May 28, 2019

Review of Key Oil Spill Response Tools: Dispersants

Tom Coolbaugh
Exxon Mobil Corporation
Spring, Texas

Key OSR Principles - General

- Prevention, including source control, is a basic design and operational goal for industry.
- Equipment + people + planning + training + drills/exercises + reviews = response capability.
- Operators should have effective and functional contingency plans, up to and including a credible worst case discharge.
- Plans must have detailed, actionable components that can be translated into a physical spill response capability.
- The Tiered Response Concept (i.e. cascading resources) remains the preferred approach for ensuring adequate resources are readily available.
- Industry continues to build capacity in all areas (planning, mechanical recovery, surveillance/monitoring/visualization, in-situ burning, dispersants, shoreline protection/recovery, comparative risk assessment, etc.).
- Spill Impact Mitigation Assessment (SIMA) should be used to evaluate all response options and select those providing the best outcome.

Optimum Response Strategy

- Use appropriate combination of response tools to minimize impacts
  - If possible, deploy mechanical in thick oil to maximize recovery
  - Consider dispersant use early in a response
  - Responder and public safety is critical
- Environmental protection priorities
  - Minimize wildlife exposure
  - Minimize habitat contamination
  - Minimize oil stranding on sensitive shorelines
- Human resource protection priorities
  - Tourist beaches
  - Marinas, commercial activities
  - Shoreline property values

Spill Response Options: The Toolbox

Monitor & Evaluate

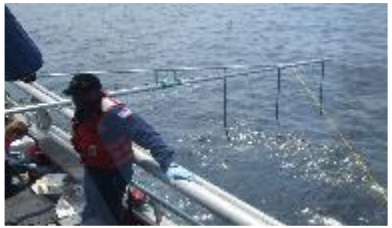
Mechanical Recovery

In-Situ Burning

Dispersants

Aerial

Vessel



Subsea

The goal is to design a response strategy based on
Net Environmental Benefit Analysis (NEBA)/Spill Impact Mitigation Assessment (SIMA)

NEBA / SIMA

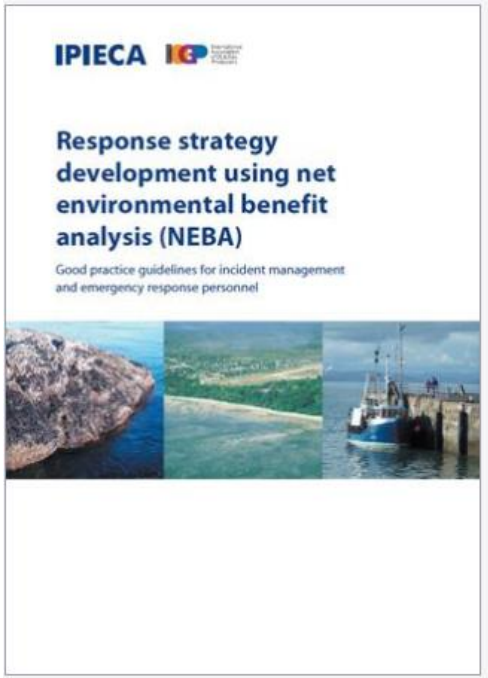
- A risk comparison process to improve decision-making
- A planning and response tool
  - Rank response options by least negative environmental consequences and effectiveness in treating/removing spilled oil
  - Speed the selection of response options for various locations, weather conditions and spill circumstances

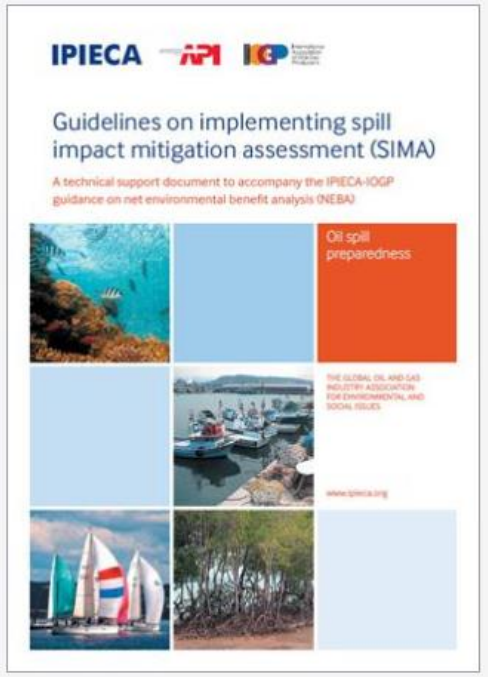
- Can be an intensive and detailed process to arrive at a consensus with respect to the response decision
  - Have the necessary discussions in advance of a spill

- SIMA: Spill Impact Mitigation Assessment includes broader socioeconomic considerations.

NEBA/SIMA Resources

- Structured approach used by the response community and stakeholders during oil spill preparedness planning and response
- Compares the environmental benefits of potential response tools
- Supports development of a response strategy that will reduce the impact of an oil spill on the environment





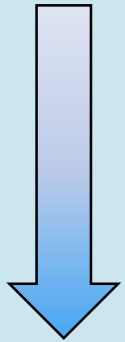
http://www.ipieca.org/resources/?themes=oil+spill

Key OSR Principles - Dispersants

- For offshore spills, SIMA/NEBA will likely support the use of dispersants as the option that best minimizes impact.
- Where applicable, subsea dispersant injection (SSDI) offers significant advantages over surface application and other tools.
  - Treats oil at the source enhancing encounter rate allowing for more effective dispersant use
  - Reduces VOCs at the surface allowing well-control operations to proceed safely
  - Increases biodegradation rates by keeping oil in the water column as smaller droplets
  - Protects surface dwelling organisms and shorelines because less oil surfaces and it is less persistent
- To inform operational decision-making, industry continues to invest in a wide variety of R&D activities including studies related to the effectiveness and fate & effects of dispersants.

http://www.oilspillprevention.org/oil-spill-research-and-development-cente

Shoreline Recovery Time May Differ by Type

Habitat	Recovery Time
Rocky Shores	
Salt Marshes	
Tidal Flats	
Coral Reefs	
Mangroves	Increasing

NEBA/SIMA Considerations Regarding Dispersants

- Oil on the Surface May Affect Birds and Habitats
- Oil in Water May Affect Marine Life

- Oil in Marshes May Affect Marsh Grass
- Oil in Water May Affect Sea Grass

- Oil on Beaches May Affect Turtle Eggs
- Oil in Water May Affect the Turtles

- Oil on the Surface May Affect Mangroves
- Oil in Water May Affect Coral

Dispersant use may provide the most acceptable result

Primary Goal of Oil Spill Response

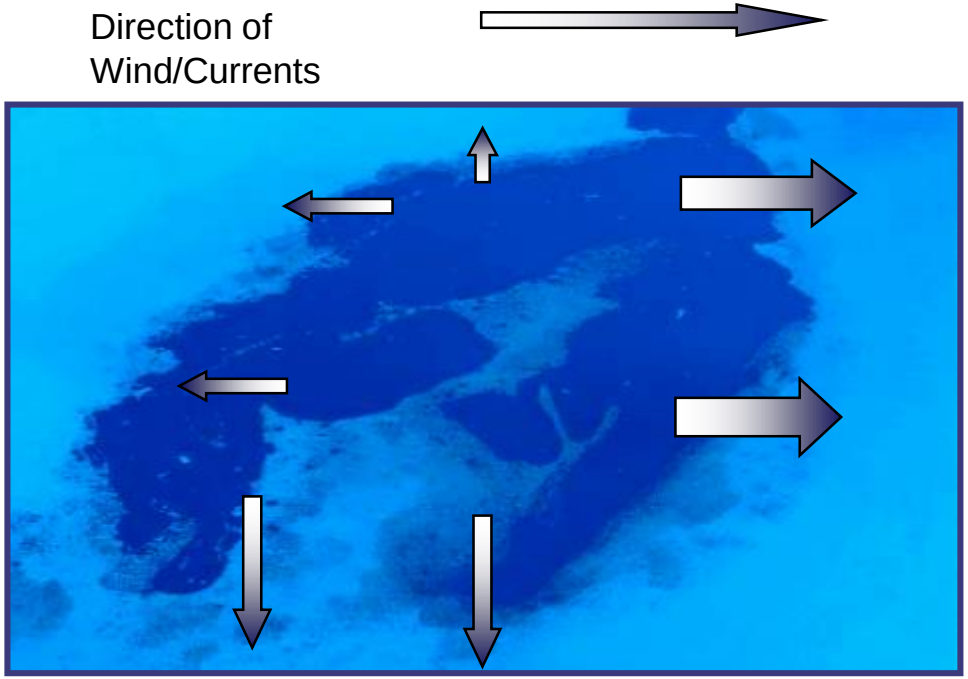
Maximize Encounter Rates and Effectiveness…

