BHP

Case study

# Responsibly managing hydraulic fracturing

3 October 2017

## Introduction

During the recent downturn in the oil and gas industry, we continued to make progress on optimising and simplifying our hydraulic fracturing operations while maintaining our strong focus on protecting the health and safety of our workers and communities and limiting our impact on the environment. Our drilling and completions activities during fiscal year FY2016 [1] were limited to Eagle Ford and Permian.

Since 2011, we have conducted onshore shale operations in the Fayetteville, Haynesville, Eagle Ford and Permian shale plays according to our North America Shale Operating Principles. These principles state our endeavour to be the safest company in the industry, protect the land where we operate, safeguard and manage water resources, minimise air emissions from our operations, and be a good neighbour to our communities. We carefully develop and rigorously implement safety and operating systems, properly train our people and do not compromise our standards. We only work with contractors who share our commitment to safety, and we develop relationships and partner with our host communities which border our areas of operation. We construct and operate our facilities in an environmentally sensitive manner and we conduct environmental assessments prior to initiating construction to minimise the impacts of our operations. All of our shale plays maintain a plan that includes controls to manage impacts to land and biodiversity, and our intent is to restore the environment to its pre-disturbance condition or better when we leave.

## Reducing and reporting toxic chemicals

We report the ingredients of the fracturing fluids used for well completions into FracFocus, the hydraulic fracturing chemical public disclosure registry. We are partnering with responsible service companies who are working to reduce the number and toxicity of chemicals that we use in fracturing fluids.

We do not use benzene, toluene, ethylbenzene or xylene (BTEX) or diesel in our fracturing fluids, and for a high percentage of our wells, we disclose all of the ingredients and additives by name and Chemical Abstracts Service Number (CAS#) with the maximum percentage utilised. For our Texas wells in the Eagle Ford and Permian shale plays, about 99 per cent of proprietary chemicals were disclosed using their chemical family name. Some proprietary chemicals were eliminated entirely from use. FracFocus allows us to work with our vendors to apply a systems approach to improve the transparency of reporting chemicals we use to the public.

In order to reduce the toxicity of fracturing fluids, our service company partners have worked since 2015 to evaluate the chemicals used in the fracturing fluid and rank them according to their environmental, physical or health hazards. In Texas at the Eagle Ford and Permian shale plays, our service companies assess our chemicals according to major hazard categories and select the most environmentally preferred option. They are working to eliminate federally listed contaminants, known carcinogens, mutagens or reproductive toxins, and other hazardous air and water pollutants from fracturing fluids. For example, one of our service companies checks the frac fluid chemicals against criteria for four tiers of contaminants: Tier 1 chemicals that do not contain federally listed priority

(1) BHP's fiscal year runs from 1 July to 30 June.

pollutants or Safe Drinking Water Act contaminants; Tier 2 chemicals that meet Tier 1 plus do not contain any known carcinogens, mutagens or reproductive toxins; Tier 3 chemicals that meet Tiers 1 and 2 plus do not contain endocrine disruptors; and Tier 4 chemicals that meet the first three tiers, plus do not contain suspected carcinogens, mutagens or reproductive toxins. About 81 per cent of the chemicals used in our frac fluids meet Tier 4 standards, and 11 per cent meet Tiers 1 to 3. The remaining eight per cent non-tier chemicals are used only when necessary. An additional service company that we have utilised since 2016 has eliminated the use of the most hazardous chemicals based upon their health, physical and environmental hazards, accounting for toxicity, mutagenicity, carcinogenicity, corrosive and other physical properties, biodegradation, bioaccumulative and other environmental criteria. Additionally, our service companies are working to develop chemical ingredients in dry form rather than liquid to reduce risk during transport. Several dry chemical alternatives are either now in use or undergoing field trials for testing. We will continue to work with our service companies to develop additional dry ingredients over time.

## Water management: sourcing, well integrity, waste management and monitoring

### Well integrity

We check the wells we drill across each shale play against our critical elements to ensure well integrity and the safety of our operations. This includes pressure tests of the casing at each section, cement evaluation and formation integrity testing of the casing shoe. The cement evaluation is conducted as needed to address well integrity anomalies; for example, in the event of a loss of cement returns to the surface. It consists of either a cement bond log, or an ultrasonic imager tool, run on wireline across the zones of interest to evaluate cement quality. Log results are evaluated by a subject matter expert for determination of whether there is good hydraulic isolation across the zone/s of interest. To protect the groundwater, surface casing is typically set at 2,500 feet – 4,500 feet in the Eagle Ford, and at about 900 feet in the Permian, and is cemented back to surface with the primary objective of isolating the ground water critical zone.

Of the 495 fractured wells completed in the last two years in all our shale plays, none of them experienced well integrity failures that resulted in releases to the environment. Please refer to the table below.

