Submission to the Australian Government Senate Inquiry into the protection of Aboriginal rock art of the Burrup Peninsula

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Summary and recommendations

TOR b) Projected emissions and likely impact on rock art, human health and the environment

Uniqueness of the rock art

- Burrup Peninsula has the largest concentration of ancient rock art in the world showing a continuous history of mankind living in a changing environment for over 40,000 years
- The rock art has the oldest known images of the human face, extinct mega-fauna, Tasmanian tigers, hunting traditions and mathematical representations or geometric forms
- Few Australians or members of the international community are aware of the existence, extraordinary beauty and diversity of this priceless and irreplaceable archaeological treasure.
- The rock art is far older than the French cave paintings at Lascaux (17,000 years), Stonehenge (4,500 years) or the pyramids (4,500 years)

Projected emissions

- Projected emissions from the new ammonium nitrate plant are extremely high
- 25.2 tonnes per year of dust sized ammonium nitrate particles are to float into the air
- Total acid load to be emitted is the highest on the international scale and known to kill fish in rivers, damage stone statues and buildings, and change vegetation
- The emissions will accumulate on rock surfaces in this arid environment and continue to increase over time
- Evidence of changes to the Burrup environment from existing industry and shipping are already apparent

Likely impacts on rock art

- Preservation of Burrup rock art depends on maintaining the integrity of the outer, desert varnish, layer of rock surfaces
- Desert varnish is formed in arid, alkaline environments by specialised microorganisms at the rate of less than one-tenth of the width of a human hair per 1000 years
- Acid emissions degrade and change the colour of desert varnish
- Ammonium nitrate particles will stimulate the growth on rock surfaces of adventitious bacteria, fungi, algae and lichens, which are known to degrade desert varnish and rock engravings
- Scientific evidence shows that the proposed emissions will destroy desert varnish and rock art over time and have detrimental impacts on human health

Recommendations for Governments and industry

- Rock art preservation requires prevention of all ammonium nitrate particle emission and limits to acid load from all Burrup industries to less than 25 milli-equivalents per square metre per year
- Such limits are possible using current scrubber and other technologies
- Ships entering the Port of Dampier should be regulated to use fuel containing a maximum of 0.10% sulphur, which is the worldwide standard for sensitive environments
- Australian authorities should emulate other countries in protecting their heritage, with potential for economic returns from tourism that may approach $10 million annually
- The French established replica drawings in adjacent caves at Lascaux to eliminate pollution from humans, while Britain is building a £1.4 billion tunnel to reduce vehicle emissions at Stonehenge

TOR c) the accuracy and adequacy of reports used by Governments

CSIRO reports

- Governments and industry continue to use three CSIRO reports to justify establishment of the ammonium nitrate production facility on Burrup Peninsula and limits to its emissions
- These three reports are flawed in terms of scientific methods, analyses and/or interpretations
- There are serious concerns about the appropriateness of instruments, methods used to measure colour and mineralogy changes at Burrup rock art sites

2007 Report

- One study involved hourly cyclical temperature and humidity changes during fumigation of Burrup rock samples with a combination of gases at two concentrations, with and without dust
- The study used gas concentrations below those projected for the ammonium nitrate plant and existing Burrup industry
- The study included either no treatment replication or insufficient replication for statistical analysis and was of no value for drawing conclusions
- A second study measured the effects of immersing iron ore in either dilute of concentrated organic compounds, acids or ammonia and measured changes in colour and mineralogy
- The results from this study have no relevance to rock art because the measurements were made on iron ore and not Burrup rock surfaces

2008 Report

- Experiments measured climatic conditions and emission concentrations at sites across Burrup Peninsula and control sites over two periods to 2008
- The experiments were sound, the data well analysed and the report well written
- Without measurement of the buffering capacity of Burrup rocks, the author concluded rock art would withstand the highest critical acid load on the international scale
- The conclusion was made based on a previous report evaluating critical acid loads for different world environments, and as stated by an author of that report was inappropriate for rock art

Colour and mineralogy changes at rock art sites from 2004 to 2014

- The authors claimed there had been no change in colour of background rock or engravings over the time of measurement without appropriate statistical analysis
- The results have been reanalysed and the CSIRO conclusions have been shown to be wrong
- An independent reviewer of the original reports and the data reanalysis report questioned seriously the integrity of the CSIRO data

CSIRO acceptance of errors

- The scientists involved in studies initially accepted the errors identified, but refused to acknowledge them after consultation within CSIRO
- The CSIRO organisation appears to be more concerned about its reputation than the fate of the world significant archaeological heritage of Burrup rock art

Governments and industry

- The Western Australian Government, Yara International and Orica should accept and acknowledge that the CSIRO reports misrepresent the effects of industrial emissions on rock art
- These organisations should take an ethical position and ensure that no ammonium nitrate particles are emitted into the atmosphere and the acid load from combined fertiliser and ammonium nitrate facilities is less than 25 meq/m^2/year

TOR d) the rigour and adequacy of the monitoring, analysis, compliance and enforcement

Granting of licences by Governments

- Yara Pilbara Nitrates have sought via Yara Pilbara Fertilisers a licence to operate the ammonium nitrate plant via an amendment to two existing licences: one for the fertiliser plant and the other for construction of the plant
- The amendments required to these licences were not stipulated
- The existing licences have conditions that are inadequate for appropriate limitation of emissions from the ammonium nitrate plant for preservation of the rock art
- The licence conditions do not apply during Start Up, Shut Down or Upset conditions, which are at least 5% of the time
- The current limits set for particle emission from the plant appear to be approximately 1000 times that set by a meeting of Environment Ministers in December 2015
- The Western Australian and Federal Governments have, at the request of the company, modified conditions set for company operations to increase emissions or reduce monitoring of the rock art

Compliance with licences

- Reports by Yara Pilbara Nitrates to State and Federal Governments show significant areas of non-compliance with licence conditions in relation to rock art monitoring and emissions measurement
- The company is required to measure PM_{10} particles, NH_3, NO_x and SO_x concentrations at five sites, including three rock art sites, and survey rock art within a 2 km radius from the plant
- Results for dust particle emissions have been reported for one site at a boundary fence only and no results from chemical emissions have yet been reported
- Dust measurements are not credible, with a maximum value of 112,020.5 $\mu g/m^3$ and a minimum value of -90,649.28 $\mu g/m^3$, when the national limit is 25 $\mu g/ m^3$: negative values are impossible
- The 2016 report to EPBC did not include information about rock art monitoring

Enforcement of licence conditions

- Governments appear to have taken no action in relation to non-compliance with licence conditions except to reduce the stringency of conditions at the request of the company
- These actions fit with Federal Government Compliance Monitoring Program, which found that 20% of projects with EPBC conditions were non-compliant, but none were prosecuted
- Instead, Governments relied on administrative measures such as variations to conditions of approval, revisions to management plans and conservation agreements
- These actions suggest that short term financial returns from industry are more important than saving for future generations the priceless and irreplaceable rock art on Burrup Peninsula

Actions needed to preserve rock art for future generations

- Governments should set strict limits on emissions of zero ammonium nitrate release to the air and a value for acid load of less than 25 $meq/m^2/year$
- Breaches of licence conditions, even during Upset conditions, should be prosecuted to ensure compliance by the company
- Preservation of the rock art for future generations, with great potential for substantial economic returns from tourism

TOR e) Projected level of fugitive gas and nitric acid leaks

Record of leaks

- Yara Pilbara Fertilisers and Yara Pilbara Nitrates have a poor record for fugitive gas and nitric acid leaks, plus other occupational health and safety breaches
- Incident Investigation Summary Reports from Yara Pilbara indicate there were at least 24 reportable incidents from January to 17 November 2015
- On 23 March 2016, 14 tonnes of ammonia were released into the atmosphere from the fertiliser plant, but atmospheric ammonia levels were not required to be recorded
- There have been two serious nitric acid leaks, one producing atmospheric concentrations for oxides of nitrogen at 1,160 mg/m^3

Government actions required

- Fugitive gas and nitric acid leaks are not covered by current Government regulations, because "Upset" conditions are exempt
- Fugitive leaks of gases and liquids from the industrial sites on Burrup Peninsula must be covered by the same emission standards as normal operations, if the rock art is to be preserved
- Prosecutions should be enforced whenever emissions exceed licence conditions, to ensure future fugitive leaks are prevented

TOR h) any related matters.

