Predicting Streamflow Patterns in Ephemeral Channels in the Southwest to Estimate Groundwater Recharge

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Floods vs Baseflows

1. Groundwater levels rise following El Niño years
2. This suggests that floods may contribute more than baseflows to groundwater recharge in the Southwest
3. Simulation modeling aids in supporting this premise
4. Documentation of spatial and temporal patterns of streamflow in ephemeral streams is lacking for calibration of streamflow simulation models

The Southwest is composed almost entirely arid or semi-arid resulting in intermittent and ephemerals streamflows, except for a few notable rivers like the Rio Grande.

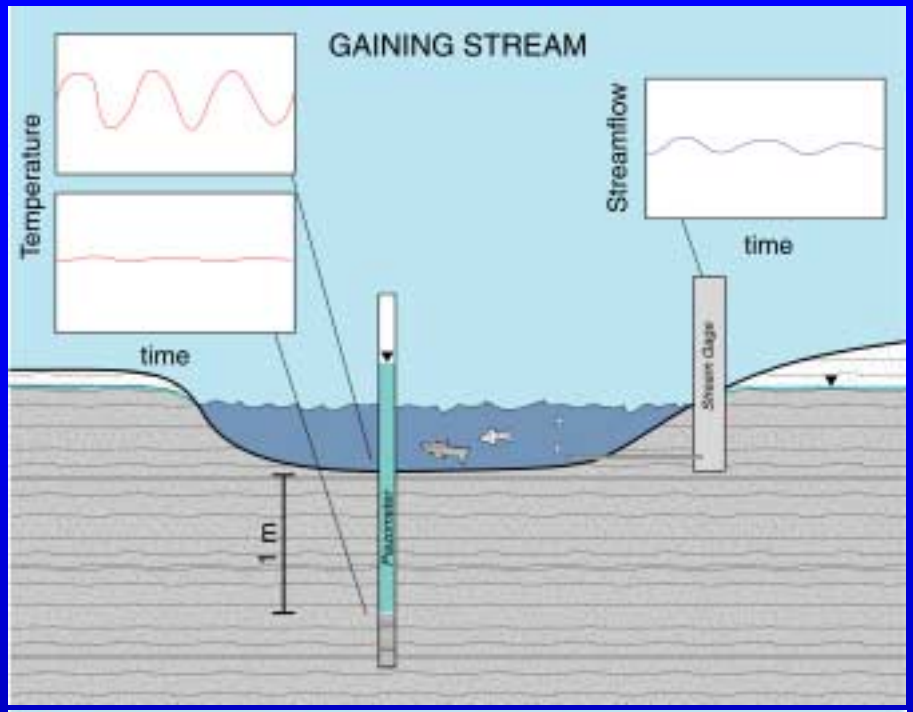
Definition of Semiarid:
Only half of the residents ride camels

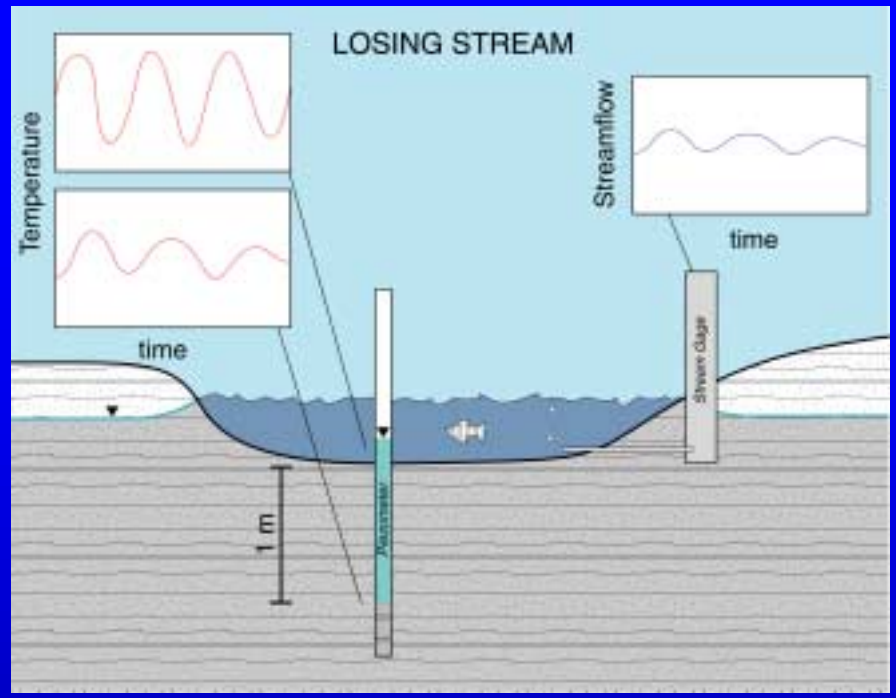
Rillito Creek, AZ near the confluence with the Santa Cruz

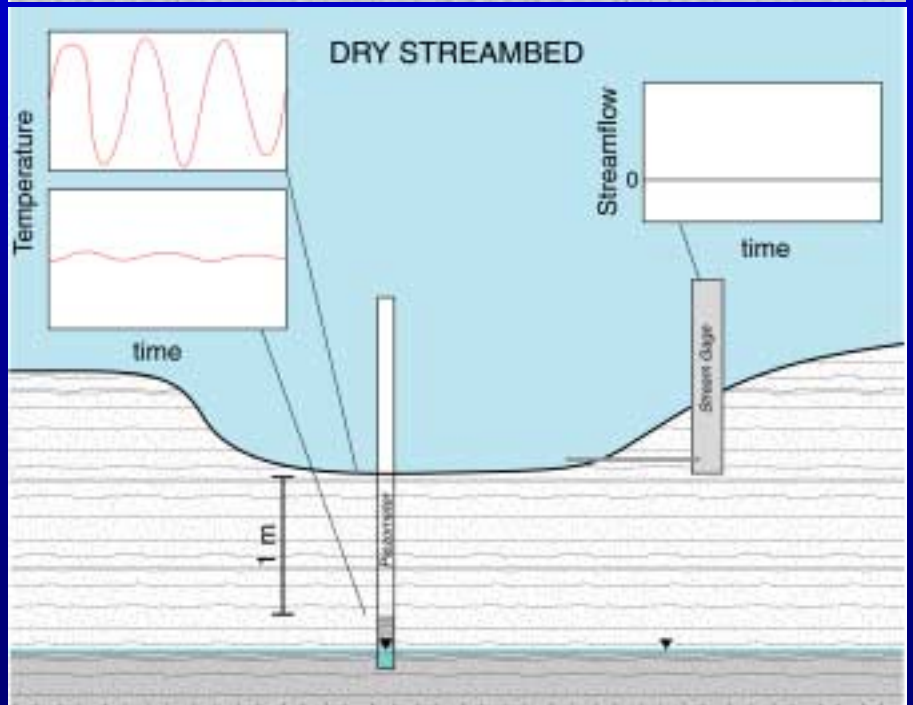
Heat as a Tracer of Stream-Groundwater Exchanges