**Percentage of wells completed that experienced well integrity failures that resulted in releases to environment**

| | FY2015 | | FY2016 | |
|---|---|---|---|---|
| **Shale play** | **#wells** | **%** | **#wells** | **%** |
| Eagle Ford | 237 | 0 | 147 | 0 |
| Fayetteville | 5 | 0 | 0 | 0 |
| Haynesville | 25 | 0 | 5 | 0 |
| Permian | 44 | 0 | 32 | 0 |
| **TOTAL** | **311** | **0** | **184** | **0** |

We conduct offset well reviews of our wells and those of other operators and identify significant hazards. We work to ensure we do not intersect existing wells and provide pathways for contaminants to enter surface or groundwater. The offset reviews also check for annulus pressures and any reported problems when drilling the well.

Our approach to managing the risk of groundwater contamination from subsurface loss of containment through drilling, completions, production and plugging and abandonment is documented in a groundwater risk management plan. The plan incorporates preventative controls to reduce the likelihood of subsurface loss of containment of hydrocarbons, including casing annulus monitoring procedures to verify the integrity of the well through annulus monitoring during the production stage. This ensures that pressure in the annulus of each well does not exceed its maximum allowable annulus surface pressure, and thereby helps prevent potential well failures from occurring. Additional preventative controls include: 1) properly designed and placed cement to prevent casing failure; 2) proper wellhead and casing design; and 3) competency assurance of trained and qualified personnel through internal specialised training in accordance with our Organisation, Development and Training Standard. Engineers, superintendents and supervisors must also maintain a well control certification. Additional training in continuous and productivity improvement and health, safety and environment (HSE) is recommended for all drilling and completions roles.

The groundwater risk management plan incorporates a formal well handover documentation system as a series of checklists executed by drilling, completions, production and intervention engineers, who must verify the list before submitting to the next engineer. This handover system communicates key well construction features and the operating envelope, and highlights any heightened risk for hydrocarbon containment based on well construction that may require additional monitoring. All well handover files are saved into BHP's document and record management system that provides enhanced security as well as record-keeping capability in compliance with current regulation requirements.

### Pre-drilling and post-drilling monitoring

Beginning in 2015, we voluntarily implemented an ongoing pre-drilling groundwater monitoring program in the active drilling areas of our shale operations, which include the Eagle Ford and Permian shale plays. Groundwater monitoring is not applicable in Fayetteville and Haynesville due to the suspension of drilling operations in FY2016. The procedure begins by identifying registered water wells within a 1,500-foot radius of each new well pad using geographic information system (GIS) mapping. We then contact landowners to confirm the locations of any water wells in use, both registered and non-registered, and obtain landowner permission and an agreed date to sample the wells. After an accredited laboratory analyses the water samples, we record the results in our internal data base, and provide a copy of the results to the landowner.

We also review baseline sampling data conducted by Texas Groundwater Conservation Districts within the vicinities of our planned drilling and completions activities for potential applicability.

We do not conduct post-drilling monitoring at this time.

**Potable/non-potable water and practices for reducing water usage**

At our drilling operations in Eagle Ford and Permian, we utilise a mobile reverse osmosis system to produce potable water and ice from local well water for workers living on-site and to treat wastewater for use down hole during drilling. This system eliminates most trucking of water and wastewater into and out of our drilling camps and reduces overall trucking on location by an average of about 39 trucks per month, equivalent to about 117,000 fewer truck miles travelled in FY2016 and eliminating 95 per cent of truck traffic into the drilling camp. It also promotes sourcing from a locally based small-to-medium enterprise.

This project was initiated in 2015 in keeping with our Company initiatives for water management to investigate new technologies and processes that are less water intensive, and to implement projects to improve the management of water resources. Over a recent 12-month period, the average potable water provided per day per rig was 1,590 gallons, and the average reclaimed water per day per rig was 1,844 gallons, for an estimated 2.8 million gallons of water recycled down hole during FY2016. The mobile reverse osmosis system produces higher quality potable water than the sourced raw water, promotes water conservation, reduces the complexity of water delivery and disposal, and reduces the use of plastic water bottles and plastic waste.

A recent report by Ceres *(Hydraulic Fracturing & Water Stress: Water Demand by the Numbers – Shareholder, Lender & Operator Guide to Water Sourcing Risks*, Feb 2014) indicates that 87 per cent of the wells in the Permian shale play are located in areas of high or extreme water stress. Our program/practice to limit water use in this area is to blend produced water into the frac mix in order to limit the quantity of fresh water needed for completion operations. Additionally, we are researching treatment systems in order to determine whether we can increase the amount of produced water we can use in the frac mix, with the goal of eliminating the consumption of fresh water for completion operations.