Need for continuous measuring of emissions, rock surface changes and simulation modelling

No certainty of continuing measurements at rock art sites

- The Burrup Rock Art Technical Working Group advising the Western Australian Government on studies relating rock art sites on Burrup Peninsula was disbanded on 30 June 2016
- There appear to have been no policy statements from the Western Australian Government on continuation of colour and mineralogy measurements at rock art beyond 2016
- Comprehensive measurements of emission concentrations in the air at Burrup rock art sites have not been reported since the study of Gillett in 2008

Need for more extensive measurements

- Sound science shows the thickness of rock patina will decrease and its colour become lighter, redder and more yellow with increased acidity and nitrogen deposition from industrial emissions
- To understand these changes, all gaseous and particle concentrations in air, anion, cation, pH and nitrate concentrations on rock surfaces, as well as microbial activity, must be measured
- An estimate of the future rate and extent of this damage through computer simulation modelling would greatly assist management decisions about controlling the environment to preserve rock art

Inadequacy of current measurements and compliance

- The integrity of scientific methods used by CSIRO and their interpretation of results have been widely criticised
- The timeliness, completeness and accuracy of reports by Yara Pilbara Nitrates are extremely poor
- These two organisations have proved themselves unsuitable for being trusted to make sound, timely and unbiased measurements of emissions and their effects on rock art
- A new, more comprehensive and industry independent scientific study is needed to help preserve rock art on Burrup Peninsula

A new scientific monitoring program

- Friends of Australian Rock Art, The Murujuga Aboriginal Corporation and the Centre for Rock Art Research + Management at the University of Western Australia are setting up a new research program
- The research is planned to be completely open to the public, governments and industry, with all information being made available through a website, with emissions measurements in real-time
- The research to be conducted, the national and international experts to be involved, the management structure and the cost have been determined and funds are currently being sought
- The program is planned to run over five years at a cost of approximately $500,000/year

Opportunities for Government contribution

- Funds are not being sought directly from industries on Burrup Peninsula
- There appears to be a great opportunity for the Western Australian and Federal Governments to contribute to this independent research project

General comments

My concerns have always been only for the future of the petroglyph engravings on Burrup Peninsula.

I have always been open with and endeavoured to collaborate with all people I have interacted with in an effort to save the rock art and obtain the most from the data that have been collected, including Government Ministers, Department employees, members of Burrup Rock Art Technical Working Group, CSIRO and industry representatives.

Addressing specific Terms of Reference

(b) the projected additional pollution load from the Yara Pilbara Fertilisers Pty Ltd ammonium nitrate plant, including the likely impacts on the Aboriginal Rock art, human health and the environment

Projected additional pollution load

The Yara Pilbara Nitrates submission to the Western Australian Government for an amendment to the Licence to operate the Ammonium Fertiliser plant (*L7997/2002/11)* cites the following emissions into the air from Technical Ammonium Nitrate Production Facility (TANPF) operation (Table 1 of Appendix 4C of the submission; Report 1379 WA EPA 11 July 2011).

Emission	Amount released
Nitrogen Oxides (NO_x)	Up to 135 t/yr
Nitrous Oxide (N_2O)	Up to 163.7 t/yr
Carbon Monoxide (CO)	Up to 41 t/yr
Methane (CH_4)	Up to 17.8 t/yr
Ammonia (NH_3)	Condition 5 from Report 1379, 11 July 2011: Best practice pollution control technology; 19.6 t/yr under initial application (calculated from EPA Report 1379, January 2011)
PM_{10} ammonium nitrate dust particles	Condition 5 from Report 1379, 11 July 2011: Best practice pollution control technology; 25.2 t/yr under initial application (EPA Report 1379, January 2011)
Sulphur Dioxide	Trace
Carbon Dioxide (CO_2)	Up to 532.6 t/yr
Total greenhouse gas emission	Approx. 84,451 t/yr

These are large emissions, equivalent to a one tonne car travelling annually approximately 100 million kilometres. These emissions reported do not appear to cover all of the plant operations, including emissions from conveying of ammonium nitrate prills; bagging, loading and transport.

The proposed emissions of acid load into the atmosphere from the plant, at 200 meq/m^2/year, is at the highest category of the international scale for environments susceptible to acids (the highest category is greater than 200 meq/m^2/year for environments not sensitive to acid). Acid emissions of the magnitude proposed are known to degrade whole ecosystems, destroy life in lakes and waterways and to deface stone statues and stone buildings around the world. An example is the Lincoln Memorial in Washington, DC, which was built in 1922 and now shows significant damage from acid rain (Figure 1).

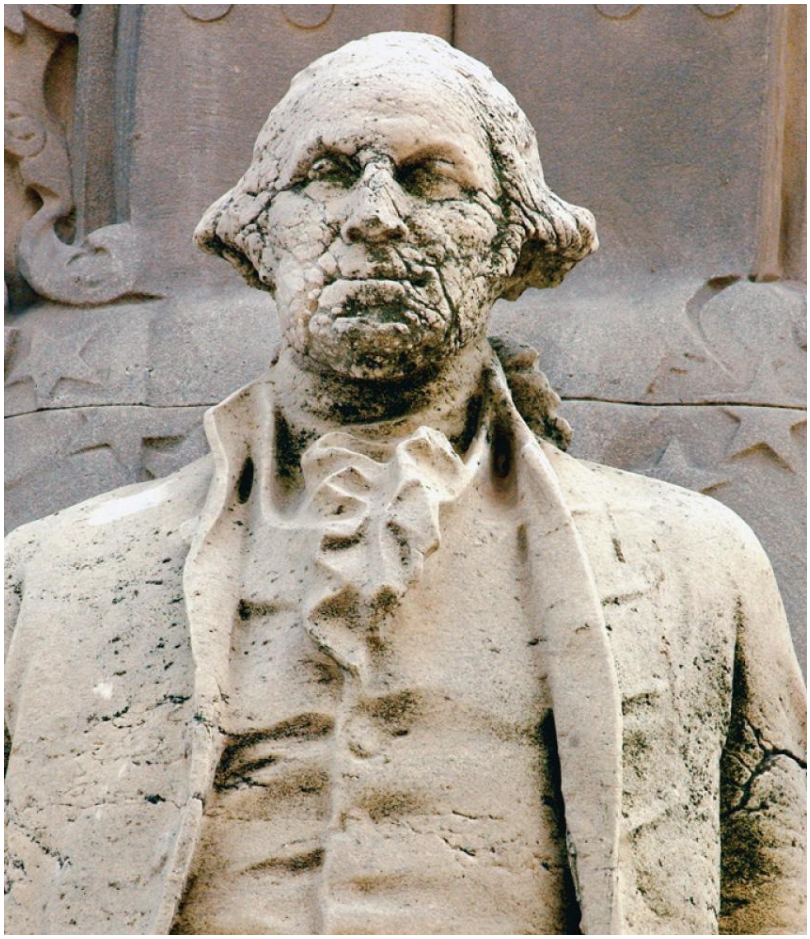

Figure 1. The impact of acid rain on the statue of the Lincoln Memorial in Washington DC.

Likely effects of additional pollution on rock art

Effects of increased acid load

There is sound scientific evidence to show that the level of emissions from the new ammonium nitrate plant, particularly when combined with emissions from the fertiliser and LNG plants, will destroy the rock art over a relatively short period of time. Effects of emissions on Burrup Peninsula are cumulative for rock art and will continue to increase over time. Rocks are not living organisms, which can digest or eliminate pollutants through their metabolism. The closest equivalent for rocks is through weathering and exfoliation of the surfaces. This is an irreversible process that will erase the rock art, but occurs to a very limited extent to rocks on Burrup Peninsula. Therefore the impact of increasing acid on Burrup rock surfaces over time is a critical factor when considering survival of the art.

Rocks on Burrup Peninsula are from igneous intrusions into the earth crust and were formed under great pressure. They are extremely hard and do not exfoliate readily into soil, but split into large blocks with flat sides. The Burrup Peninsula consists of a series of hills of stone blocks piled high, with little soil, except on the lower regions.

