Circum-Arctic Resource Appraisal: Valuation Methodology*

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Abstract

The Circum-Arctic Resource Appraisal (CARA) has three major components: a resource map, a resource assessment, and a resource valuation. This presentation will review the USGS methodology for estimating a comparative economic measure of resource value for each Assessment Unit (AU) in the CARA Assessment. A companion presentation by Mahendra Verma (Circum-Arctic Resource Appraisal: Engineering Methodology) will review the USGS methodology for estimating the capital and operating costs (CAPX & OPX) for developing, producing, and transporting Arctic oil and gas to markets.

The goals for the CARA Valuation - objective, clear, unbiased, comparable, and probabilistic required that we develop a methodology for mathematically integrating the geology, engineering, and economics dimensions of the Arctic. Our approach has been to integrate the results of three mathematical models - assessment (Gautier), engineering (Verma), and statistical cost (White) - within a full-cycle simulation to provide probabilistic oil & gas resource cost curves for each AU. The AU results are aggregated to province and Circum-Arctic totals.

The Assessment Model provides the requisite probability distributions for numbers, sizes, and risks for potential oil and gas deposits in each AU. The Engineering Model provides the requisite estimates of CAPX and OPX for a selected set of hypothetical oil & gas fields. The Cost Model provides the requisite statistical cost functions for both oil & gas fields. The Simulation Model uses the results of the Assessment Model to generate a unique geologic state of nature (GSON) in each AU for each trial in the simulation. The GSON for a trial consists of a sampled portfolio of oil and gas deposits with specific volumes, flow rates, water depths, drilling depths, and distances to shore. Next, the Simulation Model uses the results of the Cost Model to generate an estimate of CAPX & OPX for each individual field in the GSON portfolio for the trial. Finally, the Simulation Model generates a pair of oil & gas resource cost curves for each AU. A resource cost curve displays the increasing aggregate volume of oil or gas available at increasing unit cost - a good comparative economic measure of resource value - and is a precursor to a supply curve.

An example for the Northeast Greenland Province is developed.

CARA: Appraisal Methodology

(Prototype: East Greenland Rift Basins)

June 10, 2009

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OVERVIEW

Volumetric Assessment

+

Cost Assessment

=

2-D Measure of Resource Value

USGS

Appraisal Objectives

1) Add an economic dimension to our volumetric assessment in estimating resource value.

2) Extend our probabilistic volume approach to additional uncertainties in resource value.

3) Provide a comparable & consistent measure of resource value across regions & governments.

USGS

Appraisal Philosophy

- **This is to a *first approximation* – in effect, an experiment in methodology.**
- **There are *no* assumptions regarding industry or government behavior.**
- **There are *no* forecasts, just a “screening” measure of *relative* economic value.**

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Appraisal Scope, Process, Scale

- **<u>Scope</u>: Oil & gas fields, capital & operating costs, onshore & offshore.**

- **<u>Process</u>: Exploration → development → production → transportation → market.**

- **<u>Scale</u>: Field → AU → Prov → Circum-Arctic.**

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Appraisal Assumptions 1

- Our measure of resource value is lifecycle capital + operating costs per unit volume.
- Financial, fiscal, acquisition, inflation, & risk costs are not included. No discounting.
- Current technology & highest offshore cost experience are used (IHS). Ice is ignored.

USGS

Appraisal Assumptions 2

- Modular field development is assumed.
- No uncertainty in the cost data.
- Some cost model uncertainty is included.

USGS

Appraisal Work Efforts

- Run an engineering cost model (Questor, IHS) on a designed sample of hypothetical fields.
- Develop a statistical cost model - using Questor results - to relate capex & opex to field params.
- Integrate the CARA assessment with the statistical cost model in a simulation model.

Engineering Cost Model (Questor, IHS)

- **Input: An experimental design of fields with volumes, well flow rates, drill depths. . .**

- **Process: A detailed field development & production plan is generated - with costs.**

- **Output: A sample of fields with designed sets of attributes - including capex & opex .**

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Statistical Cost Modeling

- Input: The Questor output - sample fields, their attributes, & required capex & opex.

- Process: Multivariate linear regressions are fit to relate costs to field attributes.

- Output: Statistical cost functions for capex and opex.

