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Crude INTENTIONS:

Exposing the risks of drilling & spilling in the Great Australian Bight

Greenpeace Australia Pacific

Independent Expert Opinion
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A pelican sits covered with oil from the Deepwater Horizon wellhead in Barataria Bay.
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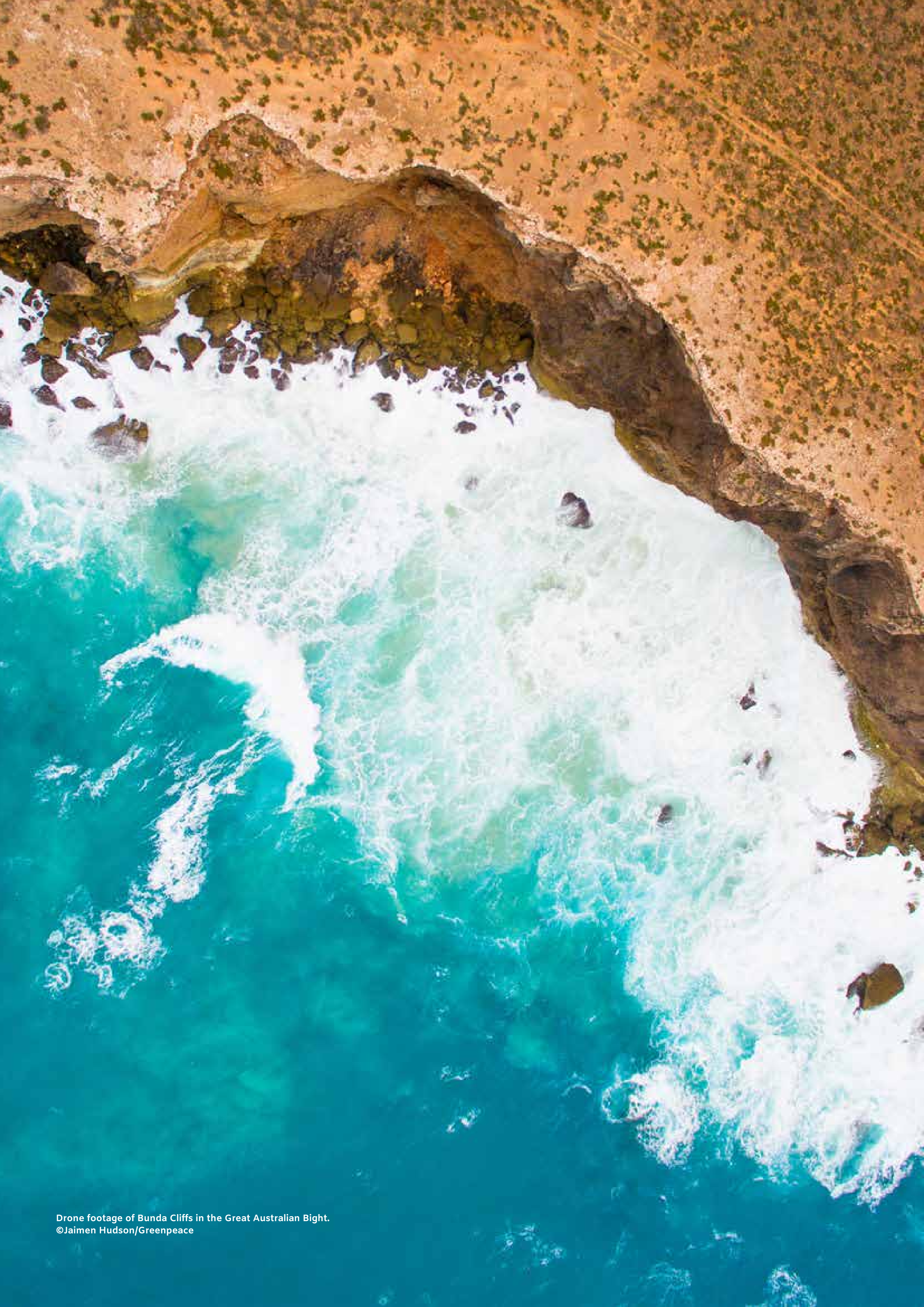

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01 EXECUTIVE SUMMARY

With no offshore oil development currently occurring between south Australia and the Antarctic, the GAB is considered an integral component of one of the largest marine wilderness areas in the world ocean today.

This assessment reviews the risk and potential impacts of a Worst Case Discharge (WCD) oil spill from the proposed exploratory drilling project at the Stromlo-1 well site, leased by Equinor (formerly Statoil), in the Great Australian Bight (GAB), Australia. The GAB marine ecosystem is one of the most unique and productive marine ecosystems in the world. An estimated 85% of known GAB species are endemic (found nowhere else in the world); the region has exceptionally productive and sensitive pelagic, benthic, nearshore and shoreline habitats; the greatest concentrations of marine mammals, seabirds, pelagic fishes, and sharks in Australia; and supports an annual multi-billion dollar fishery, aquaculture, and tourism economy.

Equinor proposes to drill one deepwater (2,239 m water depth, total drilling depth of 5,200 m – 5,700 m) exploration well ("Stromlo-1") in the GAB in summer from 1 October – 31 May (Q4-Q1) with a target to start drilling in Q4 2019 or Q4 2020. Drilling is projected to take 60 days. The risk of a WCD from the project is real, and even with the safest well design and operational controls possible, industry recognizes that catastrophic risk cannot be eliminated. While the statistical likelihood of a WCD may be low, the consequence would almost certainly be catastrophic, and as such the GAB deepwater drilling project should be considered "High Risk." Industry and government habitually understate risks and impacts of offshore drilling, and overstate their mitigation and response capabilities.

The Worst Credible Discharge estimates conducted by BP and Equinor for Stromlo-1 range from approx. 4.3 million barrels (bbls) – 7.9 million bbls, which would represent the largest accidental oil spill in history. The 2016 analysis conducted by BP (Equinor's former partner in the project) estimated initial flow rate from an uncontrolled blowout of 54,000 barrels/day (bpd) and 46 million cubic feet (cf) of gas/day. For a blowout duration of 149 days (BP's predicted time to successfully complete a Relief Well) this would result in a total discharge of 7.9 million bbls (approx. 1 million tons) of oil and 6.8 bcf (approx. 170,000 tons) of gas. This would be approx. twice the size of the Deepwater Horizon spill (4 million bbls) in the U.S. Gulf of Mexico (to date the largest accidental oil spill in history).

Equinor's 2018 Oil Pollution Emergency Plan predicts a lower Worst Case Discharge flow rate and duration, but does not adequately justify its lower estimate. Equinor estimates a Worst Case Discharge blowout for an open well bore (drill pipe removed) would flow at 8,943 m³ (56,250 bbl)/day for 129 days (Equinor's initial estimate for completing a Relief Well), for a total release of 7,256,250 bbls. But assuming the drill string remains in the well bore during the blowout and somewhat restricts outflow, Equinor estimates a Worst Credible Case Discharge (WCCD) of 6,739 m³ (42,387 bbl)/day for 102 days (its revised Relief Well time), for a total release of 4,323,474 bbls. This would be slightly more than the Deepwater Horizon release. Equinor's

2018 WCD assessment does not estimate gas release, not does it adequately substantiate the flow rate and Relief Well time being lower than BP's estimate for the same well. Given Equinor's lack of substantiation for its lower estimate, it is felt that BP's WCD estimate of 7.9 million bbls is a more appropriate for the project.

Another spill trajectory model (Lebreton, 2015) that evaluates a spill of 4.35 million barrels (approx. the size of the 2010 Deepwater Horizon and the Equinor WCCD) is summarized. This trajectory model predicts that even a much smaller (10%) release of 435,000 barrels (bbls) in summer would cover 213,000 km² of sea surface, mostly west of the drill site; and 265,000 km² in winter, mostly east of the site. The model predicts that oil could spread beyond Tasmania to New Zealand, and estimates a 70% - 80% probability of shoreline oiling in south Australia. A true WCD spill (7.9 million bbls, 18 times larger) would contaminate a considerably larger area.

The oil spill modeling for the GAB project conducted by BP predicted that for certain scenarios, the probability of oil reaching the Australia shore would be 100%, as much as 179,673 barrels (25,154 tons) could come ashore (more than from the Deepwater Horizon spill in the U.S.), oiling up to 750 km of shoreline, and oil could travel from 1,083 km - 2,664 km from the spill release site. Equinor's 2018 assessment predicts that oil from its modeled WCD spill would reach shorelines from Albany WA to Port Macquarie NSW (approx. 390 km north of Sydney). Equinor ran its spill model for 60 days beyond when the blowout would be killed with a Relief Well, but clearly oil would persist for much longer, continuing to weather and flow with surface currents. Thus, actual impacts from a Stromlo-1 WCD (particularly a true WCD of 7.9 million bbls) would likely extend much farther, with weathered oil and tar balls flowing with surface currents for an extended period.

Given other experiences with similarly large oil spills (Deepwater Horizon and Exxon Valdez), it is concluded that impacts of a WCD from the proposed GAB drilling project would almost certainly be catastrophic. Half of the oil and all of the natural gas from the deepwater release would likely remain in the water column, and spread in subsurface plumes over a vast volume of the pelagic ecosystem. Exposed organisms would suffer acute/lethal and chronic/sublethal injuries. The spill would impact plankton and early life stages of pelagic fishes, such as sardine and anchovy.

One GAB spill exposure model (Ellis, 2016) predicts that a 435,000 bbl Stromlo-1 spill (much smaller than WCD) would impact many Matters of National Environmental Significance, including up to 177 marine species; 47 species classified as vulnerable, endangered, or critically endangered; 38 marine reserves; and 50 coastal wetlands.

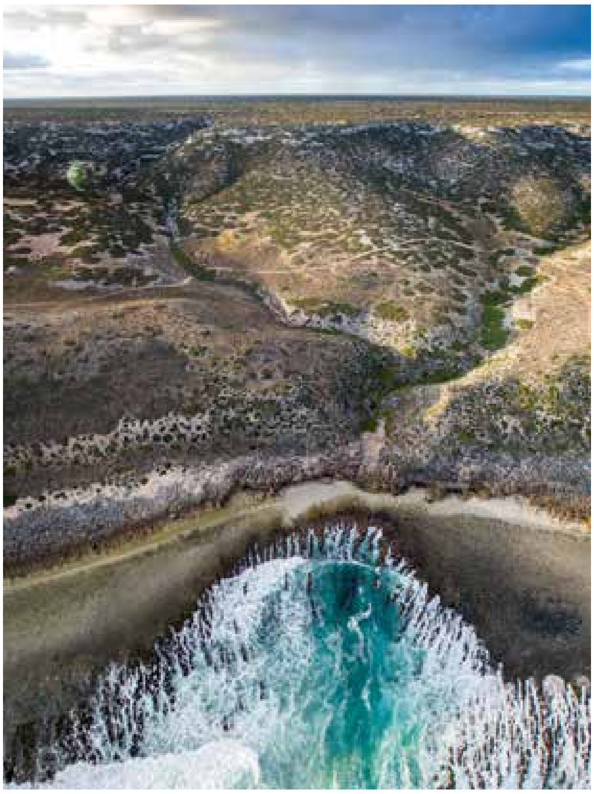
A WCD oil spill in the GAB would likely result in the mortality of hundreds of thousands of seabirds; thousands of marine mammals, including endangered Southern right whales, blue whales, killer whales, dolphins, endemic Australian sea lions, and New Zealand fur seals; and hundreds of sea turtles. Hundreds of kilometers of shoreline would be oiled, causing extensive harm to intertidal and nearshore subtidal communities. Significant injury is expected to the exceptionally diverse, unique, and productive nearshore kelp and fucoid ecosystems of the Great Southern Reef. Ecological injury from a WCD is expected to persist for decades. As specific examples of likely oil spill impacts, the report discusses potential injuries to pelagic fishes, albatrosses, killer whales, and Southern right whale calving/nursing in the Head of Bight and Twilight Marine Reserve.

The region's economy would likely suffer billions of dollars in losses from a WCD spill (potentially on the order of the $62 billion USD cost to BP for Deepwater Horizon). One researcher (Bea, 2016) calculates (using a U.S. EPA spill cost model) that at a "high-imwpact" total cost of $20,000/bbl, a 4.35 million bbl spill in the GAB would result in a total cost of $87 billion USD; and a similar high-impact cost for a 7.9 million bbl spill would result in $158 billion USD in total cost. Commercial fisheries, recreational fisheries, and aquaculture operations would be closed for a substantial period of time, and could experience long-term losses. Tourism would suffer considerable, multi-year financial losses. Social, psychological and physical health of coastal communities would be significantly impacted, likely remaining affected for years.

Response to a WCD release in the GAB would likely recover less than 5% of the total volume spilled, particularly given the exposed, high wind/wave energy, open ocean physical environment of the region. At best, spill response would be environmentally irrelevant, and more likely it would increase ecological injury. And as in other large oil spills, rehabilitating oiled wildlife would be ineffective, and ecological restoration would be impossible. One researcher (Ellis, 2016) concluded that the proposed project: *"is arguably the most environmentally constrained project proposed in Australian history."*

Governments elsewhere have protected sensitive marine regions from offshore drilling, where the risks and consequences of a large oil spill have been determined to be unacceptably high. These areas include the Lofoten archipelago in Norway, the North Aleutian Basin/Bristol Bay in Alaska, all waters off Belize, Australia's Great Barrier Reef, and international waters of the Ross Sea in Antarctica, due to the extraordinary marine environmental values that would be placed at risk from drilling. Similar protections should be considered for the GAB.

While benefit/risk and the acceptable risk tolerance for this offshore drilling proposal are matters for the citizens and government of Australia to decide, the author concludes that risks of drilling in the GAB greatly outweigh potential benefits, and respectfully recommends that the Government of Australia permanently protect the Great Australian Bight from offshore oil and gas development.



Drone footage of Bunda Cliffs in the Great Australian Bight.
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02 INTRODUCTION

This assessment, commissioned by Greenpeace Australia and Pacific, provides an overview of the risks and potential impacts of a Worst Case Discharge (WCD) of petroleum hydrocarbons from proposed deepwater exploratory drilling in the Great Australian Bight, off the south-central coast of Australia. As the oil industry and government of Australia (National Offshore Petroleum Safety and Environmental management Authority – NOPSEMA) have withheld much of the detailed information regarding the proposed drilling project, this assessment is based on the documents and scientific analyses currently available in the public domain. Although its former partner in the GAB drilling project, BP, withdrew in 2016, Norwegian oil company Equinor announced in May 2018 that it intends to proceed with the GAB drilling program in 2019.[1]

The company said in May that it has applied to extend the existing lease title for drilling in EPP 39 (where the Stromlo-1 drill site is located) until April 2020, and that:

> *"…we plan to drill one exploration well, estimated at 60 days, at the end of 2019. The application to extend the permit year to April 2020 is to provide us with operational flexibility."*[2]

Equinor proposes to drill one deepwater (2,239 m water depth, total drilling depth of 5,200 m – 5,700 m) exploration well ("Stromlo-1") in the GAB in summer from 1 October – 31 May (Q4-Q1) with a target to start drilling in Q4 2019 or Q4 2020. The drilling location is at 34° 56' 21.47" S; 130° 39' 44.61" E, and Equinor predicts the well would take 60 days to drill.[3]

Much of the information presented previously by BP with regard to the GAB drilling program is relevant in considering the Equinor proposal (for the same Stromlo-1 well), and the assessment below derives largely from those publicly available analyses.

The findings below have been developed and presented independently, with no influence by any entity, including the report sponsor. This report is intended to aid the citizens and government of Australia in their consideration of the risks and potential impacts of the proposed GAB drilling project.

03 THE GREAT AUSTRALIAN BIGHT MARINE ECOSYSTEM

By any measure, the Great Australian Bight (GAB) marine ecosystem is one of the most productive and unique anywhere in the world. Several syntheses of scientific literature and research have been compiled, notably the June 2013 "Great Australian Bight Ecosystem Study: Physical Processes, Biodiversity, and Ecology of the Great Australian Bight – A Literature Review;"[4] and the 2018 "Great Australian Bight Research Program 2013-2017" (GABRP).[5] The syntheses documents report that many of the oceanographic processes that underlie the regions productivity and migratory patterns of apex predators remain poorly understood, as are the deepwater benthic infaunal, epifaunal, and fish communities.

As summarized in GABRP 2018: "This unique marine environment is part of the world's longest southern-facing coastline, contains significant natural resources, and is of global conservation significance."[6] The GAB is generally considered to include waters from Western Australia to Tasmania, and more specifically from Cape Pasley, Western Australia, to Cape Catastrophe, Kangaroo Island, South Australia, encompassing over 150,000 km² of ecologically rich marine habitat, including 19 marine parks (covering 26,655 km²) and several marine reserves.[7] The Bunda cliffs are the world's longest uninterrupted sea cliffs, and with no offshore oil and gas development at present, the marine region that stretches south to Antarctica is an integral component of one of the largest marine wilderness areas in the world ocean.[8]

The 2013 GAB Literature Review reports that the dominant shelf current is the Leeuwin Current flowing west-to-east, and the east-to-west flowing deeper (around 600 m isobath) Flinders Current, with meso-scale (warm core) eddies along the continental shelf. The region experiences both downwelling and upwelling (described as the Great South Australia Coastal Upwelling System, or GSACUS), and significant wind and wave turbulence in surface waters, deriving from seasonally persistent storm systems in the Indian Ocean and Southern Ocean. Plankton productivity is relatively high in the western GAB region, comparable to highly productive upwelling systems off Africa and Chile.[9]

According to the GABRP:

> *"More than 85 percent of known species in the region are found nowhere else in the world. The Great Australian Bight provides critical habitats and migration pathways for iconic species and predators at the top of the food chain (apex predators), including Australian sea lions, white sharks, and pygmy blue whales. Australia's largest and most valuable stocks of fishes in the open sea (pelagic fishes), especially Australian sardine and southern blue fin tuna, occur in the Bight, and there are important coastal fisheries for crustaceans (e.g. southern rock lobster, prawns and crabs), molluscs (e.g. abalone) and finfish (e.g. snapper, King George whiting, garfish and flathead), with the majority of South Australia's valuable aquaculture farming residing in the coastal waters off Eyre Peninsula."*[10]

And, according to the 2013 Literature Review:

> *"The GAB supports the largest densities of marine mammals, seabirds, sharks, and pelagic fishes in Australia. Australian sea lions, New Zealand fur seals, common and bottlenose dolphins, white sharks, shortfin makos and little penguins are found in the GAB all year round; seasonal aggregations of albatrosses, petrels, pygmy blue whales, southern right whales, and southern bluefin tuna visit the region for feeding and/or breeding."*[11]

Thirty-seven species of cetaceans (whales, dolphins, porpoises) are reported in the GAB, several of which are listed as endangered.

