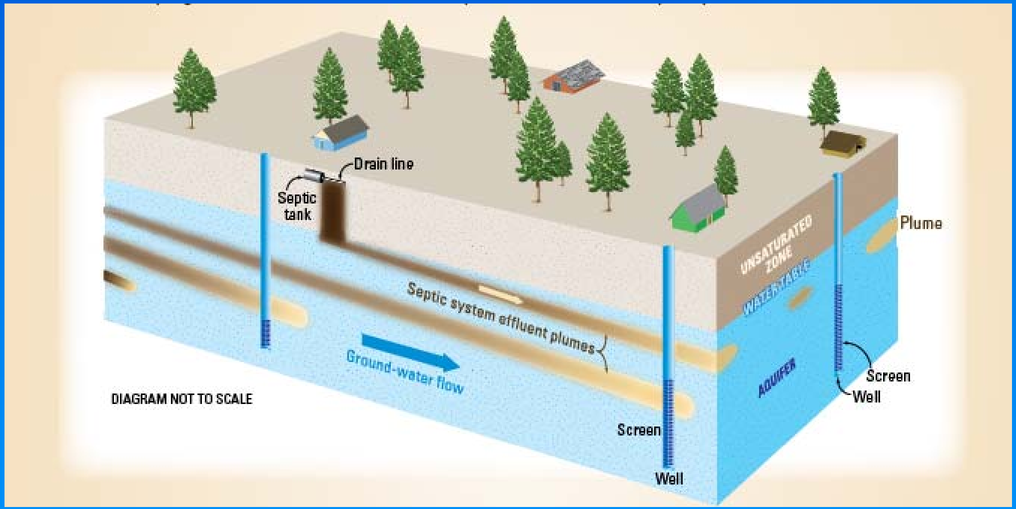
South Deschutes County Ground Water Conditions



High Groundwater Technical Committee

November 19, 2008

David S. Morgan
Oregon Water Science Center

U.S. Department of the Interior
U.S. Geological Survey

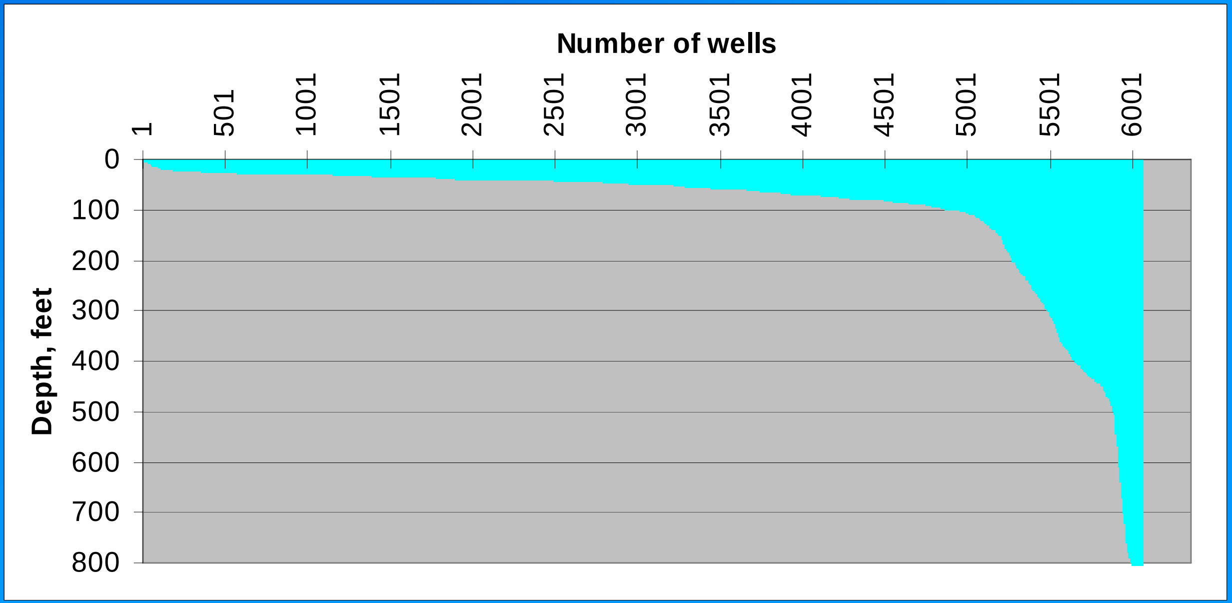
Outline

- Reasons for concern
- What has been learned
- Available tools
- Capabilities and limitations of tools
- Discussion

USGS

Drinking Water is Vulnerable

- Thin, volcanic soils; shallow water table
- Most homes have OWS & individual well
- 50% of wells less than 50 feet deep; 82% less than 100 feet.



USGS

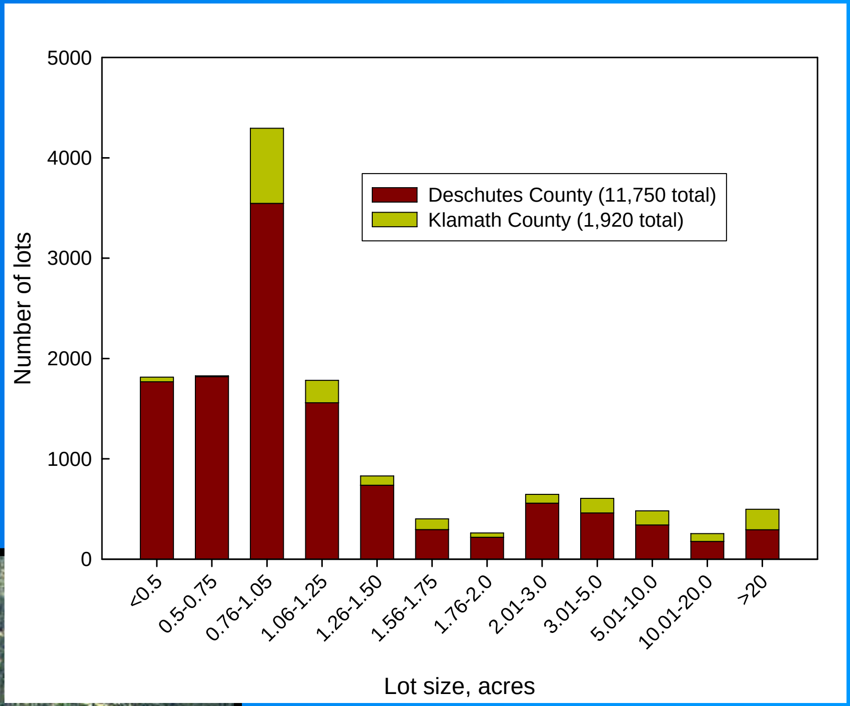
Streams Are Vulnerable

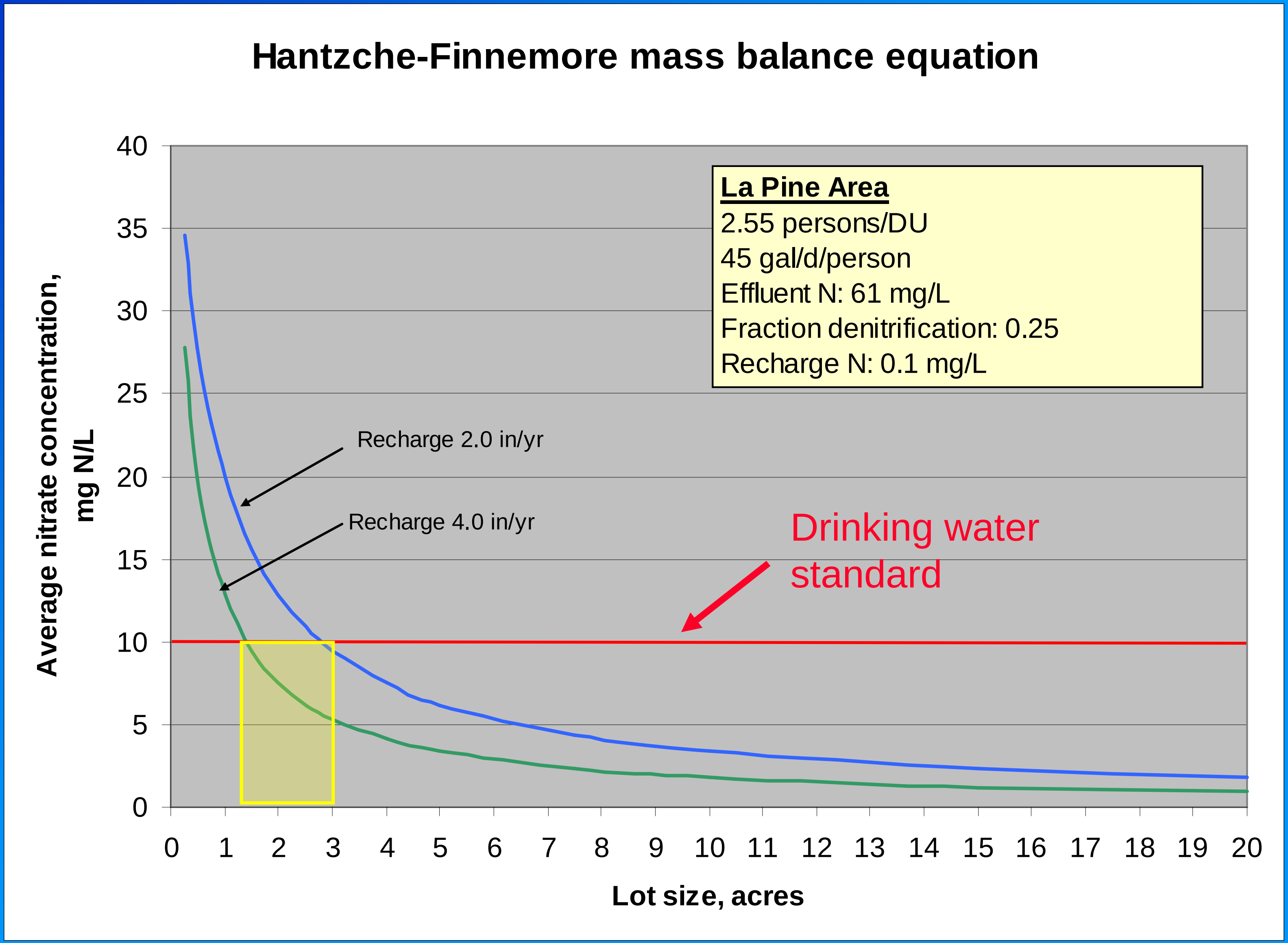
Groundwater discharges to the Deschutes and Little Deschutes Rivers in South Deschutes County

USGS

Residential Housing Density

61% of lots less than 1 acre
84% of lots less than 2 acre

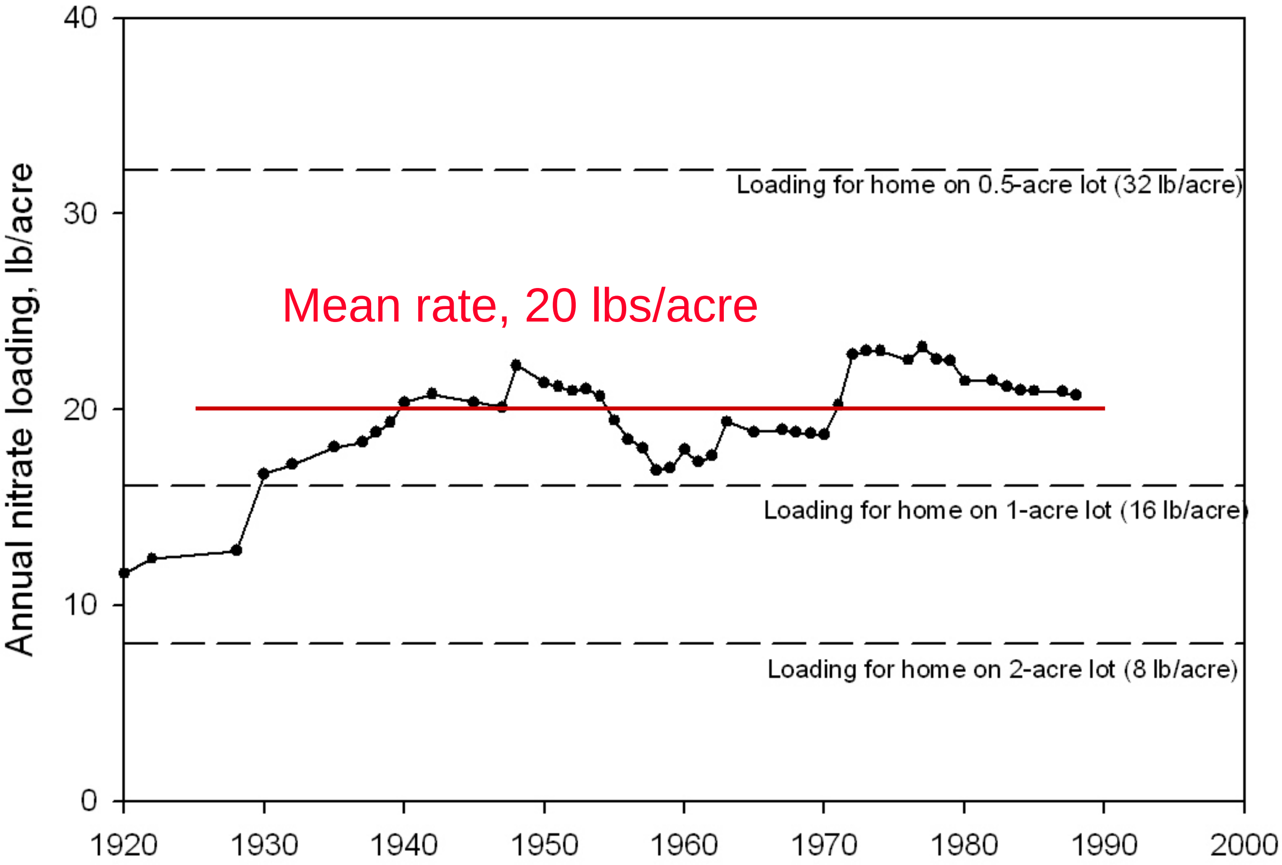




Minimum lot size ~1.5 - 3 acres

Downtown La Pine Density—Before Sewers Installed

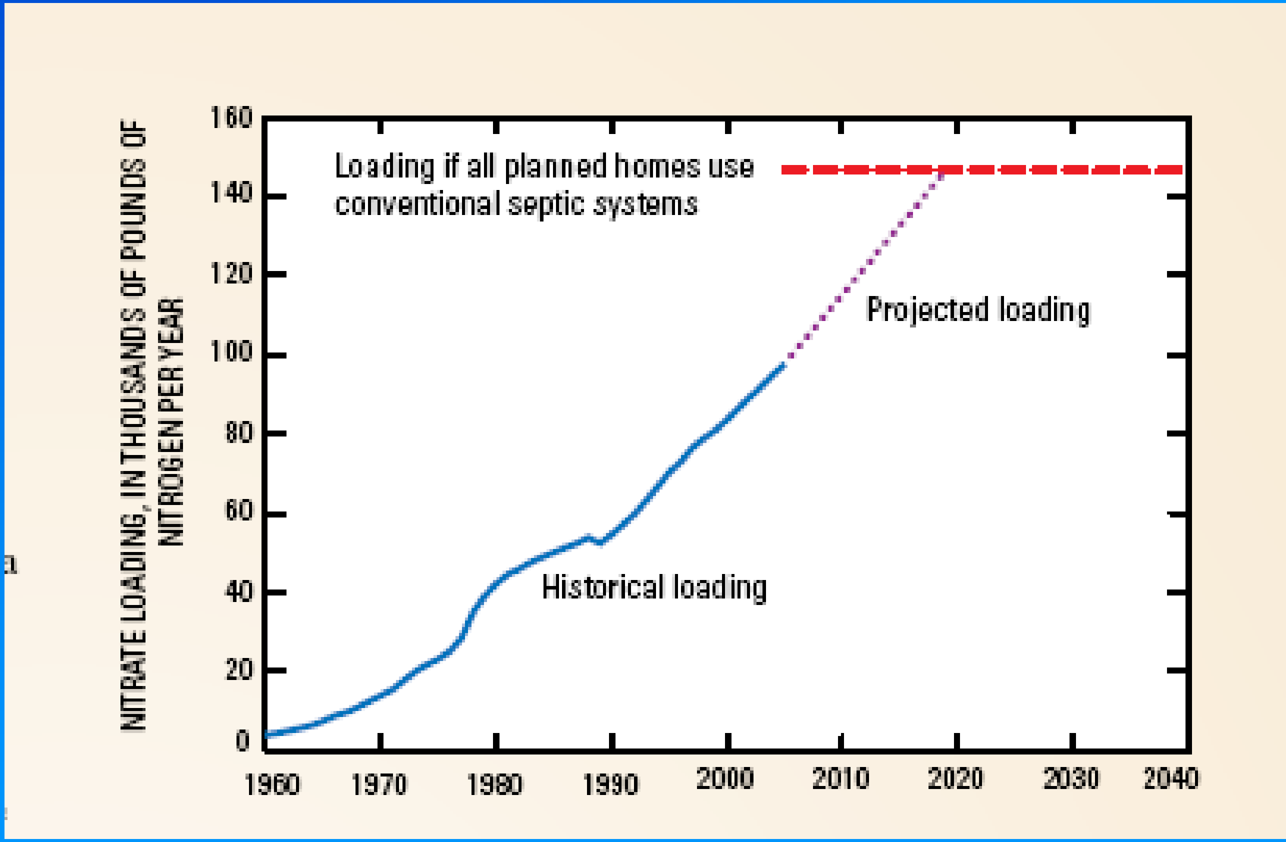
Equivalent to 0.8-acre lot size



Nitrate >10 mg/L found in 8 of 46 wells sampled in 1979

Area was sewered in 1989

Projected Growth



USGS

Purpose of study

- Understand hydrologic and chemical processes affecting movement and fate of nitrogen within the shallow aquifers of the South Deschutes County (SDC) area
- Develop tools (models) to support decisions on protection of water resources

