

# Economic Analysis of Carbon Sequestration in the BSP Region

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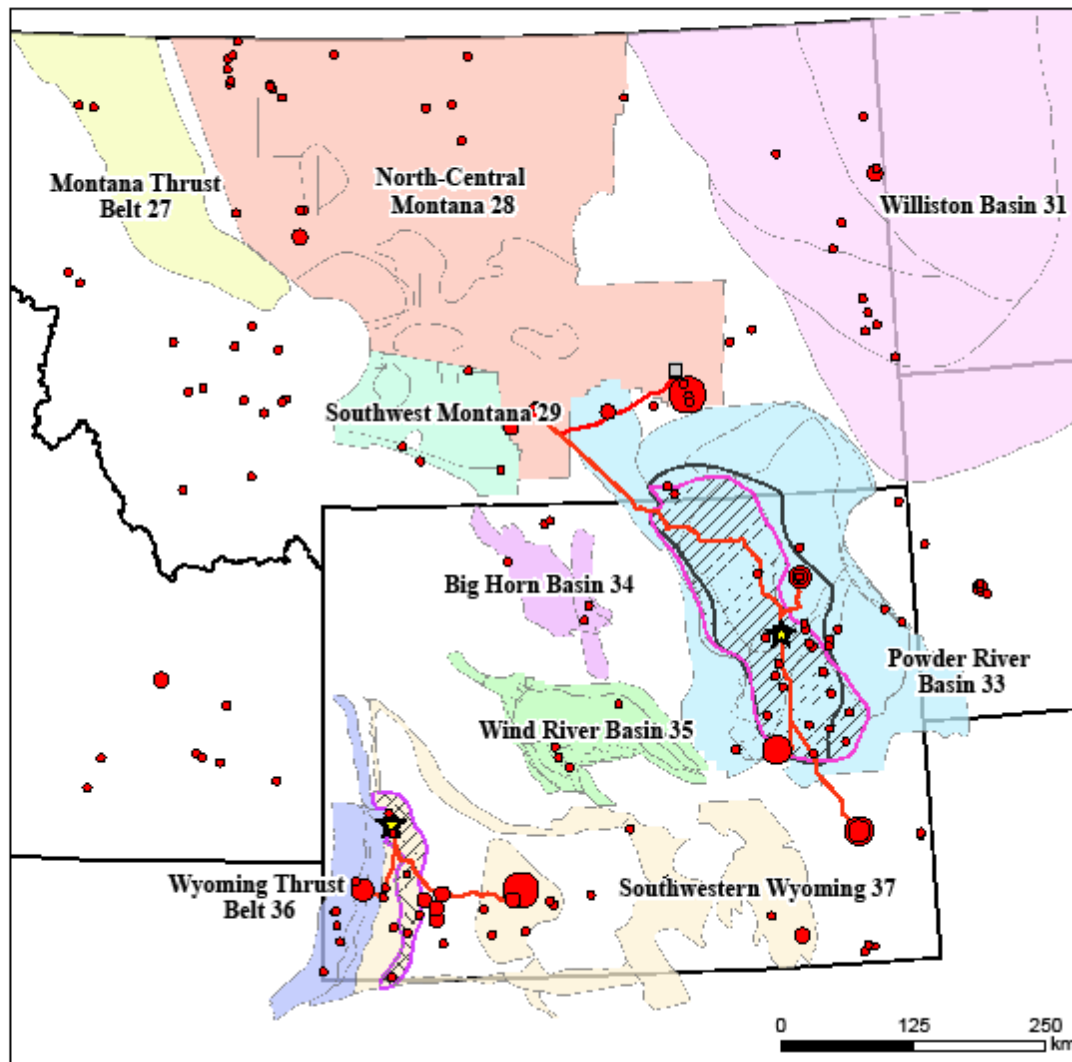
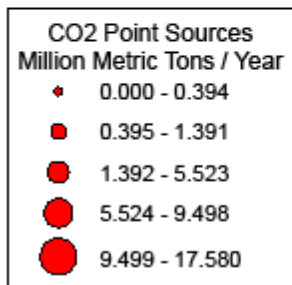
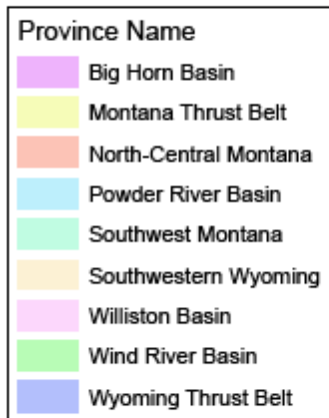
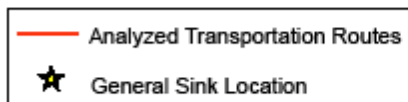
# Economic Analysis Objectives

- Assess economic potential for C sequestration in BSP region: regional C sequestration supply curve
  - Geologic (Capture, Transport, Storage)
    - EOR, ECBM
    - Saline Aquifers
    - Basalts?
  - Terrestrial
    - Afforestation
    - Agricultural soils in crops and rangelands
- Assess potential for large scale deployment
  - Sequencing type & location of sink
  - Environmental & regulatory implications of scaling up

# Geologic Modeling Strategy

- Identify main regional sources and sinks
- Quantify sequestration potential and costs
  - Capture for coal-fired power plants
  - Transport from source to sink
  - Storage (injection, some other costs)
- Integrate to estimate regional cost of C sequestration
- Identify next steps: sequencing etc.

