APPENDIX A
BREAKOUT SESSION PRODUCTS

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I. DRILLING SAFELY

OVERVIEW

The purpose of the Drilling Safely breakout session was to address research needs in the area of drilling through hydrate zones in order to access conventional hydrocarbons. The group's composition was well balanced by industry, government, and university representatives. During brainstorming, many new ideas were generated, out of the box thinking occurred, and group consensus was reached. For additional clarity of the results, several events of the session discussed in addition to the product storyboards. Occasionally questions were raised about the current status of a brainstormed idea. For example, a participant may reference his/her knowledge that some other group (not present in the session) is working on a barrier. The group decided to assume that the issue still needed to be addressed. Only when a participant himself/herself was directly involved in such work was the information considered valid.

In every portion of the breakout session one idea continued to surface – lack of data regarding hydrates and drilling through hydrates. Participants felt it was difficult to generate a complete list of barriers and opportunities. They stated that more problems and opportunities will inevitably present themselves once more research is conducted. Even when more data is obtained, no standard protocol exists for information dissemination among the workers within the organization (engineers to rig operators) or between organizations (government to industry). The group demonstrated the importance of this crosscutting issue by including a significant number of data gathering activities in the action plans.

Often when ideas were stated, a short group discussion would occur. This became very beneficial for the group members. Various representatives would recap current information from their group's perspective. This was done to keep all session participants "on the same page." Occasionally government was not aware that industry had already accomplished some task or encountered an issue and vice versa. This enabled the brainstorming to be more effective than if the group had been homogeneous.

BARRIERS

During barrier brainstorming, the participants determined that three categories of barriers existed in relation to drilling safely through hydrates:

- Well planning;
- Well execution; and
- Lack of data.

Several of the barriers were strongly supported by the group including the following:

- Lack of data about hydrates;
- Lack of data about drilling through hydrates;
- Hydrate reformation;

- Cementing and casing; and
- Well bore stability.

Traditional drilling problems compounded by the uncertainty of drilling through hydrates also were noted such as emergency disconnections, kicks and blowouts, and lack of reaction time. The group continued to stress the barriers resulting from the lack of data available. Geophysical, petrophysical, thermodynamic, geochemical, and geomechanical information needs were expressed.

OPPORTUNITIES

Participants presented a wide range of opportunities to overcome the barriers related to drilling safely through hydrates. The group organized them into the following categories:

- Fluids;
- Training and documentation;
- Stability technology;
- Field laboratory;
- Modeling;
- Real-time diagnostics;
- Predictive relationship;
- Database; and
- Other.

Four of the opportunities were selected by popular vote to be used as a basis for action plans. These top vote-getters were as follows:

- Hydrate well bore stability model;
- Hydrate drilling manual;
- Diagnostics while drilling; and
- Materials development.

Some of the other vote-receiving opportunities included improved/alternative drilling fluids, coupled drilling and reservoir modeling, and geo/petrophysical well and seismic database formation. Again, many of the opportunities related to increasing the quantity of information related to drilling safely through hydrates.

ACTION PLANS

The top four vote-receiving opportunities became the basis for detailed action plans. For each of the opportunities, the group brainstormed about the activities and products necessary to accomplish the objectives and the time frame for completion. The resources needed were indicated as well as resources currently available that could be used to accomplish the goals. Resources were not limited, and participants were encouraged to consider in-kind resources such as use of university laboratories, industry data, and rig time. The action plan included who would be involved in the actions, if collaborations between groups were possible, and whether the plan could be the basis for a JIP.

A great deal of data gathering appeared in all of the action plans. Three of the four plans involved a feasibility study first and foremost. Since the goal of the workshop focused on the upcoming two to three years, all action plans were slated for varying levels of completion in less than four years. Three of the four action plans were also deemed suitable for a JIP.

One of the action plans involved developing hydrate drilling guidelines. It was noted that a document similar in purpose currently exists, entitled *Deep Water Well Control Guidelines*. Both industry and government agreed that it would be beneficial to share information about successes, failures, lessons learned, and key contacts regarding drilling through hydrates. This could reduce multiple, identical failures by different organizations. Such a living document could be used by all interested parties to streamline their efforts and learn from one another to accomplish their goals. The remaining action plans are found in the Drilling Safely storyboards.

DRILLING SAFELY

PARTICIPANTS

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Drilling Safely: What Are the Barriers to Achieving the Goals?

WELL PLANNING	WELL EXECUTION	LACK OF DATA

• Depth challenged with slime hole
• Geomechanical behavior of hydrates
• Prediction and detection
• Lack of understanding relationship between gas hydrates and shallow water flows
• Public perception – lack of understanding has created lost opportunities
• High drilling cost
	• Hydrate reformation plugs
	• Drilling through in situ hydrates
	• Unstable well bore
	• Emergency disconnection
	• Kicks and blowouts
	• Open-hole vs. riser/BOP well control
	• Cementing casing
	• Maintaining well stability
	• Lack of reaction time
	• High drilling cost
		• LWD shallow
		• PWD shallow
		• Geophysical data
		• Petrophysical data
		• Geochemical and thermodynamic data
		• Pre-drill
		• Lack of
		  - Training
		  - Communication
		  - Sharing

Drilling Safely: What Are the R&D Opportunities to Overcoming the Barriers?

FLUIDS	TRAINING AND DOCUMENTATION	STABILITY TECHNOLOGY	FIELD LAB	MODELING	REAL-TIME DIAGNOSTICS	PREDICTIVE RELATIONSHIPS	DATABASE	OTHER
• Water base drilling fluids with adequate hydrate suppression vs. synthetic drill base **k k** • Temperature insensitive drilling fluid • Non-reactive drilling fluid chemical and thermal **k k**	• Planning/placing horizontal well bore In hydrate zone • Determine importance of hydrate properties to safety **k k** • Training sessions for drilling engineers **k** • Hydrate drilling manual **k k k k k k k k** • List drilling hazards	• Materials development - Drilling fluids - Cement - Casing **k k k k k k k k** • (Long term) insulating well bore through hydrate zone • Stabilizing techniques for well bore **k k**	• On site core analysis facility • Laboratory field study under controlled conditions over hydrate zone **k k** • Economic shallow sampling and coring • Hydrate core collection (maintain at res. Conditions) **k** • Fully instrument a demo well, drilling through hydrates with potential production **k k k k** • Dedicated shallow holes (cooperative observa-tories)	• Understanding of casing failure associated with hydrate • Coupled drilling and reservoir modeling **k k k** • Well control model **k k** • Pre-drill modeling and analysis **k** • Hydrate well bore stability model **k k k k k k k k k k** • Hydrate formation strength prediction • Well head and casing design models for hydrate drilling/production **k** • Prediction of long term reliability of well integrity; • Wider range in matrix models for hydrates • Relate drilling parameters to degradation of hydrates **k k**	• Downhole microprocess-ing and analysis • High speed/ real time shallow "IWD" system – large hole • Look ahead of bit capabilities **k** • Diagnostics while drilling **k k k k k k k k** • Downhole and floor sensor development **k k k** • Monitoring using multi-component seismic **k** • Real time detection • Real time monitoring "electronic oil field" **k**	• Calibration of geophysical data. Industry has data. **k k k** • Lab studies of hydrate/ sediment geomechanical behavior **k**	• Data bank of geophysical and petrophysical well and seismic data **k k k k** • Database of hydrates occurrence **k** • Determination of fault seal integrity/ activity	• Slim hole drilling **k** • Downhole methane conversion • Rapid annular shutoff for drilling – packoff above BHA

