Prioritizing Aquifer Monitoring in North Dakota: A Nitrate Vulnerability Assessment Tool

Scott F. Korom

Barr Engineering Company

Outline:

- **The nitrate issue.**
- **What is denitrification?**
- **DRASTIC: a common assessment method.**
- **Results from our denitrification network.**
- **Defining feature of our nitrate vulnerability assessment tool.**

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- **“Rising levels of nitrate in Minnesota drinking water are a costly challenge for homeowners” (9/6/15, St. Paul Pioneer Press).**

- **“Three out of four Minnesotans get their drinking water from groundwater,” (MPCA).**

- **“Gov. Mark Dayton struggles to reconcile desire for clean water and a strong farm economy,” (StarTribune 2/25/2016).**

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- **Last August: “I refuse to believe we have to accept this kind of contamination because it’s farm country. We don’t accept it in mining country. We don’t accept it in the metropolitan area. We are not just going to turn our backs and say we are going to provide free rein to people even if they are doing really important work. If that makes me an enemy of agriculture, I regret that, but there is too much at stake here,” (Gov. Dayton, 8/15).**

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- **“Gov. Mark Dayton struggles to reconcile desire for clean water and a strong farm economy,” (StarTribune 2/25/2016).**
- **Last August: “I refuse to believe we have to accept this kind of contamination because it’s farm country. We don’t accept it in mining country. We don’t accept it in the metropolitan area. We are not just going to turn our backs and say we are going to provide free rein to people even if they are doing really important work. If that makes me an enemy of agriculture, I regret that, but there is too much at stake here,” (Gov. Dayton, 8/15).**
- **Last week, he had softened his tone, “Agribusiness is the mainstay of our economy.”**

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“Complex water problems will require everyone’s efforts,” Gov. Dayton (StarTribune 2/27/2016).

“High Nitrate Levels Plague 60 Iowa Cities, Data Show” (7/7/15, Des Moines Register).

IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF IOWA
WESTERN DIVISION

BOARD OF WATER WORKS TRUSTEES OF THE CITY OF DES MOINES, IOWA, Plaintiff vs. SAC COUNTY BOARD OF SUPERVISORS AS TRUSTEES OF DRAINAGE DISTRICTS 32, 42, 65, 79, 81, 83, 86, and CALHOUN COUNTY BOARD OF SUPERVISORS and SAC COUNTY BOARD OF SUPERVISORS AS JOINT TRUSTEES OF DRAINAGE DISTRICTS 2 AND 51 and BUENA VISTA COUNTY BOARD OF SUPERVISORS and SAC COUNTY BOARD OF SUPERVISORS AS JOINT TRUSTEES OF DRAINAGE DISTRICTS 19 and 26 and DRAINAGE DISTRICTS 64 and 105. Defendants.	NO.: 5:15-cv-04020 **COMPLAINT** Filed 3/16/2015

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IN THE UNITED STATES DISTRICT COURT
FOR THE NORTHERN DISTRICT OF IOWA
WESTERN DIVISION

BOARD OF WATER WORKS TRUSTEES OF THE CITY OF DES MOINES, IOWA,

Plaintiff

vs.

SAC COUNTY BOARD OF SUPERVISORS AS TRUSTEES OF DRAINAGE DISTRICTS 32, 42, 65, 79, 81, 83, 86, and CALHOUN COUNTY BOARD OF SUPERVISORS and SAC COUNTY BOARD OF SUPERVISORS AS JOINT TRUSTEES OF DRAINAGE DISTRICTS 2 AND 51 and BUENA VISTA COUNTY BOARD OF SUPERVISORS and SAC COUNTY BOARD OF SUPERVISORS AS JOINT TRUSTEES OF DRAINAGE DISTRICTS 19 and 26 and DRAINAGE DISTRICTS 64 and 105.

Defendants.

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"Des Moines has declared war on rural Iowa," Gov. Branstad, 1/13/15.

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Defendants.

"The key legal claim is the drainage districts. . . artificially collect, convey and discharge polluted groundwater into Iowa's rivers and streams imposing costs on the DMWW and others who use the water. This makes the districts point sources under the CWA which need permits to discharge – no different than the discharge coming out of a pipe at a municipal sewage treatment plant or a private factory," (N. Hamilton, 3/5/15).

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Defendants.

"146. Under natural hydrologic conditions very little nitrate is discharged from groundwater to streams, but artificial subsurface drainage short-circuits the natural conditions that otherwise keep nitrate from entering streams and rivers."

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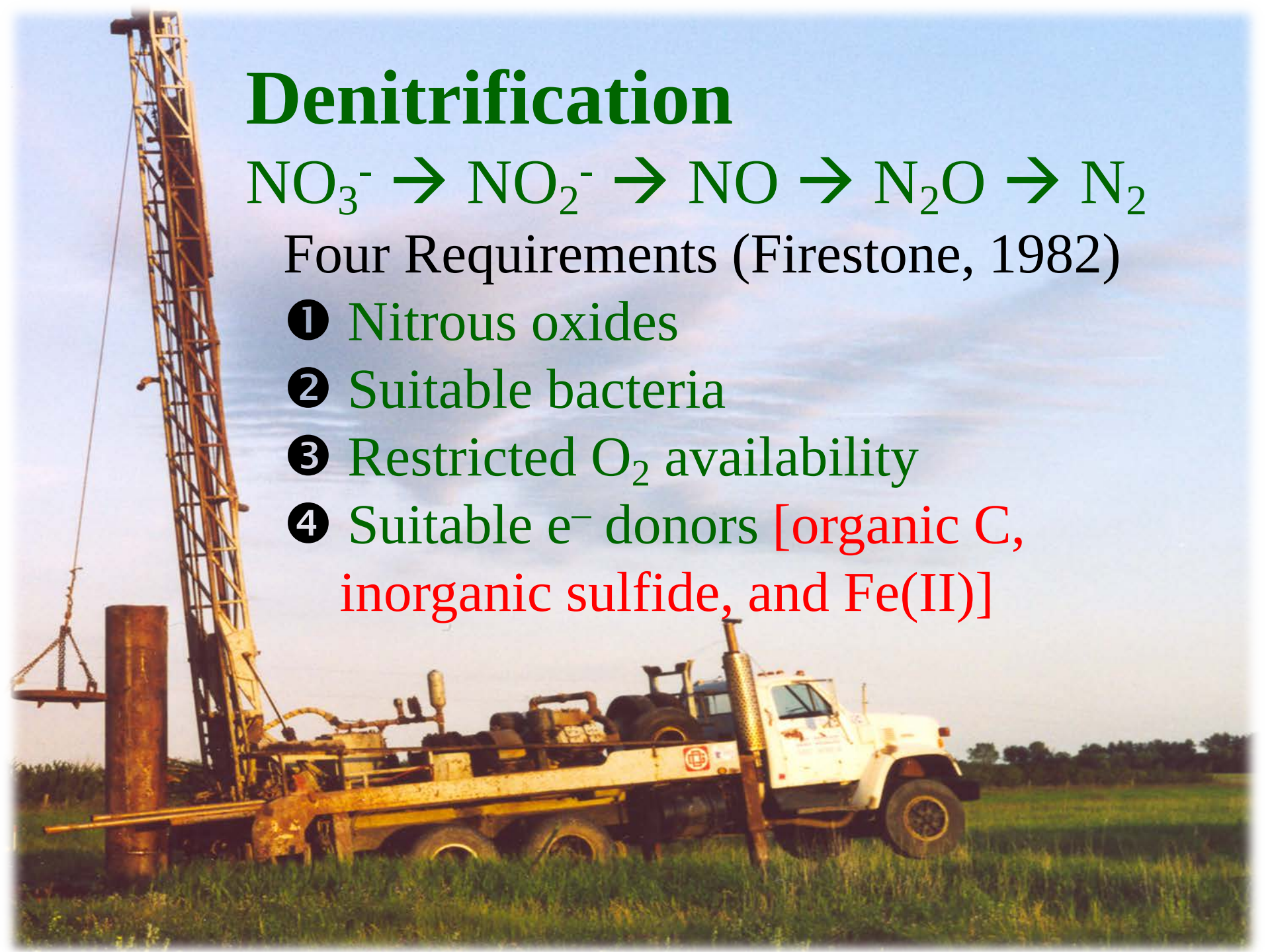


Denitrification

$NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$

Four Requirements (Firestone, 1982)

1. Nitrous oxides
2. Suitable bacteria
3. Restricted O_2 availability
4. Suitable e^- donors [organic C, inorganic sulfide, and Fe(II)]

D R A S T I C (Aller et al., 1987)

D – Depth to water

R – Recharge (Net)

A – Aquifer Media

S – Soil Media

T – Topography (Slope)