# Play and Province Map - O/G and Saline Reservoirs



# Capture Costs

- This project did not propose to develop independent estimates of capture costs
- Estimates from literature
  - Assume BSP plants are sub-critical pulverized coal
  - MIT *Future of Coal* (2007) = \$41/MgCO<sub>2</sub>
  - IPCC (2005) = \$29 – 51/MgCO<sub>2</sub>

# Transport Costs

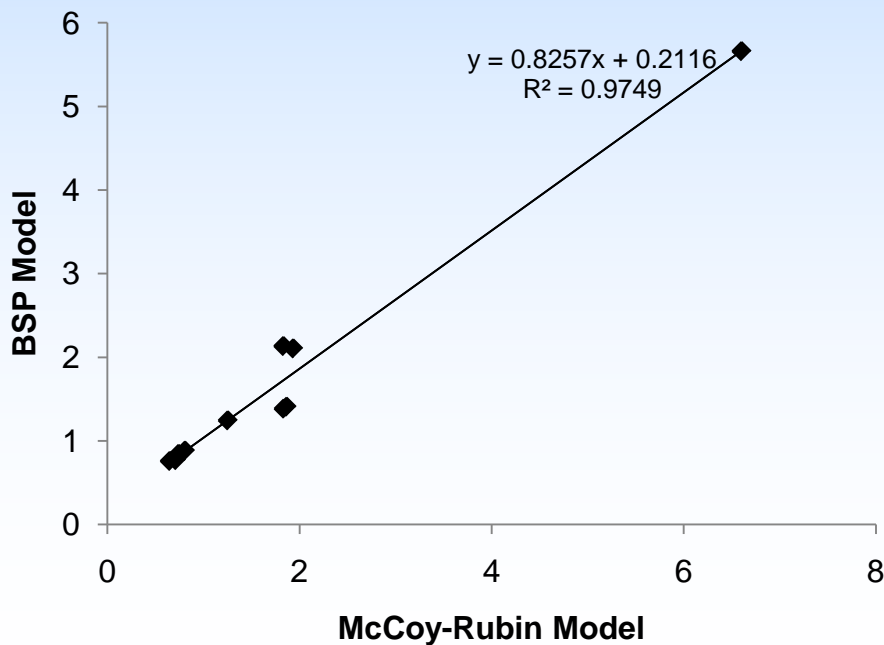
- Several models in the literature:
  - Midwest GSC: Rostam-Abadi et al. (2004)
  - McCollum & Ogden (2006)
  - McCoy and Rubin (2008)
- Approaches:
  - Assume use of existing pipeline routes as possible
  - Adapt MGSC model to BSP region
  - Use McCoy and Rubin model with regional parameters
  - Compare the two models

**Plant by plant breakdown of distance to closest sink. Plants are grouped by sinks.**

State	Source name	Pipeline Distance (mi)	Offline Distance (mi)	Offline Scaler	Offline Scaled Distance (mi)	Total Pipeline Distance (mi)	Annual CO2 Emissions (1000s of Tons)
<b>Powder River Basin - Northern House Creek Field</b>							
MT	Colstrip	287.91	16.70	1.00	16.70	304.61	17579.74
WY	Dave Johnson	82.15	0.03	1.25	0.03	82.19	6866.80
MT	J E Corette	226.60	0.36	1.00	0.36	226.95	1381.11
WY	Laramie River 1	133.18	0.50	1.25	0.63	133.81	4620.12
	Laramie River						
WY	2&3	133.18	0.50	1.25	0.63	133.81	9084.52
WY	Neil Simpson II	42.68	1.84	1.00	1.84	44.53	841.05
WY	Wygen 1	42.68	1.84	1.00	1.84	44.53	827.29
WY	Wyodak	42.68	1.84	1.00	1.84	44.53	3099.21
<b>Moxa Arch - Piney LaBarge Field</b>							
WY	Naughton	56.49	0.34	1.00	0.34	56.82	5523.31
WY	Jim Bridger	112.02	1.90	1.00	1.90	113.92	14553.70