Drilling Safely: What Actions Can Be Taken During the Next 2-3 Years to Realize the Opportunities?

OPPORTUNITIES AND OBJECTIVES	ACTIVITIES/PRODUCTS	TIMEFRAME AND RESOURCES (IN KIND)	WHO IS INVOLVED? LEADERS? COLLABORATIONS? JIP CANDIDATE?
• Diagnostics while drilling	• Feasibility study • Hydrate disassociation sensor(s) • Hydrate formation sensor(s)	• 2 Years • Need: Location/conditions to test	• National laboratories • Government • Industry • University • JIP
• Hydrate drilling guidelines	• Document current practices • Coherent vision of living version • Failures • Forum-meetings • Study well control • Successes • Lessons learned • Key contact list • Determine who maintains (keeper)	• 2 Years • Deep water well control guidelines • Industry information-transfer	• Trade group (IADC, others) • Government (MMS, DOE) • Industry • International agencies
• Hydrate well bore stability model	• Feasibility study • Data platform • Validate model • Adequate data • Model gap remedies • Test model (actual well bore) • Hydrate well bore stability model	• 3 Years end point • Need: Test facility • Need: In situ samples • Need: Existing models • Need: Information transfer • Need: Labs	• Industry participants • Service Co. (Well bore modelers) • National labs/kinetics • JIP
• Materials development cementing - For drilling safely through not production	• Feasibility study • Production model of hydrate in situ • Lab test • Long term seal • Field guidelines/field test • Data gathering - Hydrate zone - Current and alternative cement - Deficiencies and desired properties	• 3-4 Years • Need: Cement lab(s) (pressure and low-temperature test cell)	• Industry • National Lab • MMS • JIP

II. SEAFLOOR STABILITY

INTRODUCTION

The discovery of large gas hydrate accumulations off of the Gulf of Mexico has led to heightened interest in gas hydrates as a possible energy resource in the future. However, significant geological uncertainties and technical issues must be resolved before gas hydrates can become a safe, affordable source of natural gas. This breakout session examined one such issue: seafloor stability, primarily movements of the seafloor resulting from hydrate dissociation.

Hazards arise from the fact that hydrates are only quasi-stable. The dissociation of gas hydrates can be slow or explosive, depending on the chemical content and concentrations of the hydrates, as well as how fast the pressure and temperature conditions around the hydrates change. Conventional drilling operations through hydrates can cause rapid pressure and temperature changes, leading to blowouts and/or destabilization of the seafloor which may result in massive landslides or sand flows. As exploration and production continues to progress into deeper waters in the Gulf of Mexico, hydrate associated seafloor stability issues must be confronted whether considering production of natural gas from hydrates or that of conventional hydrocarbons.

Identification of seafloor stability issues, as well as ways to overcome such issues was a primary focus of the participants in this facilitated session. Participants worked together utilizing structured brainstorming and critical analysis to identify 1) barriers and issues faced while trying to meet hydrate program goals, 2) R&D opportunities to help overcome these barriers and issues, and 3) an action plan which can be taken over the next 2-3 years to realize the R&D opportunities discussed.

IDENTIFICATION OF BARRIERS TO ACHIEVING THE PROGRAM GOALS

The barriers and issues which the group identified and discussed were both technical and non-technical in nature. These barriers were categorized into four categories which included Predictive Modeling, Management/Political Barriers, Lack of Data Sharing and Data Acquisition, and Characterization and Distribution. A common theme throughout the discussions centered on information, including methods to gather it, process it, use it, and to distribute and share it. In general, the group felt that a better understanding of hydrates is needed so that industry can work with and around hydrate deposits on the seafloor.

One group of barriers identified focused on the current inadequacies in modeling technology and/or lack of information used in the development of predictive models which can be used tp forecast when seafloor failures may occur. Models to predict instability events in an timely and accurate manner are needed so that stability issues can be overcome.

Another group of barriers focused on management and political issues. While not technical in nature, the group felt that such issues impede progress towards hydrate program goals. This category included regulatory barriers associated with governmental chemosynthetic regulations, funding issues, and a lack of focus by the oil industry on hydrates as a problem. Participants indicated that there is a resistance to new hydrate information at energy companies which may be a product of fears of additional regulations and expenses associated with hydrates.

Shortcomings with current characterization technologies also make it difficult to overcome seafloor stability issues. The group indicated that there is a significant need for improved techniques to gather information throughout the hydrate stability zone. A key point was the need for continuous samples through the entire hydrate stability zone. Without such information, the industry does not have sufficient data to understand how hydrates are distributed. Furthermore, they lack vital knowledge on the physical and chemical properties of hydrates, as well as knowledge on the characteristics and properties of the sediments where hydrates are located, and this poses a significant barrier toward understanding and predicting seafloor stability events

Improvements in modeling and characterization technologies would certainly help remove barriers to understanding and predicting seafloor stability issues. However, such information would be worthless if it was not available to all of those involved throughout the industry. The inability to acquire and share data on an industry-wide basis was identified as one of the most significant issues by this group. This stands to reason because companies need information on hydrates so that they can develop an understanding of the problems associated with them. The lack of a network to share the information that is gathered is a formidable barrier which stifles the ability to develop such an understanding. While there is a need for new information to be gathered, the participants felt that a significant amount of useful data exists, but there is no way for it to be shared across the industry.

RESEARCH AND DEVELOPMENT OPPORTUNITIES TO OVERCOMING THE BARRIERS

The participants identified a number of Research and Development opportunities which could be undertaken to overcome the barriers previously identified. These were categorized into five categories which included Characterization Data (Field), Characterization Data (Lab), Policy and Regulations, Modeling, and Data Management. Each participant was given the opportunity to vote on the top five R&D opportunities, resulting in a list of what this group felt was priority.

