abundance in groundwater bores using standard techniques (pumping, phreatic nets)
- sampling of epigeal stygofauna using Bou-Rouch pumps or the Karaman-Chappuis method (digging pits beside a stream, bailing out the incoming groundwater and filtering it through a net)
- sampling of cave-dwelling stygofauna (where there is human access) using similar techniques to those employed for surface water invertebrates
- collection of concurrent water quality information that may be useful for developing predictive models of stygofaunal species distribution and biodiversity ‘hotspots’
- consideration of including stygofauna sampling during any groundwater sampling undertaken in the region, including under the water domain of the SREBA.

Pilot studies are needed to refine appropriate methods for stygofauna sampling in the Northern Territory, which may also vary between SREBA regions. This guidance will be updated as pilot studies occur, including investigation of the use of eDNA to characterise stygofaunal communities.

4.5. Synthesis

The primary objective of the SREBA is to provide adequate baseline data, in this case for aquatic ecosystems, that can be used to inform the assessment of potential impacts of development at project and regional scales. In general, the Aquatic Ecosystem domain aims to identify, map and describe aquatic ecosystems, including GDEs, identify sites with high biodiversity value, and determine the distribution of significant species. Some of the information products provided by the regional mapping and characterisation of aquatic ecosystems, and targeted surveys for significant species, are described in section 4.4 above. Additional synthesis outputs are described below.

Close collaboration between Water, Aquatic Ecosystem and Terrestrial Ecosystem domains is required during the synthesis, due to close links between the former two in relation to water-dependent ecosystems, and between the latter two in relation to describing ecological values and identifying high conservation value areas.

4.5.1. High Ecological Value Aquatic Ecosystems

High Ecological Value Aquatic Ecosystems (HEVAE) are the counterpart of "high conservation value areas" described in the terrestrial ecosystem guidance note. The assessment of HEVAEs should follow the process and criteria described in AETG (2012c), with these criteria including:

- diversity
- distinctiveness
- vital habitat
- naturalness
- representativeness

Data collected during the SREBA should allow for the 'bottom-up' approach described in AETG (2012c), with a relatively fine spatial resolution. Assessment of HEVAEs may be assisted or reviewed through the appointment of an appropriate expert reference panel.

The output from this assessment will include a set of HEVAE sites with ecological values identified, spatial layers, metadata statement and assessment report.

4.5.2 Identification of dry season refugia

Dry season refugia are areas where aquatic or water-dependent biota can survive periods of unfavourable condition, notably during the annual dry season in the northern, monsoonal Northern Territory, and during extended periods with little rain in the southern, arid Northern Territory.

The persistence of surface water and green vegetation will be assessed for all aquatic ecosystems within SREBA using time-series of remotely sensed data (section 4.4.2). The importance of aquatic ecosystems to biota during dry periods can be assessed from biodiversity sampling that incorporates seasonal and inter-annual variability (sections 4.4.2, 4.4.5), and refugia are included within the "vital habitat" criteria in assessing HEVAEs. Variation in water quality in aquatic refugia will be characterised during regional surveys (section 4.4.4).

4.5.3 Sensitivity of significant species and HEVAEs

The Final Report requires that the SREBA should characterise the dependency or degree of influence on ecosystems by groundwater, and their likely sensitivity to water extraction related to onshore gas development.

The sensitivity of surface and groundwater dependent systems to changes in water quantity will be assessed using groundwater-surface water flow models developed in the Water domain of the SREBA, with particular attention to systems identified in this domain as supporting HEVAEs or 'biodiversity hotspots' with relatively high concentrations of significant species. Data collected during the SREBA will contribute to the development or refinement of ecological conceptual models to support these sensitivity analyses.

In assessing the sensitivity of significant species to development pressures, and particularly cumulative impacts, the approach will need to be designed once both the species involved, and the likely pathway for onshore gas development in the region, are known. An important step in this process may be the development of locally relevant conceptual models that integrate current understanding of aquatic ecosystems and the ecology of threatened species. Guidance on the development of evidenced-based conceptual models of ecosystems is provided by several sources including Olander et al. (2018) and BOM (2016). Advice on the use of conceptual models in impact assessment is provided by CoA (2015). Identifying causality is also an important issue. That is, any changes that occur to aquatic ecosystems need to be able to be causally linked to impacts from gas development and separated from other major sources of disturbance such as long-term pastoral use or climate change.

The risk assessment process undertaken by the Geological and Bioregional Assessment (GBA) Program for MNES species and GDEs is a relevant example of the approach that could be taken in this sensitivity assessment, and should be considered in developing a SREBA Scope of Works.

4.5.4 Monitoring

The Final Report requires that monitoring programs be developed for any threatened species that is likely to be affected from cumulative impacts associated with onshore gas development (Rec 8.6) and, more generally, the Report describes one of the purposes of a SREBA as the collection of baseline data to provide a reference point for ongoing monitoring. Monitoring of local biodiversity values may form part of the conditions associated with authorisation for project-level development, but assessment of the longer-term, cumulative impacts of gas field development can only be achieved through monitoring at a regional scale, with adequate before-impact data.

There is an extensive literature on the design and implementation of ecological monitoring programs (e.g. Lindenmayer & Liken 2010, Lindenmayer & Gibbons 2012), including recognition of the high failure rate for monitoring programs in Australia and key attributes for success.

Data collection and analyses undertaken during the aquatic biodiversity assessment composition of a SREBA can inform the design of robust monitoring programs, including the selection of suitable indicator taxa/groups or other biodiversity attributes. Sites sampled during the SREBA assessment may be suitable for ongoing monitoring but only where they meet the objectives and design of specific monitoring program.

Detailed guidance on indicators and monitoring programs is not provided here as it is dependent on the outcomes from biodiversity assessment and analyses described in sections above, and the requirements for each SREBA should be scoped once this information is available. General considerations would include:

- clear understanding and description of purpose and objectives for monitoring
- financial resources to support and maintain monitoring over time
- access to appropriate expertise and capability

- robust sampling design including appropriate spatial and temporal scales
- the choice of simple and meaningful indicators.
- appropriate assessment of program, including feedback into decision making.

4.6. Reporting and data management

The Aquatic Ecosystems Baseline Report for a SREBA will contain detailed descriptions of the methods, results, analyses and synthesis products, as well as cataloguing the data collated and collected during the project with appropriate metadata.

Summary outputs from the assessment should be in formats that are readily available, and comprehensible, to a broad audience (such as web-enabled, interactive maps). Effective public communication of results will be informed by a SREBA-wide communication plan.

Data standards for all data collected during the regional baseline assessment will be specified in the Scope of Works. Data should be stored in the information management system developed for the SREBA and curated under a data management plan developed for the Aquatic Ecosystem component. The data management plan should identify owners and data custodians for all datasets, and any data restrictions.

In general, all data should be open-access, however access may be restricted to some data according to the sensitive data policy of the SREBA. For aquatic ecosystem data, this should apply only in very limited cases where open access to locality data may genuinely increase threats to a site or species, or where data may identify culturally sensitive sites.

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5. Guidance Note for studies of terrestrial ecosystems

5.1. Introduction

This guidance note describes the general approach and methods for terrestrial ecosystem baseline assessment, as part of a broader Strategic Regional and Environmental Baseline Assessment (SREBA).

This guidance applies to a SREBA undertaken in any region of the Northern Territory. The guidance will inform the development of a Scope of Works for terrestrial ecosystem assessment in a region subject to a SREBA, where the detailed methods will be tailored to the environmental attributes of that region.

The guidance should be read within the context provided by Sections 1 and 2 of the SREBA Framework. As there is inevitably some overlap between terrestrial and aquatic systems, the Aquatic Ecosystems Guidance Note should also be referred to while scoping a terrestrial ecosystem assessment.

5.1.1. Requirements of the Final Report

Chapter 15 of the *Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory* describes the requirement for a SREBA and the scope of objectives within each of the major domains. In relation to terrestrial ecosystems, the Final Report states the SREBA should address the following objectives:

- *identify locations of high conservation value within affected IBRA bioregions through systematic survey of vascular plants, vertebrates and selected invertebrate taxa*
- *establish current distribution and densities of occurrence of weed species throughout the region*
- *determine if any threatened species are likely to be seriously affected by the cumulative effects of habitat loss and fragmentation that could accompany any onshore shale gas development.*

These objectives are reflected in several recommendations in the Final Report as summarised below in Table 5.1.

Table 5.1. Recommendations of the Scientific Inquiry relevant to the terrestrial ecosystems component of SREBA.

Recommendation:	
8.1	*That:* • *strategic regional terrestrial biodiversity assessments be conducted as part of a SREBA prior to the granting of any further production approvals;* • *any onshore shale gas development be excluded from areas considered to be of high conservation value; and* • *the results of the SREBA must inform any decision to release land for exploration permits as specified in Recommendation 14.2 and, upon completion, must be considered by the decision-maker in the granting of any future exploration approvals.*

Recommendation:	
8.2	*That a baseline weed assessment be conducted over all areas that will be accessed by a gas company on an exploration permit prior to any exploration activities being carried out on that area and that ongoing weed monitoring be undertaken to inform any weed management measures necessary to ensure no incursions or spread of weeds.*
8.6	*That as part of a SREBA, a study be undertaken to determine if any threatened species are likely to be affected by the cumulative effects of vegetation and habitat loss, and if so, that there be ongoing monitoring of the populations of these species. If monitoring reveals a decline in populations (compared with pre-development baselines), management plans aimed at mitigating these declines must be developed and implemented.*

The Final Report also provides guidance around issues that must be addressed in designing a SREBA. For terrestrial biodiversity (Final Report section 15.3.3, p 448), the key points are:

- Regional assessments should be comprehensive, both in terms of space (covering all major vegetation types across the region) and biota (including all groups of vascular plants and terrestrial vertebrates, and representative terrestrial invertebrates). The data should be assessed for patterns of species richness and endemism, and for the occurrence of threatened species.

- Across much of the NT, there is insufficient coverage of survey data to be able to place a strong degree of reliance on existing mapping datasets. This applies especially to the coverage of ground data that will be required for a regional assessment of an industry with a potentially large footprint and a potentially significant cumulative impact, as distinct from an individual project assessment with a smaller total footprint. Significant on-ground work will therefore be needed to comprehensively map the occurrence and distribution of terrestrial biodiversity assets of regions likely to be affected by the extraction of any onshore shale gas.

- It will be critical to ensure that verifiably consistent methods are being used during the baseline assessment.

5.1.2. Additional considerations

Onshore gas development in the Northern Territory is likely to be subject to authorisation and regulation under various legislation, including:

- *Petroleum Act 1984* and Petroleum (Environmental) Regulations 2016
- *Environment Assessment Act 1989* (which will be replaced in 2020 by the Environment Protection Act 2019)
- *Environment Protection Act 2019*
- *Planning Act 1999*
- *Pastoral Land Act 1992*
- *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act)

The information requirements for assessment, approval and auditing in relation to these authorisations, including those relating to terrestrial biodiversity are described in:

- *Code of Practice: Onshore Petroleum Activities in the Northern Territory* (DENR 2019a)
- *Land Clearing Guidelines* (DENR 2019b)
- *Guidelines for Assessment of Impacts on Terrestrial Biodiversity* (NT EPA 2013)
- *NT EPA Environmental Factors and Objectives* (NT EPA 2018)
- *Significant Impact Guidelines 1.1 - Matters of National Environmental Significance* (CoA 2013)

While the SREBA does not aim to provide all the data required for local-scale, project-level environmental assessment, it should provide sufficient regional-scale context to ensure that:

- the required scope of project-level biodiversity assessment can be reliably and precisely defined
- the regional significance of biodiversity values identified at local scale can be determined
- the contribution of local-scale impacts to regional-scale cumulative impacts can be assessed.

Consequently, these biodiversity information requirements have been considered in informing the scope of the SREBA, in addition to those detailed in the Final Report.

5.2. Baseline information requirements

The environmental attributes that should be measured to provide the terrestrial ecosystem baseline for the SREBA are listed below, with further detail provided in section 5.4.

- Ecological communities
- Threatened species
- Other significant species
- Weeds
- Vascular plant species
- Terrestrial vertebrate species
- Terrestrial invertebrate species

The information products that should be derived through analysis of this baseline data are listed below, with further detail provided in sections 5.4 and 5.5.

- Regional ecosystem mapping
- Description of regional biogeographic patterns
- Spatial distribution models for significant species
- Identification and mapping of high conservation value areas
- Evaluation of sensitivity of significant species to development
- Description of indicators and methods for regional monitoring

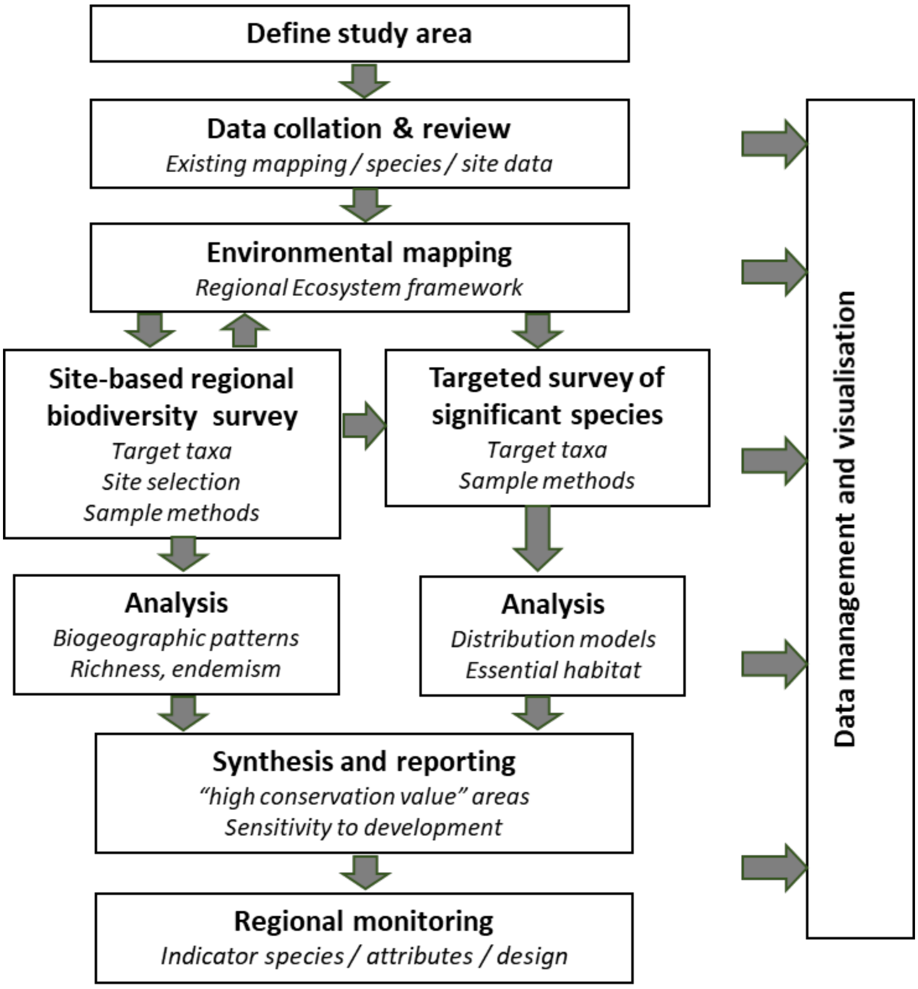
While weeds are an important environmental issue, the requirement for a baseline weed assessment (Recommendation 8.2) has been addressed through the *Code of Practice (DENR 2019a)* and associated guideline *Weed Management Planning Guide: Onshore Petroleum Projects*. Weeds are not addressed further in this document, other than to note that the presence of weed species will be recorded during site-based regional biodiversity surveys.

5.3. Assessment approach

Terrestrial biodiversity assessment for the SREBA requires the following steps, as shown in Figure 5.1 below. The key elements of each step and appropriate methods are described in section 5.4, noting that some aspects will be determined for each SREBA during the development of a Scope of Works.

1. Define study area
2. Data collation and review
3. Environmental mapping
4. Site-based regional biodiversity survey
5. Targeted survey for significant species
6. Analysis, synthesis and reporting
7. Data management
8. Development of regional monitoring

Figure 5.1. Diagrammatic representation of the key elements of the terrestrial ecosystems baseline study.



5.4. Methods

5.4.1. Boundary

The boundary of each SREBA will be determined during the development of the Scope of Works for that region, following expert advice from DENR (or an expert advisory group established to assist with this). For the ecology domains of the SREBA, this should include consideration of:

- nationally recognised biogeographic boundaries (IBRA regions and subregions)
- geological (sub)basin boundaries delimiting the gas resource
- the spatial distribution of ecological values on which gas development in that region could feasibly have an impact, including predictable indirect impacts
- boundaries of aquifers that may be subject to impact, particularly where these may determine the distribution of attributes such as groundwater dependent ecosystems
- inclusion of sufficient geographic extent to provide adequate regional context to assist the assessment of the significance of ecological values and any potential impact on them.

Where feasible, these boundaries should correspond to IBRA sub-bioregions. However, additional consideration should be given to:

- where gas development can feasibly only occur in one part of an extensive region, sub-regional boundaries may be appropriate
- where only a small portion of a bioregion overlaps the edge of an identified gas resource, that entire bioregion cannot be cost-effectively be incorporated in the SREBA, so only a portion of that subregion should be included
- where there is potential for significant downstream impacts from development (notably on the quality or quantity of ground- or surface water), the boundary may extend out of the bioregion where development will occur, likely following (sub) catchment boundaries.

5.4.2. Data collation and review

Collation and review of existing data and information at the start of the ecological studies is essential to informing environmental mapping, identifying the likely occurrence of significant species for targeted survey, informing the selection of target groups for regional biodiversity survey, and preliminary planning for these surveys. Information sources include (but are not limited to):

- climate surfaces
- geological mapping
- land resource and vegetation mapping
- topographic mapping and digital elevation models (DEM)
- Northern Territory NR Maps
- Atlas of Living Australia
- site data from soil, vegetation and wildlife surveys held by DENR
- predictive distribution models for significant species developed by ERIN (https://www.environment.gov.au/about-us/environmental-information-data) and NESP (Pintor et al 2018).

Existing data, with relevant metadata, should be collated within the data management system established for the SREBA.

5.4.3. Environmental mapping

Environmental mapping is essential to the ecology components of the SREBA as it:

- provides the environmental stratification for regionally representative, site-based sampling of biodiversity
- delineates the location and extent of rare or significant ecosystems
- may be used to design sampling for and predict the distribution of threatened or significant taxa
- allows ecosystems or habitats described at a local (project) scale to be placed in a regional context.