# Transport Costs: Results

Source	Sink	Transport Cost (\$/ton)	
		BSP	McCoy-Rubin
Colstrip	Powder River Ba.	2.103456847	1.934560125
Dave Johnson	Powder River Ba.	0.880928849	0.808002051
J E Corette Plant	Powder River Ba.	5.658776098	6.602622376
Jim Bridger	Moxa Arch	0.841683739	0.741092115
Laramie River 1	Powder River Ba.	2.131697932	1.8319343
Laramie River 2&3	Powder River Ba.	1.242565145	1.252926346
Naughton	Moxa Arch	0.757212665	0.649579145
Neil Simpson II	Powder River Ba.	1.383300239	1.835366461
Wygen 1	Powder River Ba.	1.406306585	1.865891342
Wyodak	Powder River Ba.	0.767266727	0.712588252



# Storage Costs

- Approach
  - Use WYO/BSP analysis of EOR and ECBM injection rates and costs, supplemented with McCoy-Rubin model for site characterization, MMV costs  
(for methods see <http://eori.gg.uwyo.edu/>)
  - Use McCoy-Rubin model for saline aquifers
- Preliminary analysis assumptions
  - Initial source-sink combinations
  - Sensitivity analysis of EOR vs saline sink costs rather than optimal sequencing
  - Site characterization and MMV costs based on plume size model and preliminary estimates for some sites in our region

# UWYO EOR Model: Analog method for injection cost & implied cost of CO<sub>2</sub> sequestered net of oil revenue over a specified time horizon

$$NPV = \sum_{t=1}^T \frac{PQ_t (1-x^R)(1-x^{SP}) - pq_t^p - c_t^i q_t^i - c_t^o}{(1-r)^t} - K.$$

## Incremental Variable Cost Components

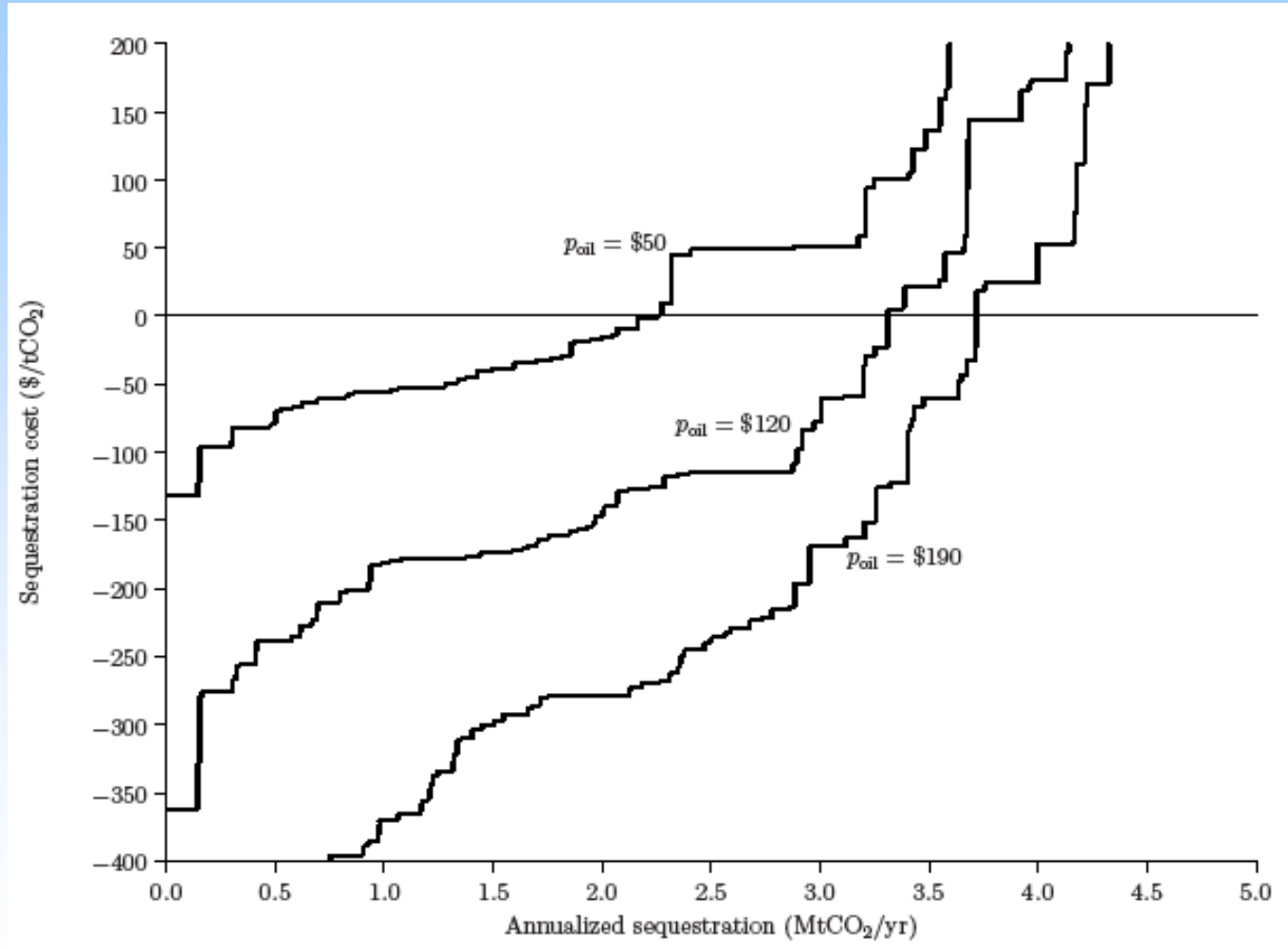
Cost Items	Cost Estimates	Notes
<b>Taxes</b>	16% Royalty Rate 6% Severance Tax 6% Property Tax	
<b>CO<sub>2</sub></b>	Qty of CO <sub>2</sub> (mcf) x Price (\$/mcf)	CO <sub>2</sub> Price Tying = \$0.50+2.5% x \$Oil
<b>Operating Dehydration &amp; Compression Plant</b>	Maintenance = \$45 per HP-yr Labor = \$25 per HP-yr Electricity = \$0.04/kWh Power = 7,000 kWh per HP-yr	Assumes Electric Motor
<b>Other Incremental Barrel Costs</b>	Variable = \$0.22 per Incremental Oil Barrel	
<b>Other Incremental Operating Costs</b>	Fixed = \$2,000 per Incremental Well/Month	An "Incremental Well" is any Newly Active Well
<b>Additional Incremental Lift Costs</b>	\$0.10 per Incremental Liquid Barrel	Liquid Includes both Oil and Water

