Deepwater Horizon Gulf Oil Spill

Coastal Response Research Center
University of New Hampshire

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CEPS Alumni Society Seminar Series
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- Kathy Mandsager
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Today’s Topics

• Oil Drilling in the U.S.
• Deepwater Horizon (DWH) Drill Rig
• Oil Spill Basics
• DWH Spill Response
• Risk Communication
• Future Offshore Drilling and Spill Response
Oil Drilling in the U.S.
783 M metric tons = 230 billion gallons

(Source: Clark, 2001)

# = million metric tons/year
Barrel = 42 U.S. gallons
7 Barrels = 1 metric ton
~63,000 miles pipeline

~4,000 offshore platforms in Gulf of Mexico
Crude Oil Imports into the U.S.

- Total: 10.4 million barrels/day = 159 billion Gallons/Yr (2010)
- Imports Through Louisiana Offshore Oil Port (LOOP) Facility
  - Handles 13% of imported oil = 20.7 billion gallons/yr
Crude Oil Production in U.S.

• Total: 79.8 billion gallons/yr (2009)
• Alaska produces 9.9 billion gallons/yr
• Gulf of Mexico (GOM) produces 23.9 billion gallons/yr (30% of total domestic crude)
Oil Consumption in U.S.

- Total: 290 billion gallons/yr
- Transportation: 72%
- Industrial: 22%
- Residential/Commercial: 5%
- Electrical Power: 1%
Deepwater Horizon Rig
DWH Rig Facts

• 33,000 Ton Drilling Rig on Pontoons (Built 2001 / $350M)
• Derrick = 20 stories above top deck
• Held in position using GPS dynamic positioning controlled thrusters
• Owner: Transocean
Mississippi Canyon Block 252 (Macondo Site)

• BP Lease Site (MC252)
  • 10% BP’s oil from GOM
  • Cost; $34M to Minerals Management Service

• Transocean’s Marianas rig started drilling at MC252 October 2009
  • Damaged in Hurricane Ida
    • November 9, 2009
  • Drill pipe 5,000 ft of water + 4,000 seabed (9,000 ft total)
Macondo Site Drilling History (cont’d)

• ~ 9,000 ft more to drill to gas and oil reservoir (~ 18,000 ft total)
• Marianas replaced by Deepwater Horizon rig
  • Est $1M /day fee
• DWH arrives at Macondo site Jan 31, 2010 and starts putting down pipe
Macondo Site Drilling History (cont’d)

• BP and partners budgeted 51 days and $96.2M for this well

• By April 20, 6 weeks behind schedule and $58M over budget

• Personnel (126 people)
  • 80 Transocean employees
  • Drilling crew and vessel management
  • Some BP engineers/geologists
  • Service workers (e.g., food, laundry)
  • Floating city
Events Leading to DWH Well Blowout

- April 2010
- DWH Rig had drilled into oil/gas reservoir
- Testing new cement seal at bottom of well (Halliburton)
DWH Well Blowout (cont’d)

• Put in temporary cement plug – 3,000ft below top of well
  • Temporary abandonment until production platform was brought in

• Skipped Schlumberger’s cement evaluation to save time and $128,000

• Positive pressure test
  • Increase pressure inside steel casing and seals to be sure they are intact
  • Acceptable results
DWH Well Blowout (cont’d)

• Negative Pressure Test
  • Reduce pressure inside well to simulate situation after rig gone (no fluids leaking into well)

• Negative Pressure Test
  • Began 5 pm, April 20
  • Pressure repeatedly increased
  • Decided to try again using “kill line” on blowout Preventer (BOP)
    • Results ok no pressure increase
    • Likely kill line was not working properly (clogged)
DWH Well Blowout (cont’d)

- Decision – OK to open BOP and replace heavy drilling need in drill pipe with seawater
  - Once that was done can put in cement plug
- 9:15 pm begin displacement seawater into bottom of well (annulus)
- ~9:40 pm hissing and high-frequency vibration
- Then mud shooting out of gas buster on rig
Then explosion killed all on drilling floor & crane operator on deck