Although the petroglyphs are found on the flat surfaces of slow weathering, hard gabbro and granophyre igneous rock, they are extremely sensitive to increased surface acidity like calciferous limestone and marble. The petroglyphs are carved into the weathering rind of the parent igneous rock types. The weathering rind varies in thickness, depending on the time from fracture of the rock surface, from a few microns (µm) to around 10 millimetres (mm) after 30,000 years. The rind has a

hard, dark-coloured outer coating, or patina, called rock, or desert varnish. This patina is thin, from <1 to 200 µm thick depending on its age. Petroglyphs are formed by breaking through the patina into the softer and lighter coloured, weathered rock consisting largely of partially formed clays. This process provides a colour and contour contrast between the petroglyph and background rock as shown in Figure 2.

The petroglyphs rarely penetrate the hard, unaltered parent rock. The example in Figure 2 reveals a relatively recent fracture (perhaps less than 1000 years), with parent rock to the right (grey) showing the weathering rind (orange) of an ancient fracture greater than 30,000 years ago. There is an ancient petroglyph on the surface of the old fracture seen only by contour contrast because desert varnish has completely grown over the original engraving. The lighter colour markings across the petroglyph have resulted from fracture of the desert varnish when the rock fell at the time of the new rock fracture. The Figure illustrates the importance of maintaining the integrity of desert varnish for preservation of the rock art. Once the varnish is destroyed, the softer underlying weathering rock is more easily degraded.

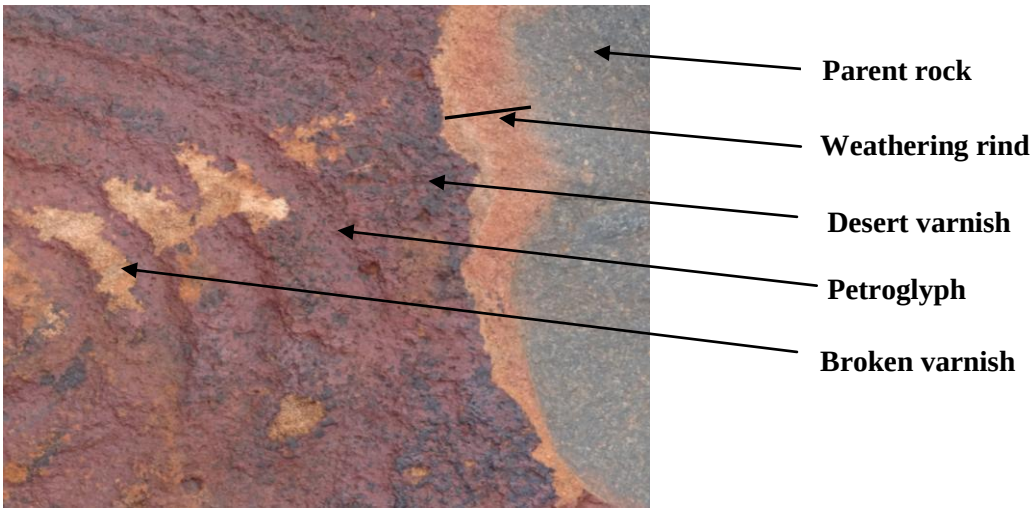

Figure 2. Burrup rock with petroglyph showing parent rock, weathering rind and desert varnish.

Desert varnish forms under low rainfall, arid environments, where rock surfaces are alkaline. The pH of normal desert rocks ranges from around 7 to 9. pH is a measure of acidity-alkalinity, with neutral =7, alkaline >7, acidity < 7 on a logarithmic scale. Desert varnish is extremely slow forming, at a rate of <1 to 10 µm per thousand years (around one tenth of the width of an average human hair in 1000 years). The desert varnish is formed by special microorganisms extracting minerals and clay from dust that lands on the rocks. The unique feature of desert varnish is the high concentration of manganese and iron compounds. Manganese and iron are concentrated by specific bacteria and micro-fungi that live on the rocks in this harsh, arid environment, where rock surface temperatures can exceed 70 degrees centigrade. The minerals are concentrated 50-300 times that found in the dust and are deposited in the outer sheath of the organisms to protect them from the harsh environment. These organisms are thought to live for hundreds of years, lie dormant most of the time and grow only when conditions are more favourable. It is thought that five of these organisms per 1000 years dying and being incorporated with clay is sufficient to form the desert varnish. Under normal alkaline desert environments, the varnish continues to increase in thickness over time.

Acids dissolve the manganese and iron compounds in desert varnish, making it thinner, weaker and lighter in colour. There is strong evidence that the acidity of rock surfaces on Burrup Peninsula has already increased dramatically since pre-industrial times. Dr Ian MacLeod (2005), former Director of the Western Australian Maritime Museum, measured acidity on rock surfaces in 2004 and found pH was as low as 4.2 compared with near neutral pH around 7 from the surface of Museum rock samples

collected before industrialisation. Most importantly, Dr MacLeod observed logarithmic increases in the solubility of manganese and iron compounds with increasing acidity of the more recently measured rocks. A theoretical evaluation, using electrochemical equilibrium principles, confirms that increasing acidity will increase the solubilisation of manganese and iron compounds (Black *et al.* 2017). Removal of darker manganese and iron compounds from the outer, desert varnish layer, and the relative increase in ferrous oxide and clays in the desert varnish will result in the rock surface layers becoming thinner, lighter, redder and more white/yellow in colour over time. The impact on engraved surfaces will be greater because the desert varnish is thinner than on the non-engraved surface rock. Pollution from industry with an increase in acidity of the rock surfaces on Burrup Peninsula is likely to destroy the rock art over time. The time needed for complete destruction of the petroglyphs is difficult to determine accurately without appropriate measurements of rock art surfaces.

Research by Professor Ronald Dorn from the University of Arizona has shown that acid fog from car exhausts and industry in California has substantially degraded the desert varnish of rocks in the Santa Monica Mountains (Figure 3). The electron micrograph on the left is from a sample of rock taken at the turn of the 20th century, whereas the ones on the right were taken from the same area in early 21st century. The pinnacles and depressions are not normal and show the different surface due to the actions of acid fog. The thickness of the desert varnish has declined from around 80 to less than 50 microns.