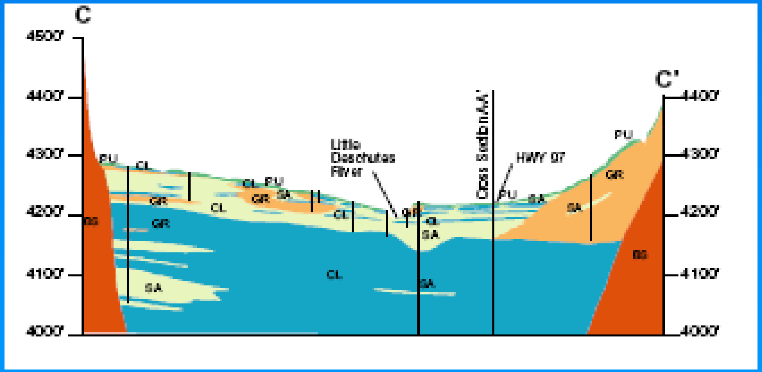
USGS

Drilling

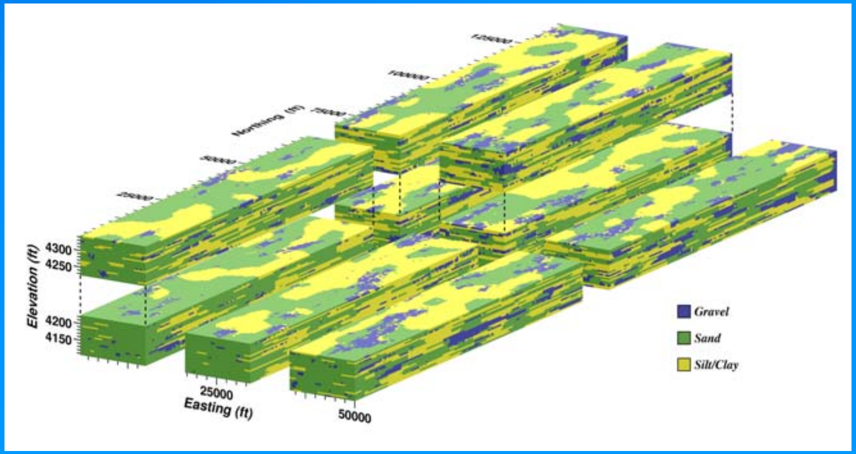
Checking core

Geology

Locating private well

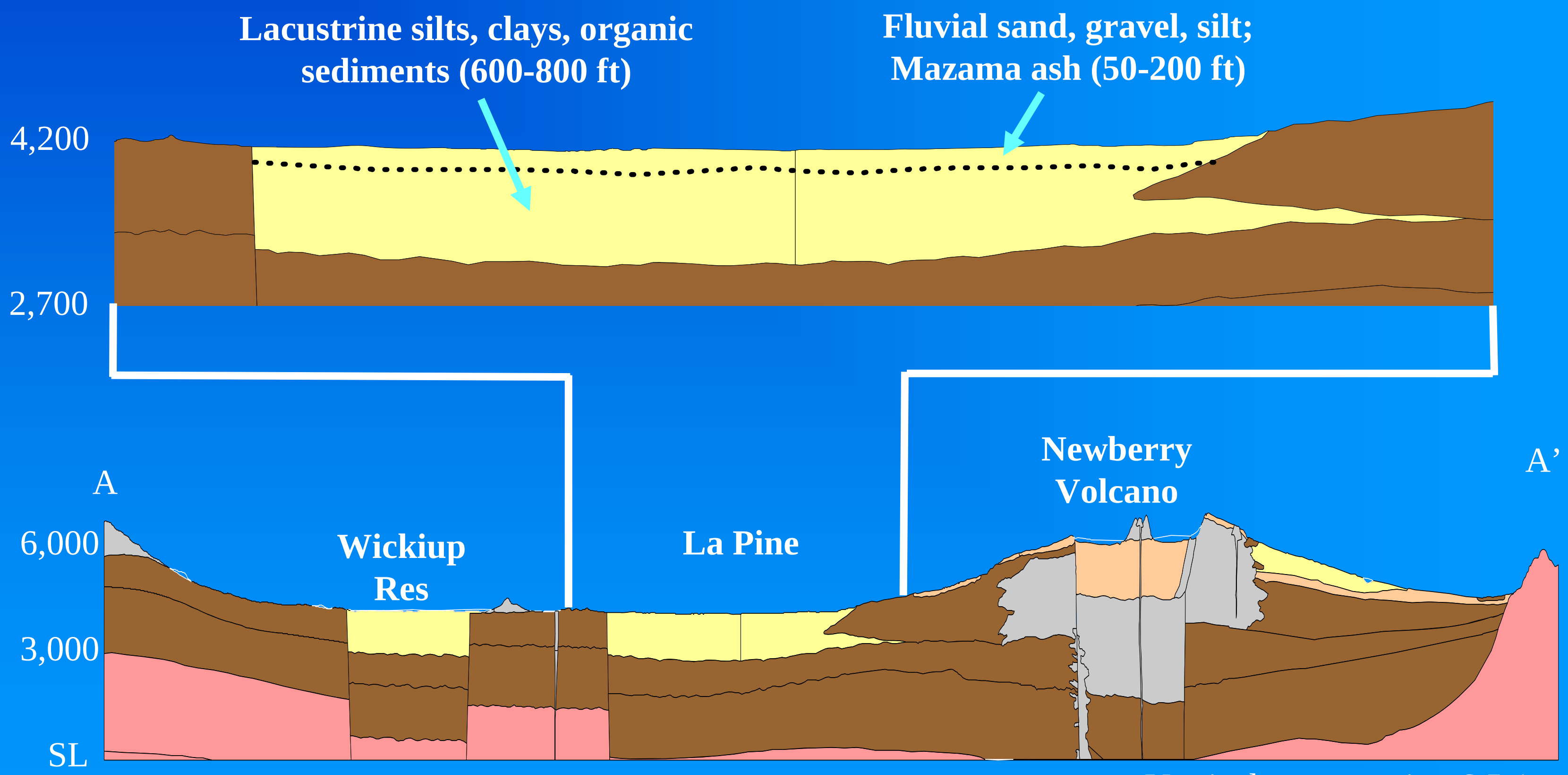


Geologic Cross-Section



3-D Geologic Model

Hydrogeologic Section



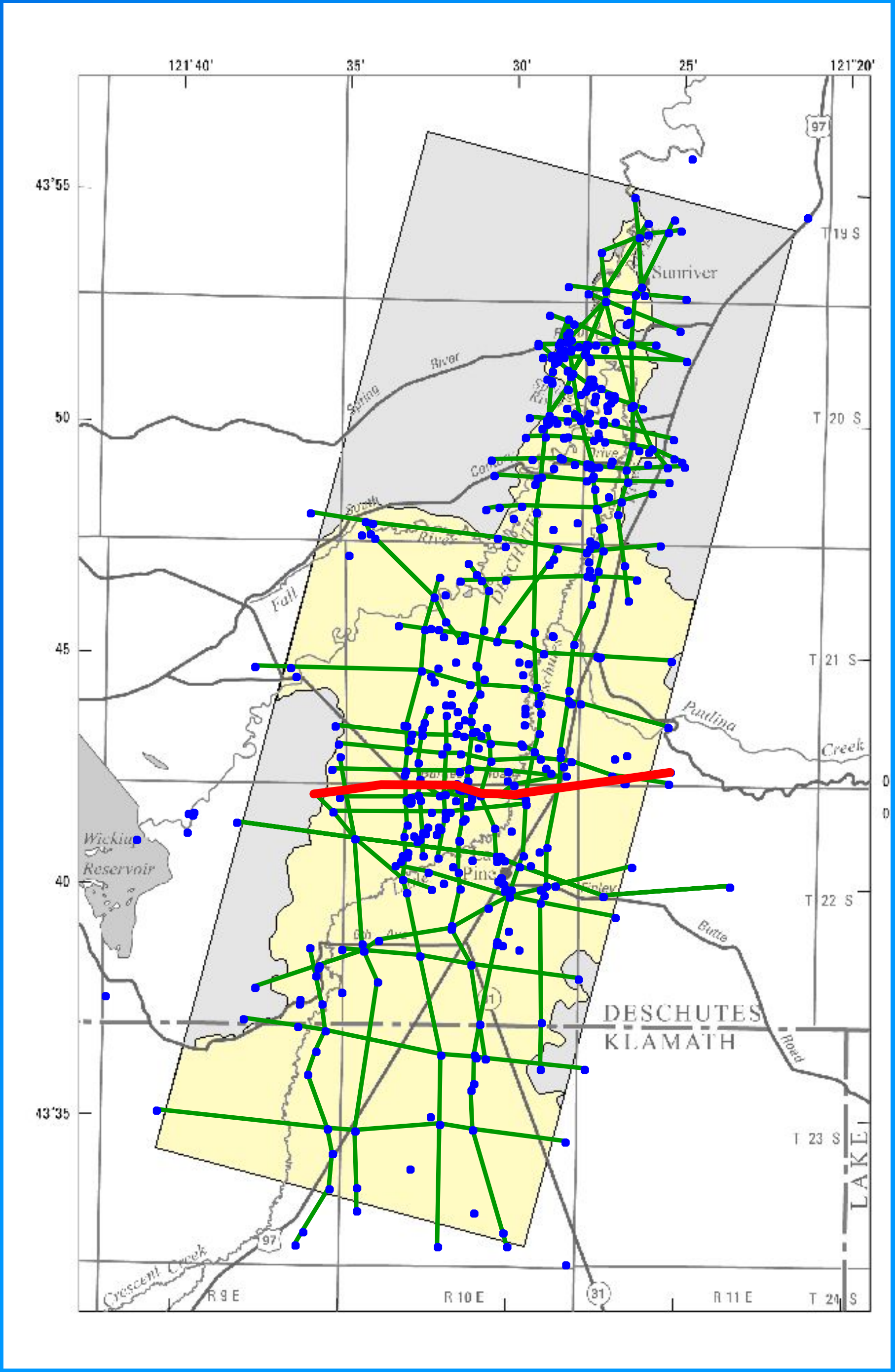
Vertical exaggeration 6.5:1

Modified after Lite and Gannett (2003)

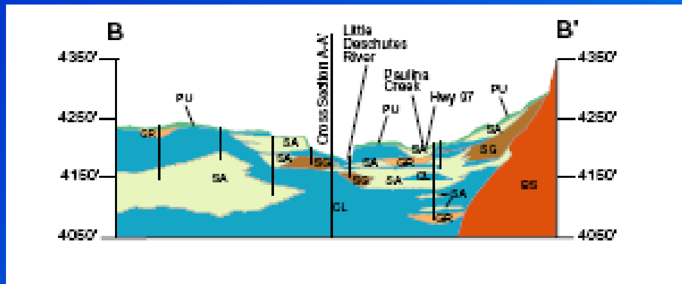
USGS

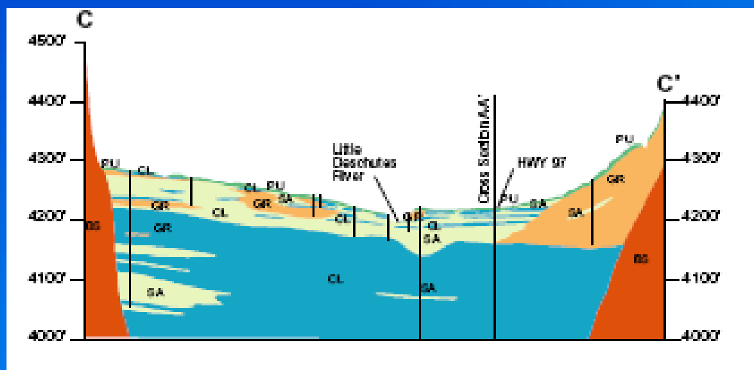
Geologic Data

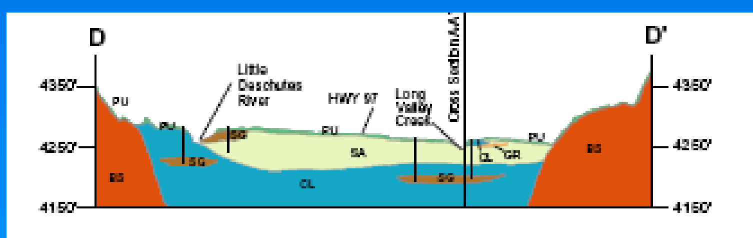
Reports from 464 wells to construct 34 2-dimensional cross-sections

