



# Environmental Review of QER Pty Ltd's Oil Shale Technology Demonstration Plant, Gladstone, Queensland

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## Executive summary

This report describes the independent verification findings by officers of the Department of Environment and Heritage Protection (EHP) of an environmental performance assessment of a pilot-scale oil shale processing facility, operated by QER Pty Ltd (QER) at its mining lease on the Stuart oil shale deposit, near Gladstone. The report verifies that QER's facility has consistently demonstrated an acceptable level of environmental performance.

In 2008, the Queensland Government responded to community concerns about the environmental impacts and land-use conflicts arising from oil shale mining and processing, by adopting a policy to restrict oil shale development in Queensland to the small-scale development of the Stuart (Gladstone) oil shale deposit. Previous processing of oil shale at Gladstone (using a different technology and operating at a much larger scale than the QER pilot facility) generated thousands of complaints from the public—with concerns including unpleasant odours, dust, toxic air emissions (dioxins) and health impacts. The 2008 government policy also required that the environmental impact of any facilities developed at Gladstone for the mining and processing of oil shale be assessed by the proponent, and that such an assessment should be independently verified by the government, within two years of commencing operation.

QER subsequently constructed and now operates an oil shale technology demonstration plant utilising a 'Paraho' vertical retort at the Gladstone site. The plant produces raw shale oil and will produce upgraded liquid fuels such as diesel and jet fuel. The facility also includes a visitor education centre to showcase the technology and its products. In September 2012, QER produced a report for the Queensland Government inter-departmental working group which addressed oil shale issues and outlined the current environmental performance of the demonstration plant.

Officers from EHP inspected QER's facility in October 2012 and reviewed the associated environmental monitoring records in order to evaluate and verify the plant's environmental performance. The review covered aspects of water releases, air emissions, odour, dioxins, waste management, rehabilitation, resource utilisation, greenhouse gases, general housekeeping, noise management and community support. Comparisons have been made in this report with the environmental performance of technology used by the previous oil shale processing plant at the site, environmental authority condition requirements and best practice environmental management. The report shows much better environmental performance by the new technology employed by QER when compared to that of the previous processing plant.

Greenhouse gas intensity of oil shale production had been a significant issue of concern for some members of the community in respect of the previous oil shale plant. QER is monitoring greenhouse gas production and researching possible greenhouse gas minimisation measures for scaled-up versions of the plant, with a focus on increased energy efficiencies.

This environmental review identifies the environmental issues successfully resolved by QER. It also identifies issues relevant to any future expansion of oil shale processing at Stuart. It concludes that QER's environmental performance is much better than that observed for the previous technology and proposes that any future expansion of the Stuart oil shale deposit could be dealt with adequately using current environmental impact assessment and approval processes.

Key factors contributing to QER plant's sound environmental performance are identified, and provide suggested benchmarks for assessing any future oil shale proposals by other operators. The findings are also used to develop lessons for environmental management of other oil shale developments to promote environmentally and socially sustainable development. Caveats of the review are also outlined.

# 1. Introduction

This report describes the findings of a verification assessment conducted by EHP of environmental performance of oil shale processing carried out by QER at its mining lease on the Stuart oil shale deposit near Gladstone. The findings are used to develop lessons for the future management of oil shale development, in order to promote environmentally and socially sustainable development of the sector.

## 1.1 Queensland Government 2008 decision on oil shale

In 2008, the Queensland Government noted that there were multiple companies in Queensland investing in alternative fuels projects. These projects could enable Queensland to become a major producer of non-conventional oil which could help meet the national oil demand and lead to the production of oil for export. It also noted that Queensland had 94% of Australia's known oil shale resources.

At that time, the government gave consideration to several potential environmental concerns related to the development of oil shale, including:

- the location of large-scale mining activity in sensitive coastal environments
- the substantial potential water and energy requirements of the sector
- air and waste emissions from oil production plants
- implications for climate change
- socio-economic impacts arising from the location of large-scale industrial development in regional communities, as well as near important tourist destinations.

In 2008 the government also noted significant potential land-use conflicts between what it saw as currently or potentially high-value land-uses that it considered to be incompatible with the development of underlying oil shale resources. These conflicts were considered to be particularly pronounced in the Proserpine Whitsunday Coast Region where the McFarlane deposit is located. Based on those considerations, in relation to the development of the McFarlane (Proserpine) deposit, the government decided to impose a 20 year moratorium on exploration, mining, processing and any preparatory activities for mining of oil shale in that region.

In relation to the Stuart (Gladstone) oil shale deposit, in the 2008 the government decided that:

1. existing entitlements under a granted mining lease and granted mineral development licences should be allowed to remain, subject to appropriate assessment and the issue of environmental authorities, under the *Environmental Protection Act 1994*
2. new tenures under the *Mineral Resources Act 1989* and variation of existing entitlements would only be granted within the Stuart area if necessary to allow a proponent to demonstrate the technical and commercial viability of processing and extraction technologies
3. in the event that facilities be developed for the sampling and processing of oil shale at Stuart (Gladstone) under ML80003, the impact of those facilities will be assessed by the proponent with independent verification by government within 2 years of commencing operation, taking into account:
  - a. the effectiveness of the technology
  - b. the impact of the processing facility on the environment and the local community
  - c. the appropriateness of oil shale as part of the fuel and energy cycle.

## 1.2 What is oil shale?

The 2010 Survey of Energy Resources by the World Energy Council estimated there to be some 4.8 trillion barrels of in-place oil shale resources in the world. The largest deposit identified was in the western United States of America (3 trillion barrels), with important deposits in China, the Russian Federation, the Democratic Republic of the Congo, Brazil, Italy, Morocco, Jordan and Estonia, as well as in Australia (Carson 2011). In 2010, only Estonia, China and Brazil produced shale oil. In each case, this was on a very small scale in relation to conventional oil production.

Oil shale is a sedimentary rock containing solid organic material that converts into a type of crude oil when it is heated. It is a fine-grained, sedimentary, hydrocarbon-bearing rock that occurs in many countries worldwide. It generally occurs at shallower (<1000 metres) depths than the deeper and hotter geologic settings required to form liquid oil. The organic matter/hydrocarbon mineral in the oil shale is called kerogen.

Oil shale is essentially a petroleum source rock which has not undergone the complete thermal maturation required to convert organic matter to oil. In addition, the further geological processes of hydrocarbon migration and accumulation which produce conventional crude oil resources trapped in subsurface reservoirs has not occurred (Geoscience Australia 2012).

There are three main types of oil shale based on their origins; terrestrial (organic origins similar to coal-forming swamps), lacustrine (organic origins from fresh or brackish water algae), and marine (organic origins from salt water life including algae and dinoflagellates). The United States Geological Survey defines oil shale as 'organic-rich shale that yields substantial quantities of oil by conventional methods of destructive distillation of the contained organic matter, which employ low confining pressures in a closed retort system' (Duncan and Swanson, 1965). They further define a minimum grade of 3.8% oil by weight.

Oil shale can be transformed into liquid hydrocarbons by mining, crushing, heating, processing and refining, or by in-situ heating, oil extraction and refining. One tonne of commercial grade oil shale may yield from 50 to 200 litres of oil. In terms of oil barrels, this equates to an approximate a third to one barrel of oil shale per tonne of oil shale (see Plate 1).

Note that oil shale is not the same as oil-bearing shales. Oil bearing shales are shale deposits containing already formed petroleum, also referred to as shale oil or tight oil, that is sometimes extracted from drilled wells using the same hydraulic fracturing (fracking) technology used in coal seam gas production. QER's retorting technology does not require the use of hydraulic fracturing processes, instead extraction is undertaken using conventional open cut mining techniques.



**Plate 1: Specimen of Oil Shale from Stuart deposit Gladstone. This rock weighs 31.25 kg and contains 4 litres of oil (courtesy QER)**

### **1.3 Where is oil shale found in Queensland?**

Geoscience Australia (2012) identified a total Australian oil shale resource of equivalent to 22 billion barrels of oil. Queensland was seen to have over 90% of that resource. Most of the deposits with commercial potential are located in central Queensland, between Proserpine and Bundaberg, is as shown in Figure 1.

In these areas, the main deposits are the Stuart, Rundle and McFarlane resources located near Gladstone and Mackay. These are lacustrine deposits, meaning they are fresh water in origin. Lesser oil shale deposits of varying quality are also found in New South Wales, Tasmania, and Western Australia in sedimentary deposits of Permian, Cretaceous and Cenozoic age (Geoscience Australia 2012).

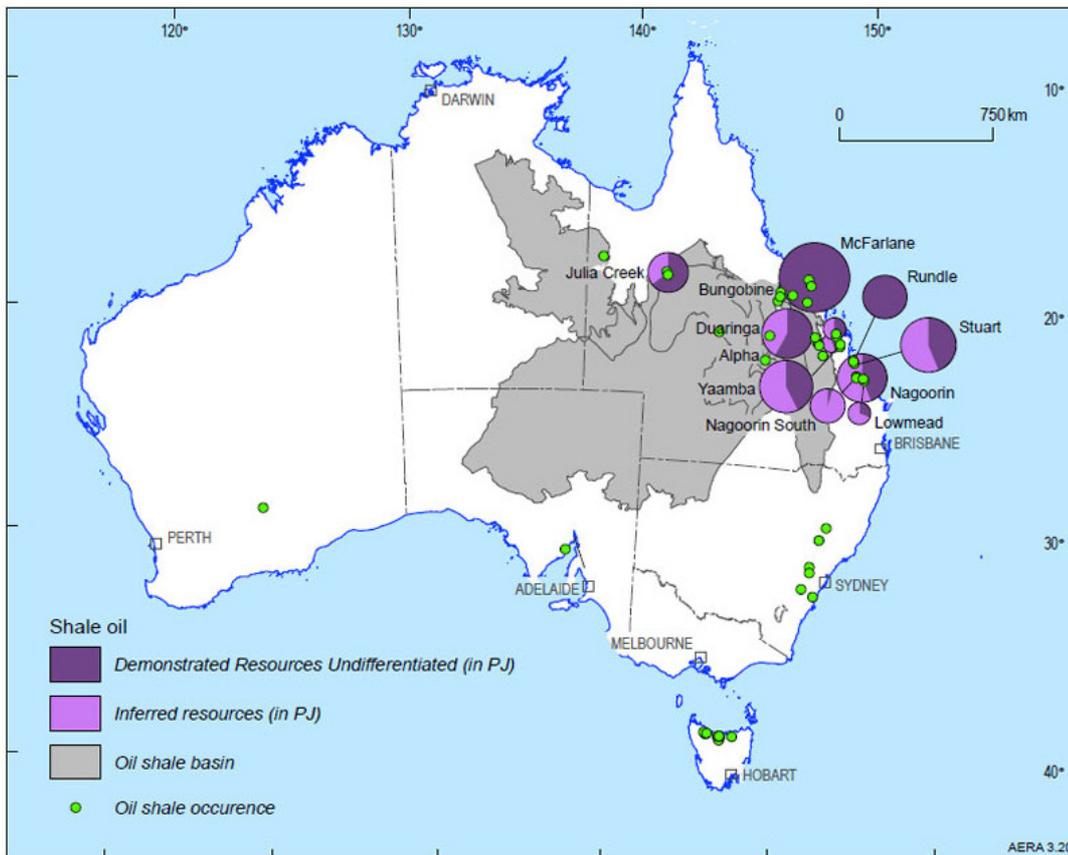


Figure 1: Oil shale resources in Australia (Source: Geoscience Australia, 2012)

### 1.4 What are the main oil shale extraction and processing technologies?

Hydrocarbons in oil shale are present in the form of solid materials and hence cannot be pumped directly out of the geologic reservoir. The rock must typically be heated to a moderate temperature to release the oil, which must be separated and collected. The heating process is called retorting (Rand 2005).

There are several oil shale processing technologies, each of which rely on a process known as 'pyrolysis', a form of treatment that chemically decomposes organic materials by heat in the absence of oxygen. These technologies may be classified in different ways, such as by: particle size; method of heating the shale; the nature of the heat carrier; and the location where pyrolysis occurs.

The location where heating and pyrolysis process occurs is the simplest way of classifying technology types. This division also reflects differing environmental issues. When contrasting technology by site of oil extraction, oil shale processing techniques fall broadly into two main classes, surface processing and in-situ processing. In the former, the oil shale is mined and brought to the surface for processing. In-situ processing leaves the shale in the ground and uses a variety of techniques to extract the petroleum product.

#### Above ground processing

Above ground processing involves 3 major steps: (1) oil shale mining and ore preparation, (2) pyrolysis of oil shale in a retort vessel to produce shale derived oil, and (3) processing shale derived oil to produce oil refinery feedstock, certified fuels in their own right and high-value chemicals. This is shown in Figure 2.

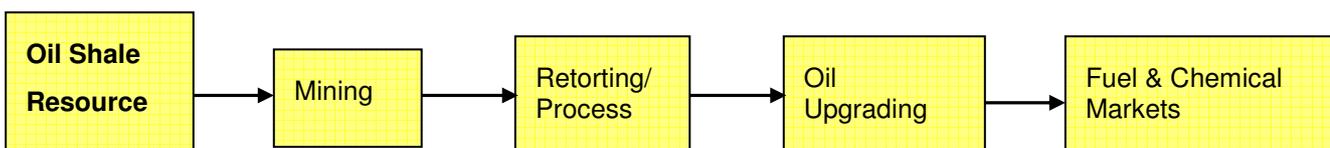


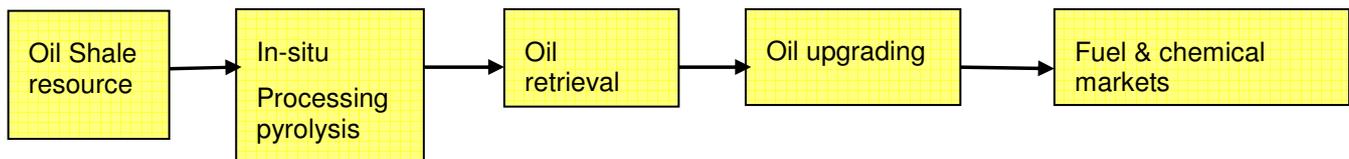
Figure 2: Generalised flowchart for above ground oil shale processing

The now defunct Southern Pacific Petroleum's Alberta Taciuk Processor (ATP) and QER's Paraho technology are examples of above ground processing that have been used in Queensland.

Mining to retrieve the resource can be either by surface mining or by underground mining. Open pit mining is usually preferred, on economic and safety grounds, where the depth of the target resource is not excessive to access by removing overburden. Overburden removal may require blasting in some cases due to the physical properties of the material but has not been necessary at the Gladstone Stuart deposit.

### In-situ processing

The other alternative to surface retorting is producing shale oil underground using in-situ technology. This is favoured for deeper, thicker deposits, not as amenable to surface or deep-mining methods. The main steps for underground in-situ processing are shown in Figure 3. This form of processing is being currently trialled in the United States. This process has the advantage of minimising, or in the case of true in-situ, eliminating the need for mining and surface pyrolysis. It does this by heating the oil shale resource in its natural depositional setting.



**Figure 3: Generalised flowchart for true in-situ oil shale processing**

In-situ processing can be as simple as turning the oil shale deposit to rubble and setting it alight, or it can involve quite complex processes. The simplest form is in-situ retorting which involves heating oil shale in place, extracting the resulting liquid petroleum product from the ground, and transporting it to an upgrading facility.

Shell (2006) contrasts its 'in-situ conversion process' (ICP) with other in-situ processes that rely on air or oxygen injection and require that relatively high permeability exist in the deposit or be created through hydraulic fracturing. Once the target deposit is fractured, air is injected, the deposit is ignited to heat the formation, and the resulting shale oil is moved through natural or man-made fractures to production holes that transport it to the surface.

Stated disadvantages of that process include difficulties in controlling the pyrolysis temperature and the flow of produced oil, resulting in poor oil and gas quality combined with low oil recovery efficiency because portions of the deposit are left unheated.

Shell's more complex ICP process involves blocking off sections of an oil shale deposit using freeze walls, heating the oil shale via conduction which releases the shale oil and oil shale gas from the rock whereby it can be pumped to the surface and further processed into fuels.

### Oil shale as a solid fuel

There are also cases in which oil shale is burned directly as a fuel without processing being undertaken to create petroleum liquids. This has been a common practice in Estonia where unprocessed oil shale is burned as boiler fuel for electric power plants.

### Other novel technologies

This review has briefly outlined the more common methods of oil shale processing which involve retorting. Other novel technologies, such as solvent extraction, are possibilities but are beyond the scope of this report. One example is the Rendall Process mooted by Blue Ensign Technologies Limited for Queensland's Julia Creek oil shale resource.

## 1.5 Role of the Department of Environment and Heritage Protection in oil shale mining and processing

EHP is primarily involved in management of oil shale activities through its role as the 'administering authority' for the *Environmental Protection Act 1994* (EP Act). This act imposes a 'general environmental duty', requiring all persons engaged in any conduct in Queensland, or outside of the state that may affect Queensland's environment, to undertake their activities using all reasonable and practicable means to avoid or minimise environmental harm.