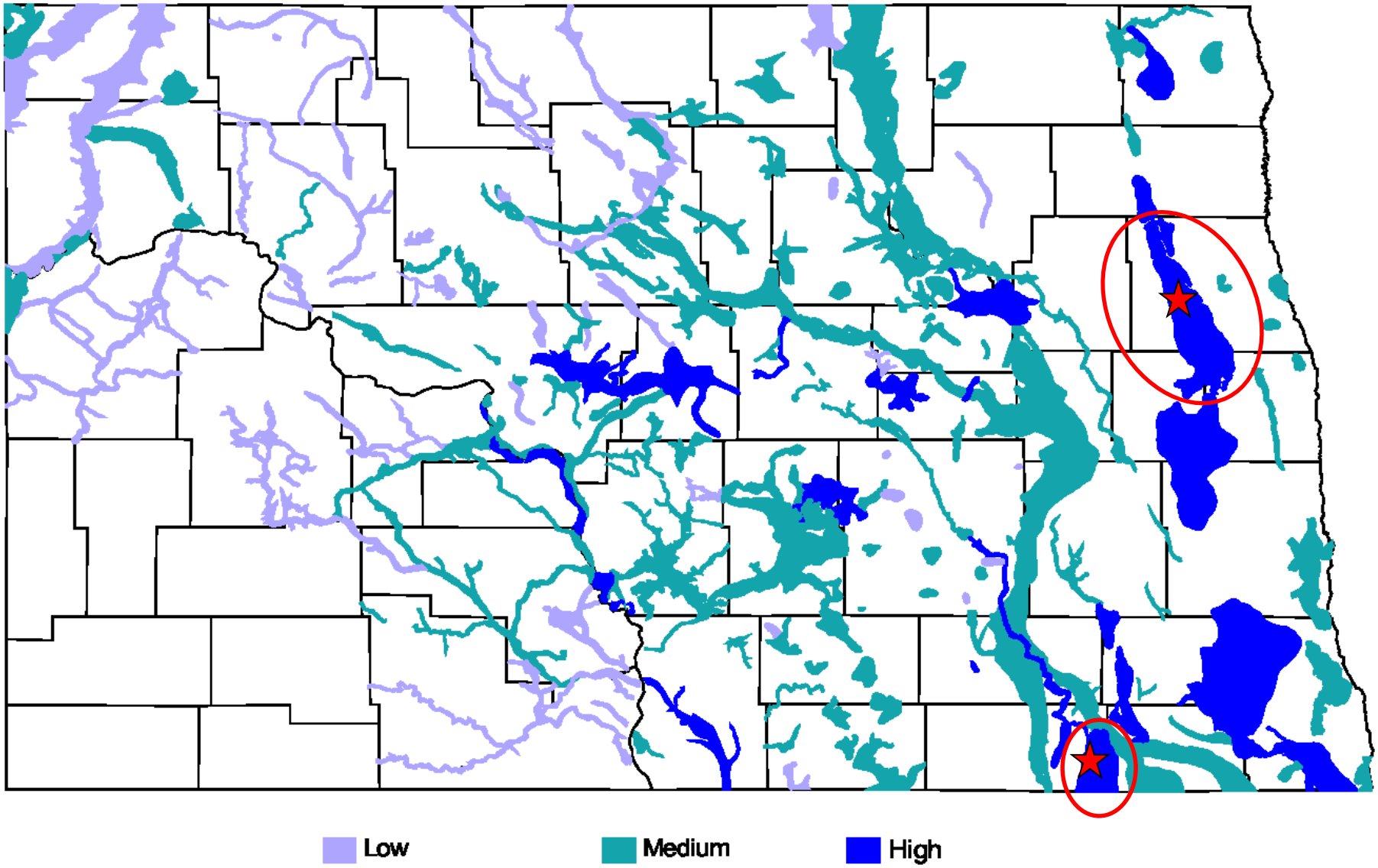
I – Impact of the Vadose Zone Media

C – Conductivity (Hydraulic) of the Aquifer

US EPA

Standardized System

Weighted sum of hydrologic factors that are related to the movement of pollutants from the ground surface to aquifers.



(NDDH, 1999)

Sources and Processes Affecting the Distribution of Dissolved Sulfate in the Elk Valley Aquifer in Grand Forks County, Eastern North Dakota

W.M. Schuh et al. (2006)
Water Resources Investigation No. 38
ND State Water Commission

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Sources and Processes Affecting the Distribution of Dissolved Sulfate in the Elk Valley Aquifer in Grand Forks County, Eastern North Dakota

"At measured nitrate loading rates there is sufficient pyrite-S in the EVA to support autotrophic denitrification for 11,000 to 175,000 years depending on location. These estimates assume non-preferential flow, and the gradual and uniform progression of nitrate."

W.M. Schuh et al. (2006)
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ND State Water Commission

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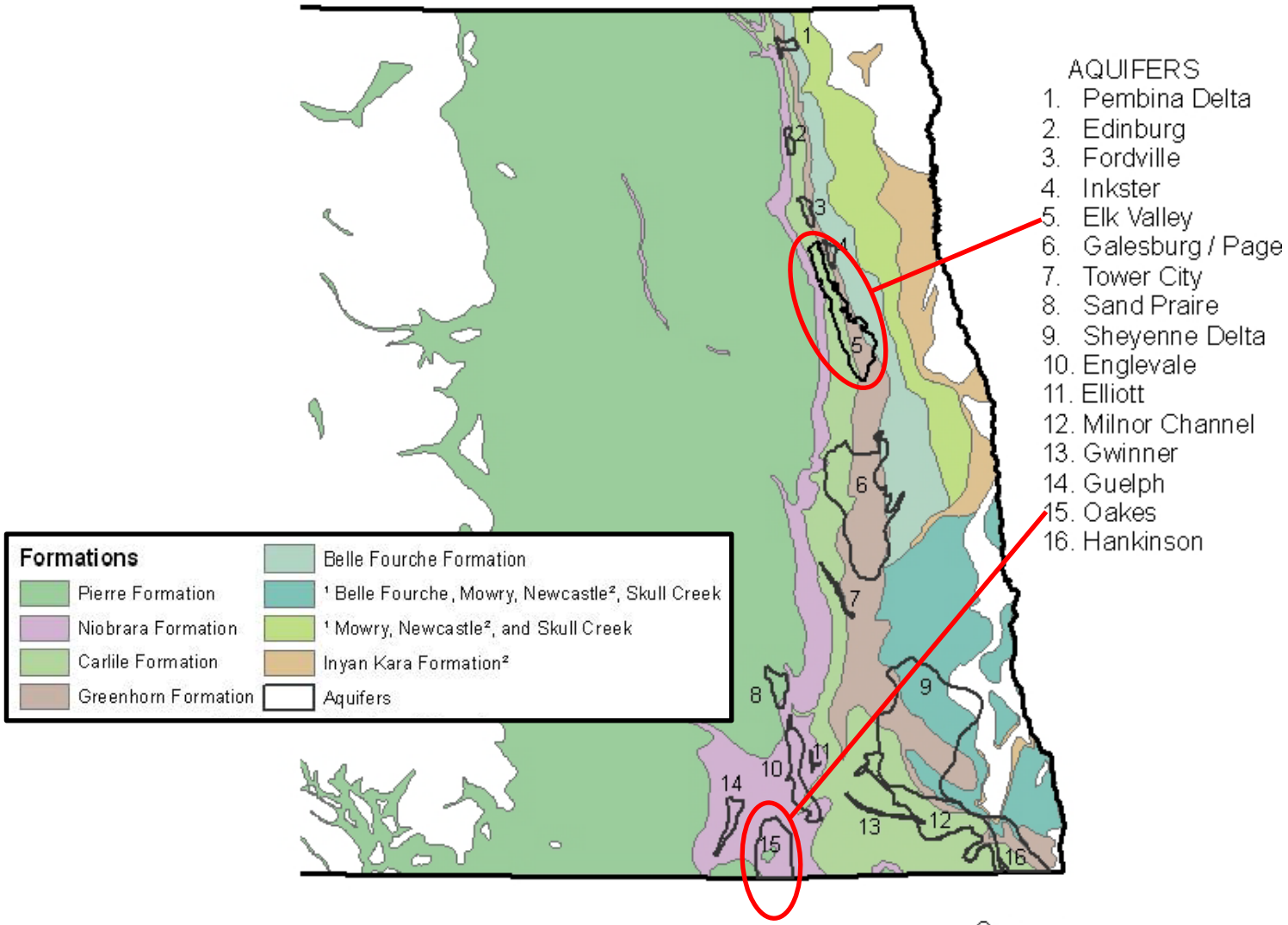
Bedrock Shale and Aquifers with High e^- Donor Potential in Eastern North Dakota



Adapted from Klapperich (2008)

Sources:
North Dakota State Water Commission
North Dakota GIS Hub
Clayton et al., 1980
Radig, 1997

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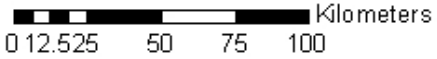
Bedrock Shale and Aquifers with High e^- Donor Potential in Eastern North Dakota

Dune sand from Pembina County (Anderson, 2011)

Adapted from Klapperich (2008)



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journal homepage: www.elsevier.com/locate/scitotenv

Modeling vulnerability of groundwater to pollution under future scenarios of climate change and biofuels-related land use change: A case study in North Dakota, USA

Ruopu Li *, James W. Merchant

Center for Advanced Land Management Information Technologies, School of Natural Resources, University of Nebraska-Lincoln, 3310 Holdrege Street, Lincoln, NE 68583-0973, United States

DRASTIC: "The model's simple formulation and the ease of integration with geographic information systems (GIC) make it well-suited for regional analyses of groundwater pollution potential. Another significant advantage of DRASTIC is it flexibility as it can be adapted to incorporate other factors, such as land use and land cover."

