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**GEOSPATIAL INFORMATION &
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Overland Flow: Comparison of Modeling Methods

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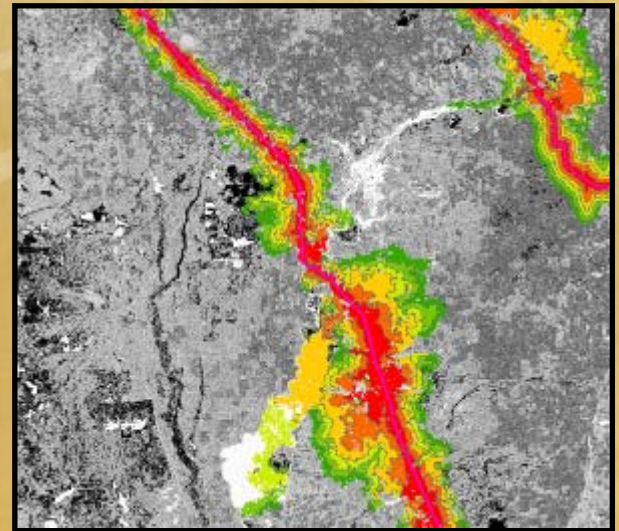
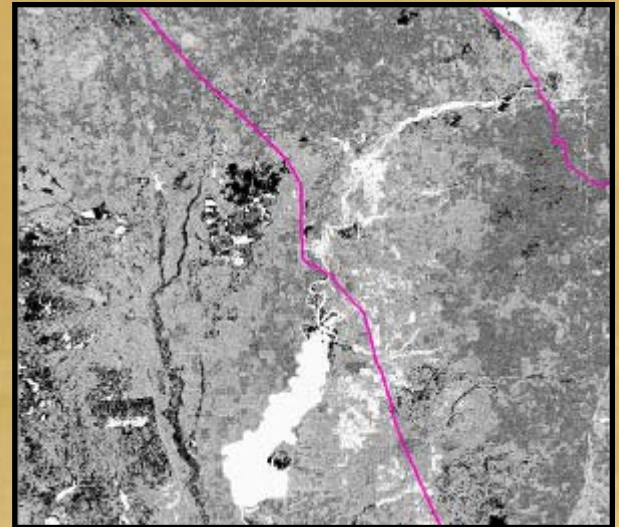
Outline

- Overview
- Regulatory Review
- Overland Flow
 - Model Considerations
 - Additional Recommendations
 - Input Parameters
 - Results
- Industry Approach
 - Modeling Approach #1
 - Modeling Approach #2
 - Modeling Approach #3
- Comparisons



Overview

- Pipeline Regulations
 - Effective Integrity Management Plan
- Industry Response
- Comprehensive Model



Pipeline System Level Results



Regulatory Review

Overland Flow Modeling



Pipeline Regulations

49 CFR Part 195 – Pipeline Integrity

- Regulatory Updates:
 - Pipeline Operators must identify where their pipelines could affect (directly or indirectly) a High Consequence Area
- High Consequence Areas Consists of:
 - High population areas
 - Other populated areas
 - Unusually sensitive areas
 - Commercially navigable waterways



Pipeline Regulations

49 CFR Part 195

- An operator must include in its integrity management program:
 - Identification of all pipeline segments that **could** affect a high consequence area
 - Consequences of a failure, and
 - Identification of measures taken to protect the High Consequence Area



Pipeline Regulations

- Guidance on factors to consider:
 1. **Terrain surrounding the pipeline.** An operator should consider the contour of the land profile and if it could allow the liquid from a release to enter a high consequence area.
 2. **Drainage systems such as small streams and other smaller waterways** that could serve as a conduit to a high consequence area.
 3. **Crossing of farm tile fields.** An operator should consider the possibility of a spillage in the field following the drain tile into a waterway.
 4. **Crossing of roadways with ditches along the side.** The ditches could carry a spillage to a waterway.



Pipeline Regulations

5. **The nature and characteristics of the product the pipeline is transporting.** A spillage could create a vapor cloud that could settle into the lower elevation of the ground profile.
6. **Physical support** of the pipeline segment such as by a cable suspension bridge.
7. **Operating condition of pipeline** (pressure, flow rate, etc.)
8. The **hydraulic gradient** of pipeline.
9. The diameter of pipeline, the **potential release volume**, and the distance between the isolation points.
10. **Potential physical pathways** between the pipeline and the high consequence area.
11. **Response capability** (time to respond, nature of response).
12. **Potential natural forces inherent in the area** (flood zones, earthquakes, subsidence areas, etc.)



Pipeline Regulations

49 CFR Part 194 – Response Planning

“Each response plan must plan for resources for responding to the maximum extent practicable to a worst case discharge and to a substantial threat of such a discharge” (194.07)



Model Considerations

Overland Flow Modeling





Regulatory Recommendations

Regulatory Recommendations

- 1.Terrain surrounding the pipeline...
- 2.Drainage systems...
- 3.Crossing of farm tiles...
- 4.Crossing of roadways...
- 5.Product characteristics...
- 6.Physical support...
- 7.Operating conditions...
- 8...Hydraulic gradient...
- 9...Potential release volume...
- 10.Potential physical pathways...
- 11.Response capability...
- 12.Potential natural forces...