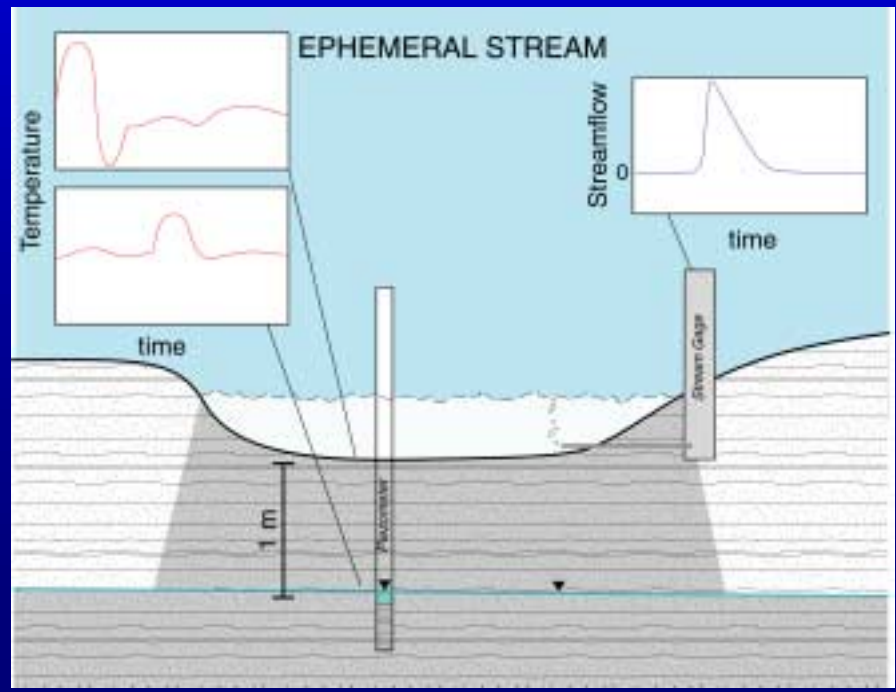
The use heat as a tracer to understand streamflow patterns is particularly well-suited for the Southwest because:

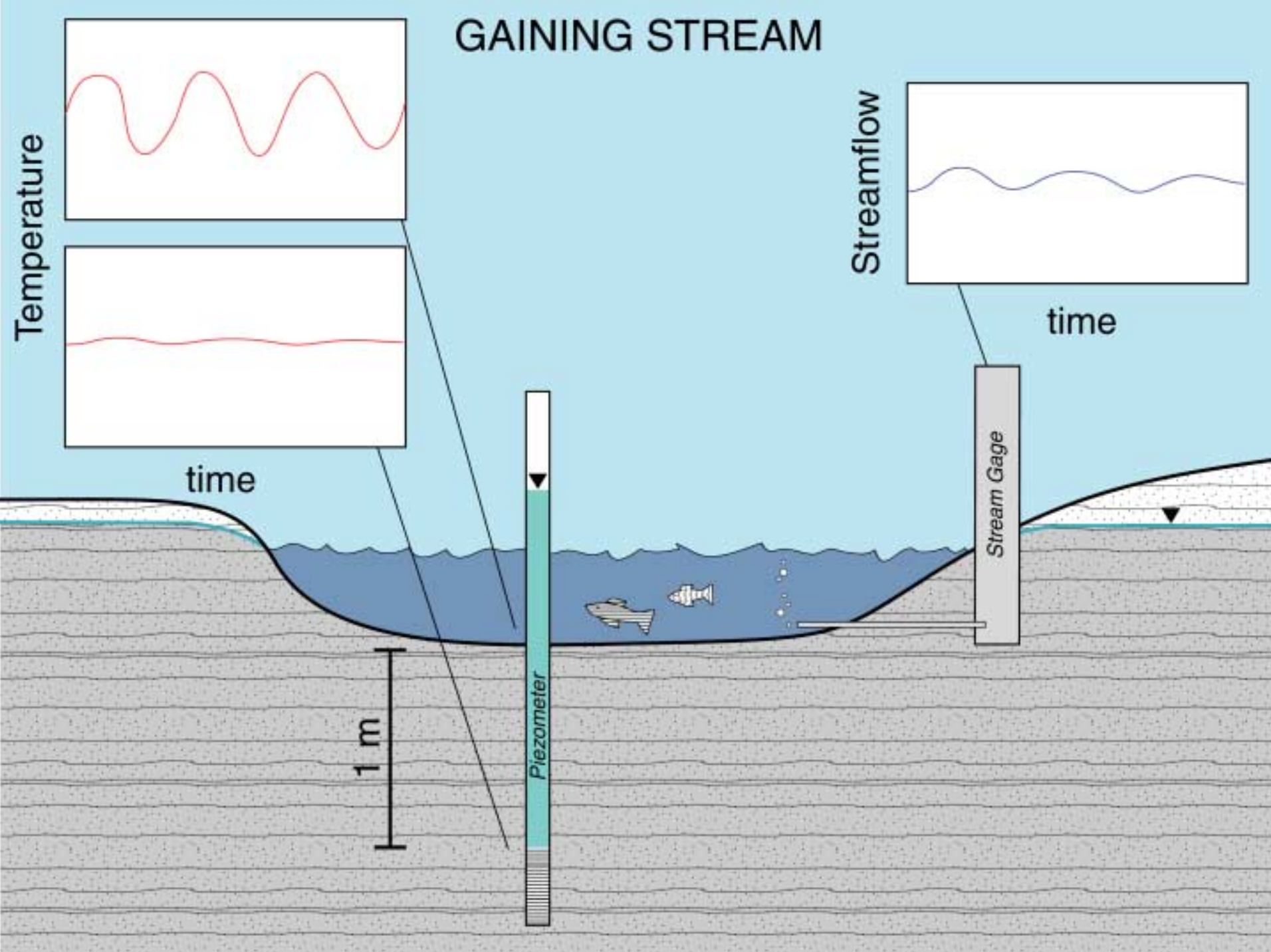
1. The Southwest possesses strong temperature variations
2. Temperature measurements are particularly robust measurements, which is a necessary requirement in the flashy environments of the Southwest