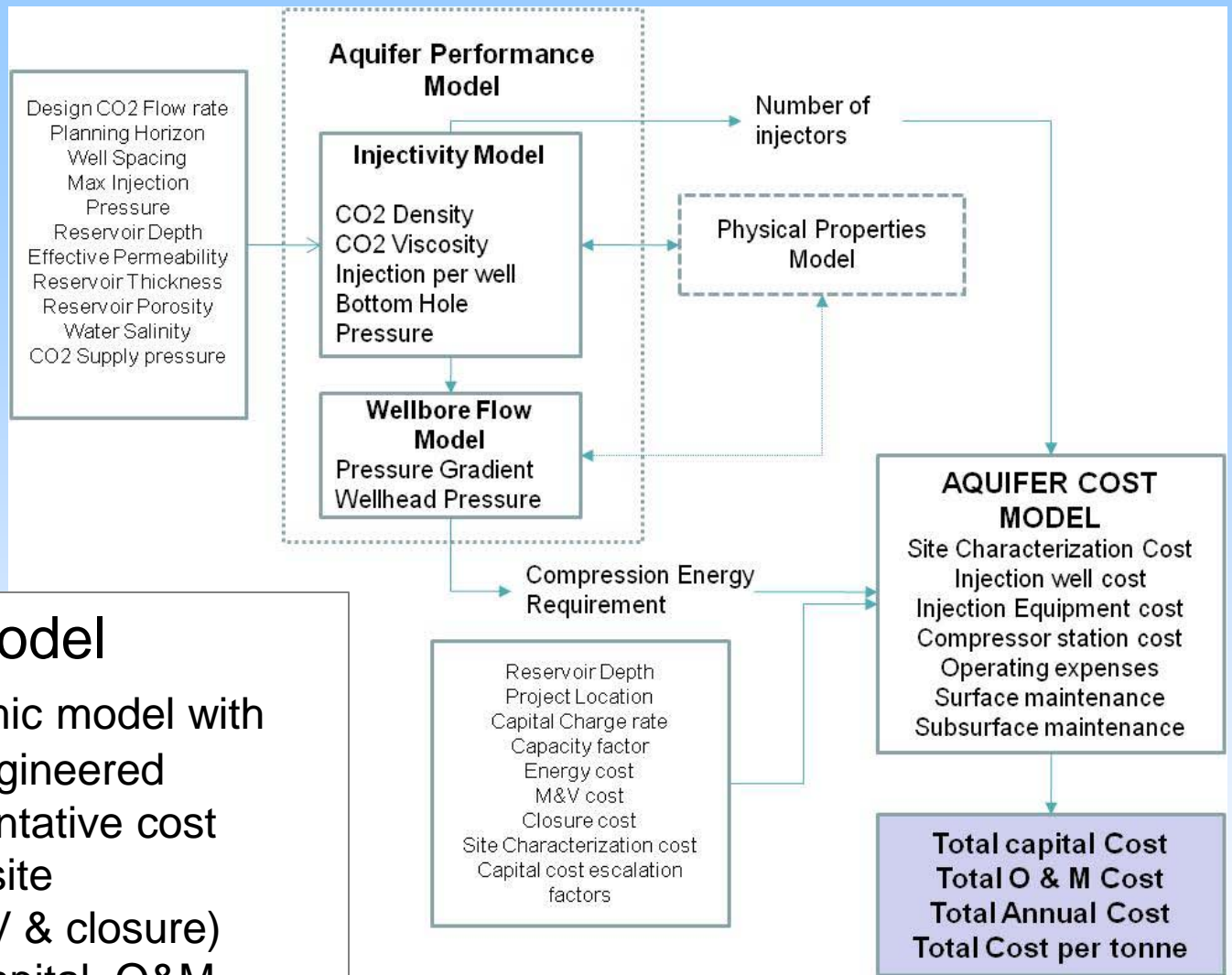
$$NPV = \sum_{t=1}^T \frac{PQ_t (1-x^R)(1-x^{SP}) - pq_t^p - c_t^i q_t^i - c_t^o}{(1-r)^t} - K.$$