All saved except 11 killed in explosion
  - Supply vessel & life raft (lowered 15ft to water)
  - Fire on rig & oil on water surface
  - Returned to shore on supply boat, except for very badly injured (by USCG helicopter to land)
DWH Oil Spill

- 1:30 am (April 21) DWH rig listing; secondary explosions & fire
- 2:50 am (April 21) span 180° and GPS dynamic positioning dead
  - DWH moved 1600 ft from well
- 3:15 am DWH listing heavily, fire continues & fire boats spraying water on rig
- 1:27 am April 22 DWH sank
DWH Blowout Causes

• Lots of individual mistakes
• Excellent source of information in Presidential Commission Report
  www.oilspillcommission.gov
• Joint US Coast Guard & Bureau of Ocean Energy Management DWH Investigation
  http://www.deepwaterinvestigation.com
A Fail-Safe Fails

A buckled piece of pipe prevented a safety device from stopping last year's Gulf of Mexico blowout, according to a report released Wednesday.

Blind shear ram
These blades are part of a suite of safety equipment that rests on the sea floor at the top of a deep-sea well head.

ALIGNED: Typically the drill pipe lies in the center of the ram.

NOT ALIGNED: Upward pressure from the flowing oil caused the pipe to buckle and slide out of place.

Hydraulic systems force the blind shear ram closed during a well blowout. They are designed to cut the steel pipe and seal a well shut, preventing any oil from flowing past.

The ram was not designed to cut an off-center pipe and failed to do so on the Deepwater Horizon well. It left a small gap of 1.44 or less that oil flowed through.

Sources: Det Norske Veritas, BP
Figure 2 NASA-Michoud Test Facility Test Pads
Oil Spill Basics
Crude Oil Properties

- Usually Floats on Water
  - May sink if associated with sediment particles

- Composition Varies with Source
  - Louisiana Sweet Crude Oil – lighter than Alaska North Slope crude

- Some Solubility
  - Soluble is most toxic fraction

- 250+ Hydrocarbons
  - Mostly carbon and hydrogen
Weathering of Oil

- Natural Processes
- Function of Environmental Conditions
  - Temperature (H₂O, Air)
  - Wind
  - Oil Type
  - Currents, Tides
DWH Spill Response
DWH

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Gulf of Mexico
Overview of DWH Spill

- DWH Blowout ~50 miles Off Mississippi River Delta
  - 5,000 ft of water
  - 13,000 ft of sediment/rock
  - Total rig to oil reservoir ~ 18,000 ft (~3.5 miles)
- April 20 – Explosion
- July 15 – Well Killed from Top Ending Release
- Total Oil Release (est.) = 200 Million Gallons
- Largest ACCIDENTAL Oil Spill in Recorded History!
Estimated Footprint (DWH vs. Valdez)

Estimate of Exxon Valdez oil footprint ~470 mi by 50 mi
DWH Response:

200 Million Gallons of Oil Released over 87 Days

Lots of Oil Over Long Time

“We faced a new spill every day for 3 months!”
Priority #1 = Stop Fire, Rescue People
Priority #2 - Stop Source of Leak

• Start Relief Well
• Install “Cap” to Stop Flow
  • High ambient water pressure, cold and dark
    • 2200 psi
  • High exit pressure of oil, hot (212°F)
    • 6500 psi
  • Well Head ~ 7 inches diameter; 1 mile below water’s surface
Initial Response Mode
Final Response Mode: Prior to Top Kill
Priority #3 - Identify Natural Resources at Risk

- Crabs, Shrimp, Oysters, Blue Fin Tuna, Charismatic Marine Mammals
- Recreational Beaches
- Commercial Fishing
- Subsistence Fishing

Shorelines on ESI maps are color-coded by sensitivity to oil. Symbols mark localized areas for biological and human-use resources.
Priority #4 – Minimize Damage to Natural Resources

- Protective Booms
  - ~5,500 miles of boom deployed
- Capture Oil in Booms (Mechanical Recovery)
  - Skim oil off surface
  - Burn oil on surface
- Disperse Oil
- Weathering of Oil
  - Evaporation