The entire GAB provides feeding and calving habitat for endangered Southern right whales, with three primary calving areas – Head of Bight, used by perhaps half the Australian population, 10% of global population (estimated at 1,500 - 12,000); Doubtful Island Bay; and Israelite Bay.[12,13,14,15]

The eastern continental shelf edge and slope at the Bonny upwelling, Kangaroo Island Canyons, Perth Canyon, and Bremer Canyon are important feeding areas for endangered blue whales, fin whales, sei whales, and pygmy blue whales, as well as sperm whales, humpback whales, beaked whales, killer whales, and dolphins.[16,17]

The GAB is also critical habitat for three pinniped (seal and sea lion) species: hosting 93% of the endangered, endemic, and declining Australian sea lion population; 98% of Australia's long-nosed (New Zealand) fur seal population (with 30 breeding sites); and 18% of the Australian fur seal population (with 10 colonies in Bass Strait).[18,19]

Four out of seven sea turtle species are found in the GAB, including Green (endangered/vulnerable); Hawksbill (critically endangered/vulnerable); Leatherback (vulnerable/endangered); and Loggerhead (vulnerable/endangered).[20,21]

Ten species of sharks utilize the GAB ecosystem, including feeding aggregations of great white sharks, all listed as threatened; the southern dogfish shark, endemic to southern Australia; and the whale shark, listed as endangered.[22,23,24]

Fish in the GAB region include 40 species of Sygnathids (seahorses, pipefishes, pipehorses, and seadragons), and the critically endangered (and commercially valuable) southern bluefin tuna and orange roughy.[25,26] Fishes endemic to the GAB ecosystem include Southern garfish, coastal stingaree, and crested threefin.[27,28] Ecologically important small pelagic fishes in the region include sardine, scaly mackerel, Australian anchovy, round herring, sandy sprat, blue sprat, jack mackerel, blue mackerel, red bait, and saury.[29]

Dolphin near Baird Bay, South Australia.
©Michaela Skovranova/Greenpeace

The Australian sardine supports the nation's largest (by weight) fishery, and these small pelagic fish are critical prey resources for many larger predators, including bluefin tuna, Samson fish, kingfish, pygmy blue whales, southern right whales, dolphins, New Zealand fur seals, Australian sea lions, arrow squid, short-tailed shearwaters, crested terns, petrels, and little penguins.[30] The Giant crab found across the GAB is endemic to south Australian waters,[31] and commercially important crustaceans include southern rock lobster, western king prawn, and western rock lobster.[32,33]

Drone footage of Bunda Cliffs in the Great Australian Bight.
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Fifty-five (55) species of birds, primarily seabirds, are found in the GAB, many of which are endangered, vulnerable, and/or migratory, including 16 species of albatrosses (6 endangered), 12 species of petrels (1 endangered), and the endemic little penguin (Australasia), black-faced cormorant (southern Australia), and shy albatross (Albatross Island, Bass Strait).[34,35]

Although GAB benthic ecosystems remain poorly studied, the area is known to support the highest level of benthic biodiversity and endemism in Australia.[36] "Where sampling has occurred on the continental shelf and slope, benthic habitats appear to support an extraordinarily high diversity of marine organisms with high endemicity."[37] Benthic surveys of the GABRP from 2013 - 2017 identified 277 species new to science and 877 species new to the Great Australian Bight.[38]

Benthic biodiversity in the GAB is exceptionally high, including 1,200 species of seaweeds; 500 species of bryozoans; 50 non-reef building coral species to depths of 900 m; over 200 species of ascidians/sea squirts (one of the richest such assemblages in the world); over 300 species of echinoderms (urchins, sea stars, sea cucumbers, feather stars) of which 90% are endemic; 500 species of molluscs (bivalves, sea slugs, octopus, squid, cuttlefish) of which 95% are endemic; 1,000 species of sponges; and one of the largest seagrass ecosystems in the world.[39]

Marine biodiversity hotspots are concentrated along the GAB continental shelf and slope, including the Albany Canyons group and shelf break, Recherche Archipelago, Ceduna Canyon, Bremer Canyon, Kangaroo Island pool/Eyre Peninsula upwelling, Bonny upwelling, Coorong, West Tasmania Canyons, and most of the continental shelf of the region.[40]

Bremer Canyon is known for its killer whale aggregations, which are thought to be independent of the central Western Australia and Ningaloo populations; calving for southern right whales; foraging for white sharks and Australian sea lions; foraging for sperm whales and beaked whales; orange roughy; and giant squid.[41,42,43]

The Recherche Archipelago exhibits high benthic endemism, 263 fish species, 347 species of molluscs, 300 species of sponges, and 242 species of macroalgae, and important haul-out and breeding colonies of Australian sea lions and New Zealand fur seals.[44,45]

The Kangaroo Island pool is a meso-scale oceanographic feature formed by nutrient-rich Eyre Peninsula upwelling, supporting high productivity of zooplankton, (including krill), small pelagic fish, squid, seabirds, blue whales, dolphins, sperm whales, New Zealand fur seals, and Australia's largest finfish fisheries for sardine and anchovy.[46,47,48]

The Coorong bioregion is known for its extensive seagrass and kelp forests, and inshore saline lagoon that provides critical nesting and feeding habitat for many waterfowl species, including over 230 migratory species from Siberia, Alaska, and Asia.[49,50] As well, the Bonny upwelling hotspot is known for its feeding aggregations of blue whales, little penguins, and Australian fur seals.[51]

The temperate macroalgal forests of the Great Southern Reef, covering 71,000 km² along 8,000 km of the GAB shoreline, support high biodiversity and commercial resources.[52] The Great Southern Reef is comprised of extensive kelp (Laminariales) and fucoid (Fucales) forests, with the highest fucoid diversity and endemism in the world.[53] These subtidal brown algae forests provide critical structure for associated benthic invertebrate and fish biodiversity; fishing and tourism economic values of $10 billion (AUD)/year; and $187 billion/year in ecological services (largely nutrient cycling).[54] The kelp forests dominated by Eklonia radiata support a complex subtidal ecosystem, with over 350 taxa of invertebrates in holdfasts, but are now in decline due to a combination of nutrient loading, overfishing, and climate change.[55]

The Bight's ocean environment provides 25% of Australia's total annual seafood production,[56] with wild fisheries and aquaculture combined providing approximately $1.4 billion annually, and approximately $350 million in household income.[57] Important commercial fisheries include abalone, bluefin tuna, blue crab, scalefish, pipi, shark, squid, prawn, rock lobster, sardine and anchovy. Important aquaculture species include abalone, oysters, mussels, bluefin tuna, yellowtail kingfish and algae.[58]

Nature-based tourism produces in excess of $1.2 billion in annual revenue and 10,000 jobs in the region, based in part of the rich marine ecosystem of the GAB.[59]

Recreational activities dependent on the GAB marine ecosystem include whale watching, shark watching, scuba diving, charter fishing, and recreational boating.

Clearly, the GAB marine ecosystem is exceptionally rich, productive, diverse, unique, and economically valuable.

Sea lions near Hopkins Island captured on a trip to visit the sea lion colony at Hopkins Island with Adventure Bay Charters, Port Lincoln, South Australia. ©Michaela Skovranova/Greenpeace

A view from an altitude of 3200 ft of the oil on the sea surface, originated by the leaking of the Deepwater Horizon wellhead disaster. ©Daniel Beltrá/Greenpeace

04 PROPOSED EQUINOR GREAT AUSTRALIAN BIGHT PROJECT

Shallow water areas of the GAB continental shelf have been partially explored for oil & gas deposits using 2D seismic surveys, and several shallow water (70 m – 260 m) wells were drilled in the region – all commercially unsuccessful.[60] In 2011, BP acquired four exploration leases in the deepwater Ceduna Basin - EPP 37, EPP 38, EPP 39, and EPP 40 – which it shared with Norwegian state oil company Statoil.

In 2015, BP (as operator) submitted Environment Plans to drill two exploratory oil wells at deepwater locations in the Ceduna sub-basin – Stromlo-1 and Whinham-1 – but only a Summary Environment Plan was made public.[61] The plans were declined by NOPSEMA due to several significant insufficiencies, notably the lack of a comprehensive risk assessment and oil spill emergency plan. BP resubmitted an Exploration Plan in 2016 to drill the two wells, but abandoned these plans in Oct. 2016. The BP 2016 Stromlo-1 Well Operations Management Plan (WOMP), which had remained "strictly confidential", was released last month to Greenpeace pursuant to a Freedom of Information request, and is discussed below.

In 2017, Statoil acquired full control of the leases previously held with BP, and Chevron abandoned its GAB drilling plans as well. In 2018, Statoil changed its corporate name to Equinor, and the government of Norway remains the majority shareholder in Equinor, holding approximately two-thirds of all shares.
The Stromlo-1 well site is 600 km west of Port Lincoln, 400 km southwest of Ceduna, in 2,239 m water depth, and the target reservoir is reportedly at an approx. depth of approximately 3,041 m beneath the seabed "mud line".[62] Total vertical depth for Stromlo-1 (sea surface to reservoir) is estimated at 5,280 m.[63] The Whinham-1 well site, previously planned with BP, is located 600 km west of Port Lincoln, 350 km southwest of Ceduna, in a shallower water depth of 1,150m.[64] Equinor proposes to drill the Stromlo-1 one well (EPP 39) in the last quarter 2019 or 2020, with a semisubmersible Mobile Offshore Drilling Unit (MODU), supported by a fleet of vessels and aircraft from shore.

BP had projected the well to take 60-75 days to drill, and Equinor predicts a 60-day drill time. Post-drilling, the well would be plugged with cement and mechanical plugs, and abandoned either for later production or permanently (if no commercially feasible oil & gas is found).[65]

As there have been no wells drilled into this or nearby formations, there is considerable uncertainty regarding reservoir temperatures and pressures expected for Stromlo-1. The 2016 BP Stromlo-1 well plan predicts a maximum reservoir pressure of 10,180 psi (in the K65 target horizon), and maximum temperature of 97° C (in the K64 target horizon).[66] These estimates are below what is normally consider High Pressure/High Temperature (HP/HT) wells, which is defined by API as reservoirs with either pressures exceeding 15,000 psi or temperatures exceeding 177° C.[67] However, the admitted high level of uncertainty with the Stromlo-1 reservoir dictates that it be treated as HP/HT until proven otherwise, requiring the most stringent well design and control.

05 BLOWOUT RISK

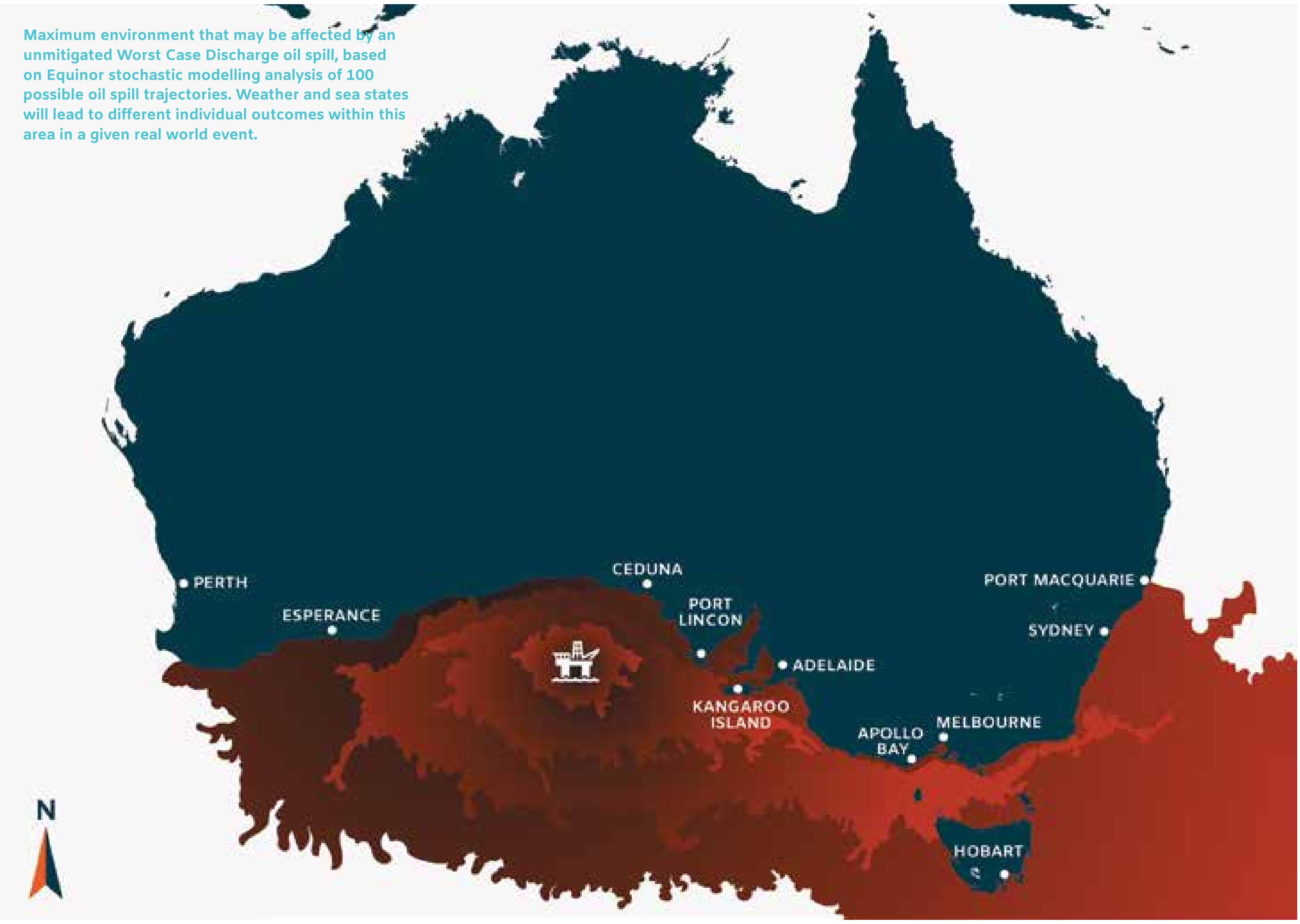
In general, oil companies understate risk of catastrophic failure in offshore drilling, overstate the potential effectiveness of their risk mitigation and response plans, and make qualitative, vague, and unsubstantiated claims regarding risk mitigation.

Even simple failures in complex industrial systems such as Equinor's proposed Stromlo-1 well can lead to catastrophic consequences for the GAB environment and economy.

Risk of an uncontrolled blowout (loss of well control) is inherent in all offshore oil and gas drilling projects, particularly deepwater wells such as those in the GAB projects.

Even with stringent new drilling safeguards enacted subsequent to the *2010 Deepwater Horizon disaster*, risk cannot be eliminated. The U.S. *Bureau of Safety and Environmental Enforcement* (BSEE) Final Rule (30 CFR Part 250) published on August 10, 2012: *Oil and Gas and Sulphur Operations on the Outer Continental Shelf*–Increased Safety Measures for Energy Development on the Outer Continental Shelf; established new casing installation requirements, new cementing requirements, requires independent third-party verification of blind shear ram capability and subsea BOP stack compatibility, requires new casing and cementing integrity tests, establishes new requirements for subsea secondary BOP intervention, requires function testing for subsea secondary BOP intervention, requires documentation for BOP inspections and maintenance, requires a Registered Professional Engineer to certify casing and cementing requirements, and establishes new requirements for specific well control training to include deepwater operations.[68]

It should be noted however, that just this year the current U.S. federal administration has relaxed some of these drilling safety requirements, including the elimination of requirements for third-party inspections of well safety valves, and the requirement that such well equipment be designed for the most extreme conditions in which they would operate.



Maximum environment that may be affected by an unmitigated Worst Case Discharge oil spill, based on Equinor stochastic modelling analysis of 100 possible oil spill trajectories. Weather and sea states will lead to different individual outcomes within this area in a given real world event.

Clean up after Exxon Valdez oil spill using hot & cold water jets, Alaska. ©Henk Merjenburgh/Greenpeace

The BP 2016 *Stromlo-1 Well Operations Management Plan* (WOMP) presents a reasonable safety case for the BP approach to the well, including proposed well design, well operations, fluid and cementing programs, organizational competency and learning, management of change, well control standards, well barrier standards, kick tolerance, personnel competency, contractor management, and well abandonment process. BP obviously learned valuable lessons from its Deepwater Horizon disaster in the Gulf of Mexico.

However, current proponent Equinor has yet to release its proposed WOMP for Stromlo-1, thus it remains to be seen if it will be as rigorous. Regardless, these are 'plans on paper', and the real test of the safety case is how rigorously these plans are implemented while drilling. As industry is aware, even with these safeguards in place, catastrophic blowout risk remains.

The International Association of Oil & Gas Producers (OGP) estimates that statistical likelihood of uncontrolled blowouts in deepwater drilling is from 0.3 – 2 per thousand wells drilled per year.[69]

Risk is generally agreed to be the likelihood (statistical probability) of an event occurring multiplied by the consequence (severity) of the event. But tolerance of risks is more complicated, including such things as access to alternatives to the risky behavior, and connection (proximity) to the consequence. If there are easily accessible alternatives to a risky behavior, then tolerance of the risky behavior is reduced. And the closer one is to the consequence of an event - geographically, emotionally, or temporally - then tolerance of the risky behavior is also reduced.

With easily accessible economic alternatives to deepwater drilling and energy development – onshore production, alternative energy, energy efficiency, fishing and tourism jobs, etc. – tolerance of drilling risk is commensurately lower. In addition, risk of a GAB drilling disaster may be more tolerable to an urban office worker in Melbourne than to a fisherman, aquaculture business, or charter boat operator in Port Lincoln.