Model Considerations

- 1.Digital Elevation Model
- 2.Hydrography
- 3.Crossings
- 4.Crossings and transportation
- 5.Fluid properties
- 6.Special Case
- 7.Operating conditions
- 8.Hydraulic gradient
- 9.Potential release volume
- 10.Potential physical travel paths
- 11.Response time
- 12.Probability

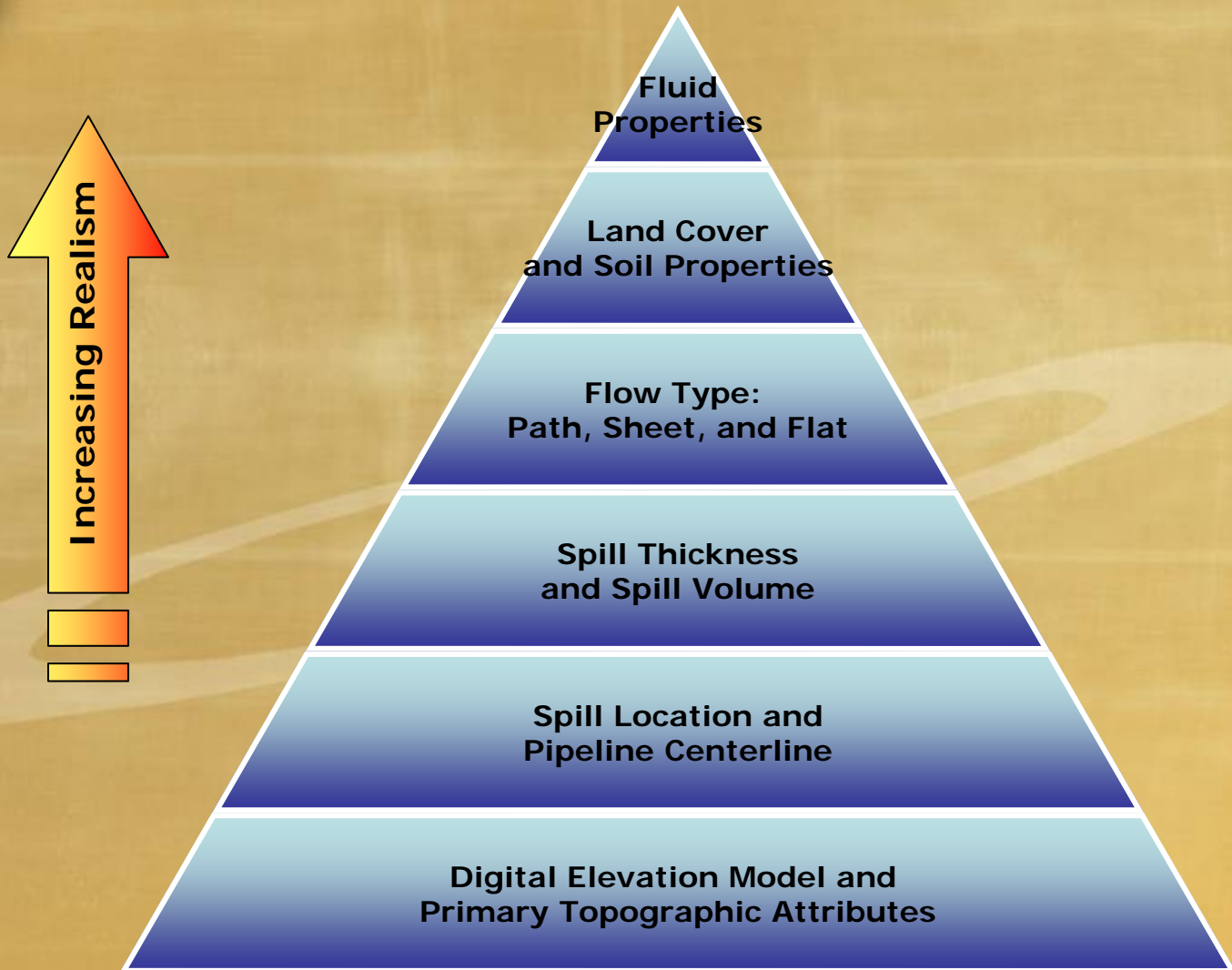


Additional Recommendations

- Land Use/Land Cover
- Soil Properties
- Flow types
- Weather conditions
- Downhill flow constraint



Fundamental Components





Fundamental Components

- Digital Elevation Model
 - Governs energy available to fluid for flow
 - Derive Slope along the path of fluid flow
 - Should include elevation changes due to Roads and Railways since these act as potential barriers



Fundamental Components

- Source Location
 - Point
 - Localized spill
 - Predefined or specified locations
 - Linear
 - Looks like a System wide spill
 - Covers all possible localized spills
 - Pipeline centerline as source