Numerous research and development opportunities for new or improved characterization technologies were discussed. The need to acquire continuous cores and downhole log data was the top priority of the group. Another top priority for field characterization data was the need for higher geophysical resolution systems to better characterize deposits. Laboratory methods to measure the properties of hydrates and hydrate containing sediments also received significant priority. Technologies are also needed to process with the data once it has been gathered. A number of opportunities were identified in the area of predictive modeling, including development of models which can combine the geophysical and geochemical data gathered so that instability events can be predicted and avoided.

Technology development opportunities in the area of information management and sharing continued to be a thrust with the group identifying the need for development a web site for worldwide gas hydrate information. This would facilitate the sharing of information so that models can be developed and areas of instability can be identified.

ACTION PLANS

Action Plan 1
An action plan was developed for the top five R&D opportunities which could be undertaken over the next 2-3 years, The need to acquire continuous, undisturbed cores through the entire hydrate stability zone was the top priority. A collaborative approach needs to be identified as the scope of this effort would be quite large. This could be accomplished by a multi-agency consortium made up of representatives from industry, government, and academia. This action plan could be carried out between 2002-2004 but would require resources such as drill rigs, ships, and experienced crews and laboratories.

Action Plan 2
The development of improved information management technology via a website for worldwide gas hydrate information would be carried out over a two phase effort. During the first phase, a metadata catalog could be created with federal and state agencies taking the lead. The existing hydrate.org website could serve as a platform for this effort. The second phase of action would include the framing of a solicitation so that the website could be developed not only as an information, but would also allow users to mine the data for their own use. This could be carried between 2002-2003 with a collaboration of state and federal agencies.

Action Plan 3
Technology development of higher resolution geophysical systems to better characterize deposits could be commence in 2001 through solicitation of competitive R&D from the industry, academia, and government. The solicitation should call for the development of "next generation" characterization technologies, as well as new techniques for higher resolution processing. The government could lead this effort with a solicitation for technology development.

Action Plan 4
Lab measurements of seismic/geotech/sediment/hydrate physical and chemical properties could be accomplished using an open solicitation. The initial step of this action would involve determining who is doing what and what information is available. Following this, development of new or improved technologies could be accomplished through competitive R&D. The data which would result from this effort would provide "ground truthing" and standards for the industry. This effort could commence as soon as 2001

Action Plan 5
The final opportunity, combining geophysics and geochemistry model results would involve the formation of multi-disciplinary teams and would result in "ground truthing" and standards, as well as system synthesis by site. This could be accomplished with an open solicitation as soon as 2001.

SEAFLOOR STABILITY

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Seafloor Stability: What Are the Barriers to Achieving the Program Goals?

PREDICTIVE MODELING	MANAGEMENT/POLITICAL BARRIERS	LACK OF DATA SHARING AND DATA ACQUISITION	CHARACTERIZATION AND DISTRIBUTION
• On a regional basis, lack of knowledge of age and timing of S.F. failures (i.e., historic episodic, continuous) and the driving forces (e.g., gravity only, sea-level changes, tides, storms) • Myth of hydrate decomposition • Hydrate induced instability/failure modes poorly understood • Inability to predict instability events accurately/timely • Lack of a predictive model for top of hydrate zone • Lack of accurate model of regional behavior, e.g., permeability, ground truth • Models relating rate of dissociation of hydrates to sediment failure mechanisms do not exist • Predictive models are needed—Do standard geotechnical approaches work?	• Be sure to not focus to drilling platform size issues only • Lack of coordination of activities nationwide • Governmental • Chemosynthetic • Protectionist • Regulations • Oil industry not focused on hydrates as an engineering problem area • Barriers - Resistance to new information at energy companies - "Tucking data" • Level of funding (too low) • Cost impact of ignoring hydrate stability not well known (field development) • Funding levels for this very costly (deep water) environment • Industry resistance on identifying another ecological/environmental/safety hazard • A definition of what aspects of "seafloor stability" we (the group) want to include	• Barrier—need deep coring ODP? • Need data on GOM temperature variations—water and sediment • Techniques to "fuse" independent data to improve understanding of sediment—hydrate relationships not well developed • Field data acquisition "long term" (no facility to gather) • Barrier: Lack of collaborative database to share information, process, who maintains costs, incentive to share information, common formatting • Data availability standardization fusion • Problems with data availability standardization figure • Lack of organized GH data/information worldwide • Need access to shallow interval of commercial seismic • Barrier: No geothermal gradients across the Gulf • Lack of sea-floor monitoring devices (e.g., tiltmeter, compliance, etc.) to test the stability of the S.F. for the continental slope	• Resolution of imagery for "deep water" scenario is not available for rapid surveys • Barriers: - Lack of continuous core samples through the entire hydrate stability zone, to evaluate physical properties, geochemistry and other parameters need to assess S.E. stability - Lack of downhole log data through the entire hydrate stability zone, to assess subsurface conditions • Do not have enough data to know how the hydrate is distributed in sediment? i.e., are they dispersed? Localized in fractures/faults? Both? • Barriers: Need more knowledge - Physical properties of hydrates - Physical properties of hydrate-sediment mix in various stages of dissociation • Obtain/preservation of natural G.H. (ephemeral nature of G.H.). Difficult to obtain samples • Barriers: Need knowledge of pore pressures in sediment during dissociation of hydrates, both by in situ measurements and numerically • Barrier: Lack of knowledge of gas hydrate geochemistry, i.e., accum-decomp. • Need detection techniques for low concentration of hydrates in seabed sediment • Need to embrace the hydrocarbon system as a whole to fully understand gas hydrates and seafloor stability • Hydrate resource characterization poorly understood • Limited knowledge of hydrated sediment strength • Relationship of "observables" to hydrate distribution and concentration not developed

Seafloor Stability: What Are the R&D Opportunities to Overcoming the Barriers?