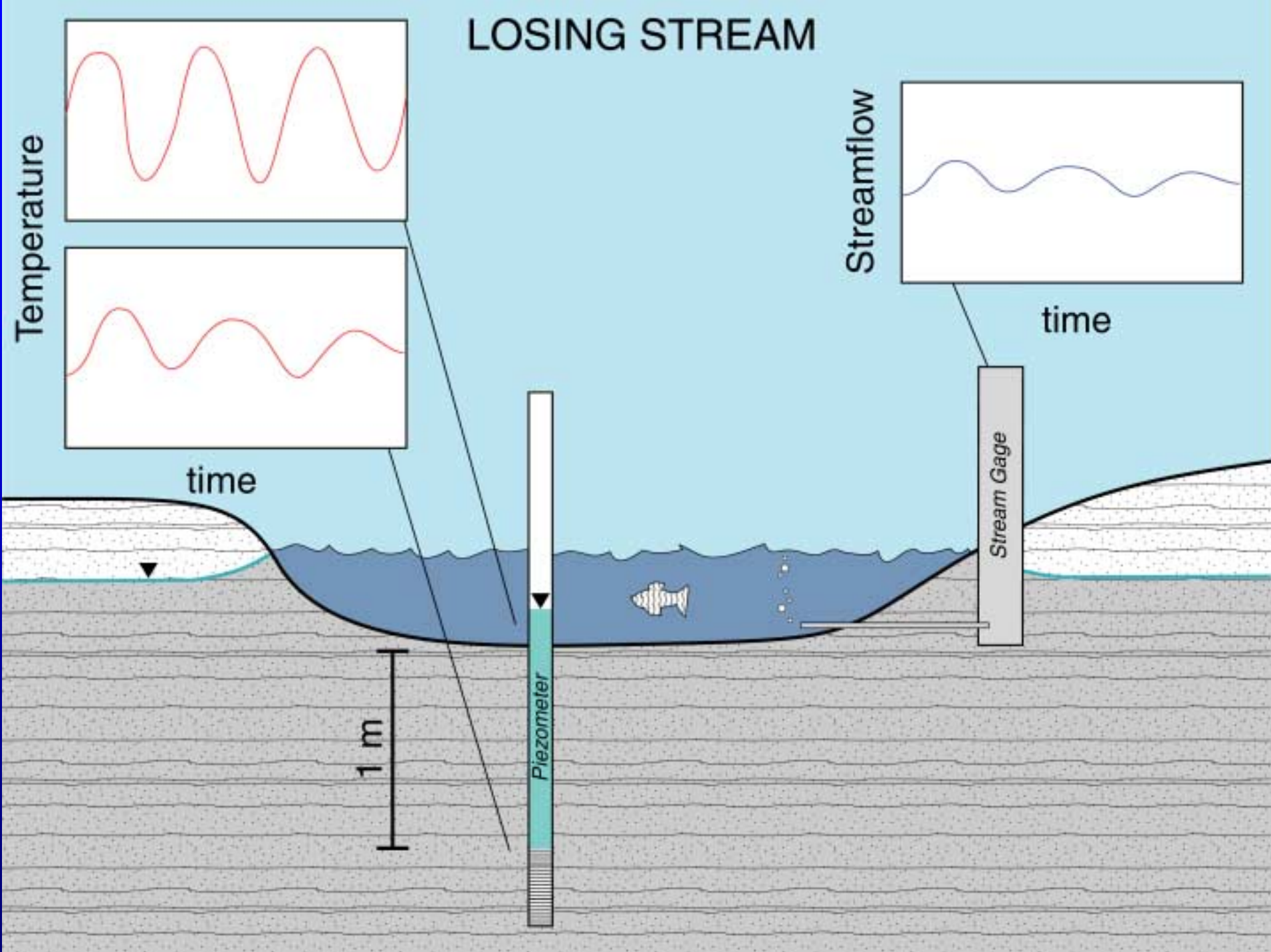

GAINING STREAM
Temperature
time
Streamflow
time
1 m
Piezometer
Stream Gage

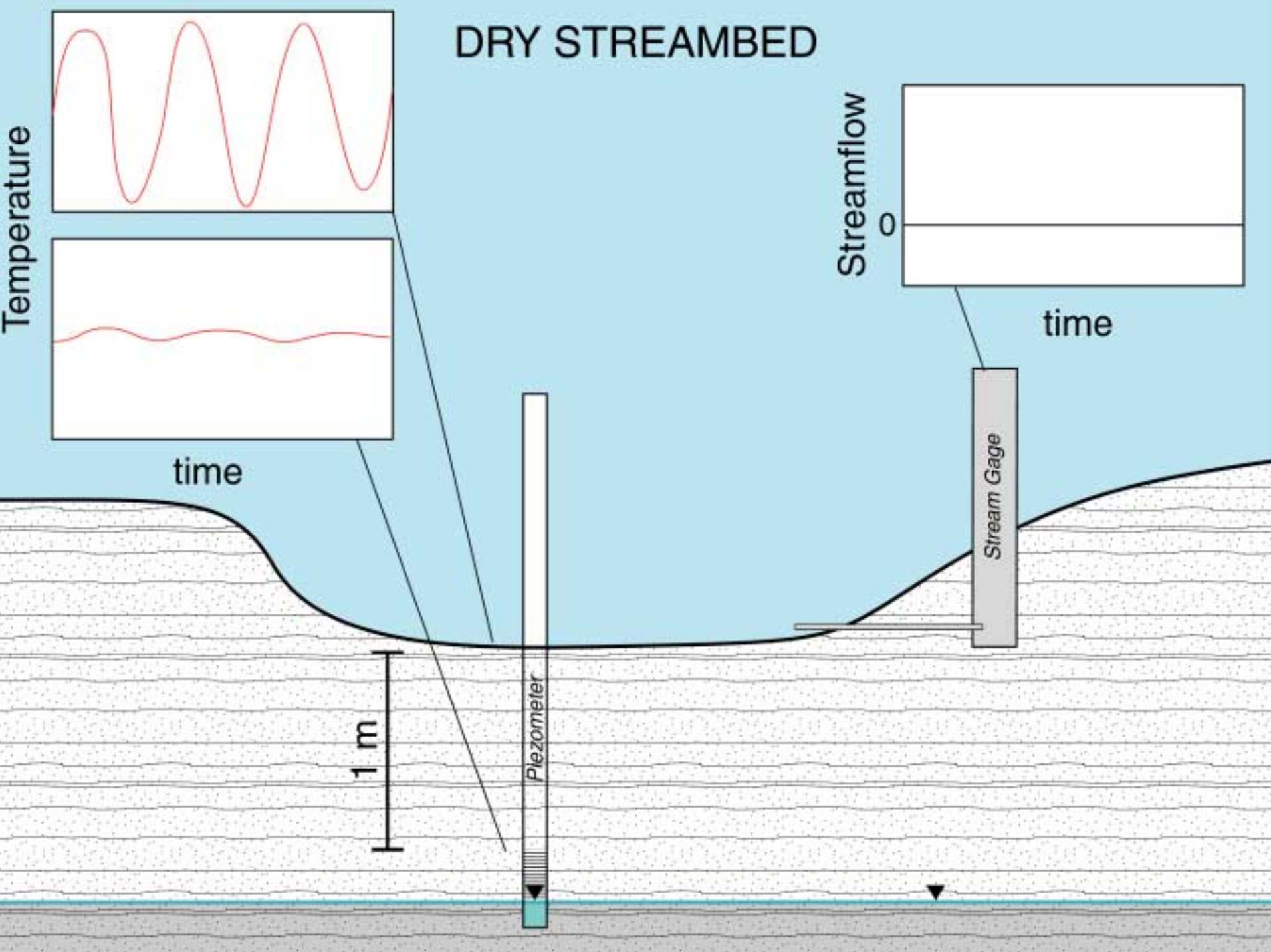

LOSING STREAM
Temperature
time
Streamflow
time
1 m
Piezometer
Stream Gage

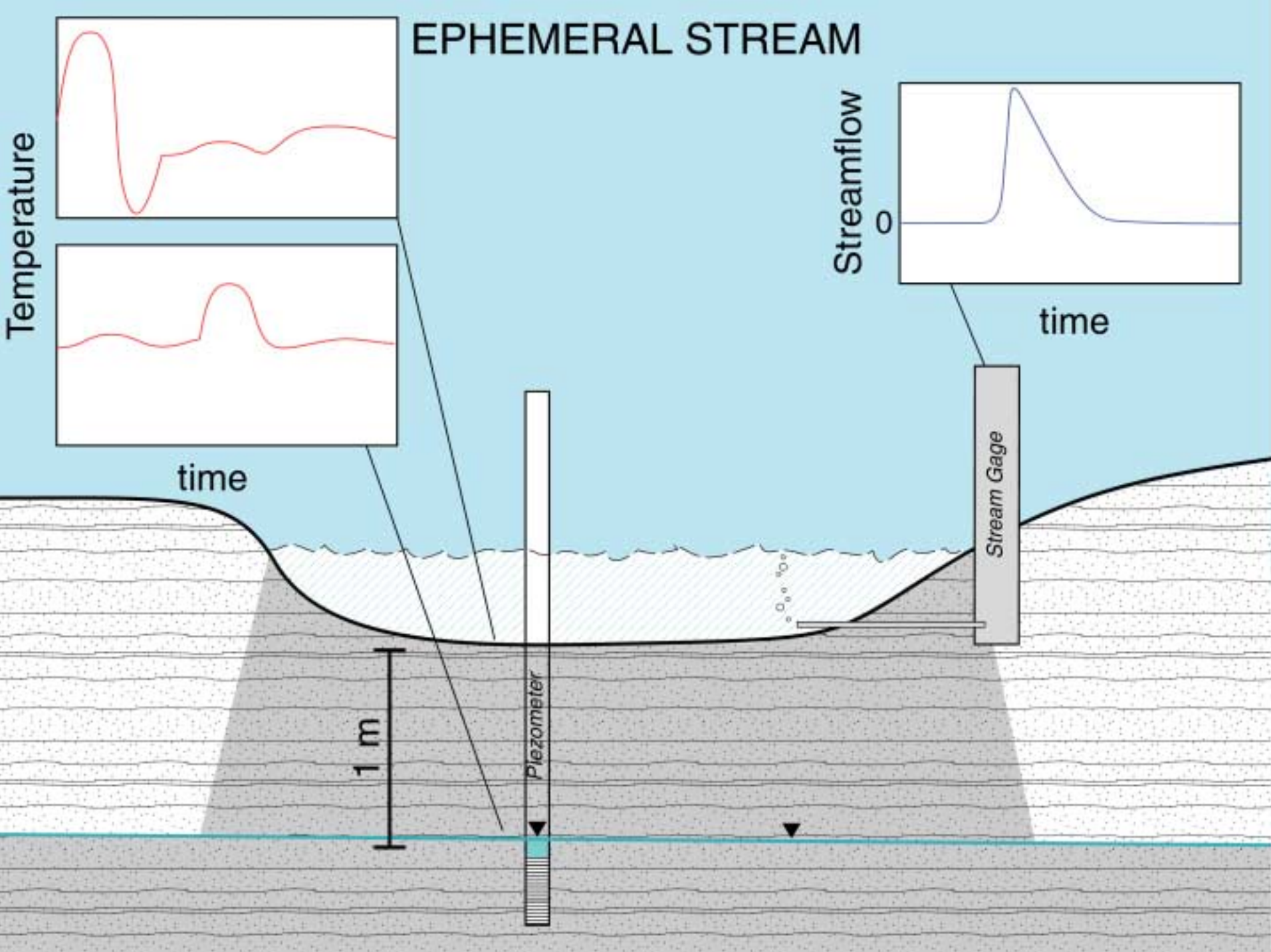

DRY STREAMBED
Temperature
time
Streamflow
0
time