## Capital Investment Cost Components (K)

Cost Items	Cost Estimates	Notes
<b>Constructing Pipeline</b>	\$70,000 per inch-mile	Includes right of way, materials and construction
<b>Metering Station</b>	\$150,000 each	Estimates range from \$100k - \$300k
<b>Installing Dehydration &amp; Compression Plant</b>	\$1,200/hp x HP	Use 2/3rds rule <1,000 HP HP depends on recycling qty and suction/discharge pressure
<b>New Drilling (per well)</b>	\$116 - \$150 per ft	Drilling cost per foot depends on well depth
<b>Working Over an Existing Producer</b>	\$80,000 per well	Cleanout/acidize, high pressure stuffing box, bop above wellhead
<b>Equipping a New Producer / Returning a TA'd Well to Production</b>	\$15 x Depth (ft) + \$225,000 per well	Open hole, acidize, tubing with rods, pumping unit, high pressure stuffing box, bop above wellhead
<b>Converting a Well to CO<sub>2</sub> Injection</b>	\$15 x Depth (ft) + \$70,000 per well	Acidize, duo-line tubing, packer, wraparound tubing hanger, stainless tubing valve
<b>Installing Surface Equipment/Facilities</b>	\$50,000 per Injector \$32,000 per Producer	Running CO <sub>2</sub> lines, installing CO <sub>2</sub> /water injection skid, running new flow-lines, seals, adding/replacing test fac.