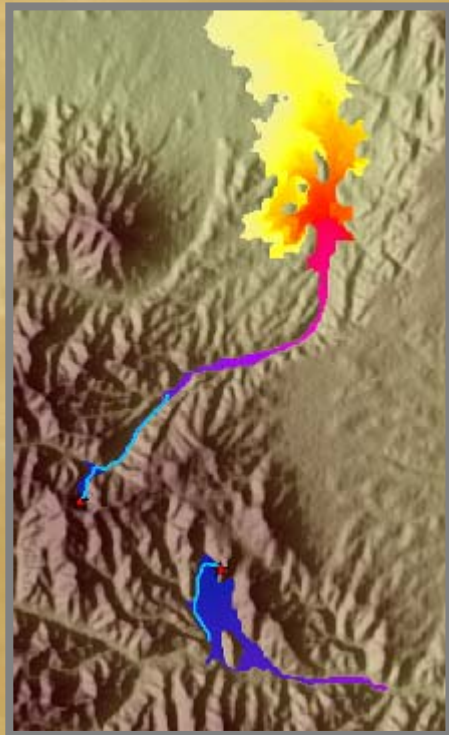


Fundamental Components

- Spill Characteristics
 - Pool Thickness
 - Common practice is use of 1 cm or 1"
 - Can be calculated from historic spills
 - Spill Volume
 - Required as a limit (end) point
 - Can be derived from pipeline hydraulics



Fundamental Components



- Terrain Dependent Flow Types
 - Path Flow
 - Severe terrain
 - Constrains flow
 - Sheet Flow
 - Terrain has mild to moderate slope
 - Flow spreads out proportional to slope
 - Flat Flow
 - Terrain is [virtually] flat
 - Flow will spread out like waves



Fundamental Components

- Land Use/Land Cover
 - Indicator of surface “density” or complexity
 - Directly related to fluid flow speed overland
 - Basis for flow resistance parameters
- Soil Properties
 - Surface permeability → fluid absorption



Fundamental Components

- Fluid Properties
 - Viscosity
 - Used in flow equations
 - “Gooier” fluids flow slower
 - Density
 - Used in flow equations
 - “Heavier” have higher mass → energy
 - Vapor Pressure
 - Used in evaporation equations
 - Classifies spill as “pool” or “plume”

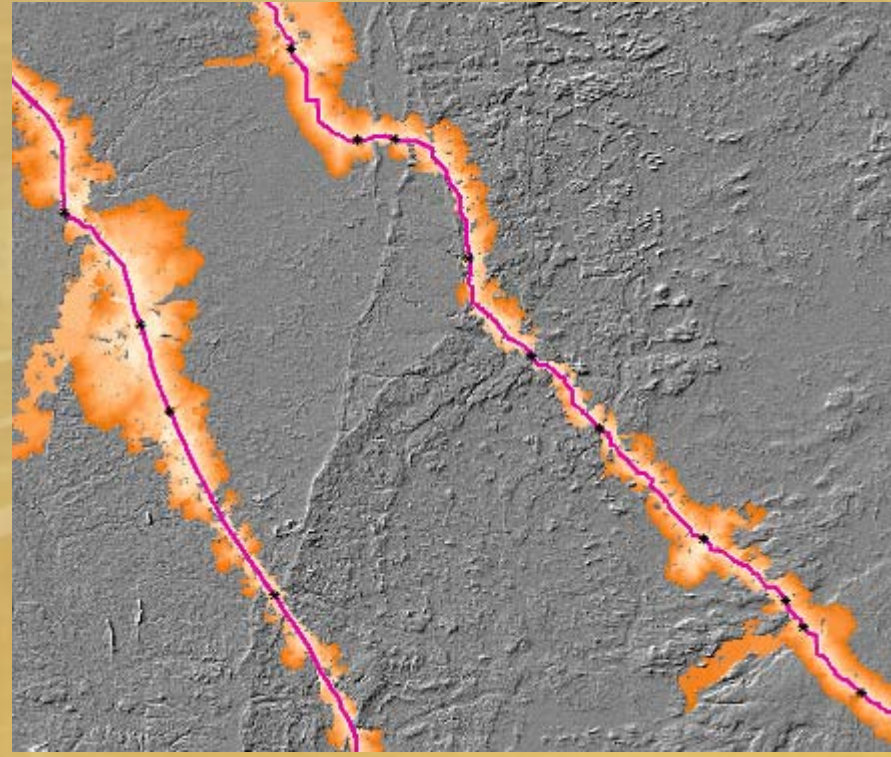
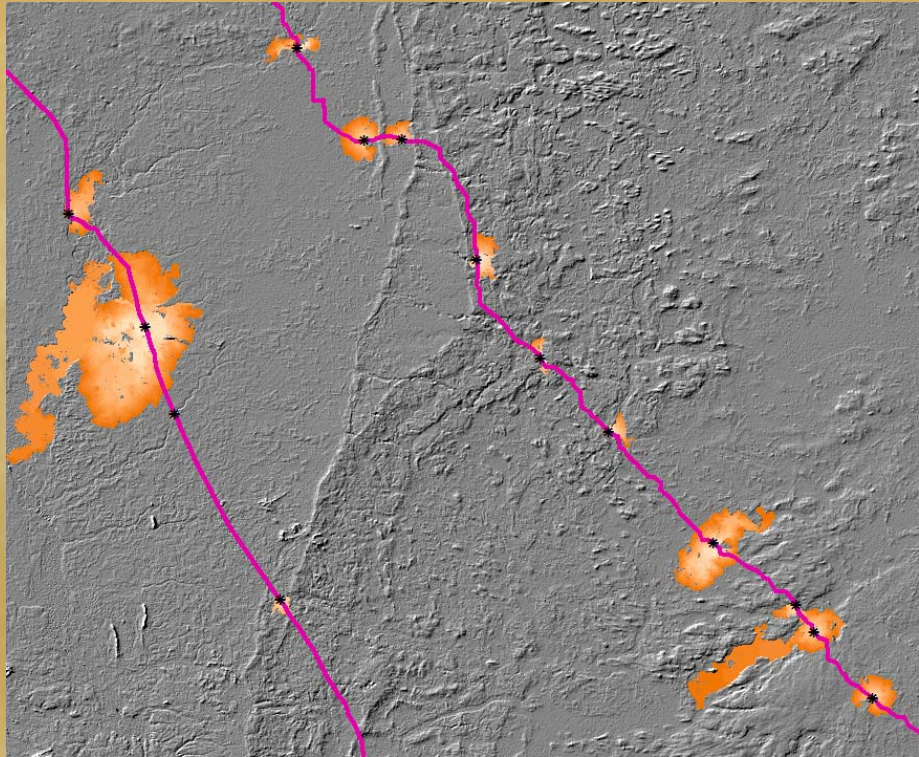