The act also creates a requirement for persons engaged in mining activities and petroleum and gas refining activities, such as oil shale mining and shale oil production, to obtain an 'environmental authority' (EA—sometimes referred to as a licence) from EHP under the EP Act. The environmental authority sets out: the operating conditions to be met to reduce the likelihood of causing environmental harm; financial assurance requirements; and rehabilitation targets. Important environmental performance issues addressed in the environmental authority include:

- air, dust and odour emissions
- groundwater protection
- management of potentially acid forming materials
- stormwater releases
- wastewater treatment
- mining and oil processing wastes
- noise management
- mining voids
- environmental monitoring.

EHP is responsible for enforcing compliance with the authority.

## 1.6 Objective of this report

This report follows on from the 2008 government decision on oil shale development in Queensland. The holder of the relevant mining lease, exploration permit for minerals and mineral development licences for the Stuart resource, QER, has developed facilities for the sampling and processing of oil shale at Stuart (Gladstone), under ML80003. They have undertaken monitoring and reporting of the impact of those facilities on the community and environment. This has involved the construction and operation of a technology demonstration plant (TD Plant) using Paraho II retorting technology and a visitor centre at its Yarwun site, and the submission of an assessment report to the Queensland Government (QER 2012).

The 2008 decision required government verification of the proponent's assessment of the impacts of the oil shale processing facility, taking into account, inter alia, the effectiveness of the technology and the impact of the processing facility on the environment and the local community.

As part of this verification, EHP staff conducted an inspection of the QER's TD plant on 23-24 October 2012, including collection of relevant environmental monitoring data for review. The broad objectives of the site inspection of the QER TD Plant were to:

- gather information required for verifying the performance of QER's TD plant, and impacts on the environment and community
- inspect the plant in operating condition and verify that all major emissions & waste outputs are monitored and fugitive emissions are minimised
- ascertain whether the significant environmental issues that arose with operation of the previous oil shale processing plant (the ATP operated by SPP) have been resolved with the new processing technology
- assess the level of compliance with the statutory requirements relating to the management of air, water, waste, and noise as specified in the environmental authority (EA) conditions
- ensure that environmental monitoring is conducted in accordance with QA/QC requirements of the monitoring methods
- assess the operation of pollution control equipment to ensure that these mitigation measures are available and effective.

The objective of this report is to detail the findings of this assessment so as to independently verify the QER (2012) impact assessment conclusions, and to facilitate informed development of any future policy on environmental management of oil shale developments.

## 2. Previous experience with oil shale processing at Gladstone

The previous holder of the Stuart oil shale tenements, Southern Pacific Petroleum (SPP) and its partner Suncor Energy, also constructed a research and development oil shale processing plant at Gladstone. SPP's plant was much larger and used different technology to that currently used by QER. It operated from 1999 to 2004, producing more than 1.5 million barrels of oil. QER purchased most of the assets of SPP and its associated companies in 2004 and subsequently decommissioned and removed the retort, dryer, oil recovery plant and much of the ancillary equipment, before installing its own facility.

SPP's oil shale processing plant caused multiple environmental problems, which created a legacy of public distrust in oil shale development, particularly in sensitive coastal environments and near urban areas. Concerns about the environmental impacts of oil shale processing were a significant factor in the former government's 2008 policy decision to place restrictions on oil shale development in Queensland

This section describes the technology used by SPP and the environmental problems that arose, to enable comparison with the environmental performance of the technology being used in QER's demonstration plant.

### 2.1 Southern Pacific Petroleum's (SPP) processing technology – the Alberta Taciuk Processor (ATP)

SPP employed Alberta Taciuk Processor (ATP) technology to extract oil from the oil shale. A schematic of the ATP processor is provided in Figure 4.

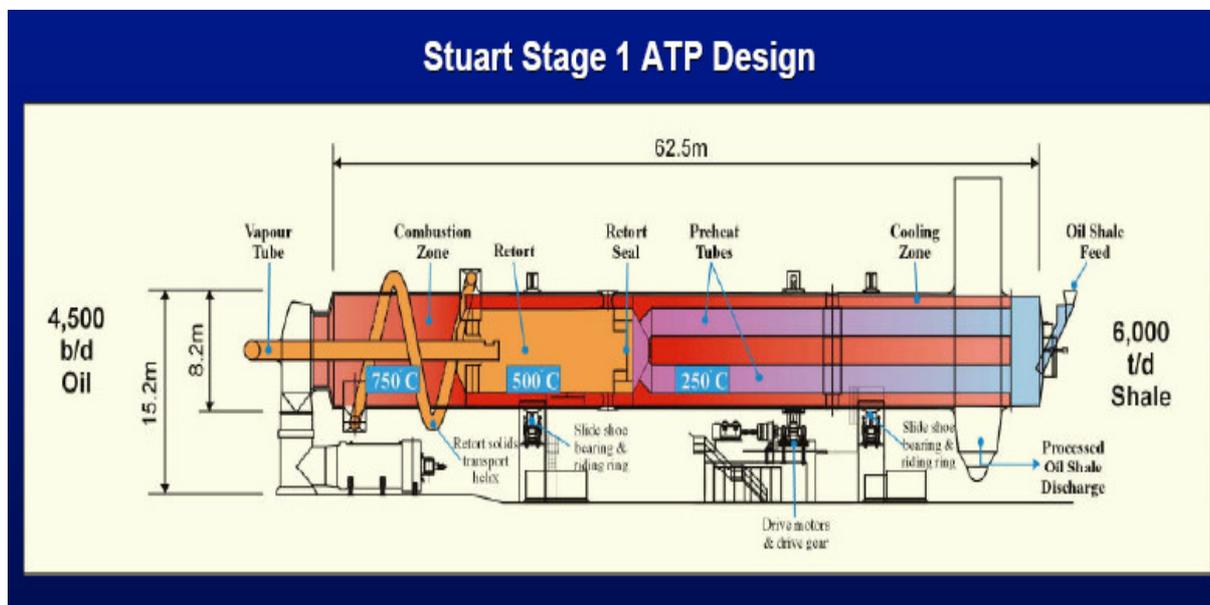


Figure 4: Schematic of Southern Pacific Petroleum's ATP processor.

The ATP operated by SPP was a horizontal rotary kiln with three separate compartments. Dried shale (supplied from a rotary dryer) was fed into the preheat zone to further dry the shale to the required moisture content. This drove off odorous 'preheat steam'. In the second stage, shale was heated to 500 °C in the retort zone in the absence of oxygen, which caused pyrolysis. Oil vapours were driven out via the vapour tube to be cleaned, upgraded and refined.

Solids passed from the retort to the combustion chamber where air was introduced to burn residual carbon, providing heat to drive the process. These hot solids were then passed back via a helix into the outer sections of the ATP where they move backwards exchanging heat with the retort and preheat zone prior to discharge near the entrance end of the ATP. Combustion emissions passed to the main stack via turbo-scrubbers to reduce particulate, sulphur dioxide and odour emissions.

## 2.2 Environmental problems experienced with SPP's processing facility

The ATP oil shale processing facility operated by SPP experienced a number of significant environmental problems. These are discussed below.

### Dioxins

Dioxins are members of a group of chemicals known as 'persistent organic pollutants' (POPs), the production and use of which was banned by the Stockholm Convention 2001. This is an international environmental treaty that Australia has signed and ratified that commits governments to reducing, and where feasible, eliminating the production and environmental releases of POPs.

During the early years of operation of the ATP plant, significant concentrations of polychlorinated dioxins and polychlorinated dibenzofurans (known collectively as dioxins) were detected in air emissions and the processed shale (Suncor Energy 2000) waste. At that time, predictions about the large amounts of waste processed shale likely to be generated from the ATP plant, together with the relatively high dioxin concentrations found in the waste, led to some predictions that the SPP oil shale facility would become Australia's largest source of and repository for dioxins (Suncor Energy 2000). Misgivings were also expressed about the potential impacts of dioxin releases on the Great Barrier World Heritage Area (Greenpeace, 2001).

SPP investigated dioxin formation in its ATP plant and introduced process changes (including altered atmospheric chemistry in the ATP and more efficient turbo-scrubbing to reduce air emission particulate levels) in an effort to resolve this issue. The environmental authority conditions at that time prohibited placement of the waste processed shale in the mining void, instead requiring the waste processed shale to be kept in a secure landfill type situation. These requirements remain in QER's current environmental authority as it manages this waste repository.

### Sterilisation of oil shale reserves

In its environmental impact statement (EIS) for the Stage 2 expansion of the mine and processing plant, SPP proposed to excavate down to the rich Kerosene Creek Member (layer) while leaving deeper oil shale sequences untouched. The EIS also proposed placing the waste processed shale (which as noted above had been found to contain high levels of dioxins) above these important deeper resources.

Given the likely groundwater connection between the mining voids and Port Curtis, and the desirability of not disturbing any repository for persistent organic pollutants, this waste management approach would very likely have sterilised significant underlying state oil shale resources and prevented future commercial extraction. This was a key consideration of the government during the evaluation of SPP's EIS for Stage 2 of the Stuart Oil Project.

### Hazardous air emissions

Given the emissions profile and nature of odours emitted from the plant, concerns were expressed to the government that the ATP plant posed a health risk to the community. Concerns centred on hazardous air pollutants such as dioxins (as discussed above), hexavalent chromium, reduced sulphur compounds and polycyclic aromatic hydrocarbons (PAH).

The government commissioned an independent Health Risk Assessment (HRA) report by the consultants, Toxikos, which was overseen by the Stuart Facilitation Working Group comprising technical and community members. The HRA report concluded that no acute or chronic health risks could be identified as a result of exposure to air emissions from the Stuart Oil Project.

However, the HRA report also concluded that some community members living near the oil shale facility would smell odours from the plant during its normal operations, and that intense, unpleasant odour would be experienced occasionally. The HRA report further concluded that a single compound, thiophene, was primarily responsible for the odour. The HRA recognised that, while not representing an acute or chronic health risk, the offensive odours emanating from the SPP plant may impact detrimentally on the health and well being of local community members.

### Noxious and offensive odours

Over two thousand public complaints were received over the several years of the ATP plant operation, particularly from the township of Targinnie but also from Gladstone, Yarwun and other industrial facilities in the Gladstone development area. Most of these concerned offensive odours. The complaint total increases in significance when one considers that the plant did not run continually over this period, but was operated for a series of campaigns.

The offensive odours produced varied in strength depending upon meteorology, dryer operations, stability of the drying and retorting processes and the less-than-perfect operational availability of air pollution control technology. Some residents complained that the odours causing tingling mucous membranes, nose bleeds, nausea and headaches. The most important odour sources were found to be the shale dryer and the preheat zone steam. Emissions from the dryer were treated to remove particulates (dust) but not odour. In addition, particulate removal did not employ best practice methods—relying solely on the use of cyclones.

The administering authority acted to reduce odorous emissions from the dryer by placing limits on its operating temperature. This approach reduced premature pyrolysis due to shale fines charring in the dryer and hence the generation of odours. However, this also restricted plant throughput and oil production. In addition, the odorous preheat steam from the ATP processor was directed to a burner at the base of the stack. This raised stack gas temperature and increased plume buoyancy as an aid to air pollutant dispersion. The burner provided some reduction in odorous emissions but also impacted on production by tripping gas safety equipment. These problems were particularly relevant in plant upset conditions when odour control was more critical.

Turbo scrubbers, were also retrofitted for the removal of sulphur dioxide and particulates from the ATP flue gas, to reduce odour concentrations. However despite very large reductions, the end result was that odour emissions were still averaging tens of thousands of odour units and the plant was still causing complaints. By contrast, no odour complaints have been received about the current QER Paraho facility and stack odour concentrations are significantly lower (see section 5.3).

### Dust nuisance

The ATP processor was designed to process fine feed-stock. The shale feed was initially around 10 mm in diameter, with further crumbling of the material as it progressed through the dryer, the ATP processor and processed shale handling equipment. The resultant waste processed shale was black, fine grained and relatively easily picked up by wind or vehicles. This led to many complaints about dust nuisance from the ATP plant. In the event of plant upsets or problems with the processed shale handling equipment, fugitive emissions of dust from the plant became a significant problem (see Plate 2). This contrasts markedly with Plate 3, showing the absence of nuisance dust emissions from QER's facility during 2012.

SPP c.2000



**Plate 2: Dust emissions from SPP Plant with processed shale handling issues evident.**

QER 2012



**Plate 3: 2012 Daytime operation of QER plant showing dust free retorting and process shale handling. Note lack of black dust.**

### Water pollution concerns

Several incidents occurred at the ATP plant, resulting in a breach of the EA's water release conditions. Issues included excessive amounts of suspended solids in the mine water discharge and (on one occasion) high ammonia concentrations in the release from the processing plant area. The ammonia was generated by the scrubbing of nitrogen from the aquatic component of the product liquid and the release was caused by a failure to adequately contain flare seal water.

The EIS for the Stage 1 operation of the ATP plant included provision for process wastewater treatment, via steam stripping, followed by biological treatment in a water treatment cell. Commitments to water treatment were included in the environmental management overview strategy for the operation and conditions for granting the mining lease. However, SPP was unable to successfully operate the water treatment cell and abandoned such treatment. Stripped sour water was instead diluted with clean water prior to moistening waste processed shale. The EA prohibited the disposal of sour water in the mine pit.

### **Excessive noise emissions**

The operation of SPP's ATP plant generated many noise complaints from local residents, many of whom complained of excessive noise and sleep disturbance. The major concern was low frequency noise identified as resonance created by gas flows through the large main stack. Noise from the ATP plant was also identified in the above-mentioned HRA report as having the potential to cause annoyance—particularly at night and during adverse weather conditions.

### **Plant upsets**

The ATP plant experienced a range of plant upset operating conditions. With experience, SPP was able to significantly reduce frequency of upset conditions. However, a key issue during upset conditions was the need to remove hot shale from the ATP and to replace it with cool inert material. Hot semi-processed shale could not be left in the processor unless it was rotating as that could have caused structural damage to the plant through warping. Problems with the processed shale handling circuit, such as clogging and failure of cyclones, led to multiple incidents involving large-scale dust emissions.

### **Greenhouse gas emissions**

Heating oil shale for retorting, whether aboveground or in-situ, requires significant energy inputs. This energy is typically sourced by burning fossil fuels, either product gas from retorting or external sources such as natural gas. Consequently, the production of petroleum products derived from oil shale is generally expected to involve greater emissions of the greenhouse gas carbon dioxide, compared with conventional crude oil production and refining. Additional carbon dioxide is produced by the high temperatures typical of surface retorting. Carbon dioxide is also emitted from thermal decomposition of the mineral carbonates contained in oil shale, commensurate with the amount of carbonate present.

Although greenhouse gas emissions were not conditioned specifically in SPP's environmental authority, they were raised as a significant issue by the environmental groups that campaigned against the industry, including agitating for product bans. Management of greenhouse gases was an important consideration in the EIS produced for SPP's proposed Stuart Oil Shale Stage 2 proposal. Greenhouse gas emissions are seen as one of the major environmental challenges for the oil shale industry in the United States. However to promote fair comparison, this is viewed on a life cycle approach with net carbon emissions desired to be equal to or less than conventional petroleum. This is the so called 'wells to wheels' comparison (Intek 2010).

### **Social impact**

SPP's operation of the ATP had a significant impact on the local community. As already noted, over two thousand complaints were received during the operational life of the plant, from residents in nearby townships and from the broader Gladstone area. Apart from the detrimental impacts on local amenity, residents also expressed concerns about the negative impacts of the ATP plant on property values.

This created a legacy of a broad community-wide distrust of oil shale development in the Gladstone area. This legacy has heightened the need for the oil shale industry to seek to adopt best practice environmental management and to communicate openly with the community about its environmental performance. As discussed later in this report, the need for such an approach has been embraced by QER as part of its 'social licence' to operate.

### 3. QER's Technology Demonstration Plant and data collection program

#### 3.1 Description of Technology Demonstration Plant

Key elements of QER's technology demonstration plant operation are:

- an open cut mine and run-of-mine (ROM) stockpile
- a feed preparation plant where ROM shale is crushed to make lump shale feed
- a briquetting plant where shale fines screened out at the feed preparation plant are moulded into briquettes
- a prepared shale stockpile, with reclaim via front end loader
- a dryer to dry the feed shale and briquettes to retort design moisture content
- the oil shale retort (Paraho II processor) and ancillary equipment
- flue gas treatment facilities for the Paraho and dryer flue gases, including bag-houses and thermal oxidisers
- processed shale moistening and transfer facilities
- oil recovery section including scrubber and electrostatic precipitator
- sour water steam stripping plant
- oil upgrading facilities including distillation and hydro-treater
- oil product storage tanks and load-out facility
- processed shale handling and disposal
- emergency gas flare
- associated utilities including natural gas burners, compressors
- support services including offices, plant control room, sewage treatment, warehouse and laboratory
- a visitor information centre.

A schematic of the overall plant which integrates drying, retorting and fuel upgrading is shown at Figure 5.