# UWYO EOR Model: Powder River Basin CO2 sequestration supply curve for alternative oil prices

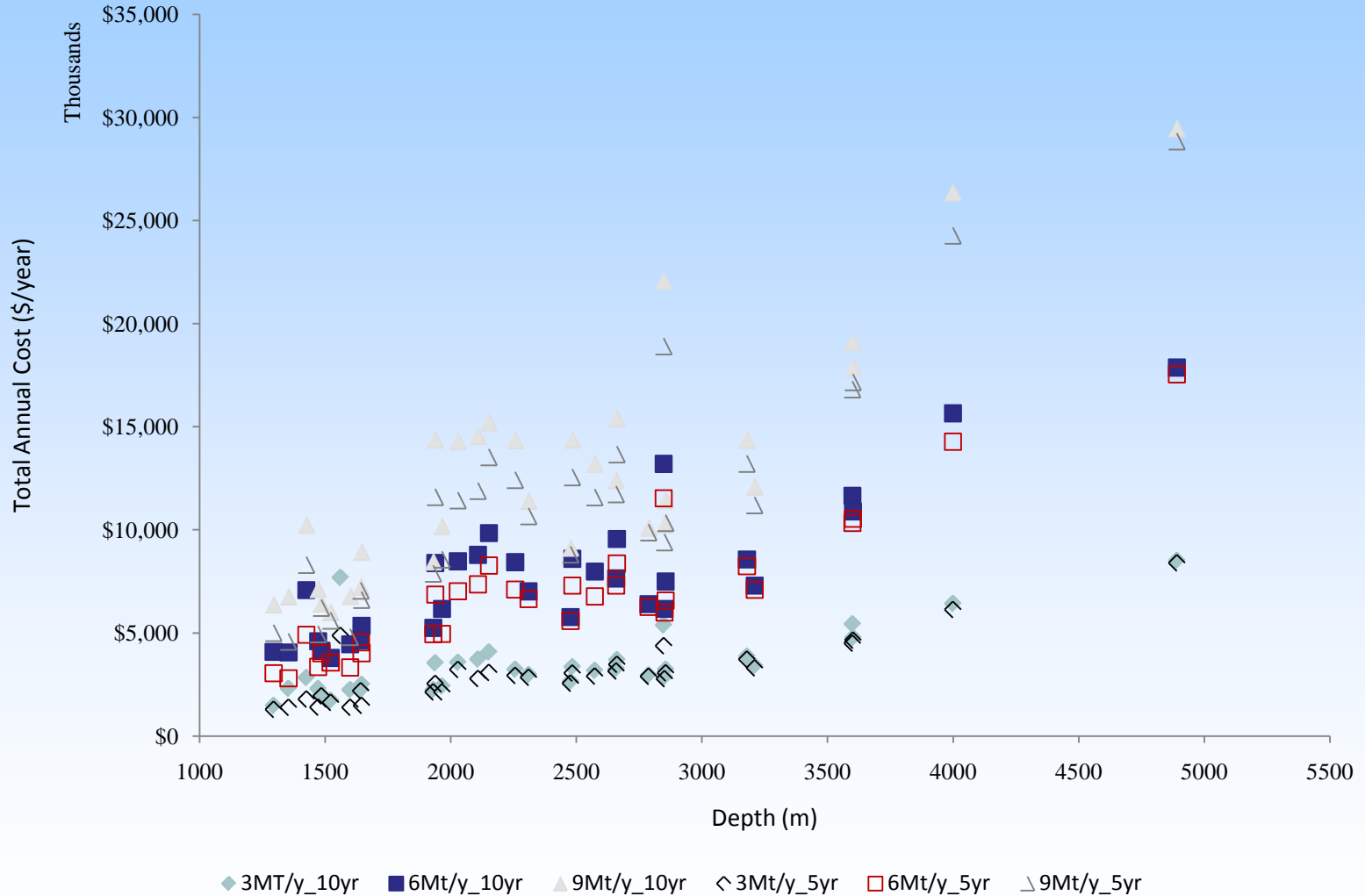




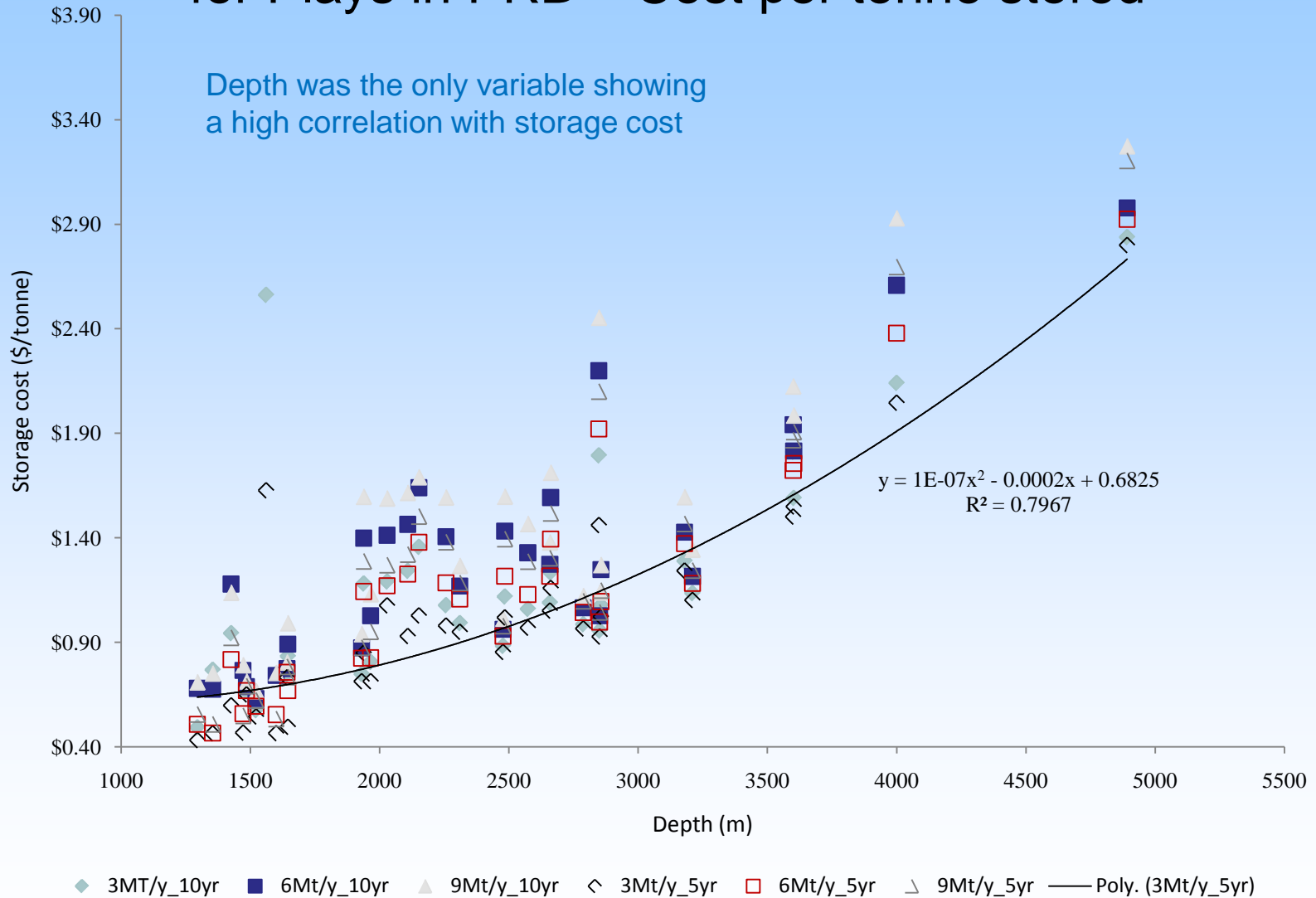
## McCoy-Rubin Model

- engineering-economic model with statistical cost and engineered relationships, representative cost parameters (e.g., for site characterization, MMV & closure)
- total & annualized capital, O&M costs, sequestration cost/MgCO<sub>2</sub>