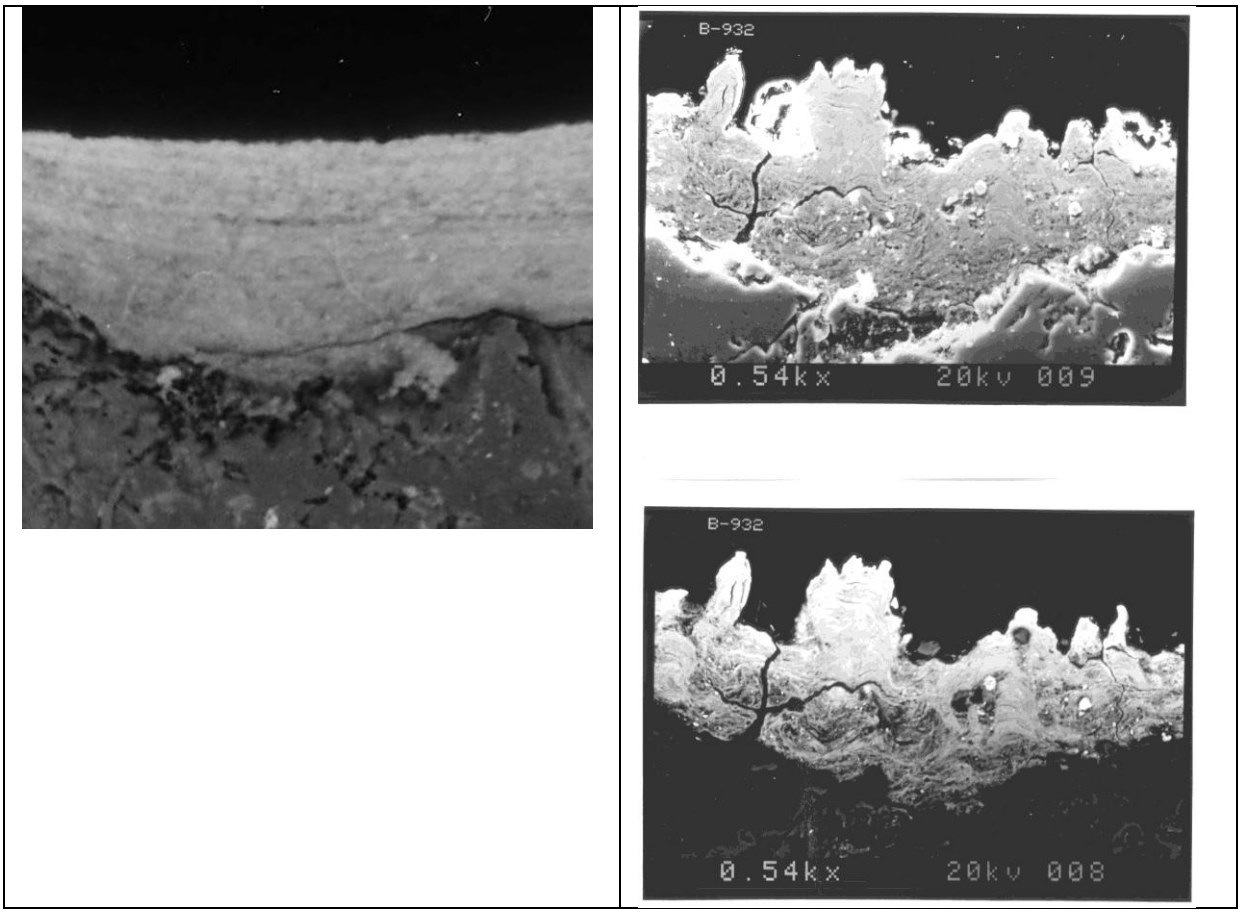

Figure 3. Evidence of effects of acid rain on thickness and integrity of desert varnish on rocks from the Santa Monica Mountains in California. The samples were taken approximately 100 years apart from the same area - Provided by Professor Ronald Dorn, Arizona State University.

Effects of increased nitrogen on rock surfaces

A major effect of the large emissions of ammonium nitrate particles (25.2 tonnes/year) onto rock surfaces will be to stimulate microbial growth. The environment of Burrup Peninsula is traditionally like much of the Australian land and highly deficient in nitrogen for the growth of plants and other organisms. Ammonium nitrate is used as a plant fertiliser as well as an explosive. The increase in nitrogen on the surface of Burrup Peninsula rocks will stimulate greatly the growth of adventitious organisms that are traditionally at very low concentrations on rock surfaces.

Dr MacLeod's research (MacLeod 2005) showed also that the growth of adventitious bacteria, algae, fungi and lichens increased logarithmically as the nitrogen content of the rock surfaces increased. These organisms will out-compete and overrun the varnish forming organisms. They produce organic acids that also increase the acidity of the rock surfaces. The adventitious organisms are known to concentrate in crevices and petroglyph engraving lines. The hyphae from the growing fungi penetrate the softer weathering rind below the desert varnish layer and break away the edges of the petroglyph engravings.

Research by Dragovich (1986) showed substantial weathering of desert varnish on rocks in outback Australia by lichens through both physical damage caused by their hyphae and complete dissolution of varnish beneath lichens is some places. This is an example of the serious effects of adventitious microorganisms increasing acidity of the rock surfaces, dissolving the manganese and iron compounds of desert varnish and degrading rock surfaces.

The combination of an increased acid load dissolving the desert varnish and growth of adventitious organisms stimulated by increased ammonium nitrate and other nitrogen rich compounds in the air will destroy the petroglyphs over time.

Evidence of existing detrimental pollution on Burrup Peninsula

A view of the Bureau of Meteorology (BOM) radar for Dampier on any day indicates it is "raining" over the industrial and port areas of Burrup Peninsula (Figure 4). However, the average rainfall at Karratha airport is just under 300 mm and it rains (1 mm or more) on average only 20 days per year (BOM Climate statistics for Australian locations, viewed 11 January 2017). The explanation can be only that the radar is identifying industrial pollution as rain, with an intensity between Light and Moderate.

There is evidence that these emissions are degrading the environment. Figure 5 shows photographs of emissions from the Woodside industrial site, the Woodside Visitors Centre and the suspected effects of emissions on paving bricks at the centre. Although, no scientific analysis of the bricks have been made to my knowledge, the photograph shows, where there is a gap between the two roofs, the bricks on the paving have been eroded and the black marking to the side suggest an increase in microbial growth. If the current emissions are already having such a marked effect on bricks, what effect are they having on the acid-sensitive desert varnish, which is so crucial for preservation of the rock art?

Figure 4. An example of the Bureau of Meteorology radar for Dampier, WA showing on everyday 'rain', despite an average of only 20 days of rain per year.

Figure 5. Emissions from the Woodside industrial plant on Burrup Peninsula (above), photograph of Woodside Visitors Centre showing small gap between two roof lines (lower left) and degradation of paving bricks where rain falls between the two roofs, with the dark colour suspected to be from microbial growth adjacent to the erosion line (lower right).

Pollution from shipping

Dampier port is one of the busiest bulk-ports in the world with 5,170 ships entering the port in the year 2014-2015 (Pilbara Ports Authority, 2015). The shipping lane and numerous anchorages are within a few kilometres of numerous rock art sites (Figure 6).

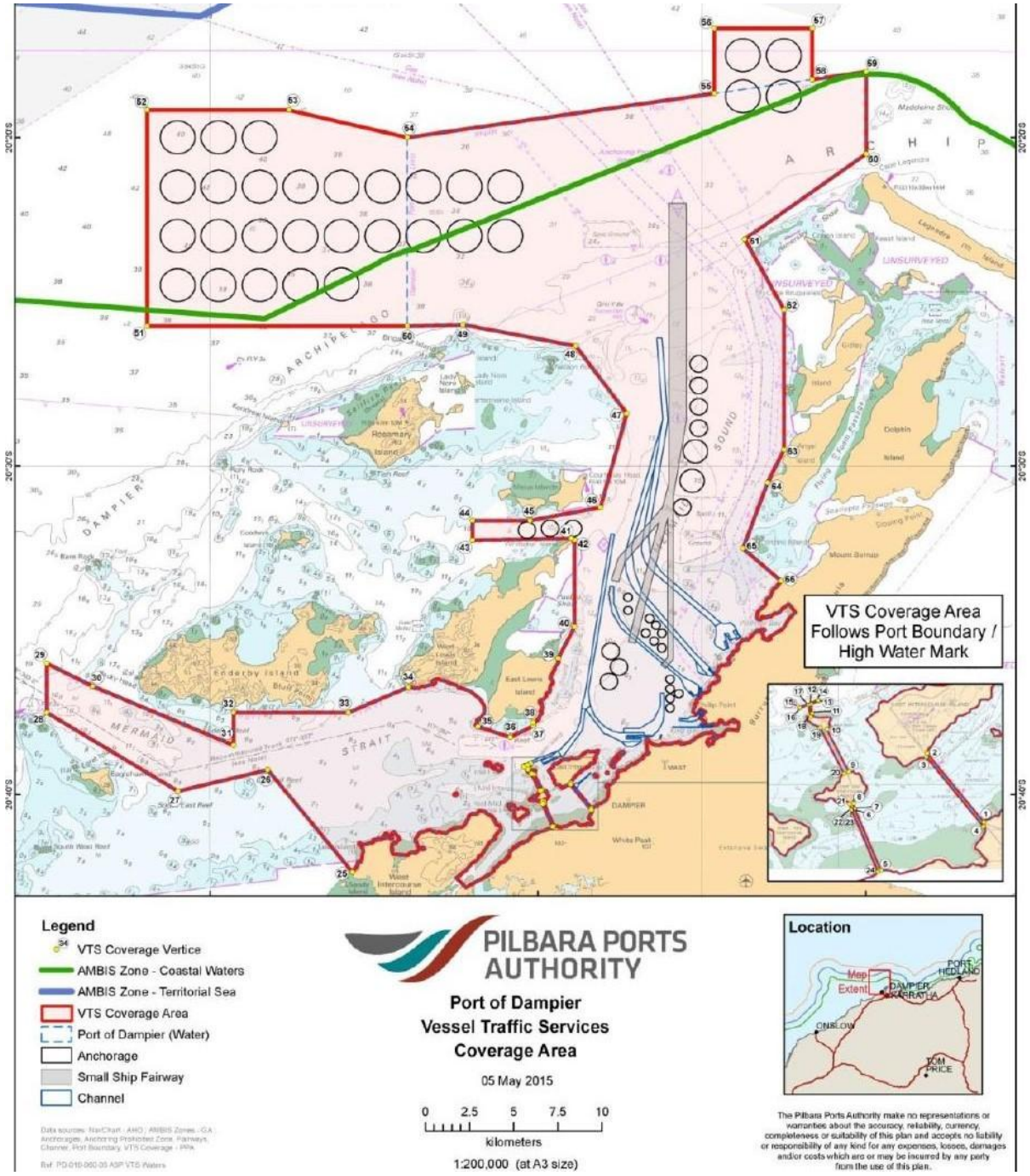

Figure 6. Map of the Dampier Archipelago showing the port of Dampier, shipping lanes and anchorages (circles) in relation to rock art sites. From Pilbara Ports Authority handbook (2015).