During FY2016, we reduced high-quality water consumption in the Permian by increasing the use of brackish water and recycled water. The water we utilise for drilling and completions in the Permian is a blend of produced formation water (approximately 30 per cent), brackish water (50 per cent) and high-quality water (20 per cent). Accordingly, the Permian shale play achieved about a 30 per cent recycling rate on average during FY2016, replacing freshwater with about 70 million gallons of recycled produced water that would have otherwise been disposed in a wastewater injection well. Also by blending our produced water, we increase the salt content in the mix, and do not have to add additional salts.

Recycling is important to our drilling and completion activities in the Permian shale play, where freshwater can at times be scarce. The Ceres report indicates that 28 per cent of wells in the Eagle Ford shale play are located in areas of high or extreme water stress. However, recycling is impractical and uneconomical at this time in the Eagle Ford due to the small amount of flow back and produced water obtained from the formations. We did not have the opportunity to recycle water in Fayetteville or Haynesville as our only drilling and completions activities occurred in the Eagle Ford and Permian during FY2016.

**Water intensity**

The water intensity of our operations is directly related to the level of drilling and hydraulic fracturing activities underway. Water intensity is not applicable in Fayetteville and Haynesville due to the suspension of drilling operations in FY2016. In the Eagle Ford and Permian shale plays, where drilling and hydraulic fracturing work continues, the water intensity is shown below. Permian total water intensity is higher because the overall production volumes from this newer shale play are lower in relation to the level of drilling and completions activity. However, the fresh water intensity is lower in the Permian due to produced water recycling and use of brackish groundwater (greater than 5,000 milligrams per litre of total dissolved solids). Please refer to the tables below.

**FY2016 Total water consumption and intensity**

| Shale play | Total water* use 1,000 bbls | Ground-water 1,000 bbls | Surface water use 1,000 bbls. | Produced water recycle 1,000 bbls | Total water intensity bbls/ mmbtu |
|---|---|---|---|---|---|
| Eagle Ford | 25,047 | 25,047 | 0 | 0 | 0.079 |
| Fayetteville | 8 | 0 | 8 | 0 | 0.0001 |
| Haynesville | 0 | 0 | 0 | 0 | 0 |
| Permian | 7,273 | 5,609 | 0 | 1,663 | 0.134 |

* Includes fresh water containing less than 5,000 mg/l total dissolved solids, brackish water and recycled produced water.

**FY2016 Fresh water consumption and intensity**

| Shale play | Total fresh water* use 1,000 bbls | Ground-water 1,000 bbls | Surface water use 1,000 bbls | Fresh water intensity bbls/ mmbtu |
|---|---|---|---|---|
| Eagle Ford | 25,047 | 25,047 | 0 | 0.079 |
| Fayetteville | 8 | 0 | 8 | 0.0001 |
| Haynesville | 0 | 0 | 0 | 0 |
| Permian | 1,579 | 1,579 | 0 | 0.029 |

* Freshwater is defined as surface or groundwater with less than 5,000 mg/l total dissolved solids.

**Produced water disposal and induced seismicity**

We actively participate in cooperative efforts with stakeholders (industry, government, science community and public) to better understand the scientific basis and promote best practice risk management of the potential for induced seismicity from saltwater disposal activities.

Our success in recycling produced formation water in Permian completions reduces the volume that we would otherwise dispose in wastewater injection wells. BHP does not currently own or operate saltwater disposal wells in Texas.

**Managing drilling residuals**

*Off-site recycling*

In FY2015, BHP's drilling organisation investigated new methods of managing our waste stream, in lieu of traditional process that utilise disposal facilities to treat and bury drill cuttings. Early in FY2016, we partnered with a facility nearby our Eagle Ford assets that converts drill cuttings waste into beneficial materials. The drill cuttings which are separated from the drilling fluid by mechanical processes on the rig site are sent to a licensed commercial facility where they are treated with a bioremediation agent to become a reusable material. Caliche and sandstone are added as aggregate. The cuttings are then recycled into mine-fill material used to fill a decommissioned uranium mine in Karnes County, or it is recycled into road-base material for construction of new roads in Karnes County. The Texas Railroad Commission regulates the minimum amount of residual total petroleum hydrocarbons on cuttings used as recycled material at one per cent or 10,000 ppm. During FY2016, approximately 126,000 tons of our drill cuttings were transported to this recycling facility and converted into a beneficial product after removing the hydrocarbons. We recondition the liquid hydrocarbons from the mud that are recovered during mechanical separation of the drill cuttings, and reuse it at the rig site.

The recycling of drill cuttings is an effective method of responsibly managing our drilling waste stream. By properly treating, stabilising and recycling drill cuttings, the end product can be converted into a beneficial material. This process also helps reduce drilling costs, but more importantly it aligns with *Our Charter* value of Sustainability by minimising the environmental impact of our operations. This process was recently highlighted by a respected oil and gas magazine as an innovative approach by BHP to repair worn roads in the Eagle Ford, while reducing landfill disposal of drilling waste (Redden, J. 'Paved with best intentions.' *World Oil*, August 2016, p. 17).