…to Minimize Impact

Rapid Response is Key

Slick Continuously Expands as Oil Thins

Direction of Wind/Currents



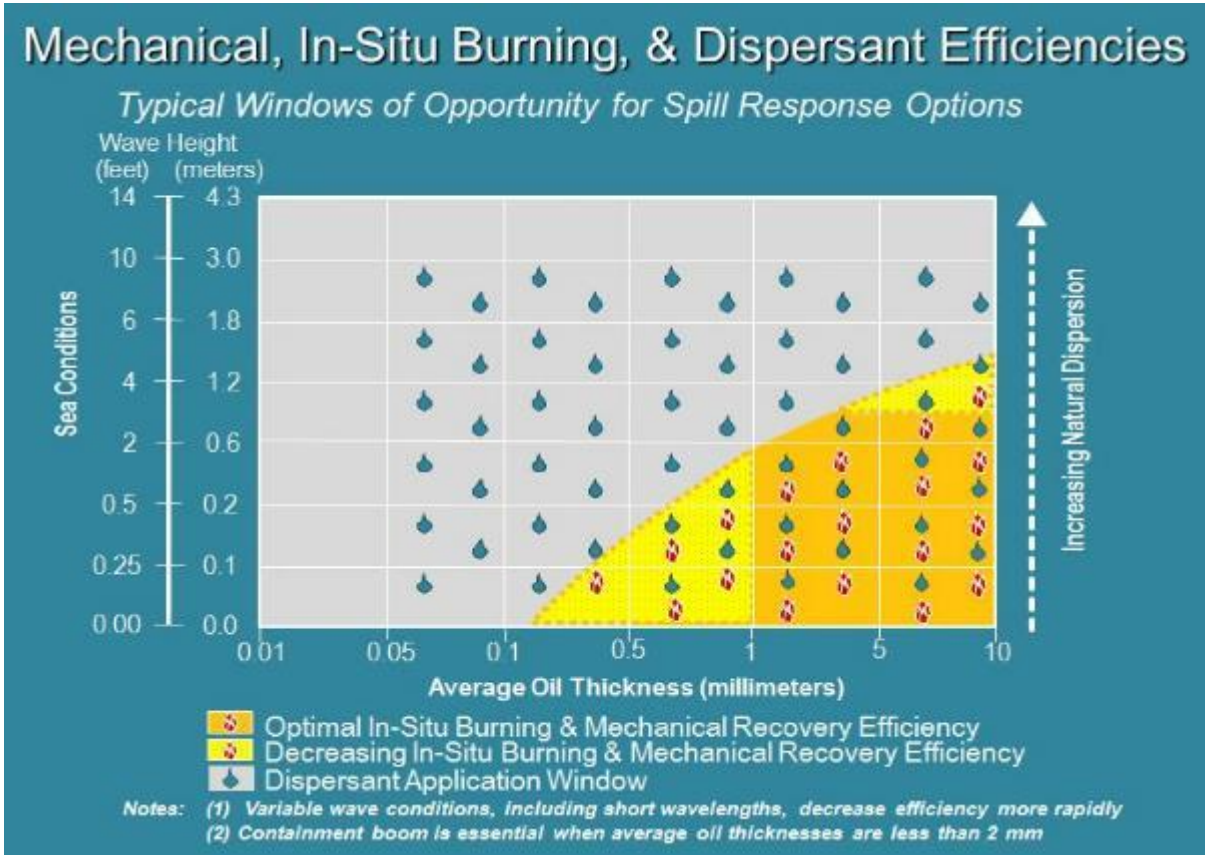
The size of the problem increases with time

Response is less efficient with time

Challenges to Oil Spill Response

- Weather
  - Recovery Impossible In Rough Seas (>2 M) or High Winds (>25 kts)
  - Safety concerns In high seas and inclement weather
- Thousands of different oils with a wide range of properties
  - Weathering Effect
- Remote locations may not have immediate logistical support
- Wide Range of Impacted Habitats
  - Rock Beaches to Sensitive Marshes
- Very little to no daylight during winter at higher latitudes
  - Some work on night operations, e.g., Hawaii approval for vessel dispersant application
  - Enhanced detection tools
- May have limited access to impacted areas

Spill Conditions May Limit Surface Response Options



Dispersants – What are they?

- Dispersants are solutions of surfactants dissolved in a solvent
- Surfactants reduce oil-water interfacial tension – allows slicks to disperse into very small droplets with minimal wave energy

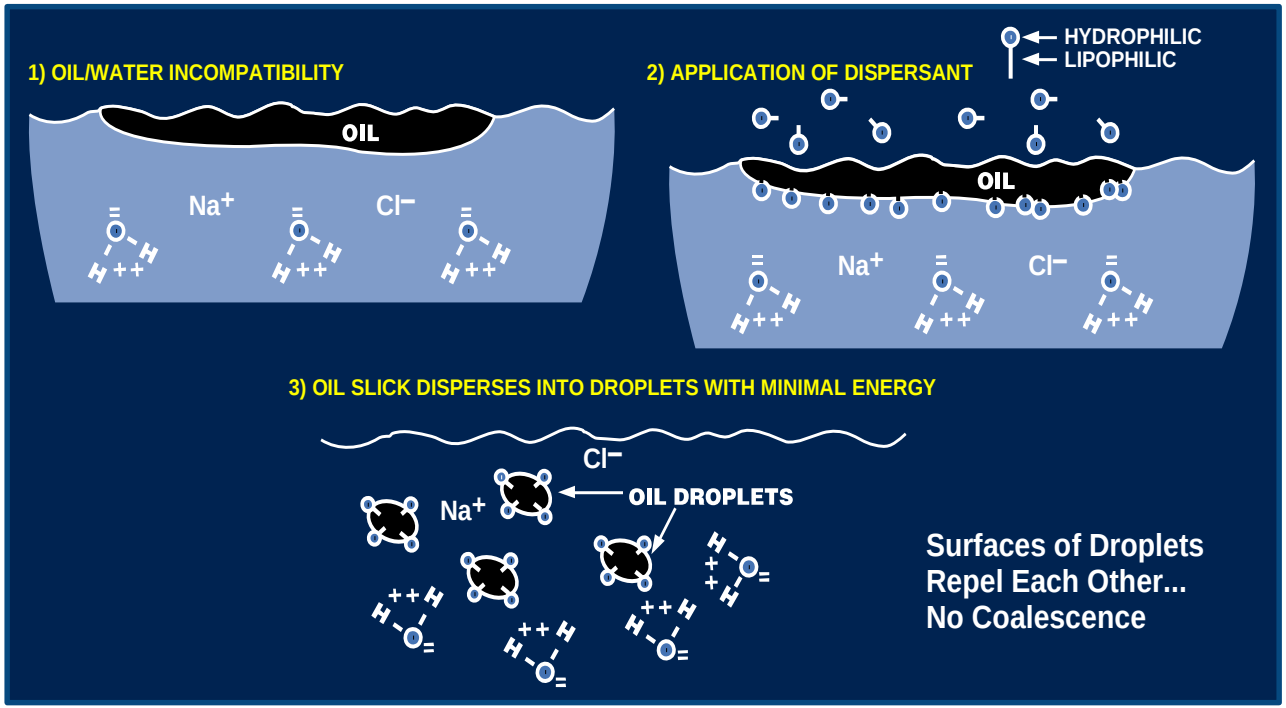
Water-Compatible (Hydrophilic)

Oil-Compatible (Lipophilic)

- Dispersed oil rapidly dilutes to concentrations <10 ppm within minutes, <1 ppm within hours, ppb range within a day