1 m
Piezometer
Stream Gage

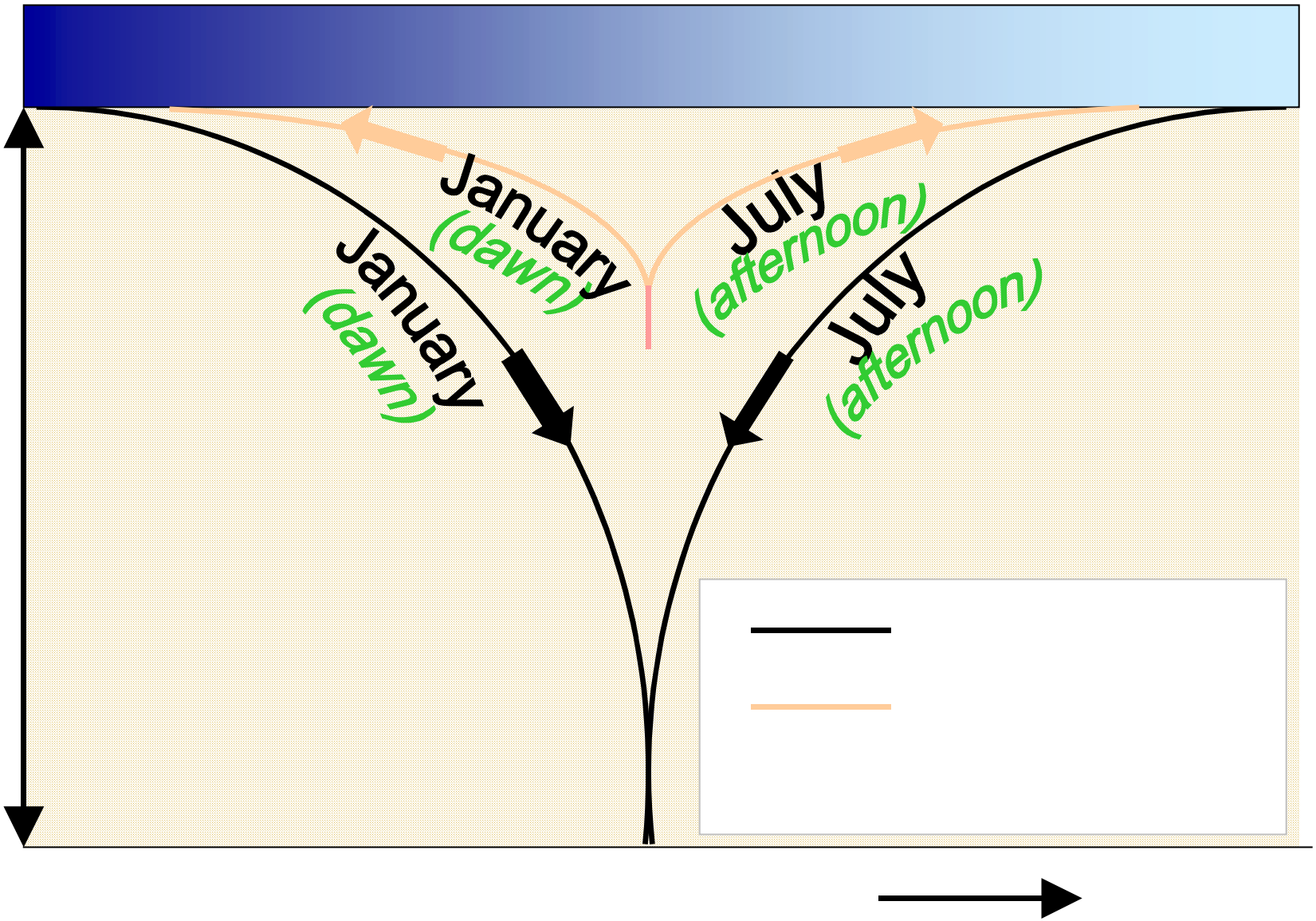

EPHEMERAL STREAM
Temperature
time
Streamflow
0
time
1 m
Piezometer
Stream Gage

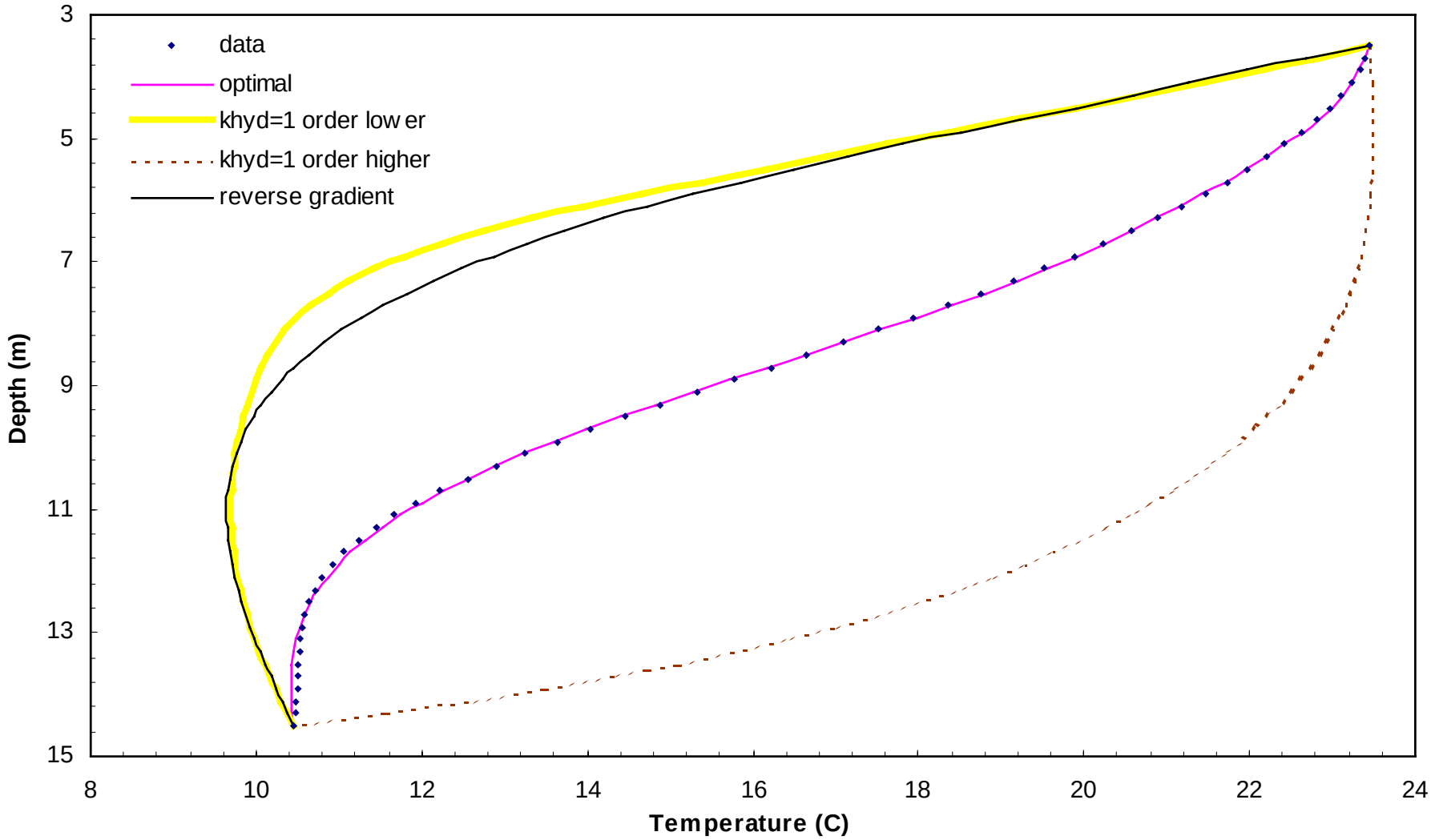

GAINING STREAM
Temperature
time
Streamflow
time
Stream Gage
Piezometer
1 m


LOSING STREAM
Temperature
time
Streamflow
time
Stream Gage