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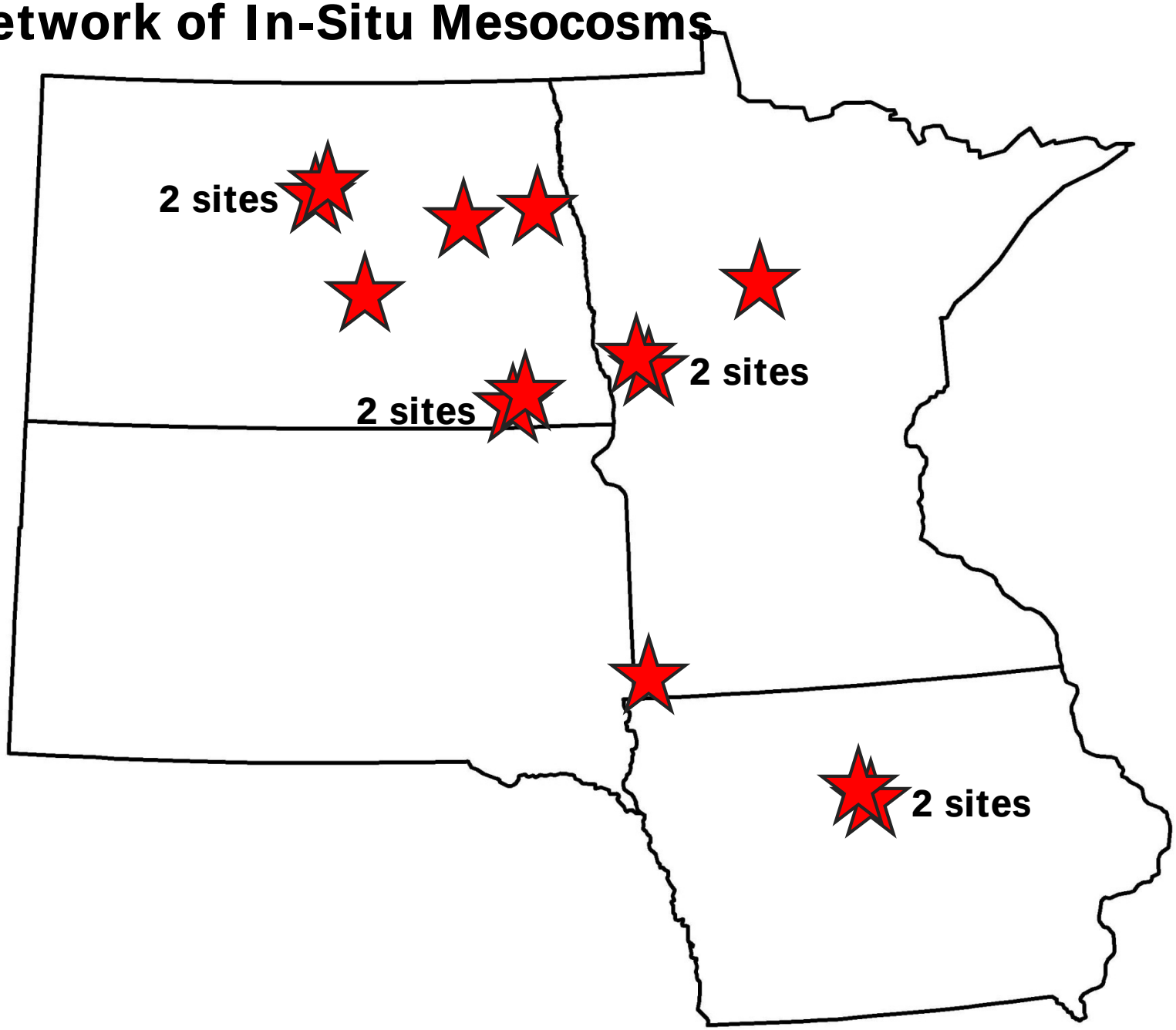
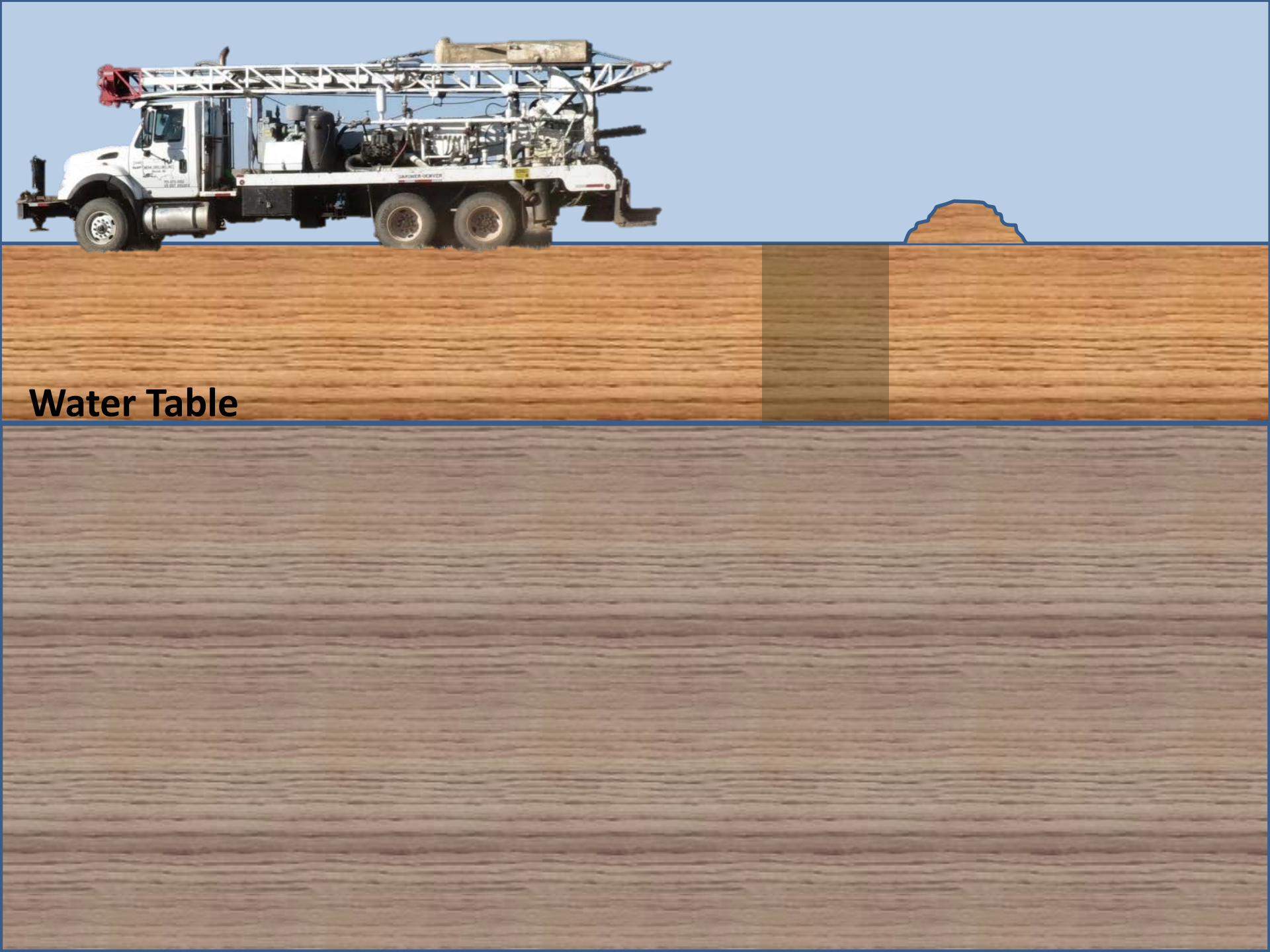
Network of In-Situ Mesocosms