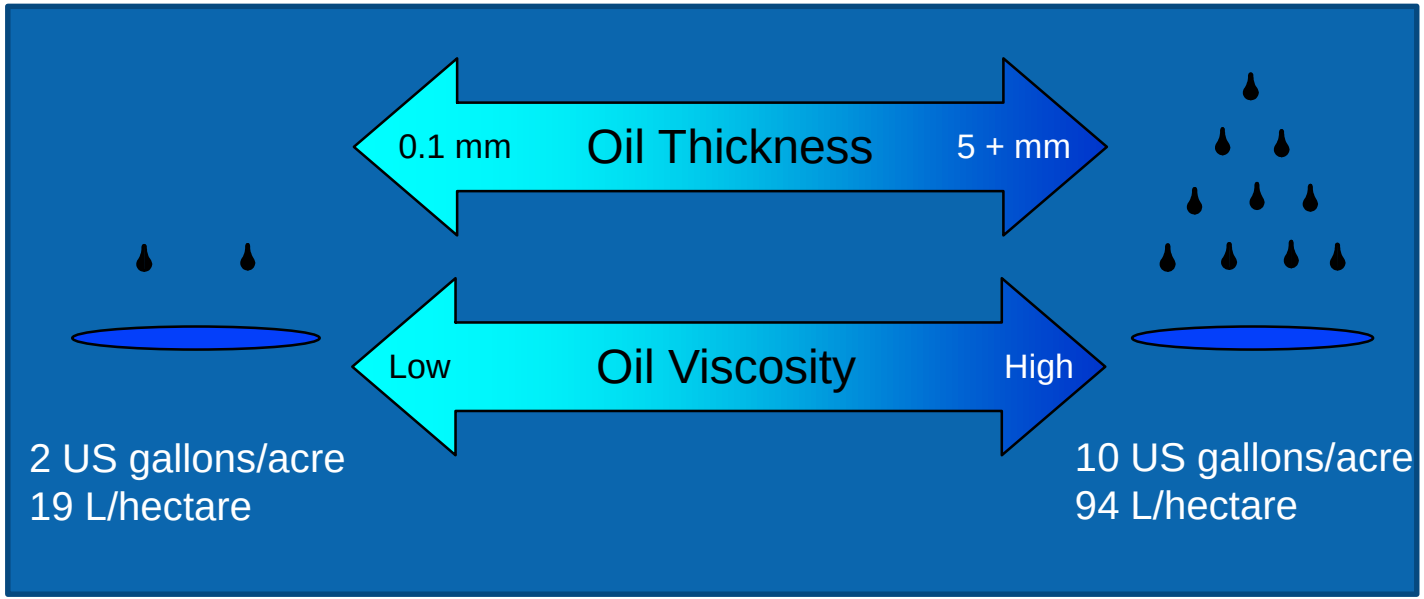
How Dispersants Work

The Goal: Rapidly Reduce Oil Concentration to Below Impact Levels Rapidly



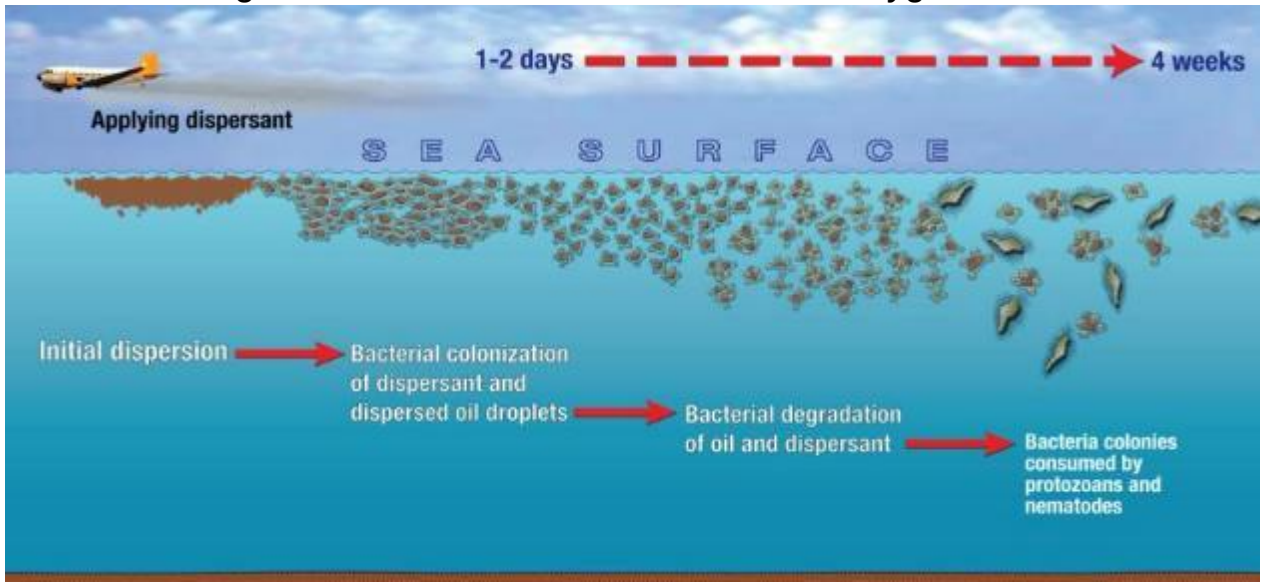
Dispersant Dosages

- Planning basis for surface spill application rate
  - 5 gallons per acre (47 liters per hectare)
  - Dispersant to oil ratio (DOR) 1:20



Dispersants – What do they do?

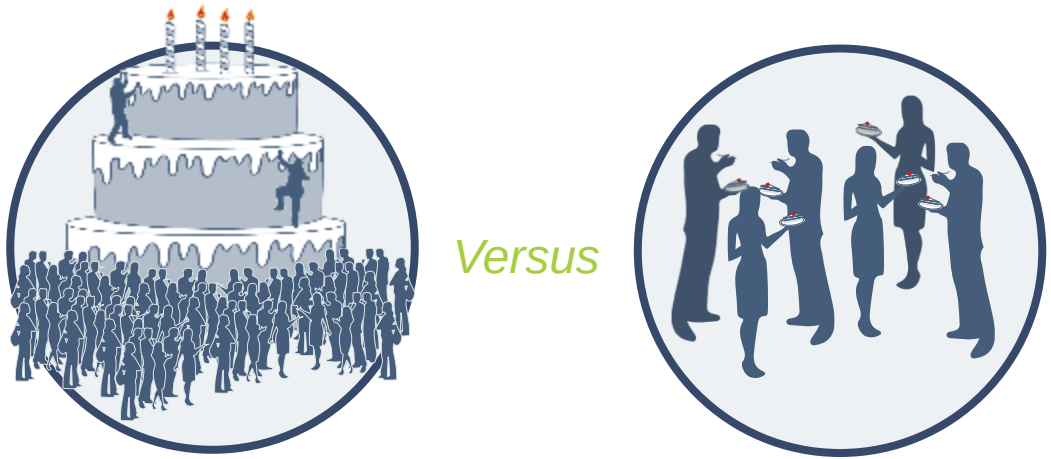
- Dispersants Enhance Removal of Oil from the Environment Through Biodegradation
  - Each dispersed oil droplet is a concentrated food source that is rapidly colonized and degraded by marine bacteria
  - Dilution allows biodegradation to occur without nutrient or oxygen limits



Graphic consistent with Venosa & Holder, EPA 2007

Dispersants Break Down Oil in the Environment

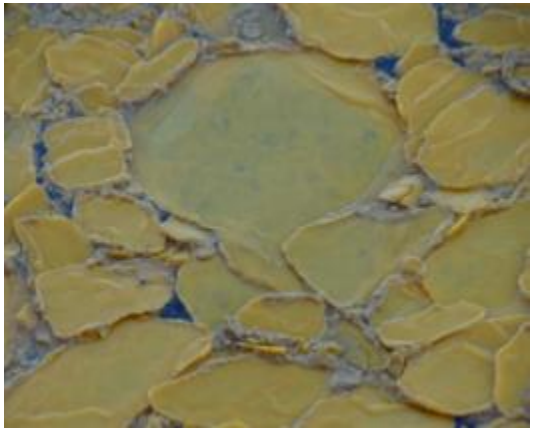
"Dispersants don't remove oil from the sea, but they are designed to help nature do so…Imagine a cake the size of a house, and a hundred thousand people trying to wolf it down at once; then imagine that cake cut into slices and passed around to the same crowd."
-The New Yorker, March 2011



- Dispersants work in a similar fashion to the cake analogy above: oil is broken into tiny droplets that are more easily consumed by microorganisms.

Factors Influencing Effectiveness

- Oil Type/Properties
  - Viscosity
  - API Gravity
  - Wax Content/Pour Point
  - Emulsifiers



- Environmental Conditions
  - Water Temperature
  - Sea State (Mixing Energy)
  - Extent of Weathering (How Long on the Sea)
  - Water Salinity

Environmental Impacts

- Toxicity of oil > toxicity of the dispersant
- Modern dispersants use ingredients found in household products
  - NALCO website*
  - Centers for Disease Control assessment supports low health risk
  - NOAA & FDA test results for dispersants in Gulf seafood, "There is no question Gulf seafood coming to market is safe from oil or dispersant residue."

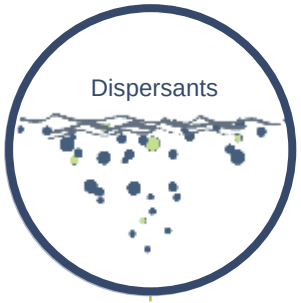
https://www.seafoodsource.com/news/food-safety-health/fda-gulf-seafood-free-of-dispersants

Other Uses of Corexit® 9500 Ingredients (from Nalco website)

Corexit® 9500 Ingredients	Common Day-to-Day Use Examples
Span™ 80 (surfactant)	Skin cream, body shampoo, emulsifier in juice
Tween® 80 (surfactant)	Baby bath, mouth wash, face lotion, emulsifier in food
Tween® 85 (surfactant)	Body/Face lotion, tanning lotions
Aerosol® OT (surfactant)	Wetting agent in cosmetic products, gelatin, beverages
Glycol butyl ether (solvent)	Household cleaning products
Isopar™ M (solvent)	Air freshener, cleaner

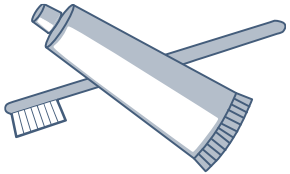
* https://www.nalcoenvironmentalsolutionsllc.com/faqs/

Understanding the Composition of Dispersants



Dispersants work just like soaps and shampoos. They clean up spills by breaking oil slicks into tiny droplets – smaller than the diameter of a human hair. Dispersants are designed to work in the marine environment and prevent oil from re-coalescing.