Piezometer
1 m

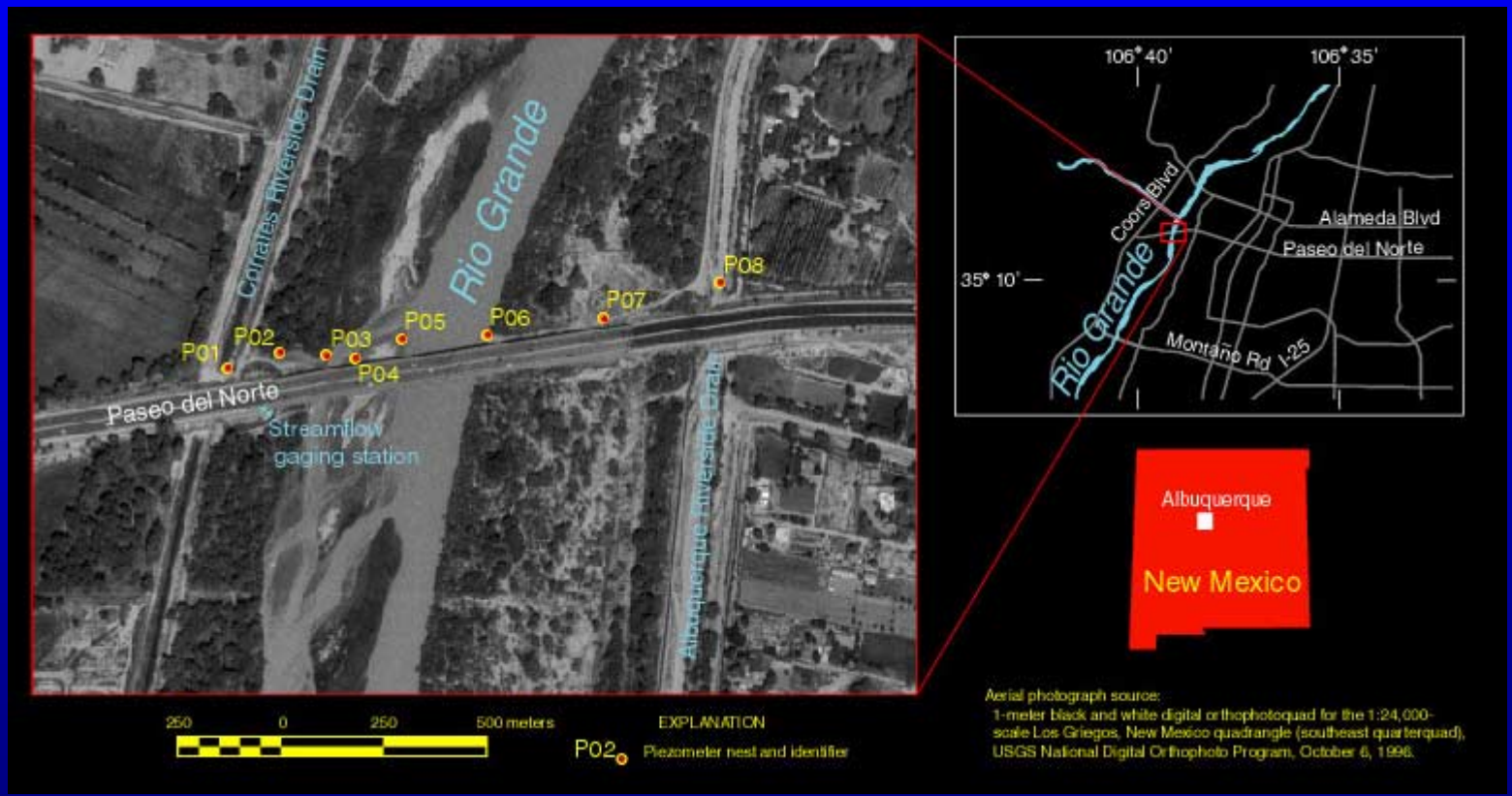

DRY STREAMBED
Temperature
time
Streamflow
0
time
Stream Gage
Piezometer
1 m


EPHEMERAL STREAM
Temperature
time
Streamflow
0
time
Stream Gage
Piezometer
1 m

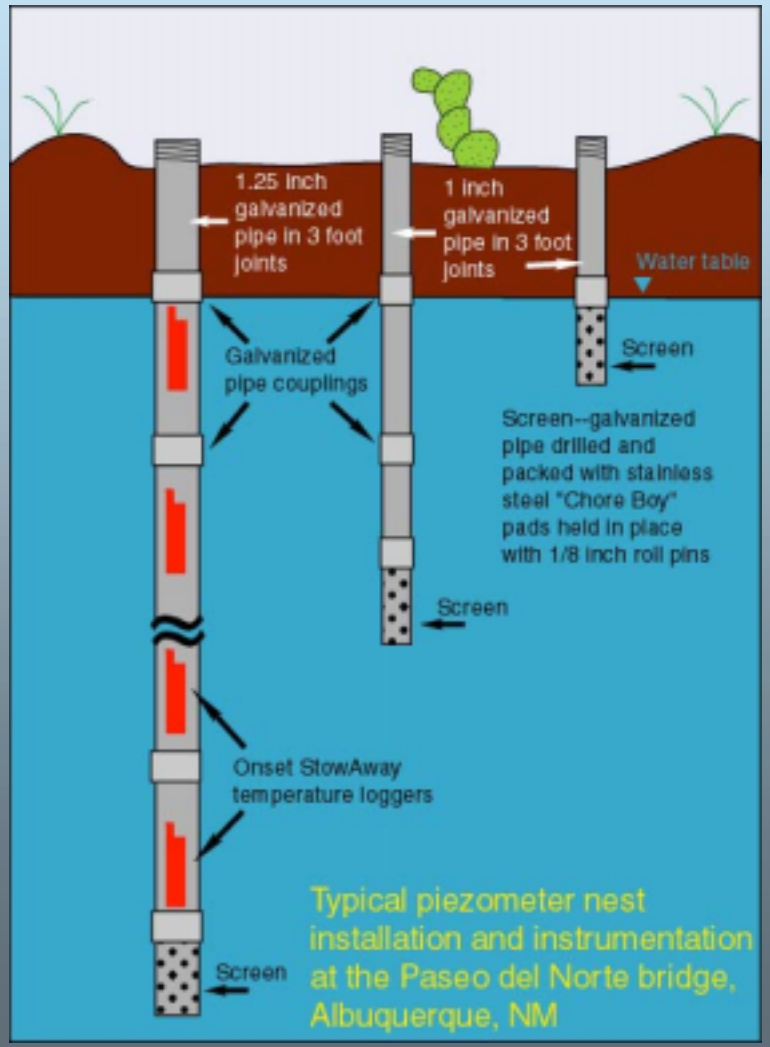

January
(dawn)
January
(dawn)
July
(afternoon)
July
(afternoon)