Characterization Data (Field)		Characterization (Lab)	Policy and Regulations	Modeling	Data Management
• Charter a drill ship to acquire continuous cores and down hole logs through the hydrate stability zone (i.e., the upper 0-700 M below the seafloor) k k k k k k k k k • Establish permanent deep water lab facility in Gulf of Mexico k k k k • Cooperatively fund ODP/NSF/ DOE offshore GOM data acquisition k k k • Need for multi-sensor equipped AUV's to facilitate task of data acquisition and extend radius of monitoring station k k • Data acquisition (R&D) and develop low(er) cost method or in situ determination or properties (penetrometers, coring) not seas and method k • Develop/lease pressurized/ temperature coring system that allows quick access to samples k • Regional shallow seismic synthesis to locate slumps and slides k • Get in situ cone penetrometer tests to characterize area around GH mounds	• Need for multisensor monitoring station in the deep GOM to enable long-term comprehensive investigations of the hydrocarbon system and seafloor station k k k • Higher resolution geophysical systems to better characterize deposits k k k k k k k k • Not knowing the influence of warm eddy (if any) currents on hydrate dissociation k k k • Detailed molecular and isotopic analysis of gas hydrate and free gas to understand processes k k • Co-located, independent measure of properties in HSZ (geophysics and geochemistry) k • Combine existing bathymetry and Acoustic Data Sets (e.g., MCS, HRS, Side seam, etc.) to develop 3-D "images" of sea-floor stability in areas of likely recently (active failures) and make hazard maps for hydrate-prone areas k • Not knowing safety limits over hydrate zones for seafloor structures/activities • Make field measurements – get core (pressurized)	• Laboratory measurement of seismic/geotech-properties. Lab measure of sediment/hydrate physical and chemical properties k k k k k k k k	• Provide industry incentives to address management/political issues k k k k k • Review of regulations that unnecessarily restrict research and exploration/production • Indoctrination create hydrate awareness in energy companies	• Combining geophysics and geochemistry model results k k k k k k k k • Develop and ???? model??? of gas migration – predict top of hydrates k k k • Numerical simulations of sediment – hydrate processes (prediction) k k	• Create web site for worldwide gas hydrate information k k k k k k k k • Identify offshore areas worldwide with known or suspected hydrate related instability problems k k k k k • Document all known chemo. Sites, worldwide data base/web page k • Data/knowledge management oriented project to focus on data sharing and information k • Hydrates hazards documentation (historic) • Gather existing data together. Develop data base to archive data. Process to gather new data for data base. • Consortia for seafloor stability characterization (university/government led group) • Develop and maintain a seabed core database • Data base – R&D) develop "offshore online" data base on hydrates • Establish guidelines for avoiding duplication of research efforts, i.e., develop national cooperative consortium for recommending guidelines

Seafloor Stability: What Actions Can Be Taken Over the Next 2-3 Years to Realize the Opportunities?

OPPORTUNITIES AND OBJECTIVES	ACTIVITIES/PRODUCTS (DELIVERABLES)	WHO DOES/LEADS AND COLLABORATIONS?	SCHEDULE AND RESOURCES
• To acquire continuous undisturbed cores and down hole log data through the hydrate stability zone	• Identify collaborative approach so that core data can be acquired	• Multi-agency consortium (industry and government agencies, academia)	• 2002-2004 rigs, ship, crews and labs (experienced)
• Create website for worldwide gas hydrates information	• Phase I: Create metadata catalog • Phase II - Frame a solicitation - Allow data mining through website	• Phase I: Federal and state agencies • Universities • Phase II: Solicitation	• Phase I: Immediate (hydrate org.) • DOE existing funding • Phase II – open solicitation • O2-O3 multiple state and federal agencies
• Higher resolution geophysical systems to better characterize deposits	• Frame a solicitation - Develop next generation characterization (geophysical - Develop new techniques for higher resolution processing	• Industry, academia, government • Government leads with solicitation (competitive)	• 2001 DOE and/or multi-agency solicitation
• Lab measurements of seismic/geotech/sediment/hydrate physical and chemical properties	• Identify who is doing what. What information is available • Product – data, ground truthing and standards	• Open solicitation	• Same as #3
• Combining geophysics and geochemistry model results	• Form multi-disciplinary teams • Ground truthing, standards • System synthesis by site	• Open solicitation	• Same as #3

III. RESOURCE CHARACTERIZATION – GROUP A

BARRIERS AND ISSUES

Lively feedback from the group was easily categorized under three topic headings: data, methodology, and modeling integration. The group then reassessed its output and added another topic, program management. Although there was no voting prioritization, one can summarize the issues as one of data compilation, assessment, and sharing among competing and governmental entities.

OPPORTUNITIES

The R&D opportunities used the same topic headers from barriers and issues. Building models and identifying sites for focus were the top two vote getters, and both were under the modeling integration topic. The model building should include geologic, geophysical and reservoir aspects. The next two highest vote getters were under the data topic for a data workshop and gathering gas hydrate kinetics and thermodynamic in porous media. All of these opportunities were carried over to the action analysis. However, the order was changed between the data workshop and identifying sites because of the natural progression. Another top vote getter, new borehole sensor requirements, was not analyzed because it is more long term in nature, whereas a more short term 2 to 3 year period was emphasized.

ACTIONS

The group produced chronological lists of activities for each action, along with credible resource requirements and timing schedules. Model building begins with an inventory, followed by specification on next generation models, and lastly the model building. A data workshop needs to occur as soon as possible with Chevron in the lead and data serving as in-kind contributions. Government would serve as a clearinghouse for information. This workshop will set the stage for the identification of sites for focus given properly formulated criteria. The inclusion of environmental collaboration was emphasized for geopolitical reasons. Gas hydrate kinetics and thermodynamic opportunities have a longer time scope and the most resource requirements.

The group ended the session by redefining the goals of the GOM hydrates program in order to emphasize the need for long-term congressional backing. The program goal is to ensure drilling and production safety in and around hydrates with the following three bullets: understand hydrate impacts on seafloor sediments and processes; determine location, characteristics, and volumes of naturally occurring gas hydrates; and develop exploration and production technology to proof of concept.

RESOURCE CHARACTERIZATION – GROUP A

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Resource Characterization - A: What Are Issues for Resource Characterization?

DATA	METHODOLOGY	PROGRAM MANAGEMENT	MODELING INTEGRATION
• We need a single data base • How much data out there? • Lack of data collection/sharing from industry drilling • Linkages between models, lab and field results • Need subsurface data (logs, cores) to validate models • Joint license for shared use of seismic data by consortium – intellectual property • Publicly available data sets for analysis (benchmark data set) • Basin analysis • Platforms cost • Identify field (in situ) "benchmark" natural laboratories of gas hydrate • Kinetic measurement in lab, in situ • Understanding hydrates in the diverse settings in which they occur • Identification and significance of hydrate type I, II, H, CO_2, biogenic, thermal • Lessons learned from others	• Development of methodology evaluation • Core analysis - Geochemistry - Physical properties • Well Logs • What can we learn from mining? Analogy to ore deposits • Other geophysical - EM - Compliance - Ocean bottom seismonitor (OBS) - Ocean bottom cable (OBC) - Etc. • Determine thickness when lack of bottom simulating reflector (BSR)? • What are seismic indicators? • Seismic acquisition processing interpretation • What new sensors are needed? • Proven remote sensing technology discriminator (need)	• Industry involvement • Who should be coordinating all this research? • Public relations • Industry, Congressional relations • What is happening overseas? (Japan, India, Canada) • Invitation to ONGC, PEMEX, global partners • Role of industry and government in collaborative projects	• Hydrate formation conditions – prediction • Reservoir performance models (need) • Assessment technology – quantitative methodology (need) • Seismic inversion (quantitative methodology) • Determine data sensitivity (What data to get next?) • Genetic models for formation of gas hydrate - Methane saturation - Microbial processes - Thermal structure - Fluid fluxes - Host sediment • Express results in terms of risk and economics-level of confidence • Well control models for drilling • Fundamental physics/ chemistry for models and biology • Understanding vertical and horizontal extent of hydrate • Relationships between hydrates and fluid flow • Mode of hydrate occurrence in coarse vs. fine sediment • Kinetics of hydrate decomposition • Hydrates and continuous source of gas