Probabilistic risk assessments do not adequately capture the risk of catastrophic failure. They are often used to justify drilling in sensitive areas and to employ less than Best Available Techniques/Technology (BAT), promoting dangerous complacency in government and industry. Industrial systems such as offshore oil drilling habitually prioritize production and financial return over costly prevention of unlikely accidents and disaster.[70]

Even competent risk assessments generally do a poor job at assessing and managing low probability/high consequence risk in complex systems. Risk assessment engineer Robert Bea (2016) notes that one of the most important contributors to failure in complex systems is the inability to assess the consequence of specific failures before they occur:

> *"Experience shows the single dominant tendency is to underestimate the true consequences of potential failures. The system operators and organizations think they are prepared to handle failures, but when the failures happen, the responses clearly show the thinking and preparations were seriously deficient. The underestimates in the consequences of failures result from a wide variety of deficiencies in the assessment processes (e.g., not recognizing long-*

> *term and off-site negative impacts effects on the public, governments, industry, and environment). Frequently, important things are simply left out and there are major flaws embedded in the assumptions concerning controllability of the consequences. In the face of evidence to the contrary, we hope that things will work as they should and the consequences will be low. Failures frequently develop because of the tendency to underestimate the consequences of failure coupled with the consequent tendency to improperly manage the consequences associated with an engineered system; the system is not properly prepared to deal with the potential consequences of the potential failures it faces."*[71]

Regardless of industry or government assurances to the contrary, and the safest system in place, such dangers would certainly exist in any GAB deepwater drilling program.

History is full of the tragic consequences of complacency, overconfidence, and arrogance in managing catastrophic risk in complex systems, including oil infrastructure. The following two historic examples may help clarify this point:

Trans-Alaska Pipeline: Seeking approval to build the 800-mile Trans Alaska (oil) Pipeline and marine terminal in the early 1970s, politicians assured the American public that "not one drop" of oil would ever be spilled into the coastal waters of Alaska, as best available technology would be used in every aspect of the project to prevent such. Regulators and industry promised double-hulled tankers, a state-of-the-art Vessel Traffic System to safely monitor all tanker transits, and robust oil spill response capability. But after securing the right-of-way to build the pipeline, these promises were quickly abandoned. Twelve years after the opening of the pipeline and marine terminal, the fully loaded, single-hulled oil supertanker Exxon Valdez grounded on a well-marked reef, spilling hundreds of thousands of barrels of toxic crude oil into the pristine coastal ecosystem of Prince William Sound, Alaska. The environmental injury was severe, and continues to this day, 30 years later (see Exxon Valdez section below).

Deepwater Horizon: Just 5 months prior to the Deepwater Horizon disaster in the U.S. Gulf of Mexico, representatives of the U.S. oil industry and government regulators, assured a U.S. Senate hearing regarding the August 2009 Montara offshore platform blowout in the West Timor Sea (NW Australia), that offshore drilling in the U.S. Gulf of Mexico was perfectly safe, and the regulatory process was sufficient to prevent such disasters. Just three weeks before the April 2010 Deepwater Horizon disaster, then U.S. President Barack Obama opened large areas of the U.S. Outer Continental Shelf (OCS) to oil and gas drilling, assuring the American public that: *"Oil rigs today generally do not cause spills. They are technologically very advanced."* Such hubris and complacency is typical of government and industry officials in their attempted justification for offshore drilling safety in sensitive environments (see Deepwater Horizon section below).

At least a dozen safety-critical errors occurred which led to the blowout and explosion on the Deepwater Horizon. Below is a summary of key findings of the Deepwater Horizon Accident Investigation regarding main causes for the blowout and disaster:[72]

1. Well Integrity was not established or failed: annulus cement barrier did not isolate hydrocarbons; shoe track barriers did not isolate hydrocarbons.

2. Hydrocarbons entered the well undetected, and well control was lost: negative pressure test was accepted although well integrity not established; influx was not recognized until hydrocarbons were in riser; well control response actions failed to regain well control.

3. Hydrocarbons ignited on Deepwater Horizon: diversion of gas/oil to mud-gas separator vented gas onto rig; fire and gas system did not prevent ignition.

4. Blowout Preventer (BOP) did not seal the well; BOP emergency modes did not function to seal well.

As with many such technological disasters, some of these causes were design flaws, some were management failures, some were mechanical failures, and some were simple human error. At the most basic level, all of these failures resulted from human error – either failures to design, maintain and inspect equipment; or mistakes made in monitoring and operating equipment.

Importantly, there are thousands of different combinations of faults/failures that can occur in exploratory deepwater drilling leading to disaster. Even with the most stringent safeguards, many of these failures are difficult to detect and correct.

The combination of unanticipated mistakes and simple failures resulted in disaster for the Deepwater Horizon and Exxon Valdez, and it is critical to recognize that even with the safest system in place in the proposed GAB drilling project (which in itself is not assured), such failures can easily lead to a similar uncontrolled spill disaster.

Ships surround a controlled burn of oil on the surface of the Gulf of Mexico near BP's Deepwater Horizon spill source. ©Daniel Beltrá/Greenpeace

06 RISK REDUCTION

While the issue of blowout risk reduction *per se* is not within the scope of this report, a few comments are in order.

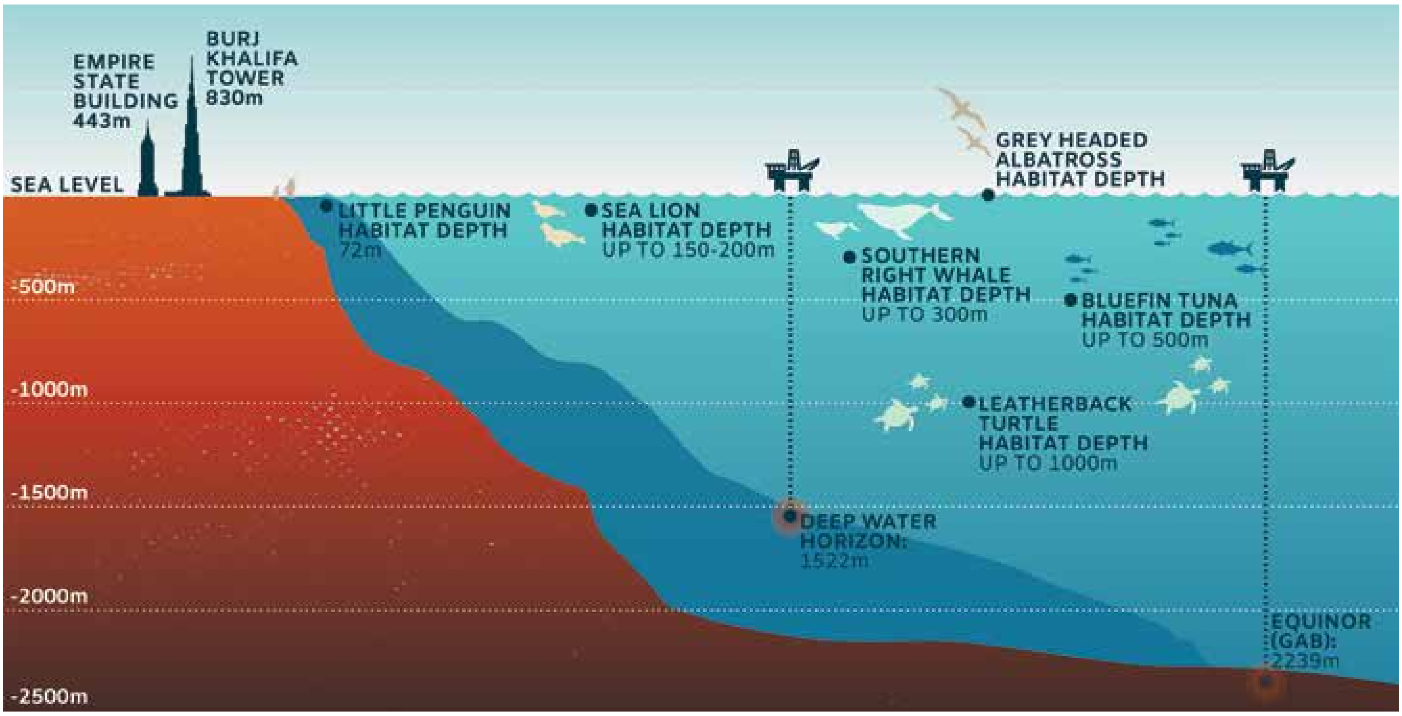
BP's 2016 Stromlo-1 well plan outlines 23 risks relevant to well integrity.[73] These include such risks as zonal isolation not achieved, uncertain pore pressure fracture gradient, loss of fluids, underbalance/overbalance, well barrier failure, BOP pressure test failure, cement failure, hanger failure, gas in the riser, etc. The contingency plans for these failures seem reasonable, but are certainly not failsafe.

It is standard industry practice to employ a Major Accident Event (MAE) risk reduction standard of As Low As Reasonably Practicable (ALARP).[74] While companies may cite their intention to employ Best Available Techniques and Technology (BAT), also called Best Available & Safest Technology (as required in U.S. and European regulation), and Best Environmental Practice (BEP), to the contrary, Equinor and other oil companies usually only commit to ALARP, due mainly to cost. Indeed, NOPSEMA only requires that risks and consequences of a MAE in offshore drilling be ALARP.[75]

An ALARP standard implies that not all Best Available Techniques and Technology measures will be incorporated into the project, particularly if, at the discretion of the company, such measures are deemed too costly, too difficult, too time-consuming, or otherwise not "reasonably practicable." In essence, ALARP is not BAT/BEP. If BAT/BEP is required, then an ALARP risk reduction standard is insufficient.

Given the sensitivity of environmental, social, and economic resources in the Great Australian Bight, the region should clearly be considered a High Consequence Area (HCA) for petroleum development (as defined in API standards), thereby requiring enhanced design and operational standards to reduce risk with BAT to As Low As Possible ("ALAP"), regardless of cost.[76] A High

Sea lions near Hopkins Island captured on a trip to visit the sea lion colony at Hopkins Island with Adventure Bay Charters, Port Lincoln, South Australia. ©Michaela Skovranova/Greenpeace



Depth comparison between the proposed Equinor Bight drilling operation, Deepwater Horizon and prominent landmarks. Images of animals and oil platforms not to scale.

Consequence Area is generally considered to include infrastructure in highly sensitive environments, where the consequences of a major accident would be severe or catastrophic. Activities in these areas then receive greater safety design and operational standards.

Industry is beginning to endorse the use of ALAP risk reduction for offshore drilling in sensitive, high consequence areas. The Norwegian marine industry classification society Det Norsk Veritas (DNV) states that "industry should be prepared for high societal expectations in terms of what companies should pay in order to lower the risks associated with economic activities" in sensitive environments.[77] And that "... in some cases it may be decided not to expose highly sensitive or important ecosystems to the risks associated with drilling for hydrocarbons."[78]

If the Australian government does opt to permit the Equinor project, it is strongly recommended that an ALAP risk reduction standard be required. An ALAP risk reduction standard for the GAB projects would, among other things, require the safest design, oversight, and operational standards possible in order to reduce the likelihood of an uncontrolled blowout as far as possible, regardless of cost. As well, ALAP would require the most effective blowout intervention contingencies possible. For instance, drilling a companion simultaneous Relief Well with another MODU adjacent to, and slightly delayed behind, the main Stromlo-1 well, would enable rapid intersection and bottom-kill of the main well in the event that it fails.[79] Additionally, an emergency Capping Stack or other Containment Response System (CRS) prepositioned on a response vessel on standby at the offshore drill site during drilling, along with a spill collection storage tanker, would shorten response time. Such measures would dramatically reduce the time needed to kill an uncontrolled blowout, but would significantly increase the cost of the project. This safety/cost trade-off would be an important decision for the people and government of Australia.

While NOPSEMA requires ALARP risk reduction, as noted in Bea's submission to the Senate Standing Committee (2016), the drilling plan proposed by BP did not even reach this standard:

> *"Results from the Quantitative Risk Assessment (QRA) based on the proposed BP GAB exploratory drilling Systems indicate the Risk of an Uncontrolled Blowout during exploratory drilling is not ALARP. Both the assessed Likelihood and Consequences exceed historic performance, economics cost-benefit, and standards-of-practice guidelines for determination of ALARP Risks associated with Major Accident Events (MAEs) (Bea 1990, 1991, 2000, 2016; Hartford, 2009)."*[80]
> *"Reduction of the Likelihood of an uncontrolled blowout to develop ALARP Risk requires the exploratory drilling System proposed by BP probability of failure (blowout not prevented) be reduced by a factor of approximately 1,000. Such reductions have proven to be possible for offshore oil and gas exploration and production Systems given the System performance characteristics are: "Outstanding, exceeding all standards and requirements" (Bea, 2000, 2002b)."*[81]

It is likely that, due to cost considerations, the Equinor GAB drilling proposal will similarly fall short with its risk reduction standards for the project.

And it must again be underscored that, even with the safest system in place reducing risk to As Low As Possible (ALAP), the risk of a WCD spill remains.

07 BLOWOUT SOURCE CONTAINMENT

Reducing the consequence of a well blowout and spill requires the operator to be able to kill the blowout as soon as possible. Immediate source control response would consist of the following three sequential methods:

1. Activating the BOP with any/all modes: Automatic Mode Function (AMF), Remotely Operated Vehicle (ROV), acoustic and electrical/hydraulic triggers;

2. Attaching a Capping Stack or other Containment Response System (CRS) to the failed wellhead or BOP;

3. Completing a Relief Well to intersect and bottom-kill the failed well.

As stated in the 2016 BP Stromlo-1 WOMP: "BP New Venture's policy is to over react and then scale down a response in order not to delay mobilization of any possible critical path equipment."[82] It is likely that Equinor would employ the same general approach.

Blowout Preventers (BOPs) are critical systems for subsea well control, but they are not failsafe. Numerous studies have documented the limited effectiveness of BOPs in sealing subsea well blowouts, and some studies report a BOP failure rate up to 45%.[83] As example, despite several activation redundancies incorporated into its design, the BOP on the Macondo well (Deepwater Horizon) failed to seal the well. The residual risk imposed by this inherent failure rate must be recognized so that industry, government, and the public do not develop a false sense of security by the installation of a BOP on the GAB wellheads.

If the BOP fails to secure a wellhead blowout, the next immediate option would be to attach a Capping Stack or other Containment Response System (CRS) to the failed BOP, wellhead, or Lower Marine Riser Package (LMRP) flex joint. BP identified the four Oil Spill Response Limited (OSRL) Capping Stacks (15,000 psi and 10,000 psi), and of these the 10,000 psi stack based in Singapore would be closest to the drilling location, and thus the primary option. BP projected it would take 35 days to successfully deploy and attach the Capping Stack and kill the well.[84] However, Equinor predicts, without substantiation, that the time necessary to kill a Stromlo-1 blowout with a Capping Stack would be 15 days.[85] Equinor also commits to immediately deploy "WellCONTAINED" Services of "Wild Well," headquartered in Houston, Texas (USA).[86]

The previous BP plan was to load the Capping Stack on a heavy-lift freight vessel at OSRL in Singapore, sail to Perth, and then transfer it onto a suitable construction vessel for transport to the Stromlo-1 well site for connection – total estimated time of 35 days. This time could be shortened considerably (perhaps 10 days or less) if the Capping Stack is pre-positioned on a standby vessel at the offshore drill site during drilling.[87]

However, the 2016 BP Stromlo-1 well plan admits that Capping Stack deployment is limited to maximum sea states of 3.5 m – 4 m, and that weather delays are a distinct possibility. Summer swells in the GAB are reported to exceed 4 m approx. 10% of the time, and seas of 0.5 – 1.5 m can develop on top of swells.[88] In winter, swells over 4 m occur one-third of the time in the region, with maximum wave heights reported at 10.8 m.[89] Thus, the ability to deploy and attach a Capping Stack would be limited much of the year. As well, an angle between BOP and Capping Stack exceeding 8.3° would necessitate a conductor-straightening operation, which would further delay a connection and well kill.[90]

In tandem with the above two source control methodologies (BOP activation and Capping Stack), the operator would begin drilling a Relief Well as soon as possible, at least 500 m offset from the main Stromlo-1 well, with which to intersect the failed well at the reservoir and bottom-kill the well by injecting heavy muds and cement. The 2016 BP Stromlo-1 WOMP states that a single Relief Well would be capable of killing the Stromlo-1 well, and a suitable rig would need to be located from the Southeast Asia/Indian Ocean/Far East or Australia/New Zealand region, subject to availability.

The BP Stromlo-1 WOMP identified several potential rigs with which to drill a Relief Well, but significantly, admitted that none were "harsh environment" rated rigs. BP planned to drill the Stromlo-1 well with a harsh environment rated rig (the Ocean GreatWhite ultra-deepwater drilling rig owned by Diamond Offshore), in order to avoid weather related down time. But the BP 2016 analysis admits: "As harsh environment rigs are rare, it is extremely unlikely one will be available in a short time frame for a relief well."[91] This could necessitate weather delays in drilling the Relief Well, particularly in winter sea states, further lengthening blowout duration and spill size.

While it took BP 152 days to complete the Relief Well for Macondo, BP had elsewhere projected 158 days (over 5 months) to complete a Relief Well on one of the deepwater GAB wells.[92] The 2016 Stromlo-1 WOMP projects 149 days to drill the Relief Well. Even in the shallow water Montara blowout in 2009, it took PTTEP 74 days to complete a Relief Well.[93] Relief Well kill-time could be significantly shortened by requiring the operator to drill a Simultaneous Relief Well along with the primary exploratory well, lagging closely behind the exploratory well.[94] Such a mitigation measure could conceivably reduce the Relief Well kill time to a matter of 20 days or less. As discussed above, an ALAP risk reduction standard would require prepositioning the Capping Stack at the drill site, and drilling a simultaneous (lagging) Relief Well along with the primary Stromlo-1 well. While these measures would add considerable cost to the project and alter the project's financial feasibility, this would clearly be the safest approach. However, it must be recognized and honestly admitted that regardless of how effective drilling safety and blowout response may be proposed for the Equinor GAB project, risk of an uncontrolled blowout and WCD spill cannot be eliminated, response may be slow or ineffective, and environmental consequences of such a spill would almost certainly be catastrophic.