The same ingredients in dispersants are also found in:



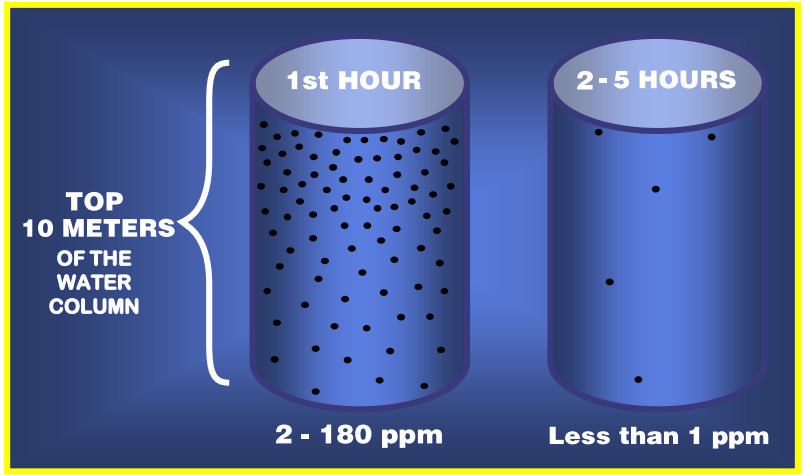
Toothpaste

Sunscreen

Juice

Environmental Impacts

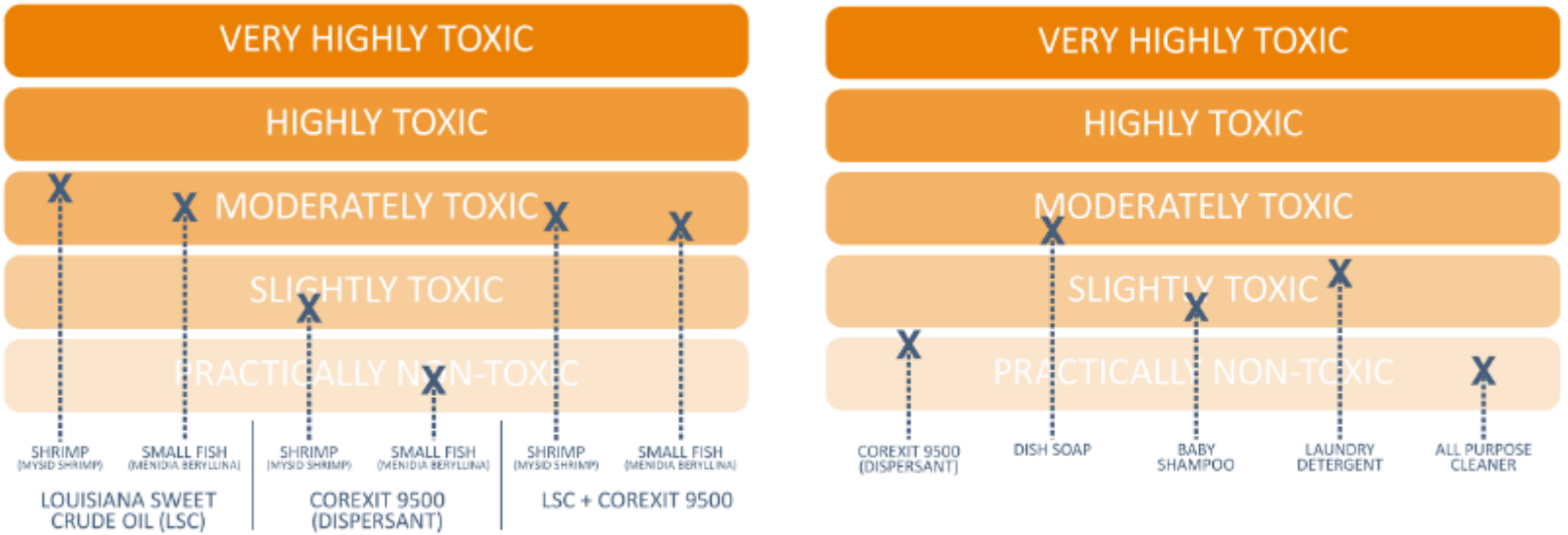
- Toxicity
  - Rapid dilution limits ecosystem impacts of both dispersant and dispersed oil
  - Concentrations start low and rapidly dilute (National Academy of Sciences, 1989)
  - Lab toxicity tests expose organisms to constant concentrations for multiple days
  - Organisms only see elevated concentrations for a few hours during a real spill
  - Dispersants are only applied in areas with high potential for dilution



Lessard, R.R. and DeMarco, G. (2000) The significance of oil spill dispersants. *Spill Science & Technology Bulletin, 6*, 59-68

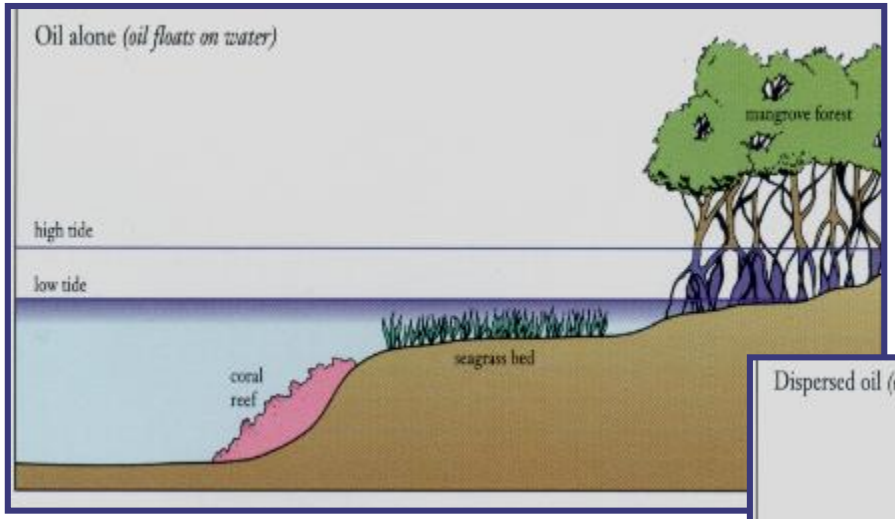
Relative Toxicity

Crude oil Dispersant Dispersed Oil Dispersant Consumer Products



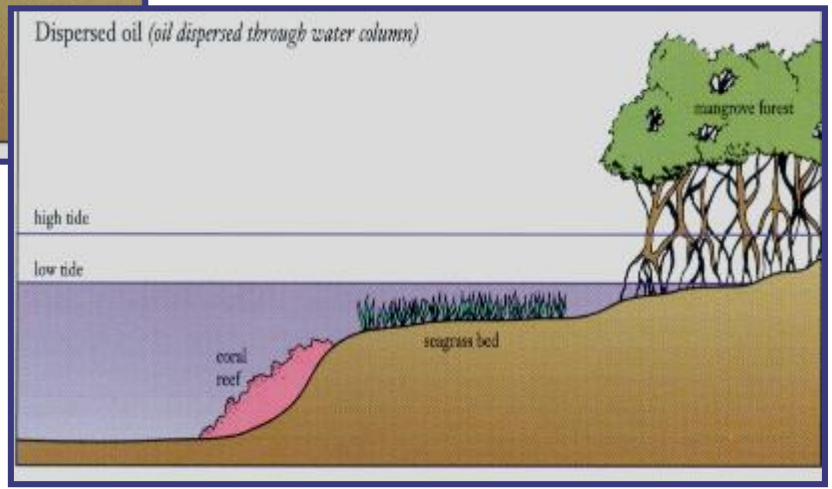
AN ENVIRONMENT CANADA STUDY FOUND DISHWASHER DETERGENT TO BE 25-27 TIMES MORE TOXIC THAN COREXIT 9500.