There are a range of approaches to environmental mapping, which place varying emphasis on attributes such as geology, topography, soils and vegetation structure and composition. SREBA will use the Queensland Regional Ecosystem framework (Sattler & William 1999, Neldner *et al* 2019a), where "regional ecosystems" are vegetation communities in a bioregion that are consistently associated with a particular combination of geology, landform and soil. This is a well-established approach that provides a hierarchical landscape classification that recognizes major variation in land zones (also called landscape classes in the NT), vegetation structure and ecologically dominant upper stratum species. It is suited to mapping at a relatively broad (bioregional) scale and describes ecosystems at a scale that is likely to be useful for predicting the distribution of many plant and animal taxa.

The approach and methods for regional ecosystem mapping are well documented (Neldner et al 2019b). For SREBA, a map resolution of 1:100,000 will generally be appropriate, with a scale of attribute classification equivalent to the plant association (Level 5; NVIS Technical Working Group (2017)). Some regionally restricted ecosystems that are likely to have a distinctive biodiversity should be mapped and classified at a finer scale with a minimum polygon size appropriate to their local patch size. These may include wetlands, riparian zones, monsoon rainforest patches, karst features or heaths, and this requirement must be determined in the SREBA scope on a regional basis, following expert advice from DENR.

Due to the large size of a SREBA study area and the limited timeframe, preliminary mapping of regional ecosystems should be developed and attributed through interpretation of remotely sensed imagery and existing independent environmental mapping and/or site-based data. Preliminary mapping of regional ecosystems will inform site selection for regional biodiversity survey, and site-based data collected during the SREBA will be used iteratively to improve, calibrate and validate delineation and description of regional ecosystems.

5.4.4. Systematic regional biodiversity survey

This survey aims to comprehensively map the occurrence and distribution of biodiversity assets across the geographic and environmental extent of the SREBA region.

Target taxa

The Final Report emphasises the need for regional biodiversity assessments to be comprehensive, in terms of the biota sampled. However, it is not feasible to sample all elements of biodiversity, so the taxonomic groups included in regional surveys need to be carefully selected, using the following criteria:

1. There must be established sampling methods for that group, that provide sufficiently high detection probability for robust analysis of geographic patterns and detection of change in community composition over time
2. Sampling methods must not have access or resource constraints (cost, personnel or time) that prevent them being effectively applied over a large number of sites within the scope of a SREBA
3. The group should not be subject to high stochastic variability in distribution and abundance
4. Groups must be taxonomically tractable, and/or taxonomic expertise must be available to resolve taxa to species, or consistently to morpho-species
5. Species within the group are likely to be sensitive to environmental change potentially arising from the development of an onshore gas industry in the study region

6. The group is likely to be a useful indicator for distribution patterns and temporal trends of other taxonomic groups.

For SREBAs in any region of the NT, the minimum set of biota that meets all or most of these criteria and which should be included in systematic regional surveys is shown in Table 5.2. Other groups may be included for a SREBA depending on the ecological characteristics of the region, or with the development of new sampling methods, and these should be considered in the scope of that SREBA following expert advice from DENR. Note that additional taxonomic groups are addressed in the Aquatic Ecology guidance note.

Table 5.2. Components of biodiversity that should be sampled in regional biodiversity surveys during a SREBA. Taxa in brackets may be appropriate in some SREBA regions and considered on a case-by-case basis.

Group	Components
Plants	All vascular plants
Terrestrial vertebrates	Mammals, (bats) Birds Reptiles (Frogs)
Terrestrial Invertebrates	Ants Beetles – Carabidae, Curculionidae (Land snails - Camaenidae)

Site selection

Regional survey sites should be located within a carefully stratified design based on the preliminary regional ecosystem mapping. In general, all regional ecosystems should be represented by multiple sites that also encompass the spatial extent of each ecosystem (particularly across any significant climate gradient). Other considerations in developing a stratified survey design include:

- Sites should be spatially independent (individual animals being surveyed cannot move among sites during the sampling period). While it is desirable to minimise spatial autocorrelation (by ensuring sites are widely spaced), logistic considerations mean that sites may be clustered. Nevertheless, there should be 2 km minimum spacing between any sites
- Access considerations will inevitably bias the location of sites. Care must be taken of unwanted consequences, such as atypical disturbance effects close to roads and tracks. Helicopter access to some remote sites is likely to be required to ensure adequate stratification
- In addition to 'natural' environmental variation, the occurrence of many species will also be influenced by landscape condition at each site, particularly the effects of land clearing, fire, grazing pressure (stock and feral animals) and weeds. In general, sites should be selected to be within relatively large areas of habitat in 'good' condition, as determined by reference to relevant spatial information (fire scar mapping, distribution of stock water points, and distance from settlement) and validated by field inspection. In some regional ecosystems, availability of 'good' condition sites may be limited, and sites in poorer condition may be required to meet the necessary replication; in this case condition should be introduced as an explicit factor in the stratification. In all cases, land condition attributes should be scored for each site, so this can be included in analysis as a covariate

- Except for extremely spatially restricted cases, there should be a minimum of five survey sites in each regional ecosystem and the number of sites will increase with the heterogeneity and spatial extent of each ecosystem (with a logarithmic rather than linear increase with area)
- Due to the sampling time per site, more vegetation sites can be sampled than fauna sites.

The total number of regional survey sites that should be sampled in a SREBA region will depend on its environmental complexity and total size. Additionally, the number of sites that can feasibly be sampled will be constrained by resources and time. It is anticipated that for most potential SREBA regions there will be:

- between 100 and 200 sites sampled for full floristics, terrestrial vertebrates and terrestrial invertebrates
- between 100 and 200 additional sites sampled for vegetation and environmental attributes.

The stratified regional survey design for a SREBA should be subject to expert review, and approval by DENR, prior to sampling commencing.

Sample methods

Key elements of the sample methods for each group are described here. Methods must be tailored to the environmental conditions in a region, so a more detailed sampling method will be described in the Scope of Works for each SREBA following expert advice from DENR.

Vascular plants

Site-based floristic surveys and vegetation description should follow Brocklehurst et al. (2007) with a plot size appropriate for the SREBA biome. Plant identification must be supported by voucher specimens where required. Full floristic sampling will be constrained by seasonal conditions and may only be possible in a subset of survey sites, and survey design must ensure that this subsample is also representative. Survey of the perennial component of the flora is less constrained, and vegetation description from a larger number of plots will also improve validation of regional ecosystems mapping.

Terrestrial vertebrates

Systematic survey methods for terrestrial vertebrates are well established in the Northern Territory (e.g. Woinarski et al. 2010, Gillespie et al. 2015) and site-based sampling should follow methods described in the current Standard Operating Procedures (SOP) used by Flora and Fauna Division of DENR, which includes a combination of:

- motion-detecting cameras (mammals, some birds and reptiles)

  live animal traps (Elliott, cages; mammals, some reptiles)
- drift fences with pits and funnels (reptiles, some mammals)
- diurnal and nocturnal timed searches (reptiles, some mammals and birds)
- repeated visual and aural census (birds).

These methods allow both occupancy and detection probabilities to be assessed for each species. Given time and resource constraints, there is generally a trade-off between sample intensity at a site (trap-nights, bird counts, etc.) and total number of sites and this can be optimised to meet specific objectives (Einoder et al. 2018). This should be addressed in the Scope of Works for the SREBA, but generally sites will be sampled for vertebrates over a three- or four-day period.

Some elements of the vertebrate biota are like to show significant seasonal variation in detectability and/or occupancy. This must be accounted for in survey design, either through constraining the sampling period or accounting for season in the stratification.

There are taxonomic uncertainties and potentially undescribed cryptic taxa for a number of mammal and reptile groups. Where possible, non-destructive tissue samples should be taken from representative captured animals.

Terrestrial invertebrates

There are a variety of methods for sampling ants and beetles, primarily through the use of pit traps. While a larger array of pits will provide a more comprehensive sample of the fauna, this also entails much greater sorting and identification time. Sampling methods should generally follow those described in Oberprieler et al. (2019). Ants, and carabid and curculionid beetles, should be sampled using the pit trap array within the sites used for vertebrate surveys. Samples should be identified to consistent morphospecies (or named species where this is possible), supported by a reference collection. Where possible, species identity should be supported by DNA barcoding.

Environmental attributes

In addition to vegetation description, environmental attributes should be scored for each survey site, which will contribute to the mapping and classification of regional ecosystems, and may be used as covariates in analyses of the environmental determinants of biogeographic patterns, as well as predictive modelling of species' distribution. Environmental attributes should also be informative about landscape condition at the site. A core set of environmental attributes is described in the current SOP used by Flora and Fauna Division of DENR, and this should be modified as required for each SREBA following expert advice from DENR.

Analysis

Analysis of data from regional biodiversity survey should include:

- Identification of floristic and faunal assemblages
- Calculation of summary biodiversity metrics (e.g. richness, diversity) at a site, assemblage and regional ecosystems scale
- Evaluation of the distribution of floristic and faunal assemblages in relation to regional ecosystems, and to environmental covariates measured and derived at a site scale
- Evaluation of the environmental determinants of summary biodiversity metrics
- Identification of assemblages and ecosystems with biodiversity values that may be relevant to impact assessment (e.g. high richness or diversity, large number of endemic or preferential species, spatially restricted extent)
- Predictive spatial models within the SREBA boundary for floristic and faunal assemblages, and appropriate summary biodiversity metrics.

5.4.5. Targeted survey for significant species

Systematic regional biodiversity surveys aim to describe fauna and flora assemblages across a region and their environmental determinants and may identify regional ecosystems that have high species richness or endemism, or distinct plant or animal composition. However, regional surveys are generally not effective for providing detailed information about the distribution of individual species that are rare, have highly restricted distribution, or are poorly detectable by the methods described above. Where this information is required for species that are considered significant, targeted survey that is tailored to the ecology of each species is required.

Target taxa

In the context of the SREBA, significant species include:

- Matters of National Environmental Significance (MNES) under the EPBC Act, i.e. species listed as threatened; migratory species listed under international agreements
- Species listed as threatened under the *NT Territory Parks and Wildlife Conservation Act 2000*
- Species listed as data-deficient or near-threatened under the *NT Territory Parks and Wildlife Conservation Act 2000*, where available ecological information indicates that additional data is likely to confirm that they are threatened, or are short-range endemics
- Species that are short-range endemics according to the criteria adopted by DENR
- Species that may form significant aggregations (see section 5.4.4).

In some cases, social impact assessment undertaking during SREBA may indicate species of particularly high cultural significance that could be included in the ecology program. Where these are common or widespread species they may also be adequately detected during regional surveys.

A list of species for targeted survey within the SREBA should be developed through analysis of existing data and information for the region (section 5.4.2). In developing this list, consideration should be given to:

- Some vertebrate species are acknowledged to be regionally extinct in some bioregions of the NT, so distribution information based on older records should be interpreted carefully
- Predictive species models for threatened species (e.g. EPBC Protected matters tool) may have low precision and in some cases choice of target species should be supported by higher precision modelling (e.g. Pintor et al. 2018) and appropriate expert opinion.
- The number of species that can be feasibly subject to targeted survey within a SREBA will be limited due to time and resource constraints. If necessary, priority should be given to species:
  - that are legislatively listed, and particularly those species that have a more severe threat category
  - that have the largest proportion of their currently known distribution within the region
  - that have higher predicted likelihood of occurrence within the region
  - for which the region contains significant areas of habitat known to be essential to the life history of the species (e.g. breeding sites)
  - for which survey protocols that maximise detectability are known and can be cost-effectively applied within the SREBA region.

The list of species for targeted survey for a SREBA should be subject to expert review, and approval by DENR.

Regional biodiversity surveys may indicate the presence of significant species that were not identified in the initial selection process. In this case, a similar process should be applied to determine if additional targeted survey is required for these species.

Sampling methods

There are a broad range of sample methods for individual species. General guidance has been developed for many MNES species (DEWHA 2010a,b,c; DSEWPC 2011a,b) and both general approaches and methods for many species are described in the scientific literature. In most cases, targeted survey involves plot- or transect-based sampling using a method that provides an acceptable detection probability for that species. For some taxa, appropriate methods may involve the use of motion-sensor cameras or songmeters, or detection via tracks, scats or environmental DNA (Day et al. in press). Sample locations for a species may be informed by preliminary spatial distribution modelling, or by knowledge of habitat requirements. In all cases, targeted species surveys should have a quantified survey effort and environmental attributes should be collected for both presence and absence locations to assist analysis and interpretation.

Once target taxa are selected, survey methods for each species should be developed through reference to published guidance and in consultation with relevant experts. Survey methods should be subject to expert review and approval by DENR.

Analysis

Analysis of targeted survey data will generally aim to develop a spatial distribution model for each species within the SREBA boundary. The appropriate analytical technique will depend on the nature of the species data and the spatial data used as environmental predictors and include occupancy modelling (MacKenzie et al. 2002) or presence-based approaches such as MaxEnt (Elith et al. 2011). In all cases modelling should quantify the uncertainty associated with the predicted distribution.

The significance of the occurrence and predicted distribution of significant species should be evaluated in the context of the species broader distribution, occurrence and habitat requirements. Where possible, analyses should delineate the extent of ecosystems within he SREBA boundary that are likely to important for the persistence of the species in the region.

5.5. Synthesis

The primary objective of the SREBA is to provide adequate baseline data, in this case for terrestrial ecosystems, to inform the assessment of potential impacts of development at project and regional scales. Some of the information products provided by analysis of the regional biodiversity survey and targeted species surveys are described in section 5.4 above.

An impact or risk assessment approach for terrestrial biodiversity attributes is not described here as part of the SREBA. However, the Final Report specified some required outputs requiring further analysis and synthesis of the baseline data collected during the SREBA.

5.5.1. Areas of high conservation value

The Final Report specified that data collected during this component of the SREBA should be used to identify "areas of high conservation value" and other Recommendations of the Report state that onshore gas development should be excluded from these areas (Rec 8.1), and that they may be declared "no-go zones" where petroleum title cannot be granted (Rec 14.4).

The Inquiry does not explicitly define "high conservation value", but this term is generally understood to refer to areas that contain biological or ecological values considered outstandingly significant at the regional, national, or global level. Ecological values that may contribute to this include concentrations of threatened or rare species and ecosystems, high levels of endemism, or important refugia.

High conservation value areas have been broadly identified at a Northern Territory scale (termed Sites of Conservation Significance) using a set of objective criteria (Ward & Harrison 2009) that included:

- concentration of threatened species
- concentration of endemic species
- wildlife aggregations
- botanical significance.

Similar criteria should be applied in identifying areas of high conservation value in a SREBA region, noting that these criteria may need to be modified to apply effectively at a regional scale (for example, essential habitat for a single endangered species or short-range endemic species may be considered an area of high conservation value). Information from the studies of aquatic ecosystems of the SREBA region will also be required to assess all of these criteria.

5.5.2. Sensitivity of significant species

The Final Report requires that the SREBA should determine if any threatened species are likely to be affected by the cumulative effects of vegetation and habitat loss (from future onshore gas development), with ongoing monitoring of the populations of any such species. Based on the requirements for the assessment and authorisation of industry development this requirement should extend, to the extent practicable, to other 'significant' species (section 5.4.6). While the Final Report sensibly identified vegetation clearance and fragmentation as a key potential pressure on terrestrial biodiversity, there may also feasibly be other significant pressures, such as alteration of fire regimes, facilitation of predators such as cats, increased vehicle activity, etc.

The assessment of cumulative impacts is very challenging and the methodology for doing so is poorly developed globally. The specific approach will need to be designed once both the species involved, and the likely pathway for onshore gas development in the region are known. Important considerations include:

- The assessment will be informed by published data and research on the effects of clearing and fragmentation on related or analogue species in comparable environments in northern Australia, nationally or globally. This should also recognise the sizeable, but underappreciated, body of research that shows positive effects for biodiversity of habitat fragmentation (e.g. Fahrig et al. 2017).

- Sensitivity to potential impact is likely to be higher for species that:
  - are dependent on a large area of continuous vegetation during one or more stages of its life cycle
  - are habitat specialists and/or have regionally restricted distribution
  - where there is significant overlap at a regional scale of areas with areas with a high probability of occurrence and the potential development footprint of the gas field.
- An important step in this process may be the development of locally relevant conceptual models that integrate current understanding of terrestrial ecosystems and the ecology of threatened species. Guidance on the development of evidenced-based conceptual models of ecosystems is provided by several sources including Olander et al. (2018) and BOM (2016). Advice on the use of conceptual models in impact assessment is provided by CoA (2015).
- Identifying causality is an important issue. That is, any changes that occur to terrestrial ecosystems need to be able to be casually linked to impacts from gas resource development and separated from other major sources of disturbance such as long-term pastoral use, or adverse fire regimes.
- The assessment must identify levels of uncertainty in both the input data and models and the subsequent sensitivity assessment.

The risk assessment process undertaken by the Geological and Bioregional Assessment (GBA) Program for MNES species and GDEs is a relevant example of the approach that could be taken in this sensitivity assessment, and should be considered in developing a SREBA Scope of Works.

5.5.3. Monitoring

The Final Report requires that monitoring programs be developed for any threatened species that is likely to be affected from cumulative impacts associated with onshore gas development (Rec 8.6) and, more generally, the Report describes one of the purposes of a SREBA as the collection of baseline data to provide a reference point for ongoing monitoring. Monitoring of particular local biodiversity values may form part of the conditions associated with authorisation for project-level development, but assessment of the longer-term, cumulative impacts of gas field development can only be achieved through monitoring at a regional scale, with adequate before-impact data.

There is an extensive literature on the design and implementation of ecological monitoring programs (e.g. Lindenmayer & Liken 2010, Lindenmayer & Gibbons 2012), including recognition of the high failure rate for monitoring programs in Australia and key attributes for success.

Data collection and analyses undertaken during the terrestrial biodiversity assessment composition of a SREBA can inform the design of robust monitoring programs, including the selection of suitable indicator taxa or other biodiversity attributes. Sites sampled during the SREBA assessment may be suitable for ongoing monitoring but only where they meet the objectives and design of specific monitoring program.