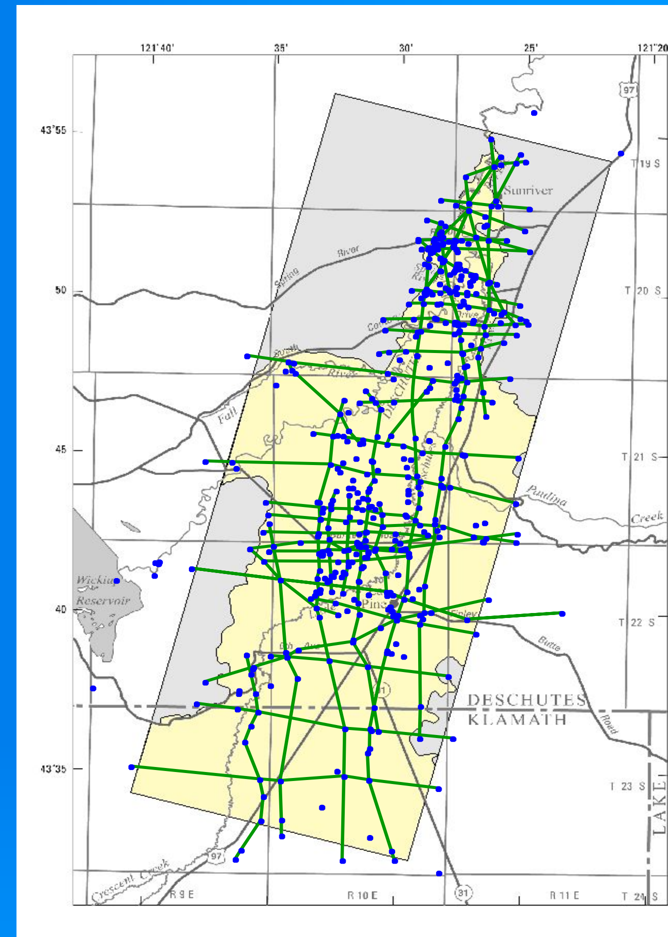


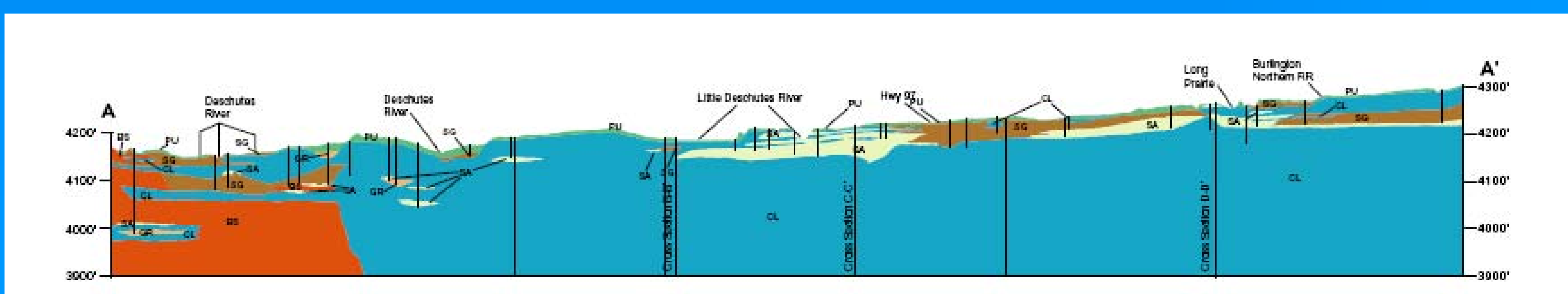
USGS


B
B'
4350'
4250'
4150'
4050'
Little Deschutes River
Cross Section A-A'
Paulina Creek
Hwy 97
PU
SA
SG
GR
CL
BS

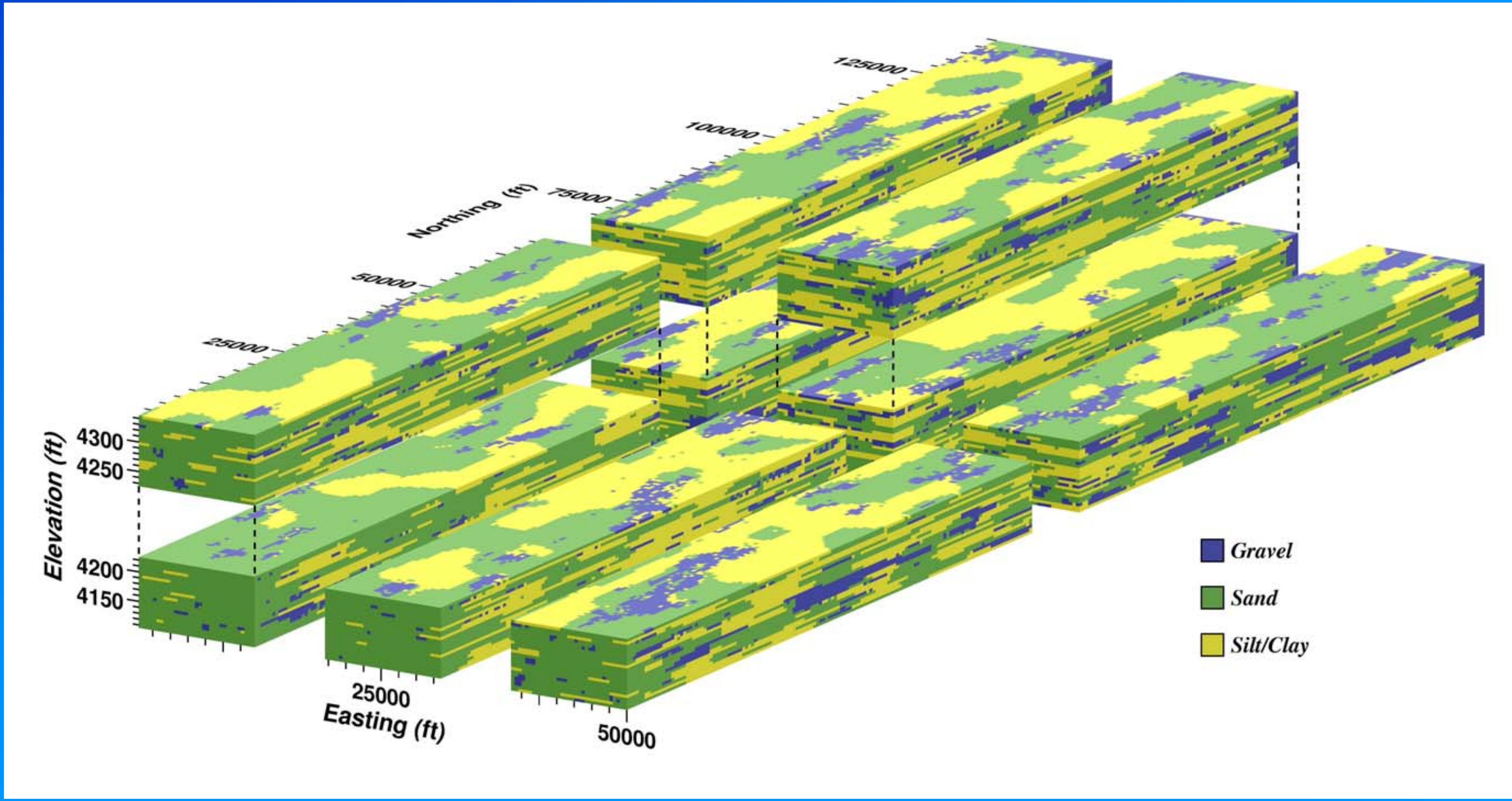

C
C'
4500'
4400'
4300'
4200'
4100'
4000'
Little Deschutes River
Cross Section A-A'
HWY 97
PU
CL
GR
SA
BS


D
D'
4350'
4250'
4150'
Little Deschutes River
HWY 97
Long Valley Creek
Cross Section A-A'
PU
SG
SA
CL
GR
BS


121°40'
35'
30'
25'
121°20'
43°55
50
45
40
43°35
T 19 S
T 20 S
T 21 S
T 22 S
T 23 S
Sunriver
Paulina
Creek
Wickiup Reservoir
DESCHUTES
KLAMATH
LAKE
R 9 E
R 10 E
R 11 E
97
31


A
A'
4300'
4200'
4100'
4000'
3900'
Deschutes River
Little Deschutes River
Hwy 97
Long Prairie
Burlington Northern RR
Cross Section B-B'
Cross Section C-C'
Cross Section D-D'
PU
SG
SA
GR
CL
BS

Geo-Model



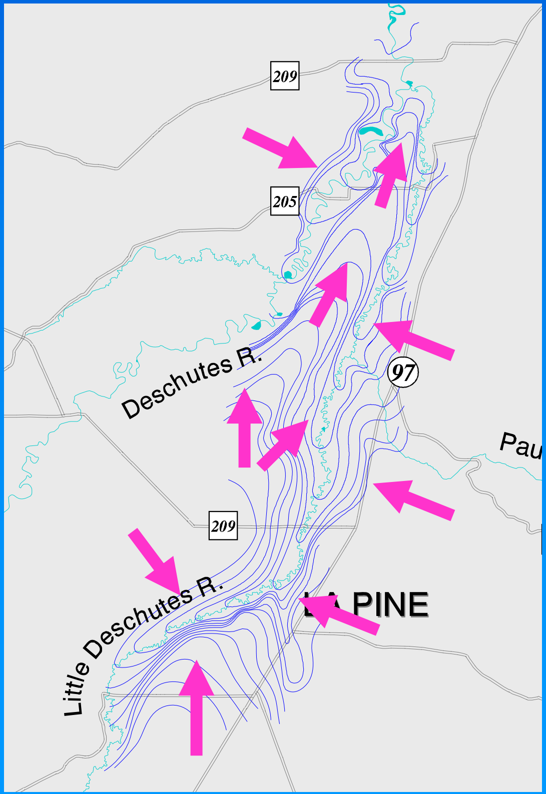
USGS

Constructed using cross-sections with Transition Probability geostatistical method

Measuring groundwater level below stream

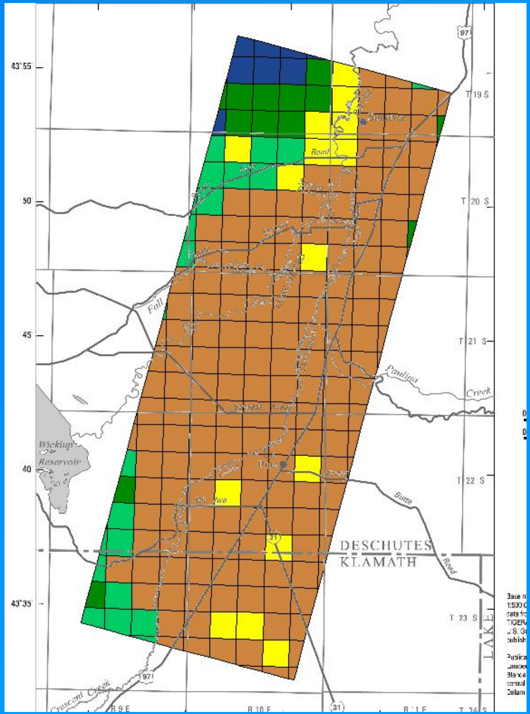
Measuring groundwater level in well

Hydrology



Map of groundwater flow directions

Map of groundwater recharge

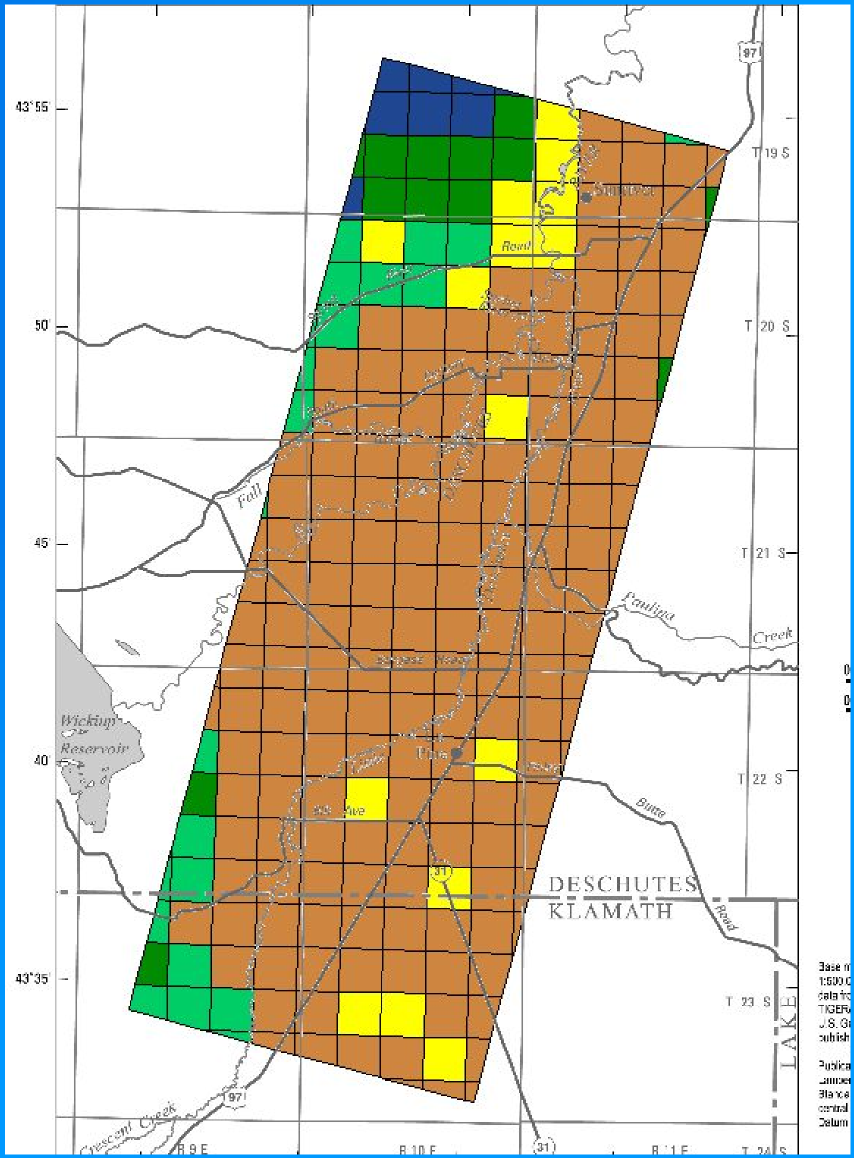


Recharge

Mean annual recharge (1993-95)

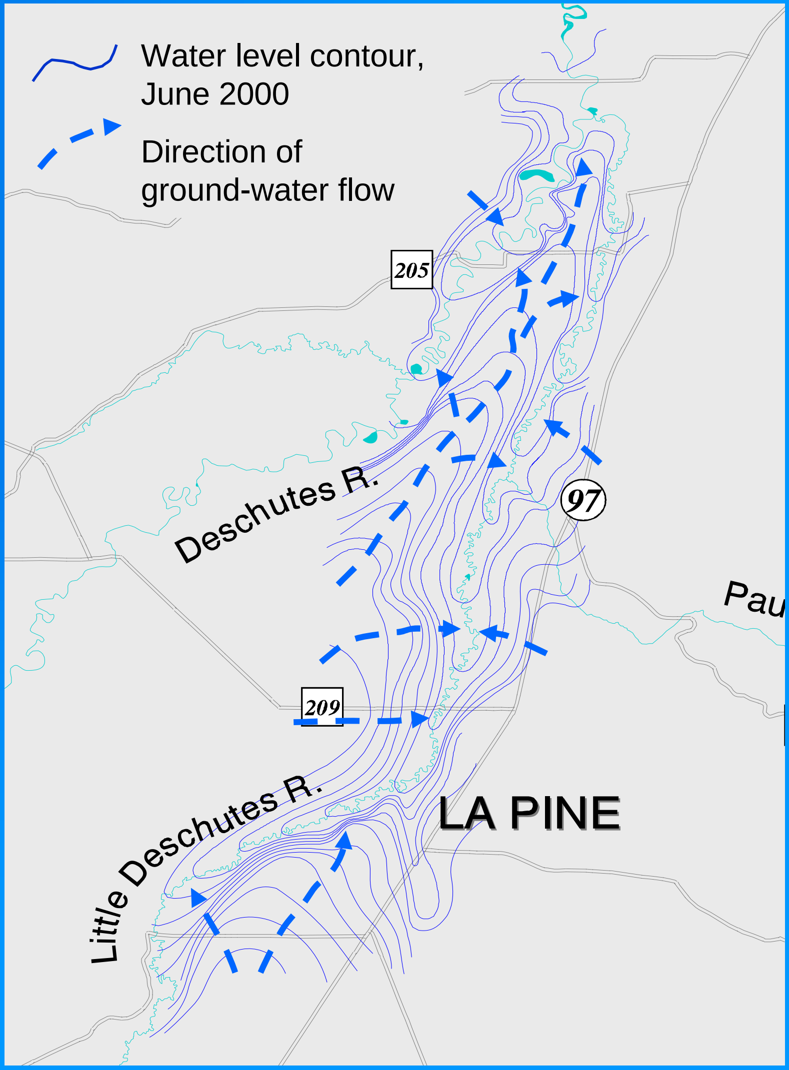
- 1.5 – 3.0 inches/yr
- 3.1 – 5.0
- 5.1 – 8.0
- 8.1 – 11.0
- 11.0 – 20.0