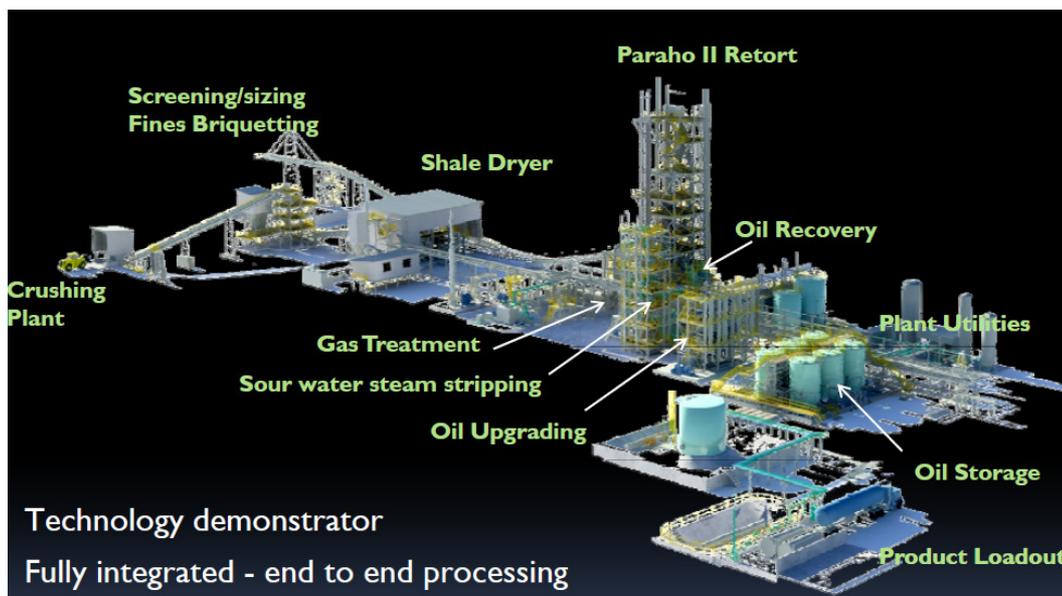


Figure 5: Schematic showing elements of QER's integrated technology demonstration plant.

At the heart of the operation is the Paraho II processor. The Paraho is a stationary vertical kiln which is fed raw shale from the top. The speed through the retort is governed by the rate at which solids are withdrawn at the bottom. There are three gas inlets or so called distributors to the retort. Oil vapours generated when the shale is heated move towards the top of the retort, where they are extracted via two vapour ducts.

The major environmental management areas for QER's oil shale feed preparation activities include:

- controlling dust during crushing, screening
- loading of shale onto conveyors and transferring to feed bins
- preventing premature pyrolysis or overheating of oil shale during drying, so as to minimise odorous emissions
- managing dryer air emissions, including the products of combustion (NO<sub>x</sub>, particulates, CO, SO<sub>2</sub>, odour and organic compounds e.g. VOC)
- ensuring effective cleaning of dryer flue gases
- minimising noise emissions from the burner, materials conveyors and bag-house cleaning equipment.

The dryer at the QER site is served by covered conveyors and a dust extraction system (bag-house) to minimise dust from material transfer. The dryer emissions are treated in a bag-house and regenerative thermal oxidiser. Odour generation is prevented and premature pyrolysis avoided by applying lower dryer operating temperatures in the belt dryer, compared to those for SPP's rotary dryer. This creates a more even and lower internal temperature profile than that for the rotary kiln used by SPP. A continuous emissions monitoring system (CEMS) measures the quality of air emissions from the dryer. After drying, the raw shale is carried to the top of the Paraho II retort for processing.

### 3.2 QER's data acquisition, monitoring and testing program

Key environmental monitoring programs undertaken by QER to characterise emissions, wastes and understand the oil production processes included programs at Rifle, Colorado, in the USA and at Gladstone in Queensland.

#### Monitoring and Testing at the Colorado Pilot Plant 2005 – 07

Monitoring and testing at the Paraho test facility at Rifle Colorado involved:

- bulk sampling from 3 locations to obtain a range of Queensland shales for testing
- shipment of the Queensland shales to the USA for processing at the Paraho pilot plant in Colorado
- detailed characterisation of the retort product gas stream—iso-kinetic testing was undertaken prior to thermal oxidation to thoroughly characterise the gases produced for each shale type (Stuart, Stuart North and McFarlane) and under each retort operating mode (heating, combustion and combined mode). A minimum of 6 samples per scenario were collected resulting in a total of over 50 iso-kinetic sample runs. A broad range of parameters (e.g. organics including PCDD/F, inorganics, metals, potentially odorous S based compounds, priority pollutants etc.) were all measured
- sour water characterisation—consistent with the approach taken for retort product gas sampling, sour water samples were collected during a broad range of operating scenarios (all combinations of shale type and retort operating mode) and the samples were analysed for a broad range of analytes.
- processed shale samples, generated under all shale type and operating mode scenarios, were collected and shipped back to Australia for further analysis. Some bulk sour water samples were also shipped back
- CSIRO was engaged to construct and operate a bench scale, 2-stage sour water stripping plant. This facility stripped the bulk sour water samples, thereby generating stripped sour water intended to be representative of stripped sour water from a larger scale plant
- leachate trials—an extensive leachate test program was undertaken to characterise processed shale generated at the Colorado pilot plant and also to characterise leachate quality using kinetic leach columns. This program also included a range of kinetic leaching column tests on mine wastes obtained predominantly from drill core sourced at QER's Stuart deposit. The environmental geochemical characterisation program, to date, has generated approximately 80,000 analytical results over some 5 years. This level of geochemical characterisation for a mining project, which is still at the conceptual stage is (according to QER) unprecedented in Australia and highlights QER's commitment to understanding and effectively managing the risks associated with the project

- a peer review was also undertaken and comprehensive quality assurance protocols applied for the geochemistry/leachate program.

## **Monitoring at the Gladstone Technology Demonstration Plant during 2011–12**

The following list details monitoring conducted at QER's Technology Demonstration (TD) Plant at Gladstone during 2011–12:

- Process variables—a vast array of process variables (~1000) are measured and logged continuously at QER's Technology Demonstration Plant.
- A stack testing program is carried out monthly and measures a broad range of parameters at the 2 main Technology Demonstration Plant stacks (i.e. at the plant thermal oxidiser (TOx) and dryer regenerative thermal oxidiser (RTOx) stack).
- Continuous monitoring of SO<sub>2</sub>, NO<sub>x</sub> and particulates is undertaken at the plant TOx and dryer RTOx stacks. All results are logged.
- Water releases from site are monitored frequently (minimum weekly) during discharge events, however the frequency of discharge occurrences is low. Since retort commissioning and operations commenced in September 2011, stormwater runoff has been mostly contained and re-used on site. A single discharge event (56ML) occurred in April 2012 due to a period of heavy rainfall in the Gladstone region. Several samples were collected at the point of release and subsequently analysed.
- Characterisation of sour water, stripped sour water and processed shale has commenced and will continue during technology demonstration plant operations. The program will monitor a broad range of parameters. This work is intended to complement results from the abovementioned leachate test program. QER undertakes a broad groundwater monitoring program including compliance bores and regional bore monitoring. An extensive stream gauging network, spanning 5 regional creeks and gullies, has been operational for several years. In addition to the stream flow data delivered by the stream gauging program, water quality determinations are also undertaken at regional sampling locations during flow events.
- QER has contributed equipment to regional air monitoring stations used in Gladstone and Targinnie in the past, and has recently confirmed agreement to contribute to the Queensland Government's Gladstone region ambient air monitoring program for the next 3 years. This will ensure that adequate ambient monitoring services, and real time data, are readily available to Gladstone and Targinnie communities, and also available to regulators and industry proponents via a publically accessible web page.
- QER is a founding member and continuing participant in the Port Curtis Integrated Monitoring Program (PCIMP) which monitors waters in Port Curtis. In mid-2012, the Premier announced that a partnership agreement would be established to ensure the ongoing monitoring and improvement of Gladstone Harbour. The Gladstone Healthy Harbour Partnership will include representatives from government, industry, research, community and other interests. QER has committed to being actively engaged in the planning and scoping phase of this partnership.
- Further detail on the test work carried out at the Gladstone is program is provided in Table 1.

**Table 1: Sampling and Analysis Program at the Gladstone Technology Demonstration Plant**

Stream sampled	Frequency	Analysis	Remarks
Feed shale (composites)	Collected automatically over 12 hours	MFA assay (% oil, % loss + gas, % retort water) Free moisture  Ultimate analysis	Establishes grade in LTOM  Selected full yield windows (C, organic C, H, N, S, O and ash)
Feed shale (grab samples)	6 hours	MFA assay Free moisture Ultimate analysis Particle size distribution	As above Used for retort balances Selected full yield windows
Processed shale (grab samples)	6 hours	MFA assay Ultimate analysis Particle size distribution % moisture	Selected full yield windows Final moisture to confirm processed shale wetting with SSW
Briquettes	As required	Tests for compressive strength and drop shatter resistance	To confirm the ability of briquettes to withstand shale feed transfers to retort
Product oil	At end of each run	% H <sub>2</sub> O Sediment Density (SG) Pour point Full analysis Simulated distillation	Selected full yield windows, including C, H, N, S, O
Centrifuge clean oil	As required	Solids in clean oil	To confirm performance of centrifuge
Retort off-gas	Selected runs	Oil mist particle size distribution	
Recycle gas	Online GC, frequency as required e.g. 2-4 hours	Primary components by online gas chromatography Detection tube estimations	N <sub>2</sub> , H <sub>2</sub> , CO, CO <sub>2</sub> , C1, C2, C3, C4, C5+, H <sub>2</sub> S  H <sub>2</sub> S, NH <sub>3</sub> , SO <sub>2</sub>
Recycle gas	As required (e.g. daily)	S and N compounds by gas sampling for analysis on lab GC	H <sub>2</sub> S, NH <sub>3</sub> , SO <sub>2</sub>
Recycle gas	Continuous	Oxygen	

Stream sampled	Frequency	Analysis	Remarks
Recycle gas	Selected runs	Gas samples taken off-site for full fuel and sulphur species (various laboratories))	N <sub>2</sub> , H <sub>2</sub> , CO, CO <sub>2</sub> , and full hydrocarbon analysis to C13+ Full sulphur speciation, including organic and inorganic compounds Other trace compounds
Product gas	Selected runs	Full sampling on-site and analysis by offsite laboratories and/or onsite mobile laboratory (note this will be done on design basis runs)	Hydrocarbons Ammonia Particulate Sulphur species Trace metals
Product gas	As required when Gas 1 running	Gas 1 overheads for NH <sub>3</sub> , SO <sub>2</sub> and H <sub>2</sub> S on lab GC Gas 1 absorber water for NH <sub>3</sub> and S species	Required to establish the partition of species to absorber water as a function of pH
Fuel gas	As required when Gas 1 and Gas 2 running	Gas 1 as above Gas 2 overheads for H <sub>2</sub> S and other species	As above  To establish final H <sub>2</sub> S in Gas 2 overheads, as well as any remaining sulphur species, and hydrocarbons in fuel gas
Sour Water	Each selected HMB run at end	Bulk characteristics Detailed analysis on selected design basis runs	Ammonia, H <sub>2</sub> S, pH, Total Organic C, Total Inorganic C Full analysis
Steam-stripped sour water	Up to hourly when plant is being steadied, otherwise 6-hourly	H <sub>2</sub> S and ammonia, pH	Required prior to sending SSW to the storage tank for use in processed shale moistening
Oil Products	As required	All tests as for raw oil (see above) Specific tests for fuel products i.e. ultra-low sulphur diesel or jet fuel	D86 distillation curve and N content done on-site, other tests offsite in specialised oil laboratories

## 4. Environmental review methodology

The QER environmental review was undertaken in general accordance with Australian Standard AS/NZS ISO 19011:2003—Guidelines for Quality and/or Environmental Management Systems Auditing. Environmental requirements and issues were identified and objective evidence sought on conformity with the requirements and presence of effective environmental management measures to address environmental issues.

An inspection of the plant and mine site was undertaken by a group of officers from EHP, on 23 and 24 October 2012, as part of the verification assessment and review conducted by EHP. The inspection focussed heavily on identifying and assessing the environmental management practices employed at the premises.

The review conducted by EHP also relied on consideration information supplied by QER, including monitoring records, management plans, presentations by QER personnel and consultants, written reports and other documents relating to the Paraho II facility. In conducting the review, prime consideration was given by EHP to the environment issues of air, water, odour, noise, waste management and general environmental housekeeping. The review was conducted in five stages, as follows:

1. Preliminary information review; including review of QER's submission to the Queensland Government Interdepartmental Working Group on Oil Shale and existing air monitoring data covering the period July 2011–June 2012.
2. On-site information gathering; including a preliminary meeting to address induction requirements, outline objectives, discuss firsthand the plant's operation with key QER personnel, and observe the plant's operation and associated environmental monitoring program.
3. Information review; covering information collected and further information provided by QER in response to questions arising during the site inspection and data review.
4. Draft review and provide opportunity for QER to comment on the report.
5. Finalising the review report after reviewing QER's comments.

In conducting the review, the departmental officers under took the following tasks:

- Identified the review criteria.
- Reviewed the background information on the activities and the process carried out at the premises.
- Inspected the plant in operating condition to verify that all major emissions & waste outputs are monitored and fugitive emissions are minimised.
- Collected and verified evidence to support findings related to the review criteria.
- Determined whether the major environmental issues that arose with operation of the previous (and now removed) shale processing plant (the ATP) by the former site owners (SPP) have been avoided or resolved with QER's new Paraho processing technology.
- Assessed environmental monitoring data to ensure that environmental monitoring is conducted in accordance with quality assurance/quality control (QA/QC) requirements of the monitoring methods.
- Assessed the performance of existing pollution control equipment to ensure that appropriate mitigation measures are available and effective.
- Reviewed the facility's compliance with legislation administered by EHP, including statutory requirements relating to the management of air, water, waste, and noise as specified in the Environmental Authority conditions.

### 4.1 Scope and criteria

The scope of the verification assessment and review conducted by EHP was limited to an examination of the activities at the QER Paraho plant, located at Yarwun near Gladstone. The mining activities at this site were generally not considered part of this review, with the exception of review of the effectiveness of the mine water management system, as this serves process plant waste disposal areas as well as the mine.

It should be noted that, due to the relatively small quantities of shale material processed through the plant, mining was not being actively carried out during the inspection. Mining had previously occurred on a campaign basis to obtain sufficient raw oil shale to allow processing for an extended period. However, crushing and screening of mined oil shale did occur during the inspection.

The time period covered by the environmental audit included 2 days of site inspection covering the environmental management practices adopted at the facility and data collected over approximately 1 year of operation. Review criteria are the requirements against which the activities carried out at the premises are assessed based on the objectives and scope of the review. The criteria chosen to ensure that the objectives were met included the following sources:

- *Environmental Protection Act 1994*, in particular the general environmental duty and best practice environmental management
- Environmental Protection (Air) Policy 2008 which includes an environmental management hierarchy, environmental values and relevant air quality objectives
- Environmental Protection (Water) Policy 2009 which includes an environmental management hierarchy for avoiding water contamination, prescribes water quality guidelines and defines environmental values of waters
- *Waste Reduction and Recycling Act 2011* which prescribes the principles of management of the waste such as the polluter pays principal, the user pays principal and the product stewardship principal
- conditions of Environmental Authority No. MIN100479806 and PEN100375209.

## 4.2 Review of existing information

Prior to visiting the site, all environmental monitoring data and the background information related to the project was reviewed by EHP. These are summarised in the following sections.

### QER September 2012 report to government

In September 2012, QER submitted a report to government entitled: QER Submission to the Queensland Government Interdepartmental Working Group on Oil Shale. The report described the performance of QER's Technology Demonstration Plant.

The information reviewed from that report includes:

- technical information about the Paraho process, product upgrading and the site operations
- a detailed description of the activities carried out on the site
- process flow diagram showing all unit operations carried out on the premises, detailed discussion of unit operations, and detailed lists of all process inputs and outputs
- pollution control equipment and pollution control techniques employed on the premises and the features used to suppress or minimise emissions, including dust and odour
- back-up measures employed that will act in the event of failure of primary measures to minimise the likelihood of plant upsets and adverse air impacts
- a description of how process water is treated and utilised
- overview of the TD plant environmental performance
- process consistency and stability under different operating conditions
- how the TD plant demonstrates compliance with the state's environmental standards
- commitment for sustainable oil shale development
- steps adopted in building community support.

## QER monitoring data

QER also provided plant environmental monitoring data for about a year of operation. This included the following information:

- Stack (air emission) monitoring data based on actual measurements on samples taken from the facility included parameters such as particulates, sulphur dioxide (SO<sub>2</sub>), nitrogen oxides (as NO<sub>x</sub>), carbon monoxide (CO), total volatile organic compounds (VOC as n-propane), speciated VOCs, hexavalent chromium (CrVI), polycyclic aromatic hydrocarbons (PAH), dioxins, trace metals and odour causing substances (such as hydrogen sulphide, thiophene, carbon disulphide, carbonyl sulphide, total reduced sulphurs and a mixture of odorants measured as odour concentration).
- Air emission data presented as concentrations at standard temperature and pressure (STP) and the oxygen reference level and the mass emission rate.
- Stack monitoring conducted when the plant was operating at full designed capacity.
- Centrifuge solids from the oil recovery plant (expected to have the highest persistent/hazardous substances) analysed for dioxin concentrations.
- Processed shale analysed for dioxin concentrations.