USGS

Appraisal Simulation Model

- **Input**: CARA assessment *inputs*, engineering parameters, and the statistical cost functions.
- **Process**: Simulate endowment, exploration, development, production & transport to market.
- **Output**: A probabilistic cost per unit volume, a cost-volume table, and a resource cost curve.

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GSON (Geologic State of Nature)

- **Input**: Distributions for COS, NFD, FSD, OVG, and water & drilling depths.
- **Process**: Monte Carlo simulation of a failed AU *or* a set of undiscovered fields each trial.
- **Output**: Portfolio of undiscovered fields, each with a unique volume, well flow rate. . .

USGS

AUFAIL (AU Failure Cost)

- Input: AU chance of success, well cost, and seismic cost.
- Process: Bayesian estimation of the number of wells needed to condemn an AU.
- Output: Expected cost of a failed AU.

USGS

EXP (Exploration)

- Input: Field portfolio, # of wells to discovery, well & seismic cost functions, failed AU cost.
- Process: Calculates the cost of discovering every field in the field portfolio.
- Output: Cost of finding all fields.

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DPT (Develop, Produce, Transport)

- **Input: Field portfolio, vols, flows, H_2O & drill depths, dist to shore, base transport dist.**

- **Process: Calculates capex & opex for fields with deliverable resource (flow > 1000 bpd).**

- **Output: Total DPT capex & opex for each produced field, Prov TX design volume.**

USGS

ITX (Incremental Transport)

- Input:, Incremental shipping and pipeline distances to market, Prov TX design vol.

- Process: Calculates capex & opex per bbl for incremental ships and pipelines.

- Output: Incremental TX capex & opex for adjusting base case TX costs.

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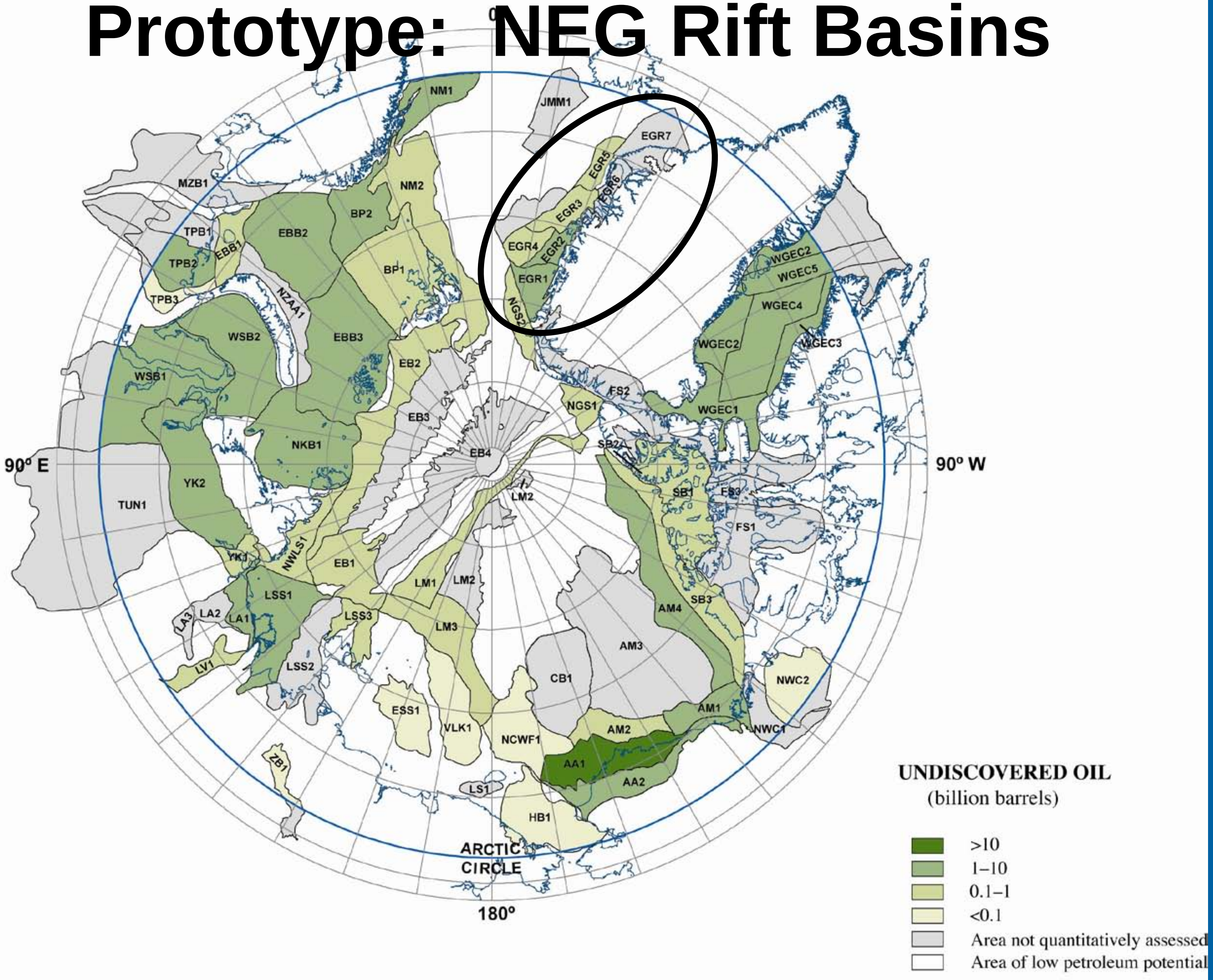
Prototype: NEG Rift Basins