Detailed guidance on indicators and monitoring programs is not provided here as it is dependent on the outcomes from biodiversity survey and analyses described in sections above, and the requirements for each SREBA should be scoped once this information is available. General considerations would include:

- clear understanding and description of purpose and objectives for monitoring

- financial resources to support and maintain monitoring over time
- access to appropriate expertise and capability
- robust sampling design including appropriate spatial and temporal scales
- the choice of simple and meaningful indicators.
- appropriate review and assessment of program, including feedbacks into decision making

5.6. Reporting and data management

The Terrestrial Ecosystems Baseline Report for a SREBA will contain detailed descriptions of the methods, results, analyses and synthesis products, as well as cataloguing the data collated and collected during the project with appropriate metadata.

Summary outputs from the assessment should be in formats that are readily available, and comprehensible, to a broad audience (such as web-enabled, interactive maps). Effective public communication of results will be informed by a SREBA-wide communication plan.

Data standards for all data collected during the regional baseline assessment will be specified in the Scope of Works. Data should be stored in the information management system developed for the SREBA and curated under a data management plan developed for the Terrestrial Ecosystem component. The data management plan should identify owners and data custodians for all datasets, and any data restrictions.

In general, all data should be open-access, however access may be restricted to some data according to the sensitive data policy of the SREBA. For terrestrial ecosystem data, this should apply only in very limited cases where open access to locality data may genuinely increase threats to a species, or where data may identify culturally sensitive sites.

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6. Guidance Note for greenhouse gas studies

6.1. Introduction

This Guidance Note describes a general methodology for undertaking pre-development baseline studies of greenhouse gases in areas of the Northern Territory with shale or unconventional petroleum resources that may be developed at some point in the future. The primary focus is on detecting and estimating methane (CH_4) emissions because these are most likely to change as a result of future development of onshore petroleum resources.

However, it can be useful to also detect carbon dioxide (CO_2) and ethane (C_2H_6) emissions at the same sources because these can indicate whether the methane emissions are produced from living organisms (biogenic), from the generation of heat such as fires or termite mounds (thermogenic), or from geological process that produce natural gas (geogenic). It is important to distinguish between different origins of greenhouse gas emissions to fully understand whether any variation is normal, or as a result of a change such as increased cattle numbers across the region, or the introduction of new infrastructure and economic activities related to the development of a petroleum basin.

This Guidance Note describes the necessary datasets, baseline studies, information and reports that the baseline studies need to deliver.

6.1.1. Objectives and Purpose

Recommendation 9.3 of the Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory states:

> *That baseline monitoring of methane concentrations is undertaken for at least six months prior to the grant of any further exploration approvals. In areas where hydraulic fracturing has already occurred, the baseline monitoring should be undertaken at least a year prior to the grant of any production approvals.*

The objective of this Guidance Note is to provide broad guidance for conducting effective baseline studies of greenhouse gas (especially methane) emissions in the gas basins of the Northern Territory. The information provided here draws on the knowledge gained from previous research undertaken in Australia and elsewhere for determining emissions and is intended to outline:

- the information required for the baseline assessment and identify the main variables that must be measured to provide this information
- the type of data necessary for ongoing monitoring to be able to detect changes in the region
- suitable methodology for conducting baseline monitoring.

Two different measures are relevant, and both are critical to the baseline studies. The measure of concentration is a measure of the abundance of methane in air, usually defined in terms of the proportion of the total volume it accounts for in air (units are often parts per million, ppm, or parts per billion, ppb). The second measure is of how much methane is added over time, referred to as the emission rate or flux and expressed as a volumetric flow (in m^3 per unit time) or mass flow (in g or kg per unit time). Measuring methane helps to locate and identify sources, and measuring emission rates makes it possible to estimate the amount of methane released to the atmosphere over time.

6.1.2. Measuring, estimating and monitoring methane emissions

Natural sources of methane emissions may be significant and include sources such as fires, production of biological methane from wetland, and natural seepage of geological methane from sedimentary basins. These emissions may vary throughout the year as seasonal conditions influence vegetation growth and decomposition of organic matter. Other major sources include agriculture (especially cattle production) and burning of biomass. None of these sources are covered by the mandated methods in Australia's National Greenhouse and Energy Reporting but an accurate inventory of these emissions is critical to establishing pre-development baseline levels against which industry emissions can be assessed. Any seasonal variation in emissions must also be accounted for in the baseline levels.

As yet, there is no universal, standard method for establishing baseline emissions in gas basins. However, a significant amount of research has been conducted worldwide to develop suitable methodology for determining regional-scale emissions within unconventional gas production regions. Since 2013, there have been detailed studies completed in Australian unconventional gas regions in Queensland, New South Wales and Western Australia aimed at developing appropriate methodology for measuring methane emissions (and other atmospheric emissions) from both gas production operations and other landscape sources (Luhar et al. 2018; Ong et al. 2017; Day et al. 2014; Day et al. 2015; Day et al. 2016). The techniques examined include mobile surveys using gas analysers mounted in vehicles or aircraft, the establishment of fixed monitoring stations, ground-based measurements such as surface flux chambers, and remote sensing using satellites and aircraft. Some of these methods are suited to conducting baseline studies within the Northern Territory gas basins and are discussed in detail in the Appendix to this Guidance Note.

The upstream activities of the gas industry involve finding, producing, processing and transporting natural gas. Upstream activities generate emissions from leakage from equipment, bores and waste streams, and are generally known as fugitive emissions. Equipment and processes are designed to minimise fugitive emissions because this equates to a loss of a product and potential income so there is an incentive to reduce fugitive emissions to as low as possible and practical. Recent surveys of above-ground gas pipelines and associated valves in the Northern Territory did not identify a significant increase in methane emissions around this infrastructure, suggesting that fugitive emission was negligible (Ong et al. 2018). However, fugitive emissions would need to be monitored if there was a substantial increase in gas-related infrastructure in the region as a result of developing petroleum resources. Fugitive emissions generally represent a small proportion of emissions from the Australian gas industry's total emissions, but they can be a significant source of emissions from industry operating outside of Australia. Many sources of fugitive emissions are difficult to measure directly and consequently, quantifying methane emissions, especially in unconventional gas production/extraction regions, is currently an active area of scientific research throughout the world.

By far the largest proportion of greenhouse gas emissions from the natural gas industry occurs at combustion (downstream) where the gas is used to make electricity, or for industrial or residential uses. Mid- and downstream activities are outside the scope of this Guidance Note.

6.2. Baseline information requirements

For a comprehensive baseline study, it is necessary to:

- assess the ambient methane concentrations across the region (including natural and anthropogenic sources)
- develop a basin conceptual model to identify areas of higher risk of geogenic emissions
- identify all of the potential methane sources contributing to the observed methane levels
- locate these sources
- determine the emission rates of each source
- examine any seasonal or annual variation
- identify indicators and methods that will be relevant for an ongoing monitoring program.

Performing these steps may be challenging depending on the size of the region, the size and distribution of the sources, access, terrain and many other factors. The design of the study will be informed by an understanding of the how natural and anthropogenic sources of methane vary across the region, and is likely to draw upon the geological mapping and resource characterisation, and ecosystem mapping and characterisation work undertaken for the ecological baseline studies within the region.

6.3. Assessment approach

In general, data gathering will focus on ambient methane concentration, although other gases including carbon dioxide and ethane may also be measured. Such atmospheric data are usually reported as volumetric concentrations or 'mixing ratios' typically in units of parts per million (ppm) or parts per billion (ppb). However, the principal metric required in baseline surveys is the emission flux from each source. Typically, these are expressed in units of mass of methane per unit time. For inventory reporting sources may be averaged over a full year so the units would be in kilograms of methane emitted per year, or kg CH_4 y^{-1}. However, many emission sources do not have constant emission rates so measurements or estimates of their emission rates must be made at the appropriate timescale. It should be noted that attempting to infer annual emissions from estimates based on short timescales without adequate knowledge of the temporal variation in the emission source can lead to large uncertainties in regional inventories.

6.4. Methods

The choice of the methods used for baselines will depend on numerous factors including:

- landscape of the region (i.e. topography, soils, vegetation etc.)
- the type, location and size of sources
- seasonal and other temporal variation in emission rate
- proximity of the source to other sources of methane
- access to the source.

Because of these factors, a combination of methods may be required, with mobile surveys likely to feature in most studies because of the ability to accurately measure emissions over a relatively large area reasonably quickly

At the present time, the state of the art for conducting baseline measurements at a remote location is mobile surveys. During the initial phases of baseline studies, mobile surveys provide the advantage of facilitating detailed examination of the region to locate and identify methane sources. Most of the equipment required for tracer methods and flux chambers can be carried in the vehicle used for mobile surveys so these methods can usually be deployed in conjunction with the surveying programme. In the future, mobile surveys could be combined with other indirect approaches such as remote sensing to provide a broad coverage of the area, as well as more targeted monitoring at specific locations previously identified as important sources of methane emissions.

Although it is conceivable that a network of fixed monitoring stations across a basin could be used to undertake continuous baseline monitoring, establishing and maintaining such a network in remote areas is logistically very challenging and fixed monitoring stations may be impractical and prohibitively costly across large gas basins such as those that exist in the Northern Territory. Hence, fixed monitoring stations may not be a feasible approach to baseline monitoring at present but could be an option in the future if the scale and breadth of production activities warranted such an investment.

In these instances, fixed monitoring stations could be established near gas processing plants or other methane sources to provide continuous methane concentration data downwind of the facility. Such monitoring sites would not generally give methane fluxes (although this may be possible at some sites, albeit with significant data processing required) but may identify significant methane release events from gas infrastructure. Additionally, since the Inquiry recommended continuous monitoring of nitrogen oxides and particulate matter be undertaken near production facilities, it would be a simple matter to co-locate the methane analysers with those installed for other atmospheric emissions. More detail on alternative data collection and estimation techniques is included in the Appendix to the Guidance Note.

In addition, the use of earth observation satellite imagery to determine the contributions from spatially large natural emissions such as fire may also be useful.

6.4.1. Boundary

The boundary of the area for the greenhouse gas baseline studies will be determined during the development of the Scope of Works for that region following expert advice from DENR (or the expert advisory group established to assist with this). The boundary should reflect the boundary of the geological (sub-) basin boundaries where the gas resource targeted for potential development occurs, with an appropriate spatial buffer.

6.4.2. Mapping and classification of potential sources

Collating and reviewing existing data and information at the start of a methane baseline study is essential to developing a preliminary methane inventory. This inventory can be used to tailor the study so there is targeted monitoring at specific locations previously identified as important sources of methane emissions.

Natural methane sources should be identified as far as possible. Important potential sources likely to be encountered in the Northern Territory include:

- wetlands
- termite mounds
- fires, including wildfires and controlled burning
- geological seeps.

Mapping work undertaken for resource characterisation or geology and ecological baseline studies can be used to define the various potential natural sources of methane emissions in region. Once the region's sources of methane are known then targeted monitoring activities can be determined.

For anthropogenic activities, the information required include potential sources of emissions such as:

- current industrial infrastructure (power generation plants, existing gas pipelines etc.)
- agricultural activities (cattle herd numbers, location of feed lots, etc.)
- water bores
- current and abandoned mining operations
- mineral, oil and gas exploration and production boreholes
- urban areas and associated wastewater treatment plants and landfills
- frequency, duration and area affected by biomass burning
- fugitive emissions of industrial infrastructure (mining operations, gas pipelines etc.). These include methane derived from leaking equipment, venting, deliberate releases that may occur during maintenance and accidental releases (such as pipeline failures).

6.4.3. Mobile Surveys

Periodic surveys of the target region can be made using a suitable gas analyser mounted in a vehicle. For this method, it is essential that a high sensitivity analyser be used (i.e. capable of reliably measuring methane concentration to 5 ppb or less). It is also important that the instrument is sufficiently robust to operate with the high levels of vibration often encountered during mobile surveys and withstand the harsh environmental conditions such as high temperatures and dust levels.

It is feasible to conduct mobile surveys from low flying aircraft or unmanned aerial vehicles (UAVs) although proven case histories of surveys using aircraft have so far been limited, especially in Australia (see for example Day et al. 2015). Apart from the cost of using aircraft or the need for a certified pilot to operate a UAV, there may be civil aviation, pastoralists/livestock or cultural restrictions associated with low altitude aerial surveys. Additionally, there are multiple complexities with the use of UAVs including accounting for wind turbulence, stability, actual measurement area and impact of the UAV operation on the measurements to name a few.

A major advantage of vehicle surveys, on the other hand, is that detailed investigations of a region can be made which greatly assists in locating and identifying methane sources. Additionally, the lower cost of ground surveys means that more frequent surveys are possible.

For ground-based mobile surveys, methane concentration measurements must be made in conjunction with continuous location data (from a GPS mounted on the vehicle). An anemometer may also be mounted on the vehicle to measure local wind speed and direction. It is essential to remove the effect of the vehicle's motion on the data measured by the anemometer, so it is generally preferred to use only wind data collected from a vehicle-mounted anemometer while the vehicle was stationary.

Combining the concentration data with the wind data and using a suitable plume dispersion model may allow flux quantification for some methane sources under favourable conditions. By traversing across a plume downwind of the source, the emission flux, *F*, may be estimated by integrating the CH_4 concentration enhancement (i.e. measured concentration minus the local background concentration), *C*, of the plume in the horizontal, *y*, and vertical, *z*, directions and multiplying by the average wind velocity, *u*, according to Equation 6.1.

$$F = u \int_{-y}^{y} \int_{0}^{z} C(y,z)\,dy\,dz \qquad \text{(Equation 6.1)}$$

Because concentration measurements are made only at ground level, the vertical dispersion must be estimated by reference to plume dispersion models such as the Pasquill-Gifford curves of σ_z (i.e. the standard deviation of the distribution of CH_4 concentration in the vertical direction) as a function of downwind distance under given atmospheric turbulence conditions (Hanna et al., 1982). In this approach we assume that the maximum CH_4 concentration in the vertical column occurs at ground level; the vertical concentration profile of CH_4 within the plume is then assumed to decrease from the ground level concentration with height according to a Gaussian distribution. Because the maximum concentration must be at ground level, the source must also be at or near ground level. The method is therefore unsuitable for elevated sources, although other plume dispersion methods can often be applied in these cases.

Surveys are done by driving over the target region and monitoring methane concentrations. Methane sources are indicated by increased methane concentrations reported by the analyser. Where elevated concentrations are detected, attempts should be made to locate and identify the source for further investigation. Because concentrations are affected by prevailing wind conditions, the distance of the vehicle from the source as well as the size of the source, concentration perturbations may vary over a large range, and it is not possible to provide a definitive concentration threshold that indicates a source. However, as a guide, concentration peaks of more than 100 ppb and lasting more than a few seconds warrant investigation. It should be noted that cattle are a very common source of methane peaks observed during surveys.

Although emission flux can be calculated occasionally using data from mobile surveys, by far most of the data from surveys will be presented as spatial concentration maps of the region. Data from the methane analyser and GPS are combined (and aligned to the same time stamp) then plotted in appropriate GIS software to yield maps showing the methane concentration along the survey route. Any concentration peaks are clearly visible on this type of map.

Prior to conducting a survey, it is good practice to determine the location of possible sources such as water bores, existing gas or petroleum wells and other infrastructure or cattle feedlots, for example. These should then be surveyed during the field campaigns.

Where methane sources are detected by ground-based surveys perpendicular transects should be made across the entire plume; concentration data from such transects may be used to determine the emission rate of the source. However, suitable transects can only be made when vehicle access to the plume is available, and the prevailing wind conditions are suitable. It is also necessary to estimate the approximate downwind distance of the vehicle from the source, which may be difficult if the source of the emissions cannot be identified. In cases where transects can be made, at least six passes should be made to provide a reasonable average. The wind speed, wind direction and temperature must also be recorded.

Vehicle surveys are usually limited to trafficable roads and tracks. Although it may be possible to survey off-track areas in some cases, the roughness of the terrain and safety considerations may limit the spatial extent of sampling in some regions of the Northern Territory.

Other methods that may be applied in monitoring methane emissions are described in Appendix 6.1.

6.5. Synthesis

The primary output from the baseline study will be a methane inventory of the study region. This should include all sources found during the monitoring campaigns and their emission rates. It is also important that natural variability in the emission rates is quantified so that the range of normal baseline emissions is established.

For subsequent surveys, especially after gas production activities commence, any changes, either above or below this normal range, should be highlighted. It should be noted that for practical reasons, baseline monitoring will be conducted in a phased approach. Consequently, reporting will reflect the phased nature of the monitoring program and inventories will develop over time.

6.6. Reporting and data management

Baseline methane monitoring will generate a very large amount of data on emissions and their spatial distribution that will require a substantial amount of processing. One effective method for interpretation and presentation of the data is by geographical information systems (GIS). With this approach, maps of the study region can be readily generated that display the background methane concentrations and any concentration peaks and associated sources (and the estimated flux).

Reports should clearly identify pre-development background levels of methane emissions, identify and explain any spatial or temporal variation across the region, and identify the variables likely to influence background levels in the future (vegetation growth, fire frequency and intensity, cattle stocking rates, vehicle traffic, number of bores, extent of gas-related infrastructure, etc.)

6.7. References

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Appendix 6.1 - Overview of data collection and estimation techniques

Previous studies of methane emissions in gas basins have used a combination of numerous methods, including airborne and satellite remote sensing, airborne concentration measurements and various ground-based measurement approaches. For the baseline studies necessary for the Northern Territory, current generation satellite remote sensing systems alone do not yet have the capability of providing the level of detail necessary to meet all the requirements of a baseline assessment. Nevertheless, satellites may provide regional-scale spatial data at a temporal rate unattainable from other methods, and hence, may provide important characterisation at a regional scale. Although it may not be possible to fully attribute these data to all sources, they may be useful to track regional-scale trends, especially where sufficient pre-exploration data were collected. These data may be usefully combined with other finer scale methodology described below. Remote sensing may be particularly useful where there are large potential source areas, such as around basin margins.

While airborne remote sensing methods have been used in some studies in the United States for estimating gas-related methane emissions and can potentially provide wide-area coverage at a fine spatial resolution, these methods are not yet widely available in the public domain and are generally still in development, often involving long-term collaboration between government research institutions and universities.

In Australia, most research into methane emissions in unconventional gas fields has involved various ground-based approaches, although some limited airborne and satellite trials have also been performed (Day et al. 2015). Life cycle analysis of gas unconventional gas production in Queensland has also been undertaken – this is useful in assessing impacts of fugitive emissions and other consequences of gas production (Schandl et al. 2019).