## 4.3 On-site collection of information

A number of meetings were held with the QER engineers and environmental professionals on 23 and 24 October 2012 to discuss the plant operations in detail. The purpose of the on-site meeting with QER was to collect on-site additional information and verifiable evidence to determine whether audit criteria were being complied with.

The New Environmental Quality (New EQ) stack testing scientists also attended the meeting to explain the stack monitoring methods used and how the related QA/QC requirements applied. A guided tour of surface water monitoring sites and a presentation on the water monitoring program was provided by QER's consultant water testing scientist.

## 4.4 Detailed plant inspection

A detailed inspection of the facility was conducted by EHP staff to allow them to understand the Paraho process, and to compare and contrast the environmental performance of the Paraho technology with SPP's ATP plant. In addition, the inspection sought evidence of environmental compliance and performance of the Paraho plant by:

- inspecting the new EQ mobile air quality monitoring lab
- making personal observations of the plant in operation
- gathering evidence of environmental management measures employed and benchmarking these against general environmental duty, environmental authority conditions and the benchmarking the operation against best practice environmental management.

Detailed inspections of the plant were conducted for about 3 hours each day. During that period the plant was operating at the normal capacity of 2.5 tonnes per hour. An inspection of the mine pit, the mine water management system, the ex-pit waste rock dump area where processed shale is disposed and general vegetation established around the mine was also included.

## 4.5 Additional information

Following the site inspections and assessment of QER's submissions and information, clarification and supporting information was sought by EHP on a number of matters. These included:

- clarification of the purpose of some items of equipment
- additional information on the Paraho process
- QA/QC measures applied to water testing
- supporting information on revegetation of waste deposits
- information on assessment of acid mine drainage potential of mined materials and processed shale
- plant status during air emission monitoring

- detailed information on hexavalent chromium and dioxin testing
- information on results of community surveys and feedback from visitors to the information centre
- detail on monitoring programs to characterise the environment, retorting process and its wastes, products and emissions
- details on the maintenance program for air pollution control equipment.

## 5. Assessment of QER's environmental performance

This chapter evaluates QER's environmental performance in relation to the key environmental issues of water management, dioxins, air emissions, solid wastes, noise emissions, land rehabilitation, industrial plant house keeping, potential resource sterilisation and community relations.

### 5.1 Water releases and management

The EA issued for the QER facility under the EP Act authorises water releases to the environment from two sources at the QER site, provided it meets the specified water quality limits. Water discharge monitoring data reviewed by EHP showed that the company has complied with these release limits. These two sources are the outlets of the mine water management system (called WP2) and its emergency spillway (called WP3) and, secondly, the outlet of the clean water holding pond (called WP1). Discharges from WP2 and WP3 flow to an ephemeral freshwater water course called Gully C and then ultimately to Port Curtis. Discharges from the clean water holding pond flow direct to Port Curtis.

Stormwater from the processing plant flows into the clean water holding pond and that from the mine, into the mine water management system. As stormwater from the plant site potentially contains oily contamination, an oil/water separation process is employed to treat potentially oily waste streams prior to them being admitted into the clean water holding pond.

Another source of waste water is from utilities including boilers, raw water treatment plant and cooling plant. Water is periodically extracted from the cooling water circuit, boiler steam circuit and raw water treatment plant to manage to acceptable levels the concentrations of salts, solids and cleaning agents in these systems. As is usual practice for such utilities, chemicals are added to these systems to prevent harmful scale build up, corrosion and biological problems such as bio-fouling growths or outbreaks of *Legionella* species.

These waters (known as 'blowdown') are discharged into the clean water holding pond. Waters in the clean water holding pond are withdrawn for a number of uses in the plant, including utility water, irrigation, processed shale cooling and fire fighting water (if ever needed).

Waters from the mine water management system may also be re-used at the plant site as well as for mine water use (e.g. haul road watering). An option exists for treated mine water to also be released via WP1 in the event of salinity issues precluding any release to the freshwater environment. WP1 flows to marine waters.

Process waste water is generated from three areas of the demonstration plant, namely the oil recovery unit, the gas cleaning unit, and the oil upgrading unit. Contaminants in this water include ammonia and hydrogen sulphide, as well as some suspended solids, colloidal matter, organics, and metals. Process waste water is treated to reduce concentrations of ammonia (NH<sub>3</sub>) and hydrogen sulphide (H<sub>2</sub>S) using a two-stage steam stripping process.

Two process waste water streams, due to the high level of contaminants expected in them relative to environmental water quality objectives, are prohibited from release into surface water (see EA condition C4). These are flare seal water and stripped sour water. The treated process waste water is used to moisten processed shale which is then placed out of the mine pit, in compliance with condition C4 of the EA

Process waste water is kept separate from potentially influencing stormwater, excepting where treated sour water is sprayed on processed shale to cool it. If not well managed, leachate from such co-disposed waste could contaminate waters. However, the waste is deposited and managed in an out of pit waste rock placement area to avoid such contamination.

The emergency flare would be expected to operate in the event of a plant upset or actuation of gas pressure relief safety devices. It is understood that there has not been any emergency flaring of process gases at the plant and so highly contaminated flare seal water does not appear to have been generated.

QER has indicated that, although steam stripping is used as the primary treatment process in the demonstration plant, a number of alternative options are being investigated to optimise process water treatment for a future commercial operation. This is expected to have benefits for solid waste management options and void water quality, as mass loads of contaminants applied in cooling processed shale would be significantly reduced (with consequent improvement in fluxes to leachate).

Limits for discharges to surface waters are contained in the environmental authority. Monitoring information for release events was compared to the above limits to check for compliance on advised release dates of 3 and 5 April 2012. Results were reported in certificates of analysis by the NATA registered ALS Group (analysis certificates EB1209380 and EB1209555 respectively). These certificates showed that water quality of the releases complied with the release limits.

Quality control is an important part of any sampling exercise. The purpose of a quality control scheme is to check whether bias, sample contamination, or analyte loss could affect the results, and so invalidate the process. EHP thus sought information from QER on the quality assurance measures applied to water release monitoring.

Information was supplied by QER's consultant water tester. This showed that monitoring was conducted in accordance with written work instructions, using accredited laboratories and calibrated field instruments, appropriate bottles for the analyses and using QA documentation.

Water samples, depending upon the quality parameter of interest, have various maximum recommended holding times between the taking of the sample and submission to a laboratory. This is due to the fact that the quantity of some substances in the sample changes over time, despite using recommended preservation techniques. The maximum holding times and other quality assurance are recommended in the Department's water monitoring and sampling manual (EHP 2010). Compliance with these sampling and monitoring methods is required by condition H13 of QER's EA.

The holding times for water release samples taken on 3 and 5 April 2012 were compared to the recommended maximum holding times. Checks were made assuming that the written work procedures for the sampling (e.g. correct bottles, icing samples) had been complied with. The results of this check identified that the recommended holding times for suspended solids and nutrients were exceeded. All other samples were analysed within the recommended holding times.

Another important aspect of quality assurance, as recommended by the EHP water monitoring and sampling manual (EHP 2010), is the taking of control samples. Control samples include:

- field spikes—uncontaminated sample water contained and preserved in an identical fashion to the field samples is spiked with contaminants of interest and accompanies the field samples during the sampling. Analysis of the spiked sample quantifies any analyte loss via comparison to the spiked concentration
- field, transport and container blanks—uncontaminated samples of the media (e.g. water) contained, handled (for example filtered) and preserved in an identical fashion to the field samples are analysed and measures of introduced contaminant (if any) are used to quantify and trace contamination problems associated with the sampling methods and materials.

These requirements reflect recommendations in relevant Australian standards (AS/NZS 5667.1:1998) and the National Water Quality Guidelines (ANZECC/ ARMCANZ 2000). Advice from QER was that control samples were not used in the water testing program, unlike the situation with QER's stack and dioxin testing programs, where such is routine.

On 26 October 2012, EHP provided recommendations to QER in relation to the need for control samples to be taken, in order to ensure sound quality control. Quality control is an integral component of water quality measurement as it increases confidence in the monitoring data obtained. QER has committed to improving quality assurance in accordance with the prescribed QA requirements.

During the inspection, some improvements to bunding of chemicals were recommended to QER. These centred on having adequate splash protection to prevent leaks over the bund wall for liquids stored adjacent to bund edges and not leaving chemicals temporarily outside bunded areas whilst not in use. QER responded positively to these suggestions and immediately instituted measures to avoid such occurrences in the future. There is no evidence that the materials handling described caused any environmental harm.

## 5.2 Persistent organic pollutants—Dioxins

Dioxins is the name given to a group of chemicals called polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF). They are not intentionally produced, but rather they are unwanted by-products of some combustion processes and chemical processes such as paper pulp bleaching and the manufacturing of chlorinated pesticides. They are also produced naturally by bushfires.

Dioxins, when released into the environment, have shown a tendency to accumulate in the food chain, particularly in animal fat, dairy products, and fish. Another property of dioxins is their poor affinity to water and greater affinity to precipitate out and become adsorbed onto particles. This means that there is greater chance of finding them adsorbed onto particles than dissolved into water. Hence, the most likely situations to find them include air emissions containing particulates, ash and sediments of waters, rather than dissolved in the water itself.

QER included monitoring to check for presence of dioxins in its environmental monitoring and waste characterisation programs. Monitoring for dioxins is undertaken for air emissions, particulate recovered from oil processing, processed shale from the process and stream sediments downstream of the processed shale placement area. Dioxins in general contain complex mixtures of different PCDD, PCDF.

The quantities of various dioxins and furans found cannot be summarised as some of them exhibit only a tiny fraction of the toxicity of others. For environmental and health risk assessments, the concept of toxic equivalency (TEQ) has thus been developed to describe the cumulative toxicity of complex mixtures of these compounds (Ahlborg et al., 1992).

The environmental authority is based on this best practice approach, and hence limits are expressed using the concept of toxic equivalents. This approach involves assigning individual toxicity equivalency factors (called TEFs) to the dioxin and furan congeners in terms of their relative toxicity compared to the most carcinogenic form, 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD).

In this schema, the concentration of the most toxic congener (i.e. 2,3,7,8-TCDD) is assigned a weight or toxicity equivalency factor (TEF) of one. The other congeners are then given weightings proportionate to their toxicity as compared to the most toxic one. For example, a congener that was half as toxic would be assigned a TEF value of 0.5.

The toxic equivalency (TEQ) of a mixture is then calculated by multiplying the concentrations of individual congeners by their respective TEF, and then adding the individual TEQs to obtain a total TEQ concentration for the mixture. There are several schemes that have been developed based on the relative toxicities compared to 2,3,7,8-TCDD. The environmental authority adopts use of the TEF values promulgated by the World Health Organisation.

In stream sediment monitoring, an additional quality step is adopted. Sediment sampling is standardised to the <63 micron sediment size fraction so that variation in particle size is removed as a source of uncertainty. This is consistent with recommendations for sediment contamination in the National Water Quality Guidelines (ANZECC /ARMCANZ 2000).

There are different conventions for how to calculate TEQ values for compounds that are not detected. Three common ways are:

- the lower bound method in which the summation of the TEF values, in which the values below the detection level are calculated as 0 ng/kg
- the medium bound method in which the summation of the TEF values, in which the values below the detection level are calculated as ½ the detection level
- the upper bound method, in which the values below the detection level are calculated as the actual detection level.

The environmental authority limit, for compliance purposes, adopts the lower bound TEQ i.e. zero (0) is substituted into the formula for any non-detectable compound.

The environmental authority requires that the processing activity must be undertaken in accordance with best practice environmental management, to reduce or eliminate dioxin production and in accordance with the waste management hierarchy and principles of the Environmental Protection (Waste Management) Policy 2000. This policy included a waste management hierarchy which prescribes a preference for avoidance of the production of waste over the disposal of waste.

The environmental authority adopts a maximum concentration of 10 ng TEQ/kg (equal to 10 parts per trillion) that should be avoided in wastes produced (e.g. processed shale) and complied with in stream sediments downstream of the site. There are also separate limits for dioxins in air emissions which are discussed separately in section 5.3 of this report.

## Processed shale

The testing program for dioxins uses an internationally recognised laboratory (Asure Quality, New Zealand) for performing the dioxin analyses. The program includes analysis of samples, blanks and reference material (power station ash) for quality assurance purposes. Recoveries are also estimated using carbon (<sup>13</sup>C) isotopes. Results for dioxins in processed shale are provided in Table 4.

**Table 4: Results for dioxins in technology demonstration plant processed shale.**

Date	Dioxin concentration pg/g (WHO-TEQ)	
	Lower bound (EA Limit = 10)	Upper bound
July 2011	0.0043	0.0131
November 2011	4.06	4.24
December 2011	0.232	5.26
January 2012	0.405	3.63
June 2012	0	1.63

These results show that processed shale to date has a maximum concentration (lower bound basis) at around 40% of the EA limit. When one looks at the upper bound value or absolute worst case scenario (which is conservative in assuming that dioxins not detected are all present at the limit of detection), compliance with the limit is still achieved.

### Solids in product stream – Centrifuge solids

Another potential source for dioxin release is via the off-gas stream, which is extracted from the top of the retort. QER investigated this possibility by conducting dioxin testing on solids centrifuged from the oil vapours extracted from the retort and did not find detectable concentrations of dioxins.

### Stream sediments

Stream sediments in a downstream location are required to be monitored for dioxins following any discharge event. Sampling was carried out in May 2012 after the April 2012 discharge event from the mine water management system (Table 5).

**Table 5: Results for dioxins in stream sediments.**

Date	Dioxin concentration pg/g (WHO-TEQ) (<63µm)	
	Lower bound (EA Limit = 10)	Upper bound
May 2012	4.65	4.83

### Conclusions

The above results show that QER is complying with the requirements to avoid, to the greatest practicable extent, any production of dioxins. QER is also responsible for managing the ex-pit processed shale placement area which contains the dioxin contaminated processed shale generated by the former operators of the ATP, Southern Pacific Petroleum. The fact that dioxin levels in downstream sediments are below environmental authority limits infers success in ensuring continuing encapsulation of this material.

## 5.3 Air emissions and management

### Emission limits

In order to assess compliance with the environmental authority, the air emission limits are relevant. These are reproduced in Table 6. These air contaminant emission limits apply specifically to the two major emission sources, namely the dryer regenerative thermal oxidiser ('RTOx') and the plant thermal oxidiser ('TOx').

**Table 6: Air release limits specified in the QER Environmental Authority.**

Air quality indicator	Limit type	Release points	Mass emission limit (Note 1)	Concentration release limit
Sulphur Dioxide, SO <sub>2</sub>	Maximum	RP1 and RP2 Combined (Plant TO + RTO)	8 grams/second	-
Nitrogen Oxides, NO <sub>x</sub>	Maximum	RP1 and RP2 Combined (Plant TO + RTO)	3 grams/second	-
Hexavalent Chromium (CrVI)	Maximum (12 months rolling average)	RP1 and RP2 Combined (Plant TO + RTO)	0.11 milligrams/second	-
Dioxins	Maximum	RP1 and RP2 (Plant TO, RTO)	-	0.1 nanograms TEQ(WHO) per standard cubic metre (dry) (Note 2)
Particulates	Maximum	RP1 and RP2 Combined (Plant TO + RTO)	1 gram/second	-
Particulates	Maximum	RP1 and RP2 (Plant TO, RTO)	-	50 milligrams per normal cubic metre (dry) (Note 3)
Volatile Organic Compounds (VOC), expressed as n-propane	Target Maximum (Note 4)	RP1 (Plant TO)	-	20 milligrams per normal cubic metre (dry) (Note 3)
	Maximum	RP1 (Plant TO)	-	40 milligrams per normal cubic metre (dry) (Note 3)
		RP2 (Plant RTO)	-	20 milligrams per normal cubic metre (dry) (Note 3)

Notes:

1 - Mass emission limits are for the aggregate sum of mass emissions from the two release points: plant TO (RP1) and dryer RTO (RP2).

2 - Oxygen reference level for plant TO (RP1) is 11%, however there is no oxygen reference level for dryer RTO (RP2).

3 - Oxygen reference level for plant TO (RP1) is 3%, however there is no oxygen reference level for dryer RTO (RP2).

4 - Thermal oxidiser serving plant TO (RP1) must use all endeavours to comply with the target maximum of 20 milligrams per cubic metre at 3% oxygen dry, but may exceed this where necessary for testing the retorting technology.