Water Table

Water Table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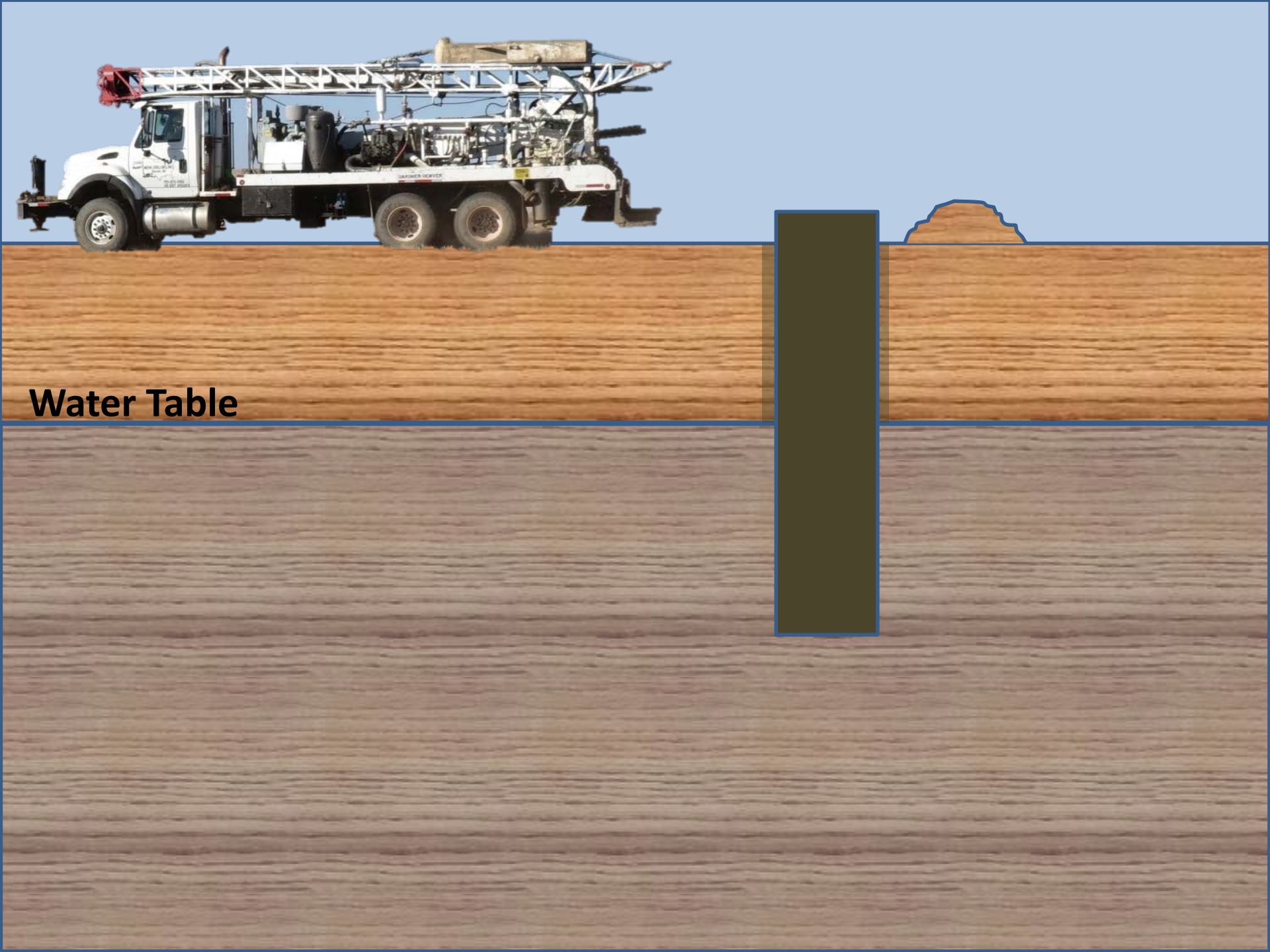
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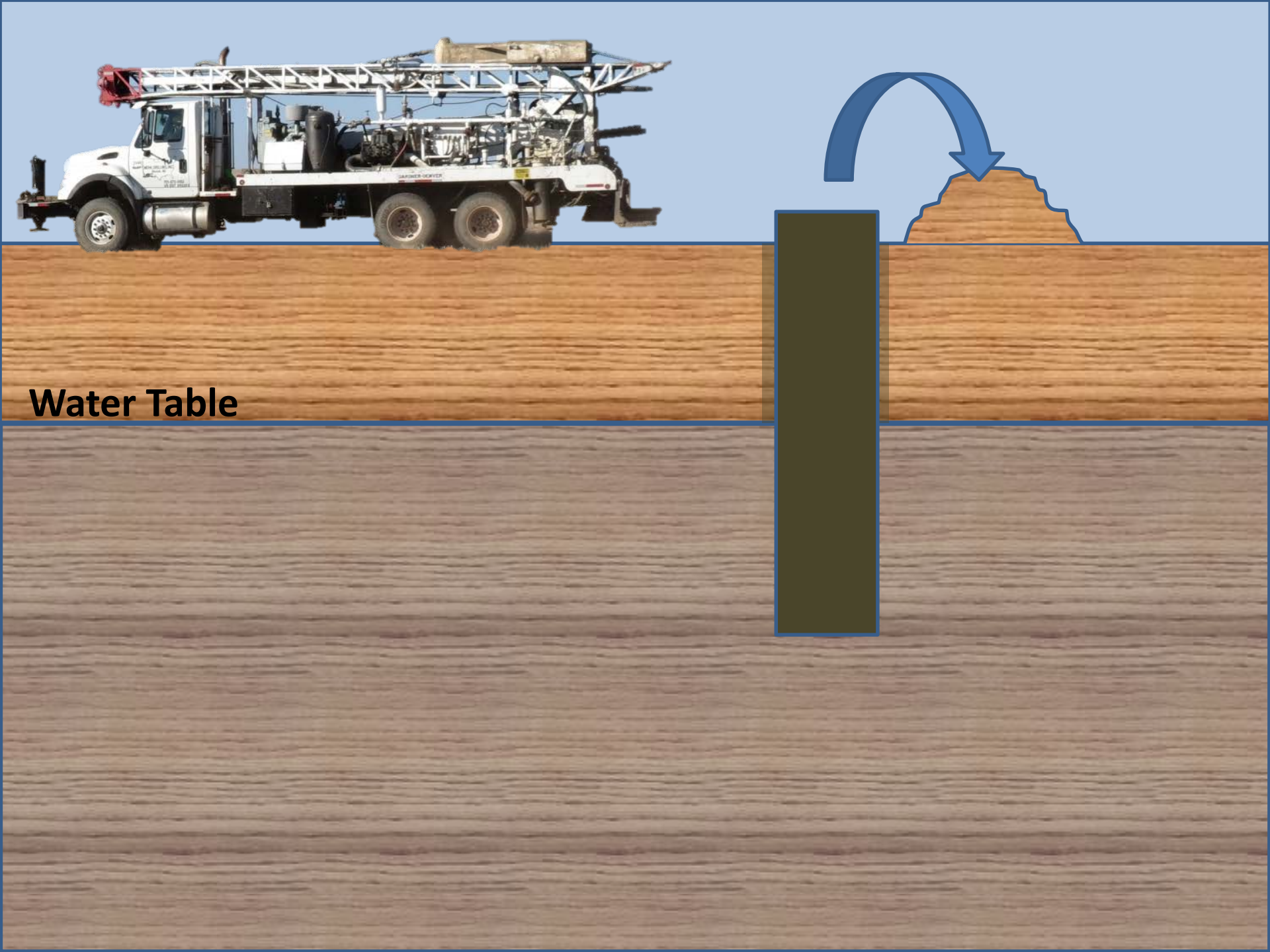
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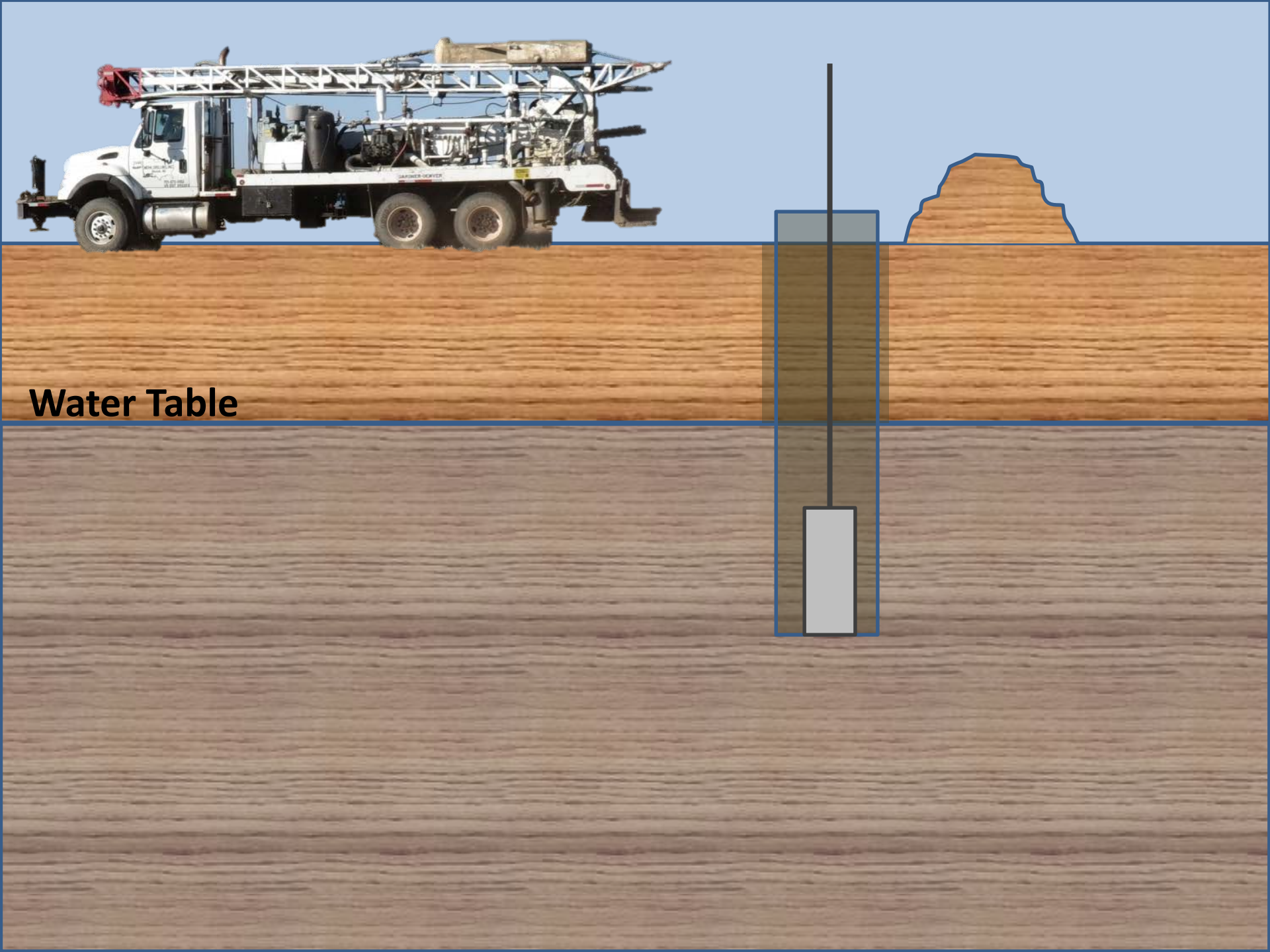
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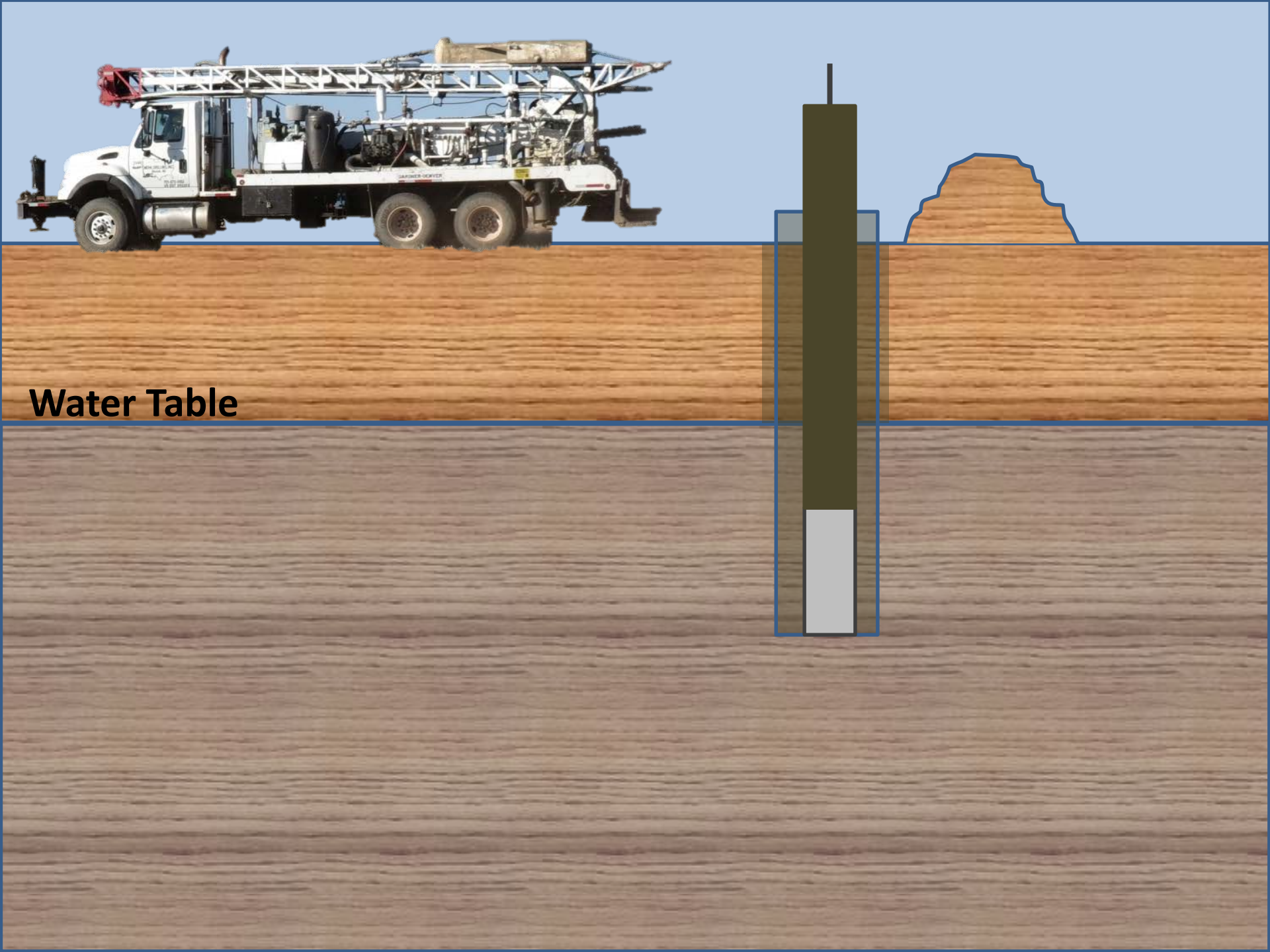
