


**WESTCARB Annual Business Meeting**

**A GIS-Based Model for CO<sub>2</sub> Pipeline Transport and Source-Sink Matching Optimization**

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## Overview

- Module to calculate pipeline diameter (D)
- Module to identify the least-cost path connecting a CO<sub>2</sub> source to a given sink (L)
- Economic module to calculate the total and annualized CO<sub>2</sub> pipeline transportation cost

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## Pipeline Diameter Calculation—Methodology

$$\frac{\Delta P}{\Delta L} = \frac{32 f \dot{m}^2}{\pi^2 \rho D^5}$$

$\Delta P / \Delta L$  : Pressure drop per length unit

$f$  : Fanning friction factor

$\dot{m}$  : CO<sub>2</sub> mass flow rate

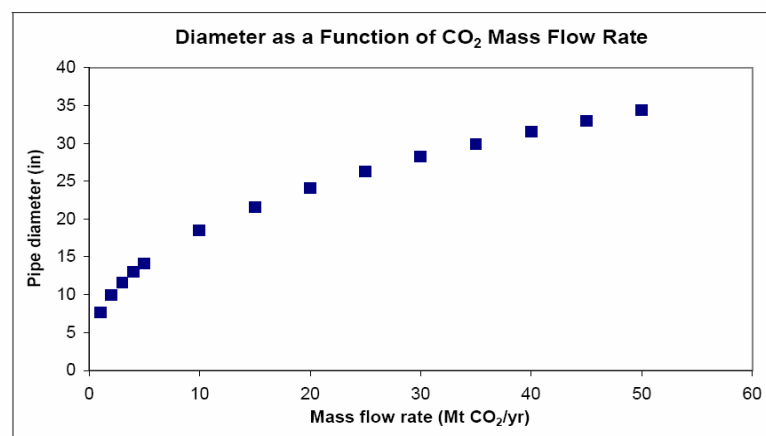
$\rho$  : CO<sub>2</sub> density

D: Pipeline diameter

- Doubling the CO<sub>2</sub> mass flow rate will increase the pipeline diameter by 32%.



## Pipeline Diameter Calculation



## Pipeline Diameter Calculation— Implementation

- Given a CO<sub>2</sub> flow rate from the user and assuming a pressure drop of 49 Pa/m, we generated a look-up table for pipeline diameter.

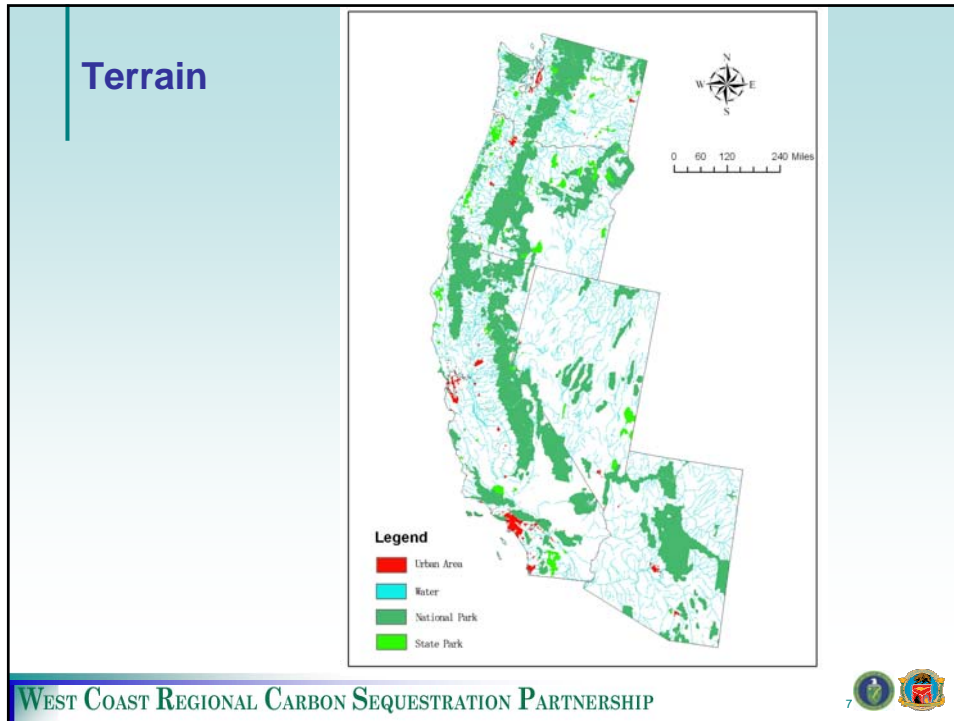
Pipeline Diameter (inch)	CO <sub>2</sub> Flow Rate (Mt/yr)	
	lower bound	upper bound
4		0.19
6	0.19	0.54
8	0.54	1.13
12	1.13	3.25
16	3.25	6.86
20	6.86	12.26
24	12.26	19.69
30	19.69	35.16
36	35.16	56.46