08 GREAT AUSTRALIAN BIGHT WORST CASE DISCHARGE (WCD)

The Worst "Credible" Discharge analysis for Stromlo-1 conducted by the proponent's previous partner in the GAB project, BP, estimates an initial flow rate from an uncontrolled blowout of 54,000 barrels/day (bpd) and 46 million cubic feet of gas/day.[95]

For a blowout duration of 35 days (estimated time to connect a Capping Stack) this would result on a total discharge of 1.9 million bbls oil and 1.6 bcf of gas; and release duration of 149 days (estimated time to complete a Relief Well) would result in a total discharge of 7.9 million bbls oil and 6.8 bcf of gas. Importantly, this would be approx. twice the size of the Deepwater Horizon spill in the U.S. Gulf of Mexico.

Equinor's 2018 Oil Pollution Emergency Plan predicts a lower Worst Case Discharge flow rate and duration, but does not adequately justify its lower estimate.[96] Equinor estimates a Worst Case Discharge blowout for an open well bore (drill pipe removed) would flow at 8,943 m³ (56,250 bbl)/day for 129 days (Equinor's initial estimate for completing a Relief Well), for a total release of 7,256,250 bbls. But assuming the drill string remains in the well bore during the blowout and somewhat restricts outflow, Equinor estimates a Worst Credible Case Discharge (WCCD) of 6,739 m³ (42,387 bbl)/day for 102 days (its revised Relief Well time), for a total release of 4,323,474 bbls.[97] This would be slightly more than the Deepwater Horizon release. Equinor's 2018 WCD assessment does not estimate gas release, not does it adequately substantiate the flow rate and Relief Well time being lower than BP's estimate for the same well. Given Equinor's lack of substantiation for its lower estimate, it is concluded here that BP's WCD estimate of 7.9 million bbls is more appropriate for the project.

To predict exposure of marine organisms to toxic levels of hydrocarbons in a GAB spill, three studies are particularly relevant: Equinor 2018, conducted stochastic and deterministic modeling of its estimated 4.32 million bbl WCD[98]; Lebreton 2015, modeled four spill scenarios, including a 4.35 million bbl WCD;[99] and Ellis 2016, used the Lebreton trajectory scenarios to predict the marine species and Matters of National Environmental Significance (MNES) that would likely be exposed to one of the more modest (not Worst Case Discharge) scenarios.[100] Taken together, these studies help predict potential oil exposure from a WCD spill from Stromlo-1, particularly shoreline exposure, but they do not discuss likely ecological impact per se (see below).

A. EQUINOR WCD MODEL (2018)

The 2018 Equinor OPEP assumes that, as the properties of oil in the Ceduna sub-basin reservoir are unknown, the oil would be of marine origin, and thus comparable to a medium weight crude oil in the North Sea - Statfjord C.[101] Statfjord C has a medium density, medium API gravity, and is considered a medium-persistence oil, with a low-volatile component of 21% and residual component of 33%.[102] Thus, over half the oil component that would be released from Stromlo-1 spill should be considered relatively persistent in the marine environment, and relatively resistant to photo-oxidation.

Equinor's detailed spill model was not available to be examined for this report (it is in its confidential Environment Plan), but the model results are summarized in the 2018 OPEP. Its stochastic WCD model was run for 100 hypothetical spills from Oct. - May, for over 129 days, which was its initial time estimated to mobilize and complete a Relief Well. It ran the model for an additional 60 days past the Relief Well kill time. The company then subjected the 129-day Relief Well time to an ALARP analysis, and without reporting any of these details, reduced its projected Relief Well kill-time to only 102 days.

As cited above, Equinor estimates a Worst Case Discharge blowout for an open well bore (drill pipe removed) would flow at 8,943 m³ (56,250 bbl)/day for 129 days, for a total release of 7,256,250 bbls. Assuming the drill string remains in the well bore during the blowout and restricts outflow, it estimates a Worst Credible Case Discharge (WCCD) of 6,739 m³ (42,387 bbl)/day for 102 days (its revised Relief Well time), for a total release of 4,323,474 bbls.[103] However, the OPEP does not report the details from which these modeled flow rates are derived.

Equinor's deterministic modeling selected spill scenarios from the 100 stochastic models, in order to generate "fastest time to shore" estimates for shoreline oiling. While these models predict that no fresh oil would reach the shore, extensive shoreline oiling would occur across a vast region of Australian shoreline. The model predicts that oil would first reach Talia and Eyre Peninsula after 21 days, and Kangaroo Island after 31 days. The deterministic model predicts that:

> *"…potentially high shoreline loadings (>1000 g/m²) are indicated from Flinders Island to the Yorke Peninsula and including Kangaroo Island, which indicates planning for shoreline and wildlife response capability would need to cover those areas."*

The Equinor spill modeling also included assessments of the impact of various source control methodologies on total oil released, including Sub Sea Dispersant Injection (SSDI), BOP intervention, and Capping Stack attachment. A SSDI, similar to BP's response in Deepwater Horizon, would cause more oil to be entrained in the water column and thus not rise to the sea surface or reach shorelines. But as in Deepwater Horizon, SSDI would also lead to greater impacts within the pelagic ecosystem. The Equinor assessment only considered reduction in shoreline oiling with SSDI, not increased impacts in the pelagic ecosystem. Successful BOP intervention on day one would quickly terminate the outflow, which Equinor's models predict

Fire boat response crews battle the blazing remnants of the off shore oil rig Deepwater Horizon.
©The United States Coast Guard

would significantly reduce shoreline oiling. And without substantiation in the OPEP, Equinor reduced the Capping Stack deployment/attachment time from 35 days (2016 BP estimate) to only 15 days.[104]

The 2018 Equinor assessment predicts that oil from its modeled WCD spill would reach shorelines from Albany WA to Port Macquarie NSW (approx. 390 km north of Sydney). Equinor only ran its spill model for 60 days beyond when the blowout would be killed with a Relief Well, but clearly oil would persist for much longer, continuing to weather and flow with currents. Thus, actual impacts from a Stromlo-1 WCD (particularly a true WCD of 7.9 million bbls) would likely extend much farther, with weathered oil and tar balls continuing to flow for an extended period of time.

B. TRAJECTORY MODEL (LEBRETON, 2015)

The submission by Lebreton (2015) to the Australian Senate Standing Committee on Environment regarding the previous BP GAB drilling plan describes four reasonable spill scenarios for the GAB deepwater wells, based on flow rates of (A) 5,000 barrels per day (bpd) and (B) 50,000 bpd; and flow duration of (1) 35 days or (2) 87 days.[105] These 4 scenarios provide the following total spill volumes:

1A 5,000 bpd x 35 days = 175,000 bbls
1B 50,000 bpd x 35 days = 1,750.000 bbls
2A 5,000 bpd x 87 days = 435,000 bbls
2B 50,000 bpd x 87 days = 4,350,000 bbls

As well, a Capping Stack or other Containment Response System could, for many reasons, fail to attach and kill a deepwater wellhead blowout, making a Relief Well the only option for a successful well kill. Many in the industry feel that Relief Wells are the only certain method to kill an uncontrolled blowout, and these are generally drilled in parallel with other source-control methodologies such as BOP control, Capping Stack, etc.[106]

For its GAB project, BP had estimated that a Relief Well would take 158 days to complete (e.g., it took BP 152 days to complete its Relief Well at Macondo). Thus, a true Worst Case Discharge (WCD) would be a blowout with duration of 158 days (over 5 months), and with a flow rate of 50,000 bpd, this would result in a total release of 7.9 million bbls. This is precisely the same total discharge estimated in the 2016 WCD analysis done by BP, at 54,000 bpd x 149 days (time to drill Relief Well), for a total discharge of 7.9 million bbls of oil.[107]

Lebreton's 2B scenario is based on a flow rate (of medium weight crude oil) of 50,000 barrels/day (bpd), with 87 days to cap the blowout, which is comparable to the 2010 Macondo blowout (Deepwater Horizon) in the US Gulf of Mexico. Flow rate from the Macondo blowout in the U.S. Gulf of Mexico was estimated between 62,000 bpd and 52,000 bpd (as reservoir pressure dropped), and continued for over 87 days, for a total release originally estimated at 4.9 million bbls (of which approximately 800,000 bbls were collected at the wellhead).[108] This release estimate was later revised downward, based on evidence presented in the U.S. District Court, to 4 million bbls total release from the wellhead, and total not collected at the wellhead (released to the marine environment) of 3.19 million bbls.[109] It should also be noted that the killed Deepwater Horizon (Macondo) wellhead continued to leak hydrocarbons at least until May 2012, likely as the result of a shattered well casing.[110]

The 5,000 bpd flow rate Scenario (A) is derived from the shallow water 2009 Montara blowout flow rate (2,000 bpd – 3,000 bpd). The 2009 Montara oil and gas platform blowout in the Timor Sea, northwest Australia, continued from Aug. 21 – Nov. 3, a total of 74 days, at an estimated flow rate of 2,000 bpd – 3,000 bpd, for a total release of 4,500 m³ – 34,000 m³ (30,600 bbls – 231,200 bbls).[111]
The 35-day duration in Scenario 1 is derived from BP's expected time to successfully deploy and attach a Capping Stack from the OSRL base in Singapore, and/or another Containment Response System (CRS) to a failed GAB well.[112]

Regardless, for planning purposes, the Worst Case Discharge (WCD) for the proposed deepwater Equinor GAB project should be the BP modeled WCD release of 7.9 million bbls.

Lebreton used the U.S. NOAA oil trajectory model "General NOAA Oil Modeling Environment" (GNOME) on the four spill scenarios, and predicted that in summer, a spill would likely impact the shoreline of Western Australia, while in winter it would most likely impact shorelines of the Eyre Peninsula and Spencer Gulf in South Australia. Over the longer term, the model predicts that oil would continue to disperse through the Bass Strait to the Tasman Sea, around Tasmania, and possibly to New Zealand waters.[113]

The dispersion model predicts that in summer, after 4 months in Scenario 2A (5,000 bpd x 87 days = 435,000 bbls), an area of 213,000 km² toward the coast of Western Australia and the Twilight Marine Reserve, would have an 80% chance of having surface oil concentrations exceeding the 10mg/m² limit that would trigger fishery closures. In winter, the same scenario would expose 265,000 km² toward the east of the drill site, toward Eyre Peninsula, Spencer Gulf, and Kangaroo Island, with areas exposed to highest oiling including West Coast Bays Marine Park, Lower Yorke Peninsula Marine Park, and Western Kangaroo Island Marine Park.[114]

Lebreton concludes that:

> *"Regardless of the oil spill scenario, the model predicted that at a minimum, there is a 70% to 80% likelihood for oil droplets reaching the Australian coastline."*[115]

BP spill modeling concluded that for certain spill scenarios, the probability of oil reaching the shore was 100%, as much as 179,673 barrels could come ashore (more than shoreline oiling estimated from Deepwater Horizon), oiling up to 750 km of shoreline, and oil could travel from 1,083 km - 2,664 km from the spill site.[116]

Thresholds used by Lebreton were: 0.01g/m² (a visible oil sheen on the sea surface), which would trigger a closure of fisheries; 10g/m² as the level likely to cause acute mortality of wildlife offshore; and 100g/m² as the level likely to cause mortality of wildlife onshore. It should be noted however that this only considers two-dimensional sea surface oiling, and not three-dimensional water column concentrations. Early life stages of marine organisms (e.g. fish eggs and larvae) can suffer toxic effects at levels considerably lower than the 10g/m² threshold used (e.g. less than 1 ppb). Even so, at the modeled WCD (2B) scenario, the Lebreton model predicts an 80% probability that an area of 14,000 km² in winter and 16,000 km² in summer would have oil thickness above the ecological mortality threshold of 10g/m². In this scenario, the Twilight Marine Reserve, a calving/nursing area for endangered Southern right whales and foraging habitat for threatened white sharks and flesh-footed shearwater, has a 50% chance of exposure to the lethal oil thickness.[117]

Shoreline oiling on the shore of the Twilight Marine Reserve predicted by the Lebreton model reaches 432 g/m² in summer, more than 4 times higher than the established shoreline mortality threshold. And shoreline oiling in winter reaches 367 g/m² on West Kangaroo Island Marine Park, some 3.5 times the mortality threshold. The probability of severe biological impact on shorelines reaches 67% under the WCD scenario.[118]

The Lebreton model predicts that a scenario 2B (WCD) release (4.35 million bbls) would result in very likely socioeconomic impacts on shorelines from West Coast Bays to Kangaroo Island; likely offshore ecological impact at the entrance to Spencer Gulf; and possible ecological impacts on Kangaroo Island. As well, the larger releases modeled lead to higher probabilities for oil reaching eastward to the Tasman Sea and New Zealand. For the WCD scenario winter release, the model predicts a 10% chance of oil reaching the west coast of New Zealand's South Island within 6 months of release. Further, after spreading eastward in winter, the westward drift in summer could expose much of Tasmania to oiling.[119]

The Quantitative Risk Assessment (QRA) conducted by Bea applied the U.S. EPA "Basic Oil Spill Cost Estimation" model to estimate costs of various spill scenarios developed by Lebreton for the GAB projects, which include response costs, environmental and socioeconomic damage.[120] For the GAB project, the EPA model resulted in a low-impact cost estimate of $2,000/bbl; a high-impact cost estimate of $20,000/bbl; and a very high-impact cost estimate of $40,000/bbl. By comparison, the BP Macondo spill was valued at approx. $20,000/bbl.[121]

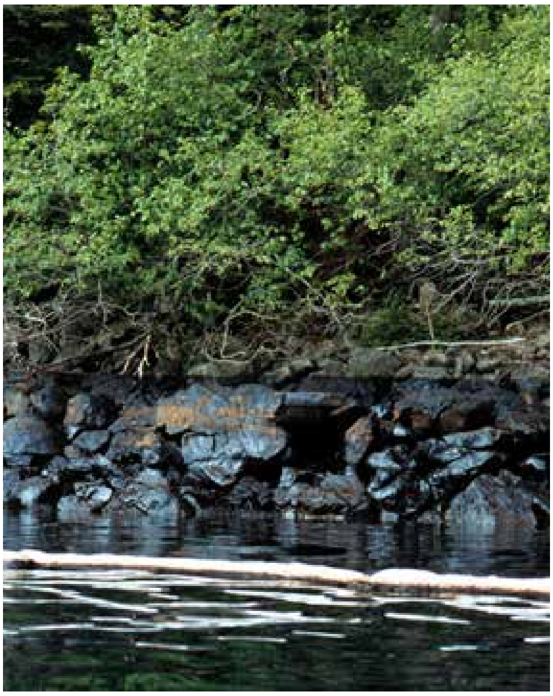
For the WCD (scenario 2B) in GAB drilling (4.35 million bbls), the high-impact cost ($20,000/bbl) results in a total cost of $87 billion.[122] For the BP WCD of 7.9 million bbls, a high-impact cost would result in a total cost of $158 billion.

C. ENVIRONMENTAL EXPOSURE MODEL (ELLIS, 2016)

Ellis (2016) analyzed the potential exposure from Lebreton's spill scenario 2A (5,000 bpd x 87 days = 435,000 bbls) to *Matters of National Environmental Significance* (MNES) listed in the 1999 Commonwealth Environment Protection Biodiversity Conservation Act.[123]

Importantly, Ellis recognizes that his MNES exposure assessment considered a less-than Worst Case Discharge (WCD) scenario, which, as discussed above, would be BP's WCD of 7.9 million bbls, or 18 times larger than the 2A scenario Ellis used. On this, Ellis states that the impacts to MNES "would be far more intense and widespread if volumes of oil were released that exceed those modeled by Lebreton's (2015) 2A models."

Leafy sea dragon in Rapid Bay, the Great Australian Bight, South Australia. ©Michaela Skovranova/Greenpeace



View from river showing oiled rocks on riverbank. ©Henk Merjenburgh/Greenpeace

Ellis describes his assessment as follows:

> *"My submission presents a conservative analysis of MNES that would be potentially, likely, or known to be impacted in the event of summer or winter oil spills at the levels sufficient to result in closures to fisheries on health grounds (hydrocarbon concentrations 10mg/m² or higher) – the summer and winter 2A oil spill models."*
>
> *"MNES include Commonwealth Threatened Species, Migratory Species, Marine Species, Threatened Ecological Communities, Critical Habitats, Commonwealth Marine Areas, Marine Regions, Marine Reserves, Commonwealth Heritage Places, Ramsar sites, World Heritage Areas, National Heritage Areas, Nationally Important Wetlands and Key Ecological Features. International Migratory Bird Agreements are also relevant to a number of the threatened, migratory and marine bird species. The potential impacts of winter and summer oil spills (2A Scenarios) on these MNES categories are discussed in my submission."*[124]

Ellis reports the following results for MNES that would be impacted by a 435,000 bbl spill in the GAB (numbers vary between summer/winter): Threatened Species 46/47; Migratory Species 80; Marine Species 177/173; Threatened Ecological Communities 2; Critical Habitats 1; Commonwealth Marine Areas 2; Commonwealth Marine Regions 2; Commonwealth Marine Reserves 32/38; Commonwealth Heritage Places 0/3; Ramsar Sites 5/10; World Heritage Properties 1; National Heritage Properties 3/4; Nationally Important Wetlands 32/50; and Key Ecological Features 11/9. The assessment finds that 46/47 (summer/winter) species classified as vulnerable, endangered, or critically endangered would be impacted by a 2A scenario (435,000 bbl) spill.

The Commonwealth Threatened Species known to occur in the area potentially affected by a 2A spill in the GAB, include the following[125]:

- **4 Fishes:** Gray Nurse Shark, Great White Shark, Whale Shark, Maugean Skate/Port Davey Skate;
- **4 Reptiles:** Loggerhead Turtle, Leatherback Turtle, Green Turtle, Flatback Turtle
- **31 Birds:** Australian Lesser Noddy, Australasian Bittern, Curlew Sandpiper, Cape Barren Goose, Southern Royal Albatross, Northern Royal Albatross, Amsterdam Albatross, Antipodean Albatross, Tristan Albatross, Gibson's Albatross, Wandering Albatross, White-bellied Storm Petrel, Blue Petrel, Southern Giant Petrel, Northern Giant Petrel, Eastern Curlew, Fairy Prion, Sooty Albatross, Gould's Petrel, Soft-plumaged Petrel, Australian Painted Snipe, Australian Fairy Tern, Buller's Albatross, Indian Yellow-nosed Albatross, Shy Albatross, Salvin's Albatross, White-capped Albatross, Grey-headed Albatross, Black-browed Albatross, Campbell Albatross, Hooded Plover;
- **7 Mammals:** Sei Whale, Blue Whale, Fin Whale, Southern Right Whale, Humpback Whale, Southern Elephant Seal, Australian Sea-lion.