data
optimal
khyd=1 order lower
khyd=1 order higher
reverse gradient
Depth (m)
3
5
7
9
11
13
15
8
10
12
14
16
18
20
22
24
Temperature (C)

Paseo bridge site map

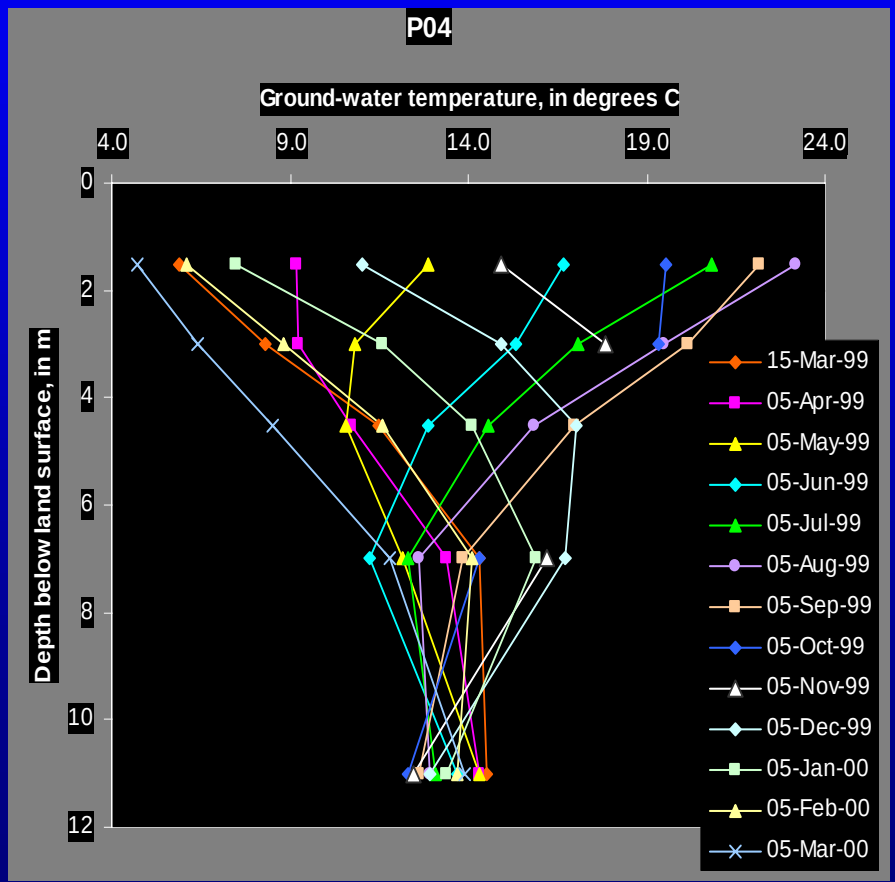


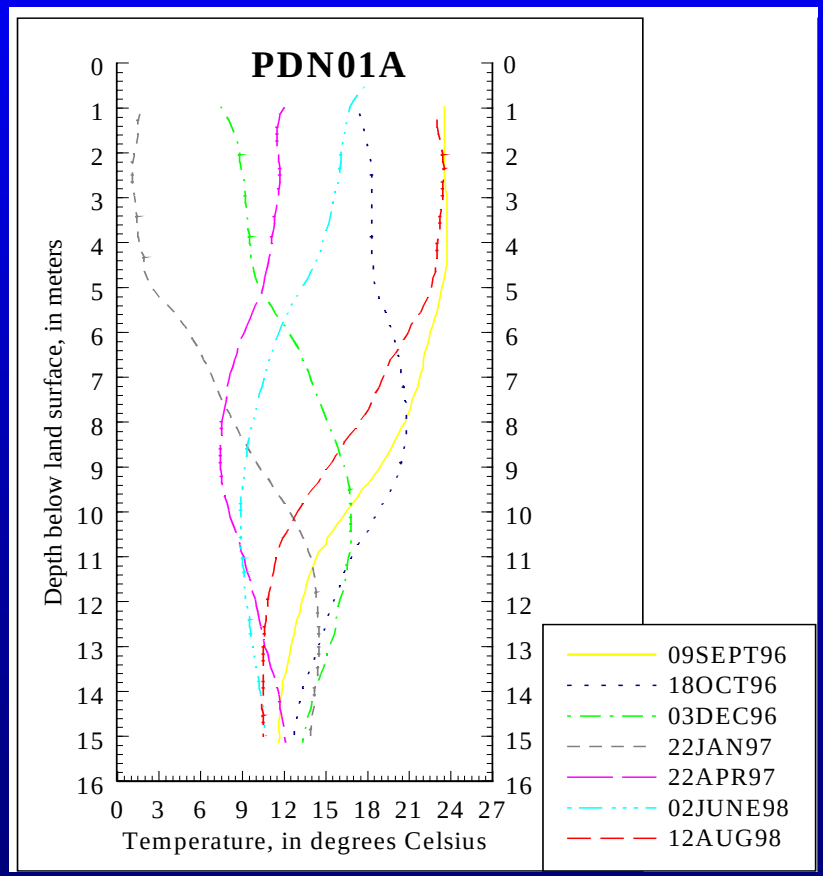
Piezometer installation

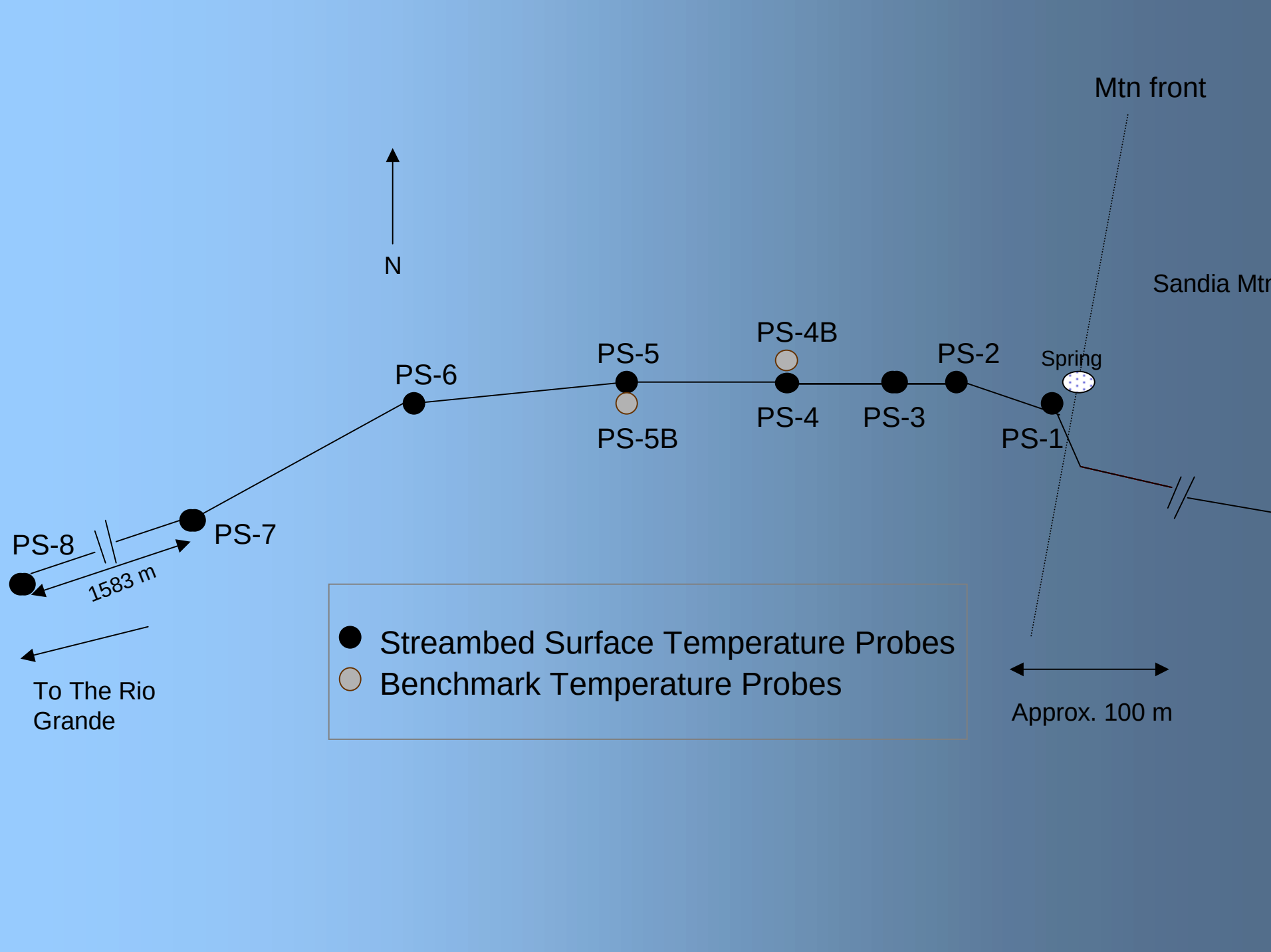


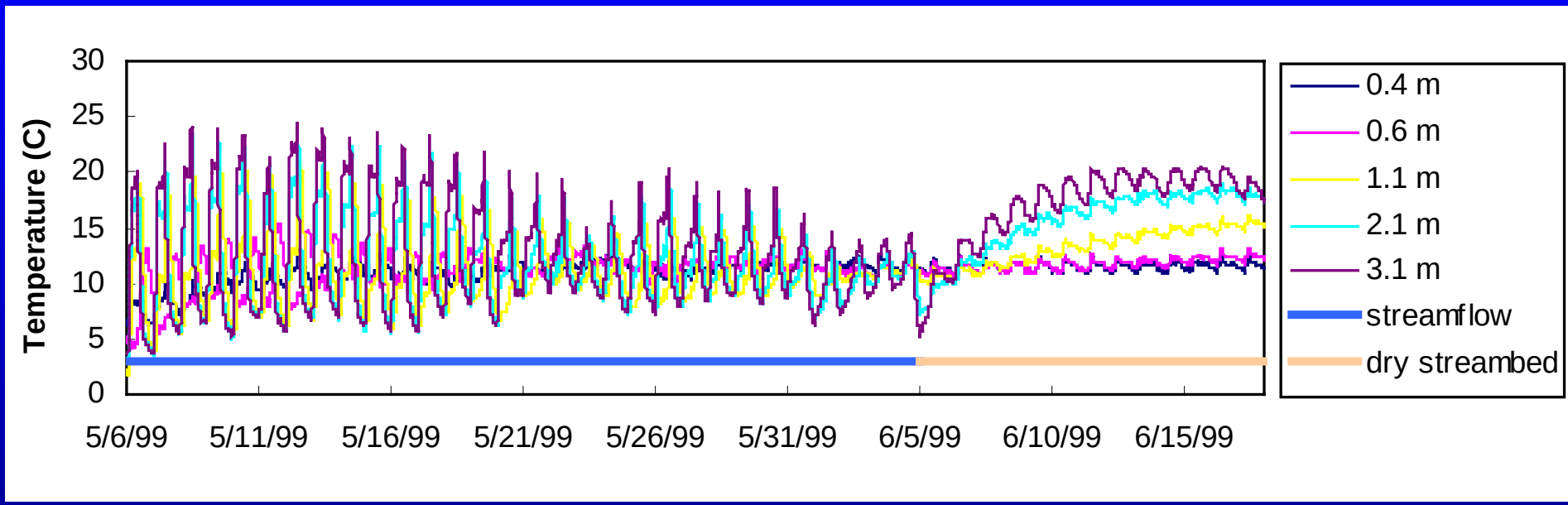