There are several ground-based techniques for detecting methane and quantifying methane sources that are suited to baseline studies, and where it is difficult to directly measure emission rates, a proxy can be adopted from previous studies using emission factors. It is possible that baseline monitoring may require more than one technique to properly characterise methane sources within a target region. In broad terms, the various approaches may be categorised as:

- Mobile surveys (described in section 6.4.3)
- Tracer gas methods
- Surface flux chambers
- Fixed ambient monitoring
- Emission factors

Tracer Gas Methods

While mobile surveys may yield data suitable for determining emission rate in some cases, this approach is highly opportunistic and requires a narrow range of suitable wind conditions, full access to the methane plume and preferably reasonably flat terrain. Where these conditions are not met, it is usually not possible to use the concentration data to determine flux. As well, even under favourable conditions, the flux estimates are subject to significant uncertainty due to the need to estimate the vertical extent of the plume using the plume model.

An alternative approach to determine emission rates is the use of a tracer gas. Here, a stable gas unrelated to the source, such as acetylene, is released at a known rate, F_{Tracer}, from the same location as the methane source. Simultaneous downwind measurements of the concentration enhancement of both the tracer, C_{Tracer}, and methane C_{CH4}, are made and the emission rate of methane, F_{CH4}, calculated according to Equation 6.2.

$$F_{CH4} = F_{Tracer} \times {}^{C_{CH4}}/_{C_{Tracer}} \qquad \text{(Equation 6.2)}$$

The tracer method avoids the need to estimate the vertical CH_4 profile in the plume. In addition, as shown in Equation 2, information on wind speed, direction or the width of the plume is not required to calculate the emission rate. The method, however, does require additional analytical capability to measure the tracer gas with sufficient accuracy and precision, and the flow rate of the tracer gas must also be measured very accurately. It is also essential that the tracer experience the same plume transport phenomena as the target, so it is important that the tracer is well mixed in the plume.

The tracer method can yield accurate emission rates for relatively small to medium sized sources. For examples, gas production wells, leaking water bores or exploration boreholes are very well suited to the tracer method. Larger sources, however, are more difficult due to the fact that it is difficult or impractical to release large amounts of tracer across the entire source.

For baseline monitoring, the tracer method would be useful for measuring sites that are known to be sources of methane (e.g. leaking water bores). Because of the low uncertainty of the method, it can provide high-quality emission data over a long period and therefore would be valuable for monitoring changes in emission behaviour over time. However, it is first necessary to identify and/or confirm areas of methane emissions using mobile concentration surveys before deploying tracer methods.

Surface Flux Chambers

Surface flux chambers provide a direct measure of methane emissions (and other gasses) from the ground surface. It is also possible to measure gas exchange with water bodies by placing a suitable chamber on the water's surface.

In the static mode of operation, a closed chamber is placed on the test surface and gas flowing from the enclosed surface is collected in the chamber. The gas concentration, *C*, increases with time, *t*, and the gas flux, *F*, is calculated from the rate of change in concentration inside the chamber, *dC/dt*, according to Equation 6.3.

$$F = \frac{dC}{dt} \times \frac{V}{A} \qquad \text{(Equation 6.3)}$$

Here, V is the volume of the chamber, and A is the area of the surface covered by the chamber. Chambers can be made to various sizes and shapes to suit the particular application and are usually constructed from metal or plastic.

Most flux chambers cover an area of less than 1 m^2, so to fully characterise a surface would require many individual measurements and consequently flux chambers alone are unsuited to wide-scale regional monitoring. Nonetheless, they provide an effective method for determining emission rates from natural soil surfaces and ground seeps or areas considered to be high-risk seepage site (e.g. outcropping permeable strata). To provide better spatial coverage, multiple chambers operating simultaneously and spread across localised areas of tens of metres are sometimes used. Note that many natural ground surfaces are nett sinks of methane rather than methane emitters.

Because flux chambers enclose a small area of ground, the units of the measurement are in terms of mass of methane per unit time per unit area (e.g. mg CH_4 day^{-1} m^{-2}). Consequently, to properly calculate the total emission rate from the source, the total area must be known; e.g. total flux (mg day^{-1}) = average flux chamber emission rate (mg CH_4 day^{-1} m^{-2}) x total source area (m^2).

Flux chambers are particularly suited to assess methane leaks outside well casings, thus are recommended when examining gas and petroleum wells, exploration boreholes and water bores.

When used with a high sensitivity gas analyser such as those suited to mobile surveys, flux chambers are effective at detecting small changes in ground gas exchange. Hence, the use of flux chamber(s) is highly recommended at sites either considered to be at risk of gas seepage (from the initial risk assessment) or known to be ground seeps. Such sites should be surveyed regularly during each baseline study to identify changes in behaviour, especially once gas production has commenced. In addition, it may be useful to collect temporal flux chamber measurements during the pre-exploration stages at well sites to better characterise the natural variation before the well is drilled.

Fixed Ambient Monitoring

Methane concentrations may be monitored using fixed stations located within the target region. Monitoring stations usually operate unattended and continuously for extended periods. Given the remote locations of any potential fixed station in the Northern Territory, the system would need to be designed so that instrument calibrations and performance checks are made automatically.

Many fixed monitoring stations are housed in purpose built sheds and in the Northern Territory, air conditioning will be required with significant power requirements. Note that generators are unsuitable for providing power due to the potential influence of exhaust emissions on the monitoring results. Instruments with low power requirements that can be operated by solar/battery systems are now commercially available (such as eddy covariance systems and some tunable laser diode analysers).

Generally, fixed monitoring stations provide concentration data, but if local meteorological data are also measured at each site, the direction of methane sources can potentially be determined. When concentration and meteorological data are combined in a suitable model, and with sufficient monitoring stations in the target region, it is feasible to locate sources and determine the emissions rate using an atmospheric transport model and model ‘inversion’ methods from each source (Luhar et al. 2018). However, this approach is extremely complex and largely at the research stage requiring significantly more development before suitable as a routine method.

Landscape methane emission rates may be measured using an eddy covariance method, which also uses fixed monitoring stations. This approach is well established and widely used although generally, the technique is intended to only measure ground fluxes of gasses over a relatively small area of no more than several hundred metres radius from the station. The small footprint of this method can mean that results are not representative in heterogeneous environments and large biases would be introduced if attempting to extrapolate results from small-scale eddy covariance stations to an entire region. Consequently, to cover large areas, a significant number of installations would be required or alternatively, the station would need to be moved regularly (or both). Although higher towers are possible (even up to hundreds of metres) the cost of installing and operating a system of tower-mounted analysers that could provide representative coverage of a large gas basin would be prohibitive. Analysis and interpretation of data from such installations to yield useful flux estimates would also be very challenging.

Overall it is considered that at present, fixed monitoring is not readily applicable to baseline monitoring in the Northern Territory gas basins. However, fixed monitoring systems may be suitable in future applications for identifying local changes in methane levels associated with gas production facilities. Indeed, The Inquiry recommended that monitoring stations be established 12 months before gas production commences and continue after the start of production. Such monitoring stations would require high sensitivity analysers of the type normally used for atmospheric monitoring – instruments used for plant safety monitoring are not usually sensitive enough to detect small variations in ambient methane concentrations.

Emission Factors

In many cases, it is difficult to directly measure emission rates, for example, because of the very large size of the source (e.g. biomass burning) or if the source is very widely distributed (e.g. grazing cattle or termite mounds). However, it may still be possible to estimate these emissions for the region using emission factors. This approach is usually used for inventory reporting of Australia's greenhouse gas emissions.

Emission factors are intended to provide a representative value of the emissions from a particular activity and are usually derived from previous measurements of similar sources. Often emission factors are based on limited information so may have high uncertainties; however, some emission factors may be well established from large datasets and hence can provide accurate estimates. For instance, emissions from cattle have been studied extensively, and the emission rates of methane have been widely published.

In the simplest application of this method, the emission rate of the source is calculated by multiplying the emission factor by an activity rate for the source (Equation 6.4).

$$F = EF \times A \qquad \text{(Equation 6.4)}$$

Where *F* is the emission rate for the entire source, *EF* is the emission factor appropriate for the source, and *A* is the activity rate of the source. The activity rate depends on the nature of the source and the units of the emissions factor. For cattle for example, the activity rate would be the number of head of cattle in the region while the emission factor would be in grams of CH_4 per animal per day.

7. Guidance Note for environmental health studies

7.1. Introduction

Human health and development are linked through a range of environmental, social, cultural and economic determinants of health. For development to capitalise on opportunities to improve health as well as effectively manage risks to health, it is critical that the links between development and health are identified and understood. This requires knowledge about both the type of health impacts that may occur and the distribution of those impacts in the affected community (enHealth 2002). This Guidance Note is based on broad risk assessment methodologies; however, it provides a more specific health characterisation of potential risks to the community from hydraulic fracturing projects.

Potential human health risks from gas extraction activities are consistently raised as an issue of concern to the community. As Keywood et al. (2018) has shown, as confidence in knowledge increases, health concerns decrease. Methodologies have been developed to evaluate health impacts related to onshore petroleum activities, such as the CSIRO's GISERA Human Health Effects Study Design Framework, outlined in Appendix 1. Many elements of the GISERA Framework are applicable to the intent of this Guidance Note for the Northern Territory and are included in this document.

Public health concerns identified in the Inquiry

The Final Report from the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory mentions two categories of risk to Human Health:

1. Adverse Health Effects in people as a result of exposure to chemicals associated with hydraulic fracturing activities either associated with the contamination of aquifers and consequent ingestion by humans or livestock through drinking water, or with airborne emissions of volatile compounds from well heads. The chemicals under consideration include those used in hydraulic fracturing fluid formulations and those of geological origin brought to the surface with flowback water.
2. Indirect negative effects associated with onshore shale gas industry on wellbeing and socioeconomic factors, such as changes to the social structure of communities, accident trauma associated with increased road traffic and the stress relating to a "boom and bust" climate.

The Final Report states that the assessment of the risks associated with the first category of risk to human health (exposure to chemicals) was generally 'low' for likelihood and 'low-moderate' for consequence, with these categorisations being highly dependent on site-specific factors, such as the proximity to habitation, potential pathways for contamination of surface and sub-surface water bodies, and the efficacy of regulatory controls over the exploration, production and decommissioning processes.

The second category of risk to human health (indirect negative effects) was considered to be difficult to categorise because the risks are highly dependent on the scope of any proposed onshore shale gas development, as well as the stage of that development (exploration, production or decommissioning). The Panel undertaking the Inquiry concluded that the potential likelihood and consequences of socioeconomic factors affecting public health will need to be considered on a local or regional basis once the scope of any proposed development has been defined, and should be measured against some baseline data collated ahead of any development This is considered separately by the Guidance Note on social, cultural and economic studies.

Key elements of the Environmental Health Baseline Study

The Environmental Health baseline study will include five activities:

Data gathering

Identification of all potential hazards associated with exploration and development will define the boundaries around what data and information should be gathered. Data gathering will involve identifying possible chemical and physical hazards and developing a community and population profile. Community consultation to understand sources of stress of concern, perceived impacts and health concerns should be a core part of this data gathering stage.

This baseline study will gather data on chemicals, water, air, soil and general as well as food sources prior to any development of onshore petroleum reserves. This data will then be used to indicate if a significant change is at risk of occurring and to identify mitigation measures such as separation distances.

Identifying potential changes associated with industry activities

Once baseline levels are established and production activities have commenced, it will be important to assess if there have been changes in health outcomes and whether these changes can be associated with industry activities. If industry moves into the production phase regular monitoring over time should involve water, air, soil and environmental food sources and chemicals of concern.

Impact analysis

Threshold values should be determined before onshore petroleum activity commences to identify when detection of chemicals or activities above baseline levels would trigger further monitoring and investigation.

Identifying the potential to mitigate adverse impacts

Strategies can be adopted that mitigate or reduce negative impacts on health and enhance positive impacts. Health effects may not necessarily be eliminated but the residual risks to health and well-being could be reduced to the lowest level achievable.

Strategies that may mitigate adverse environmental health impacts or enhance community wellbeing may include:

- Effective communication between the proponent and community – including complaint and incident reporting processes
- Separation distances and set back distances from industry activity to habitation areas and sensitive land uses
- Infrastructure development - including enhancing community infrastructure
- Industry best practice – minimising risks of incidences occurring

Reporting

Continuous and effective communication with stakeholders is recommended if the industry progresses to the development phase to ensure the community and all stakeholders have relevant and up to date information of what is happening. Baseline monitoring data, ongoing monitoring of results, any incident reports, Health Impact Assessments and Human Health Risk Assessments should all be provided to stakeholders, in forms that are comprehensible to the stakeholder, and note that measures to protect personal confidentiality and privacy are critical.

7.2. Baseline information requirements

The relatively recent emergence of development of unconventional onshore petroleum resources in Australia means information around the stressors and health impacts associated with onshore gas in Australia is still being accumulated.

The completion of regional environmental health studies and a high-level understanding of all potential hazards associated with exploration and development will provide the boundaries around what data and information should be gathered. This will include the development of a conceptual model that identifies potential hazards, exposure pathways, health concerns and confounding factors for chemical and physical stressors, and completing a community and population profile to understand potential health concerns (as outlined in Appendix 2).

Once hazards and pathways are identified from applying the conceptual model a screening plan can be developed that includes identification of the scope, resources required, and timeline needed to carry out the screening. If a chemical or physical assessment is required an Exposure Screening Assessment may be required which involves assessment and validation of existing data, including chemical levels in air, soil, water and people (e.g. blood), measures of physical stressors (light, noise), and health symptom data. If a Social Stressor Screening Assessment is required, it will be important to assess and validate existing and new data related to social risk factors and 'precursors' that may contribute to adverse health outcomes at the individual, family, or population level.

Consideration should be given to the types of data being collated when collecting information or data during the screening. The potential types of data include:

- Background information: provides context and information about the development proposal, the physical environment the proposal will be situated in and the demographics of the population that is most likely to be affected by the proposal. It is also important to put into context any monitoring that is undertaken. Appendix 2 provides examples of the type of background information that would be useful. The background information is a prelude to collecting baseline data.
- Baseline data: information and data collected before production approvals are given. This data is very important to establish the nature of the environment and the population before being influenced by the project and to provide a reference to determine whether the project is having a positive or adverse effect to environmental health.
- Ongoing monitoring data: measurement of parameters during exploration and development sites, production and decommissioning phases

- Data from incidents: incidents or adverse events that require reporting to authorities with appropriate data. Some of this may come from ongoing monitoring but some may need to be undertaken specifically in response to the event that has occurred.

Environmental parameters such as chemical concentrations in a water sample are quantitative data and tend to be more precise whereas qualitative data such as how a person feels obtained from a questionnaire is more subjective and are collected through interpretation. When making comparisons as part of a monitoring program for an onshore petroleum project, quantitative data are open to less interpretation and provide more precise comparisons.

Data required for a baseline study

The information required for baseline studies is discussed under separate headings pertaining to each element.

Chemicals

It is important to know what specific chemicals may be subsequently used in the hydraulic fracturing process as well as any geogenic chemicals that could be liberated by the production process.

Information is also required on the properties of the chemicals used and generated in the hydraulic fracturing proposal which will assist in the assessment of potential for exposure and any health effects.

The type of information that may identify chemicals of concern and subsequently inform a regional human health risk assessment (HHRA), are presented in Appendix 3. This regional HHRA can inform project-specific HHRAs required for specific projects.

The regional HHRA must identify the potential human exposures and health risks associated with the exploration for, and the production of, any shale gas development, including but not limited to, off-site transport, and the decommissioning of wells, as recommended in National Chemicals Risk Assessment (NCRA) guidance. The report should identify risk estimate assessments for exposure pathways that are deemed to be incomplete. Such information will identify information gaps that become relevant when assessing the potential effects of subsequent project proposals.

Water

Water quality has been recognised as a significant community concern due to the potential for hydraulic fracturing chemicals to contaminate surface or ground water. However, since chemicals present in gas deposits can be found in water sources before any hydraulic fracturing occurs, it is important to undertake baseline sampling. This field work may be undertaken in collaboration with other studies required for a SREBA, such as the studies of water quality and quantity.

Appendix 3 provides an example of water sampling protocols.

Air

Air quality can be more difficult to measure due to temporal and spatial variation of pollutant concentrations associated with varying local weather patterns as well as the separation distance from the proposed development. A regional risk assessment should be undertaken to determine whether the air quality of the nearby residents/community will be impacted. Such information will identify information gaps that become relevant when assessing the potential effects of subsequent project proposals.

Appendix 4 presents an air sampling protocol. The nature of any air quality monitoring to be undertaken should be determined on a case-by-case basis depending on the issues (dust, flaring, gas seepage, and pollen), weather patterns and environmental layout. For example, where dust maybe generated and impact the local population dust monitoring should be instituted.

Soil

Contamination of soil becomes important if the soil will be a reservoir of chemicals that will leach into water bodies or if contaminated areas will be grazed by livestock, particularly after decommissioning of the wells and infrastructure. An understanding of the soil types across the region will inform analyses of whether there are areas that are more vulnerable to potential contamination than others. Such information will identify information gaps that become relevant when assessing the potential effects of subsequent project proposals.

Chemicals can pollute the soil by spills, waste disposal, leakage from pits, ponds and bunded areas and the use of firefighting chemicals (equipment testing, training, fighting fires).

Appendix 6 provides an example of a soil sampling protocol.

General Health

Some direct body measurements such as blood pressure, heart rate and breathing tests can be undertaken on a regular basis and can made by the community nurse when administering a questionnaire or by the person themselves if they have the appropriate equipment (e.g. a blood pressure monitor). Other more invasive procedures such a blood sampling are not as well accepted by people on a regular basis. The usefulness of such data should be weighed against the invasiveness of the procedure and any stress that may cause.

Medical surveys or questionnaires are a useful way of gathering relevant baseline information and would only need to be done once for a baseline measurement. An example of a general health questionnaire is provided at Appendix 7.

Food sources

Any contamination of food sources becomes important in relation to public health, particularly if there is significant consumption of locally produced food. Potential monitoring programs will need to be designed to test at appropriate times. Local food sources such as fish, shellfish, molluscs and plants (wild/bush tucker or home grown) are easier and more convenient to sample than livestock. In relation to livestock the best sampling regime is to test the water supply and soil from grazing areas.

Chemical or contaminant residues in all commercially produced food must conform to the standards set in the Food Standards Code. These standards are the maximum levels legally allowed in food sold or supplied to the public. They can be used to assess contaminant levels in home grown produce.

Any health risk assessment involving food contamination will need to consider environmental degradation or bioaccumulation of chemicals as well as chemical adsorption and metabolism by plants and animals.