*Reducing waste – well design optimisation and effective solids control*

We also reduced waste generation by optimising the well design in our Eagle Ford assets. We replaced the original well design with a slimmed down casing design for a volume reduction of several hundred barrels of drill cuttings per well.

We utilise a closed loop system to manage and recycle drilling muds in all our shale plays when oil based mud is used, or if the well is located in a flood plain or other environmentally sensitive area, or if the landowner requests it. The process lowers the potential for contact of drilling fluids with the environment.

At our Eagle Ford and Permian shale plays where we currently conduct drilling and completions, we flow back wells directly into produced water closed tanks for storage prior to disposal. We employ secondary containment for oil and produced water storage tanks to minimise impacts to the environment from spills and leaks. In both Eagle Ford and Permian, the containment is lined to prevent impacts to soil. We place fencing around reserve pits and fresh water storage ponds to prevent wildlife entry. We use flares to control emissions from storage tanks and process equipment. These practices eliminate contact with wildlife and reduces spills, leaks and volatile organic emissions.

**NORM**

Our procedure for naturally occurring radioactive materials (NORM) specifies the safe storage, labelling, transportation and disposal of NORM wastes; requires monitoring and record-keeping of activities; and contains a worker protection plan to minimise exposure. Surveys are conducted every two years at each facility in each shale play by a trained surveyor using properly calibrated instruments. Surveys are documented on internal forms and are conducted at a minimum at storage sites containing used oilfield equipment or waste, and at on-site gas processing plant/treatment equipment. Surveys are also conducted prior to:

- accepting used production equipment or materials from a contractor;
- acquiring property previously used for oil and gas operations;
- transferring ownership of property, equipment, materials and facilities, including decontaminated equipment;
- transferring used oil field equipment from one site to another;
- disposal or decommissioning of any production or gas processing/treatment equipment;
- any drilling or completion activities on known NORM contaminated sites.

At all shale plays, any used and demolished equipment that exceeds NORM threshold is disposed at an approved facility. Ongoing monitoring ensures the safe handling and disposal practices.

Waste hauls are checked at the disposal site and should NORM be detected, the load is refused.

## Minimising air emissions

### Green completions

We practice green completions in our shale plays to reduce methane emissions by capturing and selling the produced natural gas that would otherwise be vented or flared.

### Low emission engines at pad operations

Since FY2014, we have worked to improve drilling efficiency across all shale plays. This has significantly reduced the number of days required to drill a well, resulting in cost savings, energy savings and lower emissions. These improvements have continued in FY2016, with the result that greenhouse gas (GHG) emissions were reduced by about 11 kilotonnes $CO_2e$ (carbon dioxide equivalent) in Eagle Ford, and over six kilotonnes $CO_2e$ in the Permian. Again, Fayetteville and Haynesville are not applicable due to the suspension of drilling operations in FY2016. In conjunction with this program, the generator used for powering the drill rigs is controlled to maximise engine efficiency, reducing both diesel fuel usage and GHG emissions. This voluntary optimisation program also reduces air pollutants associated with fuel combustion, including oxides of nitrogen ($NO_x$) and volatile organic compounds (VOCs), which contribute to ozone formation and are regulated under the Clean Air Act.

### Percentage low emission vehicle conversion

In FY2016, BHP reduced the size of its vehicle fleet by about 27 per cent, removing carbon dioxide emissions by approximately 42 per cent. Bi-fuel vehicles (compressed natural gas/gasoline) comprise about 49 per cent of the vehicle fleet in Fayetteville and about 22 per cent of the fleet in the Haynesville shale play. The ratio of CNG to gasoline was 50:50 in Fayetteville and 20:80 in Haynesville. These vehicles have an average lifecycle of 50 months or 180,000 miles before they are replaced. Bi-fuel vehicles reduce overall GHG emissions by about 10 per cent, and are cleaner burning than diesel, with lower emissions of $NO_x$, particulates, carbon monoxide, VOCs and no sulfur or lead emissions.

### Voluntary reduction of air pollution emissions

During FY2016, we optimised several compressor facilities in our Fayetteville operations through shutdown and redirection of three compressor facilities into a fourth compressor facility. This resulted in a 22,000-tonne per year reduction of GHG emissions, along with the $NO_x$ and other air pollutants associated with fuel combustion.

During FY2015, we implemented a standard facility design for producing oil and gas from wells in the Eagle Ford Shale consisting of skid-based modules. The modules contain the equipment, piping and flare and can be assembled in the field in one day. Field construction is reduced to the flow lines, sales lines and piping in the tank battery. This greatly reduces the construction duration in the field. Before the modular facility design, set-up of equipment and field routing of pipework could take up to two months. Now the same scope is completed in about two weeks, reducing the GHG, $NO_x$, VOCs and other air emissions associated with fuel combustion during field construction. During FY2016, the modular design concept was applied to Permian Shale as well. The modular design improves both safety and quality by moving work out of the field and into fabrication shops. The modular design is standardised, which drives simplicity, and it allows for future expandability. The design is currently limited to Eagle Ford and Permian and not applicable to other shale plays due to the specific design requirements of each shale play.