- Installed with NM District Geoprobe
- Continuous core collected at each nest

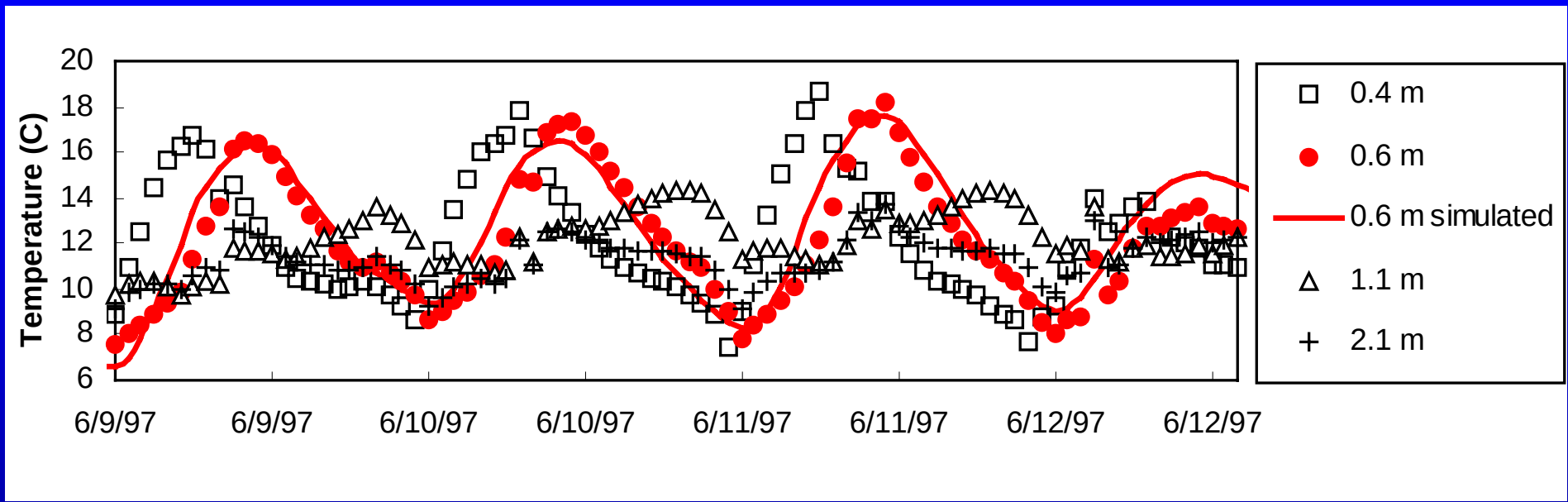
Yearly temperature envelopes






Mtn front
N
Sandia Mtn
PS-4B
PS-5
PS-2
Spring
PS-6
PS-4
PS-3
PS-1
PS-5B
PS-8
PS-7
1583 m
Streambed Surface Temperature Probes
Benchmark Temperature Probes
To The Rio Grande
Approx. 100 m