Results and Reporting

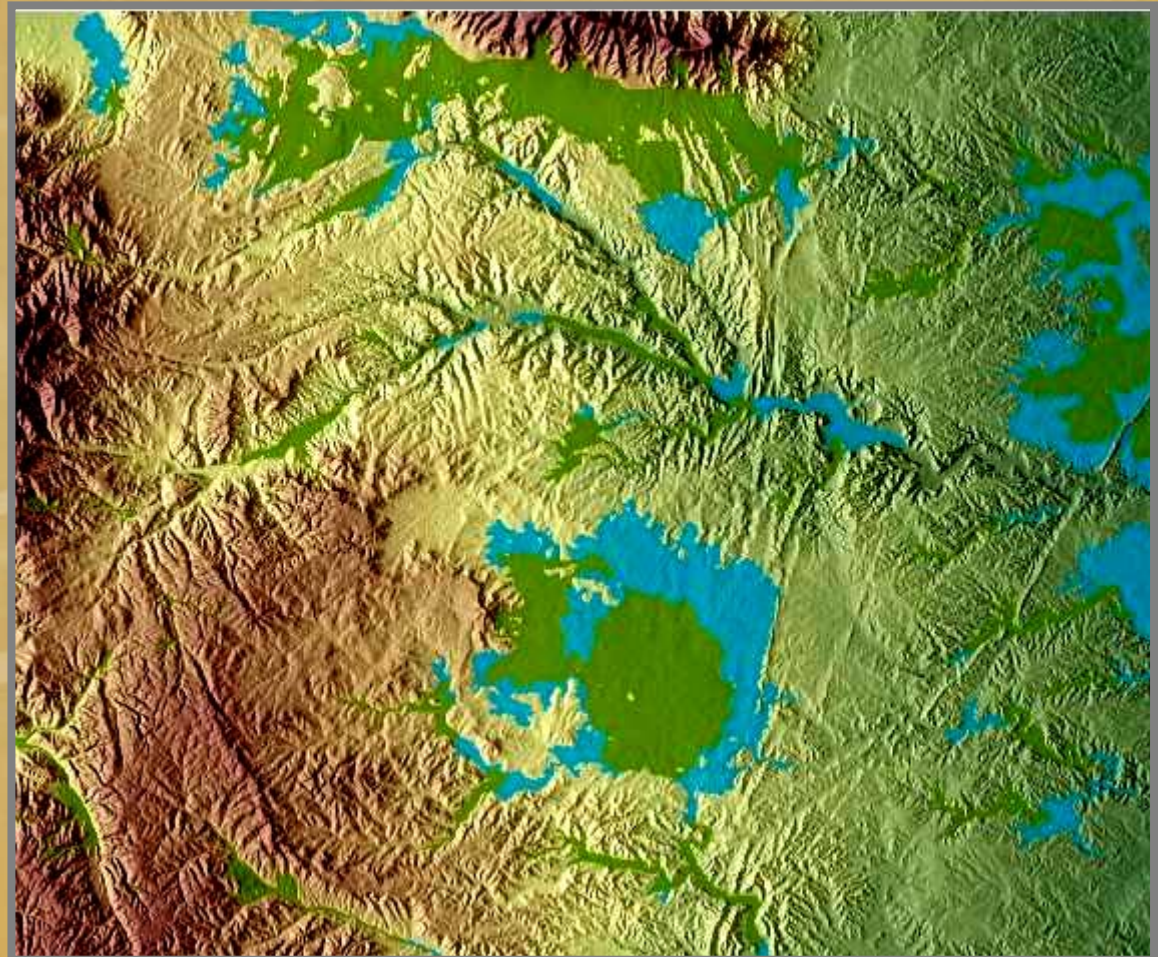
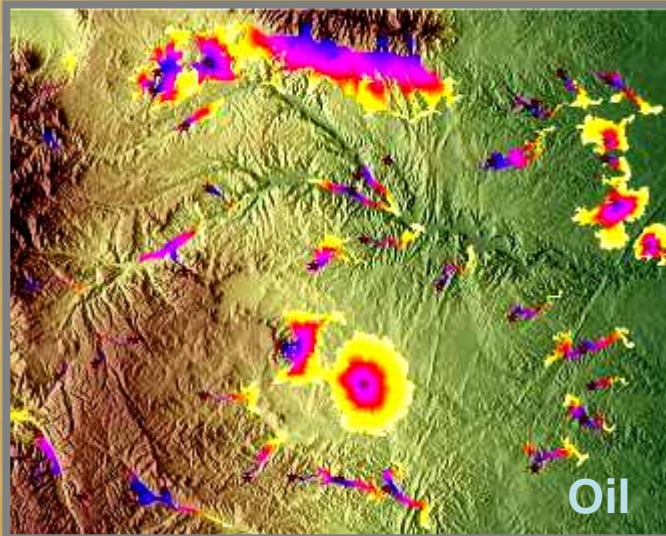
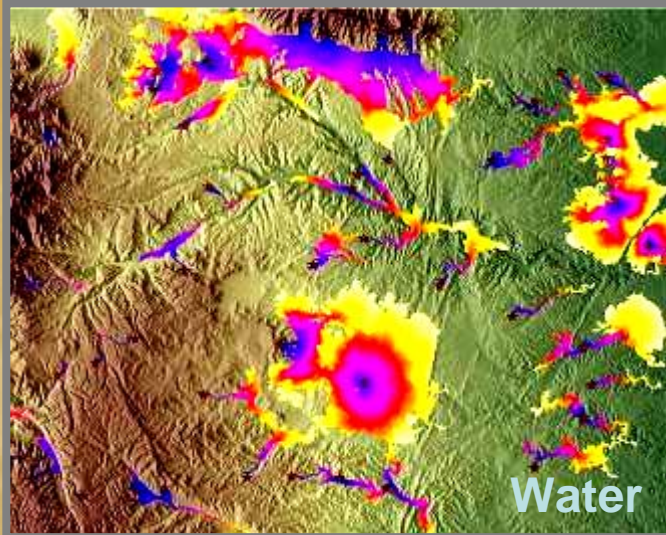
Overland Flow Modeling