## Least-cost Pipeline Path Selection and Length Calculation—Methodology

- Pipeline construction costs vary considerably according to local terrains, crossings (waterways, railways, and highways), protected areas, and populated places. Obstacle grid layers (spatial unit: 1x1 kilometer) are used to determine the least-cost pipeline route.
- Current version will identify the least-cost path and calculate its length for matching one source to one sink.



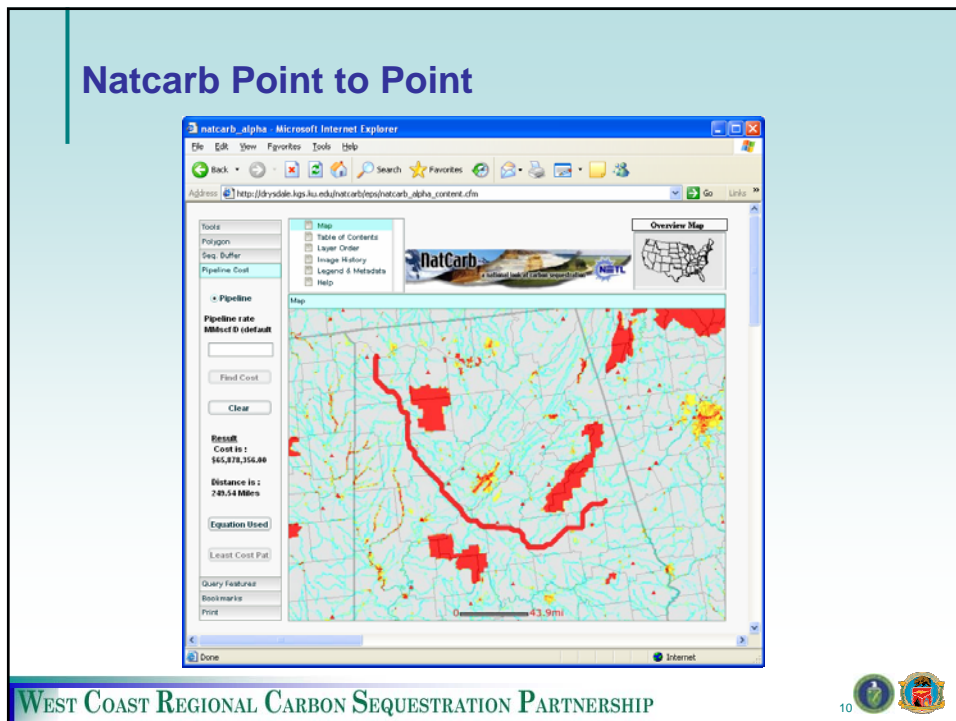
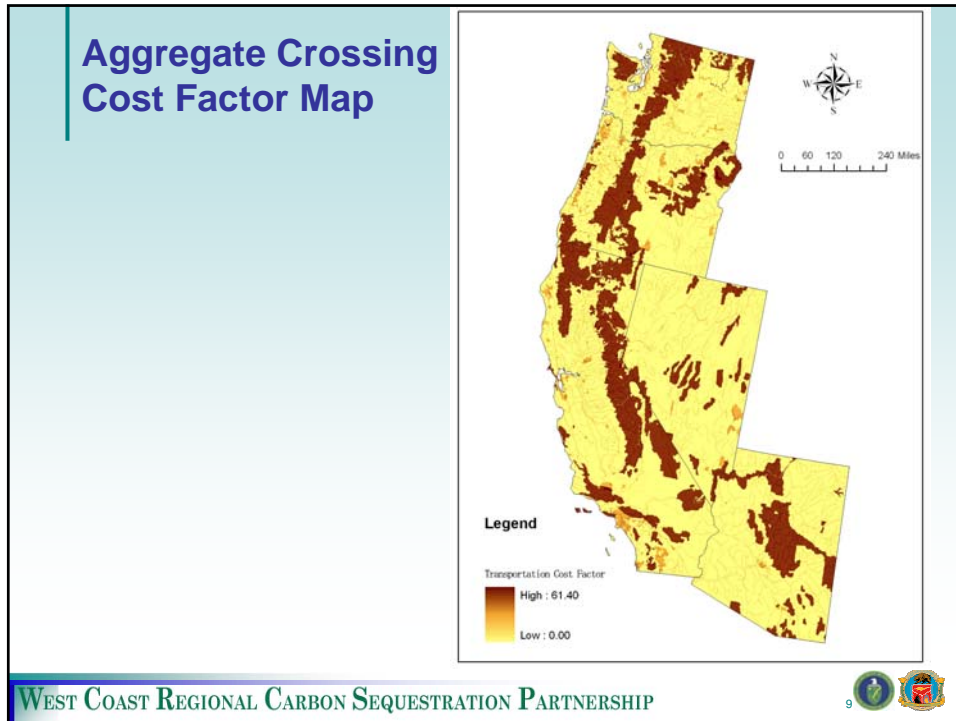