From USGS Upper Deschutes basin GW study



Hydrologic Framework

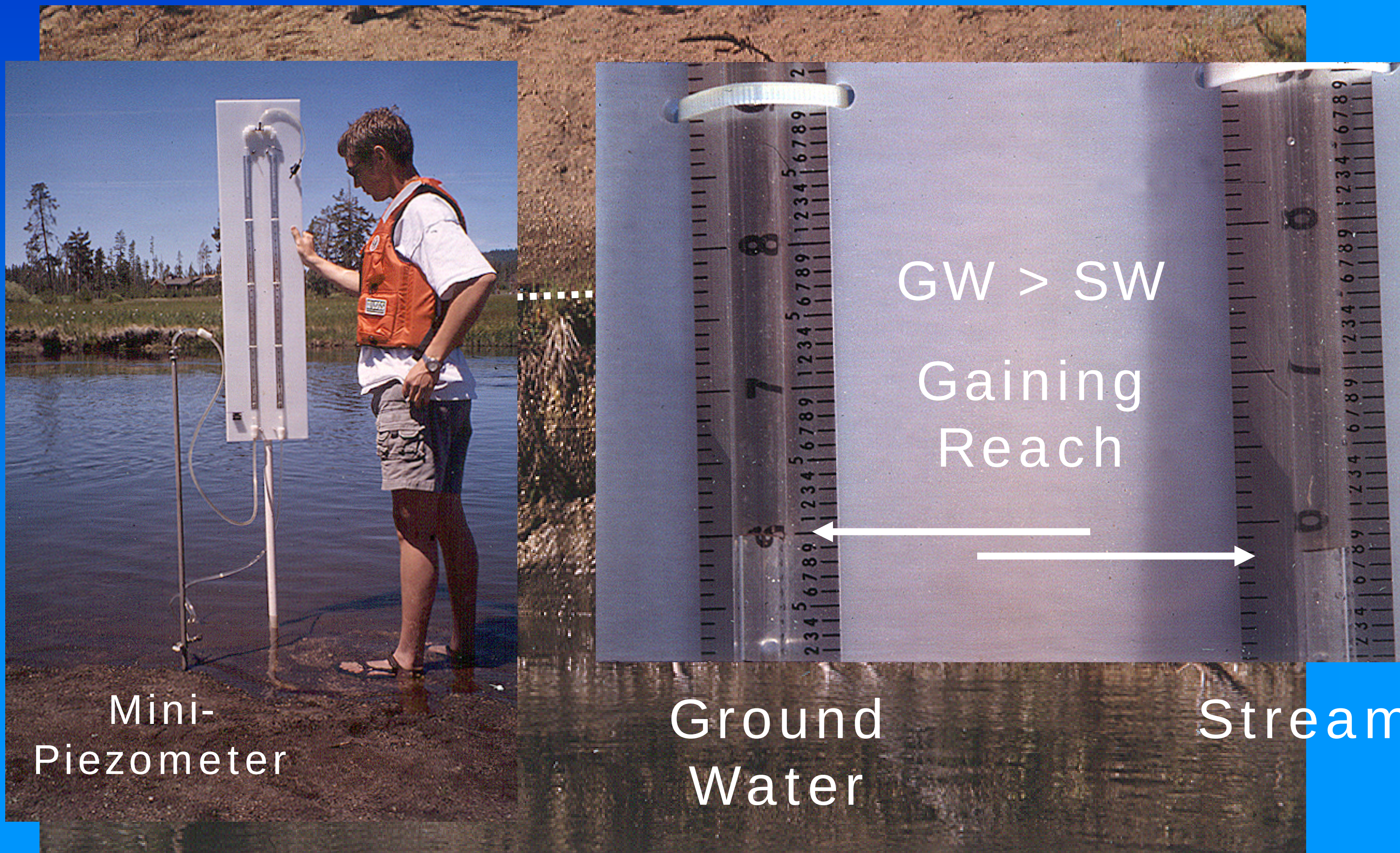
- ✓ **Flow direction and gradient**
  - ✓ **228 well mass measurement, June 2000**



Water-table map

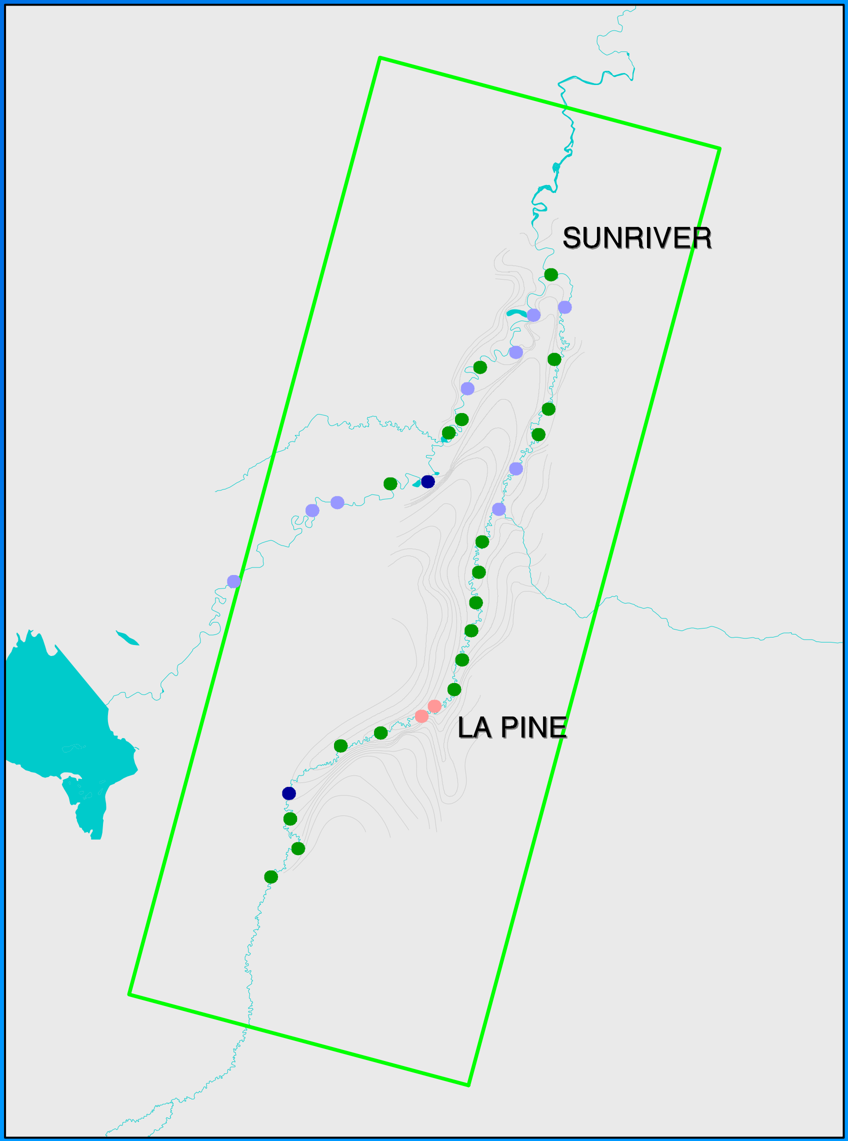
USGS

Ground-Water/Surface-Water Interaction

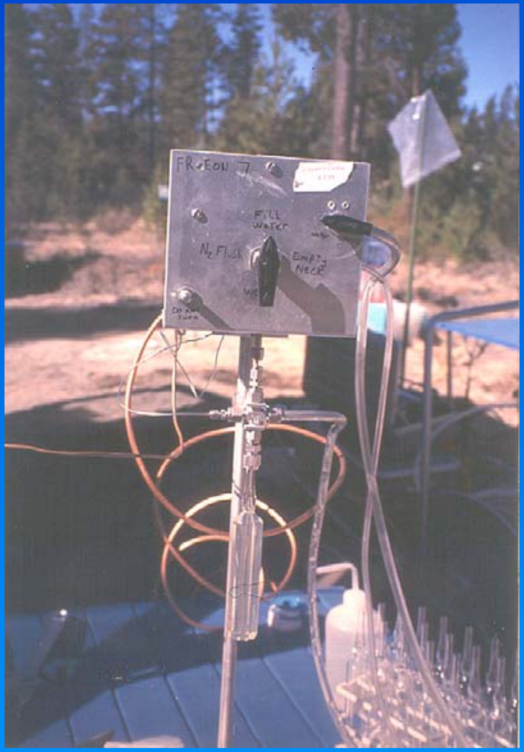


Stream-Aquifer Head Gradient Survey

Head gradient
- -0.003 - 0 (Losing)
- 0 - 0.03
- 0.03 - 0.05
- 0.05 - 0.08
- Head contours
- Model boundary

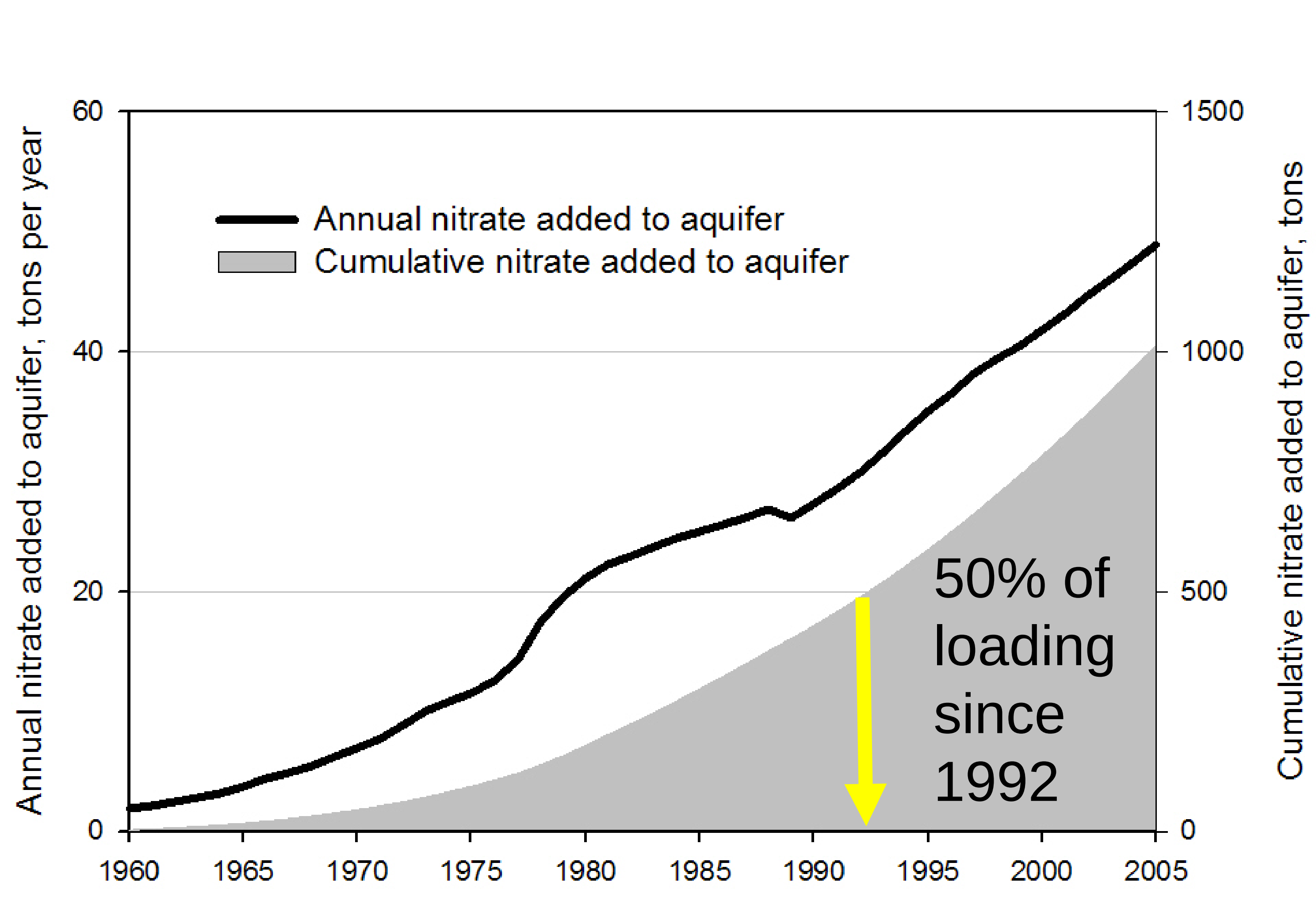


USGS



Chemistry

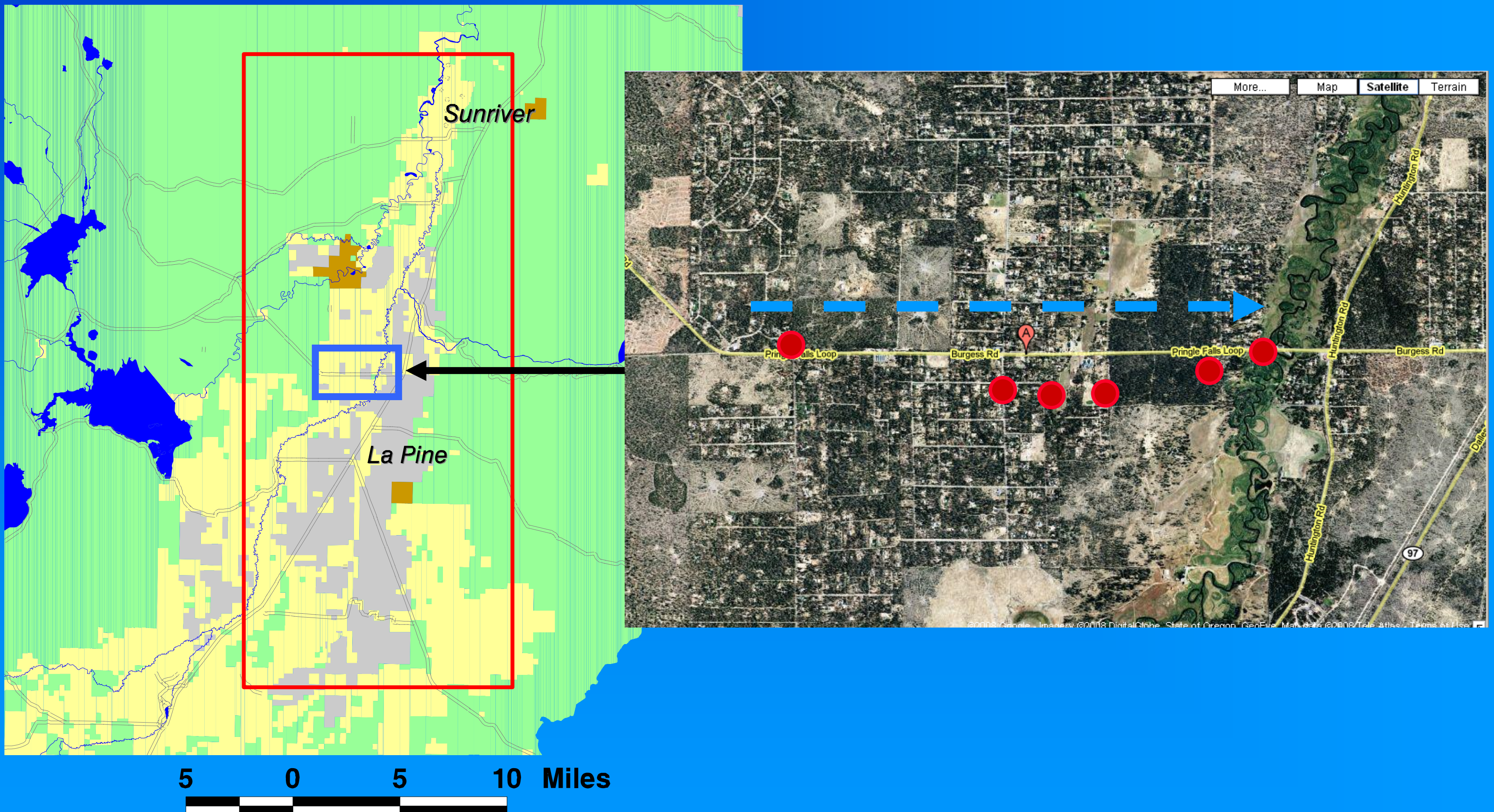
Existing Onsite Systems Nitrate Loading 1960-2005