Results: Linear vs. Point Source

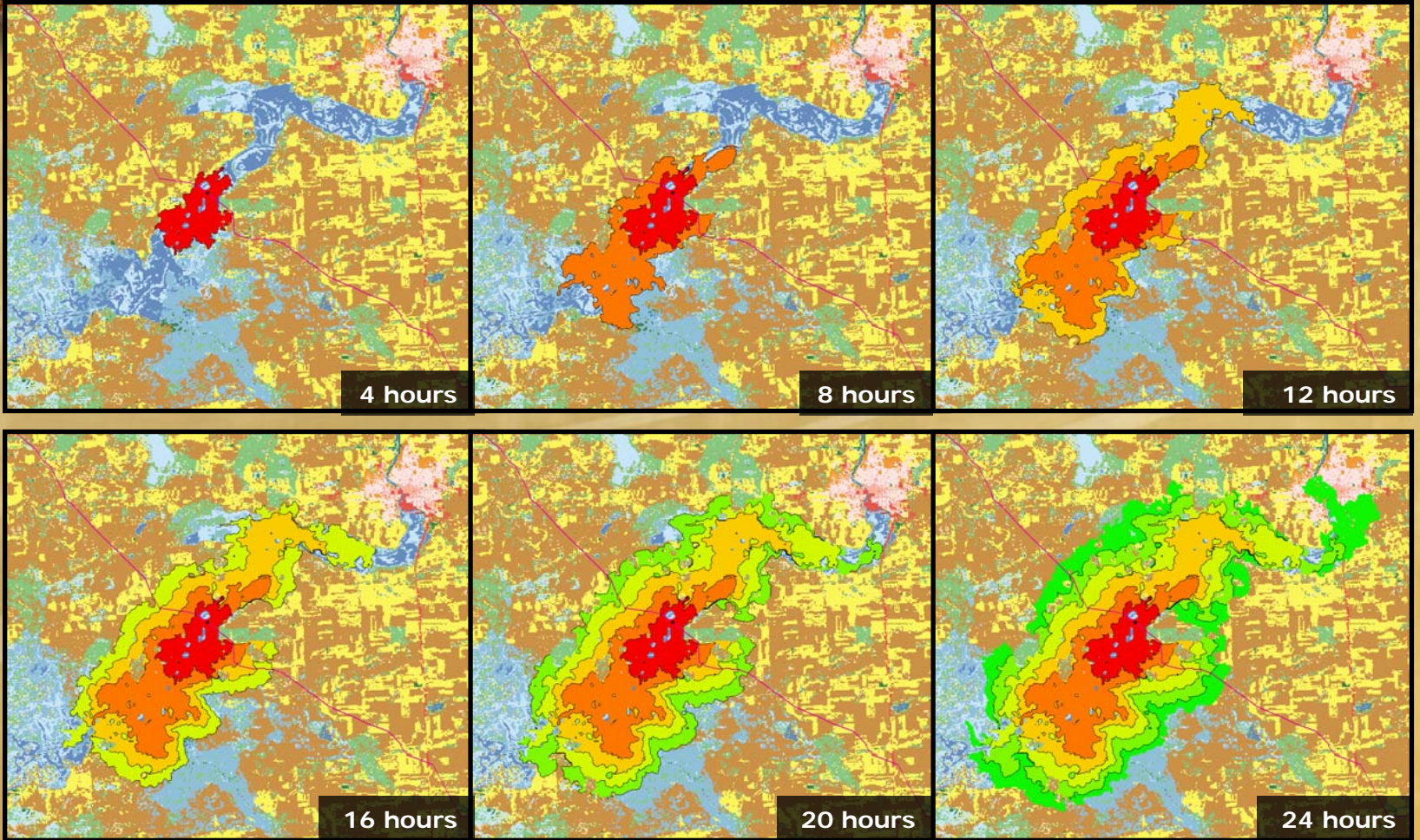


Results: Fluid Properties





Results: Temporal





Industry Response

Overland Flow Modeling





Industry Response

■ Modeling Approach #1

■ Approach

Downward flow determined by steepest path

■ Model Limitations