Resource Characterization - A: What are R&D Opportunities for Resource Characterization?

DATA	MODELING INTEGRATION	METHODOLOGY	PROGRAM MANAGEMENT
• Turn www.hydrates.org into main data base **k** • Solicit oil and gas companies for data/involvement **k k** • Ensure availability of real data to modeling community **k k k** • Data workshop **k k k k k k k k** • Amass/assess public/proprietary data available in Gulf of Mexico (GIS, etc.) **k** • Temperature and pressure data **k k k k** • Develop world-wide data base of hydrate occurrence and conditions **k k** • Hydrates as tool for conventional exploration **k** • Solicit seismic companies to release publicly available datasets for R&D • Evaluate whether existing drill logs are useful for hydrate detection/study? • Gas hydrate kinetics and thermodynamics in porous media **k k k k k k k k**	• Identify sites for focus **k k k k k k k k k k** • Identify specific conditions necessary for hydrate formation and presentation • Where? How? Why? • High resolution more complete models and high performance computing • Build models - Geologic - Geophysical - Reservoir **k k k k k k k k k k k** • Develop risk model - Confidence - Data needs - Sensitivity **k k k**	• Spec out new borehole sensor requirements **k k k k k k k** • Develop better core handling and transportation techniques • Define adequate settings for logging well drilling (LWD) tools for industry use • Develop optimum seismic data processing technique for detection and evaluation **k k** • New technology for seismic data collection, e.g., OBC **k k**	• Leverage/partner on known/planned field/lab efforts **k k k** • Central authority (interagency)

Resource Characterization - A: Action Plan for Resource Characterization

	OPPORTUNITY WITH DETAILS	ACTIVITIES, PRODUCTS, DELIVERABLES	SCHEDULE AND RESOURCES IN-KIND	WHO LEADER COLLABORATE
Action #1	• Build Models - Geologic - Geophysical - Reservoir	• Inventory existing models for geologic and geophysical - include biogeochem - reservoir already done • Assess and spec out next generation • Build models	• 6 month review, 1 person year • 2-3 years. 10 person years • 2 years, 20 person years	• Users of models, consulting firm or academia • Consortia • Consortia
Action #2	• Data workshop - Existing and to be acquired - Get new data	• Organizing committee • Solicit interest • Hold workshop • Data and protocols • Working group	• ASAP • 6 months, Data are in-kind • <1 Year • Continuous, 2 person years/Yr	• Industry, Chevron • Industry • Industry • Government/Service • Consortia
Action #3	• Identify sites for focus	• Develop criteria • Inventory sites • Assess and select	• Now through workshop, TBD • During and after workshop - iterative • After workshop	• Consortia/users/environmental • Consortia/users/environmental • Consortia/users/environmental
Action #4	• Gas hydrates kinetics and thermodynamics in porous media	• Literature search, inventory, global • Laboratory research • Field research	• 1 year, 2-3 person years • 3 years, 20-30 person years • 3 years, 20-30 person years and direct in-kind	• Academia • Consortia • Consortia

IV. RESOURCE CHARACTERIZATION – GROUP B

The group was asked to identify barriers and R&D opportunities associated with the following topic: look at the quantity, location and properties of methane hydrates in the Gulf of Mexico (GOM). This could include improved geophysical tools that increase the confidence in the presence and quantity of hydrates and help determine the mechanical properties of sediment for safety and facility design.

BARRIERS

The group identified three categories of barriers: technical/scientific, commercial, and cultural. Technical barriers pertain to the ability to understand and predict the behavior of a given geologic formation with respect to production of methane from hydrates. The barriers include: 1) the seismic (geophysical) signature of gas hydrate bearing sediment is unknown, 2) there do not exist technologies and methods for sampling hydrate-bearing sediment without altering the physical properties, and 3) the dissociation of methane from hydrate structures and the transport of methane through a hydrate-bearing formation is a poorly understood and (probably) complex process involving solid/fluid phases.

Commercial barriers pertain to the economic viability of a gas hydrates as a resource and include 1) many hydrate deposits are in deep water or polar regions where the cost of transport is high, 2) a change of state is required for methane recovery from hydrates – this is a complicated process that is not well understood and also current means of inducing the phase change (e.g., pumping hot fluids underground) are expensive, 3) recovery of hydrates from many formations is not economically viable because hydrates are diluted in a large volume of sediments – knowledge of both the porosity and percent of pore space filled with hydrates is essential for commercial assessment of a resource.

Hydrates are potentially a big pay-off / high risk opportunity, with the pay-off coming far off in the future. This is counterculture to today's oil and gas industry. A change in mindset will be needed before hydrate R&D will be pursued in the private sector at levels that are appropriate based on the size of the potential reward.

R&D OPPORTUNITIES

The group considered opportunities for gas hydrate reservoir characterization along the following R&D continuum: 1) origin and evolution, 2) detection, 3) characterization, 4) quantifying, 5) reservoir modeling, and 6) validation.

Specific R&D opportunities identified as high priority by the group include: testing multiple detection tools across known hydrate accumulations, developing methods for sampling and analyzing samples of hydrate-bearing formations, developing better seismic based methods for characterizing hydrate-bearing formations, and developing models of hydrate decomposition and flow within a reservoir. Also, the group recommended drilling production test wells to gain understanding and also establishing select sites for comprehensive hydrate R&D as needed validation activities.

ACTIONS

The group identified three top priority objectives from the list of R&D opportunities.