Balance tradeoffs – NEBA/SIMA

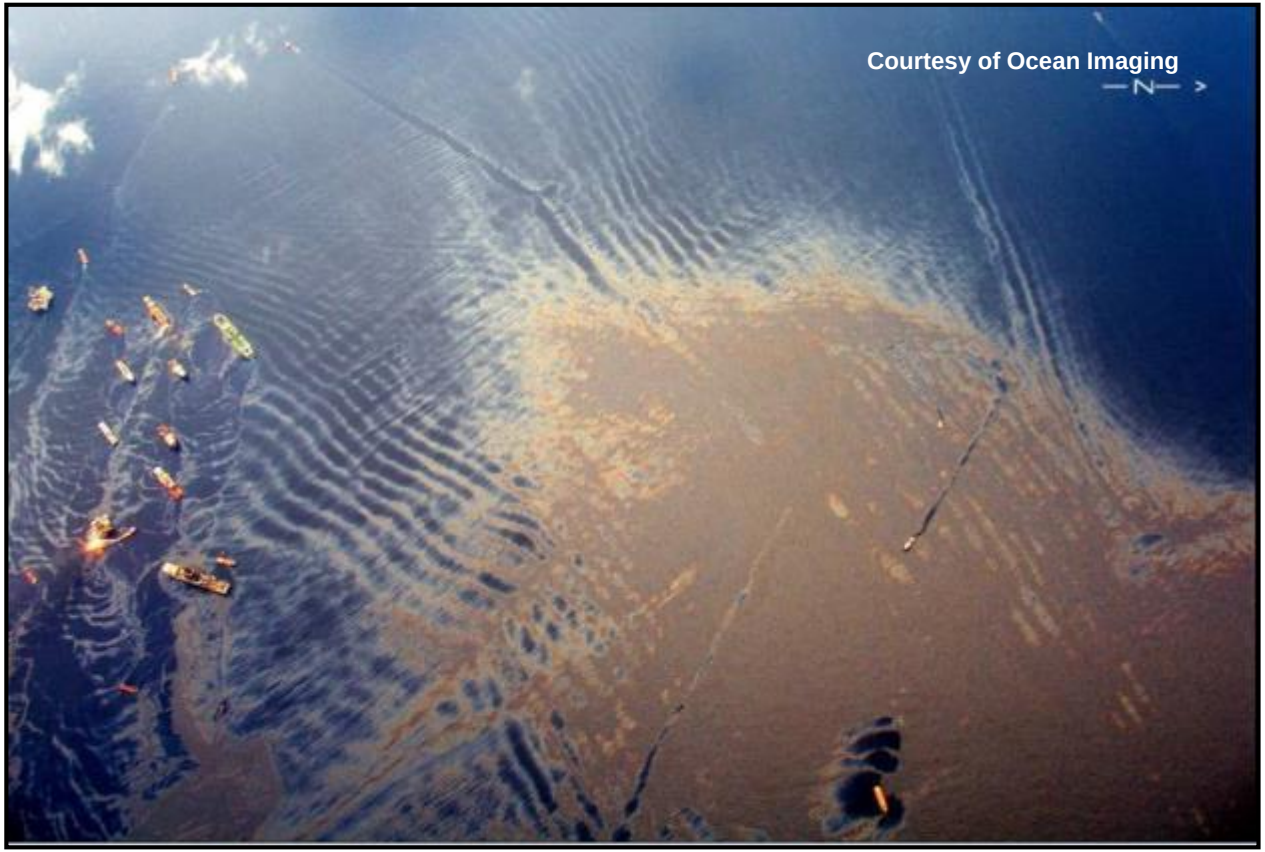


Limit Water Column Organism Exposure

Limit Surface Organism Exposure

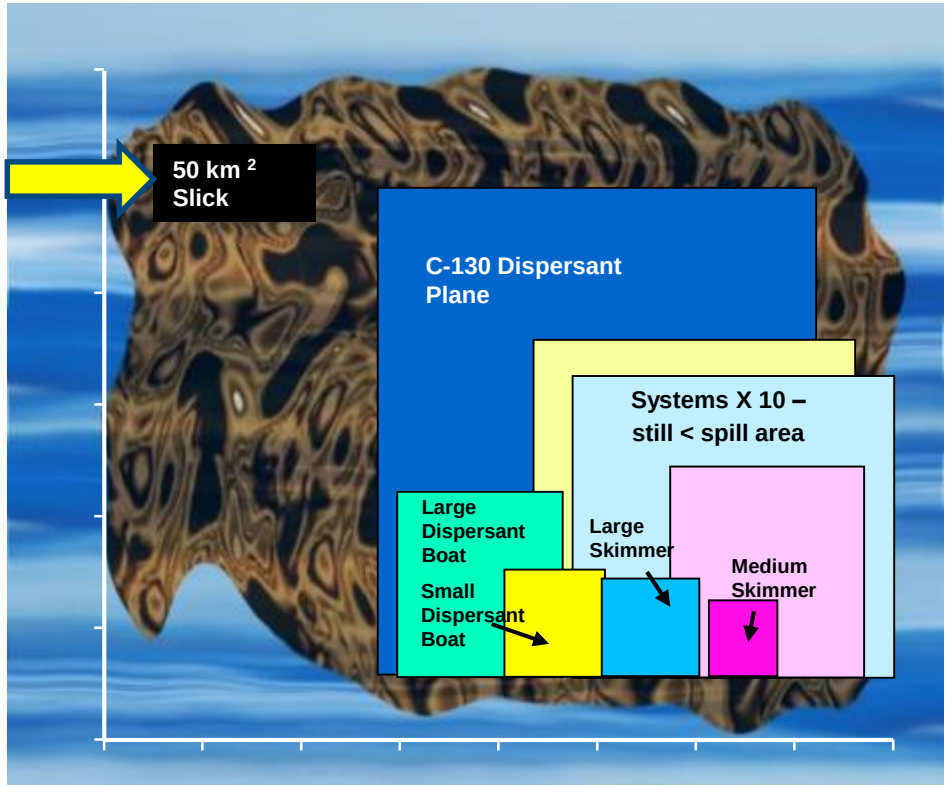


Encounter Rate is Key to Offshore Response



Dispersant Application Platform Comparison

- 5,000 MT spill (37K bbl)
  - Slick 0.1 mm thick
  - 100 MT/km^2
- 8 hrs of operation
- Continuous encounter with slick



For reference:

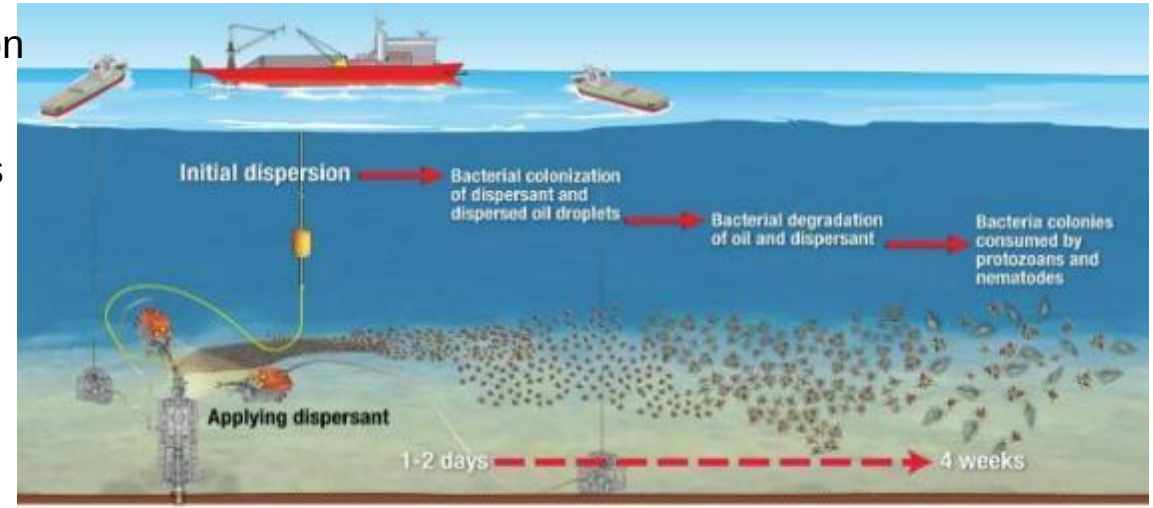
9300 American Football fields
6500 Football (soccer) fields
2900 Australian rules Football fields

Jet Platform

- Key criteria for the Boeing 727 aircraft:
  - High transit speed: 478 nautical mph (885 kph)
  - Range (with full payload): 2,140 nm (3,960 km)
- Three-engine operation, provides the following advantages:
  - High power-to-weight ratio
  - Improved long-range operations over water
  - High reliability and improved safety margins
- Spray Operations conducted at a height of 150 feet and flown at an airspeed of 150 knots
- Carries 15,000 litres of dispersant delivered at a flowrate of between 700 and 1200 litres per minute
- Aircraft, Dispersant system and Operating regime are fully certified
- Can enhance the timeliness of an offshore response

Subsea Dispersant Injection (SSDI)

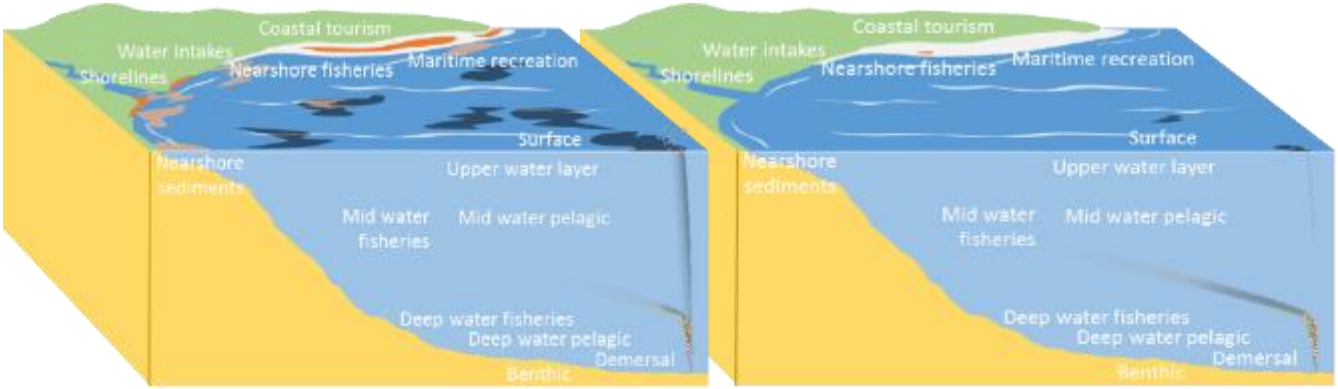
- Preliminary observations of DWH experience
- Benefits of subsea injection
- Long-term fate and effects



SIMA Considerations

- Integrates ecological, socio-economic and cultural considerations
- Promotes the full response ‘toolkit’
- A qualitative methodology to assess response options’ relative mitigation, not measuring spill damage
- Primarily applicable to larger or higher consequence oil spill incidents
- Can be used during either planning or incident response
- International publication aligned with industry-sponsored Good Practice Guidelines