Single Path

Data errors – DEM pits

Output

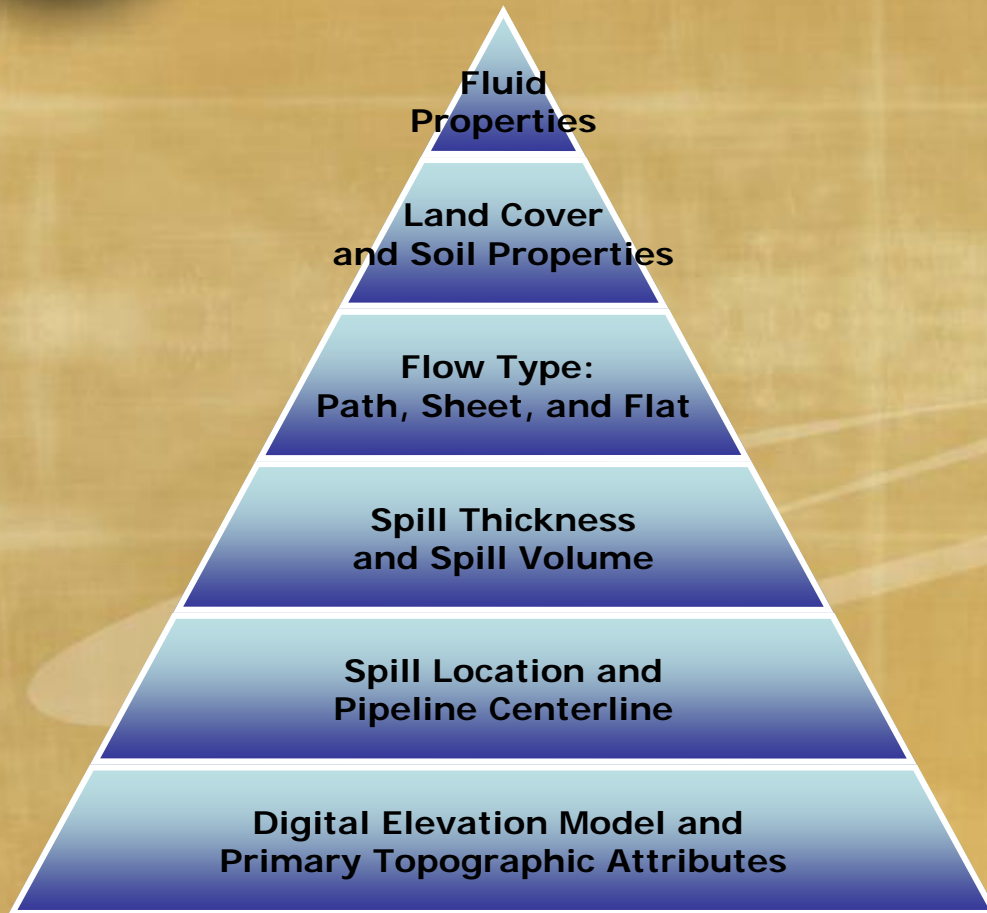
■ Components of Comprehensive Model

16	20	22
22	23	14
13	17	14

An arrow points from the cell containing the value 23 to the cell containing the value 13, indicating a downward flow path.



