GROUND WATER VULNERABILITY
An Overview of Concepts and Assessment Methodologies
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A resource at risk!!

DEFINITIONS OF GW SENSITIVITY / VULNERABILITY

- Foster (1987)
  - Aquifer Pollution Vulnerability
  - GW Pollution Risk

- Aller (1987)
  - Groundwater Pollution Potential

- US GAO (1991)
  - Hydrogeologic Vulnerability
  - Total Vulnerability

- Pettyjohn (1991)
  - Aquifer Vulnerability
  - Aquifer Sensitivity

  - Aquifer Sensitivity
  - GW Vulnerability

- NRC (1993)
  - Intrinsic GW Vulnerability
  - Specific GW Vulnerability

- US EPA Source Water Protection Program
  - Susceptibility

- Well vulnerability
  - Considers physical condition of well
MAIN CONCEPTS

➢ **GW Sensitivity** — the potential for groundwater to become contaminated based on intrinsic hydrogeologic characteristics. Sensitivity is not dependent on land use practices or contaminant properties.

➢ **GW Vulnerability** — the relative ease with which a contaminant can migrate to groundwater under a given set of land use practices, contaminant properties, and sensitivity conditions.

➢ **All groundwater is vulnerable!!**

➢ **Uncertainty is inherent!!**
DEFINITIONS OF GW SENSITIVITY / VULNERABILITY

- **Foster**
  - Aquifer Pollution Vulnerability (S)
- **Aller**
  - Groundwater Pollution Potential (S)
- **US GAO**
  - Hydrogeologic Vulnerability (S)
  - Total Vulnerability (V)
- **Pettyjohn**
  - Aquifer Vulnerability (S)
  - Aquifer Sensitivity (V)
- **US EPA**
  - Aquifer Sensitivity (S)
  - GW Vulnerability (V)
- **NRC**
  - Intrinsic GW Vulnerability (S)
  - Specific GW Vulnerability (V)
- **US EPA Source Water Protection Program**
  - Susceptibility (V)
SENSITIVITY METHODS

- Hydrogeologic Settings Classification Methods
  - Delineate / map subareas (hydrogeologic settings) within an area of assessment that have similar hydrogeologic characteristics

- Scoring Methods
  - Assign numerical ranking or rating to hydrogeologic settings with different sensitivity characteristics
  - Can also use without mapping hydrogeologic settings

- GIS based composite / derivative maps using descriptive / quantitative information
  - Hydrogeologic / hydraulic characteristics of soil, vadose zone and aquifer
  - Can be weighted for specific parameters
GW Sensitivity
Albany County, WY

*Based on*
- Topography
- Recharge
- Soil
- Geology
- Vadose zone properties
- Aquifer hydraulic properties
VULNERABILITY METHODS

- Qualitative contaminant information coupled with sensitivity
  - Areas of use
  - Toxicty rating
  - Method of use
  - Chemical properties
  - Other land use criteria
Groundwater Sensitivity / Vulnerability
Albany County, WY

Groundwater Sensitivity

Groundwater Vulnerability to Pesticides

- High
- Med High
- Medium
- Med Low
- Low
Statewide GW Sensitivity & Vulnerability Maps

Sensitivity – shallow groundwater - Illinois

GROUNDWATER VULNERABILITY – PESTICIDES - WYOMING
VULNERABILITY METHODS

- Process –based simulation models
  
  ▪ Simulate some combination of biological, physical, chemical processes that control movement of water, natural constituents & contaminants from land surface thru the soil and vadose zone to and thru the saturated zone
  
  ▪ Categories - Root zone, Vadose zone, saturated zone
  
  ▪ Product - Prediction of rates of water and contaminant movement as a function of location and time
    ▪ Zone of contribution
    ▪ Contributing recharge areas
    ▪ Used to assign relative risk
  
  ▪ TANC – USGS NAWQA – Transport of Natural and Anthropogenic Contaminants
VULNERABILITY METHODS