Schematic Example: Subsea Dispersant Use



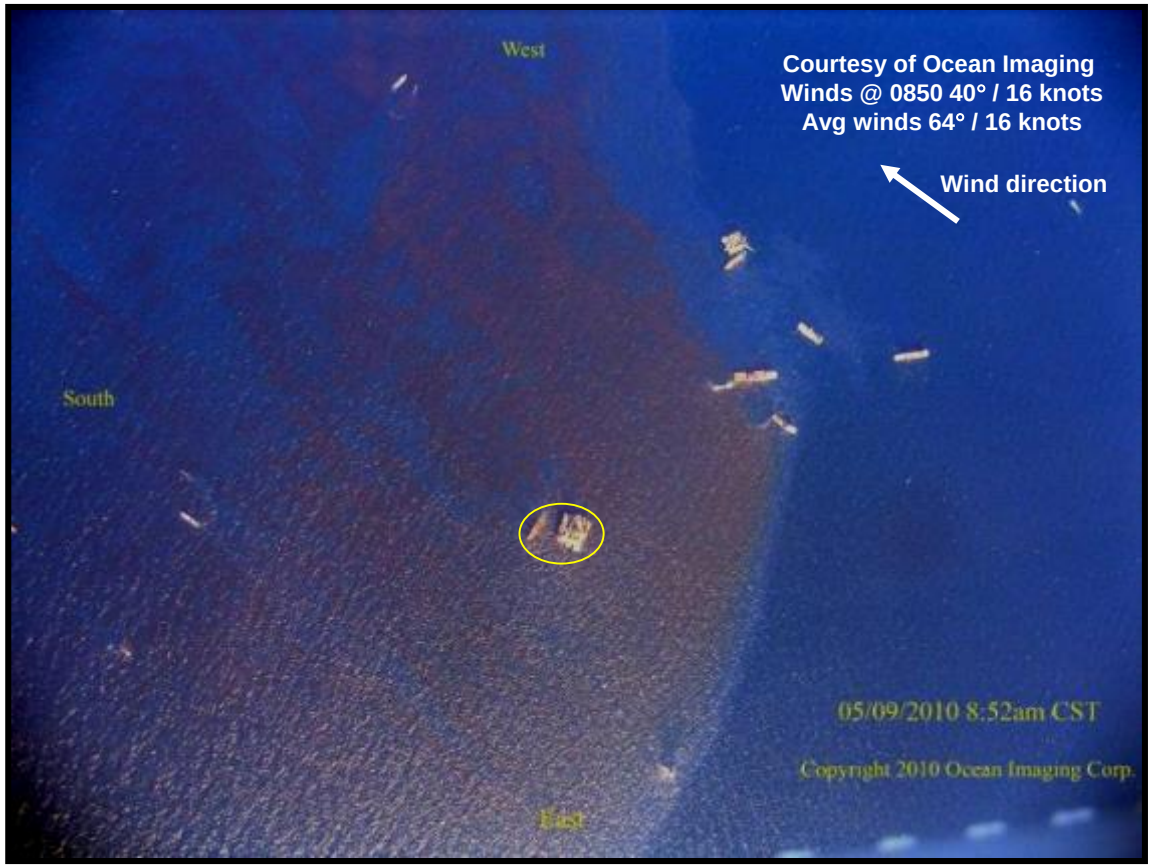
No response

With effective SSDI

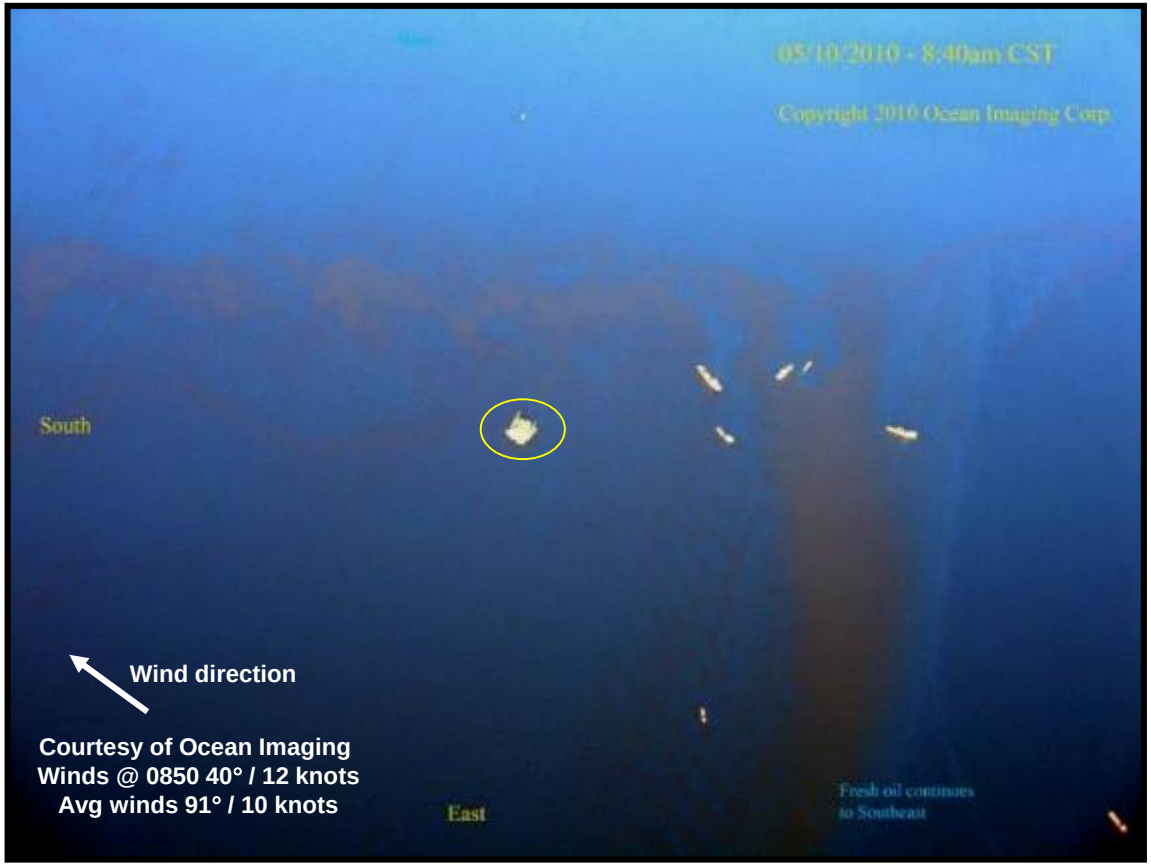
SSDI may substantially **reduce surface expression** of oil but it will **increase subsea concentrations**

SIMA Questions:
Is there a net benefit?
Can surface oil be responded to more effectively?