In addition Ellis reports that 80 migratory species are known to occur in the spill impact zone, which in addition to those cited above, include the following:

- **Fish:** Mako Shark, Porbeagle Shark, Reef Manta Ray, Giant Manta Ray;
- **Birds:** Common Sandpiper, Ruddy Turnstone, Sharp-tailed, Sanderling, Red Knot, Pectoral Sandpiper, Red-necked Stint, Great Knot, Double- headed Plover, Great an Plover, Oriental Plover, Latham's Snipe, Swinhoe's Snipe, Pin-tailed Snipe, Oriental Pratincole, Grey-tailed Tattler, Broad-billed Sandpiper, Asian Dowitcher, Bar-tailed Godwit, Black-tailed Godwit, Little Curlew, Whimbrel, Osprey, Red-necked Phalarope, Ruff, Pacific Golden Plover, Grey Plover, Wood Sandpiper, Marsh Sandpiper, Sooty Albatross, Little Tern, Bridled Tern, Caspian Tern, Flesh-footed Shearwater, Sooty Shearwater, Wedge-tailed Shearwater, Short-tailed Shearwater;
- **Mammals:** Antarctic Minke Whale, Bryde's Whale, Pygmy Right Whale, Dusky Dolphin, Killer Whale, Sperm Whale.

Ellis further reports a total of 173 Commonwealth Listed marine species occurring within the spill impact region, including 40 fishes, 4 reptiles, 90 birds, and 39 mammals. Forty-four (44) bird species potentially impacted are protected under the International Migratory Bird Agreements, including The Bonn Convention (Bonn), Japan-Australia Migratory Bird Agreement (JAMBA), China-Australia Migratory Bird Agreement (CAMBA), Republic of Korea Migratory Bird Agreement (RoKAMBA), and Agreement on the Conservation of Albatrosses and Petrels (ACAP).

Ellis concludes that, given the species and MNES potentially impacted by a large oil spill, the proposed drilling program:

> *"…is arguably the most environmentally constrained project proposed in Australian history."*

and;

> *"…if an oil spill was to occur, impacts would be far more widespread and would affect more MNES than any other project proposed in Australian history. Oil Spills in either summer or winter would lead to widespread impacts on biodiversity that extend from Western Australia to Tasmania and beyond to the south-east coast and potentially New Zealand."*[126]

This would certainly be true for a WCD spill of 7.9 million bbls. For impact assessment purposes, all of the above listed species and Matters of National Environmental Significance (MNES) should be considered to be at risk of significant exposure and impact from a GAB WCD oil spill.

D. SPILL RESPONSE CAPABILITY

Before source containment and control measures are able to shut in an uncontrolled blowout, oil would be released into the marine ecosystem (as discussed above). In response to this spilled oil, the operator would mount a "cleanup" response similar to that used by BP on the Deepwater Horizon spill. This would include use of chemical dispersants, Subsea Dispersant Injection (SSDI) at the wellhead, containment and collection with booms/skimmers, defensive booming of sensitive nearshore habitats, and shoreline cleanup/response, involving thousands of personnel, vessels, and aircraft. The 2018 Equinor OPEP states that the company would not use in-situ burning (as was used extensively in the Deepwater Horizon response), due primarily to operational difficulties and high-risk safety hazards involved with in-situ burning.[127]

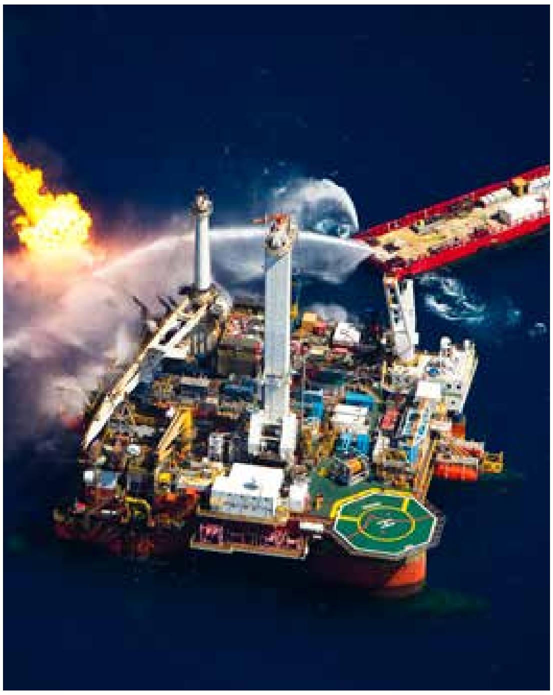
It is important to recognize that a response to large marine oil spills typically collects less than 10% of the total spill volume, and usually is either irrelevant environmentally or can actually cause more environmental injury (through use of dispersants, burning, disturbance of shoreline habitat, etc.). The 2016 BP GAB Oil Spill Response Planning Strategic Overview admits the following (emphasis added):

> *"Both containment and recovery and in-situ controlled burning (ISB) have many operational constraints within GAB, principally due to weather and sea-state constraints, and are not expected to provide significant benefit."*[128]

BP's $14 billion, 3-year response to the Deepwater Horizon spill included over 48,000 people, 7,000 vessels, 1,300 km of containment boom, 2,800 km of sorbent boom, 2,063 mechanical skimmers (including 60 offshore skimmers), 32 oil/water separators, and 6.8 million liters of chemical dispersants.[129],[130] Yet even with this massive effort, BP was only able to collect 3% of the estimated spill volume.[131] The 8% BP claims was chemically dispersed simply relocated oil and impact from the sea surface into the water column. The 5% of the spill volume that was burned created significant atmospheric contamination (particulates, dioxins, furans), and substantial volumes of heavy burn residues sank to the sea floor.

In the $2.1 billion, 3-year Exxon Valdez spill response, only about 7% of the oil was recovered (and likely far less).[132] High-pressure, hot water washing of oiled intertidal habitats of coastal Alaska was found to have caused extensive ecological injury in itself.[133] From an ecological standpoint, neither the BP or Exxon spill response was effective, and may have added to the environmental injuries. Spill response is designed largely for public relations purposes, and to mitigate financial and political liability. Similarly, attempts to capture, clean and rehabilitate oiled wildlife, and to restore the injured ecosystem would be ineffective.

Given the above, a response to surface oil from a WCD on GAB drilling would almost certainly be ineffective. Most oil would remain in the environment, and the damage would occur despite even a major response effort. This fact must be honestly admitted by the government and operator.



The Q4000 multi-purpose oil field intervention vessel, burns off material from the Deepwater Horizon wellhead near the disaster site in the Gulf of Mexico. ©Daniel Beltrá/Greenpeace

09 ECOLOGICAL IMPACTS OF MARINE OIL SPILLS - OVERVIEW

The fate, behavior, and ecological impacts of marine oil spills have been intensively studied in the past few decades, and hundreds of scientific papers have been published on these topics. While there is always more to learn, science has a fairly clear picture on how petroleum generally affects marine ecosystems.

As summarized by the U.S. National Academies of Sciences (2003), when oil is released into the sea, several physical, chemical, and biological processes begin to weather the oil, depending significantly on the characteristics of the oil, temperature, sunlight, winds, and water currents - evaporation, emulsification (water-in-oil), dissolution, photo-oxidation, microbial oxidation.[134] As well, various transport mechanisms distribute the oil - spreading, advection, wind-driven Langmuir circulation (vertical cells creating convergence and divergence at the sea surface), dispersion (vertical and horizontal), sinking and sedimentation, and biodegradation.

Deepwater oil/gas releases behave in much more complicated ways than shallow water or surface releases, and this unique deepwater dispersion dynamic must be considered in predicting the behavior of a large spill from a deepwater GAB wellhead. In a deepwater wellhead blowout, oil is initially released in a high-velocity jet phase of fluid or gas (up to 10m/sec) spreading upward in an expanding cone from the release point.[135] Jet phase momentum dissipates rapidly (within 1 m or so of the release point), followed by the formation of distinct oil droplets and gas bubbles less than 3 mm diameter.[136] In general, the higher the velocity release, the smaller the droplet/bubble size. These small droplets/bubbles then rise as an underwater plume that ascends slowly along with entrained dense seawater.[137] This deepwater entrainment may be greater if chemical dispersants are injected into the release at the wellhead.

The entrained seawater of high density (high salinity/low temperature) of the oil-gas-hydrate-seawater plume then become less buoyant than the surrounding stratified water column, and stops ascending. Typically, the plume reaches a terminal depth, and then disperses or “mushrooms” along with deepwater currents. The subsurface plume is affected by turbulence, upwelling, and downwelling dynamics, such as those found in the GAB. If significant methane hydrate forms in the plume, this further reduces plume buoyancy. Virtually all of the methane and naphthalene (toxic to marine organisms) from a deepwater release dissolves in the water column on ascent to the sea surface.[138] Gas solubility is greatly enhanced due to colder sea temperatures in the deep ocean. Thus, deepwater releases undergo far greater dissolution and emulsification than shallow spills. In a surface spill, these toxic hydrocarbon components generally evaporate, and a deepwater release presents far more of a risk to pelagic (water column) ecosystems.

Dead otter, loon, and other crude-oil covered animals decompose on the shore after the Exxon Valdez oil spill disaster. ©Ken Graham/Greenpeace

In the Deepwater Horizon release (at 1,522 m depth), an extensive subsurface plume formed, initially stretching 35 km from the wellhead.[139] To the surprise of many scientists, an estimated 50% of the total oil and 100% of the methane released never reached the sea surface.[140] The hydrocarbon plume, with elevated PAH levels, was largely concentrated between water depths 1,030 m – 1,300 m, and evidence of the plume was detected as far as 410 km from the wellhead.[141] As well, some of the subsurface oil settled over at least 3,200 km² area of deepsea benthic habitat, and this is regarded as less than 30% of the total seabed affected.

As the Deepwater Horizon spill is considered a reasonable analog for a GAB WCD, the subsurface entrainment of oil and gas must be considered in spill dispersion and impact models. Lebreton commented on the need to better understand the dynamics and dispersion of subsurface oil and gas plumes from a GAB deepwater discharge. In particular, the potential impacts of toxic subsurface plumes and seabed contamination from a GAB WCD could be extensive, and need to be fully assessed.

Ecological impacts of spills have been studied extensively, and are relatively well understood.[142]

Impacts can be acute (immediate, short-term) and chronic (either from long-term exposure or long-term, sublethal effects from acute exposure). Ecological effects can persist for decades and even permanently, as in the Exxon Valdez spill.

Effects on organisms are possible at four levels of organization: cellular and biochemical; organismal, including physiological, biochemical, and behavioral; population; and community/ecosystem. Even at levels well below those considered acutely toxic, sublethal effects from oil exposure can include impairment of development, physiology, cardiac function, feeding, migration, gonadal development, blood chemistry, reproduction, and energetics; as well as stress, disorientation, carcinogenesis, immune suppression, deformities, brain lesions, eye tumors, organ damage, and other histopathology. All such sublethal effects can affect long-term population and ecosystem dynamics. As monocyclic aromatic hydrocarbons (MAHs), such as benzene, toluene, ethylene, xylene, are lost due to weathering, the toxicity of the water-accommodated fraction is reduced. At this point, the polycyclic aromatic hydrocarbons (PAHs) contribute more to overall toxicity. PAHs are multi-ringed aromatic hydrocarbons including anthracene, phenanthrene, fluorene, chrysene, pyrene, etc.; are highly fat soluble; and have toxic, mutagenic, and carcinogenic properties.[143] The PAH component of spilled oil can be acutely toxic to fish embryos down to concentrations as low as 1 ppb (Heintz, 1999). Fish eggs exposed to PAH concentrations of 0.7 ppb showed developmental malformation, genetic damage, mortality, decreased size at hatching, and impaired swimming abilities. And PAH levels as low as 0.4 ppb were found to cause premature hatching and yolk sac edema. Such embryonic impacts can manifest in future population-level effects.

The bioavailability of spilled oil – that is, the capacity and pathways for oil to directly adsorb onto, or absorb into, organisms – includes contact with skin, gut, mouth, eye, lungs, gills, and across any cell membrane. Oil that is most bioavailable is the dissolved fraction, but oil is also ingested as it adsorbs onto particulate matter and along with contaminated prey (e.g. zooplankton), directly from oil droplets in water, and aspirated into respiratory systems. Some petroleum compounds (e.g. PAHs) exhibits high lipid solubility, and vertebrates exhibit a significant capacity for metabolizing aromatic hydrocarbons through cytochrome P450 oxidation.

In fact, P450 levels are useful in determining exposure to toxic PAHs in marine fishes, birds, and mammals. Toxic metabolites from the breakdown of PAHs in oil-exposed vertebrates can accumulate and induce toxic effects.

As marine mammals and seabirds frequently cross the air-sea interface, they are easily exposed to floating oil. Oiling of feathers and fur significantly reduces insulation for these warm-blooded vertebrates causing hypothermia. As well, oiled mammals and birds often preen themselves in attempts to self-clean, thereby ingesting additional toxic oil. Self-preening by oiled animals can become a dominant behavior for a time, rendering the animals more vulnerable to starvation or predation.

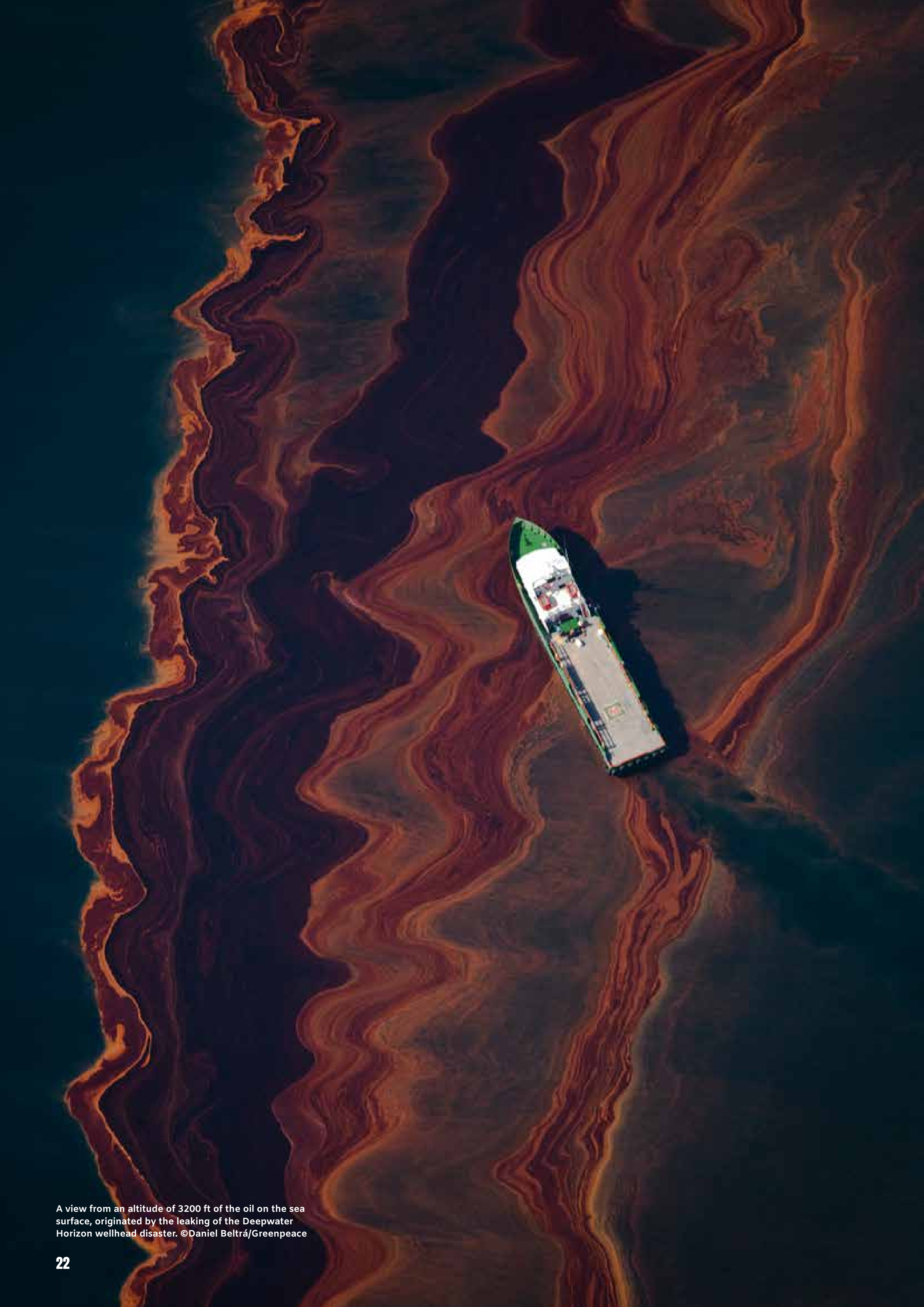
These air-breathing animals also aspirate oil (as surface tension changes at the air-sea interface), and/or volatile organic compounds (VOCs) at the sea surface, further exposing them to toxicity. Oiled birds can transfer oil from adults to eggs, which can become non-viable, as well as to juveniles via feeding. Blood chemistry effects of oil exposure can include hemolytic anemia and reduced oxygen carrying capacity of blood, which can affect dive times in both seabirds and mammals, and thus feeding and reproductive success. And spills can also cause delayed impacts in marine populations, such as seaducks and herring in Alaska after the Exxon Valdez spill. Seabirds alter feeding locations to avoid oiled intertidal habitat, and exhibit delayed growth and fledgling success post-spill.

Population effects of spills on marine mammals and seabirds can be significant and long-term, particularly if oil exposes feeding aggregations, migration, and calving/nesting areas. It is generally accepted that for every bird or mammal carcass recovered after a spill, there may be another 5-10 killed but not recovered.

Bird mortalities from oil spills can reach 300,000 (Exxon Valdez), and even 1 million (Deepwater Horizon), and manifest in multi-year impacts (Exxon Valdez).