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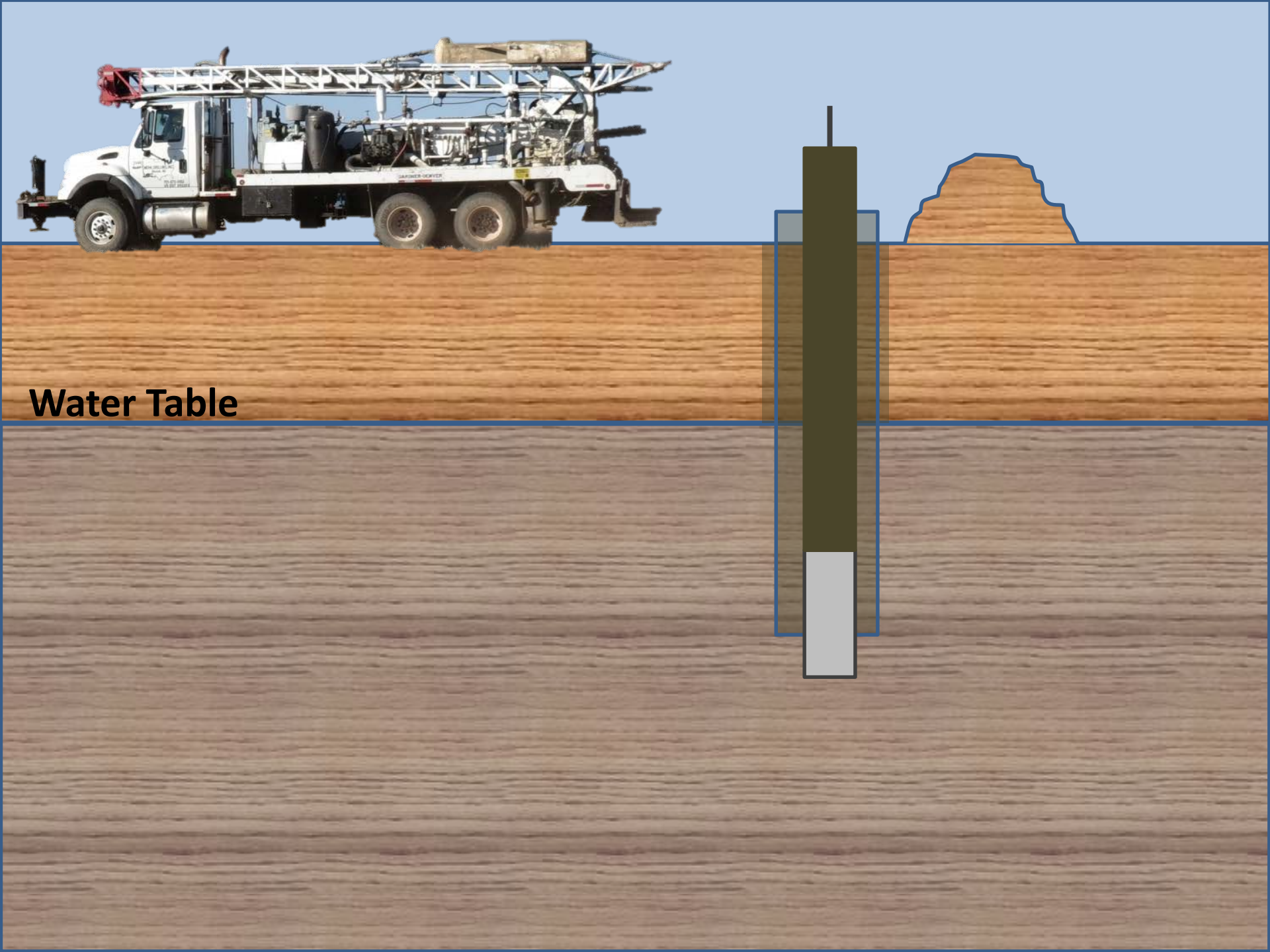
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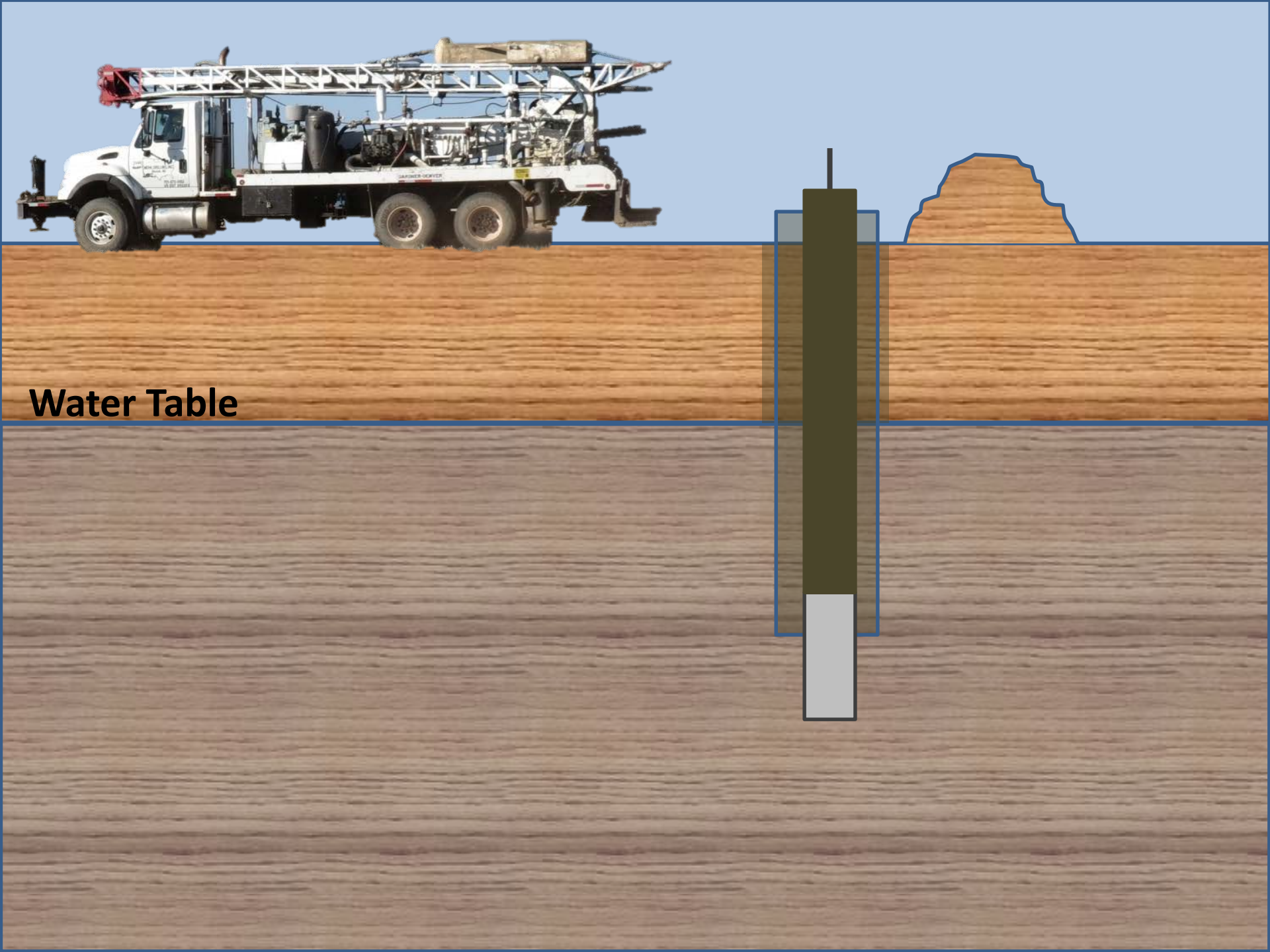
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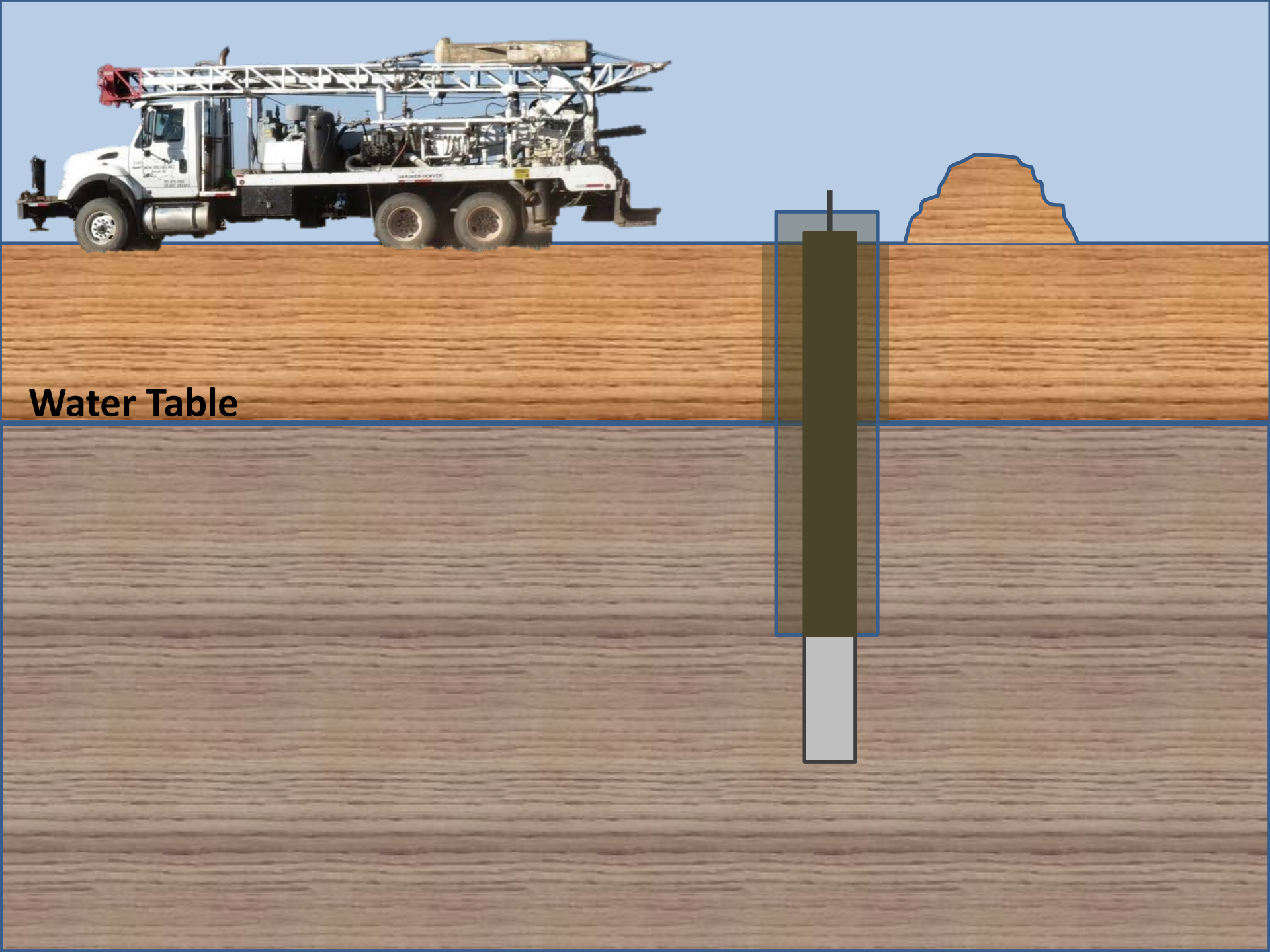
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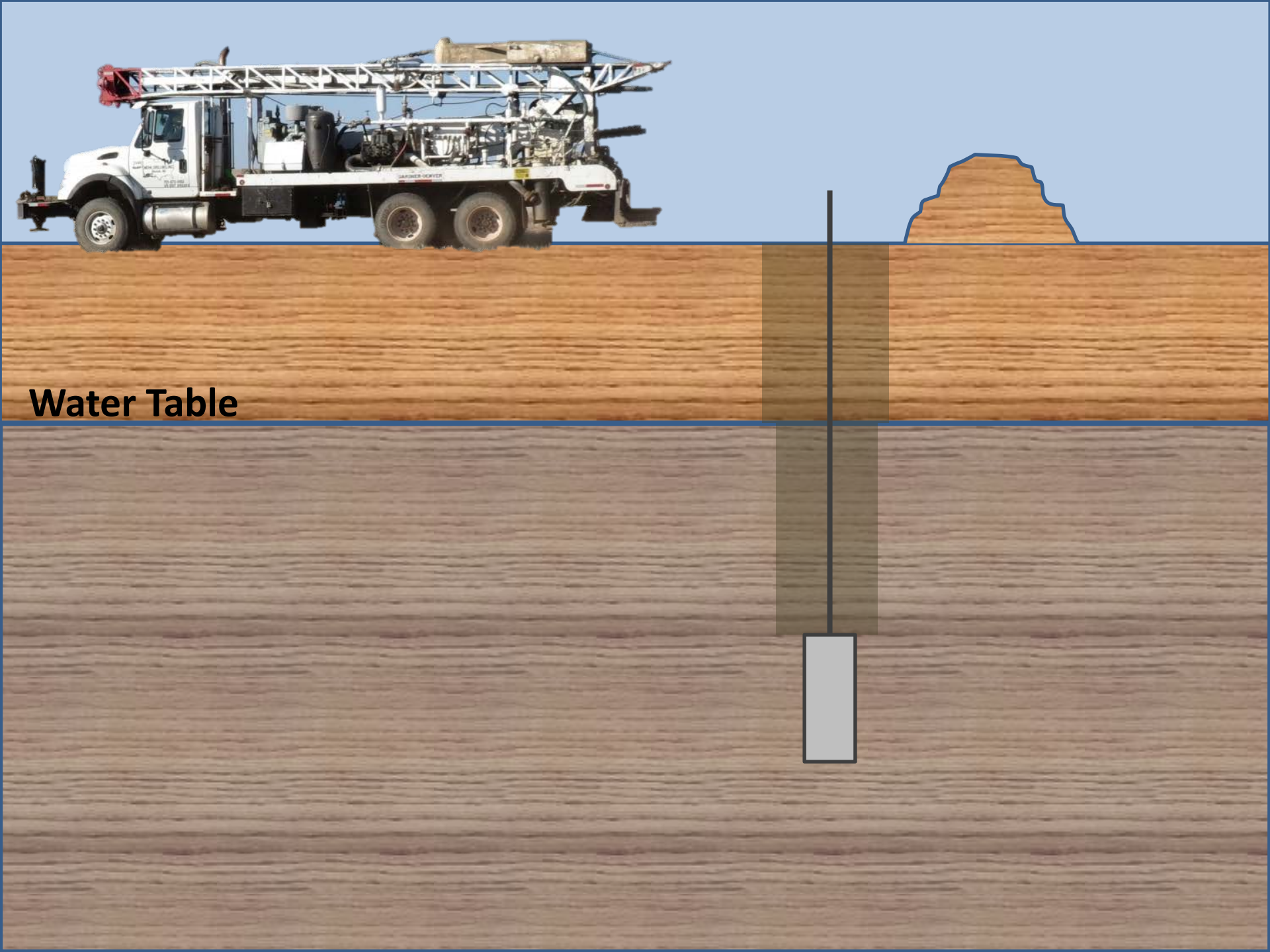