There were 19,000 ship movements near the islands in 2014-2015 (Pilbara Ports Authority, 2015). The Australian national limit for sulphur content of bunker oil is 3.5% sulphur, which is presumably

enforced by the Pilbara Ports Authority. The majority of ships will be burning high-sulphur content fuel (Figure 7). A single bulk cargo ship burning high-sulphur fuels has been estimated to release 5,200 tonnes of sulphur oxides into the atmosphere per year (Vidal 2009). The emissions are highest during start-up and shut-down (USEPA 2010), which occurs when arriving at and departing from an anchorage. Sulphur oxides combine with moisture in the air to form sulphuric acid that precipitates as acid fog or rain, with severe effects on stone buildings, rocks and rock art around the world. Lau et al. (2007) found that one molar concentration of sulphuric acid significantly changed the colour and mineralogy of iron ore, but they did not examine the effects of sulphuric acid on desert varnish of rocks containing rock art.

Figure 7. Ships at the Port of Dampier showing emission from a bulk cargo vessel under tow by tug boats and the dark haze from industrial emissions over Burrup Peninsula.

In sensitive areas of Australia, known as Emissions Control Areas, such as Sydney Harbour, the maximum sulphur content allowed in shipping fuel was reduced to 0.10% in December 2016. Rock art on Burrup Peninsula is extremely sensitive to acid pollution. It is logical that the maximum sulphur content limits for shipping fuel at the Port of Dampier should also be 0.10%

Protection of heritage sites around the World

The world famous paintings at Lascaux caves in southern France (Figure 8), which are only 17,000 years old compared with around 40, 000 years for the petroglyphs on Burrup Peninsula, are now protected from the public. The U.S. based International Committee for the Preservation of Lascaux states: "*The art of Lascaux is a legacy belonging to all mankind*". The same must also be true for petroglyphs on Burrup Peninsula, because they are older and show a continuous history of mankind living with a changing environment for 40,000 years.

After their discovery in 1940, the caves were besieged by tourists whose breath raised levels of damaging carbon dioxide and other nutrients, which stimulated the growth of fungi and other microorganisms covering the art in black spots and causing serious degradation. Conditions became so serious that French authorities closed the cave to tourists 25 years ago. Nearby, a precise replica of the two most famous rooms in the cave have been recreated to accommodate tourists.

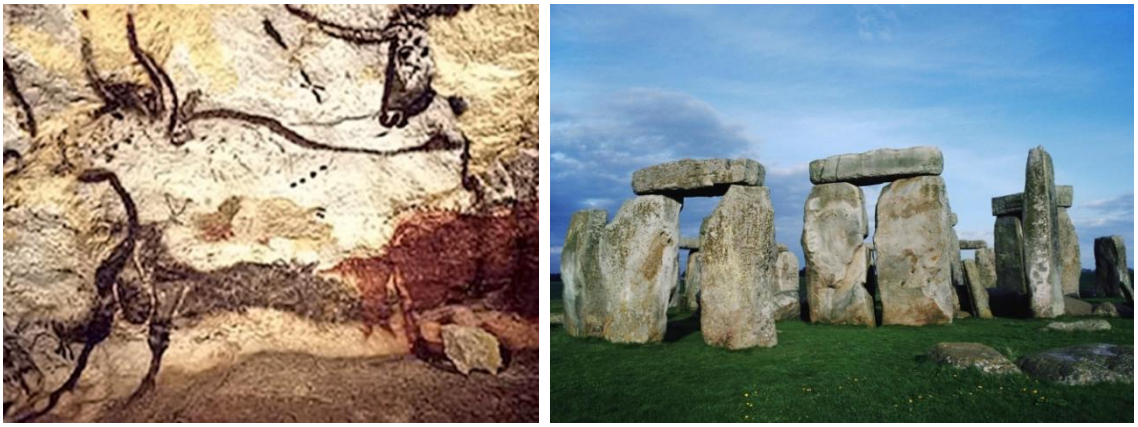

Figure 8. Image of paintings in Lascaux cave in southern France (left), which has for the last 25 years been closed to the public because nutrients from human breath stimulated growth of fungi and microbes, causing black spots over and destroying the art. A replica of the two most famous paintings has been recreated for public viewing. Image of Stonehenge (right) where the British Government has just announced the building of a £1.4 billion tunnel to protect it from vehicular emissions.

Similarly, the British Government announced on 12 January 2017 that it will build a £1.4 billion tunnel in the vicinity of Stonehenge, which is only 4,500 years old, to protect it from damage from acid pollution caused by nearby motor vehicle traffic.

It appears incongruous that in Australia we have one of the oldest and the largest congregation of rock art in the world and the Australian Governments are doing virtually nothing to protect it from industrial pollution, when compared with efforts other Governments are taking to protect their heritage.

Preservation of the unique Burrup rock art for future generations and its promotion throughout the world would create a huge opportunity for Australian economic gain long after the projected 25 year lifespan of the ammonium nitrate facility, the fertiliser and gas liquefaction plants. There are approximately 400,000 visitors annually to the Lascaux caves in France. With a similar visitor rate and a charge of only $25 per visitor, $10 million annually would be raised for Western Australia, plus all the indirect expenditure by tourists in other parts of Australia. A significant way to promote the uniqueness of petroglyphs on Burrup Peninsula and attract international visitors is to have it placed on the World Heritage list.

Likely effects of additional pollution on human health

PM_{10} ammonium nitrate particles

Ammonium nitrate PM_{10} sized and smaller particles can be inhaled and the product can be ingested. The World Health Organisation's 2005 updated guidelines (WHO 2006) recommend a maximum concentration in the air of 20 microgram per cubic metre (µg/m^3) over a year and 50 µg/m^3 over 24 hours for all PM_{10} particles without specific reference to ammonium nitrate. These values are approximately 1,000 times less than the proposed emissions from the TANPF Common stack (15 milligram per cubic metre, mg/m^3). Modelling of PM_{10} concentrations (Figure 20 of Burrup Nitrates Air Quality Assessment) within TANPF boundary fences and at many areas visited by the public, including Hearson Cove and Deep Gorge, exceed the WHO annual limit by 1.5 to 2 fold. Outputs from the CALPUFF model, used by Burrup Nitrates in their air quality assessment to predict concentrations of air contaminants at different locations, need to be treated with extreme caution because Gillett (2008, p129) showed that the CALPUFF model underestimated actual measured emissions concentrations in the air by 2-5 fold.

The limit for intake of ammonium nitrate by the body is considered to be 5mg/kg body weight/day (Wikipedia). Ammonium nitrate causes orthostatic hypotension due to rapid dilation of blood vessels, resulting in faintness, dizziness, fatigue and reflex tachycardia (increased heart rate). When ingested, it can cause nephritis (kidney inflammation), be converted to nitrite and cause nitrite poisoning (methaemoglobinemia), which dramatically reduces the capacity of the blood to carry oxygen.

A 70 kg person undergoing light activity, with a lung-minute volume of 10 litres/min, breathing air with 50 mg/m^3 ammonium nitrate particles (as may exist during upset conditions close to the Common stack) would reach the limit of exposure of 5 mg/kg/d (350 mg) in 11.6 hours. This analysis suggests airborne ammonium nitrate particles are a severe threat to the health of workers and the public and should not be released into the environment.

In summary, concentrations of ammonium nitrate proposed to be released by TANPF are at a level dangerous to human health.

Carbon monoxide

The ammonium nitrate plant documentation indicates that 41 tonnes/year of carbon monoxide (CO) will be released. Since CO is heavier than air, the risks to humans and other living organisms in the environment should be considered. Currently there appears to be no credible mitigation or management plan accompanying the Yara Pilbara Fertilisers documentation associated with the ammonium nitrate plant.

Risk from ammonium nitrate explosion

There are risks of an ammonium nitrate explosion through 'sympathetic detonation' or detonation from any other cause. The risk implications of a detonation and methods for avoidance have not been described in the application by Yara Pilbara Fertilisers for a licence to operate the ammonium nitrate plant.