# McCoy-Rubin Model – Aquifer Injection Sensitivity Analysis for Plays in PRB – Total Annual Cost



# McCoy-Rubin Model – Aquifer Injection Sensitivity Analysis for Plays in PRB – Cost per tonne stored



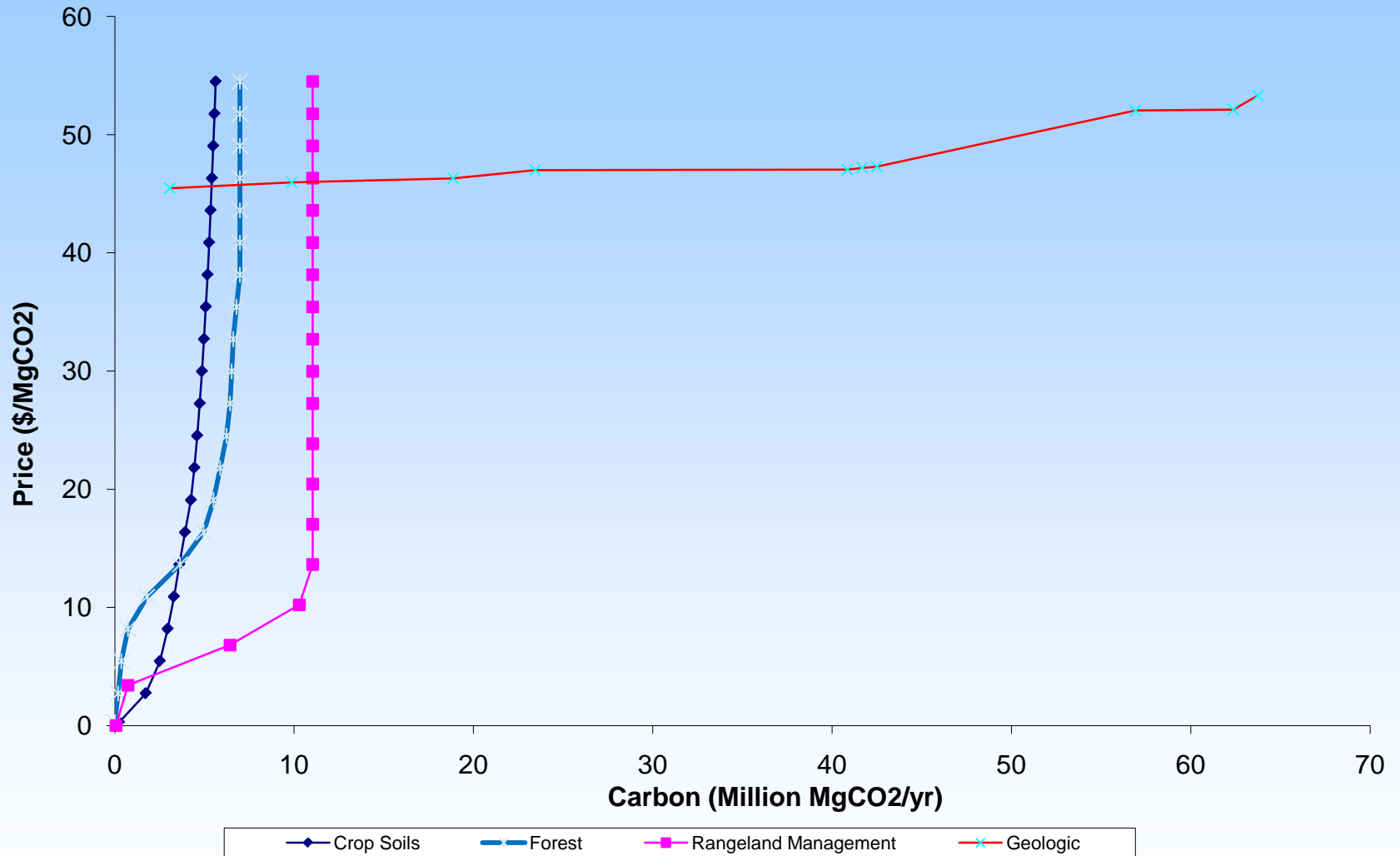
# Geologic: Implications

- Capture cost dominates CCS total cost/tonne
  - Capture = \$30-60/MgCO<sub>2</sub>
  - Transport + storage < \$5/MgCO<sub>2</sub>
- Current modeling adequate for regional assessment of potential
- For commercial implementation need more detailed cost data, particularly:
  - transport and storage costs to alternative basins
  - site characterization, MMV costs, regulatory compliance costs