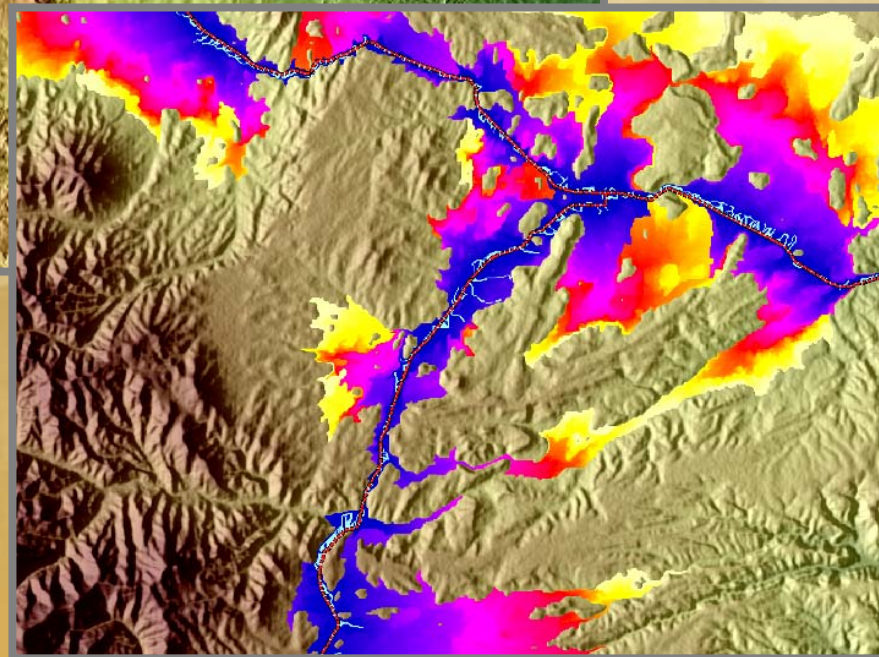
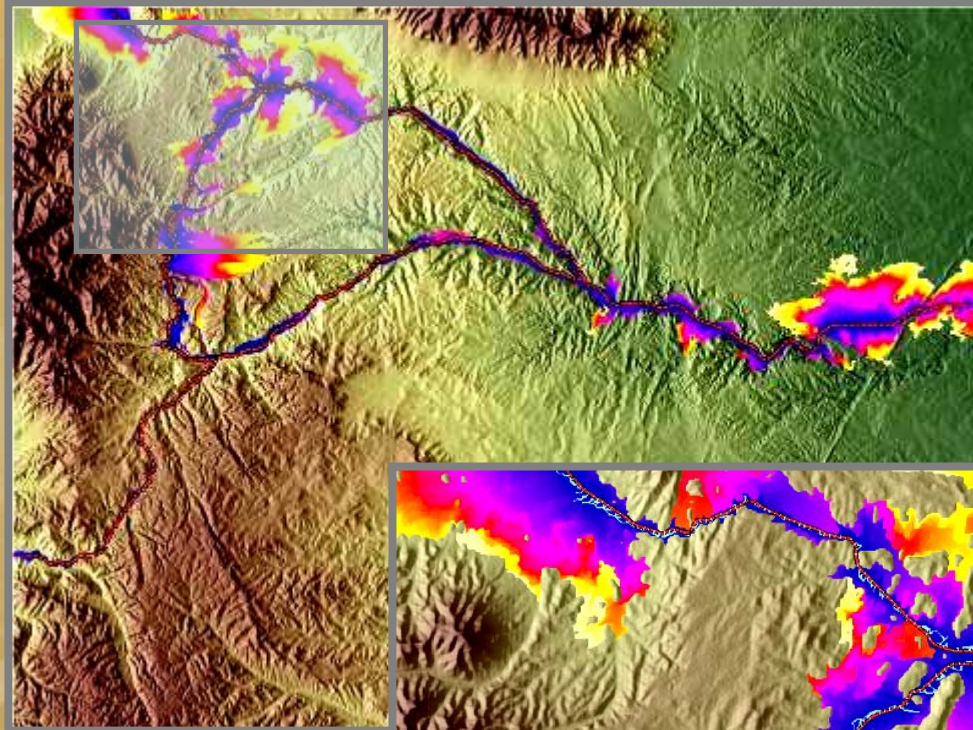
Industry Response