Long-term effects of oil spills on seabirds have been reported for African Penguins in South Africa, and Common Murres in France subsequent to Torrey Canyon and Amoco Cadiz spills. Often it is difficult to conclusively distinguish long-term effects of oil from natural variability of marine populations in changing ocean conditions, but clearly long-term effects from oil spills occur.[144]

A heavily oiled loon found dead in Kenai Fjords, Alaska after the Exxon Valdez oil spill disaster. ©Ken Graham/Greenpeace



A view from an altitude of 3200 ft of the oil on the sea surface, originated by the leaking of the Deepwater Horizon wellhead disaster. ©Daniel Beltrá/Greenpeace

10 TWO OIL SPILL CASE HISTORIES

As examples of ecological and socioeconomic damage that could be caused by a WCD from the proposed GAB project, two notable spills in the U.S. provide context.

A. 1989 EXXON VALDEZ

The March 1989 grounding of the Exxon Valdez released between 260,000 bbls and 500,000 bbls of Alaska North Slope crude oil into Prince William Sound, at the peak of spring marine biological activity.[145] The oil remaining on the grounded tanker was successfully offloaded onto lightering tankers. The oil spread on surface currents over 750 km from the site of grounding, eventually covered over 26,000 km² of Alaska's coastal ocean, and oiled over 2,100 km of pristine shoreline.

RESPONSE: The response to the spill was disorganized, slow, and ineffective. Exxon paid an estimated $2.1 billion for its 3-year cleanup attempt, which involved over 11,000 workers, 1,400 vessels, and 100 aircraft.[146] The initial response was hindered by the lack of preparedness of the Alyeska Pipeline Service Co. that owned and operated the pipeline and Valdez Marine Terminal, which had primary legal obligation to respond. Responders conducted limited tests of in-situ burning, using fire boom to encircle oil and then ignite with heli-torches, as well as a limited application of chemical dispersant (Corexit 9527), but both were ineffective.

Spill response efforts then turned to attempted containment and recovery with booms and skimmers. After a severe storm in week-one dispersed the oil downwind and down-current across a large area of Prince William Sound, containment became impossible. Attempting to deflect oil, booms were placed across sensitive shoreline habitats, such as seal and sea otter pupping areas, salmon streams, and salmon hatcheries, with modest success. As 40%-45% of the total spill volume drifted onto hundreds of km of remote shoreline, the focus of cleanup turned to high-pressure, hot water washing of oiled beaches and collecting flushed oil with booms and skimmers just offshore. Oil percolated as deep as 2 m into certain beach substrates (gravel/cobble), and became virtually impossible to remove. Limited bioremediation, with addition of nitrogen fertilizers, was attempted, with only superficial effect.

The massive response effort is estimated to have recovered only 7% of the oil that had spilled.

IMPACTS: As the ecosystem into which the spill occurred was productive and pristine, the Exxon Valdez is considered by many to be the most ecologically damaging oil spill in history. Virtually all marine organisms at the sea surface and in the path of the spill were exposed. The immediate mortality included an estimated 250,000 seabirds, 3,000 marine mammals (sea otters, harbor seals, killer whales), millions of juvenile salmon and herring, and extensive intertidal habitat. Chronic injury, including reproductive losses in subsequent years, added considerably to the spill's mortality. Ecological injury from the spill persists today (almost 30 years later), with only 15 of the 32 monitored injured species and resource services listed by government officials as fully "recovered." Some species remain listed by government as "not recovering," including Pacific herring, marbled murrelets, pigeon guillemots, and the AT1 killer whale pod.[147] The reasons for lack of recovery are complex, and vary among species, but the oil spill is a common causal agent in all.

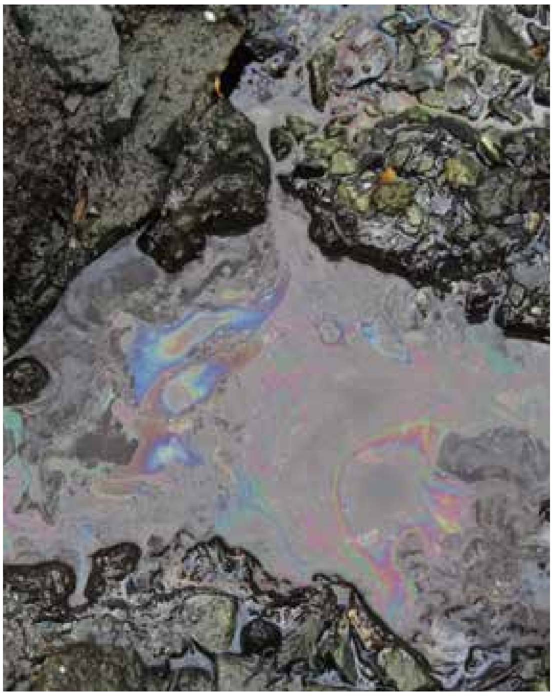
Intertidal communities suffered extensively from oil toxicity and smothering, and remain not fully recovered. Today, some Exxon Valdez oil remains trapped in wave-shadowed shoreline sediments, where degradation is reduced, and this residual shoreline oil remains unweathered and toxic. This residual toxic oil continued to affect intertidal foraging of seaducks, sea otters, and fish for decades. Salmon eggs exhibited elevated mortality in oiled spawning streams over 4 years after the spill. Chronic exposure of sea otters to residual shoreline oil by consuming contaminated clams suppressed population recovery in heavily oiled areas. Recovery of oiled intertidal mussel beds and eelgrass habitat continues today, 30 years later. Intertidal foragers such as sea otters, harlequin ducks, pigeon guillemots, and Barrow's goldeneyes showed elevated levels of the detoxification enzyme CYP1A for a decade following the spill, indicating continued chronic exposure to lingering oil. Pink salmon eggs exposed to residual oil in spawning streams exhibited stunted growth and a 50% reduction in survival at sea, as well as multi-generational reproductive impairment.[148]

Two significant indirect ecological cascades were documented from Exxon Valdez oiling. The extensive loss of the intertidal rockweed Fucus along with grazing limpets and predatory whelks opened the intertidal rock habitat to invasion by an opportunistic barnacle Chthamalus. The dense Chthamalus cover severely delayed reestablishment of Fucus. Once Fucus reestablished, it was all even-aged, and this led eventually to the simultaneous senescence and mass mortality of the even-aged Fucus cover. As a result of this indirect cascade, oiled intertidal zones remained ecologically unstable for over a decade post-spill.

The other trophic cascade from Exxon Valdez oil, although less conclusive, derived from the loss of 50% of sea otters in the oiled areas of western Prince William Sound, which reportedly released sea urchin prey populations from predation pressure by the otters. The urchins then overgrazed kelp fronds and forests, which then likely led to reduced survival of fishes dependent on the kelp forest habitat. The evidence for this cascade is less conclusive.

Impacts to herring highlight the unanticipated and delayed mechanisms oil injury can manifest in a marine ecosystem. While adult herring spawned along the heavily oiled intertidal zone and mostly survived in 1989, most eggs and larvae were killed. Herring spawning biomass continued to be robust over the following few years, but then the population unexpectedly collapsed four years after the initial

Lingering 1989 Exxon Valdez Oil in shoreline sediments. Northwest Bay, Eleanor Island, Alaska (taken July 2018). ©David Janka



Lingering 1989 Exxon Valdez Oil in shoreline sediments. Bay of Isles, Knight Island, Alaska (taken July 2018). ©David Janka

spill, and today has yet to recover. The crash is believed to have resulted from a parasite and disease epidemic caused by immunosuppression of adult herring exposed to oil in 1989. There is also evidence that oil-induced cardiotoxicity in early life stages of herring may have played a role in the collapse.[149] As herring are a critical prey resource in the marine ecosystem, the population crash has affected whales, seals, sea lions, seabird, and fish populations.

Another dramatic effect of Exxon Valdez is the likely extinction of the genetically unique AT1 killer whale pod, considered a "distinct population segment" by the U.S. National Marine Fisheries Service.

The AT1 pod was observed surfacing in oil slicks in 1989, nine of the 22 members of the pod were lost shortly after the spill, and subsequently another 6 were lost. Five carcasses were found on beaches, leading to the conclusion that these 15 members of AT1 pod were almost certainly killed by Exxon Valdez oil. Mortality likely occurred by aspirating oil at the sea surface, breathing VOCs above the slicks, consuming oil contaminated harbor seals, or a combination of these mechanisms. Today, there are no reproductive females left in the remaining 7 members of this pod, and the group is projected to go extinct. This illustrates that oil spill injuries on small, distinct, long-lived animals can be permanent.

Of approximately 180 killer whales known to regularly utilize Prince William Sound Alaska pre-Exxon Valdez, at least 29 were lost in the immediate aftermath of the spill.[150] It is widely believed that mortality of these whales was caused by inhaling surface oil and/or toxic vapors. In addition, after many gray whales were seen surfacing in oil from the Exxon Valdez in 1989, at least 25 gray whale carcasses were found in waters and on shorelines of the oiled region.[151] While necropsies were inconclusive, and it remains uncertain how many of these whales were killed by the oil, many observers feel there is a high probability that many were. Scientists now conclude that the marine ecosystem injured by the Exxon Valdez spill will never fully recover to the ecological structure and functions it would have had absent the spill.[152]

SOCIO-ECONOMY: Socioeconomic impacts of the spill were particularly severe in coastal communities reliant on the marine ecosystem for subsistence and economic activity, mainly Alaska Native villages and commercial fishing towns. Government officials closed fisheries in the oil spill region in 1989, including herring, salmon, crab, and bottomfish. The tourism industry suffered an estimated $2.8 billion (USD) in losses and reputational "brand damage." Many fishermen and other businesses filed for bankruptcy after the spill.

Litigation continued for 26 years after the spill. In 1989, Exxon paid $300 million in initial compensation to fishermen and other claimants, and in 1991, Exxon settled its damage case with the U.S. and State of Alaska for $1 billion, to be used mostly in attempt to restore the injured ecosystem. In 1994, a federal jury awarded 30,000 private plaintiffs $287 million for compensatory damages, and another $5 billion in punitive damages. Exxon appealed the federal jury verdict for 14 years, ultimately resulting in the $5 billion punitive award being reduced to just $507 million in 2008. Many plaintiffs had passed away before receiving any of the final award, and most felt betrayed by the judicial system. In 2015, the final government claim for environmental injury, that Exxon refused to pay, was withdrawn by the state and federal government.

Social and psychological effects in coastal residents were severe, and included anxiety, depression, suicide, substance abuse, domestic abuse, PTSD, distrust in social and governmental institutions, increased social conflict, and development of "corrosive communities."[153]

As well, human health impacts from oil exposure during cleanup included dizziness, headaches, eye problems, nausea, respiratory distress, fatigue, dermatitis, endocrine disruption, hypertension, and increased cancer risk.[154]

People around the world reacted with a sense of outrage at the betrayal of oil industry and government promises to avoid such an environmental disaster, and the political impacts of the Exxon Valdez persist today.

B. 2010 DEEPWATER HORIZON

The Deepwater Horizon spill caused environmental, social, and economic disaster for Gulf of Mexico and its coastal communities that persists today, more than 8 years later. In many respects, it is a model for what may occur from a WCD in the proposed GAB drilling project.

On April 20, 2010, the BP Macondo well being drilled at 1,522 m depth, 66 km off the southeast coast of Louisiana, by Transocean's Deepwater Horizon MODU failed. This caused a massive well blowout, with methane gases igniting on the rig, and the rig exploded and sank.[155] Eleven crew were killed and 17 injured. As discussed above, the blowout was caused by a sequence of simple human errors and mechanical failures. The resulting oil and gas release was the largest accidental offshore oil release in world history. An estimated 4 million bbls flowed from the failed wellhead into the deep Gulf (earlier estimates were 4.9 million bbls), with approximately 800,000 bbls collected at the wellhead, with a resulting environmental release of approx. 3.2 million bbls.

SOURCE CONTROL EFFORT: Unsuccessful efforts to kill the blowout included attempts to close the Blowout Preventer (BOP) with a Remotely Operated Vehicles (ROV); lowering a 125-ton steel "Containment Dome" over the wellhead, which clogged with methane hydrates and failed; and pumping heavy drill fluids/muds down the BOP in a top-kill attempt, which was unable to overcome the outward pressure of the blowout. Then a Riser Insertion Tube was fitted, from which some oil was collected to a surface drillship, which flared the gas. Another collection system called a "Top Hat" was fitted to the BOP, from which oil and gas were burned on drillship at the sea surface. Another attempt to top-kill the blowout was made, using mud and cement, but again failed. Finally, a specialized Containment Cap was built and attached to the well, with a valve that was slowly closed to temporarily seal the well. Two Relief Wells were drilled by two drillships. The first Relief Well intersected the failed Macondo well in September, and cement was pumped into the bottom of the well to secure the well permanently. However, due to structural damage in the upper casing caused during one of the failed top-kill attempts, oil continued to leak over the next two years, until at least Jan. 2013.[156]

FATE OF OIL/GAS: The spill contaminated more than 1,773 km of shoreline (about 500 km of which were moderately to heavily oiled), at least 3,200 km² of deep seabed habitat, and covered some 176,000 km² of ocean surface.[157] Responders applied 7.2 million liters of chemical dispersants (4 million liters to surface slicks, and 3.2 million liters injected at the wellhead) in attempts to break the oil into smaller droplets rendering it more accessible to microbial degradation.

The Q4000 multi-purpose oil field intervention vessel, burns off material from the Deepwater Horizon wellhead near the disaster site in the Gulf of Mexico. ©Daniel Beltrá/Greenpeace

As discussed above, it is estimated that 50% of the released oil and 100% of the natural gas (methane) remained entrained in the water column, and never surfaced.[158] Methane is soluble in seawater, particularly at low water temperatures in deep water, and most from the Macondo blowout did not rise to the sea surface.[159]

The hydrocarbon plume, with elevated polycyclic aromatic hydrocarbon (PAH) levels, was largely concentrated between water depths 1,030 m – 1,300 m, and evidence of the plume was detected as far as 410 km from the wellhead.[160] As well, some of the subsurface oil settled over at least 3,200 km^2 area of deepsea benthic habitat, and this is regarded as less than 30% of the total seabed affected.[161] The extensive subsurface oil/gas plume created extensive hypoxic zones levels in the water column, due to increased oxygen demand from biodegradation of hydrocarbons within the plume. The fate of Deepwater Horizon oil as estimated by the U.S. Geological Survey, was as follows: 25% evaporated/dissolved; 16% naturally dispersed; 17% direct recovery from wellhead; 8% chemically dispersed; 5% burned; 3% skimmed and recovered; and 26% residual (unaccounted for in the offshore ecosystem).[162]

RESPONSE: The response to the spill was the largest in history. Over a 3-year period, BP paid over $14 billion in its attempted cleanup operation, which included over 48,000 people, 7,000 vessels, 1,300 km of containment boom, 2,800 km of sorbent boom, 2,063 mechanical skimmers (including 60 offshore skimmers), 32 oil/water separators, 7.2 million litres of chemical dispersants, and more than 176,000 km of aerial reconnaissance flights.[163] Use of dispersants (Corexit 9500 and Corexit 9527) was particularly controversial, as they add additional chemical toxicity, and redistribute oil within the pelagic ecosystem. A total of 410 burns were conducted on surface slicks (In-Situ Burning, or ISB) burned an estimated 220,000 bbls – 310,000 bbls of oil, but also released toxins (dioxins and furans) into the air, and burn residues sank to the seafloor.[164] As the surface oil was significantly dispersed in seawater, BP then used 32 oil/water separators and reported collecting 890,000 bbls of oil. Shoreline cleanup focused on sandy beaches by sifting sand and collecting tar mats and tar balls both by hand, and mechanically. To remove oil from marshes, responders used vacuum pumps and water flushing, but with minimal success.

IMPACTS: Ecological injury was substantial to all components of the marine and coastal ecosystem, and continues today. Deepwater Horizon oil was toxic to a wide range of organisms, including fish, invertebrates, plankton, birds, sea turtles, and marine mammals, and exposure led to a wide array of acute and chronic toxic effects, including death, disease, reduced growth, impaired reproduction, and physiological impairment.

Government scientists predict that the ecological injury will persist "for generations."[165] A record number of dolphin illnesses and deaths occurred, and scientists estimate that perhaps 5,000 marine mammals (bottlenose dolphins, whales, manatees) may have been killed in immediate aftermath of the spill.[166]

Researchers found that oil caused a wide range of adverse health effects in dolphins, such as reproductive failure and organ damage, leading to the largest and longest-lasting marine mammal Unusual Mortality Event (UME) ever recorded in the Gulf of Mexico.[167]

All five species of sea turtles in the Gulf were exposed to oil, more than 1,000 sea turtles were killed, and over 2,000 have stranded ashore since.[168] Additionally, oil exposure to sea turtles caused decreased mobility, exhaustion, dehydration, overheating, and a decreased ability to feed and evade predators.

Estimates of bird mortality vary widely, but are all quite large. One estimate suggests approximately 1 million seabirds were killed by the spill.[169] Other studies estimate coastal bird mortality to be 600,000 – 800,000 birds, including 32% of the population of laughing gulls, 13% of the royal tern, 8% of the northern gannet, and 12% of the brown pelican population.[170] Offshore bird mortality was estimated at 36,000 – 670,000, with a likely number of about 200,000.[171] Other estimates suggest the spill may have resulted in the mortality between 160,000 and 1,900,000 birds.[172] Some species, such as Common loons, were reported with elevated PAH levels in tissues.