Under normal storage and transport conditions, ammonium nitrate is unlikely to explode. However, it is more likely to explode when confined and subjected to heat or a mechanical shock. Pure ammonium nitrate has a melting point of 169°C and at temperatures above 300°C the decomposition reaction is irreversible. When ammonium nitrate spontaneously decomposes, it produces oxygen that feeds the reaction and, if uncontrolled, results in an explosion. Fires in ammonium nitrate cannot be quelled by smothering, for example with steam, due to the oxygen produced and must be extinguished by large amounts of water. It is well recorded that large stockpiles of ammonium nitrate can be a major fire risk, particularly if contaminated with organic material, subjected to fire or to detonation. A substantial volume of readily accessible water must be available in the event of a fire. Where is this water stored at the ammonium nitrate plant and what equipment is in place to trigger water application and to ensure the correct amount of water can be applied?

There are many reports of explosions of ammonium nitrate during storage and transport (*Regulating security sensitive ammonium nitrates (SSAN) in Queensland, Queensland Government Department of Mines and Energy; Stephens S.H. (1997) The Texas City Disaster 1947, University of Texas Press*). The Texas City explosion was the deadliest industrial accident in US history caused when a shipment of 2,300 tons of ammonium nitrate exploded as it was being loaded onto the ship *Grandcamp* in the Port of Texas. The explosion killed 581 people, nearly 1,000 buildings were levelled, the Monsanto chemical plant was destroyed, people were forced to their knees in a town 10 miles away and windows were shattered in buildings in Houston 40 miles away. The explosion from the *Grandcamp* spontaneously ignited ammonium nitrate in another ship the *High Flyer* which itself exploded.

Similarly, on 12 August 2015, an ammonium nitrate explosion at the port of Tainjin, China killed 173 people. These examples of the Texas City and Tainjin explosions reinforce the potential extreme

danger from stored ammonium nitrate if it is ignited or undergoes sympathetic detonation or severe mechanical shock. The ammonium nitrate plant is located in a cyclone zone, where unintended mechanical shock is possible. Should an explosion occur, there would be significant damage to surrounding areas, including the rock art, adjacent industry and potentially the towns of Dampier, Karratha and Roebourne. In addition, toxic atmospheric products from the fires would have serious detrimental effects on human health.

A similar expression of concern regarding explosion, damage to Deep Gorge and human health was made in several submissions relating to the Public Environmental Review for the Burrup Nitrates Pty Ltd, Technical Ammonium Nitrate Production Facility. The response by the Environmental Protection Authority to these submissions stated that ammonium nitrate is difficult to detonate and the risk of detonation would be controlled by 'best practice' operations to be put in place by the company. This statement provides inadequate protection against the risk of a devastating explosion and subsequent large-scale destruction of rock art on the Burrup Peninsula. The risks are exacerbated because the ammonium nitrate production and storage facility is within close proximity to a huge natural gas storage and liquefaction plants. The consequences for all personnel on Burrup Peninsula, Dampier and Karratha would be devastating.

The Bureau of Meteorology states: "*The Pilbara coast experiences more cyclones than any other part of Australia. Since 1910 there have been 48 cyclones that have caused damaging wind gusts in excess of 90 km/h in the Karratha, Dampier and Roebourne region. On average this equates to about one every two years.... (many) have caused very destructive wind gusts in excess of 170 km/h* ".

The storm surge at Cossack, a short distance up the coast from Burrup Peninsula, was 7.2 metres during a cyclone on 21 January 1925. The ammonium nitrate is only 5.5 metres above sea level. With projected sea level rise of at least 6 metres by 2040 and a cyclone storm surge of 7 metres, the security of the ammonium nitrate plant and storage facility looks extremely risky.

Likely effects of additional pollution on the environment

The slow rate of degradation of the rocks on Burrup Peninsula results in a very low buffering capacity of the small amount of soil formed. Low buffering capacities in landscapes make ecosystems extremely susceptible to ecological changes from increasing acid loads. The vegetation on Burrup Peninsula is unique with many plant species common only to this area (Long *et al*. 2016). Thus, high acid emissions of 200 meq/m^2/yr are likely to make significant changes to this unique vegetation over time.

The increased nitrogen deposition on the landscape from ammonium nitrate particles will stimulate plant growth and increase the intensity of fires that result naturally from lightening strikes. Fire is known to damage rock art on Burrup Peninsula. An increase in fire intensity will increase degradation of the rock art and will hasten the changes in flora populations.

There is already evidence that increasing nitrogen on Burrup Peninsula has led to increased algal growth on the waterways. Figure 9 shows a photograph of Burrup waterways in July 2010 compared with July 2016.

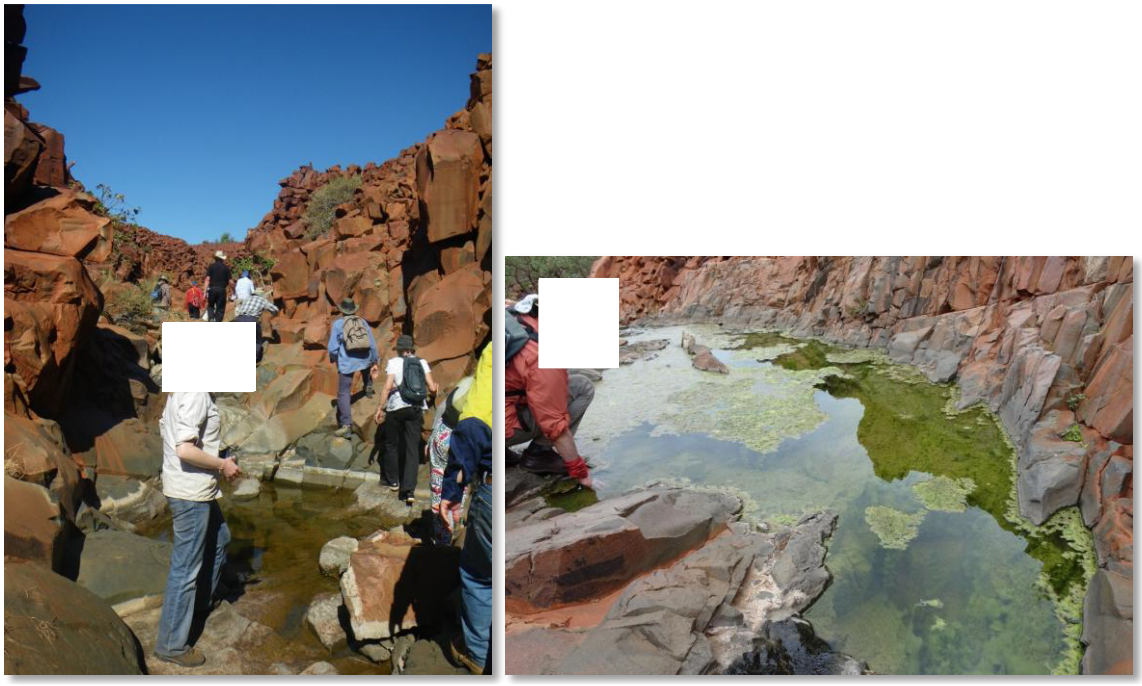

Figure 9. The left photograph shows Emu Face Valley waterhole in July 2010, while the right photograph is at Geo's Gorge waterhole in July 2016, showing a huge increase in algal growth.

Summary and Recommendation:

There is sufficient scientific evidence showing that the proposed emissions from the new Yara Pilbara Nitrates ammonium nitrate will destroy rock art in the vicinity, be a threat to human health and change the environment on Burrup Peninsula.

The site for the ammonium nitrate plant appears to be extremely risky, with its construction being only 5.5 metres above sea level and cyclone surges in the region having exceeded 7 metres at Cossack, when considered with projected future sea level rises of at least 6 metres by 2040.

To prevent this damage there should be no emissions to the air of ammonium nitrate particles and acid load should be far less than 25 meq/m^2/yr from the combined fertiliser and ammonium nitrate plants.

These restrictions are achievable using modern scrubber and other technologies.

The extreme sensitivity of petroglyphs to acid precipitation means that authorities must immediately set limits on the sulphur content of fuel used by ships entering the Port of Dampier to the international standard for sensitive environments of 0.1%.

Australia should emulate other countries like France and Britain to preserve its heritage, with the potential for tourism on Burrup Peninsula long into the future, that could raise as much as $10 million annually.