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Weathering of Oil

- Wind
- Drifting
- Photolysis
- Evaporation
- Spreading
- Water-in-oil emulsion

- Resurfacing of larger oil droplets
- Dissolution of water soluble components
- Uptake by biota
- Adsorption to particles
- Microbiological degradation
- Vertical diffusion
- Horizontal diffusion
- Sedimentation
- Uptake and release from sediment

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Oil Protection Boom
Oil Protection Boom
Oil Collection Booms and Skimmers
DWH: State-of-the-Art Mechanical Recovery

- Lots of Vessels & Boom (Vessels of Opportunity)
- Improved Designs Work in Small Waves
- Often Weather Was Not Conducive to Mechanical Recovery
  - 20+ mph winds and 3+ft waves on-shore
- Encounter Rate Low – Big Plume
- No Night Skimming
DWH: Rising Plume Effect

- Rise = 1 mile from Well to GOM Surface
- Plume on Surface = 100 mi long
- Swath Width per Skimmer = 200-500 ft
- Multiple Boats – 1750 ft
In Situ Burning

- Lots of R&D Since Exxon Valdez in 1989
- Protocol/Standards
  - Fire Retardant Boom
  - Ignition
  - Oil thickness
Dispersants

- Not Used in U.S. much
  - Dilution not typical solution to pollution
- Waves Mix Dispersant with Oil
- Dispersant Breaks Up Oil Plume into Tiny Oil Droplets
- Tiny Droplets Stay Suspended in Water
  - Oil Biodegradation

Note: The polar end of the surfactant molecule attaches to water, the non-polar end attaches to the ink particle. An emulsion is formed of the two components.
Dispersant Use

- 2.1 Million Gallons Corexit 9500
  - 2\textsuperscript{nd} largest use ever
- Used on Surface
  (Sprayed from Boats & Airplanes)
- Injected into Plume as Leaves Well
  - Subsurface injection never done before
Dispersant Use

- Spill So Big and Prolonged
  - “New” spill every day for 87 days
- Sensitive Nearshore and Salt Marshes
  - Reproductive season
  - Winds & waves blowing oil on-shore
  - Mechanical recovery & burning & boom protection could no work in these conditions
- Trade-off Dispersants: Lesser of Two Evils vs. Oiling on Shore and in Coastal Shallows
Dispersant Use

• Issue of Dispersants into Water
  • Toxicity of dispersant
  • Toxicity of dispersed oil
  • Unknown deepwater ecosystem
Estimates of Fate of Oil

- Direct Recovery from Well Head = 17%
- Natural Dispersion = 13%
- Evaporation and Dissolution = 23%
- Response Strategies = 24%
  - Burning = 5%
  - Skimming = 3%
  - Chemical Dispersion = 16%
- Other = 23% (e.g., tarballs, sediments)

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- Ultimate Fate of Dispersed, Evaporated, Dissolved and Other: (e.g., Biodegradation, Burial, Photo-oxidation, Uptake by Biota) Is Unknown
Engineering Innovations During DWH Spill Response
DWH: State-of-the-Art Monitoring Oil

- Detection of Subsurface Oil
  - Measuring for leaks and natural seeps
  - Holographic detectors from biological oceanography
- Measuring Oil Flow from Well
  - 4 methods used to get flow
- Tracking Subsurface Plume Chemistry

UNH Center for Coastal and Ocean Mapping
DWH: State-of-the-Art Managing Spill Response

- Common Operating Picture
  - All responders see same, detailed information
  - Overlay layers of information to help make decisions
    - Where beaches located?
    - Where floating oil?
    - Decide boom placement to protect beaches at risk
DWH: State-of-the-Art
Managing Spill Response

- Environmental Response Management Application
  - ERMA® - UNH/NOAA trademark
  - Developed by UNH Research Computing Center
  - Partnership with NOAA
  - www.geoplatform.gov

Has Hundreds of Layers of Data to Overlay
www.geoplatform.gov/gulfresponse
DWH: State-of-the-Art