USGS

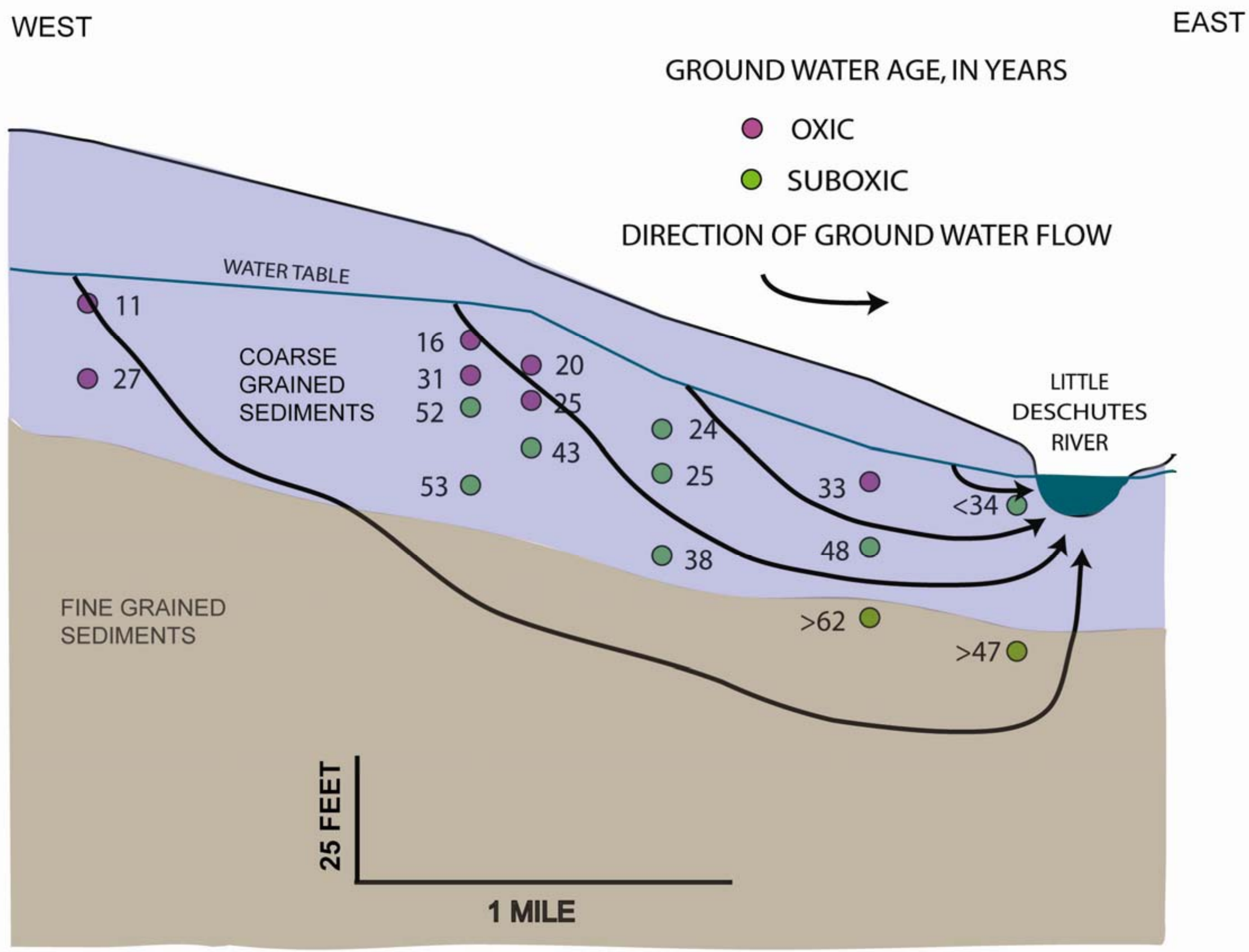
Nitrogen Dynamics

Burgess Road Transect Study

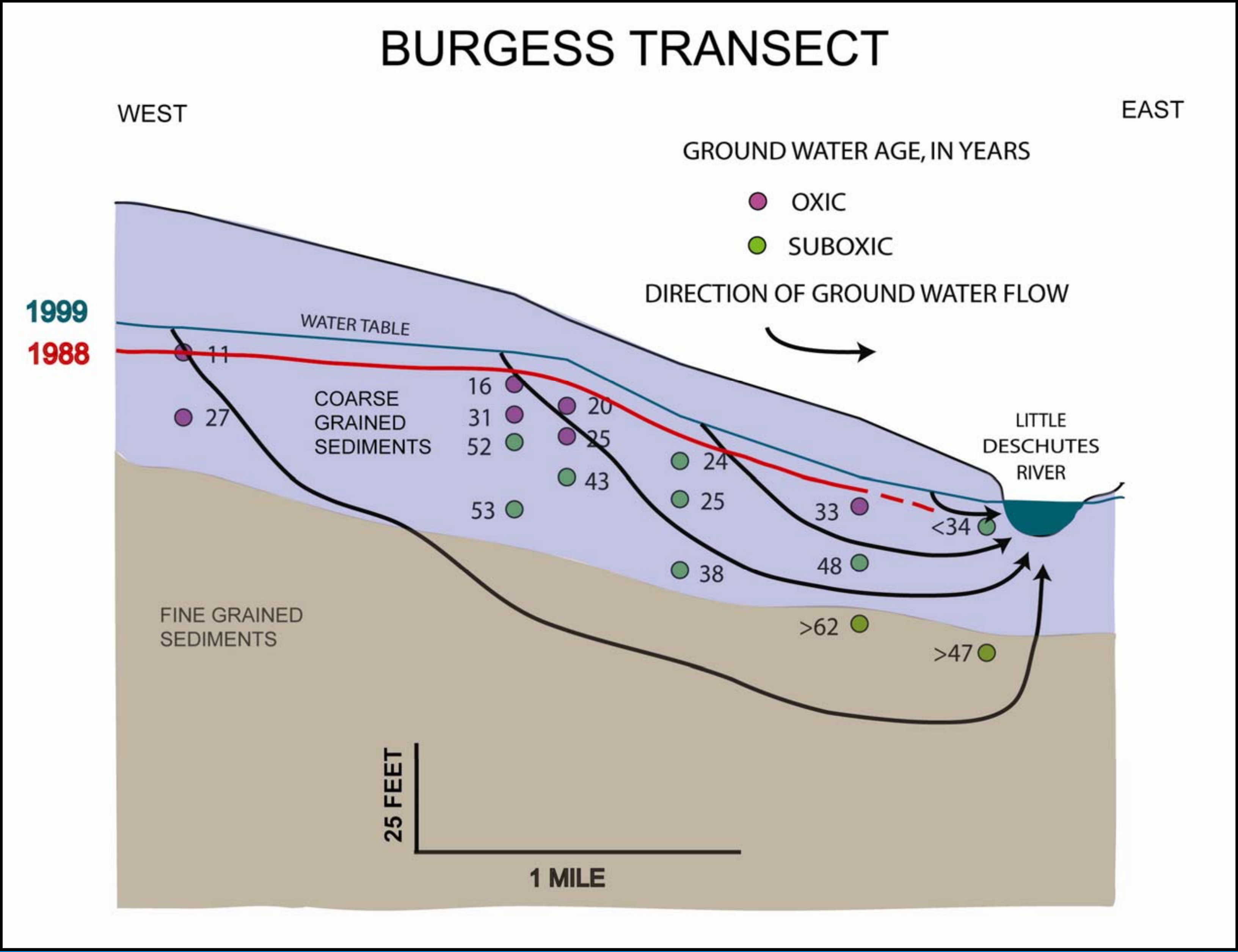


USGS

BURGESS TRANSECT



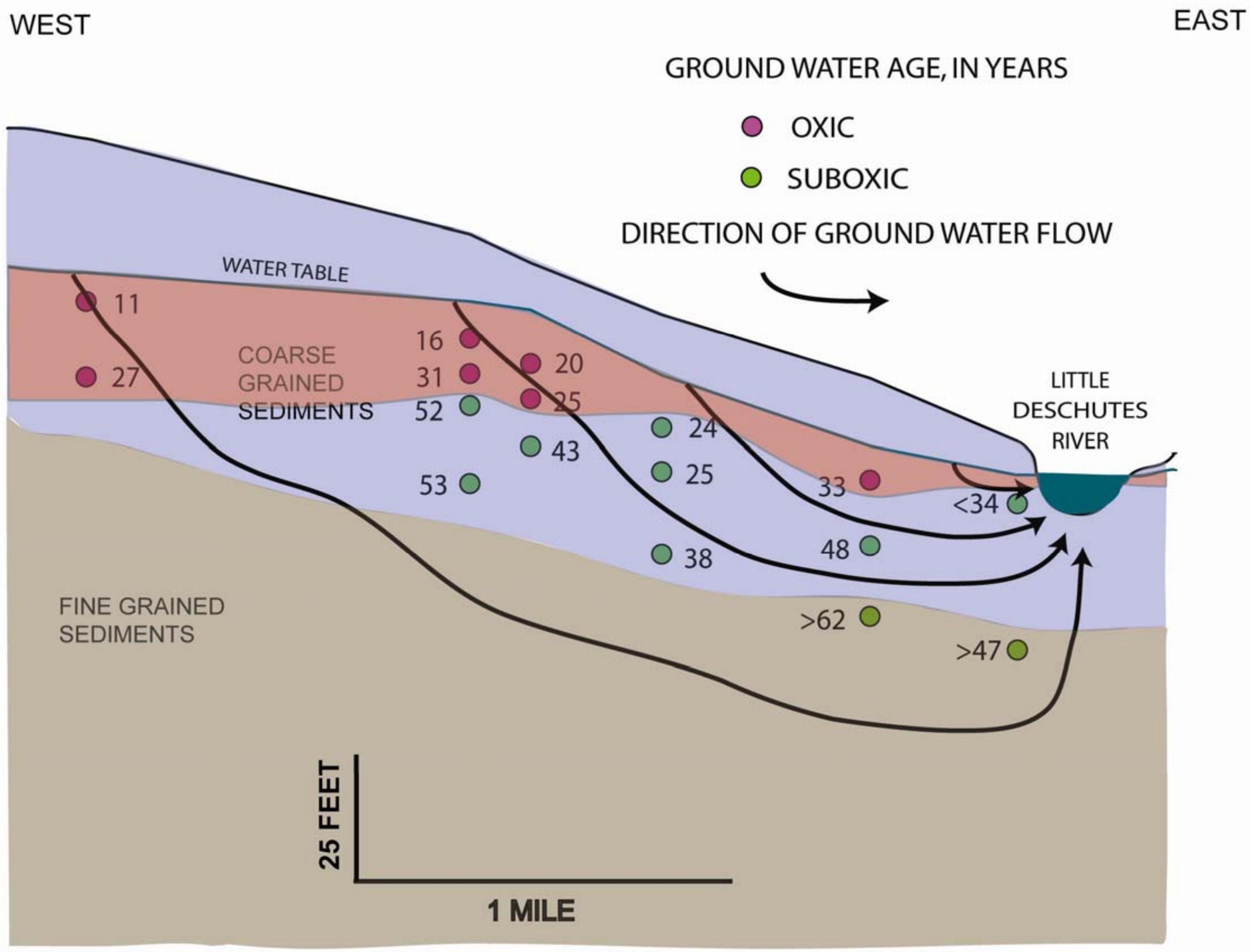
USGS



BURGESS TRANSECT
WEST
EAST
GROUND WATER AGE, IN YEARS
OXIC
SUBOXIC
DIRECTION OF GROUND WATER FLOW
1999
1988
WATER TABLE
11
27
COARSE GRAINED SEDIMENTS
16
31
52
53
20
25
43
24
25
38
33
48
>62
<34
>47
LITTLE DESCHUTES RIVER
FINE GRAINED SEDIMENTS
25 FEET
1 MILE