CARA RESOURCE APPRAISAL REPORT: OIL

MODEL = CARA1, BASE CASE, AU RISK, PROD RISK, CORR, SEED = 1, TRIALS = 50,000

DELIVERABLE (RISKED) RESOURCE TABLE: OIL (BBO)

EAST GREENLAND RIFT BASINS (52000000)

$/BBL	MEAN	STDEV	95%	50%	5%
$15	0.0	0.0	0.0	0.0	0.0
$25	0.0	0.3	0.0	0.0	0.0
$50	2.3	3.7	0.0	0.0	9.9
$75	3.4	4.3	0.0	1.9	12.0
$100	3.9	4.5	0.0	2.5	12.9
$125	4.2	4.6	0.0	2.9	13.5
$150	4.5	4.7	0.0	3.2	13.9
$175	4.7	4.8	0.0	3.5	14.2
$200	4.8	4.8	0.0	3.6	14.3
$225	5.0	4.9	0.0	3.8	14.6
$250	5.1	4.9	0.0	3.9	14.7
$275	5.2	5.0	0.0	4.1	14.9
$300	5.3	5.0	0.0	4.1	15.1

SOME PROVINCE STATISTICS

VAR	MEAN	STDEV	95%	50%	5%
DELVOL	5.6	5.1	0.0	4.5	15.7
GEOVOL	8.9	7.4	0.0	7.5	23.0
MAXFLD	2.0	2.6	0.0	1.2	7.1
PROV DCOS	0.90	0.30	0.00	1.00	1.00
AVGD $/BBL	129	55	63	118	224