### Pipeline transport of water and wastewater

During FY2016 at our Permian shale play where large quantities of produced water are generated, we substituted pipelines for trucks to transport the wastewater directly to saltwater disposal (SWD) wells. The trucks haul the wastewater to one of 23 BHP production facilities that are piped directly to SWD wells, resulting in about 12 per cent of the wastewater transported by pipeline, while also reducing truck traffic, air emissions and hauling costs. Both cost and safety were the criteria in optimising the water routes in this manner, as the new routes to the wells were safer for drivers in some cases by reducing time on busy highways. During FY2016, 454,960 bbls of water were hauled from the source to the well pads for piping to SWD wells from late November 2015 through June 2016. Eagle Ford generates a smaller amount of produced water, so this system was not implemented in that shale play and 100 per cent of wastewater is transported by trucks to SWD wells. Also in our Haynesville and Fayetteville shale plays, 100 per cent of wastewater is transported by trucks to SWD wells.

We also utilise temporary pipelines instead of trucks throughout our shale plays to supply water to our operations. In FY2016, about 99 per cent of the water for drilling and completions was transported by pipeline in the Eagle Ford shale play and about 95 per cent of the water supply was transported by pipeline in the Permian shale play. There was no drilling and completion activity in Haynesville or Fayetteville in FY2016, therefore water consumption was minimal. This further reduces emissions from truck exhaust, relieves traffic stress on local roads and communities, and reduces our risk of injury and spills associated with transportation accidents.

## Minimising methane emissions

### Leak detection technologies and frequency

We conduct leak detection and repair (LDAR) under the federal requirements of *New Source Performance Standards (NSPS) for Oil and Gas Facilities, Subpart OOOOa* for methane utilising optical gas imaging (OGI) cameras at all sites that were installed from September 2015 through August 2017. By the end of August, BHP had completed LDAR on all new well pads on 43 sites in our Permian shale operations (about 50 per cent), six sites in Eagle Ford shale operations and two sites at Haynesville shale operations (approximately one per cent). We did not conduct LDAR at our Fayetteville shale operations as no new sites were built during this timeframe so LDAR was not required.

At our Eagle Ford facilities only, we conduct LDAR monitoring at about 40 production pads and six compressor facilities for a total of 20 per cent of facilities utilising a combination of methods: 1) OGI; 2) US Environmental Protection Agency (USEPA) Method 21 leak detection; and 3) audio-visual-olfactory (AVO) methods. We monitor methane emissions from valves, pump seals, compressor seals and pressure safety valves with a Toxic Vapor Analyzer, utilising Flame Ionization Detection (FID) or Photo Ionization Detection (PID) under USEPA's Method 21 as part of our LDAR program. This helps us locate the source of leaks in order to make repairs. Our efforts resulted in greenhouse gas (GHG) reductions of about 51,050 tonnes $CO_2e$ in FY2017. On average, we conduct quarterly monitoring. Although for sites where we have completed five quarters of monitoring within a two-year period with results below a two per cent leak rate, we are allowed to monitor the valves on an annual basis. All sites are now on annual monitoring, having completed five quarters of monitoring in a two-year period with results below a two per cent leak rate.

In addition, we conduct a weekly AVO walk-through inspection of all components, including connectors and flanges at the production pads and compressor sites as required in Texas. About five per cent of the total number of components are 'difficult to monitor components', and they are monitored annually, typically during shut down activities.

At one of our Fayetteville compressor facilities, we conduct an annual survey of possible leaks as part of the USEPA's *Greenhouse Gas Reporting Program Subpart W* requirements for Petroleum and Natural Gas Systems and *Subpart C* requirements for General Stationary Fuel Combustion sources (40 CFR Part 98 of the *Code of Federal Regulations*).

We conduct monthly AVO inspections at our applicable tanks as required by the Texas Commission on Environmental Quality (TCEQ) and the USEPA. As of September 2017, we conduct weekly AVO inspections at 29 Eagle Ford sites, quarterly AVO inspections at 12 Eagle Ford sites, and monthly AVO inspections at 60 Eagle Ford sites representing approximately 33 per cent of sites. Permian conducts 90 monthly inspections (approximately 95 per cent of sites) under the federal *New Source Performance Standards Subpart OOOO* and *Subpart OOOOa* requirements for sites with affected tanks.