- **Statistical methods**
  - Provide estimates of the likelihood contamination based on the relationship of soil, hydrogeologic and/or anthropogenic factors to known or calculated contaminant distributions
  - **Statistical techniques**
    - Discriminant analysis
    - Regression analysis
    - Spatial estimation
  - Appropriate for wells not areas
EXAMPLE
VULNERABILITY OF PWS WELL TO MICROBIAL CONTAMINATION

Results of prior microbe monitoring

- Positive
  - High Vulnerability

- Negative /unknown
  - Evaluate contaminant sources
    - Low source risk
      - Low Vulnerability
    - High / unknown
      - Evaluate GW Sensitivity
        - High sensitivity
          - High Vulnerability
        - Low Sensitivity
          - Evaluate well construction
            - Acceptable
              - Low Vulnerability
            - Unacceptable
              - High Vulnerability
SCALE OF VULNERABILITY ASSESSMENT

- Scale is dependent on proposed use of assessment
- Political boundaries
  - Counties
  - States
- Hydrogeologic boundaries
  - Aquifers
  - Watersheds
- Well / wellfield
### Appropriate Scale of GW Sensitivity / Vulnerability Assessments (ASTM D 6030)

<table>
<thead>
<tr>
<th>METHOD</th>
<th>REGIONAL</th>
<th>COUNTY / AQUIFER</th>
<th>FIELD / WELLFIELD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
<td>V</td>
<td>S</td>
</tr>
<tr>
<td>Hydrg. Settings / no scoring</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Hydrg. Settings / with scoring</td>
<td>5</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>Scoring / without hydrog. settings</td>
<td>1</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Root zone models</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Vadose zone models</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Saturated zone models</td>
<td>3</td>
<td>1</td>
<td>4</td>
</tr>
</tbody>
</table>

S - sensitivity  V – vulnerability  1- least appropriate  5- most appropriate
USES FOR GW VULNERABILITY ASSESSMENTS

➢ GW resource management
  ▪ WHP/SWP
  ▪ GW discharge programs
  ▪ Non – point source programs
  ▪ GW classification

➢ Land use planning

➢ Prioritize remediation

➢ Facility siting
THE VULNERABILITY ASSESSMENT PROCESS

PURPOSE OF VULNERABILITY ASSESSMENT
- Education
- Policy analysis
- Program management
- Land use decisions

APPROACHES
- Method selection
- Uncertainty

DATA AND DATA BASES
- Topography
- Soils
- Hydrogeology
- Precipitation
- Land cover / land use

GW MANAGEMENT ACTIONS
- Land use controls
- Well siting
- Prioritize remediation
La Plata Cy, CO Groundwater Vulnerability Study

Issue – increased housing density along Animas River – w / ISDS use
GW Vulnerability – Nitrate
La Plata Cy, CO

Ground Water Nitrate/Nitrite Levels

Area A

- Sampled Wells
- Wells
- Leach fields
- Parcels
- Drastic Ratings

Drastic Ratings

0.94
0.00
0.45
0.00
0.00
0.00
0.11
0.00
0.00
0.00
0.00
2.40
...  
2.40

Area C
Area B

Animas Valley La Plata, County
EPA

Areas of one acre or less were grouped with neighboring polygons

Nitrates/Nitrates levels are reported in mg/l

Septic Siting Suitability Rating

Area A

- Leach fields
- Parcels
- Septic Ratings

Septic Ratings

1
2
4
6
10

Area C
Area B
Area A

Animas Valley La Plata, County
EPA

Areas of one acre or less were grouped with neighboring polygons

The leach fields shown here, were acquire as part of the 1995 ‘Ground Water/Septic Study’.
The Septic Rating was derived from the Soil data.
THREE IMPORTANT REFERENCES

- Ground Water Vulnerability Assessment – Contaminant Potential Under Conditions of Uncertainty - National Research Council, 1993


Thank you

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