#1	Comp
	Y
	Y
	Y
	Y
Y	Y
Y	Y



Modeling Comparison





Industry Response

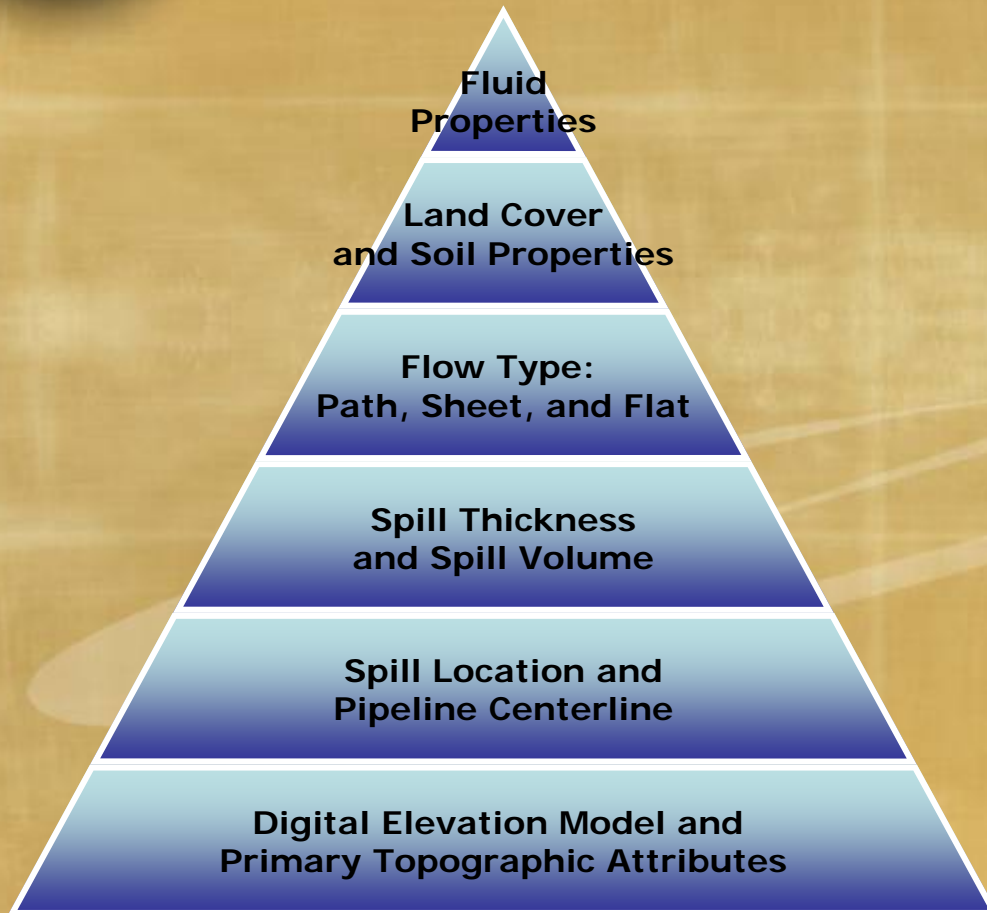
- Modeling Approach #2

- Approach
 - Potential flow areas
 - Spill Tracking
- Comparison to Comprehensive Model
 - Similar Inputs
 - Different Methods and Outputs

- Example: Ground Absorption



Industry Response



#2	#1	Comp
Y		Y
		Y
		Y
Y		Y
Y	Y	Y
Y	Y	Y



Industry Response

■ Modeling Approach #3

- Approach

 - Closest Resemblance to Comprehensive Model
 - Accounts for flow type

- Model Limitations

 - "pooling"

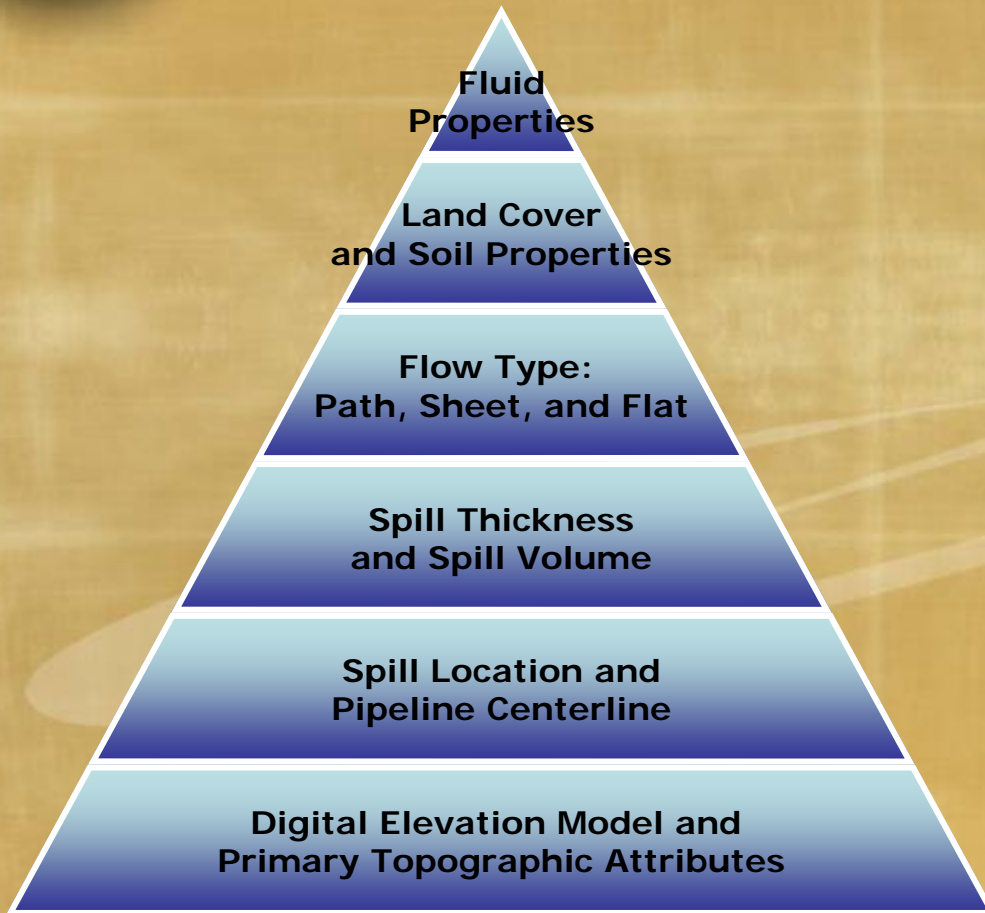
- Components of Comprehensive Model

 - Similar Inputs

 - Major Difference – Surface Flow Resistance Factors



Industry Response



#3	#2	#1	C
Y	Y		Y
N/ Y			Y
Y			Y
Y	Y		Y
Y	Y	Y	Y
Y	Y	Y	Y



Final Thoughts

Overland Flow Modeling