USGS

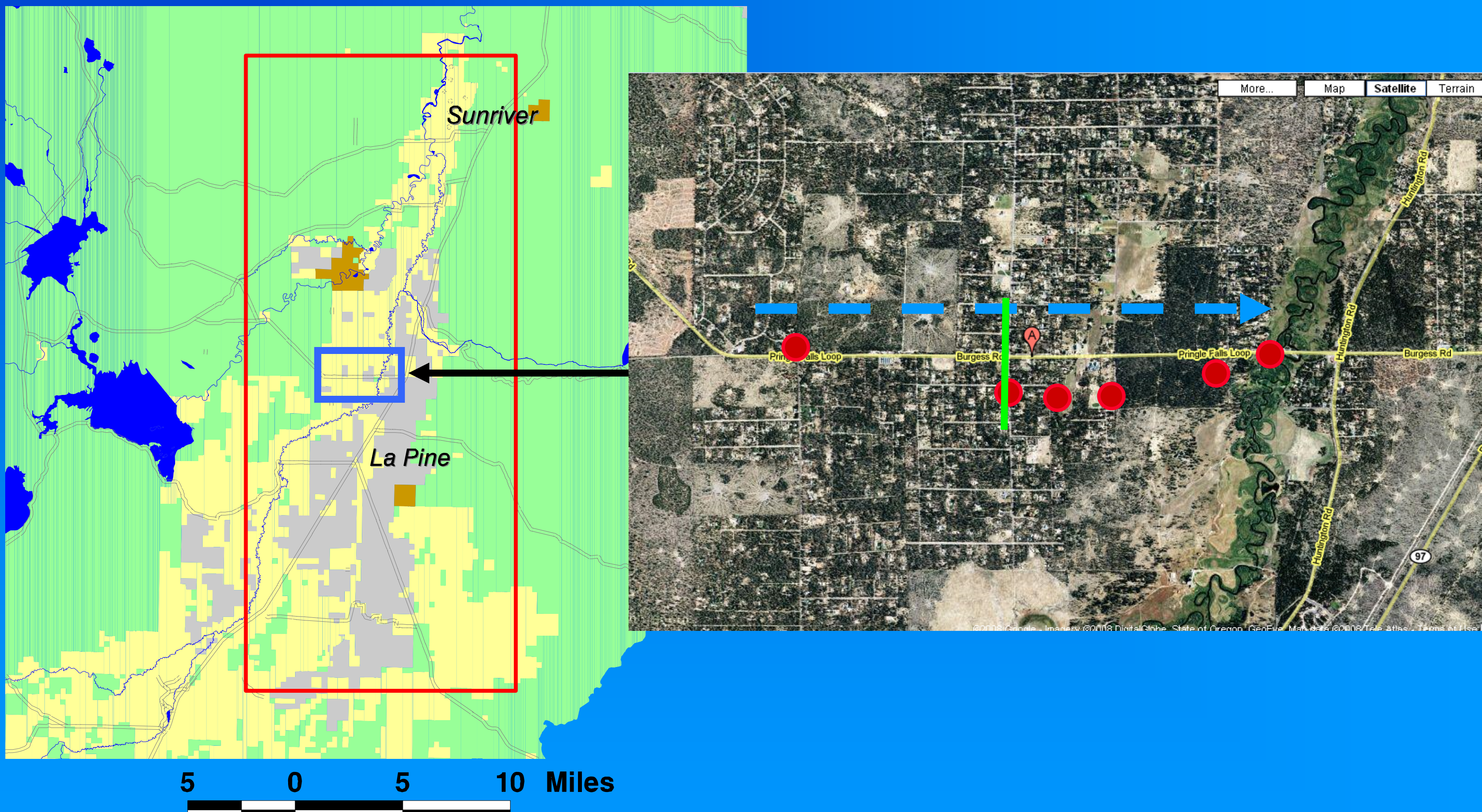
BURGESS TRANSECT



USGS

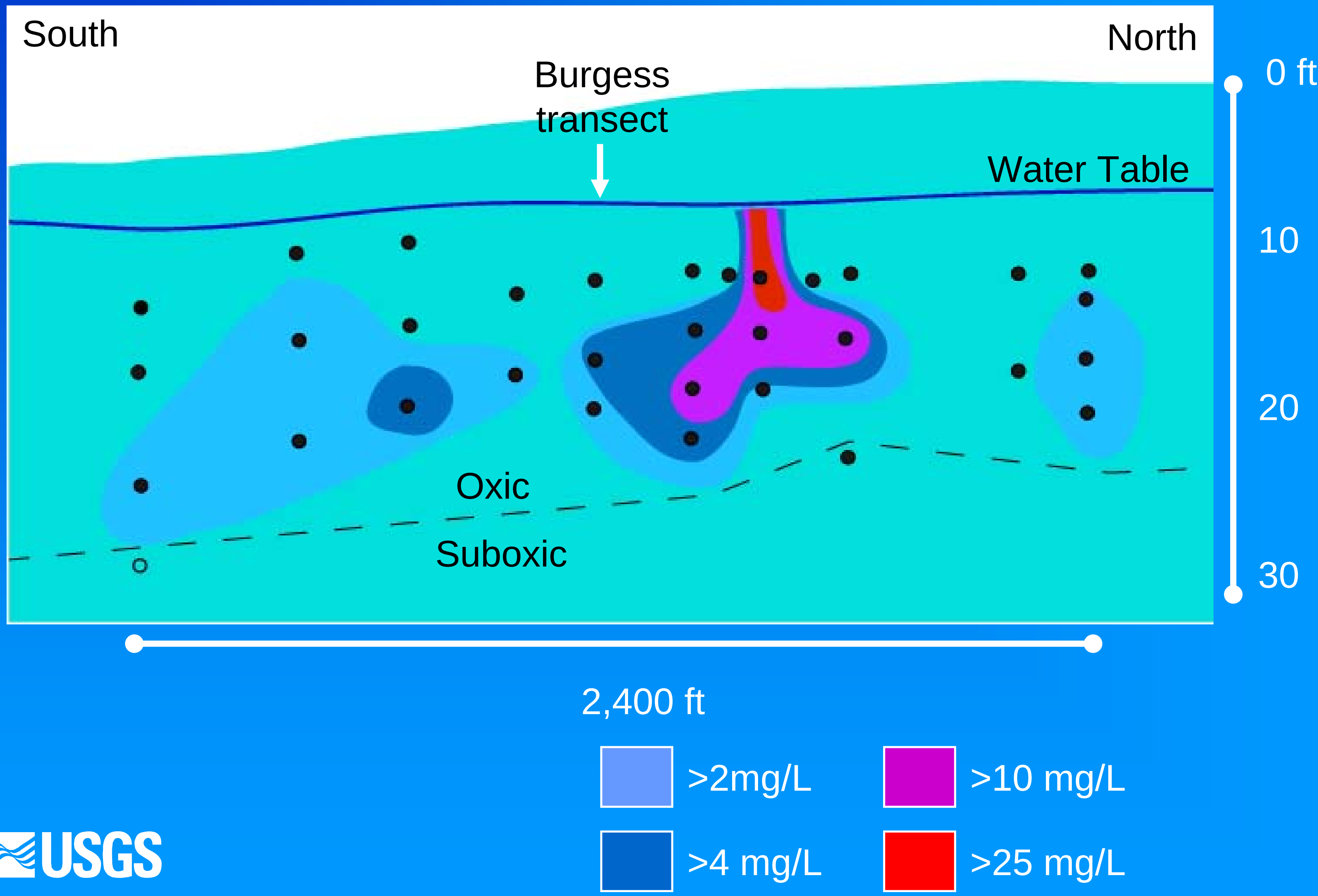
Nitrogen Dynamics

Burgess Road Transect Study



USGS

Septic Tank Effluent Creates Nitrate Plumes

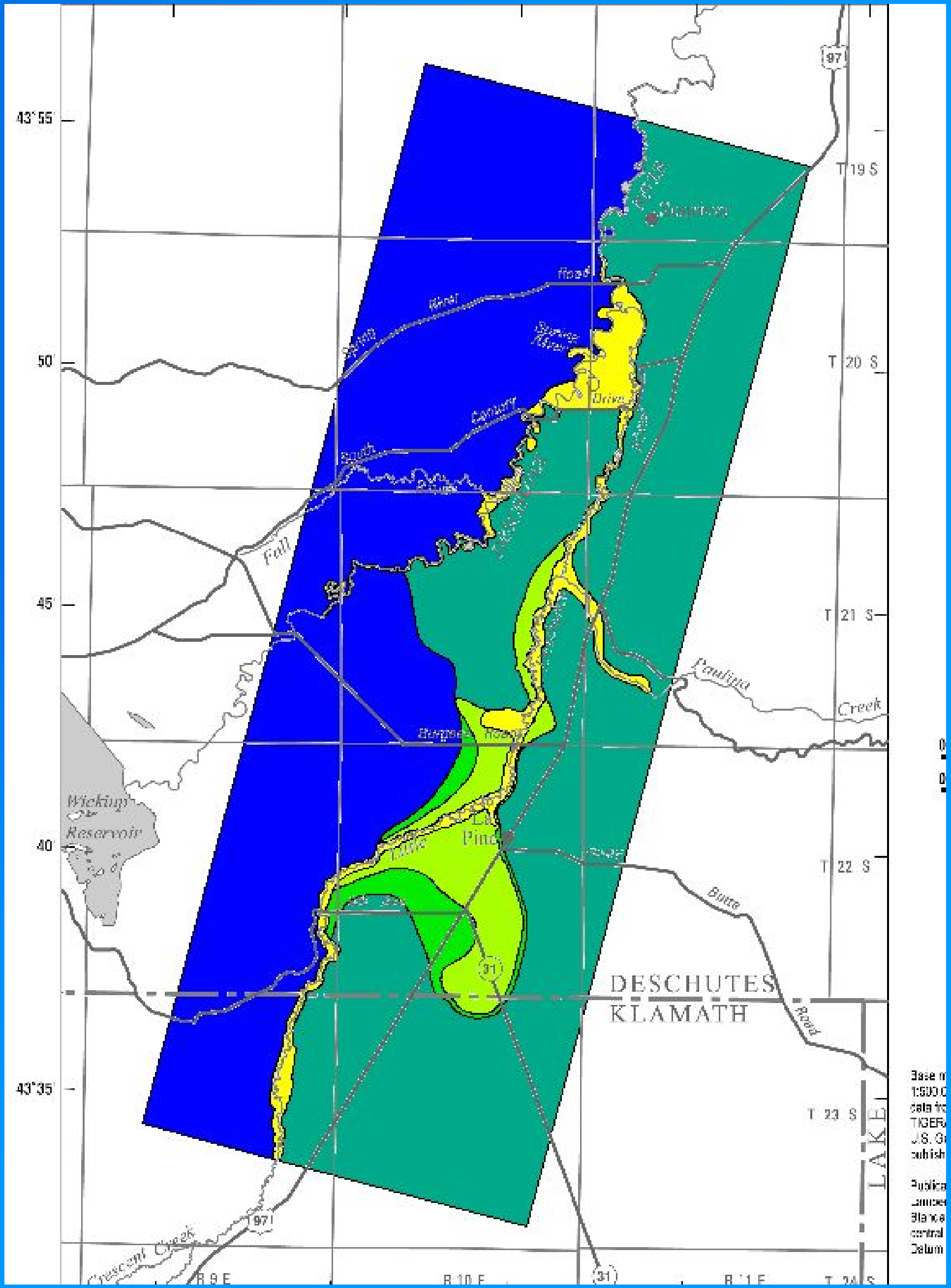


USGS

Oxic-Suboxic Boundary

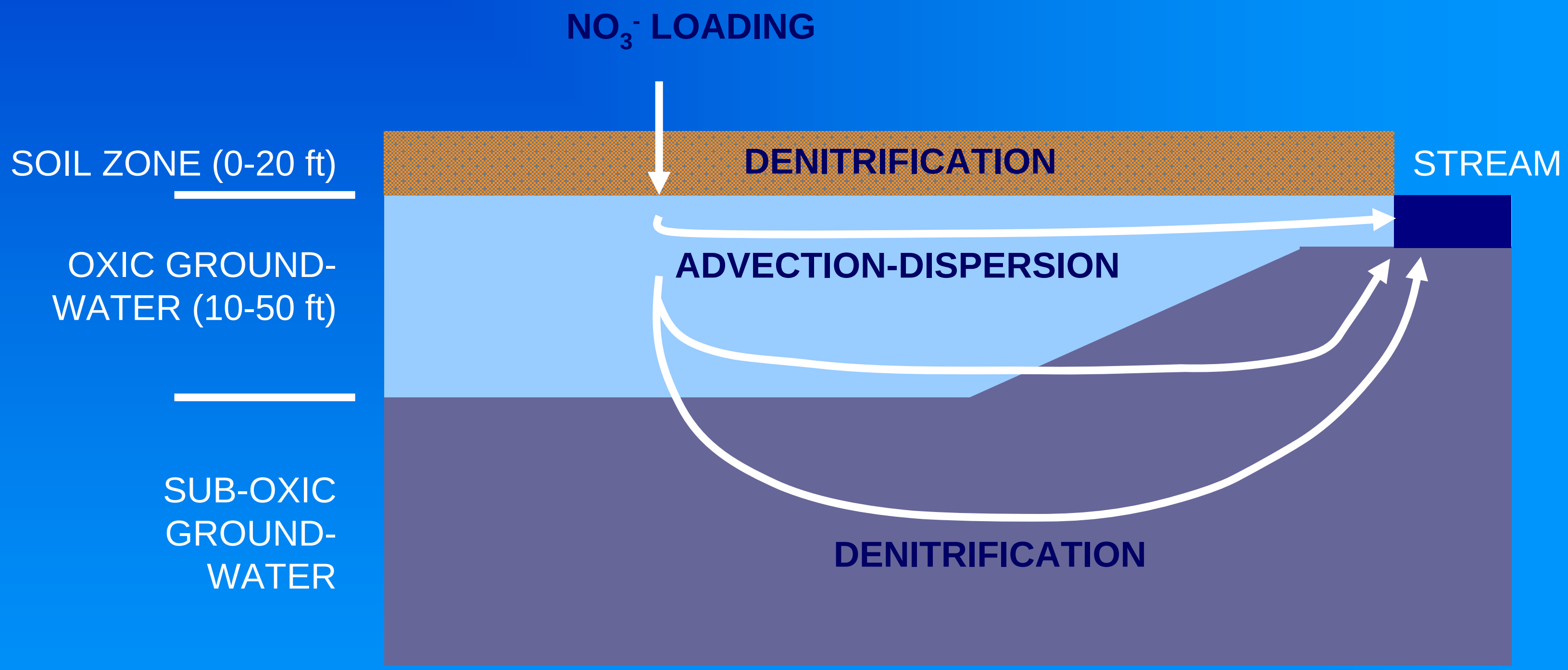
Thickness of the oxic ground-water zone, in feet below the water table