Many pelagic fish species were affected, including an estimated 12% of the bluefin tuna larvae being exposed to Deepwater Horizon oil during their 6-week spawning period, many exhibiting heart defects.[173] Some scientists speculate that long-term effects on bluefin tuna in the Gulf may not be known for decades. Other large, predatory fish species similarly affected included tunas, swordfish, amberjack, and billfish. Fish also exhibited sublethal injuries such as altered growth, development, reproduction; tissue damage; tissue damage; impairment of swimming behavior. Fish population-level impacts have not been conclusively reported. Oyster populations crashed after the spill, due in part of the huge freshwater release from the Mississippi River in attempt to keep oil offshore.[174]

The oil severely affected deepsea coral communities, including some species that are 600 years old, rare salt dome seagrass communities, and other shallower benthic communities. An estimated 22,000 tons of oil came ashore, significantly contaminating coastal marshes, mangroves, and beaches. Polycyclic aromatic hydrocarbon (PAH) levels entrained in coastal marshes are not expected to return to pre-spill background levels for decades.[175] One study reported “harmful oil agents” in the upper water column 1½ years after the spill, but the link to Deepwater Horizon oil remains speculative.[176]

At the height of the spill, 37% of federal offshore waters in the Gulf of Mexico were closed to fishing.[177] As a result of fisheries closures, the commercial fishing industry lost an estimated $247 million (USD), and recreational fishing lost $585 million.[178] One study estimates the economic loss over 10 years to Gulf fishing and aquaculture industries at $8.7 billion and 22,000 jobs.[179] Studies project the loss to tourism and “brand damage” from the spill to be $22.7 billion through 2013.[180]

In addition, several thousand coastal residents and response workers presented to medical establishment with symptoms consistent with chemical sensitivity, including skin rashes, respiratory ailments, migraines, dizziness, neurological issues, lethargy, nausea, depression, and anxiety.[181] It is believed that chemical dispersants, crude oil, and smoke plumes from surface oil in-situ burns created a toxic chemical mixture exposing thousands of people. On this issue, one local medical doctor was quoted as follows:

> *“There is a core of very sick patients who undoubtedly will be ill for the remainder of their lives as the result of exposure to chemicals involved in the Deepwater Horizon tragedy.”*[182]

The U.S. National Institute of Environmental Health Sciences is currently conducting a 10-year study of these health impacts in 33,000 exposed people along the U.S. Gulf coast. The final economic costs of the Deepwater Horizon spill have mounted to approx. $62 billion (USD),[183] which include a $20 billion victims claim fund and a $20 billion environmental damage settlement with state and federal governments.

Marine Biologist Rick Steiner collects samples of oil from the Deepwater Horizon wellhead that rests on the surface of the Gulf of Mexico near the Louisiana shore. ©Kate Davison/Greenpeace

11 PREDICTED IMPACTS OF WORST CASE DISCHARGE (WCD) SPILL IN THE GREAT AUSTRALIAN BIGHT

Lacking a comprehensive Environmental Impact Assessment for the proposed GAB drilling project, it is necessary to make qualitative predictions based on the information and analyses publicly available, as well as a scientific understanding of impacts of previous large oil spills outlined above. It is difficult to overstate the potential ecological impact of a Worst Case Discharge (WCD) oil spill in the GAB, as the impact would almost certainly be catastrophic.

SPILL TRAJECTORY AND AREA OF IMPACT: The 2016 BP Stromlo-1 Well Operations Management Plan projects a WCD of 7.9 million bbls (twice the size of 2010 Deepwater Horizon spill), and the spill model by Lebreton (2015) evaluates a WCD of 4.35 million barrels (approx. the size of the Deepwater Horizon spill). While both of these WCD estimates are indeed realistic, clearly the estimate by the former project proponent BP – 7.9 million bbls oil - should be used to represent a true WCD spill.

The Lebreton model predicts that even a much smaller release of 435,000 bbls (about 5% of actual WCD) in summer would cover 213,000 km² of sea surface mostly west of the drill site, and 265,000 km² in winter mostly east of the site. The model predicts that oil could spread beyond Tasmania to New Zealand, and estimates the probability of shoreline oiling in south Australia at 70% - 80%. An actual WCD spill (18 times larger) would obviously impact a much larger area.

The GAB oil spill modeling conducted by BP (former partner in the project) predicted that in certain scenarios, the probability of oil reaching the shore would be 100%; as much as 179,673 bbls (25,154 tons) could come ashore; up to 750 km of shoreline could be oiled; and oil could travel from 1,083 km - 2,664 km from the spill site.[184] Also of note is that the BP shoreline oil estimate for GAB (25,154 tons) is greater than the amount of oil estimated to have come ashore from the Deepwater Horizon spill (22,000 tons), even though the GAB drill site is considerably farther from shore.

Considering the oil spill trajectory and exposure modeling (summarized above), together with what is known of injury from Deepwater Horizon and Exxon Valdez spills (also summarized above), it can be concluded that a WCD (7.9 million bbls spill from Stromlo-1) would result in **extensive, severe, and long-term environmental injury in the GAB.** Even a much smaller (5% of WCD) 2A Scenario (435,000 bbls) spill would cause serious and long-term environmental injury.

Based on the Deepwater Horizon experience, it can be predicted that perhaps half of a deepwater oil release from Stromlo-1 WCD would reach the sea surface; half would remain entrained in the water column and disperse with subsurface currents in three-dimensional plumes; and all of the natural gas (methane) would dissolve in the water column and disperse down-current in subsurface plumes. Oil toxicity and hypoxia (due to microbial degradation of hydrocarbon plumes) in the pelagic system may persist for months, and expose hundreds of cubic kilometers of the offshore ecosystem. As toxicity can occur at PAH concentrations below 1 ppb, an expansive area of the pelagic ecosystem would be exposed to oil toxicity. All pelagic organisms exposed could suffer lethal or sublethal injury.

GENERAL ECOLOGICAL IMPACT: A WCD release in the GAB would cause the mortality of a huge volume of upper water column phytoplankton, zooplankton, and meroplankton (temporary planktonic life stages), which in turn would impact feeding ecology of planktivorous organisms. In addition, weathered oil and oil that had combined with sediment would settle onto several thousand km² of offshore (including deepwater) benthic habitat, significantly impacting low-energy, slow growing infaunal and epifaunal invertebrate communities. The oil that reaches the sea surface offshore would expose epipelagic organisms and organisms that depend on the sea surface, including marine mammals, seabirds, and sea turtles, which would likely suffer lethal or sublethal injuries. Atmospheric volatile organic compounds (VOCs) would cause their own impacts, and: "adverse effects that may occur from the exposure to air pollutants (from a very large oil spill) could have long-term consequences."[185]

A Worst Case Discharge (WCD) in the Great Australian Bight (GAB) is expected to cause the mortality of hundreds of thousands of birds, thousands of marine mammals, hundreds of sea turtles, population-level impacts to fish and invertebrates, extensive shoreline oiling and benthic habitat damage, long-term environmental impact, and significant socioeconomic losses.

A significant concern is the potential impact of a WCD to the Threatened Species in the GAB, which include 4 fish, 4 reptile, 31 bird, and 7 marine mammal species.[186] In addition, a WCD would seriously impact many other Matters of National Environmental Significance (identified by Ellis), including Migratory Species, Threatened Ecological Communities, Critical Habitats, Commonwealth Marine Areas, Marine Regions, Marine Reserves, Commonwealth Heritage Places, Ramsar sites, World Heritage Areas, National Heritage Areas, and Nationally Important Wetlands.[187] The lost use and intrinsic value of some of these oiled MNES resources could be substantial and long-term.

The response to a WCD spill would cause its own impacts, including the creation of carcinogenic dioxins and furans (which can bioaccumulate) if in-situ burning of surface slicks is conducted (as in the Deepwater Horizon spill). Dispersant use would distribute oil more broadly in the pelagic system, transferring contamination from sea surface more broadly into the water column and even seabed habitats. And physical disturbance caused by the response (vessels, booms, skimmers, aircraft, etc.) would be disruptive to coastal ecological and human communities for years.

SUBLETHAL IMPACTS: Chronic, sublethal injuries to long-lived marine mammals, birds, fish, and sea turtles from a WCD spill would likely persist for decades. Such impacts would include impairment of development, growth, physiology, cardiac function, feeding, migration, gonadal development, blood chemistry, reproduction, and energetics; and organisms would experience increased physiological stress, disorientation, carcinogenesis, immune suppression, morphological deformities, brain lesions, eye tumors, organ damage, and other histopathologies. All such sublethal effects should be expected to occur from a WCD, and to affect long-term population and ecosystem dynamics.

As with Exxon Valdez, ecological injuries from a GAB spill may not manifest for years, and then in unanticipated ways. For instance, herring populations exposed to Exxon Valdez oil in 1989 crashed 4 years after the initial spill, likely due to disease and parasite infections that became epidemic due to immunosuppression caused by initial oil toxicity. The impacted herring population is still listed by government agencies as “not recovering,” 30 years later. This same dynamic could occur in a GAB WCD spill, particularly with the GAB sardine population, which has previously experienced collapses due to disease outbreaks (see discussion of fish impacts below).

SHORELINES: For coastal marshes and wetlands in the GAB, oil impacts will depend on the amount of oiling, season, duration of exposure, species sensitivities, extent of exposure, substrate type and penetration of oil, wave exposure, and sand/sediment transport inshore and offshore. BP’s former shoreline oiling analysis predicted that 179,673 barrels of oil could come ashore, impacting up to 750 km of shoreline, highlighting concern even in the oil industry regarding the extent of shoreline oiling that could occur from a WCD.

The Lebreton trajectory model predicts that a WCD release of 4.35 million bbls would result in very likely socioeconomic impacts on shorelines from West Coast Bays to Kangaroo Island; likely offshore ecological impact at the entrance to Spencer Gulf; and possible ecological impacts on Kangaroo Island.[188] Again, the Lebreton dispersion model predicts shoreline oiling from a large blowout in winter could reach 367 g/m² on West Kangaroo Island Marine Park, some 3.5 times the mortality threshold. The probability of severe biological impact on shorelines reaches 67% under the WCD scenario.[189] Shoreline impacts would include injury to fisheries, marine parks, and tourism businesses. Kangaroo Island is a well-known biodiversity “hotspot” in Australia, with high diversity and endemism. A significant oiling event and large-scale cleanup effort could impact coastal vegetation and rare animal species, including federally listed Glossy Black Cockatoo, Kangaroo Island Dunnart, Southern Brown Bandicoot, and Heath Rat.[190]

As with the Exxon Valdez oil spill in coastal Alaska, oil can be expected to persist in intertidal sediments along the GAB coast for decades (e.g., Exxon Valdez oil is still present and quite toxic in intertidal beach sediments in Alaska, 30 years after the initial spill). Particularly in GAB areas where sediment oil is protected from wave action and weathering and a hard asphalt surface forms, sediment oil may remain toxic for decades. Shoreline habitats will likely be severely impacted, including mobile and sessile epibenthic and infaunal invertebrates, which are preyed upon by vertebrate populations, thus causing impacts to entire shoreline ecosystems.

BENTHIC HABITAT: Given the exceptional benthic (seafloor) endemism and biodiversity (thousands of species) reported in the region (the highest in Australia), offshore benthic habitat could experience significant impacts from oiling. As with Deepwater Horizon, a GAB WCD would be expected to contaminate several thousands km² of benthic habitat, including offshore, deepwater seabed habitats. With high biodiversity and endemism, and the fact that these benthic ecosystems remain poorly studied, there is the possibility for significant, unanticipated population and ecological impacts from a WCD spill, as has been reported in the Deepwater Horizon spill in the deep Gulf of Mexico. As species in these deepwater benthic communities are generally long-lived and very slow growing, oil impacts could persist for decades.

The inshore kelp (Eklonia) and fucoid forests of the Great Southern Reef would be particularly susceptible to extensive acute impact and long-term ecosystem instability due to oil exposure. Significant oiling can lead to direct mortality of macroalgae, and perhaps of greater concern is that oil-induced mortality of the predators of macroalgae grazers could cause a trophic cascade: an increase in grazer populations, loss of kelp and fucoid forest cover, loss of fish and other invertebrates inhabiting these productive habitats, and long-term ecological instabilities. As the kelp forests of the region are reportedly already in decline due to climate change, nutrient loading, and overfishing,[191] further disruption from a large oil spill would further compromise the integrity and recovery of this important ecological habitat.

FISH: If a WCD release occurs at a time and location of spawning of pelagic fishes (e.g. sardine, anchovy), the early life stages (e.g. eggs, larvae, juveniles) exposed to water soluble fractions and dispersed oil/water emulsions, would likely suffer extensive mortality or sublethal injuries that may impact future survival. Oil dispersed or dissolved in the water column would be absorbed across gill tissue, skin, and through ingestion. These impacts could result in long-term population level effects in several fish populations in the GAB.

Experience has shown that large oil spills can impact fish at a population-level:

> *“A very large oil spill could have population-level consequences if vital habitat areas were affected or if it occurred in spawning areas or juvenile feeding grounds when fish populations are highly concentrated. In such cases, very large oil spills could cause substantial reductions in population levels for one or more years.”*[192]

As pelagic fish are important trophic links in offshore food chains, chronic, long-term oil impacts to these pelagic fish populations (e.g. sardines, anchovy, etc.) can radiate throughout offshore ecosystems, affecting pelagic predators such as marine mammals and seabirds. Australian sardine and anchovy populations, which are important ecologically and commercially, could experience population-level impacts if significant oil exposure occurs, particularly during spawning. As sardines and anchovies spawn during summer in continental shelf waters of the region, a WCD spill at this time (when drilling is planned), could expose a significant percentage of eggs and larvae to oil toxicity. [193],[194] Such toxic exposure could cause large-scale mortality of early life stages and sublethal, long-term, population-level effects. Immunosuppression from oil could lead to future disease outbreaks in these important forage fish populations (e.g. similar to the Prince William Sound herring collapse in Alaska).

These small pelagic fish (sardines, anchovy, etc.) are critical prey resources for many larger predators in the GAB ecosystem, including bluefin tuna, Samson fish, kingfish, pygmy blue whales, southern right whales, dolphins, New Zealand fur seals, Australian sea lions, arrow squid, short-tailed shearwaters, crested terns, petrels, and little penguins.[195] Demographic effects of these oil-impacted forage fish populations could manifest in delayed and unanticipated ways in the marine ecosystem, leading to an ecosystem structured very differently than the pre-spill system.[196]

Although the only spawning area identified for southern bluefin tuna is distant from the GAB (between NW Australia/NE Indian Ocean, and Java),[197] a GAB oil spill could cause mortality of juvenile bluefin tuna in the region, as well as significant sublethal impacts affecting adult survival, fitness, feeding, migration, and future reproductive success.
Oil impacts on heart function in early life stages of pelagic fishes would be a concern in the GAB. Oil from the Deepwater Horizon was found to impact bluefin tuna, yellowfin tuna, and amberjack heart cells, where low levels of oil (1-15 ppb PAH) affected cardiac cell excitability, contraction, and relaxation, all of which are important for normal heart rhythm and pacing.[198],[199] The same fish cardiotoxicity was found in the Exxon Valdez spill in Alaska.[200] Such symptoms can impact growth, swimming ability, overall fitness, and can result in cardiac arrest and sudden cardiac death. Cardiotoxicity in early life can lead to population-level effects, and this is thought to have contributed to the collapse of herring after the Exxon Valdez spill in Alaska.[201] Researchers discovered that crude oil disrupted specialized potassium ion channel pores that control contraction in heart tissue, and resulted in arrhythmias in these predatory pelagic fish species, and likely other vertebrates.

Studies on the impacts of the Deepwater Horizon concluded that:

> *"Fish embryos are generally very sensitive to PAH-induced cardiotoxicity, and adverse changes in heart physiology and morphology can cause both acute and delayed mortality. Cardiac function is particularly important for fast-swimming pelagic predators with high aerobic demand."*[202]

A WCD in the GAB could significantly impact predator pelagic fish populations. Sharks would be exposed to oil directly, and by consuming oiled carcasses of fish, seabirds, and marine mammals in the pelagic system. Endangered whale sharks could be exposed while feeding in oiled surface waters, and as they are long-lived (70-years), sublethal impacts could persist for decades.

Nearshore aquaculture operations (e.g. Eyre Peninsula) are particularly vulnerable to a large oil spill, as they are relatively stationary. At best, defensive booming to deflect oncoming surface oil slicks would, be only partially effective, and would be entirely ineffective on dissolved hydrocarbon contamination. Impacted aquaculture businesses would need to destroy contaminated stocks, and remain closed until waters return to safe, background hydrocarbon levels.

Orange roughy may be particularly sensitive to oil impacts, as this fish species is long-lived (150 years), slow growing (20-40 years to maturity), has low fecundity/recruitment, and its eggs are planktonic, rising to within 200 m of the surface during a 1-2 week development period.[203] If planktonic eggs are exposed to oil, significant egg mortality and sublethal impacts are expected.

BIRDS: Given the important seabird and shorebird populations and habitats in the GAB, a WCD is expected to cause the acute mortality of perhaps hundreds of thousands of birds, particularly if large concentrations of feeding, nesting or chick-rearing birds are exposed. Additional mortality can be expected from sublethal impacts of oil exposure, including decreased availability of prey, physiological impairment, reduced fitness, and reduced nesting success. Blood chemistry effects in seabirds due to oil exposure would include hemolytic anemia and reduced oxygen carrying capacity of blood, restricted dive times, and reduced feeding and reproductive success. Buoyancy and thermoregulation of seabirds would be compromised by oiling of feathers, leading to hypothermia, reduced diving and feeding success, reduced fitness, and increased mortality.

Seabirds in the region at risk from oil include all 16 species of albatrosses (6 listed, including the endemic Shy albatross), black-faced cormorants (endemic to South Australia), gannets, gulls, pelicans, little penguins (endemic to Australasia), the 12 species of petrels (including the listed Southern Giant petrel), 2 prions, 4 shearwaters, and skuas.
Oil impacts would be a particular concern for ESA-listed bird species in the region. Seabirds would not only be exposed to oil directly at the sea surface, but scavengers would also ingest oiled prey at the sea surface (oiled fish carcasses, large zooplankton, etc.), thereby taking in a significant body load of hydrocarbons.

As these adults transfer oil to eggs or feed oiled prey to chicks at nesting colonies, chicks will suffer acute and chronic injuries that could reduce overall nesting success in subsequent nesting seasons. As they come ashore after offshore feeding forays, little penguins would be particularly susceptible to shoreline oiling.
In addition, the many shorebirds and migratory waterfowl along the coastline of the GAB -- Common Sandpiper, Ruddy Turnstone, Sharp-tailed Sandpiper, Sanderling, Red

Adult brown pelicans wait in a holding pen to be cleaned by volunteers at the Fort Jackson International Bird Rescue Research Center in Buras.
© Daniel Beltrá/Greenpeace

A pelican sits covered with oil from the Deepwater Horizon wellhead in Barataria Bay.
©Jose Luis Magana/Greenpeace

Knot, Pectoral Sandpiper, Red-necked Stint, Great Knot, Double-headed Plover, Great Sand Plover, Oriental Plover, Latham's Snipe, Swinhoe's Snipe, Pin-tailed Snipe, Oriental Pratincole, Grey-tailed Tattler, Broad-billed Sandpiper, Asian Dowitcher, Bar-tailed Godwit, Black-tailed Godwit, Little Curlew, Whimbrel, Osprey, Red-necked Phalarope, Ruff, Pacific Golden Plover, Grey Plover, Wood Sandpiper, Marsh Sandpiper-- would also experience significant impact from shoreline oiling.[204] Coastal wetlands and lagoons provide critical nesting and feeding habitat for these species, and even moderate shoreline oiling would disrupt reproduction, feeding, and reduce migratory fitness.