For some air contaminants, there are no specific and relevant source emission standards or guidelines. This is the case for odour causing substances such as H<sub>2</sub>S, thiophene and carbonyl sulphide. In these cases, the assessment approach relies on checking whether pollution control measures known to be effective in treating these substances are installed and operated effectively. Emission concentration for odourants may also be developed using the site specific dispersion modelling results (such as dilution factors) and odour threshold values (from literature), as follows:

- Stack emission standard = odour threshold x (Minimum Dilution factor ÷ worst case peak to mean ratio)

For larger scale activities, EHP would typically be concerned with both the mass emission rate, as this influences ambient concentrations of air contaminants, and the flue gas concentration, as this is reflective of best practice and can affect visual aesthetics. An example would be particulate emissions. A mass emission rate may protect an ambient air quality goal for particulate less than 10 microns at a sensitive place but high concentrations may appear as dark smoke belching from stacks. Also, if the mass rate was set too high, there may be little air-shed capacity left to allow a new industry to establish nearby.

Best practice management of an air shed by the administering authority thus usually involves limiting mass emission rates to ensure ambient air quality objectives are met as well as concentrations to ensure a level playing field for industry. This also ensures that one industry does not consume the total assimilative capacity of an air-shed and allows capacity in the air-shed for future industry expansion.

Due to the relatively small scale of the TD plant as compared to the previous operation, no specific limits on mass emission rates or concentrations for odour are included as EA conditions. Instead, the EA conditions prohibit the activity causing any nuisance due to noxious or offensive odours. Assessment in relation to odour focuses on whether best practice odour avoidance and treatment has been incorporated and whether any nuisance has been caused.

## Review of existing information

After reviewing the air monitoring reports supplied prior to the site visit, additional information, not previously provided in summary reports, was requested including:

- clarification regarding whether the sour water stripper and oil upgrading plant had been commissioned at the time of stack monitoring
- identification of plant areas operating at the time of sampling. For example, the thermal oxidiser feed consists of gases from (a) gas treatment plant (ammonia and hydrogen sulphide removal), (b) oil up-grader, (c) oil tank farm, (d) processed shale moistening unit and (e) off-gas from the process water stripper. These operational records need to be provided with the monitoring data
- stack gas exit velocity, temperature and volume flow rates
- further, stack testing summary reports did not provide information on toxicity equivalency factors adopted for reporting dioxins and PAH concentration values.

## On-site collection of information

EHP staff held a number of meetings with QER engineers and environmental professionals on 23 and 24 October 2012 to discuss the plant operations in details. The purpose of on-site meetings was for QER to provide additional information determined to be necessary following the abovementioned preliminary review, and for EHP to collect on-site information and verifiable evidence on environmental performance. Representatives of New Environmental Quality (New EQ), QER's stack testing scientists, also attended to discuss the stack monitoring methods and QA/QC requirements for the various monitoring methods. The items discussions are summarised below.

The need for the stack testing summary reports provided to EHP to include plant operational data applying at the time the testing was carried out. This is required by EA monitoring conditions and provides information which greatly assists in the interpretation of the air emission results. QER clarified that the data was readily available as it is recorded on their information system, but had simply not been provided in the summary reports. After the meeting, QER provided the plant operational data corresponding to those times when the emissions monitoring took place. These data showed the plant to be operating in a variety of typical states during monitoring. QER advised that it had instructed the stack testing company to include this information in all future air emission reports.

The review also sought detail about air monitoring methods. New EQ staff provided detailed information on the methods employed for the sampling and analysis of air contaminants. The monitoring was found to be in accordance with recognised methods.

For auditing purposes, EHP officers also selected at random one particular stack monitoring report to audit how the monitoring was conducted and the notified emissions rates calculated from the corresponding analysis certificates. The monitoring date chosen was December 2011. Using a spread sheet program, New EQ scientists demonstrated in detail how the sampling and analyses were conducted and how the emissions were calculated. This confirmed that information in the summary reports advising compliance with EA conditions was fully traceable to contemporaneous stack parameter measurements, quality assurance checks and analysis certificates. This demonstrates that high confidence can be placed in the reported data.

The officers asked New EQ scientists to explain the sampling and record keeping systems, with a focus on the analyses of hexavalent chromium and dioxin test results. New EQ personnel discussed the methods adopted for record keeping and presented the results using a spread sheet program. Included in the discussion were the dryer RTOx and report/plant TOx release point tests for hexavalent chromium and dioxin during the quarterly testing conducted in December 2011.

## Observations during plant inspection

During the EHP inspection all air contaminant levels measured were found to be complying with the emission limits set in the EA. The plant operational parameters were also found to be within the plant's typical operational range.

The EHP inspection commenced with a visit to the plant control room. There were a number of supervisory control and data acquisition (SCADA) systems (or computer display devices) located in the room showing the plant operational parameters and flue gas monitoring system. The control room monitoring systems were found to provide comprehensive information on how the plant units are operating.

Two Continuous Emissions Monitoring Systems (CEMS) are operating at the TD Plant. These are located on the plant thermal oxidiser stack and the dryer regenerative thermal oxidiser stack. They provide continuous online monitoring of the principal environmental variables of the stacks, including air velocity, flow rate, particulates, oxygen, nitrogen compounds, sulphur compounds, and temperature. The CEMS, in conjunction with periodic isokinetic sampling, provide data for emissions reporting and evaluation of the plants environmental performance. The data collected by CEMS was also displayed on the control room monitoring systems.

During the EHP site inspection, the New EQ mobile testing laboratory was on-site, conducting stack monitoring on the thermal oxidiser stack (i.e. release point RP1 specified in the EA). EHP officers took the opportunity to inspect New EQ's mobile laboratory and to verify the effectiveness of the equipment calibration system used.

EHP officers then inspected the various components of the TD plant, checking for any operational problems (e.g. for fugitive emissions) and assessing the overall level of environmental compliance by the plant. The plant components inspected include: retort; dryer; briquetting plant; dryer; thermal oxidisers; bag-house filters; gas treatment plant; product storage and load out areas; and the sour water stripping plant. The site inspection identified those process units and activities that were potential sources of dust and odour emissions. Checks were also made on the specific management practices adopted to prevent and minimise the release of dust and odour, and whether the control equipment appeared to be working effectively. Key features observed included odour avoidance measures, effective odour capture and treatment systems, monitoring of key parameters and the conditions under which releases occurred.

The EHP officers also walked around the general area of the TD plant to check for odour issues. No offensive odours were detected. A weak hydrocarbon type odour was detected near some of the plant units and on-site downwind near the control room. However, the odours emanating from plant and dryer were not detected at or beyond the boundaries of the premises. The EHP officers were informed that no odour or dust related complaints had been received by QER since the Paraho plant had commenced operating in September 2011. QER also informed EHP officers that there had been no odour incidents in breach of the conditions of the EA since the HD plant commenced operation. EHP staff observed that best practice environmental management was reflected in the plant operating procedures, process management and odour control technologies.

QER's TD plant dryer operates at a temperature of less than 180 °C and the waste gases are treated for odour using a regenerative thermal oxidiser. The resultant gases are then treated by a regenerative thermal oxidiser which has very high odour destruction efficiency.

The task of EHP staff included the need to compare and contrast the environmental performance of QER's HD plant with that of the much larger ATP facility previously operated at the site by SPP. As already noted, SPP's ATP facility used a rotary dryer that operated at a significantly higher temperature than the QER dryer. In addition, some odorous gases were released from the ATP facility without receiving any treatment to remove odours, while emissions (such as e.g. flue gases) were treated using a wet scrubber which had a destruction efficiency of less than 80%. These were major causes of the many odour complaints that had been received about the ATP plant.

EHP staff also noted that QER has included an additional level of assurance in their design and implemented risk assessment to minimise the likelihood of dust and odour releases from the site. A contingency plan in the event of such a release includes personnel training to shut down the plant without any release of odorous gases. It was observed that, in addition to the main bag-house filter serving the dryer, there are two additional bag-house filters serving other parts of the HD plant.

These bag-house filters are located in the following areas of the plant:

- hopper receiving fines shale (briquette plant)
- hopper receiving lump shale (upstream of the dryer).

The inspection found the technologies adopted to minimise dust and odour emissions at the QER plant to be very effective. The best practice odour and dust management practices observed during the site inspection are summarised in Section 5.3 of this report. Detailed information on the odour and dust control technologies is provided in the QER report to Government (QER 2012).

The EHP staff concluded from the inspection that: no offensive odours were emanating from the site; the general environmental duty was being complied with in respect of dust and odour control; and best environmental management measures were being used for odour and dust control at the TD plant.

## Review of Air Emissions Monitoring Program

QER has developed and implemented an environmental monitoring program for the air environment which complies with and exceeds the requirements of EA. The QER environmental monitoring program is reviewed in this section.

### Air Quality Sampling Program

The QER EA conditions require the following air quality monitoring program:

- Continuous monitoring of sulphur dioxide (SO<sub>2</sub>), nitrogen oxides (NO and NO<sub>2</sub>) and particulates for the flue gas generated from plant thermal oxidiser (TO) and dryer regenerative thermal oxidiser (RTOx).
- Quarterly isokinetic monitoring of nitrogen oxides (NO and NO<sub>2</sub>) and particulates from plant thermal oxidiser (TOx) and dryer regenerative thermal oxidiser (RTOx).
- Odour concentration monitoring of plant TOx stack and dryer RTOx stack at a frequency of two days per week during weeks (or part thereof where practicable subject to laboratory or stack testing contractor availability) in which the plant is run).
- Monthly monitoring of plant TOx stack and dryer RTOx stack for hexavalent chromium, hydrogen chloride (HCl) and hydrogen fluoride (HF), benzene, formaldehyde, PAH as benzo(α)pyrene equivalent, carbon disulphide (CS<sub>2</sub>), carbonyl sulphide (COS), thiophene, hydrogen sulphide (H<sub>2</sub>S), total reduced sulphur (TRS), volatile organic compounds (VOC) as n-propane equivalent, speciated VOC analysis, and heavy metals including total of lead, cadmium, mercury, chromium, arsenic, nickel and beryllium.
- Quarterly monitoring of dioxins for a period of 12 months from the date of commissioning of the TD Plant (then annually provided the release limit is complied with).

Key items of pollution control equipment (e.g. thermal oxidisers and bag-houses) are continuously monitored at the site. Differential pressure (dryer bag-house) and temperature (thermal oxidisers) are monitored by the control room panel operator. Alarms are configured to alert the panel operator to any atypical operating conditions which may influence the effective operation of pollution control equipment. These are sound management measures.

The site CEMS provides continuous feedback to the plant operators, where alarms have been configured to alert the operators to any atypical operating conditions. This includes availability of the system and SO<sub>2</sub>, NO<sub>x</sub>, and particulate emission levels. The site operations team has a shift run that requires a visual inspection of the CEMS systems at least once each shift. The operations teams inspect the CEMS for normal operational performance at least twice a day. The site maintenance team conducts regular inspections on the CEMS system and maintains a log book with the CEMS panels. Any important details are noted by manual addition.

In evaluating environmental monitoring data, departmental officers need to be satisfied that the data are representative of the emissions from the activity. In evaluating the data, the officers considered the following:

- appropriateness of sampling and analysis procedures, for example compliance with relevant departmental guidelines
- operating conditions at the time of the sampling
- training and qualifications of the person conducting the sampling/monitoring
- suitability of analysis processes, for example use of a laboratory that is NATA certified for that particular analysis.

Assessment of QER's monitoring program is that sampling and analysis is appropriate, operating conditions at the time of sampling were typical, experienced personnel carried out the sampling and monitoring and suitable analysis and laboratories and quality assurances were utilised.

## Assessment of environmental performance - Air

This section provides an assessment of the environmental performance of the TD plant and its effects on the surrounding environment. The air quality control procedures employed at the processing plant are discussed below. The assessment of the processing plant's environmental performance included the following elements:

- Assessment of mitigation measures adopted to address air quality issues.
- Evaluation of level of compliance with EA conditions.
- Comparison of stack emissions data against EA limits.

The assessment included the following components of the processing plant:

- lump stockpile and feeding conveyer
- fine stockpile and briquetting plant
- lump and briquette dryer plant
- bag-house filters
- dryer regenerative thermal oxidiser (RTO)
- retort and furnaces
- Oil recovery plant
- Gas treatment plant
- Sour water stripper
- Oil upgrading plant
- Thermal oxidiser for the waste gases.

### Assessment of QER's Air Pollution Control Technology

The QER pollution control technologies and odour and dust management practices observed during the auditing is summarised as follows:

- The fine shale feed bin, weigh-belt and conveying are fully ducted systems and the dust generated from these units is treated using a dedicated bag-house filter.
- Stockpile lump and briquette shale are transported to the dryer using the fully enclosed conveyor. All shale conveyors are covered and all transfer points including hoppers are ducted to bag-houses.
- The dryer is a fully covered plant that operates at low temperature (<180 degrees C) to minimise the liberation of any volatile organic compounds.
- Dust and gases generated from the dryer are treated using a bag-house filter (for dust removal) and regenerative thermal oxidiser (for odours) prior to release to the atmosphere. This treatment provides an additional level of assurance (see plate 4).
- A pair of 'rotary valves' are installed at the top of the retort and another paired valve at the bottom of retort. These valves, together with inert gas blanketing, act as a gas seal to ensure that odorous hydrocarbons are not released from the retort.
- Product gases generated from the retort after the oil recovery plant are incinerated in the plant thermal oxidiser (see plate 5).
- The plant also incorporates a gas treatment plant to treat the removal and recovery of odorous ammonia and hydrogen sulphide for use as by-products.
- Process wastewater generated in the plant has impurities such as ammonia and hydrogen sulphide. These impurities are largely removed from the sour water and recovered through a two stage steam stripping process.
- Moist air and entrained particles generated during the moistening of the processed (spent) shale is treated using a venturi scrubber.
- Waste gases from the gas treatment plant, oil up-grader, tank farm, processed shale moistening unit and sour water stripping plant are collected and treated using a thermal oxidiser prior to release to the atmosphere.

- The processed shale is transferred to a stockpile area using a conveyor. The conveyor is fully covered and material on the conveyor is not exposed to the wind. There is also a telescopic discharge chute between the conveyor and the stockpile area. The chute is maintained close to the stockpile with a minimum drop height to minimise the likelihood of fugitive windblown dust (see plate 6).



**Plate 4: Picture showing bag-house filter (red arrow), regenerative thermal oxidiser (yellow arrow) and stack serving the flue gases generated from the dryer (green structure just in the left side of the photo).**



**Plate 5: Plant thermal oxidiser treating waste gases from retorting gas treatment plant, oil up-grader, oil tank farm, processed shale moistening unit and sour water stripper.**



**Plate 6: Telescopic chute discharging processed shale in the stockpile area with a minimum drop height to minimise dust emissions.**

The review found that the TD plant was designed in a manner consistent with the air management hierarchy under the environmental protection legislation, by considering the following measures, in the order of preference:

- Using management techniques to avoid creation of odours e.g. drying raw shale at a sufficiently low temperature to avoid the generation of malodours.
- Reusing or recycling the air emissions in another industrial process e.g. using vapour recovery technologies in the plant and using it as recycle gas in the retort.
- Minimising the creation of odours and using the best practice technologies to collect and treat emissions e.g. using bag-house filters to minimise dust and a thermal oxidiser and regenerative oxidiser to treat odorous emissions.
- As a last resort, relying on buffer zones, winds and stacks to disperse emitted odours (.g. QER has installed tall stacks for major emission sources).

By comparing the pollution control technologies installed on the TD plant against the industry best practice pollution control technologies, it is evident that that the QER facility has adopted the appropriate best practice dust and odour pollution control technologies.

### **Compliance with Environmental Authority conditions**

During the audit by EHP, compliance was assessed against the EA conditions, particularly the emission limits (schedule B Air) and emission monitoring requirements (schedule H monitoring). The EA monitoring requirements are discussed above in this section and the stack emission limits shown in Tables 7 and 8. Compliance with the EA requirements was assessed using the following:

- QER's management system records e.g. environmental monitoring records
- environmental monitoring QA/QC records
- operational records at the time of monitoring
- quality checks on the environmental monitoring data.

It should be noted that some aspects of the processing operation are covered by an environmental authority for petroleum activities. This situation arises because QER has a petroleum facility licence under the *Petroleum and Gas (Production and Safety) Act 2004*, which relates to synthetic fuel production and refining. EHP has dealt with this duplication issue by ensuring these conditions are identical to those in the EA for mining. The mining EA conditions cover all facets of QER's operations including mining, material preparation, mineral processing, waste disposal, ancillary supporting activities and rehabilitation.

### **Assessment of air monitoring data - Frequency, methodology and quality assurance**

The approach and steps taken here were to review, evaluate and verify data relied upon to assess the adequacy of environmental monitoring methods and reporting system. It was found that the stack monitoring was conducted on a monthly basis for most of the parameters. There were a few exceptions when a stack wasn't tested. These were found to have occurred when the relevant section of the plant was not operational at the time testing was scheduled, and the plant was off-line for the remainder of the monitoring program for that month.