- 10 feet
- 12
- 20
- 40
- 50

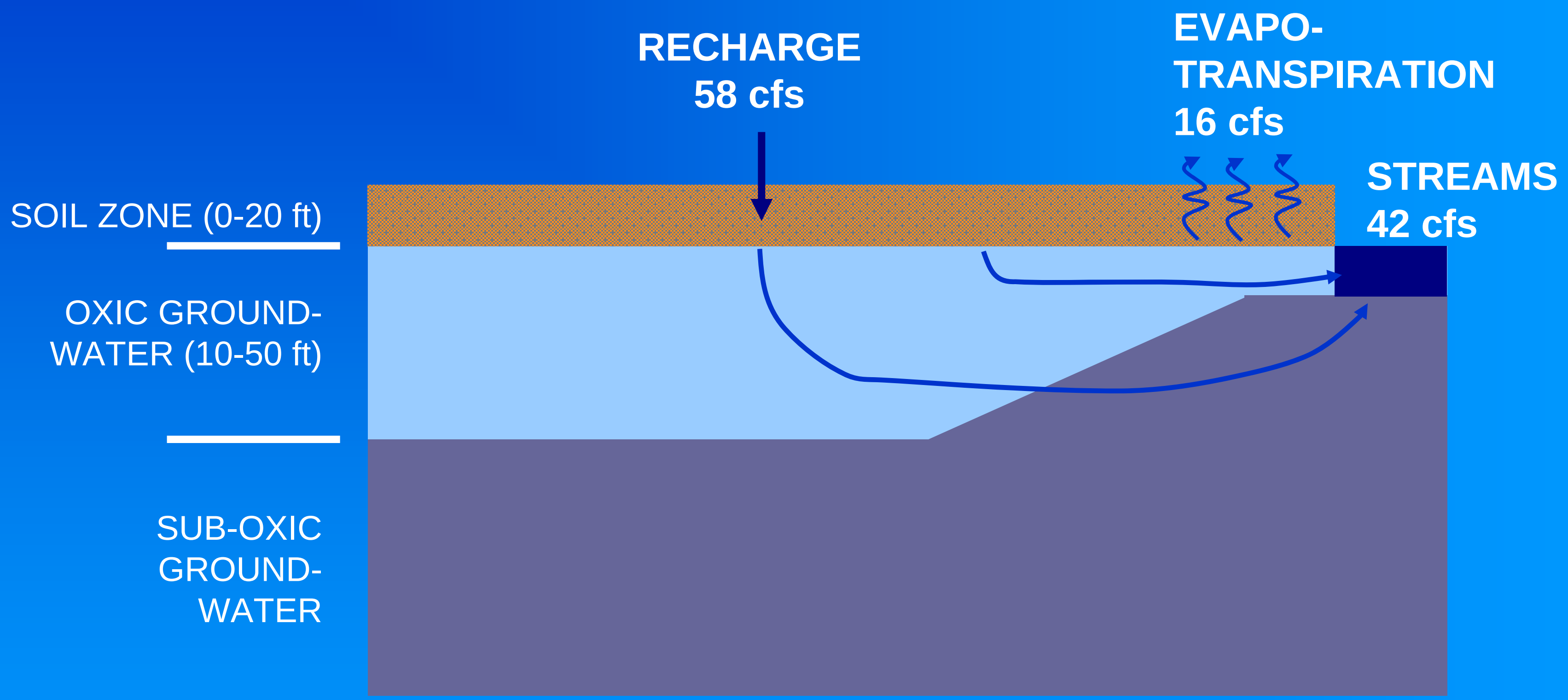


USGS

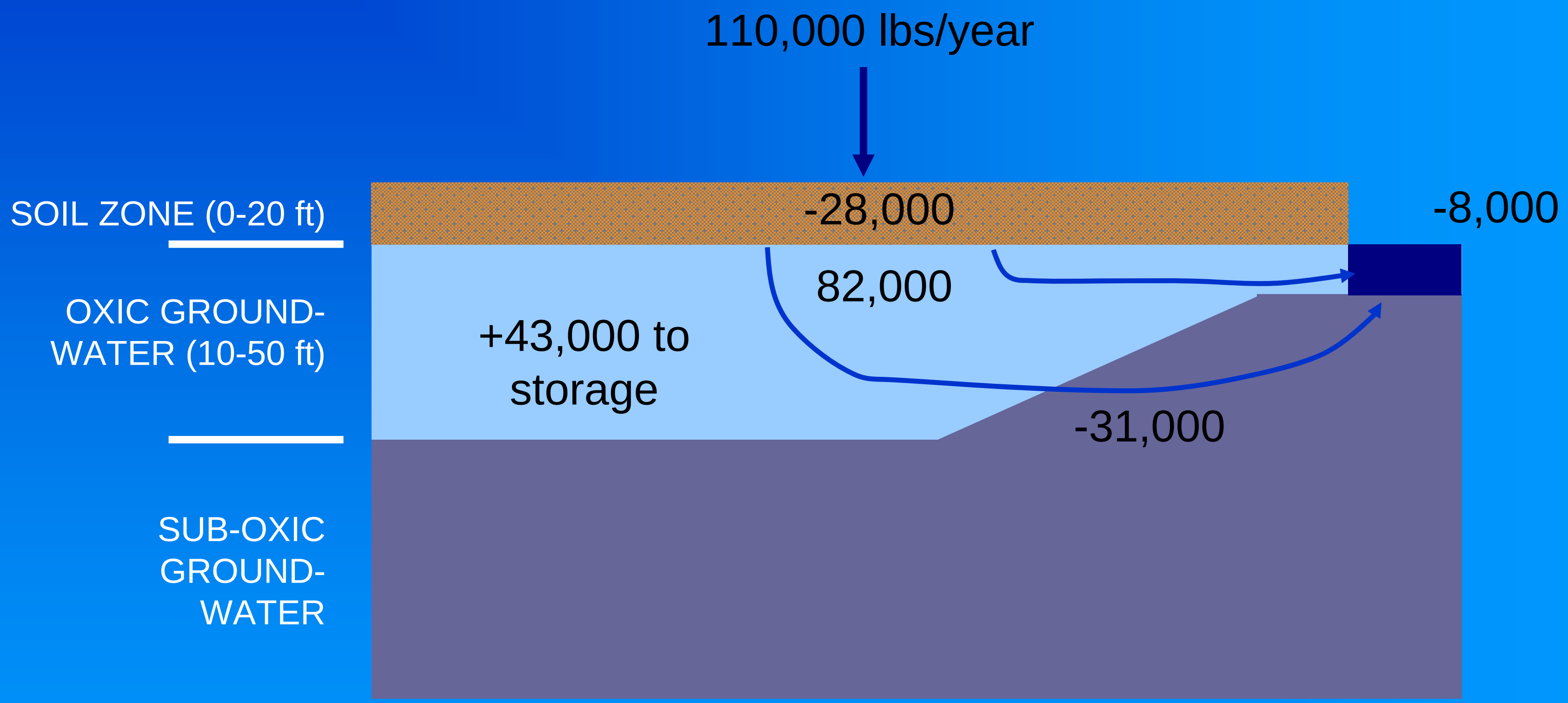
Conceptual Model: Processes



Water Budget, mean annual



Nitrogen Budget: 2000

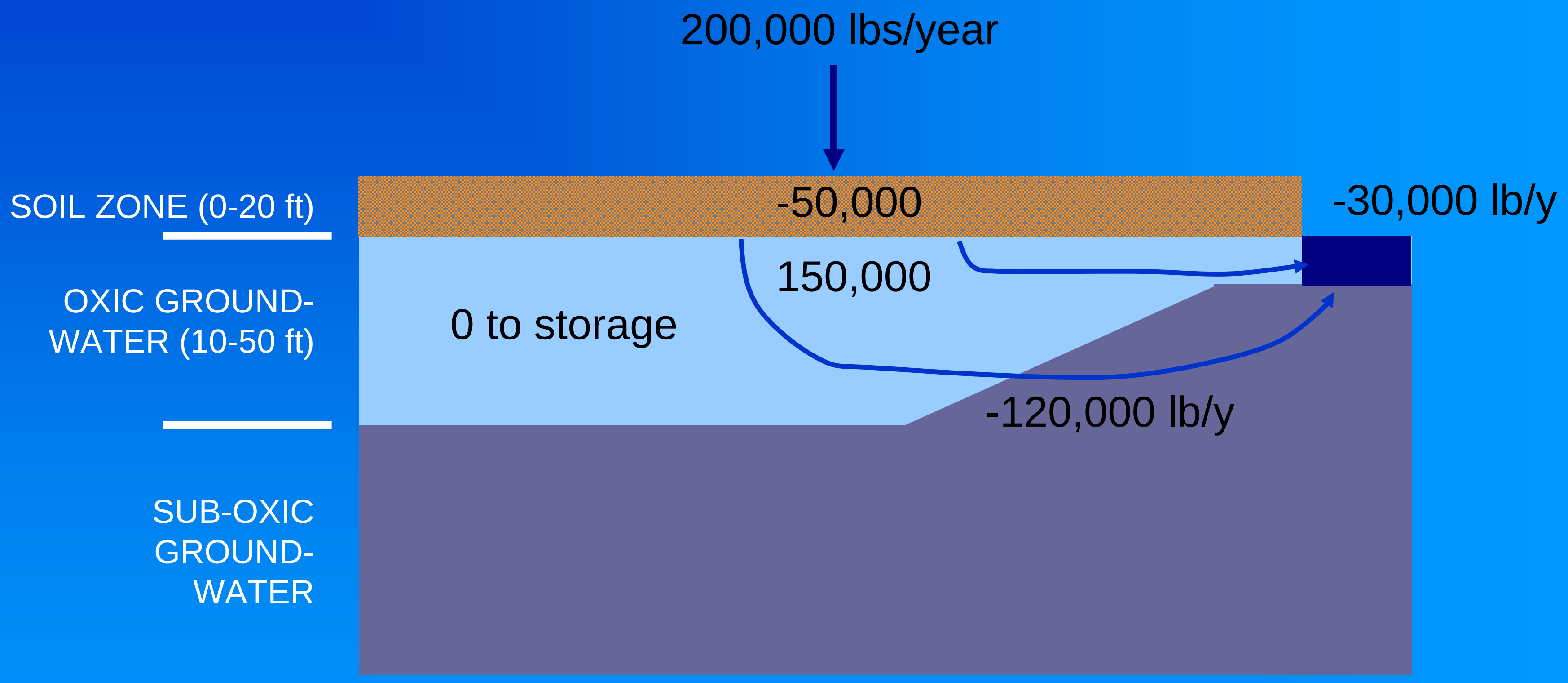


Estimated volumes of nitrate going into aquifer storage, denitrified in the sub-oxic zone, and discharged to the near-stream environment, are based on simulation model results.

USGS

Nitrogen Budget: > 100 years

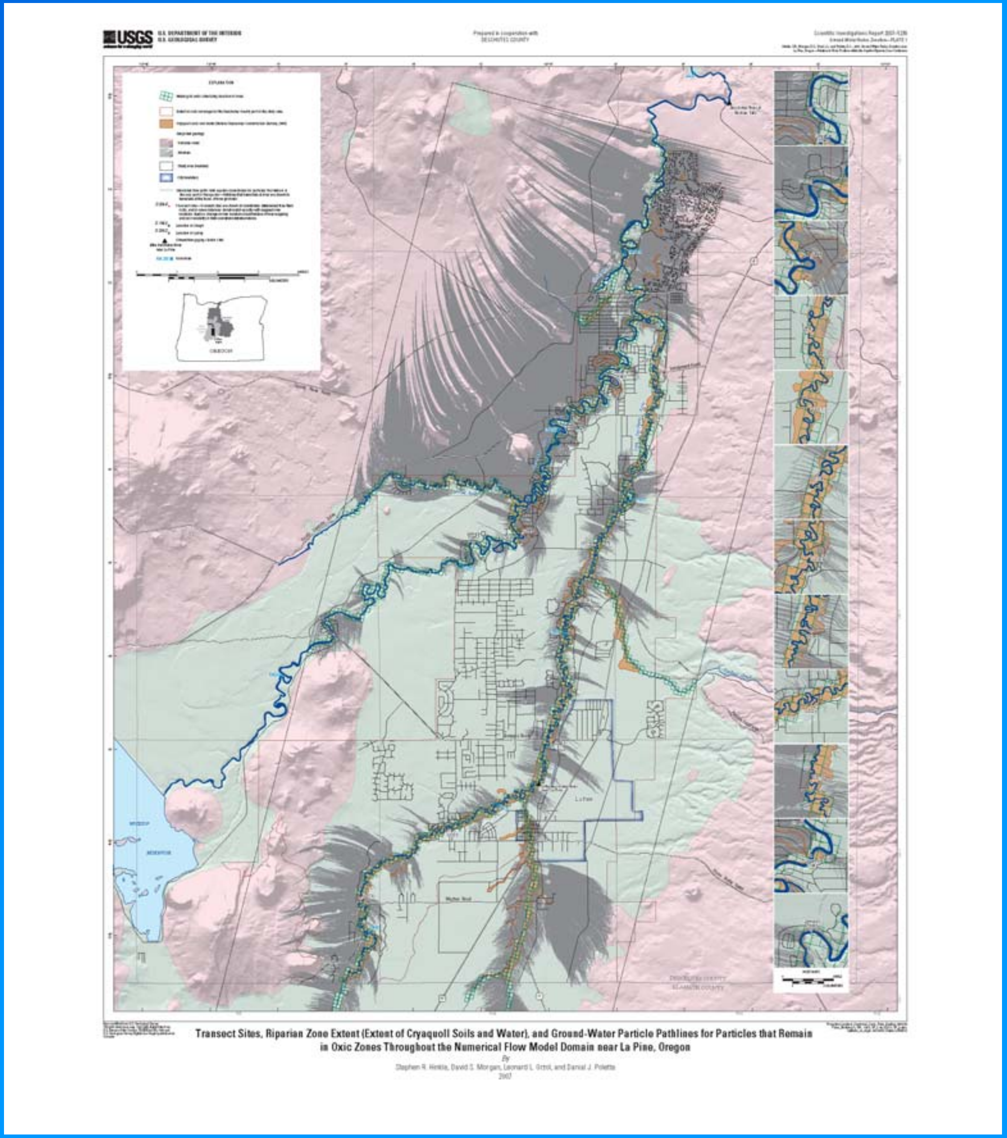
Assuming full build-out with conventional OWS



Note: Assumes no loading from high groundwater lots.

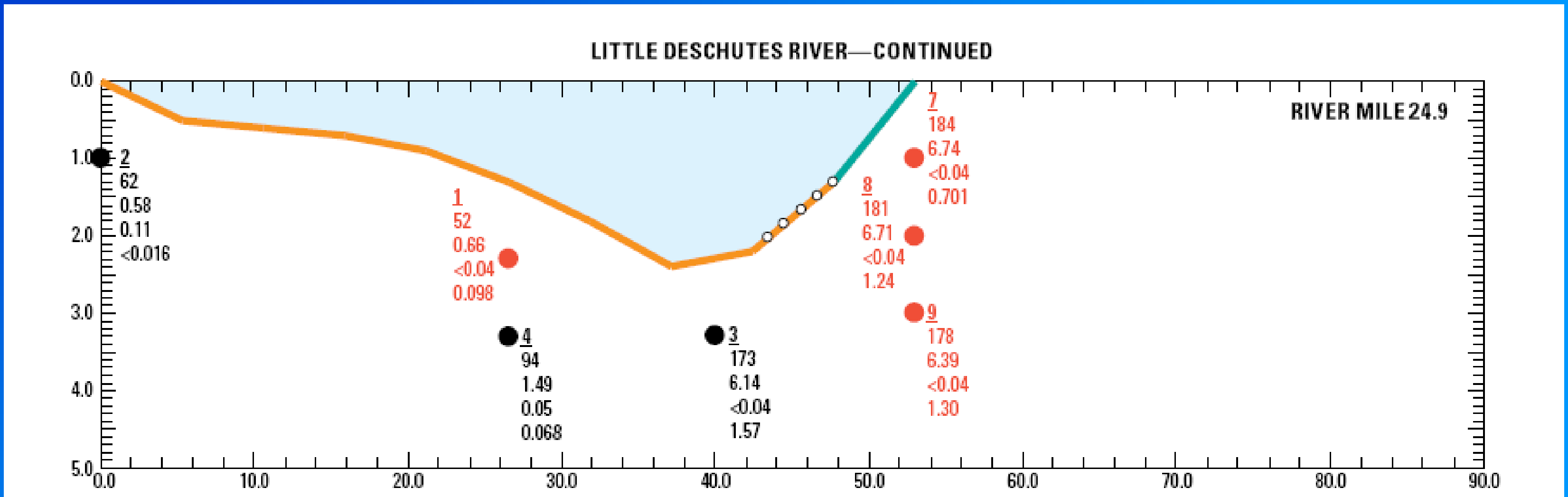
USGS

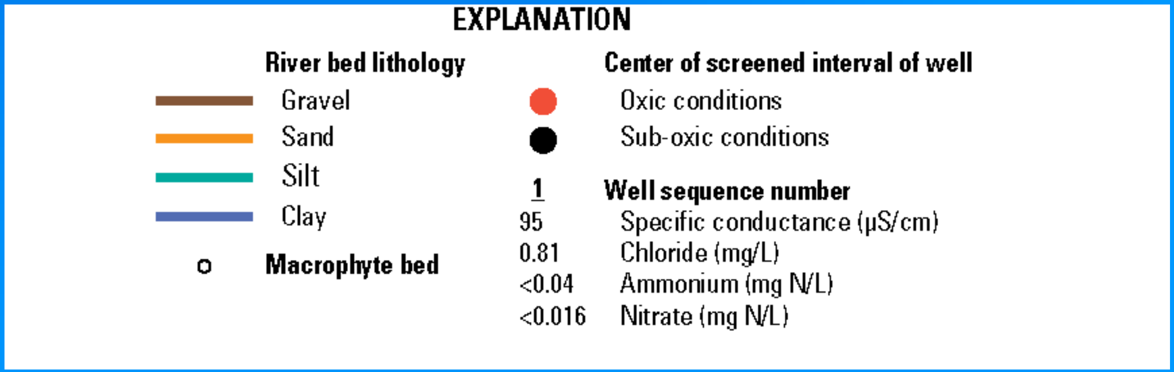
Potential for Discharge of Nitrate to Streams