Optimal imaging of hydrates. This involves applying seismic technology to the task of detecting and characterizing hydrate reservoirs. The action was described as developing 3D/3C/AVO methodology or 'aiming seismic at the upper 100 meters of the ocean floor.' The Gulf of Mexico (GOM) has some characteristics that make it difficult to perform this work there – it has a very weak BSR and collecting core samples in the GOM is difficult. Two alternative research paths were suggested. One would be to find an analogous site that did not have the aforementioned difficulties, develop seismic methods at that location, and then apply what was learned in the GOM. The second approach proposed is to work in the GOM with advanced seismic technologies and try to overcome the difficulties. The group recommended these two approaches be pursued in parallel. A needed subsequent task after success with either approach is to go from seismic data to rock and hydrate properties.

Get empirical data for calibration, modeling, and resource assessment This entails gaining information about the physical and chemical properties of hydrate-bearing formations as they exist in their natural state. This data would then serve as the basis for calibrating detection and characterization instruments, modeling hydrate formations, and developing methods for assessing the commercial value of various resources. The problem is that in conventional drilling and core sampling, hydrate structures experience phase changes (i.e., they melt) during the sampling process and much information is lost. Again two alternative R&D pathways were tendered as a means of meeting this objective. First, one could develop advanced drilling, sampling, and transport techniques so that a sample of hydrate-bearing formations could be delivered to a laboratory in its natural state. Another approach would be to perform analysis on formations in-situ, and transfer the information back to the lab. The group members agreed that both approaches would be enhanced by actual drilling and sampling in the GOM.

Develop reservoir models for hydrate production Such models would focus on representing characteristics that are important for commercial recovery of the methane in the hydrates. These include hydrate decomposition in-situ and the resulting fluid/solid interaction, flow in porous media, and veins versus continuous sands. An important first step would be to assess what the Russians and the Japanese have already accomplished in this area. A meso-scale experimental facility is needed to develop the theoretical and modeling capability.

RESOURCE CHARACTERIZATION – GROUP B

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* = Presenter for report-out

Resource Characterization - B: Barriers

TECHNICAL SCIENTIFIC	COMMERCIAL	CULTURAL
• Detect and predict behavior • Geophysical (seismic) signature of g.h.-bearing sediment unknown • Inability to determine mass and flow balance of MH balance (e.g., core vs. logs) • Lack of undeveloped biochemical effects on hydrate form • How to locate and test hydrate reserve (for field development design) (Effective well testing methods?) (Aerial extent of reserve?) • Nature of data collection-not focused on hydrate zone - Drilling - Logging - Seismics - Scientific observation and sampling - Industry scientific • Need capability to evaluate hydrate concentration at +100M from borehole • Relationship: Hydrate, free gas, other liquid HCs • No novel new tool (funding) - Nonseismic • Mapping techniques - Interphysical state - Mapping beyond BSPI • Maintain integrity of samples during transport	• Pressure transient analysis/build up tests for hydrate reserve compared to gas reservoir? - Multiphase nature • New technology too expensive for R&D (3-D, OBC) • Economic viability as resource - Depth and distance shore/polar - Change of state during access - Percent of hydrate filled with gas - Percent of pore space with hydrate • What characteristics of hydrates or hydrate-formation matrices will be limiting to production, e.g., permeability, heat transfer?	• Focus on qualitative - Models data • Risk taking mentality - Hydrate pay-off in long term • No industry/government partnerships in CH_4 hydrates - Industry government R&D

Resource Characterization - B: Opportunities

ORIGIN AND EVOLUTION	DETECTION	CHARACTERIZATION	QUANTIFYING	RESERVOIR MODELING	VALIDATION
• Carbon dating for stability/age of deposit **k k** • Complement interagency multidisciplinary field-scale to lab-scale H.H. measurements • Gulf of Mexico of hydrates are thermogenic?	• Test multiple detection tools across known hydrate accumulation **k k k k k k k** • Develop optical technologies for high rez seafloor mapping **k** -	SAMPLING AND ANALYSIS • Continuous core through hydrate deposit with full log suite • Develop better sampling capabilities, i.e., CP with AUVs **k k k** • In situ thermal diffusivity, heat flux measurement technique **k** • Develop sampling, preservation, and testing systems for natural samples **k k k k k k k k k k** BETTER SEISMIC • Seismic 3D/3C/AVO methodology **k k k k k k k k k k k** - Aiming seis at upper 1000 M occur floor • Develop 3-C borehole seismic source for better in situ characterization - Wellbore seismic for lateral hydrate continuity **k k**	• Bioagent effects on formation kinetics surface adsorption, and gas capacity **k k** DEVELOP TEST METHODS FOR HYDRATE RESERVOIR - Flow testing - Build up/draw down - Composition/ phase behavior - Develop diag. Tools and standardized methods **k k k k k** • Determining phase-change related flow properties of gas hydrates through sediments **k k k** NOVEL TOOLS, e.g., - Micro earthquakes as a source - Ground-penetrating radar - Electro magnetics - Chemistry/ multi-tool suites **k k k**	• Reservoir modeling of hydrate resource - Hydrate decomposition "in situ" - Flow in porous - Veins vs. cont. sands **k k k k k k k k** • Method for rapid hydrate decomposition: High heat transfer rates **k** • Inferring system behavior from - Data (field experiment) - Modeling (scint. theory) • Link core exp to field-scale volume and flux rates	• Select sites for comprehensive research (including drilling) using broad scale survey techniques **k k k k k k k** • Drill production test wells (onshore and offshore) **k k k k k k**

Resource Characterization - B: Actions

DEVELOP SAMPLE PRESERVATION AND TESTING SYSTEM FOR NATURAL SAMPLES	SEISMIC 3D/3C/AVO METHODOLOGY, I.E., AIMING SEISMIC AT UPPER 1000 M OF OCEAN FLOOR	RESERVOIR MODELING OF HYDRATE RESOURCES HYDRATE DECOMP INS FLOW IN POROUS MEDIC VEINS/CONT. SANDS
Get empirical data for calibration, modeling and resource assessment • Drill and sample Gulf of Mexico hydrates – multiple sites • Bore hole measurement • Hydrate sampling • Large number of groups with expertise • 2001 Gulf of Mexico hydrate conference • 2002 Gulf Coast SEPM resource conference hydrate • Calibration	Optimal Imaging of Hydrates • Find a good analogue • Re-analyzing existing data over known hydra • Apply methods in Gulf of Mexico • Apply state of art seismic techniques in Gulf of Mexico • Go from seismic data to rock and hydrate properties	Develop reservoir models for production • Talk to the Russians and Japanese - Modify for deep sea • Support basic R&D • Develop meso scale experimental facility • Develop theoretical and modeling capability

V. PRODUCTION TECHNOLOGY

The foremost need in the area of production technology that will support the goals put forth for Gulf of Mexico (GOM) Hydrates R&D is the undertaking of field tests. Basic field data on hydrates do not exist. There are no proven theories on hydrate production or dissociation rates; nor are there any reliable data on what effect hydrate dissociation will have on the surrounding sub-sea terrain and on the natural gas that exists under the hydrate "cap." This problem is exacerbated by the perceived impact both from a safety and long-term environmental standpoint of a natural gas release caused by hydrate breakdown. In addition, financial considerations weigh heavily on hydrate issues: How quickly will there be a return on investment, and how well do hydrates compete economically with other potential natural gas reserves?