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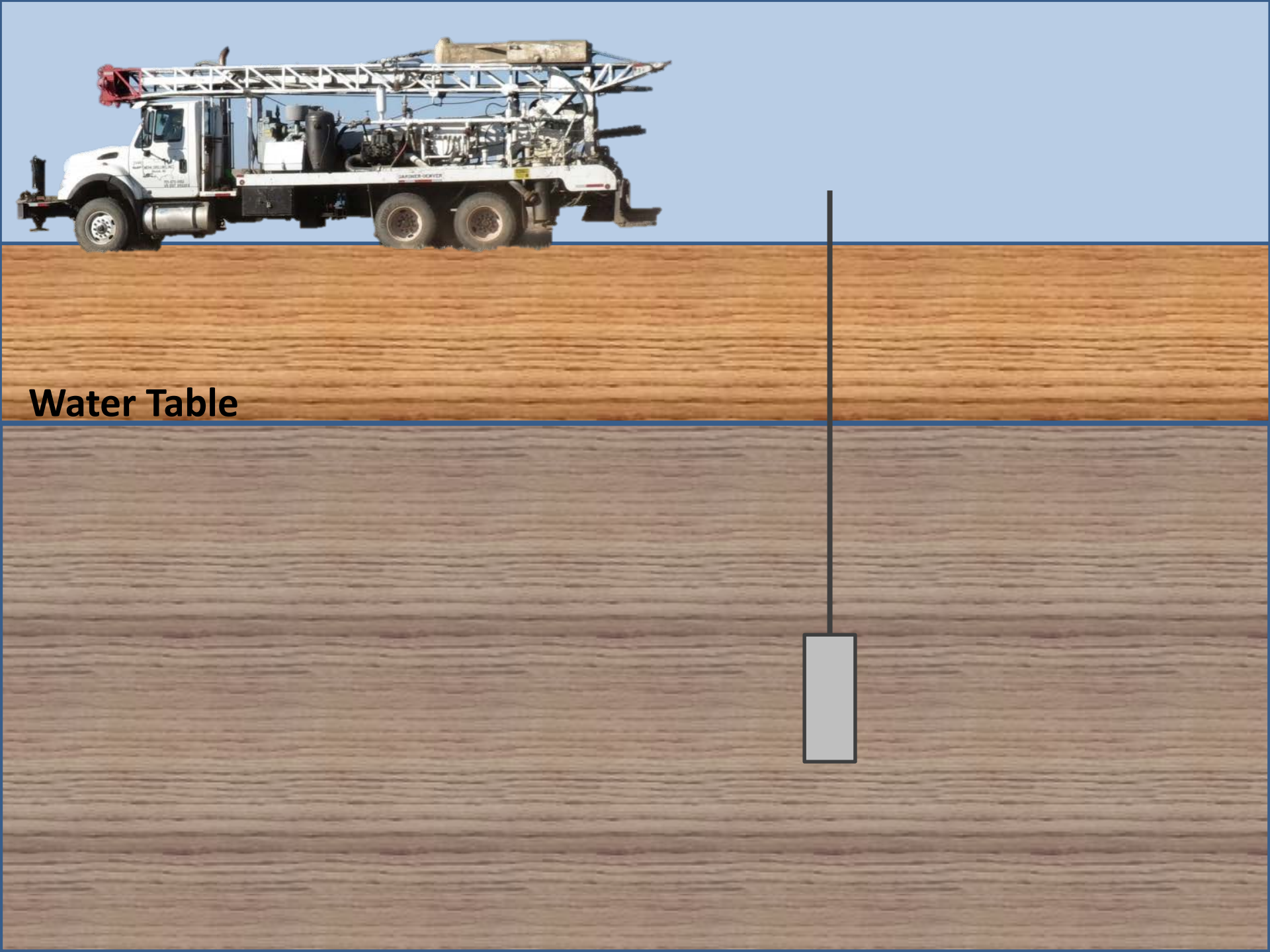
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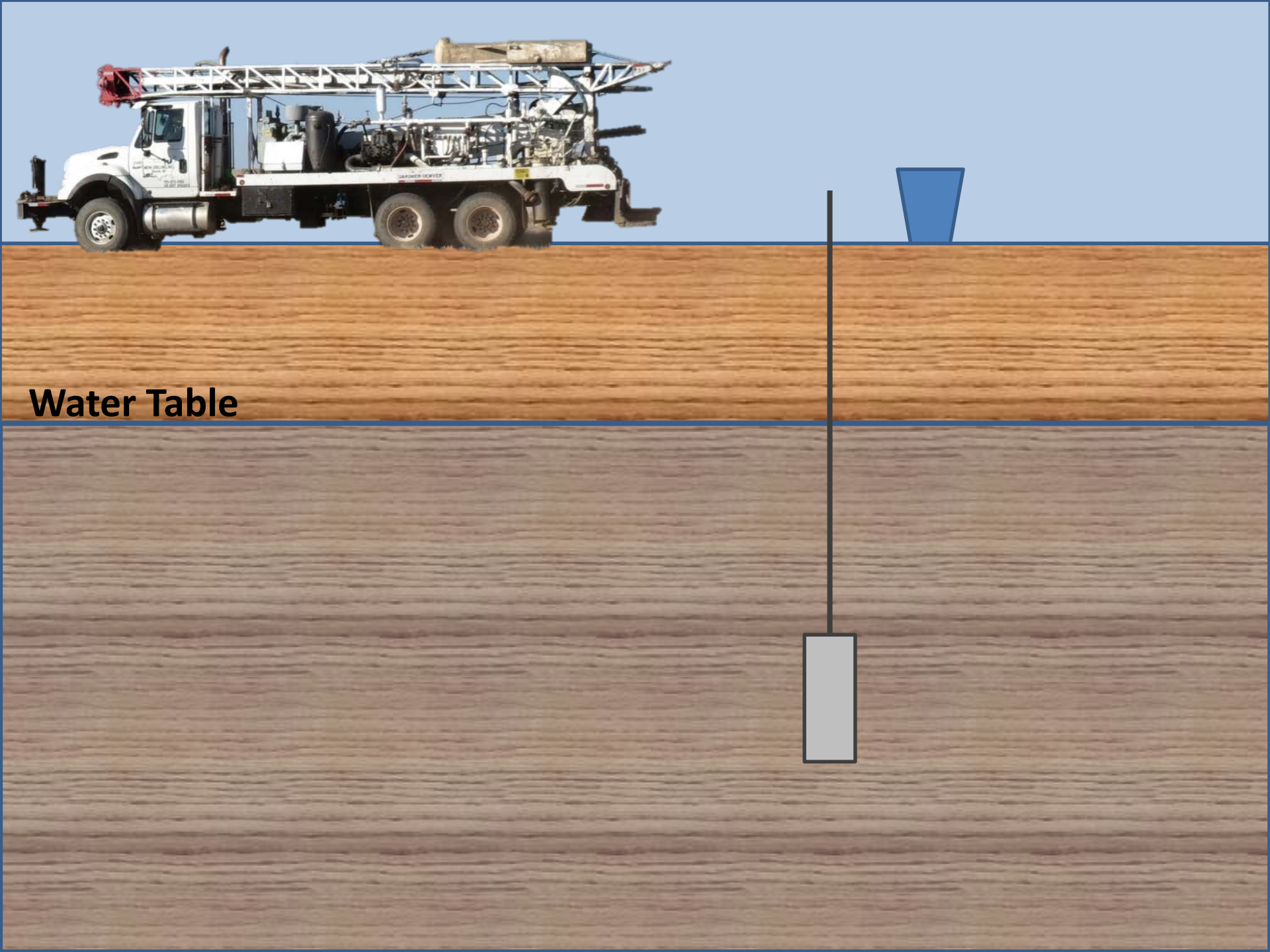
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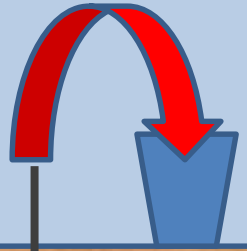
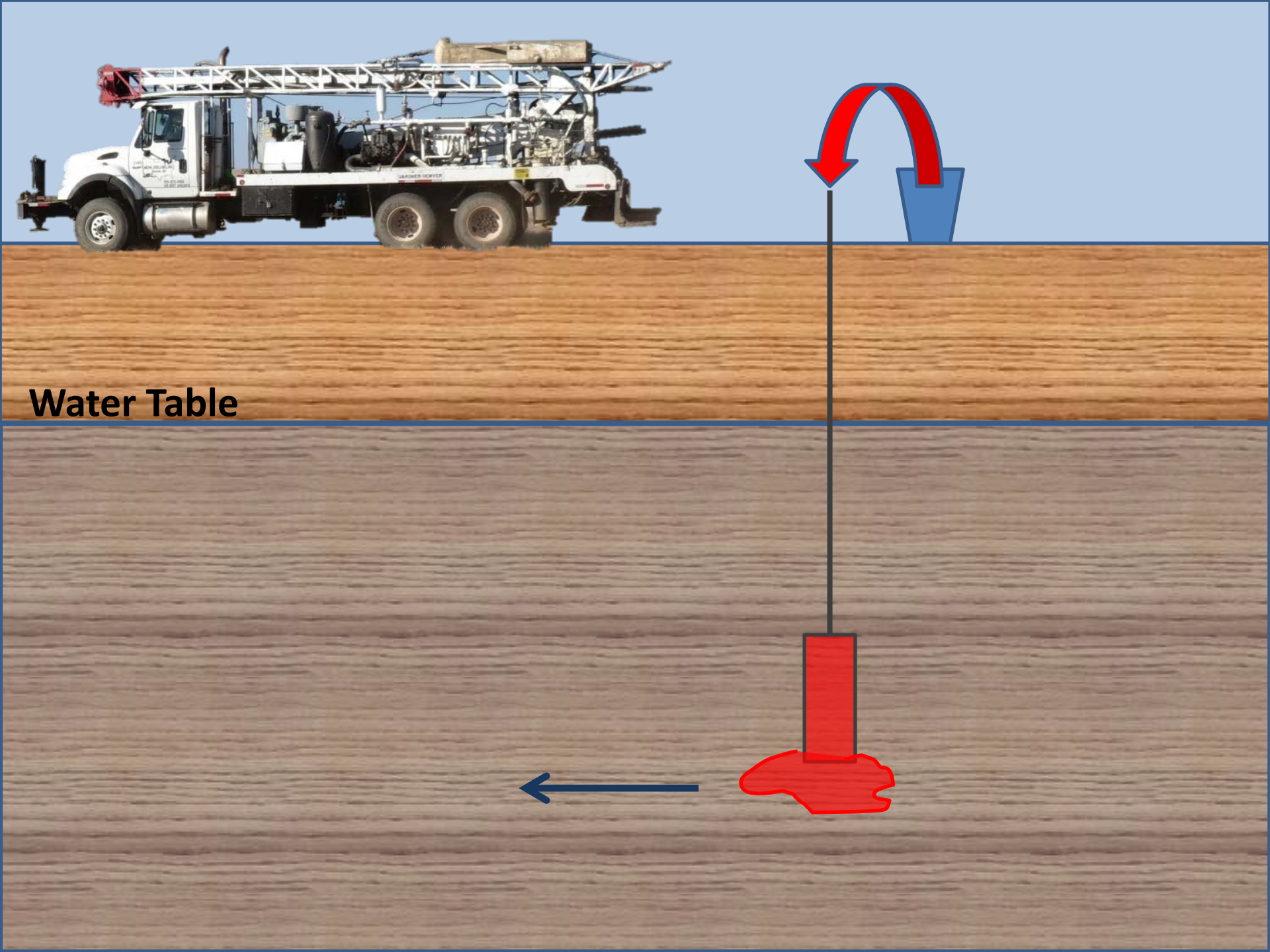