Appendix 8 provides a sampling protocol for food sources.

7.3. Assessment approach

Identifying changes that may be associated with industry activities

Possible public health information or reference sources include:

- Health statistics based on regional or local government areas.
- Local medical practitioners or nurses (although since people do not always visit doctors and in a remote location it may be inconvenient or not be easy to do so).
- Indigenous community health data
- State based health statistics, particularly for cancer or birthing data or for particular population sub-groups
- Occupational health data from the unconventional gas workforce where relevant
- Pre-established groups not affected by unconventional gas and used as a control cohort. e.g. a nearby property or a specific site

Once baseline levels are established and the industry progresses to the production phase, it will be important to assess if there have been changes in the environmental parameters or health outcomes and whether these changes can be associated with industry activities.

Environmental parameters such as water, air, soil and environmental food sources are the most convenient elements to regularly monitor over time. They may also be the first indicators of change. Continuous monitoring of water is important due to the potential for water contamination and heightened community concerns about water contamination. Identified chemicals of concern should be monitored post baseline study completion.

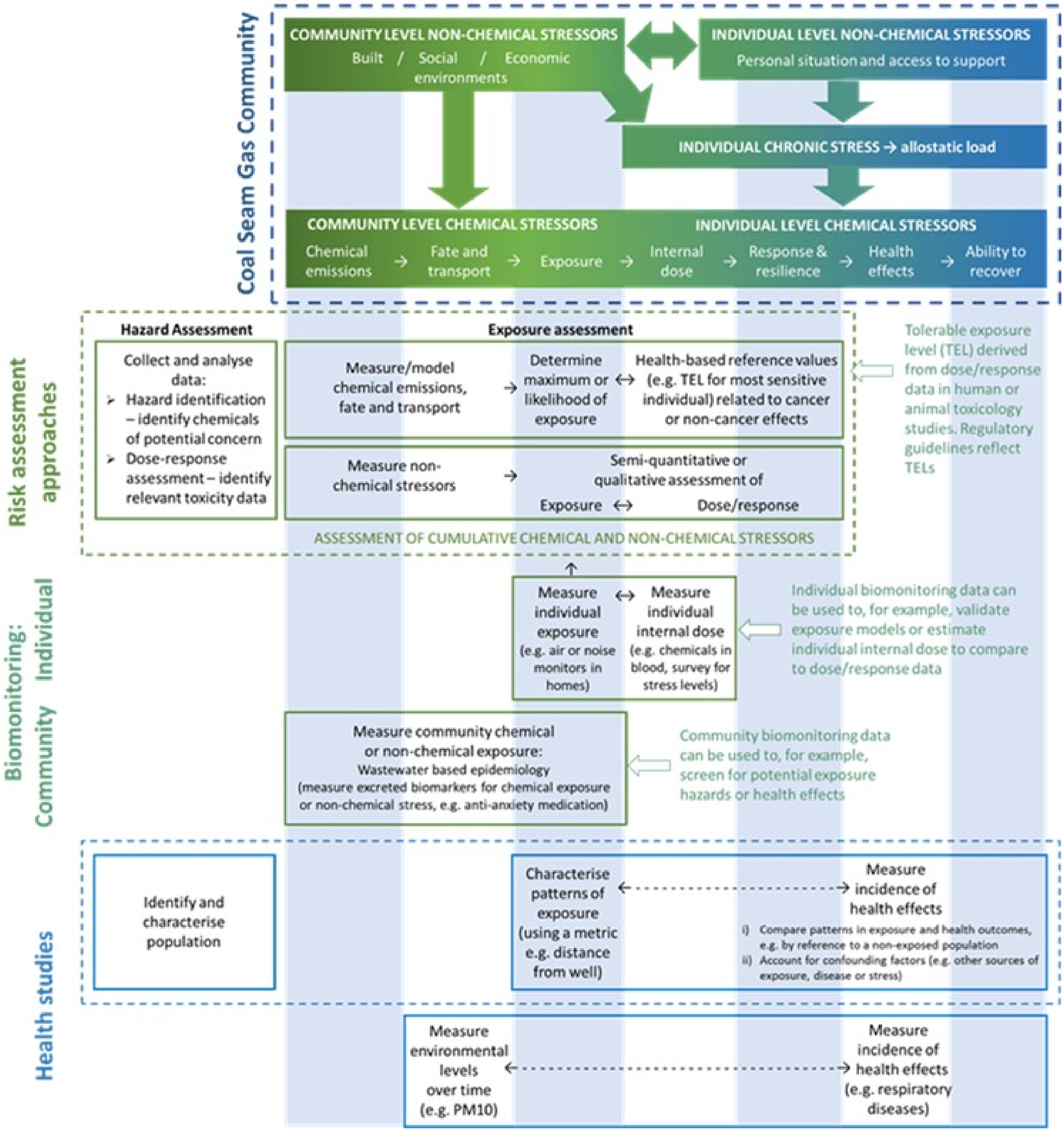
However, not all baseline information must be continuously monitored. Some baseline information may only need to be repeated when incidents arise. As incidents occur, a monitoring program must be instituted to determine the source and extent of the problem and then continued until the issue has been resolved and the environment remediated.

A Further Assessment Stage may be included in a post-development monitoring program to identify if industry activity has resulted in an associated health outcome. The factors to consider in such a monitoring program should be identified as part of the baseline study. A risk assessment approach or a health outcome assessment approach is most amenable at this stage, such as outlined in Figure 1 based on a GISERA study of human health impacts from coal seam gas (CSG):

- An in-depth exposure and risk assessment approach involves quantifying the exposure of the population to pollutants associated with the activity through environmental or bio-monitoring, spatial modelling of the distribution of stressors, comparison to relevant health-based guidance values and development of exposure maps. This stage may involve the initiation of a program to collect data and environmental/bio samples and retain in a publicly available repository/archive.

- In addition, a Health Outcome Assessment may be required which will use suitable epidemiological and other approaches (e.g. cluster, longitudinal, cross sectional or case control study(s)) to measure incidence or prevalence of health effects and compare to patterns of exposure established in the in-depth assessment. It will be important to identify any association between outcomes and industry activities. The types of health outcomes assessments that could be utilised are described in Appendix 9.

Figure 1 - A schematic comparison of different health assessment approaches that could be considered when designing a post-development monitoring program (from Keywood et al., 2018)



As described in Appendix 9, a number of the types of health assessments involve comparison to a suitable reference or control site. Such sites may be difficult to identify, particularly if the affected stakeholder community or group is small and isolated. A control population that has a similar demographic and characteristics of the population concerned is preferred. Comparison to a large urban population may not be appropriate though it may be the only available population data source.

7.4. Methods

Each specific basin or resource is likely to have its own unique environmental and affected population characteristics and therefore the methodology chosen to investigate environmental health issues should be determined on a case-by-case basis.

Thresholds that may indicate a significant change is at risk of occurring

In relation to public health, the most relevant thresholds to use to signal the potential for significant change or adverse events occurring are those related to environmental parameters such as chemical concentrations in water or air. The ultimate public health thresholds are the Australian Drinking Water Guidelines (ADWG) for water or the National Environmental Protection Measures (NEPMs) for air and soil.

Where no ADWG or NEPM guidelines are available other appropriate national or international guidelines may need to be considered, including guidelines of the World Health Organisation, the United Kingdom, European Union, the United States Environment Protection Authority, Centre for Disease Control and National Toxicology Program, or US State Guidelines. The enHealth Council has detailed the sources of guidelines and grouped them into 'levels' of preference.

Health-based guidelines represent a safe threshold for health impacts. Usually threshold levels are set at 50% of the health guideline but the precise value will depend on the limit of reporting for the analytical method and whether the chemical is present in baseline testing. When this threshold is exceeded, an investigation as to the source and cause and more frequent monitoring should be instituted. Another possible threshold that could be adopted is the detection of the chemical above baseline levels which would then trigger further monitoring and investigation. Such thresholds should be determined before hydraulic fracturing commences.

In relation to food that is sold, gathered or supplied to the public, the Maximum Residue Limits and maximum Limits set in the Food Standards Code apply.

Mitigating adverse impacts

Mitigation criteria are risk management strategies that reduce negative impacts on health and enhance positive impacts. Health effects may not necessarily be eliminated however, residual risks to health are minimised. If health impacts are identified it is important to initiate a systematic program to collect longitudinal health data that are retained in a publicly available repository/archive.

Mitigation strategies that minimise adverse impacts on physiological health are particularly important considering the difficulty measuring these impacts. Such strategies should include changing industry practices, formulating and obtaining commitment to proposed mitigation actions and monitoring the effectiveness of mitigation actions.

The study should identify a number of strategies that may mitigate adverse environmental health impacts such as those listed below. This will identify opportunities and/or information gaps that become relevant when assessing the potential effects of subsequent project proposals.

Effective communication/consultation

A communication plan between the proponent and the land occupier/user should be developed. The communication should commence well before the site is developed and continue through the operational phase. It should include regular updates on testing and monitoring. Some chemical testing and ongoing monitoring results can be supplied real-time electronically. Also included should be complaint and incident reporting processes.

Separation distances

Separation distances are important when considering the mental health and wellbeing effects of noise, light, dust, water quality, vibration, odour, flaring and air quality including fumes from transport vehicles and machinery.

In general, separation distances from non-enclosed or open industry to the nearest sensitive land use that have predominantly noise, dust, odour and chemical issues range from 1 km or greater. The Final Report recommended a minimum set-back distance of 2 km from dwellings and habitation (Recommendation 10.2).

Precise determinations of separation distances can be done on a case-by-case basis considering factors such as topography and wind direction and strength of the factor being mitigated against.

Infrastructure development

Development or enhancement of property or community infrastructure such as roads, fencing, stock yards, improved bores or community buildings

Industry best practice

The adoption of current industry best practice during construction and operation of the hydraulic fracturing facility can alleviate environmental health concerns and decrease the impact on wellbeing. For example, best practice drilling technologies and techniques may provide confidence in minimising risks to water supplies.

7.5. Synthesis

The primary output from the baseline study will be a regional environmental health assessment of the study region. This should consider all potential environmental sources. In general, the environmental health baseline study aims to identify hazards, estimate exposure and characterise risk.

Collaboration with the Social, Cultural and Economic studies is recommended to identify broader health and well-being effects not included in the environmental health study.

7.6. Reporting and data management

Monitoring results should be reported real-time or as collated reports. Data may be published online and/or in dedicated reports since it is beneficial to have baseline monitoring data published as a stand-alone report and be available to stakeholders before industry commences its production activities.

Incident reports and overall project outcomes should be published as peer reviewed publicly available documents.

Human Health Risk Assessments (HHRAs) addressing health impacts be published as peer reviewed publicly available documents noting that measures to protect personal confidentiality and privacy will be critical.

7.7. References

enHealth (2002). Environmental Health Risk Assessment: Guidelines for assessing human health risks from environmental hazards. June 2002 pages 88-89.

Keywood, M., Grant, S., Walton, A., Aylward, L., Rifkin, W., Witt, K., Kumar, A. and Williams, M. (2018). Human Health Effects of Coal Seam Gas Activities- A Study Design Framework, CSIRO January 2018.

Appendix 1 – Overview of the GISERA Human Health Risk Assessment

The GISERA Framework documented in Keywood et al (2018) is based on a Health Impact Assessment Framework and includes parallel streams of research:

1. Conducting exposure and health impact assessments for chemical and physical stressors.
2. Identifying activities potentially contributing to social stress and defining effective intervention and mitigation strategies to reduce exposure to these stressors, while maximising benefits in the context of the community's overall resilience.

The GISERA Framework includes a series of staged steps shown in Figure 2 and described below

1. A *Scoping and Planning* stage defines the overall structure for a study in a given location, including strategies for involving stakeholders, communicating findings and meeting research ethics requirements. This stage establishes processes to support the quality and legitimacy of the research.
2. The *Identification and Screening* stages establish the potential sources of chemical and physical hazards (air, water, soil, noise and light) and other stressors, such as social stressors. They also define how community members near activities might be exposed. These stages compile existing data, assess the data for quality and validity, and establish a data archive. Through these processes, gaps in knowledge are identified.
3. The *Further Assessment* stage involves in-depth assessments of exposures and risks as well as health outcome assessments. This stage addresses gaps in data in relation to relevant chemical and physical stressors. This stage also identifies social stress status as well as needs and mitigation opportunities to minimise social stress impact.
4. The *Recommendations* stage is the final stage in the framework and integrates findings, draws conclusions and makes recommendations, including identifying needs for ongoing monitoring.

The key principles of the GISERA Framework are:

1. All aspects of the study should be open and transparent, and outcomes must be publicly available, working within ethical approval guidelines.
2. The study should seek community and stakeholder involvement throughout the process, from scoping to recommendations.
3. The study should result in recommendations to mitigate negative health impacts and promote positive impacts, that is, benefits to the community and individual health.

Confounding factors should be also be considered when conducting an investigation. Confounding factors are factors not associated with the activity of interest that independently affect the risk of developing a health outcome. Confounding factors can make it difficult to assign a single association between an exposure and an outcome. Confounding factors can include the other industries in a region that may be an alternative source of chemical, physical and social stress and can also include pre-existing sources of chemical contamination before the activity of interest commenced. Ensuring that confounding factors are identified, documented and accounted for in the study design is part of the Identification stage of the framework.

Appendix 2 – Background information sources

A conceptual site model should be used to represent the following information:

Physical environment:

1. topography (and how it may influence air and water flow)
2. groundwater profile (e.g. depth, flow, quality)
3. surface water profile
4. hydrogeology
5. local weather conditions (wind and rainfall)

Important background information about the proposed project:

1. well location/s
2. proposed hydraulic fracturing zone
3. timeframes (construction, drilling, close out)
4. transport routes
5. vehicle movements (type, frequency, when)

Population and social environment:

1. Demographics
2. Location in relation to project and other communities
3. Facilities available to the population of concern
4. community or family structure and relationships
5. behaviour/lifestyle
6. housing
7. employment status
8. income
9. education
10. occupational environment
11. social contacts/networks

Appendix 3 – Information required for chemicals used or produced in hydraulic fracturing

Information on chemicals used in or produced by hydraulic fracturing is required to determine the potential effects of the chemical on local ground and/or surface waters, soil and air quality as well as identifying potential health hazards.

As well as knowing the health effects that could be caused by a chemical it is also important to know if there are standards or guidelines against which an effect can be compared and how the chemical is expected to behave in the environment (i.e. what chances are there for exposure to the chemical). Information on chemicals to include:

a) Physico-chemical properties:

1. Water Solubility (Sw) (mg/L, ppm)
2. Distribution Coefficient (Kd)
3. Henry's Law Constant (Kh) (atm m3 mol-1)
4. Organic Carbon Sorption Coefficient (Koc) (cm3/g)
5. Hydrolysis Half-life (HT50)
6. Photolysis Half-life (PT50)
7. Dissipation Half-life (DT50)
8. Vapour Pressure (mPa)
9. Octanol water partition coefficient (Kow)
10. Bioconcentration factors (BCF)

b) Toxicological profile:

1. Acute toxicity profile (acute oral LD50 (mg/kg), acute inhalation LC50 (mg/m3 – 4h, irritation/sensitivity potential)
2. Carcinogenicity classification
3. Teratogenicity/Reproductive toxicity classification
4. Target organ toxicity (mammalian)
5. Has the chemical been reviewed by a regulatory authority (e.g. NICNAS. US EPA, WHO)

c) Guidelines or standards:

1. Australian Drinking Water Guideline (ADWG)
2. WHO Drinking Water Guideline
3. US EPA, UK or EU Drinking Water Guideline
4. Air quality guidelines national or international

5. Acceptable Daily Intake (ADI) or Tolerable Daily Intake (TDI) (mg/kg bwt/d)
6. Acute Reference Dose (ARfD) (mg/kg bwt/d)

Appendix 4 – Water sampling protocol

The scientific literature and Legislative reviews indicate one of the major risks of hydraulic fracturing is the contamination of ground and surface water with chemicals. The pathways by which chemicals can contaminate water are:

The scientific literature and Legislative reviews indicate one of the major risks of hydraulic fracturing is the contamination of ground and surface water with chemicals. The pathways by which chemicals can contaminate water are:

- Retrograde flow
- Returning fluid
- Gaseous seepage
- Spillage of stored or waste chemicals
- Leakage of bunded areas, wastewater pits or ponds
- Firefighting chemicals (equipment testing, training, incidents)

Water contamination can affect health via direct consumption of contaminants or indirectly by contact during swimming, contaminating the food supply (fish, livestock, crops, home gardens, and native food sources) or limiting water availability.

Sampling of ground and surface water (where applicable) to include:

a) Sampling locations (can vary depending on specific hydrogeology and should be based on information from the conceptual site model):

1. Bores drilled into underground aquifers specifically to monitor water quality
2. Bores used for potable water
3. bores used for livestock watering
4. down and upstream of flowing water bodies
5. nearby stationary water bodies
6. production waters, flowback water, treated water

b) Sampling methods

1. where, including depth if from a ground water source
2. how
3. quantity sampled

4. bore details or surface water sampling point
5. when
6. transport conditions of sample

c) Sampling frequency

1. Initial baseline monitoring which may require multiple sampling times depending on hydrogeology and seasonal events
2. Regular monitoring throughout the life of active well
3. Incidents (leaks, spills etc.)
4. After decommissioning

d) Laboratory testing information

1. Limit of reporting (LOR)
2. NATA accreditation of laboratory if applicable
3. test method accreditation if applicable
4. recoveries

e) Attachment of maps identifying:

1. drilling sites and hydraulic fracturing zone
2. location of bores (monitoring, community, household, stock or commercial)
3. location of water bodies
4. location of sampling points (including GPS coordinates)
5. location of dwellings and community infrastructure.

The environmental monitoring report needs to address the following:

1. data and information from a) to e) above
2. results of analytical testing
3. the discussion to include:

   Soil type and profile.

1. Topography of the local area.
2. Depth to ground water sources.
3. Amount of rainfall (if applicable).
4. Rainfall and/or irrigation events that may influence water movement

Appendix 5 – Air sampling protocol

Measuring concentrations of and subsequent exposure to air-borne chemicals is more complex and fraught with difficulties compared with measuring chemicals in water or soil. The pathways by which chemicals can pollute the air are:

1. During gas production
2. During dewatering
3. flaring
4. during construction phase (diesel exhaust and dust)
5. transport (diesel exhaust and dust)
6. from wastewater
7. release of ground gases

The type of chemicals that could be released to the atmosphere during hydraulic fracturing are dust (silica and particulate matter [PM 2.5, PM 10 and coarse particulates]), methane, hydrogen sulphide and a range of volatile organic compounds (VOCs). VOCs can increase ozone formation. Of these, dust is probably the easiest to measure and to make reasonable comparisons over time.