The audit found the specifications of environmental monitoring system employed at the plant comply with the following EA requirements:

- All determinations of air contaminant releases to the atmosphere were made in accordance with the methods prescribed in the EHP's Air Quality Sampling Manual. Where monitoring methods of a specific contaminant are not specified in EHP's Air Quality Sampling Manual, monitoring protocols were adopted in accordance with the methods as approved by environmental regulators in New South Wales, Victorian or the USA.
- All odour sampling and measurement were based on the Australian and New Zealand Standard, namely: AS/NZS 4323.3:2001, Stationary source emissions—Determination of odour concentration by dynamic olfactometry.
- The laboratory or person performing sampling and analyses or on-site monitoring of emissions for the purposes of this investigation are accredited by the National Association of Testing Authorities (NATA) for all the tests concerned.
- The continuous emission monitoring systems (CEMS) employed at the site comply with the US EPA Performance Specification referenced in the Department's Air Quality Sampling Manual.

After reviewing the air monitoring data, it was concluded that QER's air quality monitoring program satisfied the EA frequency, methodology and quality assurance requirements.

### **Assessment of air monitoring data - Compliance with Environmental Authority limits**

The stack monitoring data were compared against the environmental authority limits. Note that the measured mass emission results and the EA requirements in Table 7 are presented as the aggregate sum of mass emissions from the two release points: plant TOx stack (RP1) and dryer RTOx stack (RP2).

#### **Particulates, sulphur dioxide, nitrogen oxides, hexavalent chromium**

The stack monitoring results for particulates, sulfur dioxide, nitrogen dioxide and hexavalent chromium were compared against the EA emission limits and found to be in full compliance with the EA limits. These limits are specified as mass emission rates (i.e. mass of contaminant per unit of time). The maximum emission results for each air pollutant were also calculated as a percentage of the maximum allowable. These percentages are detailed below and also presented in Figure 6.

This analysis shows that the highest recorded maximum mass emission rates (RP1 and RP2 combined) against the EA limits are:

- Particulates: 0.029 g/s (2.9 % of EA limit)
- Sulphur dioxide: 0.308 g/s (3.8 % of EA limit)
- Nitrogen oxides: 0.573 g/s (19.1 % of EA limit)
- Hexavalent chromium: 0.017 mg/s (15.5 % of EA limit).

**Table 7: Comparison of combined RP1 and RP2 stack monitoring data (maximum 1hr average, combined mass emissions) against the emission limits.**

Testing Date	Particulates (g/s)	Sulphur Dioxide (g/s)	Nitrogen Oxides (g/s)	Hexavalent Chromium (mg/s)
4-8 July 2011 (3)	0.004	<0.007	0.135	<0.004
21-27 Sep 2011 (3)	0.019	<0.007	0.059	<0.004
7-22 Oct 2011 (2)	0.029	<0.180	0.190	<0.005
15-24 Nov 2011 (4)	0.009	<0.214	0.255	<0.006
9-15 Dec 2011 (4)	0.020	0.2000	0.223	<0.009
17-21 Jan 2012 (4)	0.0136	NT	NT	<0.010
29Feb-4Mar 2012 (4)	<0.015	NT	NT	<0.005
30Mar-4Apr 2012 (4)	0.012	0.308	0.573	0.017
22May-1Jun 2012 (4)	0.007	NT	NT	<0.005
Combined (RP1+RP2) Emission Limit (1)	1 g/s	8 g/s	3 g/s	0.11 mg/s

## Notes:

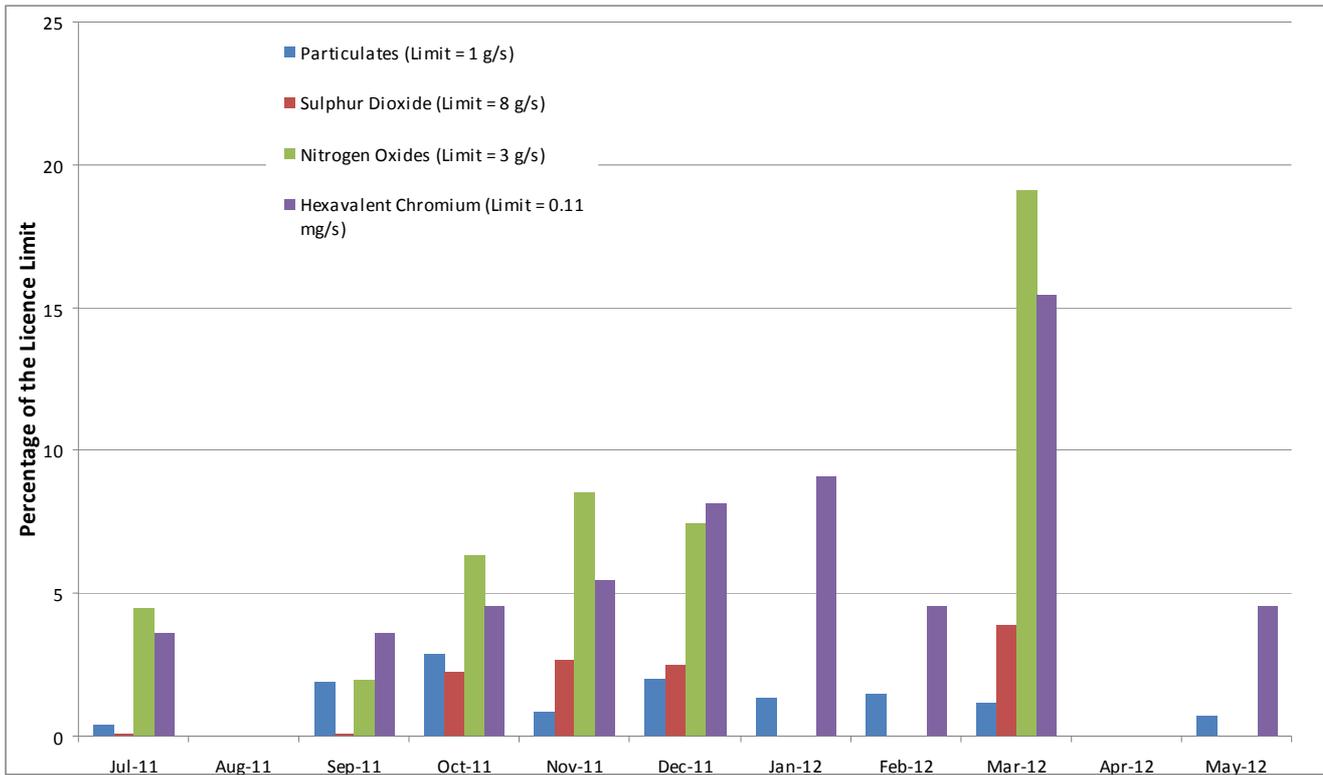
1 – Mass emission limits are for the aggregate sum of mass emissions from the two release points RP1 and RP2.

2 – Only plant TO (RP1) was monitored.

3 – Only dryer RTO (RP2) was monitored.

4 – Both plant TO (RP1) and dryer RTO (RP2) were monitored.

NT – Not required to be tested e.g. due to source equipment not being operated or EA testing frequency requirements .



**Figure 6: Combined emissions for RP1 and RP2 as a percentage of the environmental authority limit - Particulates, Sulfur Dioxide, Nitrogen Oxides & Hexavalent Chromium.**

The highest recorded maximum concentrations of VOC and dioxins and their respective emission limits are presented in Table 8. These results indicate full compliance with the EA limits. The emissions as a percentage of maximum allowable concentrations are calculated and presented in Figure 7.

This shows that the highest recorded maximum concentrations of RP1 and RP2 against the EA limits are:

- VOC from release point RP1: 3.76 mg/Nm<sup>3</sup> (18.8 % of EA limit)
- VOC from release point RP2: 2.06 mg/Nm<sup>3</sup> (10.3 % of EA limit)
- Dioxins from release point RP1: 0.00182 ng/Nm<sup>3</sup> (1.8 % of EA limit)
- Dioxins from release point RP2: 0.0032 ng/Nm<sup>3</sup> (3.2 % of EA limit).

From the above analysis, the measured emission data demonstrate compliance with the emission limits specified in the EA. It can also be seen that the highest recorded emission values are typically only a very small percentage of the EA limits. It should also be noted that these mass emissions rates are very small in the context of the mass emissions of similar contaminants authorised to be released to the Gladstone air shed by other heavy industry and power production facilities.

**Table 8: Comparison of RP1 and RP2 stack monitoring data (maximum 1-hr average, concentrations) against the emission limits for VOC and Dioxins.**

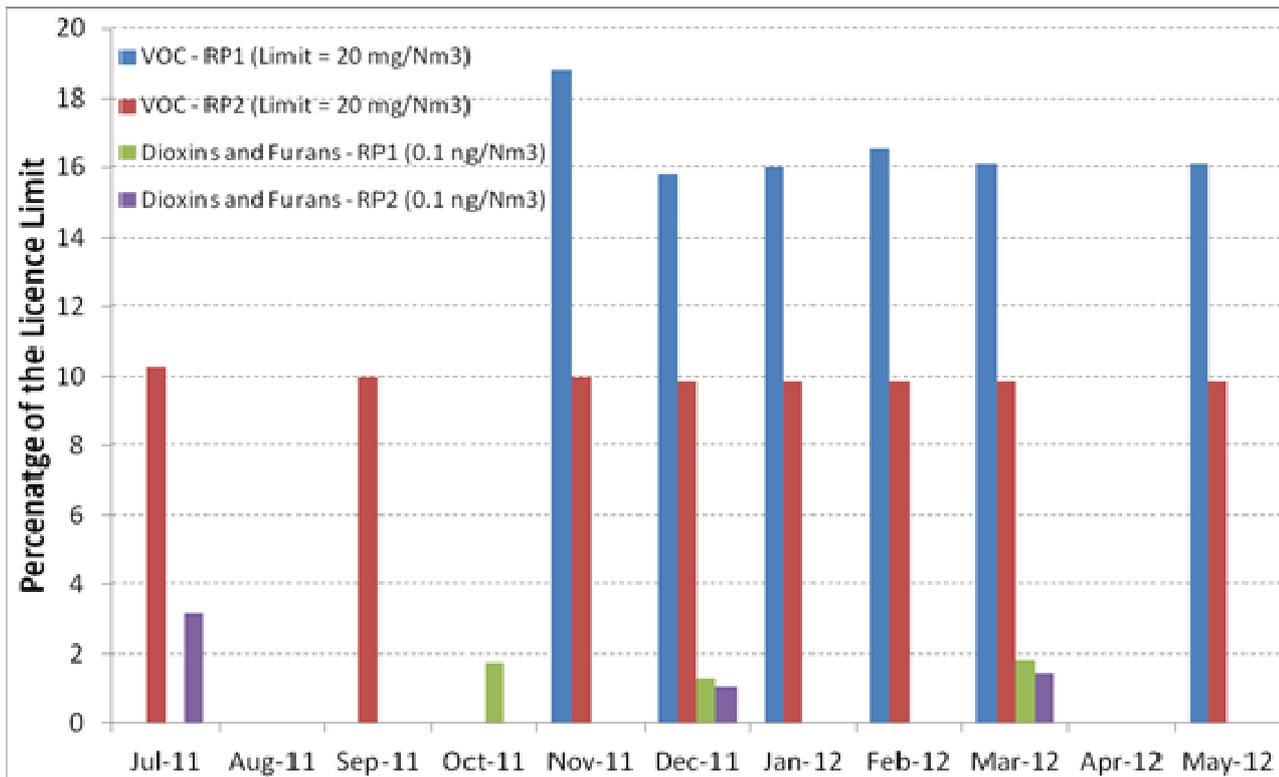
Testing Date	VOC (mg/Nm <sup>3</sup> , dry, as n-propane) (Note 1)		Dioxins (ng/Nm <sup>3</sup> , dry) (WHO TEQ Upper bound) (Notes 2 & 3)	
	RP1	RP2	RP1	RP2
4-8 July 2011	Not required	2.06	Not required	0.0032
21-27 Sep 2011	Not required	<2.00	Not required	Not required
7-22 Oct 2011	Not required	Not required	0.00175	Not required
15-24 Nov 2011	3.76	<2.00	Not required	Not required
9-15 Dec 2011	<3.16	<1.97	0.00127	0.00106
17-21 Jan 2012	<3.20	<1.97	Not required	Not required
29 Feb-4 Mar 2012	<3.31	<1.97	Not required	Not required
30 Mar-4 Apr 2012	<3.22	<1.97	0.00182	0.00146
22 May-1 Jun 2012	<3.22	<1.97	Not required	Not required
Emission Limit	20 mg/Nm <sup>3</sup> (dry, as n-propane)		0.1 ng/Nm <sup>3</sup> (dry, WHO TEQ)	

Notes:

1 - Oxygen reference level for plant TO (RP1) is 3%, however there is no oxygen reference level for dryer RTO (RP2).

2 - Oxygen reference level for plant TO (RP1) is 11%, however there is no oxygen reference level for dryer RTO (RP2).

3 - EA limit is the lower bound. The results here (expressed as an upper bound) are used to illustrate that the laboratory detection limits are acceptably low to provide confidence that the testing is sound.



**Figure 7: Combined emissions for RP1 and RP2 as a percentage of the environmental authority (EA) limit - Volatile organic compounds (VOC) and dioxins.**

**Comparison against Best Practice Source Emission Standards**

This section evaluates the stack monitoring data provided against the best practice emission standards that EHP would likely consider when assessing any application for an industry likely to emit material quantities of air pollutants into the atmosphere. The concentration criteria chosen are those considered relevant for a gas fired dryer and an oil processing plant. As discussed above, it needs to be acknowledged that concentration criteria for sulfur dioxide and nitrogen oxides are not conditions of the EA. The current EA, being predicted on a small scale pilot plant, limits these specific air pollutants using a mass emissions approach, whereby the mass emitted at any one time is limited to a very small amount commensurate with the size of the facility. QER has fully complied with these EA mass limits.

Checking whether the emissions from the TD plant are consistent with 'best practice source emission standards' or would be amenable to achieving best practice is seen as legitimate and reasonable. This is so that judgements can be made about comparative performance to other industries and also to gain an insight into any issues that may need to be addressed in a scaled up commercial plant. Performance with respect to emission concentration benchmarks achieved nationally and internationally is used by administering authorities to gauge best practice performance and also promote a level playing field for industry.

The stack monitoring data for RP1 and RP2 between July 2011 and June 2012 for particulates, nitrogen oxides, volatile organic compounds and carbon monoxide were compared against the New South Wales Protection of the Environment Operations (POEO) (Clean Air) Regulation (NSW DECCW 2010), which is considered to contain the best practice source emission standards for Australia.

**Release Point RP1**

The RP1 stack emission data demonstrated compliance with the best practice sources emission standards with a single exception (1-hour average maximum nitrogen dioxide concentration for the 30 March to 4 April 2012 test). This shows that TD Plant, although not specifically designed to meet these benchmarks, almost universally achieves them at the time of inspection.

The significance of the single exception also must be put in context. The result was obtained when the plant was both retorting and incinerating gases from sour water treatment. Thus, it is apparent that the mass of nitrogen in the combined RP1 flue gas was being impacted by the relatively large proportion of nitrogen (as ammonia) extracted from the sour water.

Sour water is a name applied to process waste water separated from shale oil vapours as it contains large quantities of hydrogen sulphide, but also ammonia. In the TD Plant up to the time of inspection, the sour water treatment was effected by two stage steam stripping ammonia to demonstrate a potential process waste water treatment solution. The waste nitrogen and sulfur extracted from the sour water has been incinerated due to the small quantities involved whereas in a commercial plant, QER intend to retain and reuse these substances.

To demonstrate practicality of this resource recovery solution in a commercial plant, QER has installed at the TD plant gas treatment equipment. This is essentially an ammonia and sulfur recovery plant. This gas treatment plant commenced operation in November 2012, subsequent to the EHP inspection the above emission test results. In other words, the above mentioned NOx result is not likely to be representative of performance of any scaled up plant as QER have designed, installed and are testing a likely solution.

**Release Point RP2**

The data for RP2 showed that the highest recorded maximum concentrations of all air pollutants released, when benchmarked against the best practice source emission criteria, fully met the benchmarks.

**Odour emissions**

The highest recorded maximum 1-hour concentrations of odour causing substances such as hydrogen sulphide, thiophene, carbon disulphide, carbonyl sulphide and total reduced sulphurs released from RP1 and RP2 are presented in Tables 8 and 9 respectively. These results indicate very low odour concentrations.

**Table 9 Emissions of odour causing substances for RP1 (maximum 1-hr average).**

Testing Date	Hydrogen sulphide (mg/Nm <sup>3</sup> dry)*	Thiophene (mg/Nm <sup>3</sup> dry)*	Carbonyl Sulphide (mg/Nm <sup>3</sup> dry)*	Carbon Disulphide (mg/Nm <sup>3</sup> dry)*	Total Reduced Sulphur, as H <sub>2</sub> S (mg/Nm <sup>3</sup> dry)*
7-22 Oct 2011	<0.91	NT	<1.34	<1.02	1.22
15-24 Nov 2011	NT	<0.142	NT	NT	NT
9-15 Dec 2011	<0.91	<0.015	<1.34	<1.02	1.58
17-21 Jan 2012	<0.91	<0.247	<1.34	<1.19	1.11
29 Feb-4Mar 2012	<0.44	<0.137	2.28	<0.97	<0.76
30 Mar-4Apr 2012	<0.76	<0.0157	<0.805	6.46	<0.24
22 May-1Jun 2012	<0.61	<0.0144	<0.805	<1.02	<0.23

\* Oxygen reference level for plant TO is 3%.