Water Table

NaBr +

$NaNO_3$

Water Table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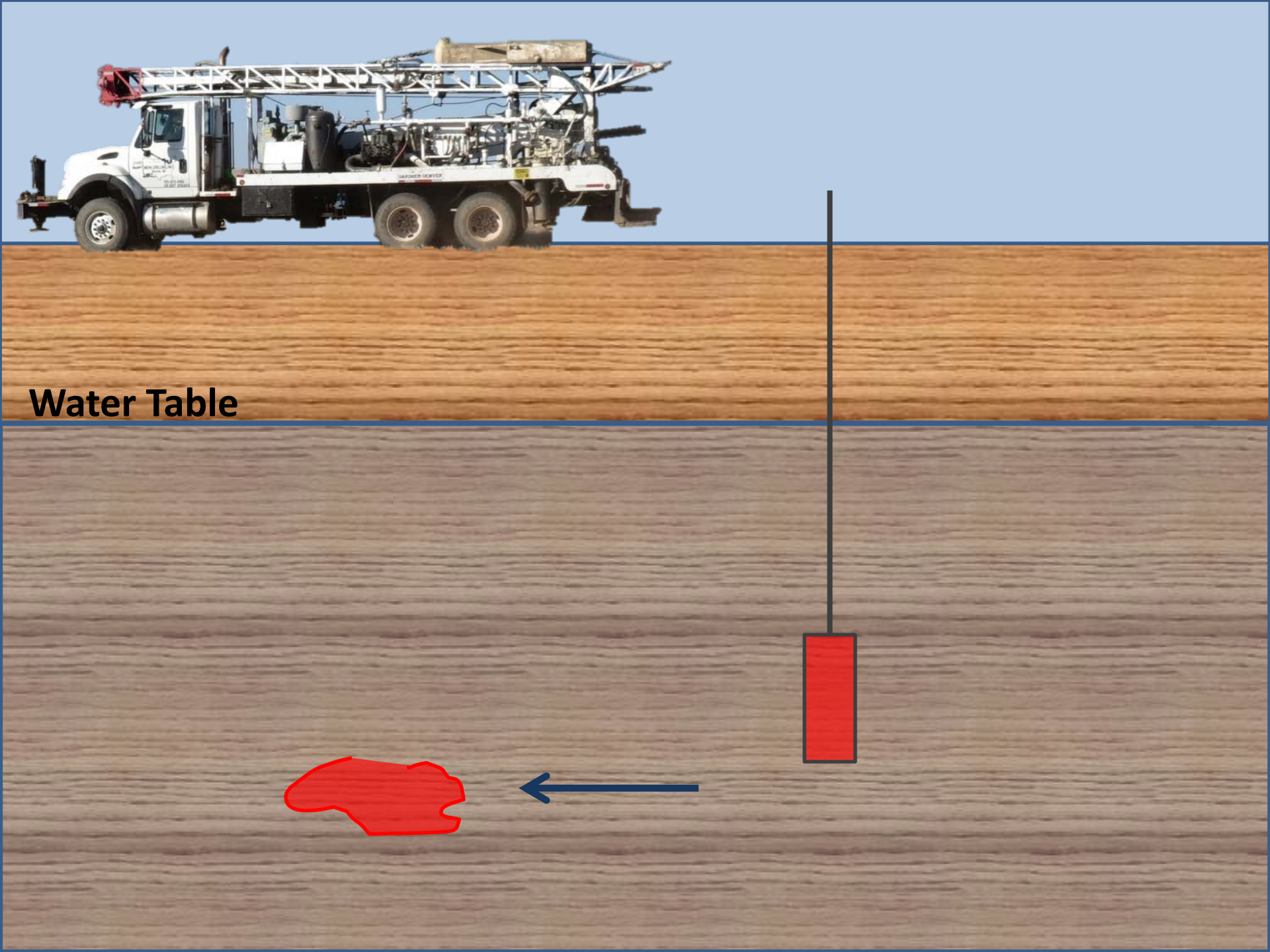
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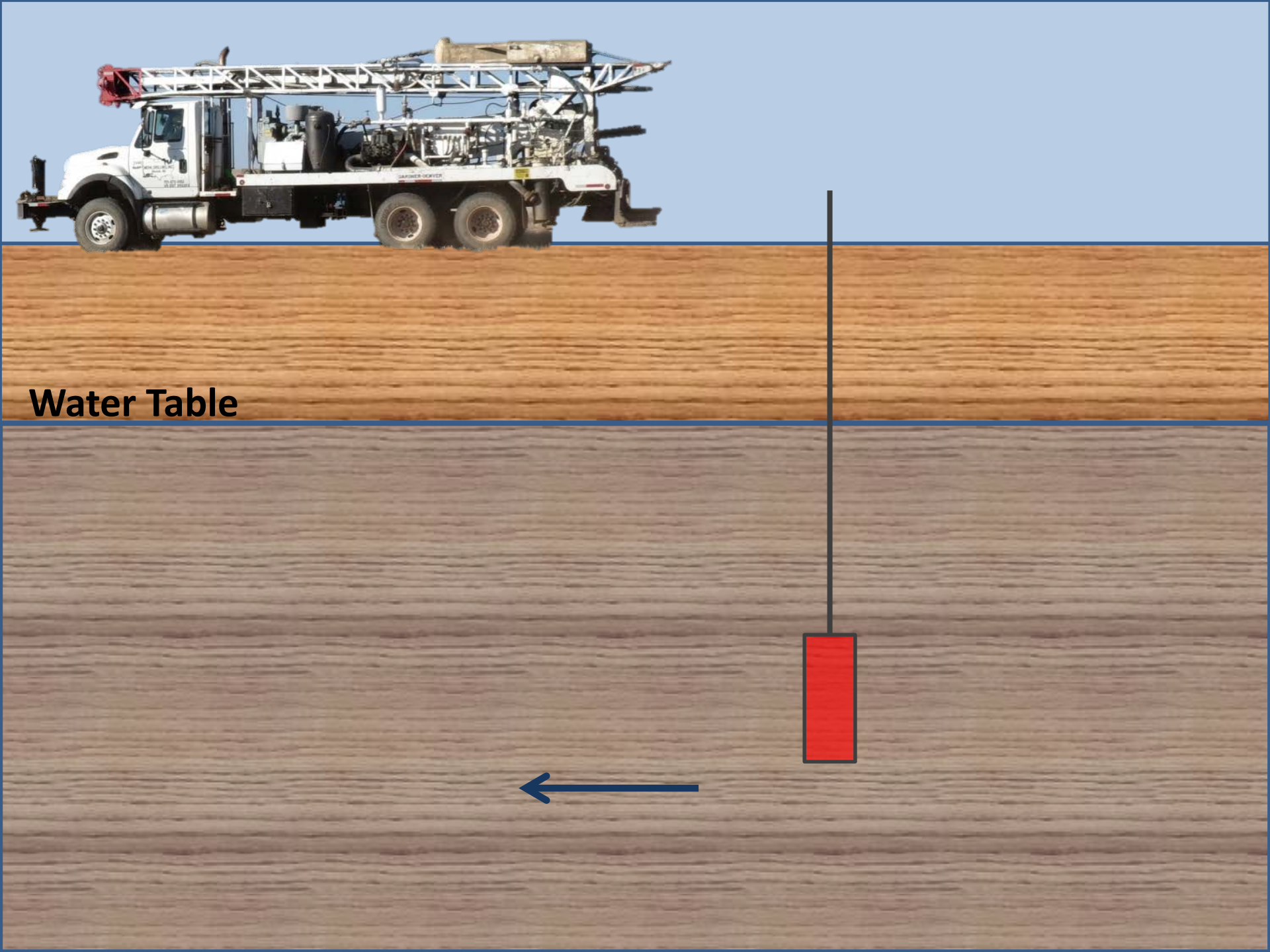
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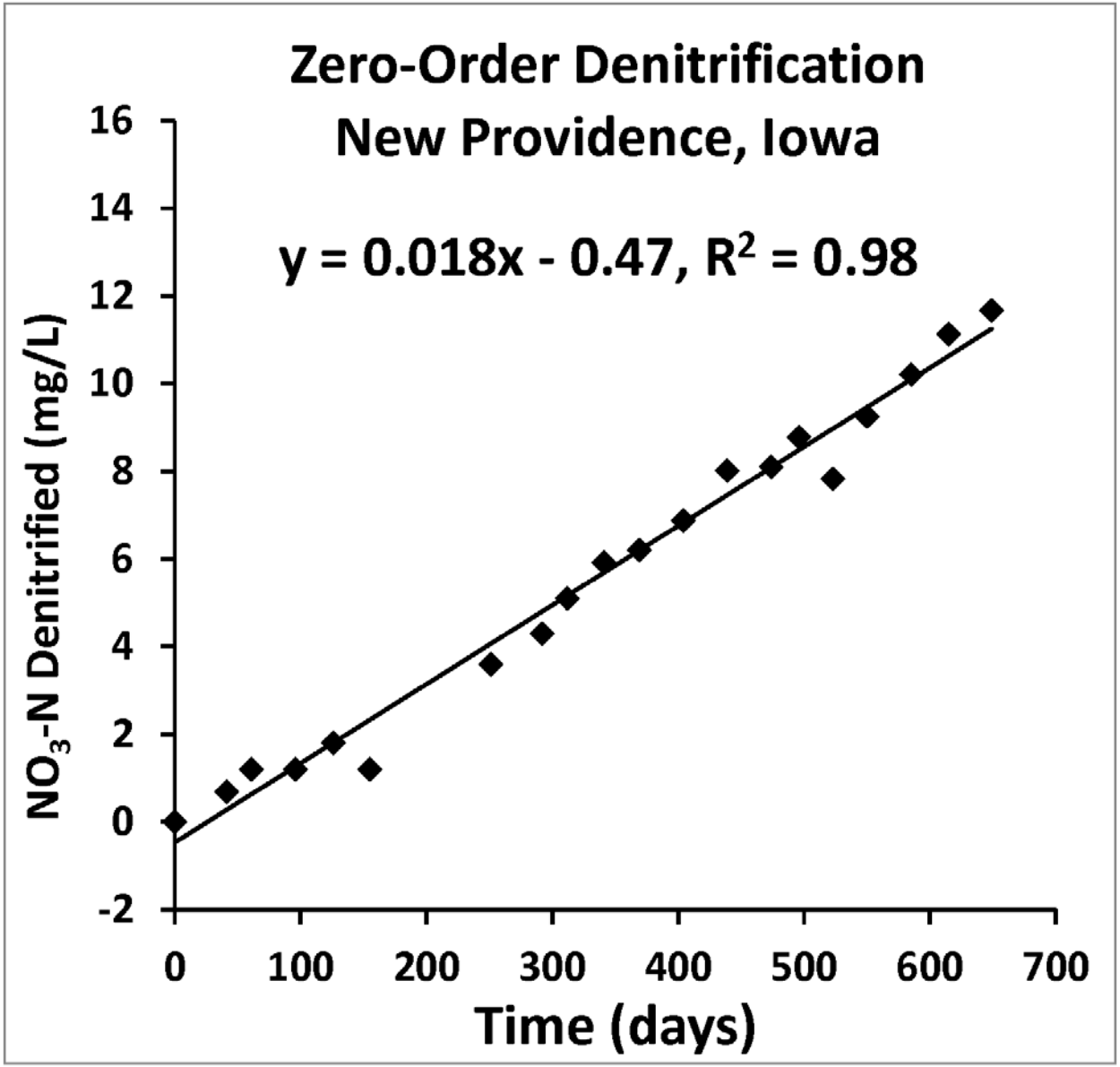
Zero-Order Denitrification
New Providence, Iowa
y = 0.018x - 0.47, R2 = 0.98
NO3-N Denitrified (mg/L)
16
14
12
10
8
6
4
2
0
-2
0
100
200
300
400
500
600
700
Time (days)