**Leak repair procedures**

We follow the leak detection procedures required by the regulations, using best industry practices. All leaks detected over 500 ppm are treated the same way; that is, when we find a leak we repair it within the regulatory requirements. We attempt to repair all leaks within 15 days. If it is unfeasible to make the repair in the 15-day window, the leak goes on a 'delay of repair' list and is scheduled for repair based on the next scheduled shutdown. If a repair is unsuccessful, a second attempt is made within 15 days. When inspecting with OGI, if any leak is observed, we would attempt to repair within 30 days.

**Engineering and maintenance practices**

We conduct strategic maintenance incorporating OGI on methane emission leak points; for example, points on pneumatic controls in the Oil Unit (Eagle Ford and Permian). We established a new program of well pad preventative maintenance during OGI camera surveys in the Eagle Ford shale play and will implement it in the Eagle Ford midstream operations and the Permian during FY2018. Where practical, we implement leak repair at the time a leak is detected using best practice techniques. If not practical to do so, the repair is specified in our strategic maintenance planning as urgent, where large leaks are to be repaired within one week or in our planned maintenance. When we find components that leak more frequently, we focus our preventative maintenance on those components.

**Leak detection training**

We train our employees on the proper use of the OGI cameras for methane leak detection, and the best practice techniques for repairing leaks. Our vendors provided training when we purchased the OGI cameras. Those employees that were trained by the vendors and had experience using the cameras now provide internal training to others.

We do not provide specific training for Method 21 methane leak detection. We utilise one professional service company to conduct monitoring and the vendor provides on-the-job training and knowledge/competency evaluation of its employees. We hire a vendor that provides this as a specific service and they are routinely audited by state and federal agencies.

**ONE Future – methane emissions reduction target**

BHP is a founding member of ONE Future – where ONE stands for 'Our Nation's Energy' future. ONE Future is a consortium of natural gas producing, processing, transmission and distribution companies whose vision is to enhance the energy delivery efficiency of the natural gas supply chain in the United States by limiting energy waste and by achieving a methane 'leak/loss rate' of no more than one per cent of gross production. ONE Future advocates for voluntary performance-based standards to achieve this reduction goal.

The USEPA estimated a methane leakage rate in 2012 of about 1.44 per cent of gross production, equivalent to 0.40 trillion cubic feet (tcf) of natural gas lost in the supply chain, resulting in a $1.5 billion/year product loss. This includes 0.164 tcf loss from production, with the remaining from processing, transmission and storage, and distribution. Accordingly, ONE Future has developed a performance-based program for reducing methane emissions from the natural gas supply chain that is flexible and more cost-effective than traditional technology-based command-and-control programs. Each sector of the value chain will have a target tailored to its contribution to the overall leakage rate; for example, the production sector has a target to achieve a leakage rate of no more than 0.36 per cent of gross production by year 2025.

BHP supports this flexible approach, and actively participates with ONE Future in encouraging the USEPA to adopt a voluntary approach instead of the federal rulemaking process to achieve their methane emissions reduction goals. We expect to continue to manage our methane emissions in line with ONE Future goals, in which no more than 0.36 per cent of methane production is leaked or lost from the production sector in which we operate.

### Methane venting and flaring practices

Our company-wide practice is to avoid venting methane as much as possible. For example, during maintenance operations, we typically blowdown to a flare or other control device in order to minimise venting to the atmosphere. Pneumatic pump exhaust is routinely tied into a flare system. At central delivery points (CDPs), we capture gas from compressor packing vent seals to flare. Pressure safety valves are tied into flare systems at the CDPs.

Our company-wide practice is to minimise flaring of methane where possible. Our latest well pad facility design incorporates capture of low pressure gas that would otherwise go to flare. The operations in our Permian shale play successfully reduce production down time and consequential flaring during cold winter weather through site design optimisation. This effort consists of optimising chemical injection points, compression sizing and strategy, and the introduction of catalytic heaters and power redundancy to prevent gas lines from freezing and pressure drops. The process minimises facility downtime and more efficiently captures gas streams that may have otherwise been flared, and reduced 169,000 tonnes of GHG emissions during FY2017.

### Methane emissions and intensity

The table below shows our total methane emissions as $CH_4$ (methane) and $CO_2e$ (carbon dioxide equivalent) for FY2017 from production from each shale play. These emissions occur predominately from pneumatic controls and other fugitive emissions. Methane intensity refers to total methane emissions as a percentage of natural gas production, shown in the last column.

**Total methane emissions FY2017**

| Shale play | Total methane kilotonnes as $CH_4$ | Total methane kilotonnes as $CO_2e$ | Methane emissions intensity as % of production |
|---|---|---|---|
| Eagle Ford | 6.89 | 172.19 | 0.30 |
| Fayetteville | 5.20 | 130.03 | 0.28 |
| Haynesville | 2.50 | 62.58 | 0.14 |
| Permian | 1.68 | 41.92 | 0.23 |

### Measuring and reporting methane emissions

It's not practical to directly measure methane, so we measure throughput, which goes into our calculations. Under the USEPA *GHG Reporting Program*, GHG emissions are calculated as prescribed by the Subpart W (Petroleum and Natural Gas Systems) and Subpart C (General Stationary Fuel Combustion) GHG reporting requirements of 40 *CFR* Part 98. Few calculation methodologies require direct measurement of methane. Inputs to equations for methane emission calculations are based on measured values; for example, fuel volume, production volumes and equipment counts.