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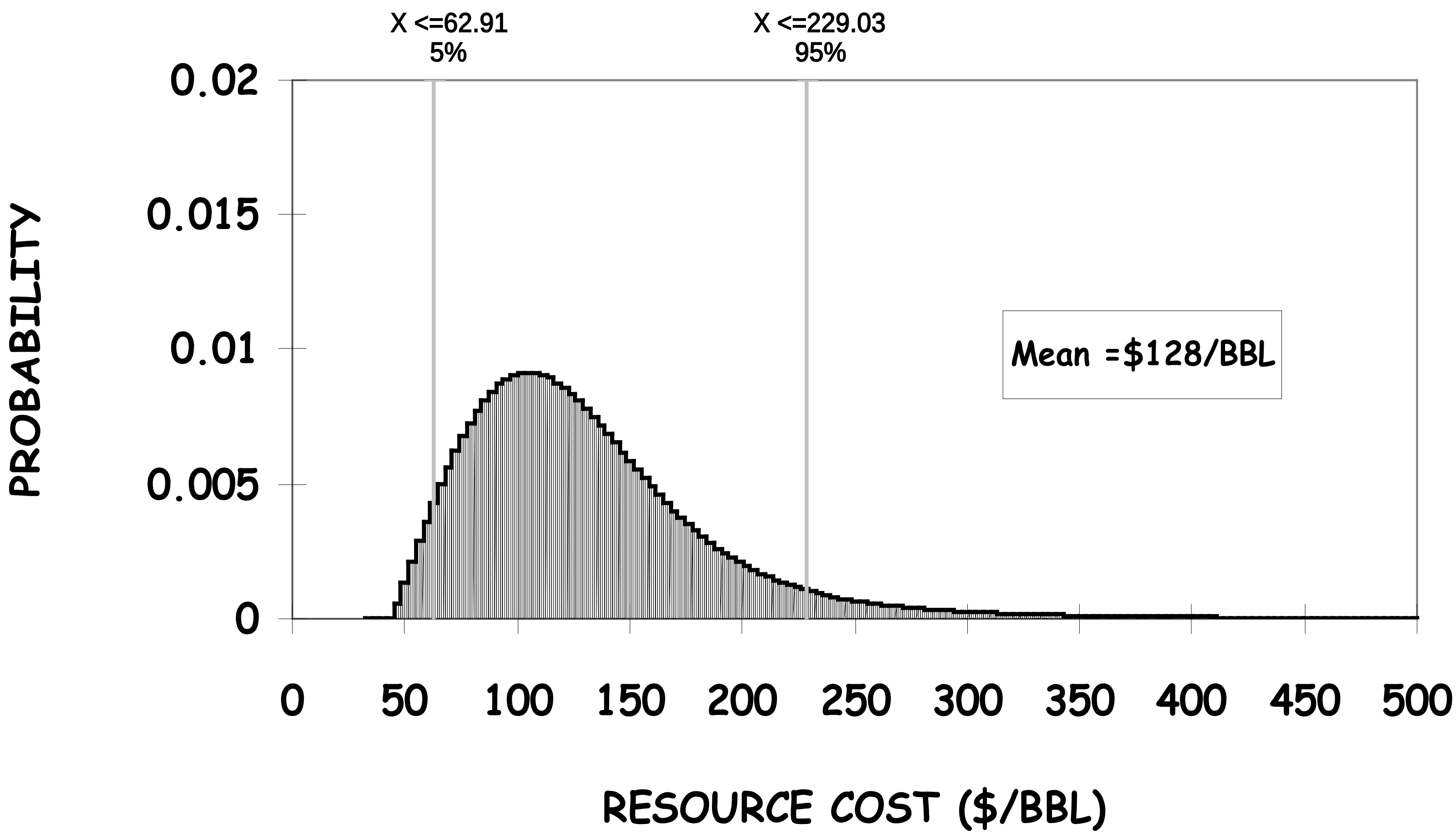
EAST GREENLAND RIFT BASINS