Methane is addressed by the Guidance Note for studies of greenhouse gases. Liquefied petroleum can be associated with shale gas deposits which may result in vaporisation of volatile organic compounds that have the potential to adversely affect air quality. In such cases, VOCs (e.g. benzene, toluene, ethylbenzene, xylene) should be included in air monitoring programs.

Dust deposition gauges and dust tract monitoring can be utilised when there are concerns or incidents associated with dust. Rooves of buildings can be used as surrogate dust deposition surfaces. Chemical analysis of dust is warranted if there are specific contaminates identified including pollen.

The following variables need to be considered when designing the air sampling studies:

a) Sampling locations

1. wellheads and bores
2. down and upwind of flaring points
3. residences or community precinct
4. transport routes

b) Sampling methods

1. location of measurements
2. instruments to be used
3. frequency of sampling
4. sample handling
5. sampling equipment calibration details

c) Sampling Periods

1. Before production = baseline
2. Monitoring frequency needs to take into account seasonality of weather conditions and any patterns highlighted by baseline monitoring
3. Incidents, with sampling to include post-incident monitoring

d) Laboratory testing information required

1. Limit of reporting (LOR) should be relevant to concentrations likely to be measured
2. NATA accreditation of laboratory if applicable
3. test method accreditation if applicable
4. recoveries should be reported

e) Meta data to be collected

1. location of fracturing infrastructure
2. location of residents and nearby community
3. location of roadways
4. Location of sampling points (including GPS coordinates)
5. Meteorological data

For further information on the monitoring and assessment of $PM_{2.5}$, PM_{10}, ozone, carbon monoxide, nitrogen dioxide, sulfur dioxide and lead see the National Environment Protection (Ambient Air Quality) Measure http://www.nepc.gov.au/nepms/ambient-air-quality

For further information on the monitoring and assessment of benzene, toluene, formaldehyde, xylene, benzo (a) pyrene as a marker for PAHs see schedule 3 of the National Environment Protection (Air Toxics) Measure http://www.nepc.gov.au/nepms/air-toxics

Where complaints relate to diesel vehicles, particularly where there is heavy vehicle traffic, vehicle diesel emissions testing could be undertaken. For further information on vehicle diesel testing see National Environment Protection (Diesel Vehicle Emissions) Measure http://www.nepc.gov.au/nepms/diesel-vehicle-emissions

Appendix 6 – Soil sampling protocol

The pathways by which chemicals can pollute the soil are:

1. Chemical spills
2. Waste disposal
3. Leakage from pits, ponds and bunded areas
4. Firefighting chemicals (equipment testing, training, incidents)

Soil sampling studies need to be designed to consider:

a) Sampling locations

1. Wastewater storage areas
2. Chemical storage areas
3. Around waste disposal areas

b) Sampling methods

1. where
2. depth of sample
3. quantity sampled
4. when
5. transport conditions of sample

c) Sampling frequency

1. Before production = baseline
2. At decommissioning
3. Spillage/incident clean-up

d) Laboratory testing information

1. Limit of reporting (LOR)
2. NATA accreditation of laboratory if applicable
3. test method accreditation if applicable
4. recoveries

e) Attachment of maps identifying

1. areas where spills or leaks have occurred
2. Location of chemical storage areas
3. Location of wastewater and waste storage areas
4. Location of sampling points (including GPS coordinates)

For further information on the monitoring and assessment of soil contaminants see the National Environment Protection (Assessment of Site Contamination) Measure

http://www.nepc.gov.au/nepms/assessment-site-contamination

Appendix 7 – Example of a potential general health questionnaire

Health surveys should be developed for each specific community and can also ask what health information is important to that community. The questionnaire could be utilised at different times, such as:

1. Baseline – before any work commences. This is important to derive a source of baseline information for future comparison if required.
2. When work is to commence– could serve as a useful secondary baseline, particularly if there has been a considerable time elapsed from the original survey and if there have been changes in the population
3. For any new members of the population of concern
4. At key stages:
   - Construction
   - Drilling
   - Gas production

Have you experienced or have any of the following symptoms					
Body system	Symptom/type*	Severity	Frequency	When	persistence
Skin					
Eyes					
Nose					
Ears					
Headache					
sleep					
cough					
Mouth/lips					

* for example: *Eyes/ears/nose*: itchy, watery, sore; *nose*: sneezing; *Skin*: itchy, sore, rash, numb, prickly; *Mouth*: taste, sore, irritated; *Cough*: dry, productive; *Sleep*: restless

Do you have or have had any of the following medical conditions			
condition	*Yes/No*	*Do you take medication?*	*When is it worse?*
asthma			
Lung problems			
Heart disease			
High blood pressure			
diabetes			
Do you smoke?			

Appendix 8 – Food sampling protocols

The pathways by which chemicals enter the food supply are mainly via contaminated water and soil from chemical spills, leakage of wastewater holding areas and local waste disposal.

Food sampling studies need to be designed to consider:

a) Sampling locations and species

1. Identify what was sampled and where. Also include any wildlife that are affected
2. Water living species: fish, shellfish, bivalve molluscs
3. Plant based foods
4. Sampling livestock may be difficult, and it may be easier to monitor the chemicals in the environment.

b) Sampling methods

1. quantity sampled
2. tissues sampled or whole organism
3. when, and to take into account any seasonal variation
4. transport and storage conditions of sample

c) Sampling frequency

1. Before production = baseline
2. At decommissioning if required
3. Spillage/incident clean-up. Note that any sampling also needs to include the source of chemical contamination, either water or soil or both.

d) Laboratory testing information

1. Limit of reporting (LOR)
2. NATA accreditation of laboratory if applicable
3. test method accreditation if applicable
4. recoveries
5. tissues sampled, i.e. whole plant or animal or specific tissues
6. if sample aggregation of smaller species was required

e) Attachment of maps identifying

1. Location of water sources
2. Location of sampling points
3. Location/movements of relevant livestock or other animals
4. areas where spills or leaks have occurred

f) Comparison to Food standards Code

1. Schedule 19: Maximum Levels (MLs)
2. Schedule 20: Maximum Residue Levels (MRLs)

Appendix 9 – Different types of Health Assessment

The table below summarises different types of health assessment, drawn from GISERA's Health Impact Assessment Framework (Keywood et al., 2018).

Assessment Type	Inputs/Data Required	Applications	Strengths	Limitations
Exposure Assessment	Physical stressors (noise, vibration, light, trucks), Social & chemical Stressors (Air, Water, Soil)	Is there a likelihood of exposure from CSG? Qualitative & quantitative Yes – No	Proof of exposure (not necessarily cause) High demand Could decrease worry Source attribution Can inform mitigation The community are likely to understand Potentially lower uncertainty	Trustworthiness Can't assess everything Can't assess cumulative effects Could create fear Community 'doesn't buy' it – acceptable level Identified exposure pathway isn't the only exposure pathway Broader view of 'damage' beyond humans – cows, aquatic life
Human Health Risk Assessment (Hazard & Exposure)	Requires toxicity assessment & requires an exposure assessment	Prioritising and screening	Prioritisation tool to tell us if exposures are well below, close to, or well above levels that may be associated with health outcomes	Unknown / lack of toxicity data Over-estimation of toxicity for known chemicals Gives answer that doesn't predict health

Assessment Type	**Inputs/Data Required**	**Applications**	**Strengths**	**Limitations**
				outcome or a particular risk Uncertainty is high risk for people, a challenge for communities to understand / abstract More subjective & open for dispute (assumptions) Lack of information on toxicity at low levels and in early life as a limitation.
Cluster Investigation	Other non-CSG studies as inputs Common (shared) community complaints (People or GPs? Public health?) Health data sets Need a reference or a control population Geographically identified Community	Common community concern Perception or occurrence	Community is responsive Can be carried out on small populations Community reassurance	Clusters can occur randomly – not causal Could require a labour-intensive process to confirm cases Could be politically contentious No choice – when it presents, you must respond
Longitudinal Studies (Cohort)	Time Identify baseline data Agreeable, participatory community Informed consent	If there are known / expected changes to a community and their environment	'Gold standard' in environmental epidemiology Better for common outcomes	population loss to follow-up Resource intensive Ongoing commitment of resources and loss of staff

Assessment Type	Inputs/Data Required	Applications	Strengths	Limitations
	Hypothesis Registry data doesn't require informed consent	If we suspect delayed effect – lateness Can look at lots of different health outcomes Monitoring & surveillance Relatively common outcomes	Powerful study design – can watch population over time As close as environmental health gets to cause & effect Can measure many outcomes Can control for other exposures and individual characteristics that may act as potential confounders, effect modifiers or effect the health outcome independently Can do nested cross-sectional and case-control studies	Requires special set or circumstances Not applicable to rare outcomes
Cross-Sectional Study	Range of exposures (e.g. proximity to wells) Willing population supported by register data if required	Quick result Quick comparison method Can be hypothesis generating Exploratory	Demonstrates responsiveness to community Looking at individuals Can control for other exposures / factors	Resistance to environment? Single time point – doesn't prove causation or capture changes over time
Case Control Studies	Compares levels of exposures between people with (cases) and people without (controls) disease/	If a rare outcome presents Range of exposures	Can be powerful for hypothesis building for cohort studies; identifying outbreaks; investigating risk	Need a rare outcome to present / be noticed Can be bias towards a false positive

Assessment Type	Inputs/Data Required	Applications	Strengths	Limitations
	health outcome retrospectively Hypothesis that guides investigation (e.g. suicide) Informed consent Registry data doesn't require informed consent		factors for a rare outcome. Can be high profile	Can't quite claim causality Can be high profile

8. Guidance Note for social, cultural and economic studies

8.1 Introduction

This Guidance Note describes the approach and government expectations of researchers and specialists contracted by Government to undertake the Social, Cultural and Economic Baseline Studies (Baseline Studies) and associated Social, Cultural and Economic Strategic Regional Assessment (Strategic Regional Assessment), as part of the SREBA work program.

The terms 'Baseline Studies' and 'Strategic Regional Assessment' are used for the purposes of this Guidance Note, to ensure there is a clear differentiation between project-specific Social Impact Assessment (SIA) and the interchangeably used terms from the Fracking Inquiry : 'Strategic SIA' 'SIA' and 'Strategic Assessment.' Through initial consultations and workshops in developing this Guidance Note this was a cause for confusion, as project-level SIA and regional assessment are different and require different levels of information to undertake.

The objective of these Baseline Studies and Strategic Regional Assessment is to develop an understanding of the social, cultural and economic environments across a region, to identify aspects that may be sensitive to development and to consider the potential cumulative impacts of multiple projects.

Independently led research undertaken to establish the Baseline Studies and Strategic Regional Assessment will be outsourced to appropriately qualified, interdisciplinary researchers, experts and their support teams, independent of government. Criteria for researchers will be further defined in the Scope of Works for these studies and require local ownership from the region where the SREBA will be applied.

8.2 Baseline information requirements

This Guidance Note will provide direction for independent contracted researchers to report back to the NT Government to study three separate, but interrelated areas of study as shown on the following page.

Figure 1 – Social, Cultural and Economic Baseline Studies and Strategic Regional Assessment

The Baseline Studies and Strategic Regional Assessment will not replace or duplicate current statutory processes that already take place through Land Councils, Aboriginal Areas Protection Authority or the project-specific social impact assessment. The Baseline Studies and Strategic Regional Assessment aims to provide valuable information that informs the development of project-level SIAs, to limit duplication and consultation fatigue, by identifying features at a regional level that individual projects should consider and develop appropriate management and mitigation strategies for.

> The Baseline Studies and Strategic Regional Assessment will provide information that is complementary to and informs the development of petroleum companies' individual impact assessments and reports, by providing evidence-based, region specific resources and comprehensive social, cultural and economic data and information, informed by independent experts.

The existence of a Strategic Regional Assessment may strengthen the Northern Territory Environment Protection Authority's (NT EPA) ability to assess social, cultural and economic impacts, and advise the Minister for Environment and Natural Resources on social, cultural and economic environmental aspects that may be affected by proposed development within the region. The Northern Territory Government will also introduce a Social Impact Policy to help guide proponents in relation to project-specific social impact assessment.

8.3 Assessment approach

Social, cultural and economic baseline studies will:

- establish baseline data, around identified themes, inclusive of qualitative information such as values, beliefs, goals, aspirations, perceptions, attitudes and capital across a region
- determine and correlate locally agreed indicators from baseline data and information for future monitoring of impacts and outcomes.

The collection of baseline data and information is an essential component in undertaking the subsequent Strategic Regional Assessment. Baseline data reflects the current situation or conditions in a potentially affected community or region at a point in time. Data may be qualitative (attitudes and perceptions) and quantitative (such as demographic data from the ABS Census or data on health status or demand for government services from departmental annual reports).

The data and information produced from the Baseline Studies will be collated and reviewed to ensure it does not breach cultural, privacy or commercial confidentiality requirements before being published.

The Baseline Studies should explain the established data, analysis, data collection and engagement methodologies used. There should also be an explanation on how the proposed indicators were established or agreed upon with the region, with an established participatory methodology to track change over time from industry development and associated impacts.

8.3.1 Baseline Themes

The baseline information for social, cultural and economic features of a region can be diverse yet interrelated, and grouping them into a number of categories or themes is helpful.

The International Association for Impact Assessment (IAIA) Principles for Social Impact Assessment (Vanclay, 2003) categorises social impacts as changes to:

- **people's way of life:** how they live, work, play and interact with each other on a day-to-day basis;
- **their culture:** their shared beliefs, customs, values and language or dialect;
- **their community:** its cohesion, stability, character, services and facilities;
- **their political systems:** the extent to which people are able to take part in decisions that affect their lives, their level of democratisation and resources provided for this purpose;
- **their natural or physical environment:** the quality of air and water people use; the availability and quality of the food they eat; the level of hazard or risk, dust and noise they are exposed to; the adequacy of sanitation; their physical safety and access to and control over resources;
- **their health and wellbeing:** health is a state of complete physical, mental, social and spiritual wellbeing and not merely the absence of diseases or infirmity;
- **their personal and property rights,** particularly if people are economically affected or experience personal disadvantage such as threats to their civil liberties;
- **their fears and aspirations** (known as psychosocial impacts) which includes perceptions about their safety, fears about the future of their community and aspirations for their future and the future of their children.

In developing this Guidance Note, the above categories were considered during a workshop held in January 2019 and arranged into the following 'themes' to reflect the Northern Territory's context. It is anticipated that Baseline Studies will group baseline data and information under these themes:

- People and Communities
- Cultural Identity
- Economies
- Strong Voice
- Living Environment
- Healthy Country
- Infrastructure and services

Each region in the Northern Territory is different. The type of baseline information collected from each region needs to be established in a participatory process, considering the availability of data, and the potential impacts on communities in the region from informed information regarding potential development.

It may not be possible to source information on all aspects of the region because information may not be collected, accurate, reliable, conveniently grouped to coincide with the boundaries of the region, or collecting and analysing the information could breach the requirement for cultural, privacy or commercial confidentiality. These data gaps, sensitivities and determination of additional data required will be identified and collected in consultation with the region applicable to the SREBA.

The themes are represented in Figure 2 below, to provide further context to how they will be useful for identifying the expertise required of researchers undertaking the Baseline Studies. The Baseline Studies will determine the values that are important to a particular community through participatory engagement methods as part of establishing baseline data. Separate studies will be designed for the social, cultural and economic domains, with the possibility that the studies are undertaken concurrently or by the same teams in order to avoid duplication and potential imposts on communities and stakeholders.

Figure 2 – Social, cultural and economic themes to be used for the Baseline Studies and Strategic Regional Assessment

Figure 2 above identifies examples of the type of information, or values that may be relevant under each of the seven themes. To be region-specific, they must be established in partnership with communities in the region during fieldwork.

The Cultural Identity Theme

The Cultural Identity theme aims to undertake a cultural impact assessment of the region with a central focus on the broader Aboriginal community and their self-defined identity and social organisation including cultural groups, languages and cultural practices; Indigenous traditional knowledge and land management, sustainability, observations and concerns. This high-level assessment does not seek to consider information previously recorded by the Land Councils or Aboriginal Areas Protection Authority (AAPA). These groups may not wish to share or document customary laws or traditional practices in any detail in the baseline cultural studies as most of this is knowable only to initiated persons. However, they may wish to identify whether they rely upon these values in their decision-making.

8.3.2 Strategic Regional Assessment

The Strategic Regional Assessment aims to deliver an independent and valuable resource for proponents, government and the NT EPA in their role of assessing project-specific SIAs. It will do this through the identification, mapping and comprehensive assessment of the social, cultural and economic environments of a region, as well as provide a mechanism for cumulative impact assessment, monitoring and evaluation.

The Strategic Regional assessment brings together information regarding potential industry development together with information from the Baseline Studies to:

- assess potential cumulative impacts of industry development in the region
- determine regional development aspirations and potential outcomes
- establish regional monitoring framework.

The purpose of a Strategic Regional Assessment is to understand how industry development may affect people and their surroundings, including lifestyle, cultural and spiritual practices, livelihood, perceptions, expectations and values. These can be both opportunities and benefits for the community and potential negative impacts from industry development in order for appropriate strategies and mitigation plans to be established. The Strategic Regional Assessment will also identify features that may be sensitive to development and consider the potential cumulative impacts of multiple activities. This analysis can only be undertaken by exploring how communities living within the region may be affected by potential industry development.

The Strategic Regional Assessment is not a one-off piece of work. It needs to be ongoing to monitor, evaluate and determine cumulative effects of industry development, if and when it grows. Cumulative impacts on the social, cultural and economic environments from individual or multiple industry activities can be from the successive, incremental and combined activities of industry. A full appreciation of cumulative impacts can only be gained after the industry has shared detailed development plans and the information on project activity, duration, scale and scope is better known.

The Strategic Regional Assessment aims to assess the social, cultural and economic environments and potential cumulative impacts of development in the region, not social impacts of individual developments. This is important in understanding the difference between the role of the Strategic Regional Assessment and project-specific SIA.

Potential impacts on communities living within the region will make part of the Strategic Regional Assessment. The information may be valuable to communities and landholders within the region to explore and understand different development options, and to those parties interested in structuring their development proposals to avoid concerns and maximise benefits to resident communities.