### Obstacle Conditions and Their Relative Cost Factors

Construction Condition	Raw Data Source	Cost Factor
Base Case		1
Slope	ESRI Digital Elevation Model	
10-20%		0.1
20-30%		0.4
>30%		0.8
Protected Area		
Populated Place	ESRI Data & Maps	15
Wetland	USGS LULC Data	15
National Park	ESRI Data & Maps	30
State Park	ESRI Data & Maps	15
Crossing		
Waterway Crossing	ESRI Data & Maps	10
Railroad Crossing	ESRI Data & Maps	3
Highway Crossing	ESRI Data & Maps	3

\* Values and/or methodology may be updated after reviewing with industry;  
\* Values are based on 8-inch diameter pipelines

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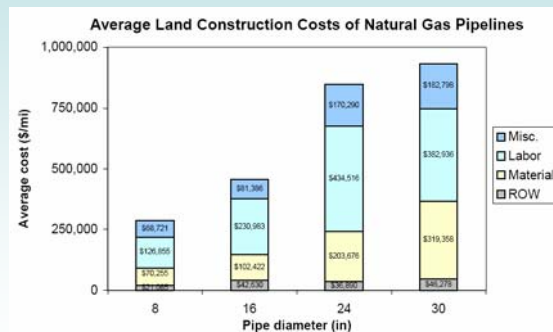


## Pipeline Total Cost

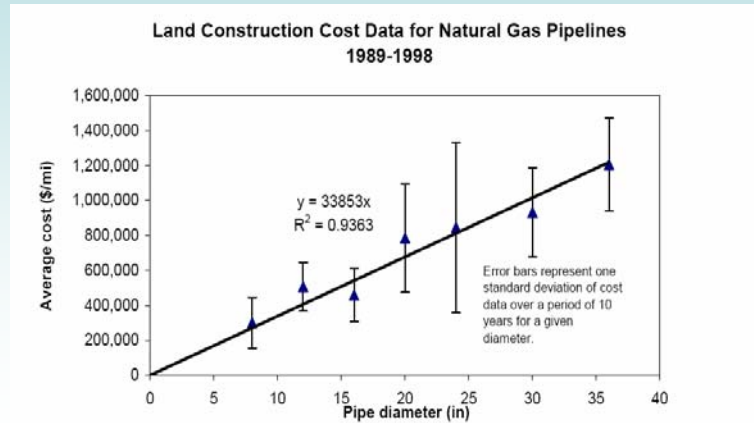
- General Equation
  - Annualized Cost = Land Construction Cost \* Capital Charge Factor + O&M Cost
- Capital Charge Factor
  - Use 0.15 by default
- O&M Cost
  - The O&M cost is estimated to be \$5,000\*Length (in mile) per year, independent of pipeline diameter

## Pipeline Land Construction Cost

- Land Construction Cost
  - Material
  - Labor
  - ROW
  - Misc.
- O&M Cost



## Pipeline Land Construction Cost Model



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## Land Construction Cost (LCC) Calculation

### ■ MIT Correlation

–  $LCC = a * D * L$

- $a = \$33,853$ ;
- $D$ : pipeline diameter in inches (function of  $CO_2$  flow rate);
- $L$ : least-cost pipeline path length in miles;
- Users are allowed to replace the default  $a$  value in the MIT correlation.