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(d) the rigour and adequacy of the monitoring, analysis, compliance and enforcement performed by the Western Australian and Commonwealth government agencies in carrying out their legislated responsibilities in overseeing industries on the Burrup Peninsula;

This submission deals only with aspects relating to the Yara Pilbara Technical Ammonium Nitrate Production Facility (TANPF) and fertiliser plants. Considered are:

- Granting of licences by the Western Australian and Commonwealth Governments and modification of licence conditions over time
- Adherence by the company to licence conditions and enforcement by governments

Granting of licences for the ammonium nitrate plant by the Western Australian and Commonwealth Governments and modification of licence conditions over time

Licence to operate the new ammonium nitrate plant - Western Australian Government

The Western Australian Government called for submissions from the public on 11 July 2016 to comment on the Yara Pilbara Fertilisers application for a licence to operate the new ammonium nitrate facility. The company did not request a new licence, but sought amendment to two existing licences: licence L7997/2002/11 for operation of the Yara Pilbara Fertilisers, fertiliser plant, and W4701/2010/1, a Works licence to Yara Pilbara Nitrates for construction of the TANPF.

There was no clear statement by the company about changes they were requesting to be made as amendments to these licences. It is presumed that the company was attempting to have the operation of the TANPF added to the existing licences without changes to those licences. Seeking amendments to the existing licences, rather than applying for a new licence to operate the TANPF would appear to be a way of avoiding limits being placed on emissions from the new plant that were not included in the other licences.

A renewal to the licence to operate the Fertiliser plant (L7997/2002/11), through the 7997 Yara-Ministerial Statement 586, was granted on 16 April 2015 by Jonathon Bailes from the Department of Environment Regulation (DER). The attachment to Ministerial statement 586 outlines the capacity and outputs from the Fertiliser plant for ammonia production. The Decision Table on page 8 of the Decision Document appended to the licence states that '*Yara has been liaising with the Environmental Protection Authority (EPA) to progress an amendment to MS586 or remove the limits contained in MS586.*' A modification to the licence dated 20 April 2016 lists only two emissions limits, both for NO_x of 130 mg/m^3 averaged over 60 minutes from the Primary Reformer stack and 350 mg/m^3 from the Package Boiler stack.

Limitations to the licence L7997/2002/11 for protection of rock art and the environment

- Emissions from only two point sources are included in the licence. Emissions from Front and Back vents and from the flare are not considered.
- No limits are placed on the emission of ammonia, yet there were numerous uncontrolled leaks of ammonia from the plant during 2015-16, with 14 tonnes being emitted to the atmosphere on 23 March 2016.
- The licence specifically exempts the company from abiding by the emission limits during Start Up, Shut Down and Upset conditions - these are periods when emissions are greatest.

Works Licence W4701/2010/1

Works licence W4701/2010/1 to construct and commission the TANPF was granted to Yara Pilbara Nitrates by the Western Australian Government on 29 July 2013 and twice extended until December 2017. The licence includes emission limits from the Common Stack and Nitric Acid Plant Stack for

particles (PM_{10}, ammonia, nitrogen dioxide and nitrous oxide). The release of ammonium nitrate particles is extremely important when considering preservation of the rock art, because the nitrogen being deposited from the 25.2 tonnes of ammonium nitrate released into the atmosphere will stimulate microbial growth on rock surfaces and change the environment, vegetation and waterways.

There is considerable confusion about the concentrations of ammonium nitrate PM_{10} that will actually be released into the atmosphere by the TANPF. In the documentation submitted to the Western Australian Government when applying for the amendment to existing licences to operate the plant, Yara Pilbara stated that it has adopted the European Fertiliser best practice guidelines, which suggest the combined release from the prilling tower and ammonium nitrate cooling beds would be 26.25 mg/m^3 (milligrams per cubic metre) for ammonium nitrate particles. However, Yara Pilbara's current amendment application states ammonia emissions from the combined process will be 15 mg/m^3. These latter values differ from Table 3.3 of the Air Quality Management Plan, prepared in February 2013 for the Commonwealth in relation to EPBC conditions, which shows that Yara Pilbara will comply with emissions of PM_{10} of 50 mg/m^3 over a month and 30 mg/m^3 over the year. The values in the Air Quality Management Plan are well above the concentration stated in the current application and contained in the Works licence W4701/2010/1, at 15 mg/m^3. Yara Pilbara, in a response on 17 June 2016 to queries from DER, indicated that emissions from the Common Stack are likely to be 100 mg/m^3 for 5% of the time the TANPF is in operation. As several documents were submitted for consideration by DER, it is unclear what level of emissions Yara Pilbara is seeking in the amendments to existing licences.

As mentioned in my response to Term of Reference (b), the concentration of PM_{10} dust particles allowed in licence W4701/2010/1 is 15 milligrams per cubic metre (mg/m^3), whereas the standard set in the Agreed Statement from a meeting of Australian Environment Ministers on 15 December 2015 for PM_{10} particles in the air is 25 micrograms per cubic metre ($\mu g/ m^3$), with it being lowered to 20 $\mu g/ m^3$ in several states and territories. The standard set for airborne particles for workers on Burrup Peninsula is almost 1000 times higher than has been accepted for the general public of Australia.

The difference in air quality standards for workers and rock art on Burrup Peninsula compared with the general Australian public would appear unacceptable.

Licence to construct and operate the new ammonium nitrate plant - Federal Government

Approval for construction and operation of the TANPF was granted by the Federal Government on 14 September 2011 (2008/4546). The approval included many conditions applied under the Environment Protection and Biodiversity Conservation (EPBC) Act 1999. These conditions were established to protect the rock art and fauna and flora. In relation to the rock art, condition 8 d) (i), stated that a suitably qualified person must survey the rock art sites within a two kilometre radius of the project site from the time construction commences. This condition was not immediately implemented and it has now been amended twice (18 December 2013 and 10 February 2014) on request by the company, to reduce the level of surveillance. The company has notified Federal Government in its 2016 Annual Compliance report under EPBC (2008/4546) that it will seek a further change to Condition 10.

Government priorities appear to be with companies rather than the environment and heritage

The Federal Government Compliance Monitoring Program 2016-2017 found that 20% of projects with EPBC conditions were non compliant. None of the companies in breach of EPBC conditions were prosecuted. Instead, the Department relied on administrative measures such as variations to conditions of approval, revisions to management plans and conservation agreements.

The changes made to conditions in licences given by both the Western Australian and Federal governments to Yara Pilbra in relation to construction and operation of the TANPF suggest to the public that short term financial returns from industry are more important than saving for future generations the priceless, irreplaceable and world significant rock art on Burrup Peninsula.

Adherence by the company to licence conditions and enforcement of conditions

The latest reports by Yara Pilbara Nitrates to the Western Australian (MS870) and Federal governments (EPBC 2008/4546) show areas of non compliance in relation to rock art monitoring and emissions measurements. The 2016 report to EPBC did not include information about rock art monitoring.

In accordance with condition 5.1 of MS870 for the Western Australian Government, the company has established five air-quality and weather-monitoring stations on the western and eastern boundary of TANPF and at Burrup Road, the Water Tanks and Deep Gorge (TAN Burrup Project 2016). The company is required to measure PM_{10} particles, NH_3, NO_x and SO_x concentrations at these sites. Results are presented in the latest report for PM_{10} and weather measurements for only one site on the western boundary. Results are presented only from 01/01/15 to 17/02/15. The remainder of the Table to 30/06/15 states No Data. Although the company is obliged to provide concentrations of listed chemicals in the air at the sites, no results relating to chemical emissions have yet been provided. Thus, the background emissions prior to the plant being commissioned have not been reported.

The results provided in the company report for PM_{10} particles are unrealistic, with a maximum value of 112,020.5 $\mu g/m^3$ and a minimum value of -90,649.28 $\mu g/m^3$, when the limit established by the Australian Environment Ministers on 15 December 2015 was 25 $\mu g/ m^3$. Negative values for PM_{10} particle emissions are impossible. Reliability of the data presented in these reports is clearly extremely poor.

Although the report for MS870 has been submitted to the Western Australian government, there is little evidence that it has been thoroughly reviewed. No action appears to have been taken by the Western Australian government in relation to the extensive areas on non-compliance.