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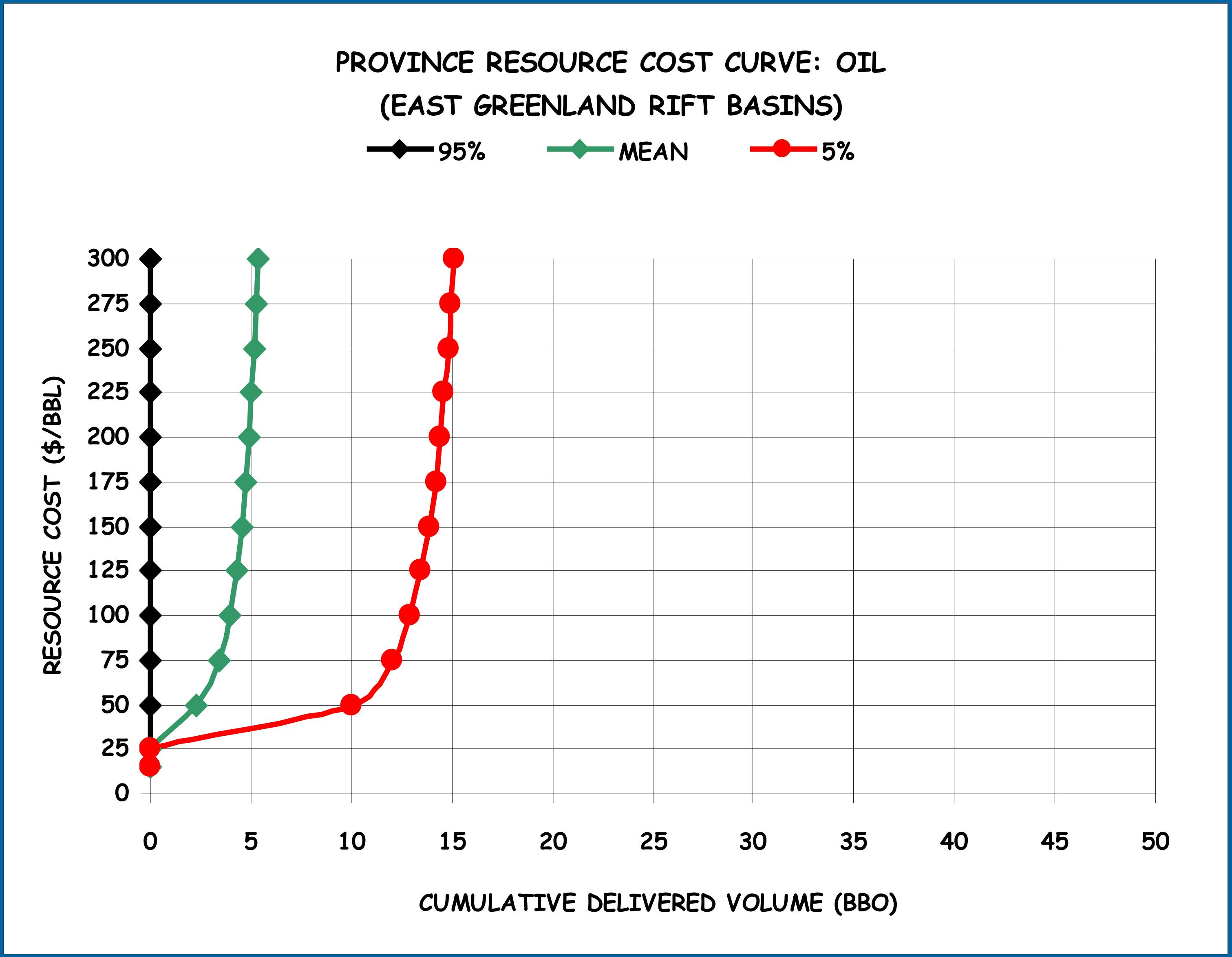
PROVINCE RESOURCE COST CURVE: OIL
(EAST GREENLAND RIFT BASINS)
95%
MEAN
5%
RESOURCE COST ($/BBL)
300
275
250
225
200
175
150
125
100
75
50
25
0
0
5
10
15
20
25
30
35
40
45
50
CUMULATIVE DELIVERED VOLUME (BBO)

USGS

Appraisal Next Steps

- Complete development of a transportation network for each Province.

- Model runs for the 25 Provinces.

- Report results at the 3P Conf in Moscow.

USGS

Appraisal Computation

- Hardware: HP xw8400 Workstation, 8 procs.
- Software: Excel, @RISK, Statgraphics.
- Simulation Model (CARA1):
  - 6 Meg Excel workbook.
  - Runtime for 50,000 trials < 1 hour.
  - No VBA code.
  - No hidden constants.
  - Some internal documentation.