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## Land Construction Cost (LCC) Calculation (cont'd)

- CMU Correlation

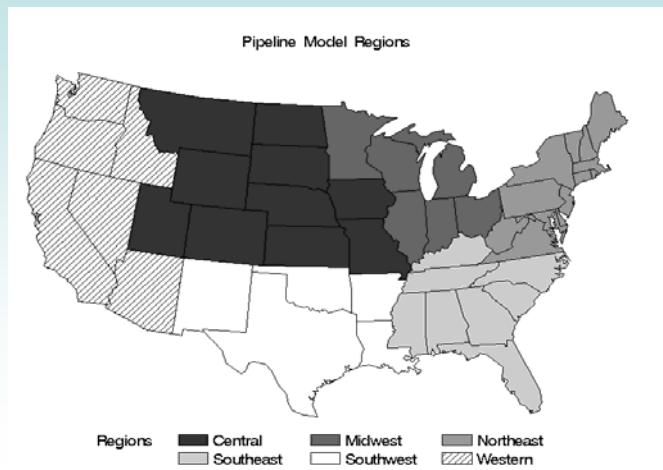
- $LCC = a \cdot D^x \cdot L^y \cdot z$

- z: region weights;
    - a = \$42,404;
    - x = 1.035, y = 0.853;
    - z values