Release Site May 9: Prior to Injection

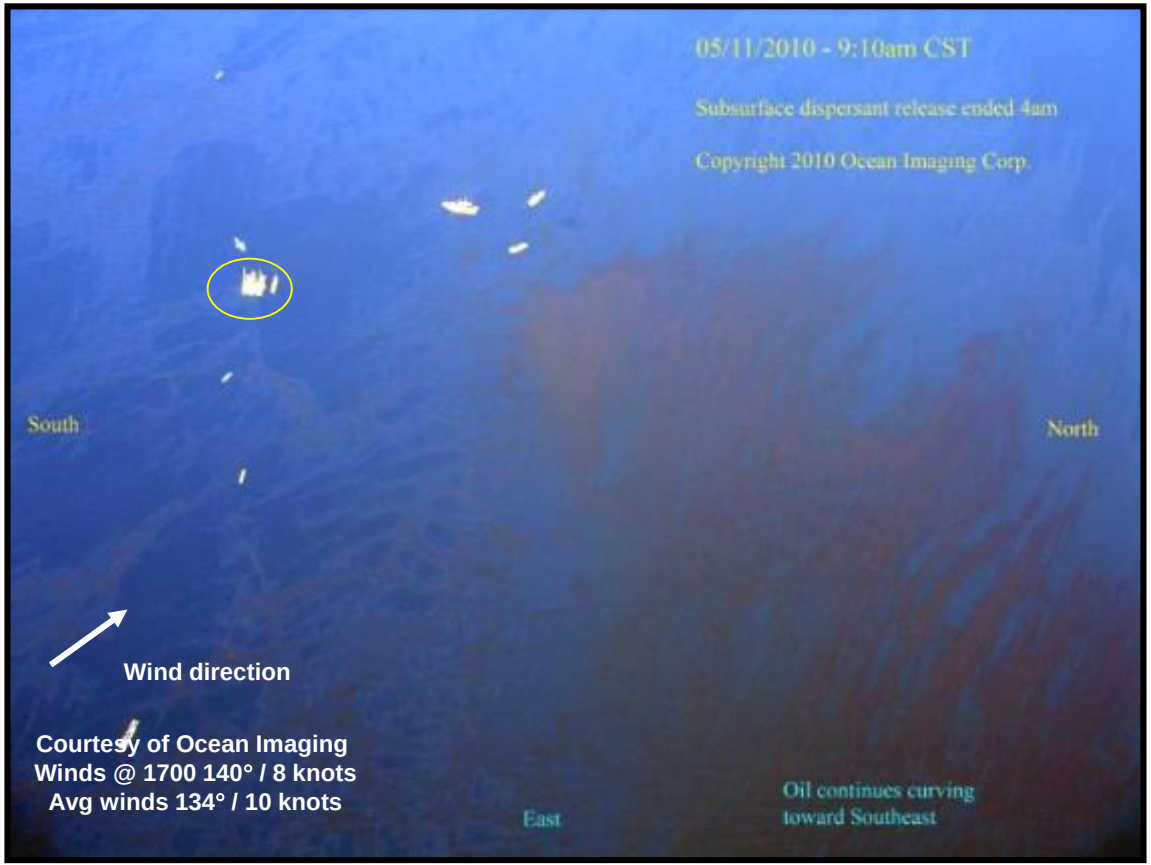


Release Site May 10: 3 hrs of Injection

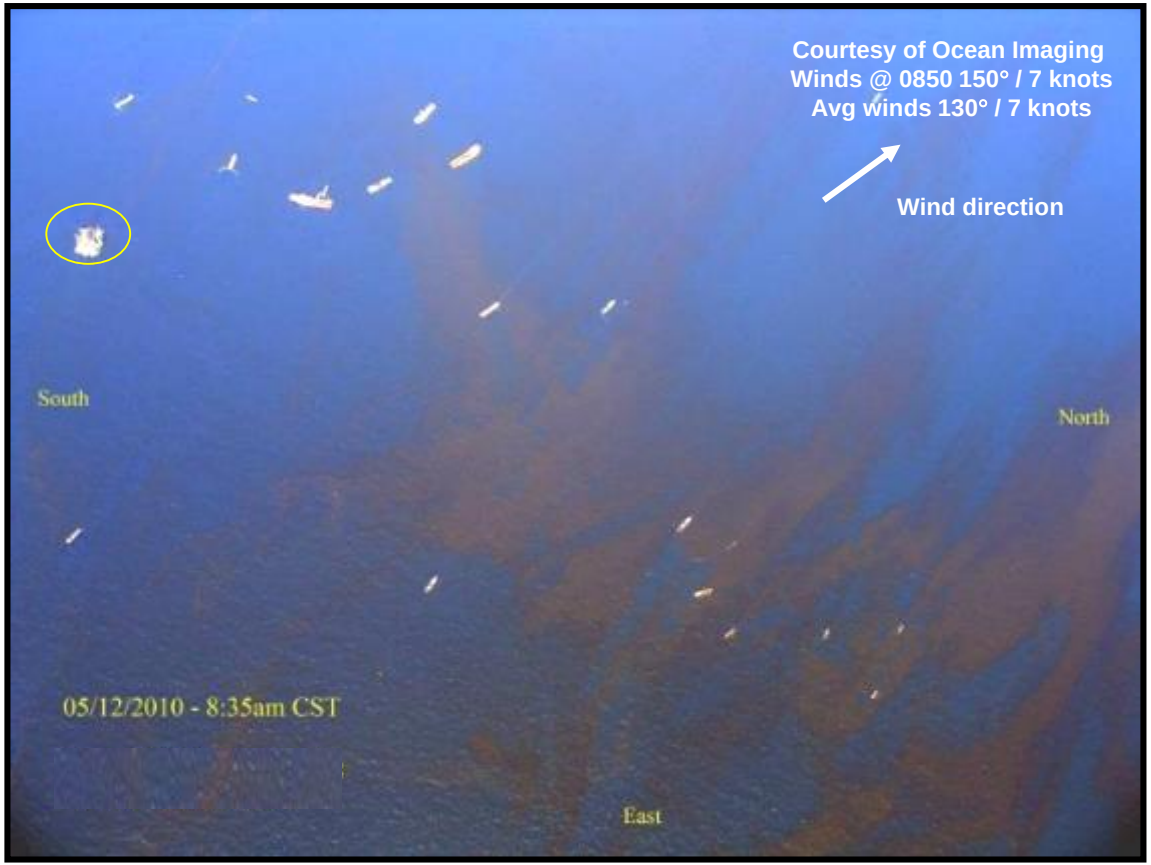


Release Site May 10: 11 hrs of Injection

Release Site May 11: 5 hrs after Injection Ended

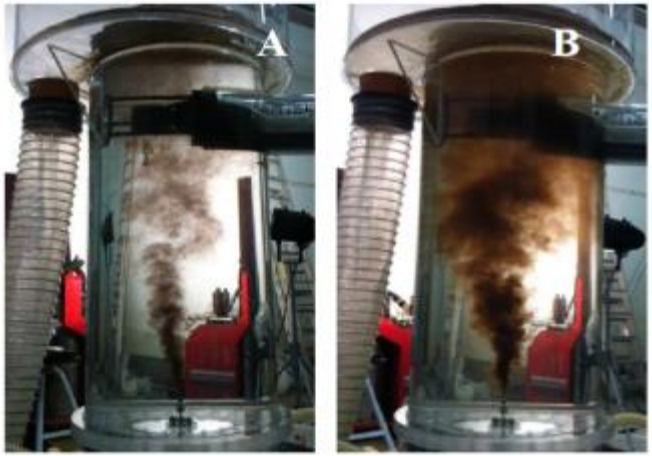


Release Site May 12: 28 hrs After Injection Ended

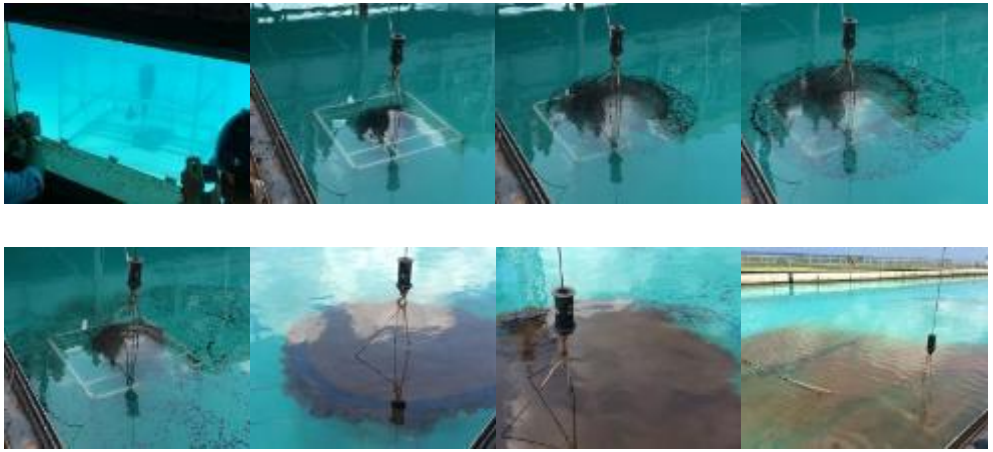


Key SSDI Dispersant R&D Findings: Effectiveness

- SSDI Effectiveness confirmed under various conditions (pressure, temperature, gas/oil ratio).
- SSDI effectiveness is not sensitive to the injection point.
- 20% of surface dosage rates is sufficient to reduce droplet size by a factor of 10 and thus minimize/eliminate oil reaching the surface.



SINTEF (Norway)Bench Studies



US Bureau of Safety and Environmental Enforcement

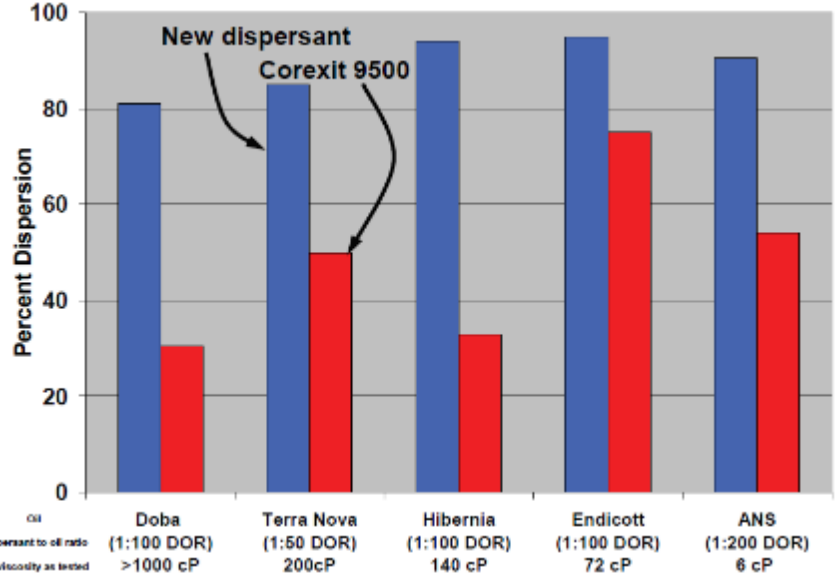
Wave Tank Demonstration

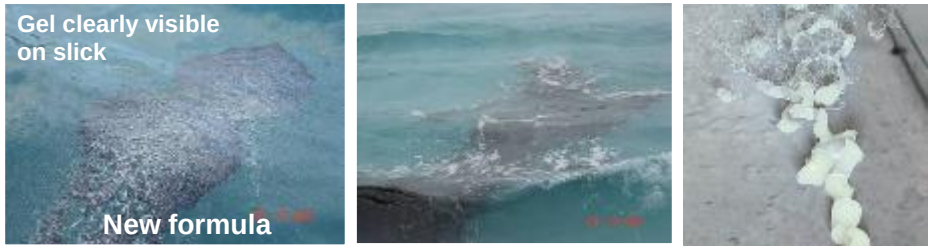
API JIP Website-http://www.oilspillprevention.org/oil-spill-research-and-development-cente

IOGP/IPIECA JIP Website -http://www.oilspillresponseproject.org/response/

Development of New Dispersant Gel

- Advantages
  - May triple delivery capacity
  - Allows dispersion of viscous oil
  - Reduces spray drift
  - Visible after application
  - Buoyant, cohesive drops
- Recent activities
  - Near commercialization





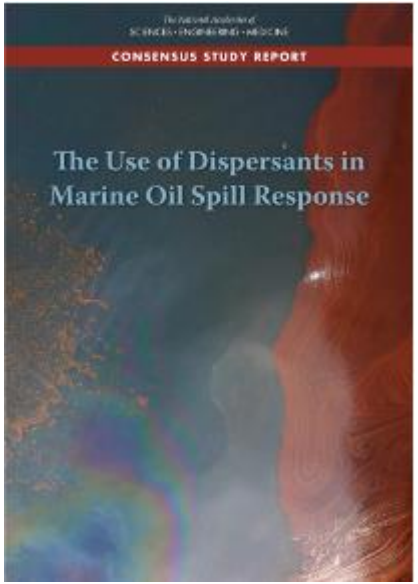
OHMSETT Wave Tank

Key Dispersant R&D Findings – Fate & Effects

- SSDI reduced the concentrations of VOCs in the vicinity of the well site.
- Deep sea species are no more sensitive to impacts of oil than pelagic species.
- Dissolved oil not gas is key driver; pressure reduces the aquatic toxicity of dissolved oil.
- Microbes that biodegrade oil are ubiquitous including in the deep sea.
- Oil biodegrades in aerobic marine waters with an effective half life of days to months while oil that reaches shorelines is likely to persist far longer.
- Overall exposure to valuable ecosystem components (VECs) is minimized by SSDI.
  - Decreased oil exposure to shorelines, surface wildlife and most aquatic life VECs.
  - Increased oil exposure at depth where organisms are less abundant.
- Comparative Risk Assessments continue to suggest that dispersant use can minimize overall spill impacts in many cases.
- 2019 NASEM committee report on the evaluation of oil spill dispersants supports their use as an effective means to minimize overall harm under certain conditions.