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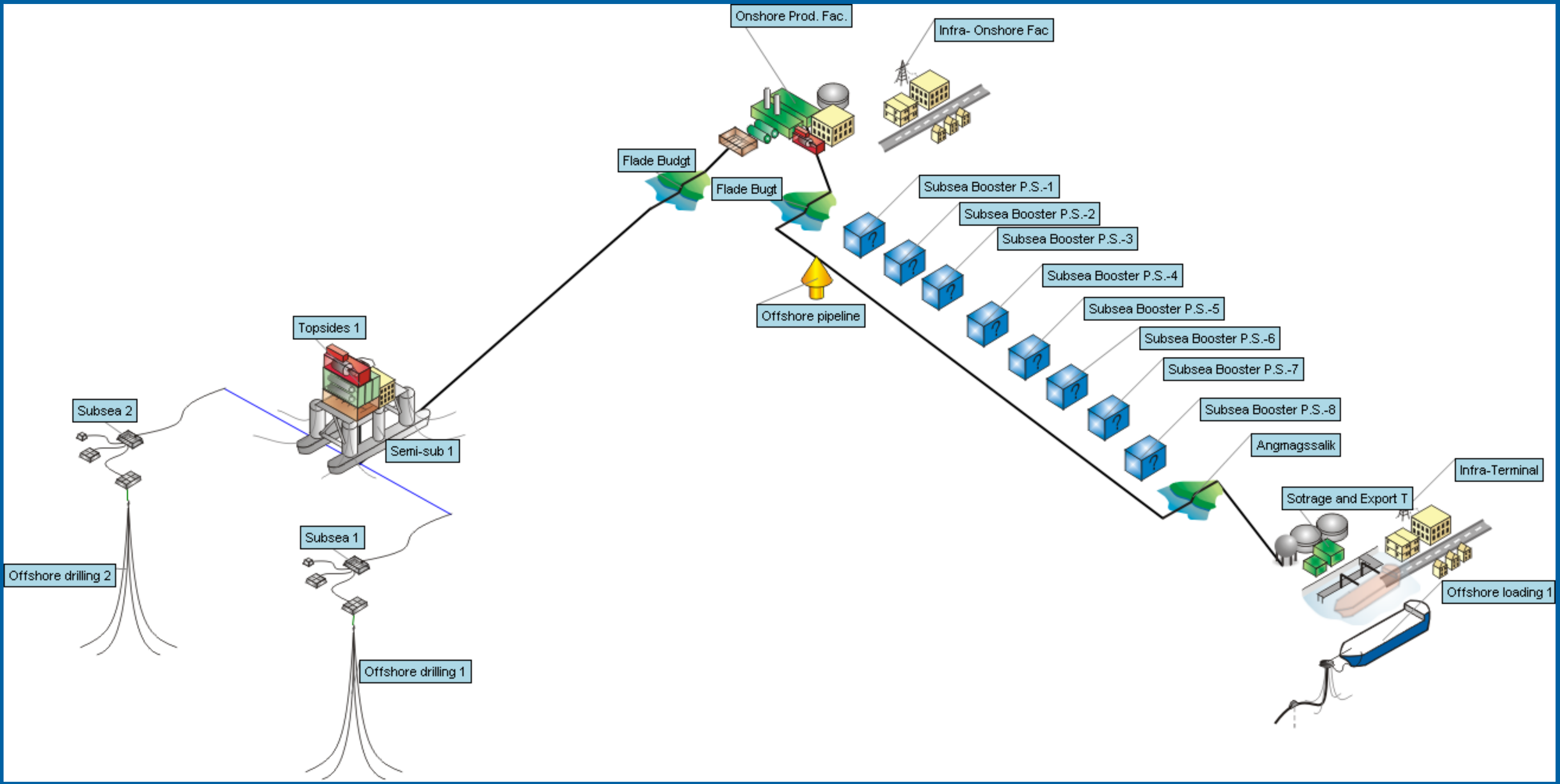
A schematic of the facility design for an offshore oil field



Appraisal Results

- **Probabilistic cost per unit volume –**
  (Total cost to deliver) / (Total Vol).

- **Probabilistic volume at given costs –**
  a resource volume-cost table.