### Low-bleed control valves

We have replaced 100 per cent of the high-bleed pneumatic control valves with low-bleed control valves that emit significantly less methane during operation at all of our well sites in each shale play.

### Methane reduction awareness

BHP is a founding member of ONE Future, described above. ONE Future is cooperating in a work program with the National Energy Technology Laboratory that includes the assessment of greenhouse gas emissions and performance-based emissions management practices, including leak detection and repair efforts to reduce the greenhouse gas burdens across the natural gas value chain. The goal is to increase the awareness of ONE Future coalition achievements, quantitatively benchmark the value and opportunity for greater methane reduction with industry wide adoption, and increase awareness of methane reduction activities underway and necessary to meet the US policy objectives.

### GHG reduction targets and incentives

As a global organisation operating in an energy intensive industry, we recognise our responsibility to constructively engage on climate change issues and actively manage the associated risks. We are committed to delivering GHG emission reductions and to transparent public reporting of our GHG emissions. For example, over the past several years, we've optimised several compressor facilities in our Fayetteville operations, including shutdown and redirection of three compressor facilities into a fourth compressor facility. In FY2017, these efforts resulted in a 23,000-tonne reduction of GHG emissions, along with the $NO_x$ and other air pollutants associated with fuel combustion.

Across all our operations, we strive to continually improve our energy use and management of GHG. We identify, evaluate and implement projects that prevent or minimise GHG emissions, both in project design and equipment selection. BHP set a five-year public target to keep our absolute FY2017 GHG emissions below our FY2006 baseline levels, and we achieved our target while continuing to grow our business. Our new five-year public target for GHG is to maintain FY2022 GHG emissions at or below FY2017 levels, while we continue to grow our business.

BHP's Annual and Sustainability Reports indicate the link between remuneration to senior management and the Company's Health, Safety, Environment and Community (HSEC) performance. HSEC performance and environmental indicators are measured as a balanced scorecard within the overall annual bonus assessment. GHG is an environmental indicator and methane emissions are captured as significantly contributing to overall GHG emissions. Refer to the *BHP Annual Report 2017* and the *BHP Sustainability Report 2017* for details.

## Community impacts

In all of our shale plays, we seek to understand the social and economic environment of our host communities and to identify investment areas that will impact key quality-of-life indicators, fill gaps and develop further opportunities for community engagement and development. To achieve this, we complete social baseline studies and social impact and opportunity assessments across all of our assets every five years, and community perception surveys every three years. In addition, we engage in open and honest dialogue with our stakeholders to understand their concerns and interests, all of which informs our community engagement and social investment planning.

We develop and implement Community Reference Groups (CRGs) in each of our shale regions. These CRGs are comprised of a broad cross section of the community, ensuring key concerns and needs for the community are represented, as well as the more marginalised or vulnerable groups. The CRGs are an integral part of assessing, testing and mitigating any potential impacts our operations have on the community.

For example, communities across all our shale plays are highly dependent on the oil and gas sector, which can make them vulnerable to the often volatile economic cycles of commodity prices. In response, counties and parishes aim to strengthen their economies through business diversification and the investment of oil and gas related revenues to develop their communities into more sustainable and livable communities. BHP's social investment plan is aligned to supporting more sustainable livable communities by investing in projects that address community-identified needs, have a sustainability plan and promote positive change in quality of life. Some key projects BHP has supported include $10.6 million to develop a new YMCA facility and Red River Nature Campus in Shreveport, Louisiana. This facility is designed to address the recreational and healthy lifestyle needs identified in the area. In West Texas, food insecurity has been identified as a significant issue. As a result, we have invested $900,000 in the West Texas Food Bank to deliver a range of programs to support needy families in the region, including the development of a community kitchen, Food to Kids backpack programs and a refrigerated 18-wheeler, to collect and deliver donated produce.

### Community complaints

We address community concerns and complaints through a complaints and grievances process in each shale play, where they are acknowledged, documented, investigated, resolved and reported back to the complainant. We register and track all community complaints in our global SAP database system, allowing local concerns to be aggregated and reported upward through to Petroleum leadership and ultimately to our corporate office in Melbourne, Australia. We implement several mechanisms across all our shale plays to communicate to our stakeholders, including vulnerable and disadvantaged groups, of the complaints and grievances process. Included in that communication is a '1-800' number that goes directly to our community hot line resource desk located in Houston and a dedicated email address.