- **UNH Hubbard Center for Genomics Study**
  - Examine Who’s There Before and After Using Sophisticated Methods with DNA/RNA
  - Using frozen samples of GOM sediment for baseline

- **Chronic Impacts by Looking at DNA/RNA in GOM Organisms**
  - What oil caused it?
    - DWH or Natural Seeps or Other Spills
    - 2000-2009: 91,000 oil spills in LA

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Marine Well Containment Company

- Industry’s $1B R&D company
  - Created July 2010
  - ExxonMobil, Chevron, BP, Conoco-Phillips, Royal Dutch Shell

- Interim subsurface cap stack
  - Shut in oil flow
  - Attach flexible pipes and risers to divert oil flow to surface vessels
Interim Containment System
Some Issues in DWH
The Imbroglio

Explosion of Science and Engineering Complexity

Public’s Limited Scientific and Engineering Literacy

Politics Local, State, Federal

24/7 Information Can we believe it?
imbroglio \im-BROHL-yoh\, noun:

1. A complicated and embarrassing state of things.
2. A confused or complicated disagreement or misunderstanding.
3. An intricate, complicated plot, as of a drama or work of fiction.
4. A confused mass; a tangle.
The Imbroglio

- Explosion of Science and Engineering Complexity
- Public’s Limited Scientific and Engineering Literacy
- Politics Local, State, Federal
- 24/7 Information Can we believe it?
Scientific / Engineering Complexity

• Oil Spill Scientists/Engineers
  • Very small & underfunded community
  • Insular

• Oceanographers & Ocean Engineers
  • Little knowledge of response issues or oil properties
  • Safety and response protocols at spill site

• Misunderstandings Resulted Between Two Groups
Scientific Literacy

• Complex Response & Science Concepts to Convey
• Literacy Issue for Public, Government Officials and Reporters
• Responders and Scientists Are Not Always Best Teachers
24/7 Information
(Is it True?)

- Experts Everywhere
- “Lure” of being rock star
  - Report data before fully analyzed
- Scientists/Engineers are not always best communicators
- What Gets Reported?
  - What will reporter report?
- Is What Reported True?
  - When bloggers become experts
Scientific Peer Review
vs.
24/7 Information

• Scientific Peer Review Takes Months
• Data Reported in Journals Today Is Months Old
  • Public Thinks It Is Today
    • August journal articles report June’s data
  • Data can seem contradictory when it is not
    • Camilli et al. vs. Hazen et al.
    • Both in Science August 2010
A Model Misunderstood

http://www.youtube.com/watch?v=pE-1G_476nA
Politics and Response
A Bad Combination!

- Survey of GOM Coastal Residents
  - Public does not trust government or industry
  - Public trusts scientists (especially those who report data that supports THEIR world view)
- UNH Casey Institute
- Hurricanes Katrina/Rita Aftermath
  - Skepticism and discontent
- Politicians Exploit the DWH Situation
  - Louisiana berm boondoggle
Will DWH Really Change Anything?

- Deepwater Drilling Will Occur
  - Brazil, West Africa
  - U.S.???
- Arctic Drilling Will Occur
  - Norway, Canada, Russia
  - U.S. (Alaska)
Will DWH Really Change Anything?

Short Term

• Federal Legislation
• Improved Command Structure
• More Drills and Exercises
• Industry Liability Increased
• Better On Site Capping and Prevention Equipment
Will DWH Really Change Anything?

- Next Spill Will Be Different
  - Reaction vs. foresight
- “Flash in the Pan” Effect

\[ R&D\ Funding\ vs.\ Time \]

\[ s_t = s_o e^{-kt} \]
Coastal Response Research Center (CRRC)

• NOAA’s Office of Response and Restoration (ORR)/UNH spill partnership since 2004
• Funding for oil spill research decreasing
  • Government
  • Private sector
• Many research needs exist regarding spill response, recovery and restoration
CRRC Mission

• Conduct and Oversee **Basic and Applied** Research and Outreach on Spill Response and Restoration

• Transform Research **Results into Practice**

• Serve as **Hub for Oil Spill R&D**

• **Educate/Train Students** Who will Pursue Careers in Spill Response and Restoration