The lack of enforcement of licence conditions by the Western Australian and Federal governments fits closely with the assessment of non compliance found by the Federal Government Compliance Monitoring Program 2016-2017. The lack of enforcement of compliance with licence conditions suggests that the conditions are basically worthless and governments are more interested in assisting industry than preserving national heritage.

Summary and Recommendation

Yara Pilbara, the Western Australian and Federal governments appear to be more concerned about short term financial returns from industry than saving for future generations the priceless, irreplaceable and world significant rock art on Burrup Peninsula.

Yara Pilbara have sought amendments to existing licences rather than a new licence to operate the TANPF, which limits conditions set on the new plant and should, on sound scientific grounds, set limits to ammonium nitrate particle emission to zero and acid load to less than 25 meq/m^3/year. The current limit for dust particles in the air is almost 1000 times that set in December 2015 by Australian Environment Ministers.

There is currently no evidence of effective monitoring of gaseous emissions by Yara Pilbara.

Both the Western Australian State and Federal governments have, at the request of the company, modified conditions set for company operations to either increase the level of emissions or reduce monitoring of rock art.

Governments must consider preservation of the Australian and World significant petroglyphs on Burrup Peninsula rather than short term financial gain. This can be achieved by ensuring

all industry on Burrup Peninsula reduce emissions to maintain an acid load from all sources to below 25 meq/m^3/year. These low emissions can be achieved using modern gas and particle scrubbing technologies.

Governments should enforce penalties whenever specified limits are exceeded or evidence of non-compliance exists to ensure protection of the rock art and the opportunity for large financial returns from tourism.

(e) the projected level of fugitive gas and nitric acid leaks from the Yara Pilbara fertiliser and ammonium nitrate plants, their effects on human health, likely effects on rock art and the general environment, and the adequacy of the company responses

I am not in a position to comment on projected levels of fugitive gas or nitric acid leaks. However, Yara Pilbara Fertilisers and Yara Pilbara Nitrates have a substantial record for fugitive gas and nitric acid leaks, plus other occupational health and safety breaches. Incident Investigation Summary Reports from Yara Pilbara indicate there were at least 24 reportable incidents from January to 17 November 2015. Ammonia leak was a common cause of the incidents. Many reports had a severity classification of 4 or 5, with 5 being the most severe on the scale. Many incidents required hospital treatment of workers. Between 16 January 2016 and 20 January 2016, 4,601 tonnes of gas were released into the atmosphere. On 23 March 2016, 14 tonnes of ammonia were released into the atmosphere from the fertiliser plant. There have been at least eight reported incidents in 2016 including two incidences of nitric acid leaks. There are no records of the concentrations of ammonia in the atmosphere in these events. This lack of records is because there is no requirement for the fertiliser plant to record ammonia in the atmosphere as Burrup Fertilisers Pty Ltd argued: "*With respect to emissions of ammonia (NH3), it is very unlikely that the proposed ammonia plant will emit ammonia vapours to the atmosphere. It has been estimated in the PER document (Section 7.2.1.10) that the probability of such an event occurring will be less than 1-in-100 years.*" This supposition is clearly incorrect.

There have been at least two nitric acid leaks during commissioning of the ammonium nitrate plant. One leak on 27 April 2016 released NO_x that triggered the closest alarm at 100 ppm. The second leak on 30 April 2016 released an estimated 337 kg of oxides of nitrogen into the atmosphere with a concentration of 600 ppm (1,160 mg/m^3).

This extremely poor record of controlling unintended emissions to the atmosphere requires strict penalties as an incentive to upgrade standard operating procedures and to protect rock art and human health.

A major concern is that the company is not bound by conditions set in Licence L7997/2002/11 for operation of the fertiliser plant under "Upset" conditions, when these fugitive gas leaks occur.

Summary and Recommendation

There have been numerous unintended gas, ammonia and nitric acid from the Yara Pilbara fertiliser and TANPF operations. Many of these leaks have been serious, requiring hospitalisation of workers. Fugitive leaks are not currently covered in State or Federal government licence conditions, with specific exemptions for Start Up, Shut Down and Upset conditions.

Fugitive leaks of gases and liquids from the industrial sites on Burrup Peninsula must be covered by the same emission standards as normal operations. Prosecutions should be enforced whenever emissions exceed licence conditions.

(h) any related matters.

Need for continuous measuring of emissions, rock surface changes and simulation modelling

The Burrup Rock Art Technical Working Group (BRATWG) advising the Western Australian Government on studies measuring changes to the environment and rock art sites on Burrup Peninsula was disbanded by the government on 30 June 2016. Measurement of colour and mineralogy have been undertaken by CSIRO for the 2016 year at the seven sites measured since 2004, plus the three new sites required for Yara Pilbara Nitrates under the EPBC conditions for construction and operation of the ammonium nitrate plant. The report on measurements made by CSIRO in 2015 has not been released to the public. There appear to have been no policy statements from the Western Australian Government on continuation of these measurements.

Yara Pilbara Nitrates are required under the EPBC conditions (10 a),b)) to provide an amount, not exceeding $15,000, for two years to assist with the colour and mineralogy monitoring and, for an additional five year period, if the monitoring is continued by the Western Australian Government. Yara has contributed funds for the compulsory two years. However, this will not continue unless the monitoring program is maintained by the Western Australian Government.

The evidence presented in this submission for Terms of Reference b) and c) show, on the basis of sound scientific principles, that the thickness of the rock patina will decrease and its colour become lighter, redder and more yellow with increased acidity and nitrogen deposition from industrial emissions. These predicted changes in rock surface colour have been confirmed by thorough statistical analysis of the CSIRO colour monitoring data. Further changes to the rock art can only be identified if extensive measurements continue. Comprehensive measurements of emission concentrations in the air at Burrup rock art sites have not been reported since the study of Gillett (2008).

However, the measurements taken must be extended beyond those of rock colour changes so the causes of these changes can be identified. The measurements should include continuous monitoring of all gaseous and particle concentrations in air, anion, cation, pH and nitrate concentrations on background rock and on petroglyphs, as well as microbial activity on the rocks, especially after rain.

Although the measurements recommended are essential to identify the magnitude and possible causes for changes over time, damage to the petroglyphs is likely to continue. An estimate of the future rate and extent of this damage would greatly assist management decisions about controlling the environment on Burrup Peninsula. A similar situation exists for global climate change. Climate simulation models are being used to predict from current knowledge the likely climate in future years. I believe there is sufficient fundamental scientific information to develop a simulation model to predict the likely impact of emissions on the weathering rate of rocks and petroglyphs on Burrup Peninsula.

The integrity of scientific methods used by CSIRO and their interpretation of results in the colour/mineralogy monitoring program have been highly criticised by me and the Western Australian Government appointed independent reviewer. The timeliness, completeness and accuracy of reports by Yara Pilbara Nitrates are extremely poor (Term of Reference d), above). I believe these two organisations have proved themselves unsuitable for being trusted to make sound, timely and unbiased measurements of emissions and their effects on rock art.

Consequently, Friends of Australian Rock Art (FARA), The Murujuga Aboriginal Corporation and the Centre for Rock Art Research + Management at the University of Western Australia are setting up an independent research project to monitor emissions and changes to the surfaces of rocks at numerous sites on Burrup Peninsula with appropriate controls.

Twenty five thousand dollars were raised by FARA in April 2016 to establish a scoping study for identifying the research to be conducted, the national and international experts to be involved, the management structure and the cost. This scoping study was completed in October 2016. Currently, FARA and the University of Western Australia are raising funds for the project, which will extend over 5 years and is estimated to cost approximately $500,000 per year.

The research is planned to be completely open to the public, governments and industry with all information being made available through a dedicated website. We anticipate that concentrations of emissions in the air will be measured in real-time. We are looking to cooperate with all industries on Burrup Peninsula and governments, so the knowledge about emission levels, rock surface changes and modelled projected changes are available to all to assist in appropriate management and preservation of the rock art.

I see a great opportunity for the Western Australian and Federal Governments to contribute to this independent research project.

Summary and Recommendation

The Burrup Rock Art Technical Working Group was disbanded by the Western Australian Government on 30 June 2016. No policy has been released about continuing measurement of colour/mineralogy changes at rock art sites. No comprehensive measurements of emissions at rock art sites have been made since 2008.

The Western Australian and Federal Governments could consider partially funding a new, open and comprehensive emissions monitoring, rock surface change and modelling project to provide a sound basis for management and preservation of the rock art on Burrup Peninsula.