Of the complaints we receive, noise is one of the more common issues identified. When drilling and completing new wells in urban areas, we deploy 32-foot sound barriers completely around the location to mitigate noise from our drilling operations. This has the added benefit of mitigating light spill. When working in all shale areas, we routinely utilise dust suppression mechanisms. To date, we have not received, odour complaints and therefore have not found it necessary to implement odour mitigation measures. It should be noted that a high percentage of existing and future operational locations are in remote areas with limited impact on communities.

### Traffic congestion and driver training

Road safety is a key industry challenge throughout all shale plays. Due to the increased traffic on roads that were not built to sustain such heavy equipment, BHP has been actively involved with our host communities, as well as at the state level, to address the issue. In FY2016, we paid $600,000 for public road repairs in the Permian and about $100,000 in Haynesville. The majority of the work done on these roads was through private contractors. No major payments were made to public agencies.

We engage with our Local Emergency Planning Committees in all shale plays regarding traffic mitigation, especially in urban well delivery areas where our activities may impact school bus or emergency responder vehicle movements. In our urban well locations, we routinely work with the local school administration and emergency preparedness officials to consider and implement school bus routes and times when planning for drilling and completions activities. This process applies in all of our shale plays wherever we have operations in proximity of any school or inhabited building requiring logistics planning. BHP works closely with municipal leadership across our shale plays, especially the Eagle Ford and Permian, where we are currently drilling, to address county concerns and requests.

We've trained all our asset teams in a safe driving campaign as a preventative control in mitigating traffic related accidents and incidents. Driver training is required for employees and agency contractors that drive company vehicles. Vehicles are equipped to monitor driver behaviours and track the location and route of the vehicle. A driver behaviour report is generated monthly and reviewed by supervisors and managers. The feedback is also reviewed in monthly safety meetings and one-on-one with the driver. BHP's fatigue management plan regulates commute time with work hours to minimise fatigue issues. Our operations' site traffic management field plan outlines requirements for traffic on-site.

BHP does not provide training to third party contractors nor designate, prescribe or track their routes. However, vehicle safety is part of the HSE Safety Management System Audit Protocol, and third party contractors must provide a driver safety procedure through ISNet World third party database, described below.

### Management and accountability

BHP's Annual Report and Sustainability Report indicate the link between remuneration to senior management and the Company's Health, Safety, Environment and Community (HSEC) performance. HSEC performance and environmental indicators are measured as a balanced scorecard within the overall annual bonus assessment. Refer to the BHP Annual Report 2017 and Sustainability Report 2017 for details.

**Third party auditing of contractors and HSE functions**

We utilise the ISNet World third party database to collect and verify health, safety and environment statistics from our contractors and suppliers to assist in our hiring decisions.

KPMG prepared an independent assurance report of the annual Sustainability Report 2017. Refer to BHP's Sustainability Report 2017 for additional details.

**NOVs, fines and trends**

The following enforcement actions occurring between 2013 and 2015 are resolved and closed.

1. 2 January 2013 – Haynesville Shale, Elm Grove, Louisiana wells – Louisiana Department of Environmental Quality (LDEQ) – air permitting issues. LDEQ withdrew the enforcement action on 11 March 2015 for no penalty.
2. 14 June 2013 – Eagle Ford Shale, Seahawk Terminal – Texas General Land Office – discharge of oil to water. Settled for penalty of $250 paid 17 July 2013.
3. 1 July 2013 – Eagle Ford Shale, Karnes CDP – Texas Commission on Environmental Quality (TCEQ) – visible emissions from flare. Resolved in October 2013 for no penalty.
4. 20 September 2013 – Eagle Ford Shale, Hawkville Northeast CDP – Texas Commission on Environmental Quality – late reporting of emission event. Resolved via 31 October 2013 letter from TCEQ for no penalty.
5. 11 June 2014 – Eagle Ford Shale, Hawkville Northeast CDP – Texas Commission on Environmental Quality – delay in repair of storage tank. Resolved via 8 October 2014 letter from TCEQ with no penalty.
6. 22 July 2014 – Eagle Ford Shale, Black Hawk Southwest CDP – EPA Region 6 – EPA's Risk Management Program regulations. Settled for penalty of $1,000 paid on 13 October 2014.
7. 26 January 2015 – Haynesville Shale, p 20 Salt Water Disposal Well #1, Louisiana – Louisiana Department of Environmental Quality – release of produced water on 3 August 2013 and 26 January 2014. This matter was resolved by payment of a $4,305.40 penalty to LDEQ on 15 March 2016. This matter is now closed.

There was only one notice of violation during FY2016, dated 28 August 2015 from the Texas Railroad Commission concerning storm water runoff/erosion issues from the Black Hawk Southwest facility in our Eagle Ford operations. We are pursuing work on an off-site landowner's property to correct the issue.

The number of enforcement actions is trending downward over the past four years, with four in 2013, two in 2014, and only one in 2015 and 2016.