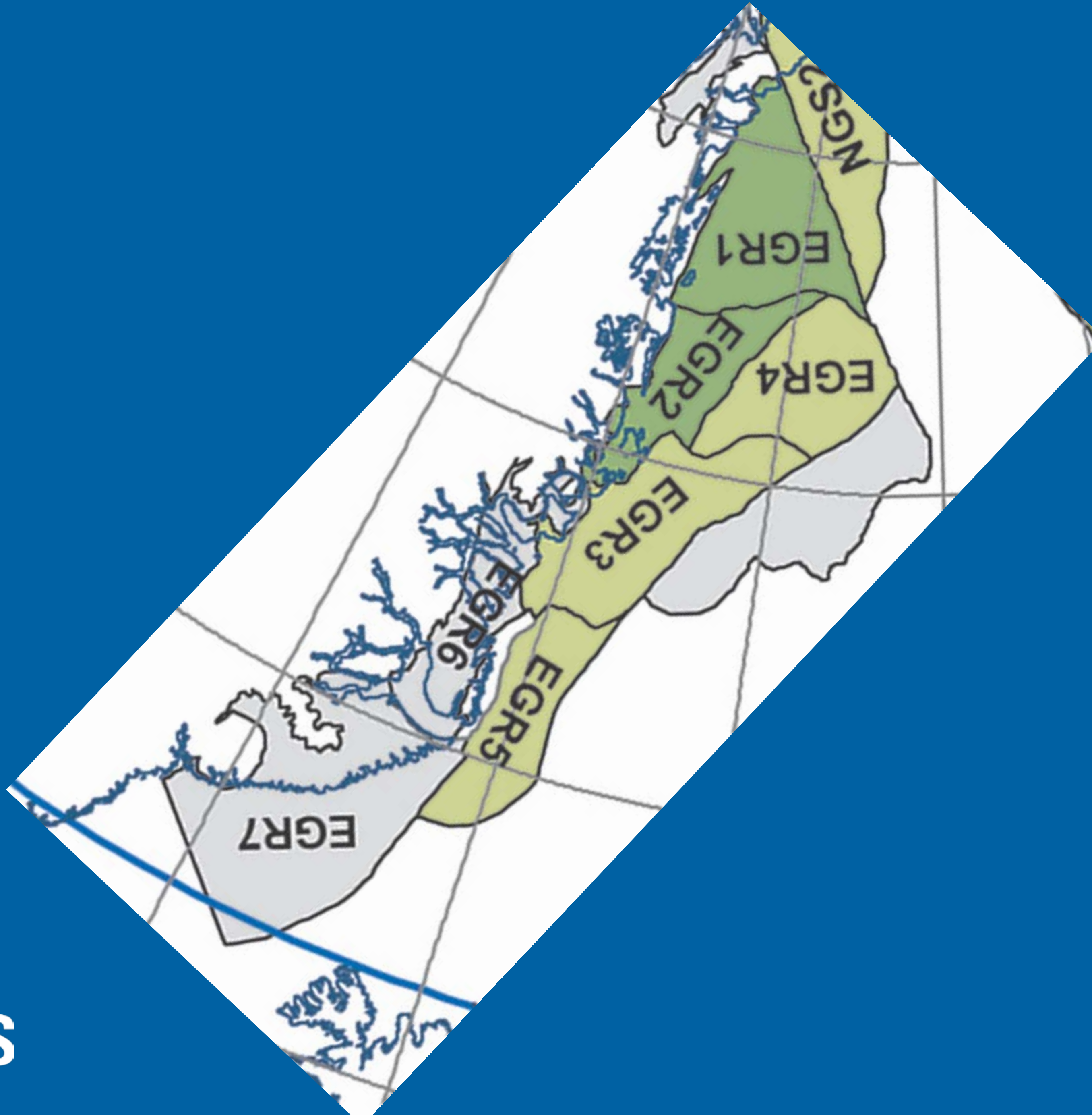
- **A Probabilistic resource cost curve –**
  a cost/unit vol versus cumulative vol.

USGS

Process Models in Simulation

- GSON: Builds a random geologic state of nature.
- AUFAIL: Estimates the costs of failed AU's.
- EXP: Estimates the costs of finding all fields.
- DPT: Estimates the costs of Dev, Prod, & TX.
- ITX: Estimates the costs of incremental TX.
- RVC: Builds the Resource Volume-Cost Table.
- RPT: Generates reports for the final results.