The potential impacts of development can be anything that affects people and their surroundings, including lifestyle, cultural and spiritual practices, livelihood, perceptions, expectations and values. There can be both benefits and opportunities, and negative impacts from project development.

Potential social, cultural and economic impacts included in the Final Report

Some of the social, economic and cultural impacts identified in the Final Report are listed below and are examples of what might be found as part of the Strategic Regional Assessment. This is not to suggest that these potential effects will occur in every case, or be felt by everyone:

- Diversification of the regional and Territory economy, including downstream manufacturing opportunities
- opportunities for local jobs, capacity development and procurement, although there were comments about the potential short-term nature of gas industry work
- positive and negative impacts on public infrastructure, such as roads, health services and schools
- reduced road safety, with more industrial traffic on public roads, particularly during the construction phase
- potential 'boom and bust' pressure on house prices, rents and council rates (noting that the Queensland experience with fly in fly out workers is likely to be different in the Territory where a high proportion of remote residents live in public housing)
- decreased availability and affordability of housing in regional towns
- decreased capacity to influence local governance
- reduced trust in government
- cost pressures on local businesses through wages pressures
- difficulties obtaining insurance against damage caused to pastoral properties by onshore gas operations
- reduced investment in other economic sectors, such as pastoral and horticultural operations, due to uncertainty over long-term sustainability of water resources
- reduced community cohesion due to transient workforces and community conflict
- psychosocial impacts from anxiety about a lost sense of identity and place (referred to as solastalgia)
- anxiety about the availability and quality of groundwater
- intergenerational equity issues, particularly in relation to the effects of climate change
- damage to sacred sites, including songlines and subsurface sites, and other places of spiritual significance to Aboriginal people
- feelings of powerlessness at losing access to sacred sites for the education of future generations
- anxiety and stress at decision-making, such as balancing potential economic returns against the need to protect traditional culture

- loss of groundwater, often associated with sacred sites, which is important for resource use, culture and identity
- concerns about the reduced quality and availability of drinking water
- stress and reduced social harmony in areas where hydraulic fracturing is proposed, partly due to a lack of reliable and accessible information
- kinship pressures from the differential distribution of jobs and compensation payments
- anxiety that local workers will miss out to interstate FIFO workers
- reduced pastoral property values (largely based on the experience of Queensland);
- improved value of pastoral properties from infrastructure upgrades, such as roads and bores
- disruption to pastoral activities, such as mustering, introduction of weeds
- division in the community over inequitable distribution of economic benefits
- potential displacement of the agricultural, pastoral and tourism sectors
- localised inflationary pressures on the price of food, goods and services

8.4 Industry development

In order to undertake the Baseline Studies and subsequent Strategic Regional Assessment, it is important this work is placed in context to ensure there is an understanding of the potential industry development, the potential for multiple projects and their associated stages of development.

The Final Report identified *'there is a clear need to gather and provide relevant and reliable information about the industry and its potential impacts to reduce uncertainty to an acceptable level.' (page 301)*. Understanding potential industry development will also be important in how regional boundaries are set to enable the Baseline Studies and Strategic Regional Assessment to take place.

8.5 Principles underpinning delivery of the studies

The following principles are intended to guide delivery of the studies to ensure they are conducted in a way that is respectful, meets stakeholder expectations and are appropriate to the Northern Territory context, in particular when working with Aboriginal communities:

a. **Purposeful** - the purpose and intended outcomes must be clear
b. **Proportionate** - to the likely level of disturbance and community sensitivity
c. **Participative** – culturally appropriate processes, early and meaningful engagement and communication
d. **Procedural fairness –** good process that gives the community an influential voice in decisions
e. **Equitable** - must consider all impacted people and communities, in particular those who may be marginalised, disadvantaged or hard to reach
f. **Subsidiarity** – decisions should be made closest to those affected
g. **Respectful** - acknowledging Aboriginal cultural authority and knowledge systems and how knowledge is owned, produced and shared

h. **Ethical** – in line with industry and professional codes of conduct
i. **Social justice and human rights** focussed, including the principle of Free, Prior and Informed Consent
j. **Proactive –** considers how development can contribute to communities' wellbeing and capacity
k. **Flexible and adaptive –** responding to the context of the area under study and informing adaptive management and a whole-of-life-cycle approach.

8.6 Roles, responsibilities and expectations for undertaking studies

Research undertaken for the Baseline Studies and Strategic Regional Assessment will be outsourced to appropriately qualified, interdisciplinary researchers, specialists and their support teams, independent of government. Criteria for researchers will be further defined in the Scope of Works.

The Final Report and a working group that contributed content for this Guidance Note identified key criteria that must be considered when engaging researchers to undertake the Baseline Studies and Strategic Regional Assessment. There was agreement on the following general expectations that Government must be consider when engaging researchers:

- The themes identified as research areas require experts with interdisciplinary knowledge in social, cultural, economic and demographic fields, along with inter-cultural expertise and relevant anthropological/local expertise
- Engage with, and communicate findings to affected communities in a culturally appropriate manner and, when required, using interpreters or publishing information in language
- Be impartial and independent of government and industry
- Experienced in participatory engagement methods
- Actively involve people living in the region, and those with ties to the region such as Traditional Owners, to identify key local issues and aspirations of development matters
- Work in partnership with local Aboriginal research partners or employed Aboriginal community members to design and undertake baseline field research and, where possible, support the analysis stage
- Engage with diversity of genders, ages and demographics of the region.

Ethics and standards

The standards set out by the National Statement on Ethical Conduct in Human Research (National Health and Medical Research Council, 2018) should be adopted. In 2018 the National Health and Medical Research Council released updated guidelines for conducting research with Aboriginal and Torres Strait Islander people. Formal agreements between parties may be required. For example, some ethics committees such as Charles Darwin University's Ethics Committee (www.cdu.edu.au/research/ori/human-ethics) stipulate that ethics clearance will be accompanied by an agreement between researchers and relevant peoples and communities that:

- delineates how researchers and communities will work together respectfully
- defines roles and responsibilities throughout the research process
- identifies conflict resolution and complaints processes
- outlines communication and dissemination strategies

- outlines protection of intellectual property
- is endorsed and signed by appropriate Aboriginal people or community representatives.

Research with Aboriginal communities should include cross-disciplinary teams, preferably including members with anthropological, inter-cultural expertise and local Aboriginal researchers.

Privacy

Collection and publication of data must adhere to the Northern Territory's Information Privacy Principles as described in the Information Act: https://infocomm.nt.gov.au/privacy/information-privacy-principles

Consider the remoteness and physical spread of affected peoples

The design of the studies and selection of methods needs to recognise that for many regional communities, organising meetings or public information sessions may require people to drive (or fly) hundreds of kilometres, and phone surveys may not be suitable, particularly where English is often a second, third or fourth language. Some groups such as pastoralists undertake activities such as mustering or maintenance that mean they are unavailable at different times of the year, so they may be unable to attend local branch meetings, and/or may not be members of an industry association who might otherwise contribute on their behalf. Many residents, including both Aboriginal Traditional Owners and pastoralists, have lived on the land for generations and have obligations that may affect their availability at different times.

Recognise diverse community views and values

The potential for diverse community views and values means that consultation needs to be designed carefully and undertaken respectfully. Identifying existing consultative mechanisms such as Aboriginal, business, industry associations, local councils and government departments is a starting point, but communities within the region should be asked how they want to be consulted. There may also be a risk of over-consultation with some groups.

Managing expectations

It is important to manage expectations regarding how the studies will be undertaken, and the potential speed, extent and outcomes of future development. Meaningful participation requires that people are given timely, relevant, "jargon-free" and impartial information so they are aware of the implications of the studies and can make an objective assessment of how they might be affected. All consultation should clearly describe data gathering methods, and present data in a way that local communities can relate to. Communities should be given the opportunity to see how their input was considered, and provide feedback on the preliminary study results before these results are finalised and are more widely available. The intent reflected in the IAP2's Quality Assurance Framework (2015) is a useful model for engaging and managing expectations from community engagement.

An independent and community focussed process

Each stakeholder contributing to a Baseline Studies and Strategic Regional Assessment will play an important role in understanding how future development may affect the region, and contributing to the design of programs to monitor, evaluate and track progress if unconventional gas successfully develops into an industry in the Northern Territory.

This field of work is new for the Northern Territory, this will be the Territory's first Strategic Regional Assessment. Due to this, it is important we draw from those experienced in undertaking such social, cultural and economic assessments.

The Final Report highlighted the importance of several key components to supporting independence and transparency in undertaking the Baseline Studies and Strategic Regional Assessment (page 312):

- ***Independently led social baseline assessment****: using agreed indicators to measure impacts and sustainability outcomes (the indicators should be selected in consultation with local people, communities, and stakeholders) with participatory, ongoing monitoring of impacts and outcomes*
- ***Independently led community engagement program:*** *using affected stakeholder groups to discern the significance of impacts and to co-develop acceptable and appropriate mitigation and enhancement strategies*
- ***Open data policy:*** *regular and open reporting on the social, economic and environmental performance of the onshore shale gas industry*.

Stakeholder participation and engagement

Stakeholder engagement for the Baseline Studies and Strategic Regional Assessment aims to ensure the research and methodologies used to collect and assess data and information reflect the values of the region anticipated to experience unconventional gas development.

For this to occur, engagement methods need to be fit-for-purpose and appropriate to relevant stakeholders including consideration of literacy, culture, gender, age and language. This is important in the Northern Territory where engaging with remote and Aboriginal communities requires proponents to take into account cultural protocols, language and associated sensitivities.

There are many methodologies and guidance materials that can be used to assist in gaining the best outcome from stakeholder engagement for all parties involved.

Any preferred method can be used as deemed appropriate by the contracted researcher(s), however it is recommended that the core values of engagement outlined in the International Association for Public Participation's (IAP2) Quality Assurance Standard for Community and Stakeholder Engagement be considered to guide stakeholder engagement:

- Stakeholder participation is based on the belief that those who are affected by a decision have a right to be involved in the decision-making process
- Stakeholder participation includes the promise that the stakeholder's contribution will influence the decision

- Stakeholder participation promotes sustainable decisions by recognising and communicating the needs and interests of all participants, including decision makers
- Stakeholder participation seeks out and facilitates the participation of those potentially affected by or interested in a decision
- Stakeholder participation seeks input from participants in designing how they participate
- Stakeholder participation provides participants with the information they need to participate in a meaningful way
- Stakeholder participation communicates to participants how their input affected the proposal and decision.

It is recommended that methodologies used to identify and undertake stakeholder engagement be articulated in the Baseline Studies and Strategic Regional Assessment.

Aboriginal Territorians' Culture and Values

In the Northern Territory consideration of Aboriginal culture and values are fundamental components to a Strategic Regional Assessment. It is expected that when undertaking a Strategic Regional Assessment in the Northern Territory it be all-inclusive of cultural awareness, the indigenous estate and local decision making practices. This can only take place with "on-country" engagement.

Respect for culture requires working with communities to establish protocols for studies, being clear on the parameters, agreeing on terms of reference and avoiding raising unrealistic expectations. Interviews need to be conducted in culturally appropriate ways, which may require trained interpreters such as the Aboriginal Interpreter Service[3].

Incorporating cultural and spiritual considerations into business practice such as cultural land and sea knowledge can enhance project prosperity, along with protecting Aboriginal Territorians' rights, traditions and ways of life.

For Aboriginal peoples, country is much more than a place. Rock, tree, river, hill, animal, human – all were formed of the same substance by the Ancestors who continue to live in land, water, sky. Country is filled with relations speaking language and following Law, no matter whether the shape of that relation is human, rock, crow, wattle. Country is loved, needed, and cared for, and country loves, needs, and cares for her peoples in turn. Country is family, culture, identity. Country is self[4].

[3] https://nt.gov.au/community/interpreting-and-translating-services/aboriginal-interpreter-service

[4] 'Seeing the Light: Aboriginal Law, Learning and Sustainable Living in Country', Ambelin Kwaymullina, Indigenous Law Bulletin May/June 2005, Volume 6, Issue 11

Expectations of those working with Aboriginal communities and landholders in developing Baseline Studies and Strategic Regional Assessment include:

- constructive engagement that respects their cultural and spiritual ties to country as well as good communication, so people can make informed decisions about proposed development in their region
- culturally appropriate participation in the design of research, identification of issues and appropriate indicators
- use of Aboriginal research partners or community members in baseline research and, where practicable, analysis and interpretation of the findings
- inclusive processes with both men and women, a diversity of age segments and both traditional owners and other affected Aboriginal groups
- considering whether interpreters are needed and giving people time to absorb and consider information and express their views
- interdisciplinary teams incorporating members such as anthropologists with local intercultural expertise
- not undermining the authority of Land Councils by making independent findings of the legal or anthropological nature of groups and land in a particular region
- respect for the privacy and sensitivity of some issues
- clearly communicating the findings of studies to affected groups
- independent and impartial research
- taking care not to raise unrealistic expectations: be clear about the purpose and parameters of studies and likely decisions to be informed
- Aboriginal Territorians, their laws, customs and connections to land are to be included in decision-making
- respect, value and incorporate traditional knowledge, and protecting elements that define Aboriginal Territorians' identity (spirituality, language, culture and livelihood)
- Aboriginal Territorians living within the region have the opportunity to review the outcomes of the baseline studies and contribute to the Strategic Regional Assessment
- the values of communities living within the region are reflected in the baseline studies and Strategic Regional Assessment
- compliance with legislated/statutory and/or regulatory requirements that include Aboriginal engagement:
    - *Aboriginal Land Rights (Northern Territory) Act 1976* (Cth): the four land councils (Northern, Central, Tiwi and Anindilyakwa), established under this Act, determine the identity of traditional Aboriginal owners to facilitate discussions, determine people's wishes and opinions, protect people's interests and consult with Aboriginal people on any proposals relating to the use of Aboriginal land.

- *Native Title* Act 1993 (Cth): the Northern Land Council and the Central Land Council are the two designated representative bodies for the holders of native tile rights, and the National Native Title Tribunal is an independent agency established under the Act with statutory responsibilities to consult, assist, and mediate with a view to negotiating Indigenous Land Use Agreements.
- *Northern Territory Aboriginal Sacred Sites Act 1989:* Aboriginal sacred sites are recognised and protected in the Northern Territory. Under the Act, the AAPA has a statutory obligation to consult with custodians of sacred sites on or near the vicinity of the land which the proposals may affect.
- *Northern Territory Heritage Act 2011:* protects areas of cultural significance by providing for the conservation of the Northern Territory's cultural and natural heritage. The NT Heritage Register lists all declared heritage places. All Aboriginal and Macassan archaeological places and objects are heritage places and objects under the terms of the *Northern Territory Heritage Act 2011* and are automatically protected, whether they are known about or not. It is an offence to disturb, damage or destroy an Aboriginal or Macassan archaeological place or object without permission.

The resources and considerations expected to guide engagement with Aboriginal Territorians include:

- United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP)
- Free Prior and Informed Consent (FPIC) Principles:
    - FPIC must be demonstrated, especially when operating with Aboriginal communities in the Northern Territory

'FPIC is a procedural mechanism developed to assist in ensuring the right of Indigenous peoples to self-determination. It is a concept that gained status by its inclusion in the 2007 [UNDRIP][5]'

- Aboriginal Peak Organisations Northern Territory's (APONT) Principles
- Remote Engagement and Coordination online toolkit (online) or strategy.

Land Councils and the Aboriginal Areas Protection Authority

The Northern Territory's four Aboriginal Land Councils (Northern, Central, Tiwi Islands and Anindilyakwa) and the AAPA can provide a key role in supporting the baseline studies and strategic regional assessments within their jurisdiction and this can be discussed and determined very early on in the process when these studies are being designed. The Land Councils have statutory responsibilities under the *Aboriginal Land Rights Act 1976* and *Native Title Act 1993* and these responsibilities may influence the contribution they seek or need to make to these studies. The Land Councils and AAPA can provide advice on appropriate conduct of research, but the exact nature of their contribution may be determined by their mandate and resources available.

[5] https://www.iaia.org/uploads/pdf/SIA_Guidance_Document_IAIA.pdf

Regional communities

Communities living in the region already have a significant amount of knowledge and information required to develop a locally-relevant Strategic Regional Assessment. These communities can play a significant role in:

- collecting and establishing regional baseline data and information, particularly regarding local values and context that may not be available through data sets such as ABS and Census
- advising on priorities, issues and aspirations for the region
- identifying and refining a set of locally meaningful indicators
- advising on methods for working with the community, such as local reference/working groups
- generating ideas for strategies to mitigate development-related impacts that support community needs and aspirations, and may be relevant to subsequent project-specific assessments.

Pastoral industry

Pastoralists and their employees are an important stakeholder group within the region where arrangements need to be in place for the pastoral and petroleum industries to successfully co-exist within the region. Pastoralists have been an important feature of the Territory's history for over 150 years and many of the families working in the industry and in the regions today are linked with that history of involvement and are strongly connected to the land. Pastoralism will continue to be an important part of the Territory's economic future and significant investments are being made in regional infrastructure and facilities to support this. Pastoralists and the pastoral workforce are an important stakeholder group and their values, views and aspirations need to be reflected in the Baseline Studies and Strategic Regional Assessment.

Unconventional Onshore Gas Industry and local suppliers

The unconventional onshore gas industry is currently, relatively small in the Northern Territory as exploration activities recommence, however it is recognised to have the potential to expand if exploration outcomes are positive and the petroleum resources can be commercially developed. The industry will draw on local businesses and suppliers for a range of inputs and services so the scale of the industry and its extended network could be significant, especially when considered in a regional context.

The industry and its network of local service providers are an important stakeholder group and their values, views and aspirations need to be reflected in the Baseline Studies and Strategic Regional Assessment. If the industry proceeds to the development phase, individual companies will develop project-specific proposals, including Social Impact Assessments (SIAs), which are outside the scope of this guidance note.

Other industries and stakeholders in the region

Other industries such as tourism, mining and horticulture may exist in the region and make an important contribution to the livelihoods, values and economy of the area and could be affected by the emergence of an onshore petroleum industry. Their contribution and overlap with the values and aspirations of other groups may vary across regions so the study design needs to ensure this is taken into consideration. The values, views and aspirations of other stakeholders in the region need to be reflected in the Baseline Studies and Strategic Regional Assessment.