WHAT ARE THE BARRIERS TO ACHIEVING THE GOALS?

Barriers that currently stand in the way of production technology of GOM hydrates are technical, financial, and policy oriented. While production technology issues must be addressed by answering technical questions, public acceptance of hydrate utilization is necessary. This can only come about when people believe that hydrate "mining" is safe and ecologically benign. In addition, it is necessary to know when this type of technology is actually needed. Without a quick return, companies are unlikely to invest in hydrate production technologies.

All of this aside, however, there is a large technical database that must be built. Field data must be generated that provide physical properties information on hydrates, and that address decomposition issues. Reservoir dynamics must be addressed via models and model validation. Test sites must be identified, and effective means of getting increased production rates must be developed. Finally, geotechnical and mechanical issues involving sediment properties, sand control, and fracturing cannot be ignored. Thus, there is an overlap between production technology and other areas of concern such as drilling safely and sea-floor stability.

WHAT ARE THE R&D OPPORTUNITIES TO OVERCOME THE BARRIERS?

The most important R&D work that needs to be accomplished involves identifying test sites and collecting and analyzing samples both *in situ* and in the laboratory. The preservation of the core samples under temperature and pressure is an essential component of this process. This work can be complemented by the preparation and testing of synthetic samples in the laboratory. This will lead to an understanding of hydrate behavior. Accompanying this should be a development of reservoir models that include analyses of sediment rheology and hydrate kinetics.

In order to best overcome the barriers, new technologies must be developed. Among these should be methods that result in new hydrate dissociation techniques as well as novel methods to best transport natural gas to market. One method suggested involves transport via hydrate slurries. Moreover, these novel technologies will be developed most efficiently if the process includes critical literature reviews and technology transfers from industry both in the United States and in other countries.

The R&D work should be accompanied by economic models that ask the question, "where do we need to get?" This will enable the setting of economic targets. This can be partially leveraged by looking at synergies for co-producing hydrates and more conventional natural gas in the GOM.

ACTIONS

The methodology for implementing the more important R&D activities is discussed here in a series of action plans. They include field-testing activities such as production data acquisition and sample analysis, laboratory production and testing of samples that cannot be acquired in the field, and the development of reservoir models.

Production Data – Test Wells

In order to acquire production data, a test site must first be identified. This effort should be led by a Joint Industry Project (JIP), but will require some government funding. Once a site is identified (which could take up to a year) a shallow or mid-depth well should be drilled at the site. This 18-month project should be led by the operating company and should also involve service companies and the government. The service companies should supply logging and coring resources.

These two activities would likely use up the three-year time period allotted for the hydrate work. The necessary data acquisition including a production rate test, a field demonstration, and the dissemination of results would follow in the out years.

Collection and Analysis of Samples

After the test well is drilled (see above) it will be possible to begin the act of collecting and testing samples. In the meantime, however, existing sample gathering tools and testing methodologies can be identified under the lead of a JIP using the knowledge of the service companies, the United States Geological Survey (USGS) and academia. Tools and methodologies that do not currently exist must then be developed. In parallel, academia must review existing hydrate data.

After two years (that is, when the sampling site is ready) sample collection and analysis can commence. A "round" of collection and analysis will take about a year, but should be ongoing thereafter. The cost should be about $1 million/ year for collection and half that much for analysis, with service companies providing sampling tools, and laboratories providing testing equipment. The effort is led by a JIP.

Develop Representative Data and Relationships Describing Hydrate Behavior under Lab and Field Conditions

In parallel with the above activities is a project that allows for the development and testing of synthetic laboratory samples that cannot be obtained in the field. A JIP would lead the initial six-month to one-year effort in which synthetic sample criteria and the criteria and range for testing conditions will be established. The JIP would then issue a solicitation that will result in awards to laboratories to test samples. Testing can then commence on an ongoing basis at a cost of about $200-250 thousand per lab per year. The laboratories will provide the testing equipment. Results will be analyzed and compared to existing data as well as being compared laboratory to laboratory.

Reservoir Models Including Sediment Rheology and Non-Darcian Flow

A three-year project would proceed in parallel with the actions described above which will address reservoir models. This project, also a JIP, and involving government laboratories and academia, would involve reviewing existing models, adding hydrate information to these models, and then validating the models against laboratory data. Overall, this effort should take three years at a cost of $6 million per year. Crucial to the success of this project is the willingness of the participating laboratories to share the results of their modeling efforts.

PRODUCTION TECHNOLOGY

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Production Technology: What Are the Barriers to Achieving the Goals?

FACILITIES	POLICY INCLUDING ENVIRONMENT	FINANCIAL (BUSINESS) DECISION	BASIC/FIELD DATA GENERATION	RESERVOIR DYNAMICS	GEOTECHNICAL/ MECHANICAL ISSUES
• Intervention - Wellbore - Flowline/pipeline (i.e., maintenance) • Product containment • Flow assurance • Separation of gas from muck subsea level • Transport infrastructure	• Overcoming perceived environmental impact of uncontrolled release • Public acceptance: Demonstration that hydrates are safe and environmentally friendly • Ecological impact • Identify w hen technology needed • Deployment time for new technologies	• Immediate return on investment mentality • Low hydrate concentration per unit volume • Acceptance of new technology by project/asset mgrs • Economics. Other low cost sources available (e.g., stranded gas) • Identify target cost • Fear of unproven technology	• Lack of proven theory and rate data on hydrate dissociation • Insufficient/nonexistent field information - Properties - Quantitative relationships - Lack of accurate theory and phase behavior data – dynamics hysteresis phenomenon • Lack of data on hydrate fields • Production rate data • Lack of model validation • Lab production experiments and interpretation are needed • Effects of hydrate decomposition on 3-phase flow and physical properties are unknown	• Major chemical-physical limitation on production rate is unknown • Reservoir simulation to ascertain prod. rate by depletion involving heat flow • Rate of decomposition of hydrate reserve • Economics: - Reducing production cost - reducing drilling cost - Increasing production rate • Location and dynamics • Need reservoir/economic models to guide R&D and investment decisions • Effective method to get high production • Choice of methods of energy inputs to dissociate hydrates • Miing?	• Completion and stimulation - Cementing - Sand control - Stimulation, e.g., fracturing • Properties of the sediment - Unconsolidated sediments - Sediment formation integrity • Effective identification and completion/isolation of the reserve • Estimation of loss of competence of cap-room in case of hydrate melting and subsidience

Production Technology: What Are the R&D Opportunities to Overcome the Barriers?