USGS

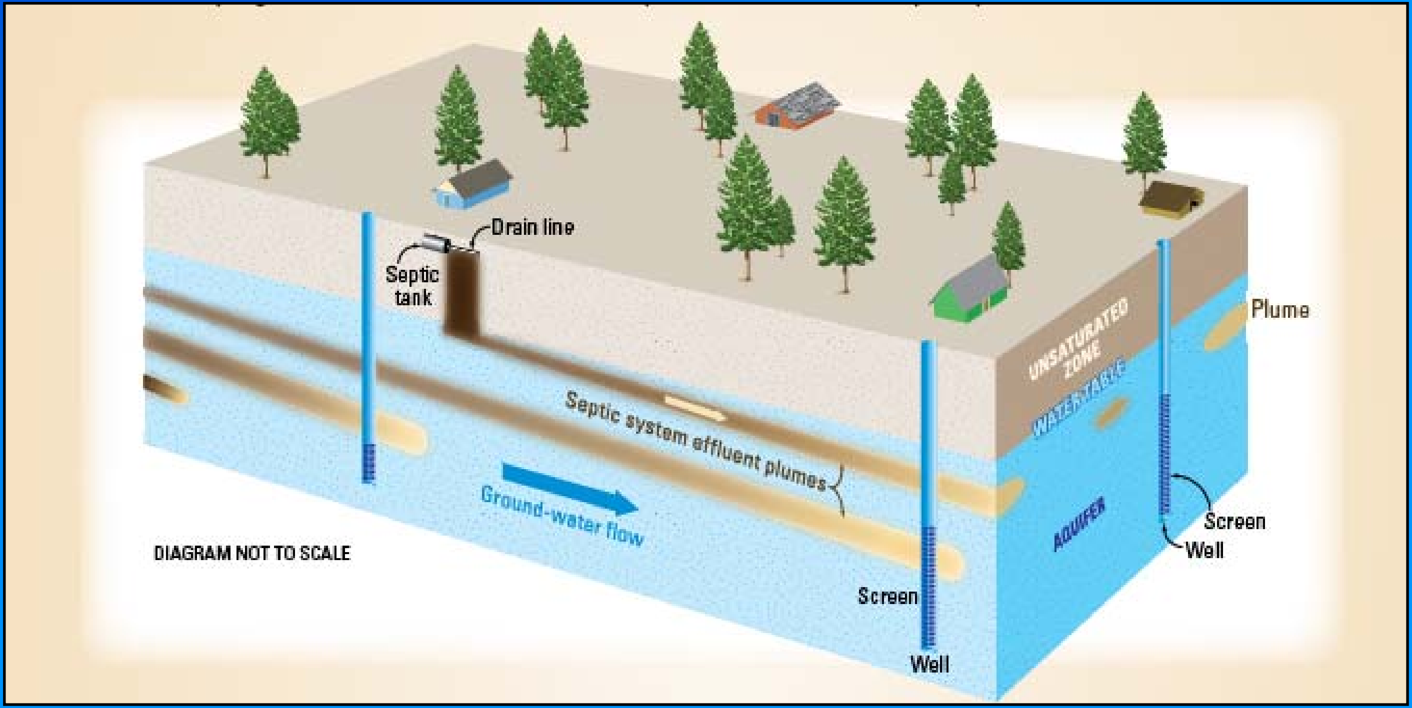
USGS


LITTLE DESCHUTES RIVER—CONTINUED
RIVER MILE 24.9
0.0
1.0
2.0
3.0
4.0
5.0
0.0
10.0
20.0
30.0
40.0
50.0
60.0
70.0
80.0
90.0
2
62
0.58
0.11
<0.016
1
52
0.66
<0.04
0.098
4
94
1.49
0.05
0.068
3
173
6.14
<0.04
1.57
8
181
6.71
<0.04
1.24
7
184
6.74
<0.04
0.701
9
178
6.39
<0.04
1.30


EXPLANATION
River bed lithology
Gravel
Sand
Silt
Clay
Macrophyte bed
Center of screened interval of well
Oxic conditions
Sub-oxic conditions
1
Well sequence number
95
Specific conductance (µS/cm)
0.81
Chloride (mg/L)
<0.04
Ammonium (mg N/L)
<0.016
Nitrate (mg N/L)

USGS

From Conceptual Model to Computer Model

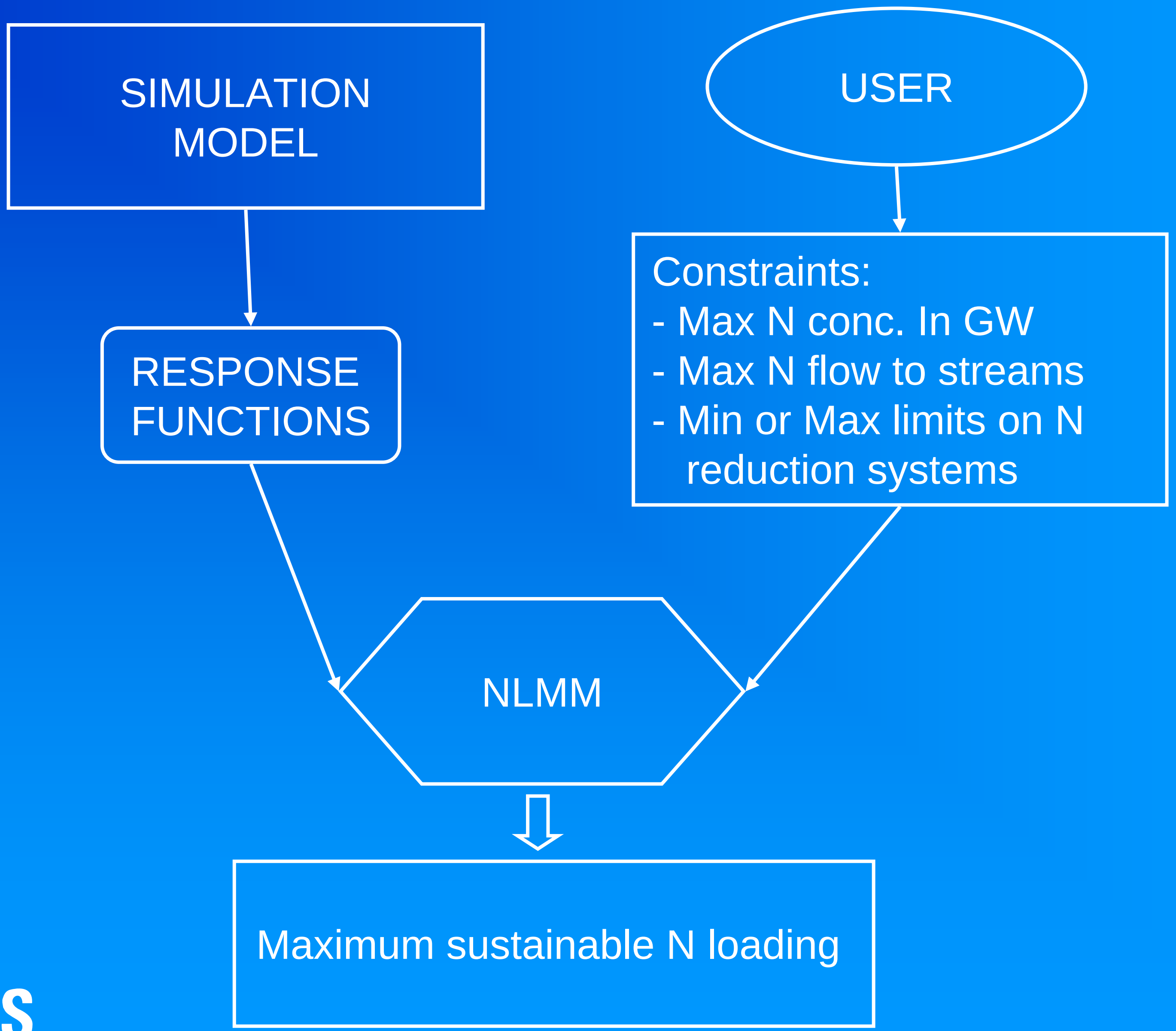


USGS

Two Models

- Simulation model
  - Physically based, includes key processes in conceptual model
  - Calibrated and tested
  - Use requires special training, experience
- Nitrate Loading Management Model (NLMM)
  - Computes maximum sustainable N-loading by area
  - Incorporates relations between loading and N concentration from simulation model
  - Excel interface, can be used by planning and resource protection agencies

USGS


SIMULATION MODEL
USER
Constraints:
- Max N conc. In GW
- Max N flow to streams
- Min or Max limits on N reduction systems
RESPONSE FUNCTIONS
NLMM
Maximum sustainable N loading

The LINDO™ solver is implemented in a standard spreadsheet interface (Whats Best!™)

Microsoft Excel - NLMM_3.5.xls

File Edit View Insert Format Tools Data Window Help WB! Adobe PDF

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	La Pine Nitrate Loading Management Model								Version 3.5	Last update:8-21-06		Includes new decisi lots. New constraint lots, and cost factor	
2	CONSTRAINTS												Notes:
3	GW Quality		Cost Factors		Stream loading reduction			Max loading Reduction		Min Loading Reduxtion			Well c
4	GW NO3- max, mg/L		per kg/day reduction					Percent		Percent			
5	7 Shallow		1.00 Existing		0 percent			100 Existing		0 Existing			
6	3 Deep		1.00 Future					100 Future		0 Future			
7	99 Alternate		1.00 Red					100 High GW		0 High GW			Unmai
8	RESULTS SUMMARY												
9	Minimize this:		Existing	Future	Subtotal	Red	Total	River	RIVERS	L. Deschutes	Deschutes	Total	
10	Objective function	Base	127.78	65.68	193.46	34.61	228.07	43.76	Base	16.27	27.49	43.76	
11	131	Reduction:	68.64	38.17	106.82	24.53	131.34	27.83	Reduction:	6.16	21.67	27.83	
12	(arbitrary units)	Remaining	59.14	27.51	86.64	10.09	96.73	15.93	Remaining	10.11	5.82	15.93	2
13		% reduction:	54%	58%	55%	71%	58%	64%	% reduction	38%	79%	64%	
14								Unmgd	Base	Target		Optimal	
15	Obs_ID	MA	Obs_Type	Seqnum	Layer	Row	Column	Conc/load	Conc/load	Reduction	Operand	Reduction	ma_0
16	01_e-004756-S	01_e	Shallow	4756	2	48	56	4.67	389.07	285.40	<=	377.40	27
17	02_e-004749-S	02_e	Shallow	4749	2	48	49	0.00	1.40	-5.60	<=	0.00	0
18	02_f-004150-S	02_f	Shallow	4150	2	42	50	0.00	4.26	-2.74	<=	0.97	0
19	02_r-004851-S	02_r	Shallow	4851	2	49	51	0.01	1.66	-5.35	<=	0.29	0
20	03_f-004355-S	03_f	Shallow	4355	2	44	55	0.21	51.54	44.33	<=	45.24	1
21	04_f-006576-S	04_f	Shallow	6576	2	66	76	0.00	105.46	6.46	<=	98.46	
22	05_f-004259-S	05_f	Shallow	4259	2	43	59	0.24	74.95	-24.29	<=	67.71	1
23	05_r-004260-S	05_r	Shallow	4260	2	43	60	0.30	102.34	3.04	<=	95.04	1
24	06_f-005161-S	06_f	Shallow	5161	2	52	61	1.36	64.46	56.10	=<=	56.10	1
25	06_r-005162-S	06_r	Shallow	5162	2	52	62	1.00	61.78	53.77	=<=	53.77	1

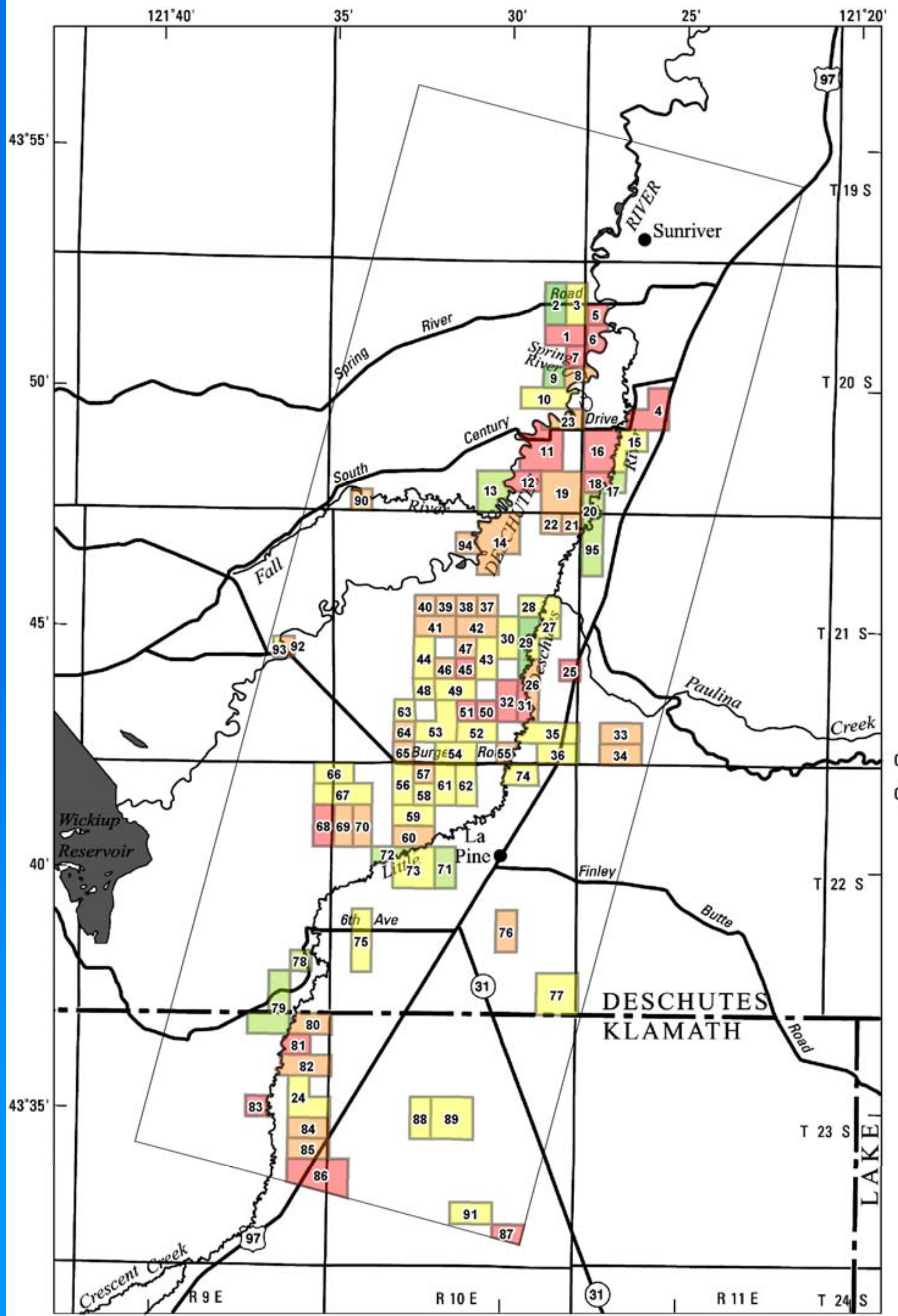
WB! Status | NLMM | GIS Output

Ready NUM

USGS

Nitrate loading capacity, kg/d

Red	0.0 – 0.5
Orange	0.5 – 1.0
Yellow	1.0 – 2.0
Yellow-green	2.0 – 4.0
Green	4.0 -15



Constraint values

GW conc: 7 mg/L shallow

3 mg/L deep

SW discharge: none

USGS

Limitations

- N-transport in near-stream environment is complex--
  - Extent of oxic pathways to stream
  - Riparian uptake of water and nutrients
- Steady-state ground-water flow
  - Near-stream flow dynamics, flushing
- Sensitivity to location of constraints
  - Shallow part of system more sensitive—limits loading
- Management area boundaries are not hydrologic, geologic, or chemical boundaries—can lead to sharp changes in loading capacity between areas

Information needs

- Ground-water flow and nitrogen dynamics in the near-stream environment
  - Better definition of oxic pathways would allow more accurate estimation of N discharge to swtreams
  - Evaluation of ET and nutrient uptake in developed and undeveloped near-stream areas.
- Monitoring
  - Sustained, systematic, well-designed

USGS

High Groundwater Areas

- HG lots (aka “red lots”) are included in the NLMM (done for 2005 Advisory Comm.)
- NLMM can be used to determine loading capacity of HG areas
- Capacity in HG areas will be more sensitive to constraints on N discharge to streams

USGS

Effects of Sewers

- NLMM can be used to estimate how reduction of loading will affect capacity of adjacent areas
- Sewering will decrease recharge
- NLMM can not be used to assess effects on groundwater availability or stream flow
- Would require water budget analysis or new simulation model runs.