**Table 10: Emissions of odour causing substances for RP2 (maximum 1-hr average).**

Testing Date	Hydrogen sulphide (mg/Nm <sup>3</sup> dry)*	Thiophene (mg/Nm <sup>3</sup> dry)*	Carbonyl Sulphide (mg/Nm <sup>3</sup> dry)*	Carbon Disulphide (mg/Nm <sup>3</sup> dry)*	Total Reduced Sulphur, as H <sub>2</sub> S (mg/Nm <sup>3</sup> dry)*
4-8 July 2011	<0.43	<0.42	<0.75	<0.95	2.59
21-27 Sep 2011	<1.07	<0.33	<1.34	<1.02	0.719
15-24 Nov 2011	<0.91	<0.14	<1.34	<1.02	1.38
9-15 Dec 2011	<0.91	<0.02	<1.34	<1.02	1.59
17-21 Jan 2012	<0.91	<0.25	<1.34	<1.02	<0.63
29 Feb-4Mar 2012	<0.31	<0.00	<0.55	<0.70	<0.85
30 Mar-4Apr 2012	<0.76	<0.014	<0.80	<1.02	<0.16
22 May-1Jun 2012	<0.61	<0.015	<0.80	<1.02	<0.20

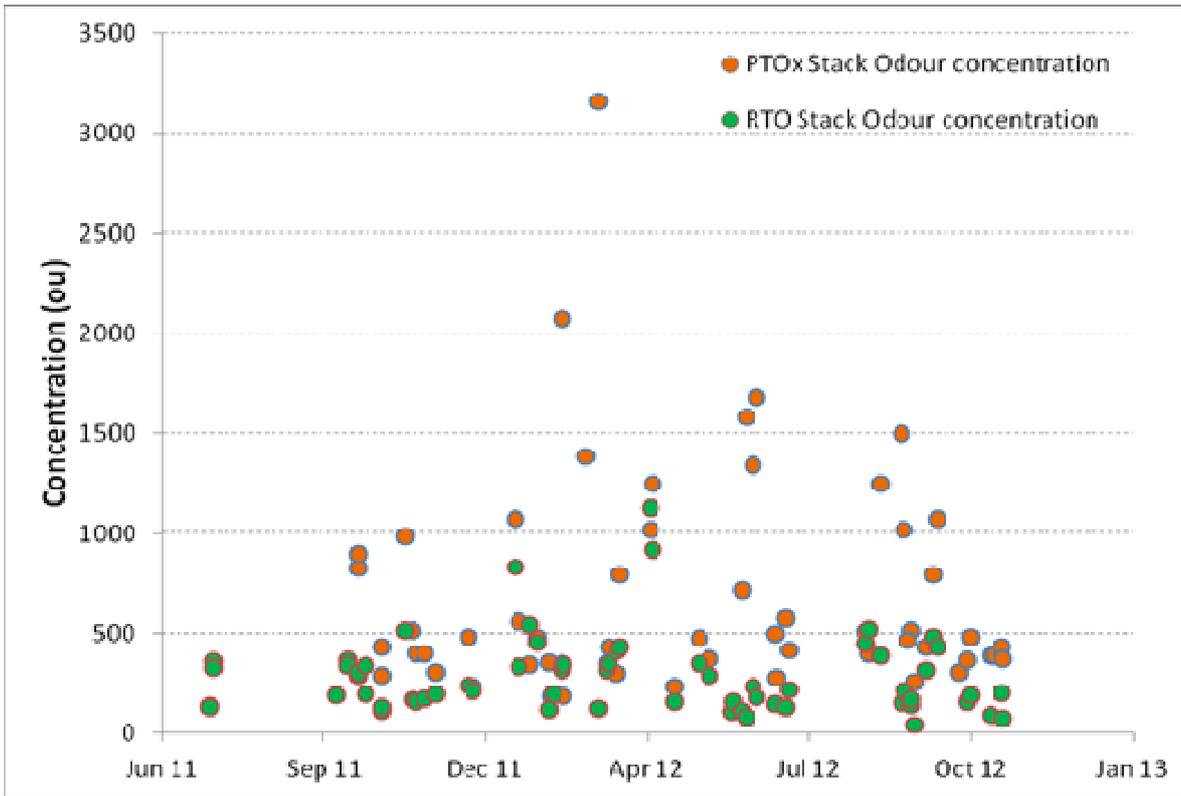
\* Oxygen reference level does not apply to the dryer RTO (RP2).

There are no specific emission standards for these pollutants. The site specific emission standards of odour causing substances can be designed using the dispersion modelling results (or dilution factors) and the odour threshold values. Odour monitoring of release points RP1 and RP2 was also conducted using dynamic olfactory and reported as a mixture of odorant measured as odour concentration. The frequency of this monitoring was more than one day per week where practicable subject to laboratory or stack testing contractor availability and the plant operability. Odour sampling and measurements were conducted in accordance with Australian and New Zealand Standard AS/NZS 4323.3:2001 - Stationary source emissions - Determination of odour concentration by dynamic olfactometry.

The measurement unit for odour concentration is the "odour unit". One odour unit (OU) is defined as the number of times the sample must be diluted with neutral gas in a dynamic olfactory laboratory to reach odour detection threshold of a calibrated panel of humans. Odour detection threshold is the value at which 50 percent of the panellists can just detect the odour. For example, if an odour sample were diluted with 1000 volumes of odour free air to reach the odour detection threshold, then the odour concentration of the sample would be given as 1000 OU. The stack odour monitoring results are presented in Figure 8. Odour emission limits are not specified in the EA. Therefore odour concentration monitoring results cannot be compared against any specific licence or standards. However, based on the odour profile of Figure 8, it is revealed that most of the time the odour concentration was below 2000 OU.

During the site inspection, it was also observed that odour was not detected at the site boundary or at the front car park but could be readily noticed at various downwind locations inside the plant site, for example near the plant room. Fugitive odour would require careful management measures in any larger scale plant. It is interesting to compare the current Paraho II oil processing plant odour emissions data with the Stuart ATP plant monitoring data of 2000 and 2001. By this time, average odour concentrations from the former operation had been significantly reduced by over 90% and were in the order of about 25,000 to 50,000 OU (PAE et. al. 2002). At that level, odour complaints were still being caused by the former operation. In contrast, the stack odour concentrations for the QER operation are reduced to less than 3300 OU (see Figure 8) with the new technology.

In relation to odour, the QER environmental authority prohibits the activity from causing any environmental nuisance due to noxious or offensive odour. The TD plant has operated without causing any such nuisance.



**Figure 8: Odour emission profile of plant thermal oxidiser (PTOx = RP1) and dryer regenerative thermal oxidiser (RTO = RP2) (odour concentrations reported as odour units).**

**Conclusions - Air**

The data and information on which the review of air emissions considered in forming these opinions constitutes an adequate basis for the opinions. The stack measured level of air emissions were compared against the emission limits specified in the QER Environmental Authority (EA) No. Min 100479806. The measured emission data demonstrate compliance with the emission limits specified in the QER EA.

The measured level of air emissions were also compared against the New South Wales DECCW (ex EPA) Protection of the Environment Operations (Clean Air) Regulation. These are considered best practice source emission criteria. The stack emissions monitoring data demonstrate achievement of these concentrations even though the TD plant was not specifically designed to achieve them. QER has installed and is trialling gas treatment technology to further reduce emission concentrations in any scale up of the plant. It is expected that any commercial plant would also be likely to meet best practice emission standards, based on this information.

In reaching its conclusion about QER's TD plant air pollution control systems, the EHP officers compared the QER adopted technology with the industry best practice pollution control technology, and found that the TD plant incorporates best practice environmental management. This provides a marked contrast to the air emissions performance of the former operation by Southern Pacific Petroleum that was discussed in Chapter 2.

## 5.4 Solid waste management

Oil shale mining and processing generates a large quantity of solid waste, primarily overburden and inter-burden and processed shale. A key issue with these wastes is whether they have potential to pollute the environment via mechanisms such as oxidation to produce acid mine drainage or saline drainage. This is especially a concern due to the proximity to and potential connectivity to the waters the Great Barrier Reef World Heritage Area, including nearby Port Curtis.

As any mining plan would be expected to include retention of freshwater lakes from mining voids as well as significant waste placement areas, understanding the properties of wastes and likely leachate quality formed under field conditions is considered crucial to understanding and managing potential environmental impacts.

QER has conducted a comprehensive peer reviewed program to assess the acid mine drainage and leachate potential of mine waste and processed shale. This test work is summarised in a report by Terrenus (2011). The results to date illustrate that generally spoil and processed shale materials are largely benign producing no acidic mine drainage with only a small proportion classed as potentially acid forming. Low to no toxic metal/metalloid production has been measured, depending upon which metal/metalloid species is considered. Salinity has been assessed as low to moderate depending upon the material.

With respect to the water quality characteristics of run-off or seepage from mining wastes, there are no specifically relevant Australian or Queensland leachate quality guidelines as, for example, there are for the classification of wastes directed to landfills. Water Quality Guidelines such as ANZECC / ARMCANZ (2000) are focussed on receiving environmental values such as stock use, various groundwater uses, recreation and aquatic ecosystem protection.

Therefore, it is not appropriate to directly compare water quality results from laboratory-scale characterisation studies to absolute receiving water quality guidelines other than to identify broad scale risks. QER intend to use the water quality data generated through the laboratory-scale characterisation programs for geochemical, hydrological and hydro-geological modelling, for the design of scaled-up field programs, and to aid in the mine design.

There is very low, if any, organic loading in leachate. Material levels of nitrogen have been identified in some leachates, in concentrations sufficient to trigger further investigation. Salinity and nutrients are an important issue for void water management as they can cause adverse water quality impacts. As these are lab scale trials, QER plan further testing using larger field methods. These will involve several tonnes of material of sizes expected to be produced by the plant. It is also expected that the quality of pit waters, which are known to become acidic, will be taken into account in field testing.

It is understood that further field work combined with information from design and siting of the overburden/waste placement areas will provide more detailed information on seepage/run-off quality (physical and chemical) from mining wastes enabling a more informed assessment of impacts on receiving water quality objectives. The results from the geochemical characterisation program will be utilised for mine planning purposes. The data will be an important consideration when designing scaled-up test programs and would be useful for the impact assessment of various aspects of the project, for example groundwater solute transport and final void impact.

The quality and comprehensiveness of the characterisation work to date together with ongoing work by QER on further treatment and reuse of stripped sour water, (which is a potential large load of nutrients and salinity to leachate), lend confidence to a view that QER will develop a solution allowing future in-pit disposal of mining waste, a practice currently prohibited under the TD Plant environmental authority conditions.

## 5.5 Noise issues

There have been no noise complaints received by either EHP or QER about the operation of the demonstration plant. There are a number of obvious noise sources that stand out and for a large plant would likely require attention to acoustic design and treatment. These include the compressor station, conveyance of rocky lumps that create clunking noises on metal transfer surfaces, crushing and screening equipment, and bag house cleaning pulses.

## 5.6 Re-vegetation of waste

One possible concern with retorting large volumes of oil shale is whether the resulting processed shale would be amenable to revegetation which typically occurs progressively as the mine progresses and ultimately prior to mine closure. Inspection of the mine site showed ready establishment of pioneer species (e.g. Acacias) on disturbed lands, including areas underlain with processed shale.

QER has provided photographs of vegetation establishment success on waste deposits (see Plates 7 and 8). This promotes confidence that revegetation to a natural ecosystem, as envisaged by the environmental authority conditions, will be achievable.



**Plate 7: Examples of revegetation of mine and processing waste including processed shale.**



**Plate 8: Examples of revegetation of mine and processing waste including processed shale.**

## 5.7 General housekeeping

The standard of housekeeping, which essentially involves environmentally relevant tidiness, at the technology demonstration plant is exemplary. Good housekeeping for any activity typically translates into significantly reduced potential for stormwater contamination, odour, dust and other fugitive air releases. On another level, good housekeeping typically inculcates staff culture to reinforce an attitude of striving for environmental excellence.

## 5.8 Resource sterilisation issue

An issue which arose with previous proposals for expanded oil shale development on the Stuart resource was that deeper oil shale deposits were to be land-filled over with hazardous processed shale and other process wastes. Once this was done, extreme difficulties were foreseen in later accessing the deeper deposits.

This was due to the fact that it would involve disturbing the processed shale landfill, a process which may lead to environmental harm from the mobilisation of contaminated dust or sediment transport during the disturbance.

This sterilisation issue and potential impacts related to the mining of deeper valuable oil shale deposits that would have been covered with contaminated processed shale and other wastes was a matter raised by the Coordinator General in considering the Stage 2 Environmental Impact Statement submitted by SPP. Stage 2 was a 'state significant' project which was assessed by the State Government and also the Commonwealth Government by environmental impact statement.

Given the results of dioxin monitoring show that they are not being created in concentrations that would cause concern, the favourable findings relating to potential acid formation from mining and process waste, and assuming positive outcomes from waste water treatment investigations to minimise contaminants co-disposed with the processed shale, this issue is likely to have been successfully resolved by QER.

Information provided by QER has also shown that the Paraho process to be effective and efficient in recovering oil from the oil shale.

## 5.9 Community relations

The former mine and industrial plant operated by SPP generated thousands of complaints including concerns about odour and dust impacts, alleged ill-health effects and dioxin production. The current oil shale processing plant, in contrast, has not generated a single complaint to EHP.

To build community understanding of its activities and plans, QER has constructed and staffed a visitor education centre opposite its processing plant. The centre explains what oil shale is, how it is mined and processed, QER's environmental performance, its synthetic fuel products and visions for the future.

A log of visitor's comments is kept to provide feedback on community attitudes.

QER has also carried out regular surveys of attitudes of the Gladstone community for the past four years, with the most recent undertaken in late August/ early September 2012. The surveys have been conducted by a recognised research organisation, Woolcott Research. Whilst the majority of surveys conducted since 2008 have included national and Queensland components (1300 respondents in total with 400 in Gladstone), the most recent survey (Sept 2012) was of Gladstone residents only. This involved around 600 respondents. The survey was broadly based, including respondents evenly determined across gender and demographic categories.

The survey shows strong majority support for QER's technology demonstration plant project to allow Australia a capability to produce its own heavy transport fuels. While QER reported finding that there are some concerns regarding health, environmental and town planning issues, a strong majority of people in Gladstone believe industrial development is important to the community's economic welfare and needs to be maintained.

QER observed that there is some general concern around industrial development which it attributed to the large scale industrial projects currently under construction and a range of other major capital projects which are planned for Gladstone, in progress or recently completed. Against this background, QER feels the support it encountered for development of oil shale is even more significant. The surveys did uncover some opposition to the project. However, it was found that 40% of those who oppose the project have heard of QER. QER's analysis suggested that a number of respondents have based their adverse opinions on what they had heard about the previous plant, and some due to the general development concern in Gladstone as discussed above.

Supportive articles have also appeared in the local press, once a significant critic of the former operation. All these factors contribute to a view that QER has taken strong actions to overturn the past adverse legacy of oil shale processing on site and earn a licence to operate with a positive social footprint.

## 6. Conclusions

### 6.1 Comparison of QER's operation with previous operations

It is clear that QER's technology demonstration plant operation has numerous apparent advantages over the previous operation which used different technologies. The Paraho II positive features have been evident in a greatly improved environmental performance compared to that of the previous technology. These advantages are outlined below.

#### Dioxins

The technology demonstration plant does not have the dioxin formation problems that occurred during the earlier operations at the previous operation. Monitoring data show dioxin concentrations are within EHP environmental authority standards. This may be due to the fact that the process does not hold significant quantities of processed shale fines over an extended period of time in the temperature range that favours de-novo synthesis of dioxins. Also, in the Paraho retort heating mode of operation, there is no combustion of the oil shale.

#### Air emissions

The concentrations and mass emissions of QER's technology demonstration plant air emissions have been consistently in compliance with the emission limits of QER's environmental authority. No complaints of offensive odours or adverse health impacts of the releases have been received. Best practice air emission control technology is fitted to the plant. This contrasts with the former operation which suffered breaches of emission limits for SO<sub>2</sub>, particulate and NO<sub>x</sub> as well as causing a serious offensive odour nuisance. It is expected that best practice emission controls could be easily fitted to a larger Paraho style plant.

#### Plant upsets

QER's technology demonstration plant appears much simpler to operate than the previous plant. This means there is less chance for human error or equipment malfunctions to create problems. The Paraho II has a single chamber in the retort versus three, and shale moves down vertically under gravity rather than horizontally due to rotational forces. The ATP had to continually turn to expel the hot processed shale material, even if there was a plant upset condition. The Paraho also has less moving parts and less output streams than the ATP. These are:

- Paraho: retort product gas, processed shale, gas-fired heater emissions
- ATP: retort product gas, processed shale, combustion flue gas, preheat flue gas.