Region	C	SW	W	MW	SE	NE
z value	1.000	1.248	1.341	1.516	1.687	1.783



## Region Map

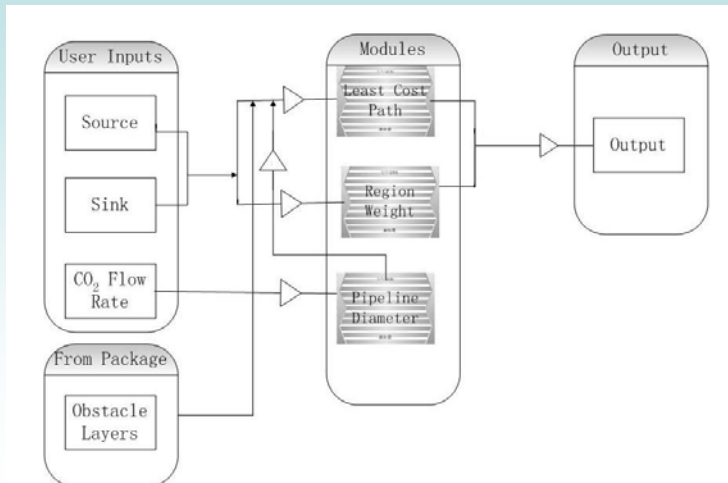


## MIT-CMU LCC Comparison

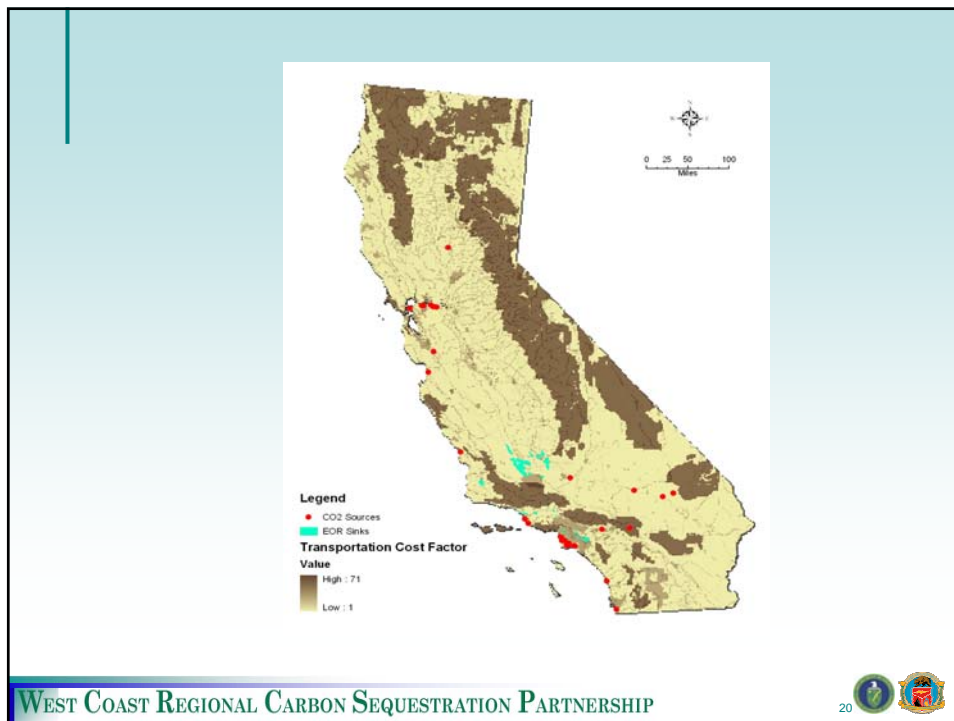
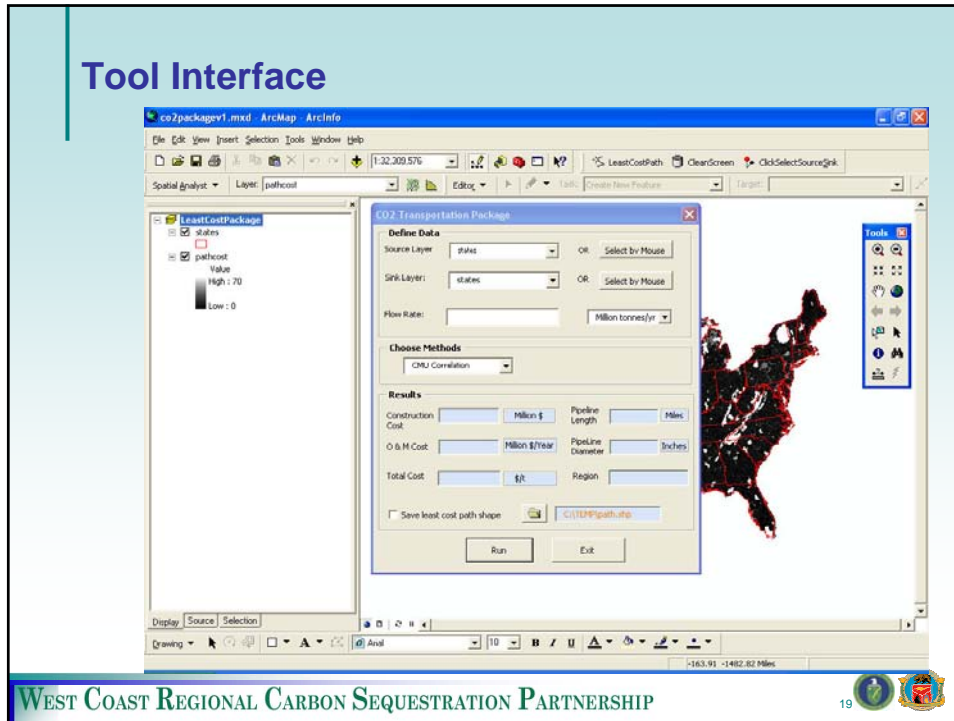
- MIT Correlation: \$33,853/in/mile
- CMU Correlation: (\$/in/mile)

	Central		Southwest		West	
	100 mile	1000 mile	100 mile	1000 mile	100 mile	1000 mile
<b>8 inch</b>	\$23,210	\$16,560	\$28,962	\$20,664	\$31,117	\$22,202
<b>16 inch</b>	\$23,777	\$16,965	\$29,671	\$21,170	\$31,879	\$22,745
<b>24 inch</b>	\$24,116	\$17,207	\$30,093	\$21,471	\$32,332	\$23,069
	Midwest		Southeast		Northeast	
	100 mile	1000 mile	100 mile	1000 mile	100 mile	1000 mile
<b>8 inch</b>	\$35,194	\$25,111	\$39,151	\$27,934	\$41,376	\$29,522
<b>16 inch</b>	\$36,055	\$25,725	\$40,108	\$28,617	\$42,388	\$30,244
<b>24 inch</b>	\$36,568	\$26,091	\$40,679	\$29,024	\$42,992	\$30,674

## MIT CO<sub>2</sub> Transportation Cost Calculation Tool Structure



## Tool Interface



**CO2 Transportation Package**

**Define Data**

Source Layer: CA\_source OR Select by Mouse

Sink Layer: CA\_source OR Select by Mouse

Flow Rate: 12 Million tonnes/yr

**Choose Methods**

MIT Correlation

**Results**

Construction Cost: 83.2 Million \$ Pipeline Length: 122.85 Miles

O & M Cost: 0.61 Million \$/Year Pipeline Diameter: 20 Inches

Total Cost: 1.09 \$/t

Save least cost path shape C:\TEMP\path.shp

Run Exit

**Legend**

- Pipe\_leastCostPath
- CA\_source
- CA\_sink
- pathcost

Value

High: 50.000000

Low: 0.000000

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## Future Work

- Implement many-source-to-many-sink matching (system optimization)
- Update the obstacle layers and the associated relative weights
- Allow users revise the pipeline diameter calculation by changing the pressure drop default

## Contact Information

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