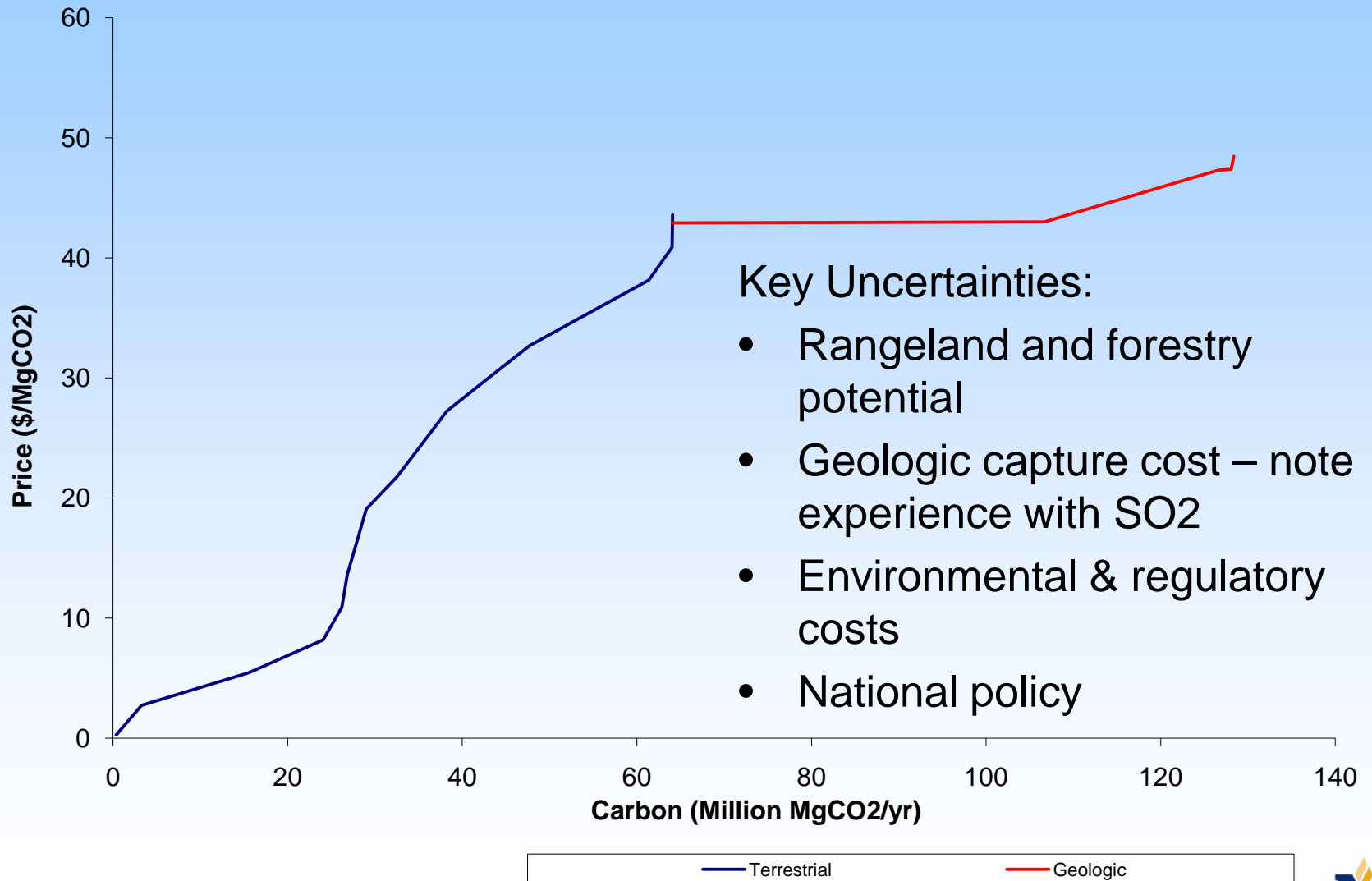
# Terrestrial Sequestration Modeling

- Crop Soils
  - Regional estimates available from prior work, revised with recent results on N<sub>2</sub>O and fuel
- Forestry
  - OSU collaborators adapted national model to BSP region
- Rangelands
  - Estimates made based on “minimum-data” models for C rates, economic analysis

# C Sequestration Components in BSP Region



# BSP Regional Supply Curve



## Key Uncertainties:

- Rangeland and forestry potential
- Geologic capture cost – note experience with SO<sub>2</sub>
- Environmental & regulatory costs
- National policy

# Completing Phase II

- Terrestrial reports completed
- Geologic model reports in preparation
  - UWYO EOR/ECBM model & analysis
  - MSU regional model (capture, transport, storage)
  - On-going work on regional integration of transport and storage analysis (in collaboration with OSU)
  - Report on environmental and regulatory issues
- Incorporate into LSC report