2019 NASEM Report: Key Findings

- Surface and subsurface dispersant application represents a useful tool for oil spill response
- When used appropriately, dispersants decrease the amount of oil at the surface, thereby-
  - Reducing the potential exposure of response personnel to VOCs
  - Decreasing the extent of oiled areas encountered by marine species on the water's surface and in shoreline habitats
- Decision makers should use NEBA tools to assess comparative environmental benefits and drawbacks of various options
- If dispersants shorten the duration of a spill, overall impacts on worker and community health should be less
- Understanding impacts of dispersants has been advanced by laboratory experiments and modeling but these efforts are limited by an inability to capture the complexity or scale found in the field



The Global Dispersant Stockpile

- Investment in 5,000 m^3 of the three primary commercially available dispersants was made by industry (managed by OSRL) and placed in locations around the world
  - Represented an increase of ~50% of the total global dispersant inventory at the time

Specification and locations

Type	Quantity (m^3) / US Gal*	Location
Dasic Slickgone NS	500 / 132,500 350 / 92,750	Southampton, UK Singapore, Singapore
Finasol OSR 52	500 / 132,500 350 / 92,750 1,500 / 397,500 800 / 212,000	Southampton, UK Singapore, Singapore Vatry, France Cape Town, South Africa
Corexit EC9500A	500 / 132,500 500 / 132,500	Fort Lauderdale,USA Rio de Janeiro, Brazil

*Quantities at each location are provisional figures only and may be subject to change

Oil Spill Response

Dispersant technical information sheets – conveying multifaceted toxicity and effectiveness data

Rob Holland, Geeva Varghese, Lucy Heathcote (OSRL), Victoria Broje (Shell) & Tom Coolbaugh (ExxonMobil)

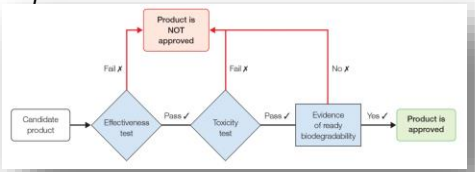
Oil Spill Response
IOSC 2017

OSRL manages global dispersant stockpiles of:
- Corexit® EC 9500A
- Finasol® OSR52
- Dasic Slickgone® NS

Selection is based on:
- low toxicity,
- high effectiveness
- broad regulatory approvals

Dispersant approval requirements outline:
- ***which*** dispersants are listed for potential use
- ***how*** dispersants can be added to an approved list by meeting requirements of specified laboratory-based tests.

Additional guidance available in:
IPIECA –IOGP JIP Report (2014)
Regulatory approval of dispersant products and authorisation of their use



http://www.oilspillresponseproject.org

Effectiveness
- Requirements
- Country specific data
- Test results

Toxicity
- Requirements
- Relative toxicity data
- Test results/Species data

Free downloads available: https://www.oilspillresponse.com/technical-library/
Contact details: geeva.varghese@oilspillresponse.com

Dispersant Approval Across the Globe

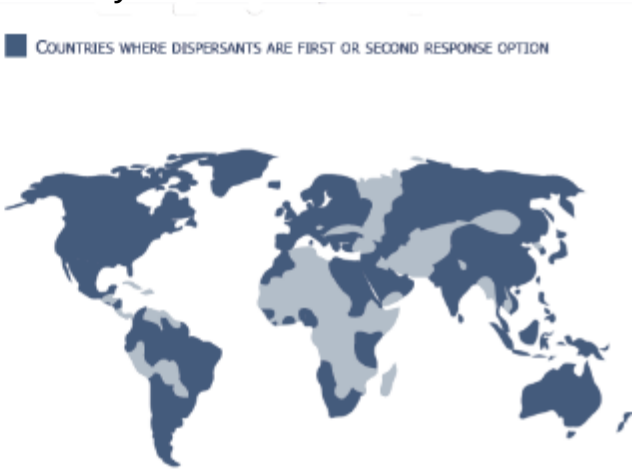
- Dispersants are a first or second response option in many countries today
- Dispersant approvals in Asia-Pacific vary with respect to 3 main dispersants

Table 4: Asia Pacific Approval Status for the Global Dispersant Stockpile

S/N	Country	Global Dispersant Stockpiles		
		Slickgone® NS	Corexit® 9500	Finasol® OSR 52
1	Australia	Yes	"Yes"	No
2	Brunei	Yes	Yes	No
3	Cambodia	Yes	No	Yes
4	China	No	No	No
5	Hong Kong	No	Yes	No
6	India	No	No	Yes
7	Indonesia	No	No	Yes
8	Japan	No	No	No
9	Malaysia	Yes	No	Yes
10	New Zealand	Yes	Yes	No
11	Philippines	Yes	No	No
12	Singapore	Yes	Yes	Yes
13	South Korea	No	No	No
14	Thailand	Yes	Yes	Yes
15	Vietnam	No	No	No
	No of countries approved =	9	7	6

Global Dispersant Approvals in Asia Pacific – Current Status and On Going Challenges
Thomas Coolbaugh, Geeva Varghese and Lau Siau Li
International Oil Spill Conference Proceedings May 2017, Vol. 2017, No. 1 (May 2017) pp. 657-677

- Angola
- Argentina
- Australia
- Belgium
- Brazil
- Brunei
- Cameroon
- Canada
- Chile
- China
- Columbia
- Côte d'Ivoire
- Croatia
- Cyprus
- Denmark
- Djibouti
- Ecuador
- Egypt
- El Salvador
- Eritrea
- France
- French Guiana
- Gabon
- Georgia
- Germany
- Ghana
- Greece
- Greenland
- Iceland
- India
- Indonesia
- Ireland
- Israel
- Italy
- Japan
- Kenya
- Kuwait
- Lebanon
- Libya
- Malaysia
- Malta
- Mexico
- Montenegro
- Morocco
- Namibia
- Nicaragua
- Netherlands
- New Zealand
- Nigeria
- Norway
- Oman
- Pakistan
- Papua New Guinea
- Philippines
- Poland
- Portugal
- Qatar
- Russia
- Saudi Arabia
- Senegal
- Sierra Leone
- Singapore
- South Africa
- South Korea
- Spain
- Sri Lanka
- Sudan
- Syria
- Tanzania
- Thailand
- UAE
- UK
- Uruguay
- US
- Vietnam



Many countries consider dispersants an important tool in oil spill response. However, there is global inconsistency in the types of approved dispersants and how and when to use them.

Source: International Tanker Owners Pollution Federation (ITOPF)

Used with permission of the API

Dispersant Inventory Management

- As dispersant stockpiles age, there is value in implementing a rational plan to manage them on a logical and systematic schedule.
    - Some governments may require routine testing of stockpiled dispersants for effectiveness (UK, France, Italy, Norway, for example), but the frequency of testing and pass/ fail criteria can vary widely
- The potential risk of testing dispersant stockpiles on a frequent, routine basis is that the opening and re-opening of containers risks exposing the dispersant to contamination from introduced humidity or foreign debris, as well as the risk of improper resealing due to human error
    - This could result in compromised product integrity for stockpiles that would otherwise remain viable over long periods of time, e.g., decades
- OSROs such as AMOSC and OSRL have developed stockpile maintenance and management procedures and key components include:
    - Storage strategies to minimize potential adverse environmental impacts
    - Establishing proper maintenance protocols to ensure routine inspection for any adverse impacts, e.g., visual inspection of containers and contents

Source Control: Capping Stacks

- Capping Stacks are now situated around the world in strategic locations
  - Air freightable proof of performance was recently demonstrated by Oil Spill Response Ltd (OSRL)
- Dispersant use can reduce VOC levels near responders during the early stages of source control efforts

Figure 9: A snapshot of commercially available capping stacks as at 2018 which gives a sense of where equipment is strategically located (NOROG NCS Wells Capping Status Report 2016)

Summary

- Along with prevention, robust oil spill response (OSR) is critical
- Highest priority in emergency response is human health and safety
- Basic strategy for addressing oil spilled from an offshore well
  - Respond as close to the source as possible
  - Utilize all appropriate tools to keep oil from reaching shorelines
- Dispersant use presents significant advantages over the limitations of mechanical recovery and should be considered as a primary response option
- Subsea injection is a step-change advance that may reduce spill impacts by an order of magnitude

Thanks for listening.

Any Questions?