Further, impacts of a large-scale spill response effort -- with thousands of workers, boats, aircraft, etc., over several years -- would cause significant impacts to coastal birds, including the hazing/displacement away from critical nesting and feeding habitats for months or years.

MARINE MAMMALS: Effects of a WCD to GAB marine mammals could be similarly severe, particularly as they are directly exposed to oil through skin contact, ingestion, ingestion of oiled prey, and inhaling/aspirating toxic vapors or oil/water emulsions. A WCD oil spill could potentially impact all 40 species of marine mammals found in the GAB - 37 cetaceans (whales, dolphins, porpoises), and 3 pinnipeds (seal and sea lion).

Oil exposure would likely result in significant acute mortalities of marine mammals, as well as long-term chronic impacts persisting for at least one or two generations (15+ years),[205] and may cause permanent impacts. As example, given the losses and impending extinction of the genetically unique AT1 pod of killer whales in Alaska due to the Exxon Valdez spill, it is possible that genetically distinct components within the Bremer Canyon killer whale aggregations, also thought to be independent of the central Western Australia and Ningaloo populations, may be similarly vulnerable to extinction.

Given that 54 whales (29 killer whales and 25 gray whales) were lost after Exxon Valdez in Alaska, it is reasonable to expect a WCD in the GAB would also cause significant mortality in exposed whales, and possibly long-term impacts.

Impacts of a WCD spill to whales in the GAB would be particularly severe if mother/calf pairs are exposed to oil spills on calving/nursery grounds. An example is Southern right whale calving/nursing in the Twilight Marine Reserve or Head of Bight. In 2016, researchers counted 172 individual whales in Head of Bight, of which 81 were mother/calf pairs.[206] If significant oil flows into these protected nearshore calving/nursery areas when mother/calf pairs are abundant (e.g., at one of their triennial calving peaks), these mother/calf pairs would likely suffer acute mortality as well as serious sublethal injuries (e.g. physiological stress, organ damage, behavioral impacts, and reduced fitness).

Right whale mothers nursing calves would have restricted ability to migrate away from oiled nearshore areas, thus increasing their toxic exposure. Alternatively, if they are displaced by oil from these critical nursery areas, they may be more vulnerable to predation and other stresses from being displaced into more exposed offshore environments. Right whale mothers are known to be under significant nutritional stress during this period as they are not feeding while nursing calves, and they exhibit significantly reduced body weights during this critical time.[207] If mothers or calves experience reduced fitness on the calving grounds due to a large oil spill, they may experience greater physiological difficulty on their southward migration to their Antarctic feeding grounds.

As with many Right whale populations, the Southern right whale exhibits high site fidelity to breeding/nursing habitat, returning to the same location to breed and nurse calves. If this breeding/nursing habitat is significantly oiled or disturbed by a large-scale oil spill response effort, these mother/calf pairs could be displaced from this critical habitat area for some time. Such impacts would be relatively more severe if oil spreads to waters used by the southeastern subpopulation of Southern right whales (e.g. Tasmania), with only perhaps 300 individuals remaining.[208] And the endangered, endemic, and declining Australian sea lion population could experience significant impact from a WCD spill, as well as New Zealand (long-nosed) fur seals and dolphins.

OTHER: Terrestrial mammals, birds, reptiles, and other terrestrial organisms along the GAB shoreline would also be exposed to shoreline oiling, and some would experience lethal and sublethal injuries from ingesting, inhaling, or absorbing toxic hydrocarbons.

RESPONSE: Spill response poses significant impacts itself to ecological communities, largely through hazing/displacement due to vessel and aircraft disturbance, emissions, dispersant use, in-situ burning, etc. Experience with large marine oil spills across the world indicates that for a GAB WCD spill, cleanup, wildlife rescue and rehabilitation, and ecological restoration will be ineffective, if not impossible. Further, it is unclear that liability statutes in Australia and the financial ability of Equinor to cover all costs of a WCD (which were $62 billion to BP for the Deepwater Horizon) are sufficient (see discussion below).

SOCIO-ECONOMY: Socioeconomic impacts of a WCD would similarly be devastating. Bea (2016) applied a U.S. EPA spill cost model, and calculates that a 4.35 million bbl spill at a “high-impact” cost ($20,000 USD/bbl) would result in $87 billion (USD) in losses; and a high-impact cost for a 7.9 million bbl (WCD) spill would rise to $187 billion. Economic losses from a WCD spill would certainly be in the billions of dollars, and would persist for years. Commercial and recreational fisheries would be closed for a significant period over a large area of potential oil exposure, perhaps a year or more, and coastal tourism would suffer significant losses for years.

Community impacts would include social and psychological stress, anxiety disorder, substance abuse, and reduced social cohesion seen in other major oil spills, and would likewise persist for years.[209] Citizens would feel a sense of betrayal by their government and industrial institutions, which could manifest politically for decades (as with the two major spills in the U.S.).

Dolphins on the bow, Kangaroo Island, South Australia
©Ella Colley/Greenpeace

Young leatherback turtle crawling towards the sea.
©Jacques Fretey/Greenpeace

12 RISKS OF OTHER OIL SPILLS

Although not within the scope of this assessment, it is important to consider all oil spill risks to Australian waters. It is recommended that the Government of Australia redouble efforts to ensure the safety of all offshore drilling and ship traffic in Australian waters. For offshore drilling, this would require establishing the Independent Expert ALARP (or ALAP) Risk Panel to review all projects (ongoing and proposed), as recommended by Bea (discussed above). For shipping, this would include a comprehensive risk assessment for all tanker and freight vessel traffic in Australian waters, prepositioned rescue tug assets to render assistance to disabled tankers or freight vessels, tug escorts in hazardous waterways, expanded Vessel Traffic Systems (VTS) for vessel tracking, expanded Automatic Identification Systems (AIS), vessel routing agreements and traffic separation schemes, Areas To Be Avoided (ATBAs), improved aids to navigation, enhanced pilotage, and enhanced vessel inspections.

Also, the government should consider nominating the GAB as a Particularly Sensitive Sea Area (PSSA) within the International Maritime Organization (IMO) framework, similar to the Great Barrier Reef and its extension to the Torres Strait and Southwest Coral Sea. IMO's criteria for designating PSSAs include:

> *"…ecological criteria, such as unique or rare ecosystem, diversity of the ecosystem or vulnerability to degradation by natural events or human activities; social, cultural and economic criteria, such as significance of the area for recreation or tourism; and scientific and educational criteria, such as biological research or historical value."*[210]

Much of this rationale applies to the GAB.
Finally, it is imperative that Australia review its oil spill liability regime, ensuring sufficient financial coverage (including environmental damage) for all Worst Case Discharge scenarios. This should provide unlimited liability in instances of gross negligence, and proof of the ability of all operators to pay such damages.

Australia is a member of the International Oil Pollution Compensation (IOPC) Funds covering liability from crude oil tankers, including the 1969 CLC, 1971 Fund Convention, 1992 CLC, 1992 Fund Convention, and the Supplementary Fund. It is also a member of the 2001 Bunker Convention (International Convention on Civil Liability for Bunker Oil Pollution). But Australia is not a member of the 2010 HNS (Hazardous and Noxious Substances) Convention, covering spills of chemicals, condensate, and LNG.

It is important to note that none of these international liability conventions provide sufficient coverage for environmental damage. This is a significant gap in coverage, and should raise concerns in Australia. And there is no international liability regime for offshore drilling. An alternative to the international liability regime is for a government to establish its own spill liability regime, as in the U.S. with the Oil Pollution Act of 1990.

Pelicans at Kingscote, the Great Australian Bight, South Australia. ©Daniel Beltrá/Greenpeace

Fur seal in Kingscote, Kangaroo Island, South Australia ©Ella Colley/Greenpeace

13 CONCLUSION

The proposed Equinor GAB drilling project poses high risk to the ecosystems, economy, and communities of southern Australia.

Despite the highest safeguards employed, the risk of an uncontrolled blowout remains. Industry's estimated Worst Case Discharge of 7.9 million barrels of oil from the Stromlo-1 well is twice the size of the largest accidental oil spill in history – the 2010 Deepwater Horizon in the U.S. Gulf of Mexico. The impacts of such a release would almost certainly be catastrophic.

Elsewhere in the world, where the consequences of a large oil spill have been determined to be unacceptable, governments have protected sensitive marine areas from the risks of offshore drilling. This includes the Lofoten archipelago in Norway (fisheries and tourism values), the North Aleutian Basin/Bristol Bay in Alaska (fisheries value), waters off Belize (ecological and tourism value), Australia's Great Barrier Reef (ecological and tourism value), and the recently established 1.5 million km² Ross Sea Marine Protected Area in Antarctica (ecological value), due to the extraordinary marine environmental values in these marine ecosystems that would be placed at unacceptable risk of catastrophic spills from offshore drilling. Other governments have prohibited new offshore drilling primarily due to climate change concerns (e.g., the need to reduce development and use of hydrocarbons), including New Zealand, France, Ireland, Costa Rica, and coastal waters of Denmark.[211] These same arguments can be made to prohibit drilling in the Great Australian Bight.

While benefit/risk and the acceptable risk tolerance for the proposed project is a matter for the citizens of Australia to determine, this author concludes that risks of drilling in the GAB greatly outweigh potential benefits, and respectfully recommends that the project be declined and the GAB be permanently protected from any further offshore oil and gas development. Such a policy decision would offer the best opportunity for a sustainable future for the Great Australian Bight.

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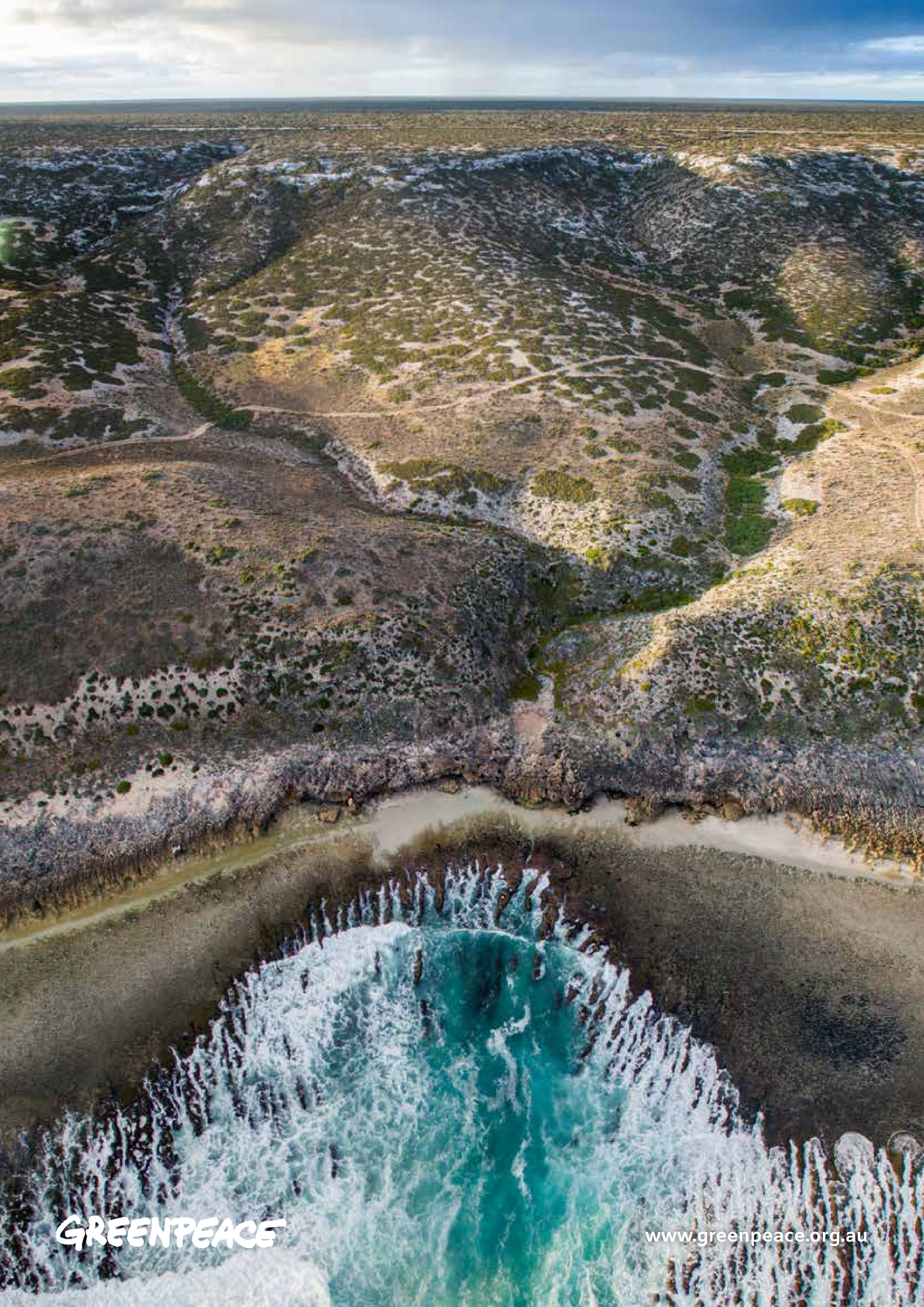
15 APPENDIX

Summary of author Prof. Richard Steiner's oil/environment experience:

- **Alaska** – Professor and marine conservation biologist with the University of Alaska School of Fisheries and Ocean Sciences from 1980 – 2010. In early 1980s (stationed in Arctic Alaska) conducted workshops in Arctic coastal communities re: risks of offshore oil development; stationed in Prince William Sound 1983-1996, participated in 1989 Exxon Valdez oil spill -- advised emergency response, helped develop the U.S. Oil Pollution Act of 1990, co-founded the Prince William Sound Science Center, initiated establishment of the Regional Citizens Advisory Councils (RCACs), and proposed settlement of government/Exxon legal case and use of funds for habitat protection; continued public outreach on offshore oil/environment issues. Founded and served as Facilitator of Shipping Safety Partnership to reduce risk of ship casualties in Aleutians and Arctic.
- **Russia** – Co-Principal Investigator for project on oil spill prevention and response on Sakhalin Island; served as foreign technical expert on public review commission for the Siberia Pacific Pipeline project; taught oil spill workshops in Russia Far East, Siberia, and Western Russia; advised Russian government and Duma on oil royalty and taxation issues; and served as oil spill expert on IUCN/Shell Independent Scientific Review Panel to review the Sakhalin II project and its threat to the critically endangered Western Pacific Gray Whale.
- **Kazakhstan and Azerbaijan** - Worked with civil society groups to enhance oil sector and government transparency, and enhance government take of oil revenues.
- **Africa** – Nigeria, worked with Nigeria Ministry of Environment, NGOs, and state governments in assessing and mitigating damage from oil development in Niger Delta; advised Delta State governor; and served as expert witness in lawsuits re: environmental damage from oil spills; organized and directed Natural Resource Damage Assessments (NRDAs) of oil spills in Niger Delta. In Mauritania, worked to enhance citizen involvement in offshore oil sector oversight.
- **Pakistan** - Developed and served for Pakistan Environmental Protection Agency and UNDP as Chief Technical Advisor for first comprehensive oil spill Natural Resource Damage Assessment in a developing nation, for Tasman Spirit oil spill in Arabian Sea (2003-2004)
- **Lebanon** - During Israeli/Hezbollah war of 2006, advised the government of Lebanon on issues regarding the Jiyeh oil spill caused by Israeli air strikes; briefed the Israeli government in Tel Aviv on the spill and recommended financial settlement from Israel to Lebanon (2006-2007).
- **Israel** – Wrote Independent Expert Opinion on Leviathan Offshore Gas Project, for several NGOs in Israel, July 2018; presented Expert Opinion at conference in Israel, government agencies, and media (2018).
- **China** – Conducted rapid response mission to Dalian oil spill, advised Chinese NGOs and media on spill, 2010. Advised NGOs, media, and governments re: Sanchi condensate tanker disaster in East Sea (2018).
- **Gulf of Finland** – Conducted workshops on behalf of U.S. State Department on oil spill prevention, response, damage assessment, and restoration in Finland, Russia, Estonia (2005).
- **Canada** – Advised Indigenous tribes in B.C. re: risks of oil shipping and pipelines proposed to north coast (2010-2012), advised NGOs on risks of arctic offshore drilling in Canadian Arctic (2018).
- **U.K.** – Advised Shetland Island Council government, and media on Braer Oil Spill (1993), testified to UK House of Commons Committee on the Arctic, (2014).
- **U.S.** – Conducted several projects in U.S. re: oil spill prevention and response, including for State of Hawaii, advised groups in Gulf of Mexico BP Deepwater Horizon spill in 2010, many speaking engagements re: risks of oil, etc.
- **Belize** – Conducted rapid assessment of environmental aspects of oil development in Belize for citizen's coalition (2011).
- **Japan** – Conducted oil spill prevention, response, and impact workshops around Hokkaido Island (2004).
- **Spain/Canary Islands** – Served as technical expert for Fuerteventura Council, Canary Islands, in review of deepwater drilling proposal in Canary Islands, Spain (2013).
- **New Zealand** – Provided expert witness affidavits for offshore oil exploratory drilling legal cases (2012 and 2015).
- **Norway/Svalbard** – Co-principal scientist for research cruise re: offshore oil drilling off Svalbard Norway, Barents Sea (2014).
- **Other** - Authored dozens of technical and popular publications on environmental risks of oil, including the U.N. Manual on Environmental Damage Assessment and Restoration after Large Marine Oil Spills for UNEP and IMO, commented regularly to media on oil risks, etc.



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