8.7 Governance arrangements

The Baseline Studies and Strategic Regional Assessment of the social, cultural and economic environment of a region is only one of seven components of a SREBA. Governance arrangements will be introduced to manage the SREBA as a whole, but the nature of the social, cultural and economic studies requires additional mechanisms to oversee these specific studies.

A Terms of Reference will be tailored with the region, to ensure that potential social, cultural and economic impacts from onshore unconventional gas activities are broadly identified, understood and relevant to the people and communities in the defined geographic boundary.

It is expected that either a community advisory group be established or existing engagement mechanisms be identified with the region in the early planning stages of the studies. It is important that local residents and stakeholders have the opportunity to act as a reference point on the proposed design of the studies and community engagement, advise on sources of local information and opportunities for local people to participate in the studies, and act as a broader conduit between the group(s) undertaking the studies and the broader community.

8.8 Reporting and data management

Data gathered for the Baseline Studies, Strategic Regional Assessment, and for ongoing monitoring and evaluation will be publicly available online as long as doing so does not breach privacy, cultural or commercial confidentiality requirements. Transparency in how the data will be collected and ensuring the information and reports are publicly available will be important to manage sustainable development in a region. Datasets must adhere to the NT Open Data Policy and meet the data standard: https://dcis.nt.gov.au/office-of-digital-government.

A reflexive and ongoing process is anticipated as part of ongoing monitoring and reporting. As part of the Strategic Regional Assessment a periodic, standardised reporting system needs to be established.

8.9 Project-Based Social Impact Assessments (SIA)

The Baseline Studies and Strategic Regional Assessment will provide information that is complementary to, and informs the development of proponent's individual impact assessments, by providing evidence-based, region specific resources and comprehensive social, cultural and economic data and information, informed by independent experts.

A project-level SIA and associated management plan is only required if it is necessary under the *Environmental Assessment Act 1982* (not all projects in the Northern Territory are assessed under this Act).

A broader, separate Social Impact Policy is also being developed with associated guidelines specific to project-based SIA. This will address recommendations from the Inquiry related to project-specific SIA to assist industry in their mitigation of negative impacts and their ability to enhance positive social outcomes.

To further understand SIA, the International Association for Impact Assessment (IAIA) has produced a document *'Social Impact Assessment: Guidance for assessing and managing the social impacts of projects'* that provides comprehensive and best practice information regarding SIA (see Vanclay, 2003).

> *'Project-specific social impacts vary greatly in their nature, causation, magnitude and other characteristics. Depending on the context, different receiving environments (such as a social or cultural group, or a geographic region) may experience the same impacts differently. As such, it becomes the responsibility of the gas company, in consultation with affected people and other stakeholders, to ensure that all the relevant issues and impacts are identified and considered.'*

8.10 References

IAP2's Quality Assurance Framework (2015). https://iap2.org.au/wp-content/uploads/2019/07/IAP2_Quality_Assurance_Standard_2015.pdf

Scientific Inquiry (2018). *Final Report of the Scientific Inquiry into Hydraulic Fracturing in the Northern Territory*. Darwin. https://frackinginquiry.nt.gov.au/inquiry-reports?a=494286

Vanclay, F., et al (2015). International Association for Impact Assessment, *Social Impact Assessment: Guidance for assessing and managing the social impacts of projects.* https://www.iaia.org/uploads/pdf/SIA_Guidance_Document_IAIA.pdf

Vanclay, F (2003)., *International Principles For Social Impact Assessment* https://www.iaia.org/uploads/pdf/IAIA-SIA-International-Principles.pdf

9. Glossary

Term	Definition
Aquatic ecosystems	any area within the NT that is inundated, or contains water, or high levels of soil moisture outside precipitation periods, that is it is associated with water permanently or periodically; and any aquifer with connectivity to the surface (for example, plant roots or groundwater expressions)
Australian Drinking Water Guidelines (ADWG)	Guidelines produced by Australia's National Health and Medical Research Council (NHMRC)
Baseflow	Water derived from aquifers to feed into surface water
Biogenic	Arising from biological origins
Chemical of concern	A substance that has potential to impact public health and could be found in concentrations higher than regulatory guidelines
Concentration (of gasses)	Atmospheric concentrations of gasses are usually reported on a volumetric basis; i.e. the ratio of the volume of the constituent gas to the total volume of the gas mixture. Gas concentrations are typically expressed as percent, parts per million (ppm) or parts per billion (ppb). The global average background atmospheric concentration of methane is currently about 1.85 ppm – the concentration in the southern hemisphere is slightly lower at approximately 1.80 ppm (as measured at the CSIRO atmospheric monitoring station at Cape Grim in Tasmania). Note that ambient methane concentrations are subject to seasonal variation; e.g. at Cape Grim, monthly methane concentrations during 2017 varied between approximately 1.78 and 1.82 ppm. Much larger variations are frequently observed at local levels due to local sources and changing atmospheric conditions.
Confounding factors	Factors not associated with the activity of interest that independently affect the risk of developing a health outcome. Confounding factors can make it difficult to assign a single association between an exposure and an outcome. Confounding factors can include the other industries in a region that may be an alternative source of chemical, physical and social stress and can also include pre-existing sources of chemical contamination before the activity of interest commenced.
Data loggers	recording devices to record field data
Downgradient	down the groundwater flow direction relative to a given location

Term	Definition
Emission rate or flux	These terms refer to the rate of volume or mass flow of methane from a source per unit time, i.e. how much methane is emitted to the atmosphere through time. The emission rate may be expressed as a volumetric flow (e.g. in m^3 of methane per unit time) or mass flow (e.g. in g or kg of methane per unit time). Molar flux (i.e. moles of methane) is also sometimes used. Both concentration and emission rate data are required for baseline studies since areas of elevated methane concentrations help in locating and identifying sources while emission rates yield the amount of methane being released to the atmosphere, which is necessary for developing emission inventories. Concentration data on their own, however, have little value since they provide no information on the amount of methane emitted to the atmosphere.
Exposure screening assessment	Assessment and validation of existing environmental data for assessment of potential health impacts, including chemical levels in air, soil, water and people (e.g. blood), measures of physical stressors (light, noise), and health symptom data.
Fugitive emissions	The term fugitive emissions in relation to the oil and gas industry refers to all non-combustion sources of greenhouse gasses (mainly methane) but also to the disposal of waste streams either by venting or flaring. Note that although flaring is a combustion process, emissions associated with flaring waste gas are still counted as fugitive emissions. Sources of fugitive emissions include: • equipment leaks • leakage from outside well casings • process venting (such as emissions from equipment designed to vent during normal operation, and maintenance activities where gas is released to the atmosphere); • waste streams (venting and flaring) • accidents and equipment failures (e.g. pipe ruptures, tank explosions)
Geogenic	Arising from geological origins
Groundwater dependent ecosystems (GDEs)	Ecosystems that rely on groundwater for some or all of their water requirements. They can occur on the surface, subsurface or in aquifers
Health Impact Assessment	The process of estimating the potential impact of a chemical, biological, physical or social agent on a specified human population system under a specific set of conditions and for a certain timeframe.
Hydrostratigraphy	An analysis of how different layers of porous material affect the flow of groundwater
Human Health Risk Assessment, or HHRAs	An assessment of the effects that exposure to pollutants may have on key biological, chemical and physical processes that affect human health.

Term	Definition
IBRA region, or Interim Biogeographic Regionalisation for Australia region	A scientific framework which allows scientists to accurately describe and classify Australian landscapes into 89 bioregions and 419 subregions, considering the landform, and associated resources such as soil, water, and vegetation.
Maximum Limit, or ML	The highest amount of chemical that is legally allowed in a food product sold in Australia whether the food product is produced domestically or imported.
Maximum Residue Limit, or MRL	The highest amount of an agricultural or veterinary chemical residue, or its breakdown products, that is legally allowed in a food product sold in Australia whether the food product is produced domestically or imported.
Metadata	Information that describes other data that is collected, for example, author, date created and date modified and file size.
NATA	National Association of Testing Authorities is Australia's national accreditation body for the accreditation of laboratories
NEPM	National Environmental Protection Measures are established by the National Environment Protection Council to assist in protecting or managing particular aspects of the environment in Australia.
NICNAS	National Industrial Chemicals Notification and Assessment Scheme. Is the Australian Governments regulatory body for the assessment of industrial chemicals.
Pressure transducer	is used to convert pressure into an electrical output signal such as voltage, current, or frequency and are responsive to changes in both pressure and temperature. Pressure Transducers are often used to gauge pressure measurements for leak detection
Qualitative data	Information that is observed and recorded
Quantitative data	Information that can be measured and assigned a numerical value.
Refugia	An area in which a population of organisms can survive through a period of unfavourable conditions
Separation distance	Set back distance is the distance between the hydraulic fracturing infrastructure and the nearby community (includes dwellings or other infrastructure such as bores) and water sources.

Term	Definition
Spatial analysis	A spatially explicit analysis of aquatic ecosystems which includes an overlay of factors driving aquatic ecosystems existence and dynamics such as groundwater and surface water supply. This analysis may also include modelling and prediction of spatial ecosystem components (such as biodiversity) and water changes over time (such as groundwater modelling predictions). Uncertainty estimation plays an important role in these type of analyses to support the requirements of assessing impacts and risks
Stakeholder	Those who have an interest in a proposal or who may be affected in some way by the proposal.
Stygofauna	Animals living in aquifers and interstitial spaces of the subsurface. They are the fauna of aquifer and subsurface GDEs
Survey protocols	Survey protocols outline the methods, including sampling of organisms and water parameters, time frames and repetition of aquatic ecosystem surveys. They include a description of target organisms, and provide the taxa level resolution requirement and taxonomic identification approaches
Thermogenic	Arising from the generation of heat, or combustion
Upgradient	Up the groundwater flow direction relative to a given location
Water Allocation Plan (WAP)	A plan developed for a specific region within a designated Water Control District in the Northern Territory which aims to protect the environment and allocates the available water between users whilst ensuring the long term sustainability of the water resource. A Water Allocation Plan is developed through technical and scientific assessments, and extensve community participation and consultation.
Water Control District (WCD)	Water Control Districts are areas where there is an identified need for improved management of water resources to avoid overusing groundwater reserves, river flows or wetlands. A Water Control District may require one or multiple Water Allocation Plans depending upon the nature of the water resources within the area.

10. List of SREBA related Inquiry recommendations

The Final Report included three specific recommendations on the delivery of a SREBA (Recommendations 15.1, 15.2 and 15.3), but there are another 32 recommendations that make a general reference to baseline studies, or refer to baseline studies for the Beetaloo Sub-basin. All recommendations are listed below in the order they appear in the Final Report:

Recommendation 7.4

That the Government develops specific guidelines for human health and environmental risk assessments for all onshore shale gas developments consistent with the National Chemicals Risk Assessment framework, including the national guidance manual for human and environmental risk assessment for chemicals associated with CSG extraction.

Recommendation 7.5

That before any further production approvals are granted, a regional water assessment be conducted as part of a SREBA for any prospective shale gas basin, commencing with the Beetaloo Sub-basin. The regional assessment should focus on surface and groundwater quality and quantity (recharge and flow), characterisation of surface and groundwater-dependent ecosystems, and the development of a regional groundwater model to assess the effects of proposed water extraction of the onshore shale gas industry on the dynamics and yield of the regional aquifer system.

Recommendation 7.13

Upon a gas company undertaking any exploration activity or production activity, monitoring of the groundwater must be implemented around each well pad to detect any groundwater contamination, adopting the monitoring outlined in Recommendation 7.11. If contamination is detected, remediation must commence immediately.

Recommendation 7.16

That appropriate modelling of the local and regional groundwater system must be undertaken before any production approvals are granted to ensure that there are no unacceptable impacts on groundwater quality and quantity. This modelling should be undertaken as part of a SREBA.

Recommendation 7.19

That the SREBA undertaken for the Beetaloo Sub-basin must take into account groundwater-dependent ecosystems in the Roper River region, including identification and characterisation of aquatic ecosystems, and provide measures to ensure the protection of these ecosystems.

Recommendation 7.20

That the Beetaloo Sub-basin SREBA must identify and characterise all subterranean aquatic ecosystems, with particular emphasis on the Roper River region.

Recommendation 8.1

That:

- strategic regional terrestrial biodiversity assessments be conducted as part of a SREBA prior to the granting of any further production approvals
- any onshore shale gas development be excluded from areas considered to be of high conservation value
- the results of the SREBA must inform any decision to release land for exploration permits as specified in Recommendation 14.2 and, upon completion, must be considered by the decision-maker in the granting of any future exploration approvals.

Recommendation 8.2

That a baseline weed assessment be conducted over all areas that will be accessed by a gas company on an exploration permit prior to any exploration activities being carried out on that area and that ongoing weed monitoring be undertaken to inform any weed management measures necessary to ensure no incursions or spread of weeds.

Recommendation 8.6

That as part of a SREBA, a study be undertaken to determine if any threatened species are likely to be affected by the cumulative effects of vegetation and habitat loss, and if so, that there be ongoing monitoring of the populations of these species.

If monitoring reveals a decline in populations (compared with pre-development baselines), management plans aimed at mitigating these declines must be developed and implemented.

Recommendation 8.9

That to compensate for any local vegetation, habitat and biodiversity loss, the Government develops and implements an environmental offset policy to ensure that, where environmental impacts and risks are unable to be avoided or adequately mitigated, they are offset.

That the Government considers the funding of local Aboriginal land ranger programs to undertake land conservation activities as an appropriate offset.

Recommendation 8.10

That gas companies be required to identify critical habitats during corridor construction and select an appropriate mechanism to avoid any impact on them.

Recommendation 9.3

That baseline monitoring of methane concentrations be undertaken for at least six months prior to the grant of any further exploration approvals. In areas where hydraulic fracturing has already occurred, the baseline monitoring should be undertaken at least a year prior to the grant of any production approvals.

Recommendation 9.4

That baseline and ongoing monitoring be the responsibility of the regulator and funded by the gas industry.

Recommendation 9.5

That all monitoring results must be made publically available online on a continuous basis in real time.

Recommendation 9.8

That the NT and Australian governments seek to ensure that there is no net increase in the life cycle GHG emissions emitted in Australia from any onshore shale gas produced in the NT.

Recommendation 10.1

That formal site or regional-specific HHRA reports be prepared and approved by the regulator prior to the grant of any production approvals.

Such HHRA reports must address the potential human exposures and health risks associated with the exploration for, and the production of, any shale gas development, off-site transport, and the decommissioning of wells, as recommended in NCRA guidance. The HHRA reports must include risk estimate assessments for exposure pathways that are deemed to be incomplete.

Recommendation 11.8

That a comprehensive assessment of the cultural impacts of any onshore shale gas industry must be completed prior to the grant of any production approvals. The cultural assessment must:

- be designed in consultation with Land Councils and AAPA;
- engage traditional Aboriginal owners, native title holders and the affected Aboriginal communities, and be conducted in accordance with world-leading practice; and
- be resourced by the gas industry.

Recommendation 12.1

That a strategic SIA, separate from an EIS, must be conducted for any onshore shale gas development prior to any production approvals being granted.

Recommendation 12.2

That the strategic SIA be funded by the gas industry.

Recommendation 12.3

That the strategic SIA must be conducted comprehensively and in such a manner that it will anticipate any expected impacts on infrastructure and services and to mitigate potential negative impacts.

Recommendation 12.4

That early engagement and communication of the findings of the strategic SIA be systematically undertaken with all potentially affected communities, all levels of government and potentially affected stakeholders, including Land Councils, to ensure that unintended consequences are limited, and that shared understanding of roles and responsibilities, including financial responsibilities, can be developed.

Recommendation 12.5

That ongoing monitoring and measurement of social and cumulative impacts be undertaken, with the results being made publicly available online as soon as they are available.

Recommendation 12.6

That a strategic SIA be conducted as part of any SREBA to obtain essential baseline data.

Recommendation 12.7

That in order to operationalise an SIA framework in the NT, the Government must:

- give the regulator power to request information from, and to facilitate the collaboration between, individual gas companies, government agencies (including local government), Land Councils, communities and potentially affected landholders;
- establish a long-term participatory regional monitoring framework, overseen by the regulator, with secure funding from the gas industry and able to endure multiple election cycles; and
- establish periodic and standardised reporting to communities on the social, cultural, economic and environmental performance of the industry through either the regulator or a specialised research institution. This includes information from the monitoring of key indicators, and an industry-wide complaints and escalation process.

Recommendation 12.8

That as part of any strategic SIA and prior to any significant increase in traffic as a result of any onshore shale gas industry, consultation must be undertaken on road use and related infrastructure requirements that results in road upgrades and work schedules to the appropriate Austroad standards and commensurate with the anticipated vehicle type required for any onshore shale gas industry.

Recommendation 12.11

That gas companies be required to work closely with all levels of government, Land Councils and local communities early in any onshore shale gas development project to quantify the potential impacts on health and educational services and ensure steps to mitigate adverse impacts are implemented.

Recommendation 12.12

That any strategic SIA anticipate the long-term impacts and requirements for housing (not just through the construction phase) to adequately mitigate the risk of inflated real estate prices and shortages within a community.

Recommendation 12.20

That as part of the SREBA for the Beetaloo Sub-basin, a strategic SIA be conducted to obtain essential baseline data prior to the granting of any further production approvals.

Recommendation 14.1

That prior to the granting of any further production approvals, the Government designs and implements a full cost recovery system for the regulation of any onshore shale gas industry.

Recommendation 14.4

That prior to the grant of any further exploration approvals, the following areas must be declared reserved blocks under section 9 of the Petroleum Act, each with an appropriate buffer zone:

- areas of high tourism value;
- towns and residential areas (including areas that have assets of strategic importance to nearby residential areas);
- national parks;
- conservation reserves;
- areas of high ecological value;
- areas of cultural significance; and
- Indigenous Protected Areas

Recommendation 14.21

That as part of the environmental assessment and approval process for all exploration and production approvals, the Minister be required to consider the cumulative impacts of any proposed onshore shale gas activity.

Recommendation 14.22

That prior to the granting of any further production approvals, the Government considers developing and implementing regional or area-based assessment for the regulation of any onshore shale gas industry in the NT.

Recommendation 15.1

That a strategic regional environmental and baseline assessment (SREBA) be undertaken prior to the granting of any further production approvals

Recommendation 15.2

That the regulator oversees the auditing and the data-collection processes and provides a central repository for all data informing any SREBA

Recommendation 15.3

That a SREBA should be completed within five years from the first grant of exploration approvals; and must be completed prior to the grant of any production approvals.