There are three ways to operate the Paraho II oil shale processor compared to only one for the ATP. QER have advised that the different modes provide versatility to process a range of different oil shales. In summary, the current process appears more robust and seems less prone to upsets than the previous process. QER report long plant runs uninterrupted by equipment breakdown.

#### Noise

The most significant noise sources for the QER's technology demonstration plant are the noticeable clunking of rocks in feeding the dryer and retort. The other main sources are compressors located at ground level near the retort.

There have been no noise verified complaints and excessive noise is not evident outside the plant site. Nevertheless, QER's technology demonstration plant is only one one-hundredth the size of the previous plant. Noise emissions from these sources would be expected to be incrementally greater with a much larger Paraho plant. Noise abatement measures applied to quarry industries should be readily transferable to the Paraho process to reduce rock clunking noise. Standard noise abatement measures such as acoustic enclosure could also be readily applied to the compressor station. Another potential noise issue that may arise with a large scale up would be noise from crushing and screening raw shale. Again, standard noise abatement measures used in quarries could be applied to these sources.

#### Dust

QER's technology demonstration plant doesn't produce very fine processed shale like the previous plant. Paraho II is a lump processor as compared to the ATP which was a fines processor. This translates into a reduced potential for dust nuisance compared to the previous operation.

In the event of a plant upset such as a power outage, QER's technology demonstration plant doesn't have to be kept turning and emptied of very hot processed shale and part-processed oil shale as was the case for the previous plant. The shale can be held in the processor indefinitely while the process steps that result in heating of the oil shale e.g. hot gas recycle and or combustion air introductions can be suspended.

A power outage will not cause any plant upset nor cause any need to evacuate shale out of the retort. Paraho processed shale exits the processor much cooler at approximately 150 °C as opposed to 415 °C for the ATP. This creates less of a risk should a significant incident with processed shale handling occur. Another potential dust issue that may arise with a large scale up would be dust emissions from crushing and screening raw shale. Again, standard dust abatement measures used in quarries could be applied to these sources, for example, water sprays, enclosure and dust extraction systems.

## **Stack odour**

The belt dryer at QER's technology demonstration plant operates at a much lower temperature and is thus less likely to overheat raw oil shale and create offensive odours than the rotary dryer at the previous plant, which reached temperatures of the order of 600 °C. The installation of a bag-house and regenerative thermal oxidiser to treat dryer flue gases is also an improvement on the former operation and also acts as a fail safe and to further minimise odorous emissions.

The partial incineration of odorous ATP preheat steam provided by a burner at the base of the ATP main stack suffered reliability issues as it sometimes had to be turned off due to gas safety requirements when high odours were expected. QER have not experienced and do not expect any similar reliability issues with the two thermal oxidisers.

Retort off-gas is treated to recover oil and remove solids prior to being recycled back to the retort. Excess fuel gas is exported on the TD plant to be incinerated in the thermal oxidiser. This facilitates odour reduction. There is also no equivalent waste stream to the ATP's very odorous preheat steam with the Paraho processor.

Shale oil odour (similar to that detected from a steam train or oil refinery) was discernible locally around the plant site and downwind near the control room. No noticeable emissions from processing equipment were evident and the most likely source was product. Measures to minimise fugitive odour e.g. moistening processed shale, sour water, product tanks would be required in a large plant. Stack odour is expected to be much reduced due to the use of thermal oxidisers.

## **Fugitive odour**

Shale oil has a distinct smell. This odour was readily discernible at several places around the processing plant site, but not beyond the boundary. This observation is consistent with the record of nil odour complaints for the facility in over one year's operation. Given that the plant operates at only one percent the processing rate of the previous plant, it will be necessary that all reasonable and practicable measures to minimise fugitive odour e.g. processed shale moistening, sour water, product tanks would be required in a larger plant.

## **Waste and process characterisation**

As evident from section 3.2, QER has placed a strong emphasis on detailed characterisation of waste streams and understanding of the process to assess environmental implications. This lack of data was a significant issue with SPP's stage 2 EIS process.

## **Water**

QER's technology demonstration plant has not had any incidents of oily waters, sour water or flare seal water being released from the process or to any waters. The sour water is treated via an improved steam stripping process, namely a two stage versus the single stage stripping process used at the previous operation. Operating conditions in each stripper can be separately optimised for ammonia and hydrogen sulphide removal instead at an average compromise condition for these two contaminants.

Sour water, even following steam stripping, contains environmentally significant concentrations of carbon, nitrogen and sulphur compounds. Large volumes of stripped sour water if disposed in a manner where such wastes are in contact with or migrate to surface or groundwater could pose significant risks due to the large mass loads of contaminants involved. Carbon compounds generally reduce dissolved oxygen levels as they are oxygen demanding substances, ammonia nitrogen is a toxicant to aquatic life and a nutrient that can promote harmful algal blooms. Sulfur compounds increase salinity and as sulfate can, at elevated concentrations, adversely affect suitability of the water for stock or human drinking use.

These mass loads are not permitted under the current environmental authority conditions to be co-disposed with processed shale in the mining pit as the portions of the mining pit at mine closure may be filled with water to create a freshwater lake which could overtop in high rainfall events and flow into Port Curtis. This is because, via the above mechanisms, poorly treated sour water may adversely affect environmental values of groundwater and surface waters.

The administering authority has previously advised QER that best practice secondary or tertiary treatment of stripped sour waters or equivalent would be necessary. This is what occurs with wastewaters of this nature at oil refineries in Brisbane. This approach is consistent with the waste management hierarchy prescribed in the Environmental Protection (Water) Policy 2009.

QER have indicated that sour water steam stripping may not be the preferred approach for the project going forward, with an alternate more effective treatment to recover nitrogen and sulphur currently being investigated. The final concentrations of contaminants in the treated waste water are not known to EHP at this stage. However, the commitment and efforts to resolve other environmental issues by QER provides confidence of a positive resolution to this issue.

## **Plant housekeeping**

The standard of housekeeping, which essentially involves environmentally relevant tidiness, at the QER site is exemplary. The site is much tidier than the previous operation. Good housekeeping for any activity typically translates into significantly reduced potential for stormwater contamination, odour and other fugitive air releases. On another level, good housekeeping typically inculcates staff culture to reinforce an attitude of striving for environmental excellence.

## **Community support**

QER has demonstrated a solid environmental performance and a commitment to achieving excellence in environmental management and sound community support. This is exemplified by the comprehensive monitoring program to characterise processes, emissions and environmental impacts, openness to receiving feedback and the visitor information centre at the plant site. This support contrasts with the adverse community reaction to the previous operation.

## **Greenhouse gas**

Greenhouse gas intensity of synthetic fuel production was a significant criticism by some members of the community in respect of the previous oil shale plant. SPP were researching measures to reduce or offset greenhouse gas intensity of their operation, including improved energy efficiency and offsets using forestry programs.

QER are monitoring greenhouse production and researching possible greenhouse gas reduction measures for scaled up versions of the plant, with a focus on increased energy efficiencies. There are also now in place measures to price carbon emissions which may impact on what options are favoured for a future larger plant depending upon the scheme in place at that time.

Whatever approach is taken, but particularly for energy efficiency gains, it will be important for QER and EHP to establish whether any heat recovery mechanisms for greenhouse gas emission reduction purposes slow down the gas cooling process or prolonging the residence times for processed shale at critical temperatures that favour de novo dioxins formation so as to avoid inadvertently creating these compounds.

## **6.2 Implications for an expansion of oil shale processing by QER at Gladstone**

The advantages of the Paraho II processor and methodical research based approach to development of the project hold the promise of improved environmental performance for larger scale oil shale processing at this site as compared to the experiences with previous operation of the project. This would be expected to be reflected in reduced emissions per unit of production e.g. odours, sulphur dioxide, fugitive emissions, particulates and less likelihood of adverse operating conditions.

There are still numerous environmental issues to be managed in any scale up of the activity, but the nature of these, given the substantial body of work QER has undertaken on this particular process and this oil shale deposit, are not materially different than any other proponent would typically need to address via an environmental impact statement process under State and Commonwealth legislation.

There are several caveats that should be noted in considering this assessment. This review is based on the site inspection and the evaluation of environmental monitoring of a small demonstration plant of 2.5 tonnes per hour.

The emissions and impacts from a large scale commercial plant may be different as compared to the demonstration plant. It needs to be noted that the Paraho II technology demonstration plant has a nameplate throughput only one percent of the previous plant - 2.5 tonnes per hour versus 250 tonnes per hour.

The performance of a much larger Paraho plant can not necessarily be predicted by multiplying emission rates based on 2.5 tonnes per hour by a scaling factor commensurate with a greater production rate. It is likely that for some air contaminants, further emission controls may be necessary to achieve legislated air quality standards. Also, although fugitive emissions do not present a problem at the current plant size, greater control will likely be needed to manage these in a larger plant. Options include avoidance, and additional fugitive odour capture and treatment.

Findings are based on information from departmental files, information provided by QER and the observations made during the site inspection. This review also was limited to reviewing the QER compliance with legislation administered by EHP or statutory instruments issued by EHP, for the activities that have the potential to cause air, water and noise contamination or environmental harm. It did not address resolution of conflict of interest issues that arise sometimes between open cut mining and other land uses.

It is noteworthy that QER has also demonstrated a commitment to openly identify and resolve environmental issues in a cooperative manner with State Agencies and the community, using best practice approaches.

### **6.3 Lessons for other oil shale proposals**

Oil shale processing involves a large range of potential environmental impacts which, if not appropriately managed, may adversely impact on the environment and the community. These potentially include:

- dioxins in air emissions and solid wastes
- excessive dust emissions
- criteria air pollutants such as volatile organic compounds, particulates, nitrogen oxides and sulphur dioxide
- hazardous air pollutants such as PAH, reduced sulphur compounds and hexavalent chromium
- noxious and offensive odours
- water pollution from suspended sediments, hydrocarbons, oxygen demanding substances, nitrogen and sulphur compounds in sour water that may create nutrient enrichment and salinity problems respectively
- processed shale disposal
- noise
- land use conflicts with other land uses.

Oil shale processing using underground methods such as in-situ retorting and upgrading would involve additional issues, particularly risks to groundwater quality. Oil shale mining using open cut methods entails the same environmental issues that arise in other open cut operations such as coal mining. These typically may include land disturbance, conflict with other land uses, mining voids, potential for acid mine drainage and saline drainage, sedimentation, excessive dust, stream diversion, groundwater impacts, loss of flora and fauna and water quality issues.

The mine and processing plant that previously operated at the Stuart site showed the large scale environmental and community impacts that can occur if environmental issues are not adequately investigated and resolved during scale up operations. The ATP was a 75 times scale up of a laboratory pilot plant developed in Canada to successfully process soils contaminated with oils and hydrocarbons.

The ATP used was a very large scale application of complex technology originally designed for processing something different from oil shale. It was a plant designed to research oil shale production yet did this at a semi commercial scale, processing 100 times more raw shale per hour than QER's TD plant. The ATP also was not fitted with best practice air pollution control technology. For example, it lacked the thermal oxidisers and bag houses fitted to QER's technology demonstration plant. Issues which became problematic during scale up such as odours and dioxins were not characterised in the preliminary stages, relying on remedies to be trialled as problems occurred.

By way of contrast, the QER Paraho scale up was only 2.5 times and of a simpler technology, already well proven on oil shale. QER spent two years processing 8000 tonnes of Queensland oil shales in a 1 tonne per hour Paraho retort in Colorado obtaining process, engineering and environmental data.

A comprehensive monitoring program of the process, its emissions, wastes and impact on the community and environmental setting has been integral to QER's operations. QER proposes a staged well researched methodical approach to project development (Figure 9) which if followed should ensure that the environmental operating difficulties that beset the larger-scale ATP facility are avoided.

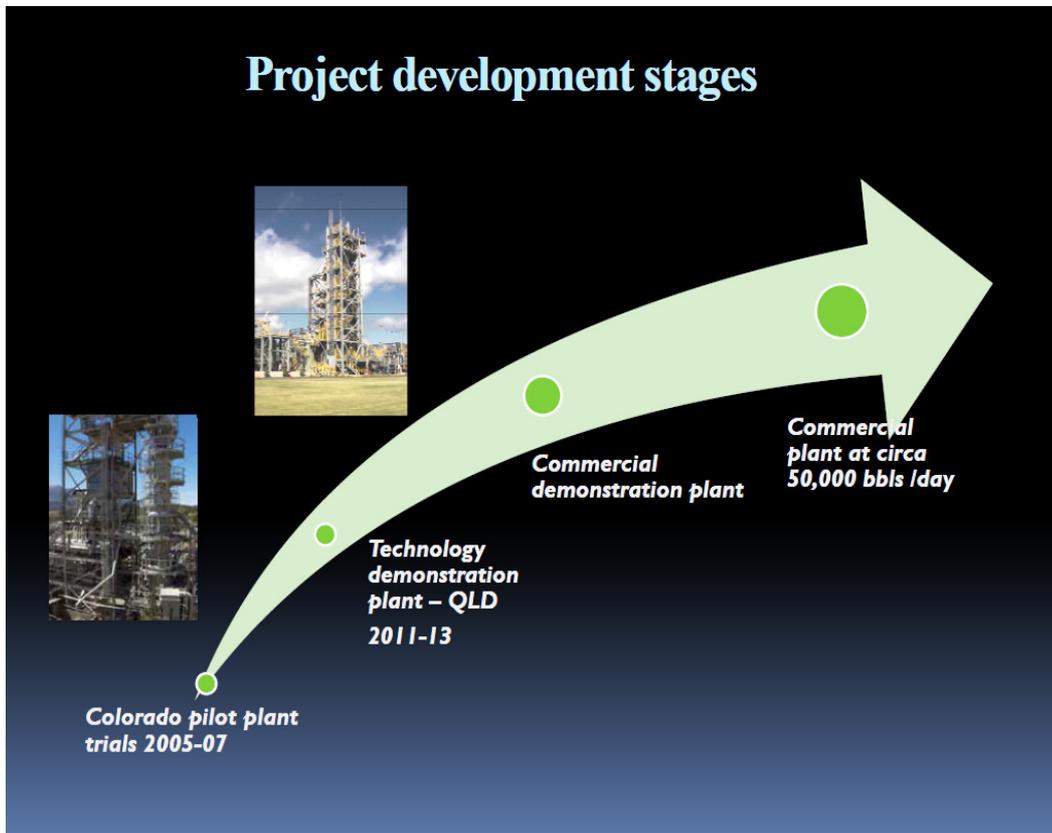


Figure 9: Stage development approach proposed by QER.

Key features of QER's successful program are considered recommended benchmarks for other proponents. These include:

1. comprehensive characterisation of the environmental setting in which the activity takes place, including the natural environment, acoustic environment, groundwater, surface water and air quality
2. choice of a proven above ground retorting technology, thus minimising potential for harm to groundwater by using underground methods
3. adoption of best practice environmental management to deal with environmental issues in processing and up-grading products
4. implementation of a comprehensive monitoring program of the raw feed quality, the extraction process, its emissions, wastes and impacts on the environment and the community
5. openness and strong efforts at engendering community support
6. sound financial backing to allow sufficient resources to be allocated to resolving any unforeseen environmental issues that arise
7. doing a trial at a size that is commensurate with the proven experiences with that technology so that the inevitable technical, engineering and environmental issues are readily manageable.

The sound performance of the Paraho processor does not automatically translate to sound environmental performance by other oil shale extraction technologies. There are a large range of technologies, above ground and underground, trialled and mooted, from nuclear explosions, burning oil shale underground thorough in-situ induction heating, electro-fracking, many above ground retorting technologies and possibly solvent dissolution techniques. QER's work concerns above-ground retorting using proven technology.

The United States has the majority of the world's oil shale resources but no commercial oil shale industry. The richest and most abundant oil shale resources are on US Federal lands (Rand 2005). To allow development of an oil shale industry, the US Government has in place a long term program which involves permitting a small number of well-resourced and monitored trials of oil shale technology. Prior to these research and development leases being granted, potential environmental impacts must be addressed by a public impact assessment process.

The development of an economically, socially and environmentally sustainable oil shale industry is envisaged in the USA as a long-term, methodical, well researched undertaking, as illustrated in Figure 10 (Rand 2005). This methodical approach is also obvious in the work being undertaken by QER. It is recommended as a way forward for other proponents. It would also be advantageous for Queensland agencies to follow progress and lessons in oil shale development in other jurisdictions that have sound environmental monitoring and assessment processes, such as the USA and European Union.

**Stages of Oil Shale Commercial Development**

Development stage	Research and development	Scale-up and confirmation	Initial commercial operations	Production growth	
Facility size	Laboratory to pilot plant	1,000–5,000 bpd <sup>a</sup>	> 50,000 bpd	> 100,000 bpd	
Years to transition <sup>b</sup>	0	6–8	12–16	>20	>30
Total production (million bpd)	N/A	N/A	>0.1	>1	>3

<sup>a</sup>bpd = barrels per day.

<sup>b</sup>Beginning with transition from research and development.

RAND MG414-3.4

**Figure 10: Staged approach suggested to commercial scale oil shale development (Rand 2005).**

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