						e donors (%)
ISM Identification	Rate (mg/L/yr)	Clay+silt (%)	Inorganic S (%)	Organic C (%)	Fe(II)	IS + OC + Fe(II)
Hamar, ND	< 1.3	9.2	0.011	0.040	0.048	0.099
New Prov.-S, IA	2.6	7.1	0.011	0.007	0.094	0.112
Karlsruhe-G, ND	3.5	4.4	0.190	0.044	0.277	0.511
New Prov.-D, IA	6.6	7.6	0.005	0.016	0.115	0.136
Robinson, ND	4.0 - 10.2	8.7	0.022	0.072	0.160	0.254
Luverne, MN	8.4	10.1	0.014	0.004	0.014	0.032
Akeley, MN	12.8	36.3	0.007	0.024	0.113	0.144
Perham-W, MN	12.8	4.4	0.017	0.000	0.389	0.406
Perham-M, MN	12.8	4.4	0.115	0.011	0.192	0.318
Karlsruhe-S, ND	15.0 - 28.1	3.3	0.177	0.016	0.447	0.639
Oakes-C, ND	22.4	9.3	0.020	0.990	0.287	1.296
Larimore, ND	33.8 - 83.8	20.2	0.232	0.333	0.261	0.826
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“A review of the published rates suggests that denitrification tends to occur more quickly when linked with sulfide oxidation than with carbon oxidation,” (Tesoriero and Puckett, 2011).

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Two categories:

If e donor < 0.6%, denitrification rate < 14 mg N/L/yr (1 mM/yr)

If e donor > 0.6%, denitrification rate > 14 mg N/L/yr (1 mM/yr)

Conclusions:

- **Nitrate vulnerability assessment tools need to consider the fundamental requirement for groundwater denitrification: supply of e^- donors.**
  - **Denitrification rates are fastest with e^- donor concentrations > 0.6%.**

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  - **ND has at least two "super-denitrifying" aquifers.**

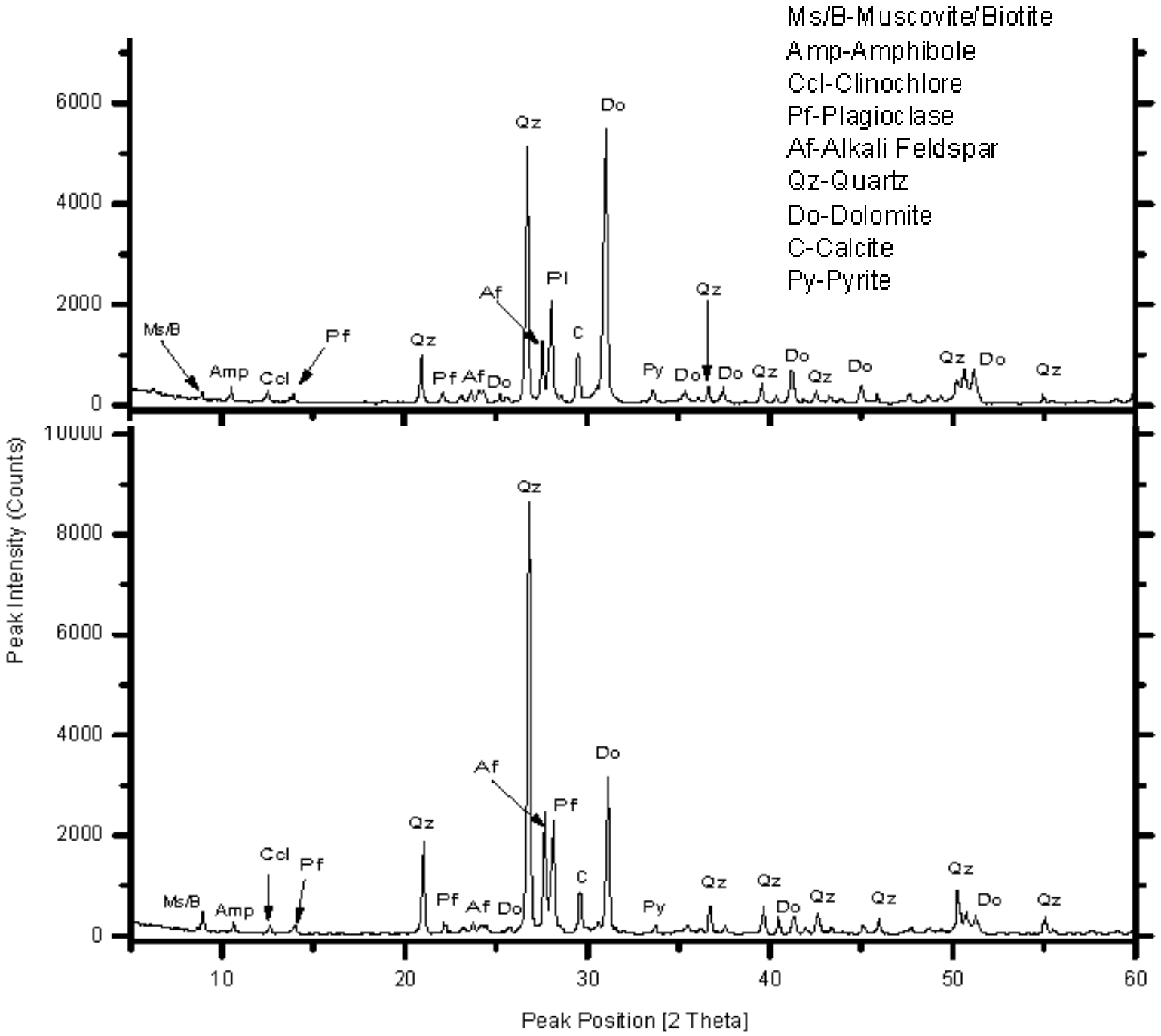
Conclusions:

- **Nitrate vulnerability assessment tools need to consider the fundamental requirement for groundwater denitrification: supply of e^- donors.**
  - **Denitrification rates are fastest with e^- donor concentrations > 0.6%.**
  - **ND has at least two "super-denitrifying" aquifers.**
  - **MN?**
  - **IA?**

Acknowledgments:

- Luverne Municipal Utilities
- MN Dept. of Agriculture
- MN Dept. of Health
- MN Pollution Control Agency
- ND Dept. of Health
- ND Rural Water Users Systems Association
- NDSU
- ND State Water Commission (Bill Schuh)
- ND Water Resources Research Institute
- UND
- US EPA Section 319 funding
- USGS
- Private land owners
- Graduate students (Schlag, Kammer, Warne, Skubinna, Spencer, Tesfay, Klapperich, Mahargan, Christenson, Krieger)

BARR


Ms/B-Muscovite/Biotite
Amp-Amphibole
Ccl-Clinochlore
Pf-Plagioclase
Af-Alkali Feldspar
Qz-Quartz
Do-Dolomite
C-Calcite
Py-Pyrite
Peak Intensity (Counts)
Peak Position [2 Theta]
Ms/B
Amp
Ccl
Pf
Qz
Af
Pl
C
Do
Py