SYSTEM MODELING AND ECONOMIC ANALYSIS	NEW/NOVEL TECHNOLOGIES	LAB DATA (SYNTHETIC SAMPLES)	FIELD DATA	RESERVOIR MODELS
• State-of-art economics to ID economic targets – where are we now? Where need to get? **k k k k k k** - Capital cost sensitivity analysis - Synergies for co-production with conventional oil and gas in Gulf of Mexico • Investigate strategies for CH_4 production from hydrate deposits **k k** • Develop $ urgency of need to develop Hydrate as gas source • "Exploration" or "sweet spot" detection technologies **k k k**	• Test new gas transportation technologies to move gas to market (hydrate slurry, etc.) **k k k k k k** • Well completions - Horizontal - Stimulation - Fracturing **k k k** • Novel hydrate disassociation techniques **k k k k k k** • In situ combustion • Seafloor/subsea gas compression and water separation **k** • Critical review and assessment of the state-of-the-art hydrate literature **k k k** • Technology transfer from Russia and industry files **k k k** • Reservoir integrity stabilization techniques **k** • Down hole steam generators • Improved insulation technology • Flow assurance models/ simulation **k**	• Perform and interpret lab. Production experiments **k** • Phase behavior data and description considering hysthresis effect • Perform and interpret 3-phase flow and physical-properties experiments • Develop representative data and relationships describing hydrate behavior under lab and field conditions **k k k k k k k**	• Production data test well(s) - Obtain test site - Production rate test - Perform field demonstrations collect field data - Gather and disseminate formation data measured in situ **k k k k k k k k k k k** • Collection and analysis of samples **k k k k k k k k k** - Measurement of mechanical and thermal properties of sediments - Collect and analyze cores (pressure and temperature preserved) - Harvest samples for lab tests and characterization - Petrophysical properties of hydrate-bearing formation	• Develop a hydrate kinetics model for dissociation **k k k k** • Reservoir models including sediment rheology and non-Darcian flow **k k k k k k k**

Production Technology: Actions

ACTIVITIES/PRODUCTS	SCHEDULE AND RESOURCES (INCLUDING "IN-KIND" RESOURCES)	WHO LEADS?/ WHO COLLABORATES
ACTION 1: PRODUCTION DATA – TEST WELL(S)		
• Obtain test site	• Start immediately, complete in 6 months to 1 year • Site may be given to program for administrative $ • Project management $500 K, site acquisition and planning	• JIP lead and collab
• Drill a Test well (shallow or mid-depth)	• 12-18 months following ID • Minerals Management Service (MMS) buy-in needed • $6 million (from JIP and government) • Logging and coring resources from service indl. St.	• Lead – operating company • Collab – service co., government
• Create (drill or modify) test production well	• TBD probably 3+ years	• TBD probably 3+ years
• Production rate test	• TBD probably 3+ years	• TBD probably 3+ years
• Perform field demo/collect field data	• TBD probably 3+ years	• TBD probably 3+ years
• Gather and disseminate formation data measured in situ	• TBD probably 3+ years	• TBD probably 3+ years

ACTIVITIES/PRODUCTS	SCHEDULE AND RESOURCES (INCLUDING "IN-KIND" RESOURCES)	WHO LEADS?/ WHO COLLABORATES
ACTION 2: COLLECTION AND ANALYSIS OF SAMPLES		
• I.D. tools and analytical procedures needed	• 3-6 months • $100 K • Knowledge of service co., academia and U.S.G.S.	• Lead: JIP • Collab: Service Co., academic, USGS and other countries
• Develop tools and analytical procedures that are not available	• 2-5 years • $1 M/Year • Knowledge and equip from service companies	• Lead: Service companies • Collab: JIP, DOE
• Review existing data	• 6-months – 1 year • $200 K	• Academia
• Collect samples	• First round of sample collection starts after 2 years takes 1 year (then ongoing collection) • $1 M/Year • Tool owners: Service cos., government agencies, providing tools	• Lead: JIP • Collab: Service cos., DOE, USGS, other countries
• Analyze samples	• First round follows sample collection • $500 K/Year (W.A.G.) • Lab equipment (national laboratories, USGS, academia, service cos.	• Lead; JIP • Collab: Service co., academic, USGS

ACTIVITIES/PRODUCTS	SCHEDULE AND RESOURCES (INCLUDING "IN-KIND" RESOURCES)	WHO LEADS?/ WHO COLLABORATES
ACTION 3: DEVELOP REPRESENTATIVE DATA AND RELATIONSHIPS DESCRIBING HYDRATE BEHAVIOR UNDER LAB AND FIELD CONDITIONS		
• Develop criteria for synthetic samples	• 6 months – 1 year • $200 K	• Lead: JIP • Collab: USGS Labs, academia, others
• Establish criteria and range of testing conditions	• 6 months – 1 year (parallel) • $200 K	• Lead: JIP • Collab: USGS labs, academia, others
• Select test sites	• 6 months • $50 K	• Solicitation with evaluation by JIP
• Test samples	• Start after 1 year, ongoing • $200 K per lab per year ($250 for national labs) • Lab provides lab equipment	• Lead: JIP • Collab: Labs, federal agencies
• Compare results within this project and to existing data	• Follows testing • $150 K/Year • In-kind funding, by lab to increase range of analysis	• Lead: JIP • Collab: Academia/labs

ACTIVITIES/PRODUCTS	SCHEDULE AND RESOURCES (INCLUDING "IN-KIND" RESOURCES)	WHO LEADS?/ WHO COLLABORATES
ACTION 4: RESERVOIR MODELS INCLUDING SEDIMENT RHEOLOGY AND NON-DARCIAN FLOW		
• Review existing models	• 3 Years • $2 M/Years • Industry sharing results of their models	• Lead: JIP • Collab: Government, laboratories, academia
• Add hydrate package to existing models	• 3 Years • $2 M/Years • Industry sharing results of their models	• Lead: JIP • Collab: Government, laboratories, academia
• Validate models by running against lab data	• 3 Years • $2 M/Years • Industry sharing results of their models	• Lead: JIP • Collab: Government, laboratories, academia