USGS



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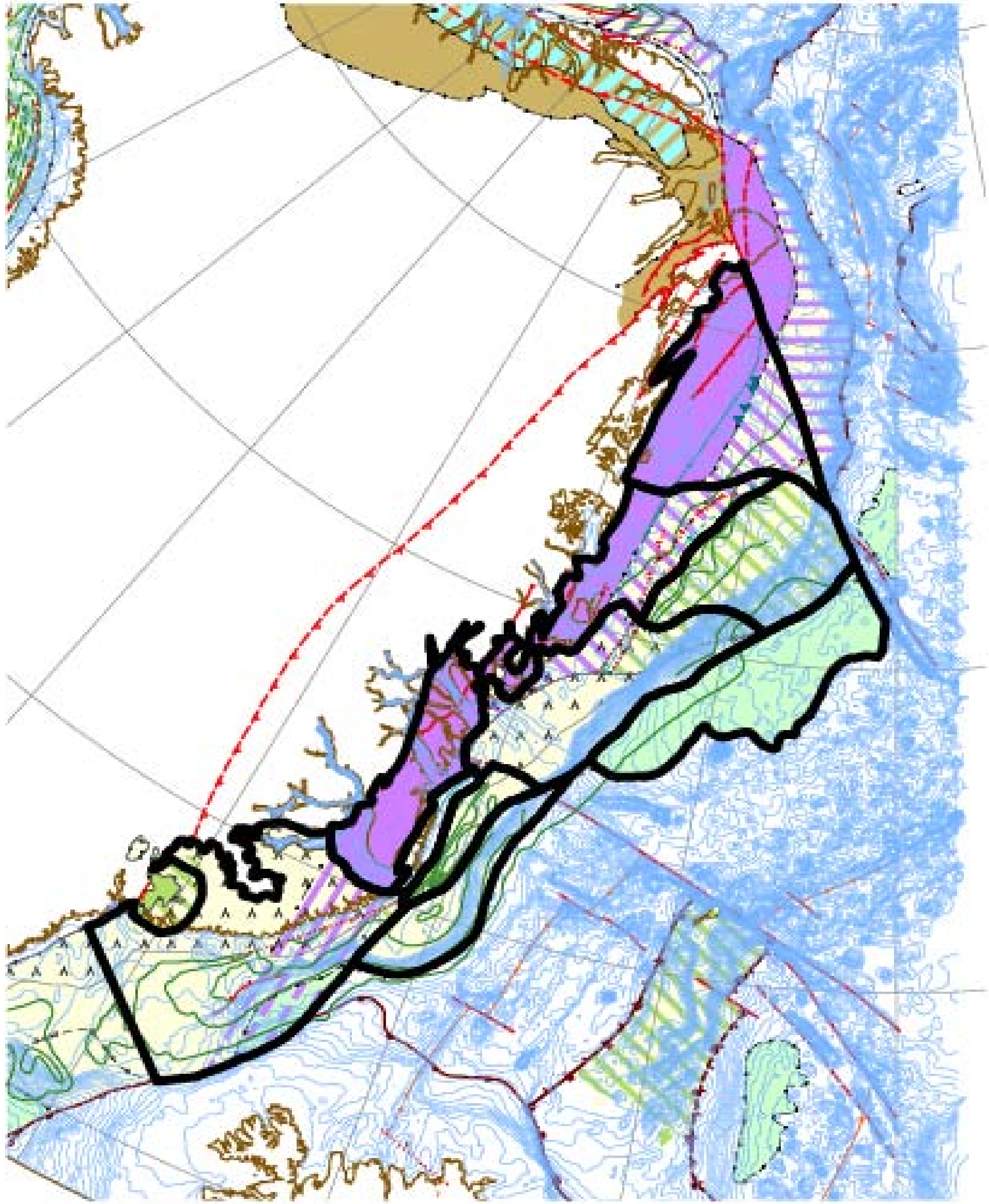
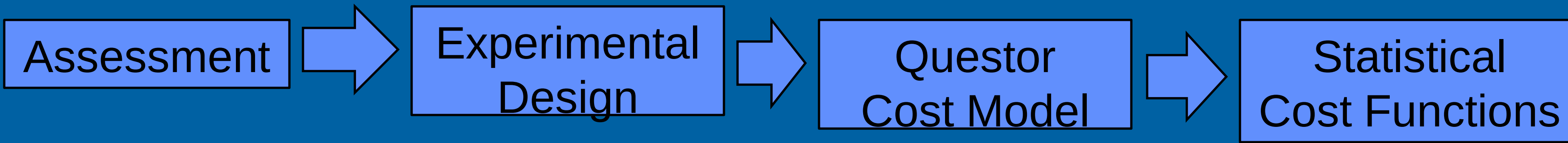
Prototype Results: East Greenland Rift Basins (5 AU's)




Assessment
Experimental Design
Questor Cost Model
Statistical Cost Functions

USGS