Temperature (C)
30
25
20
15
10
5
0
5/6/99
5/11/99
5/16/99
5/21/99
5/26/99
5/31/99
6/5/99
6/10/99
6/15/99
0.4 m
0.6 m
1.1 m
2.1 m
3.1 m
streamflow
dry streambed


Temperature (C)
20
18
16
14
12
10
8
6
6/9/97
6/9/97
6/10/97
6/10/97
6/11/97
6/11/97
6/12/97
6/12/97
0.4 m
0.6 m
0.6 m simulated
1.1 m
2.1 m

1. Heat can be used to look at spatial and temporal patterns of streamflow

2. Heat can be used to determine streambed infiltration and transmission loss

3. These streamflow and channel loss characteristics aid in simulation modeling


Simulation of Streamflows in large ephemeral stream channels

Abo Arroyo from 30,000 feet

Abo Arroyo from 30,000 feet

Abo Arroyo ground zero

Stream gage

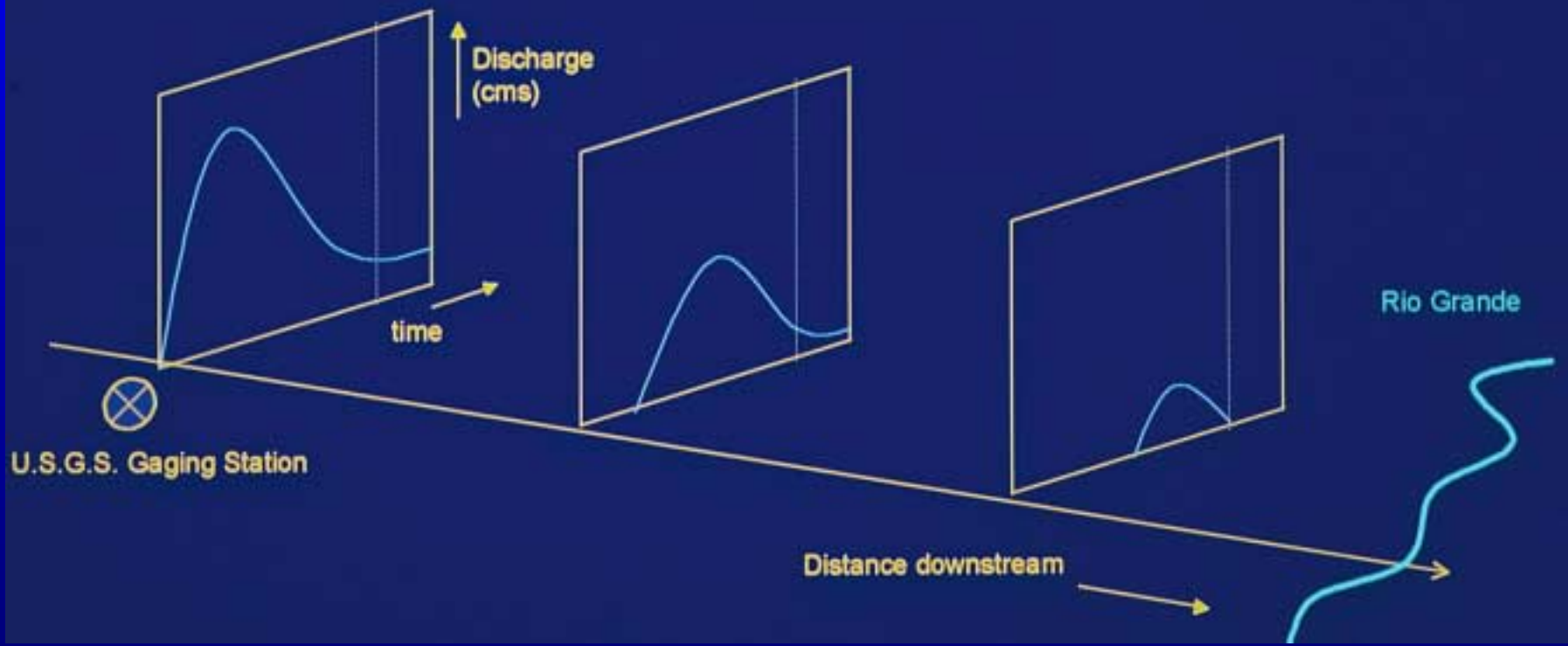
Hwy 47

Abo Arroyo

Rio Grande

Spatial and Temporal Ephemeral Streamflow Patterns

1) Delay in peak flows down-channel
2) Decrease in amplitude of peak flows down-channel
3) Decrease in duration of streamflow down-channel



Project Goals

Develop techniques for field data collection in large ephemeral streams

- presence/absence of streamflow
- duration of streamflow

Model surfacewater and groundwater interactions

- match/calibrate with collected data
- predictive

Field Sites

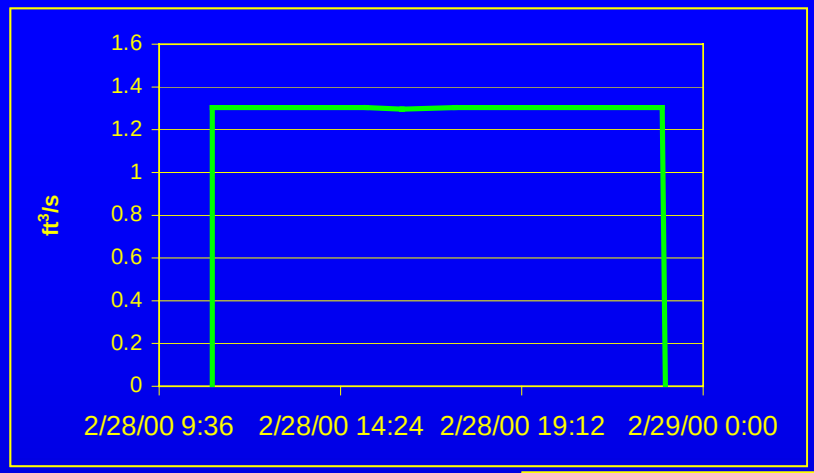
Isleta Arroyo

Abo Arroyo

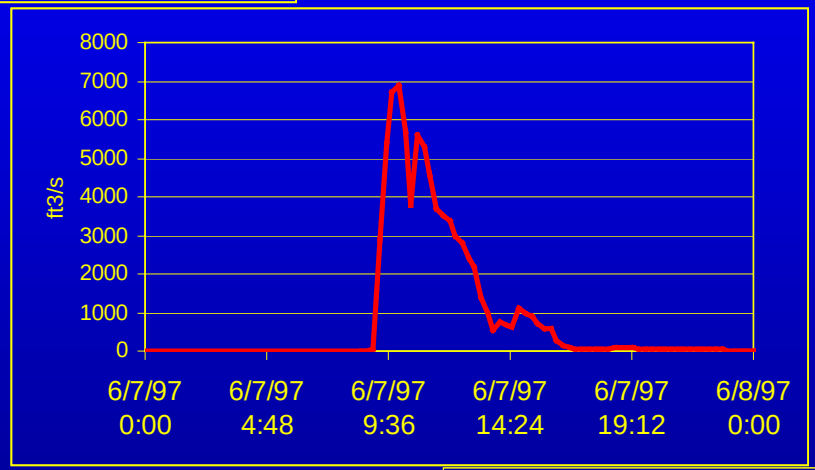
Amargosa River

Comparison of Sites

	Study Reach length	Average Depth of channel	Flow "season"	characteristics
Isleta Arroyo	1.6 km	10 cm	3 weeks in 2000	Monitored pump test outflow, sent into small dry arroyo
Abo Arroyo	30 km	4 m	Summer monsoon season	Wide, deep channel from mtns to Rio Grande
Amargosa River	40 km	1 m	Winter Frontal storms	Wide shallow channel from Beatty, NV to Death Valley

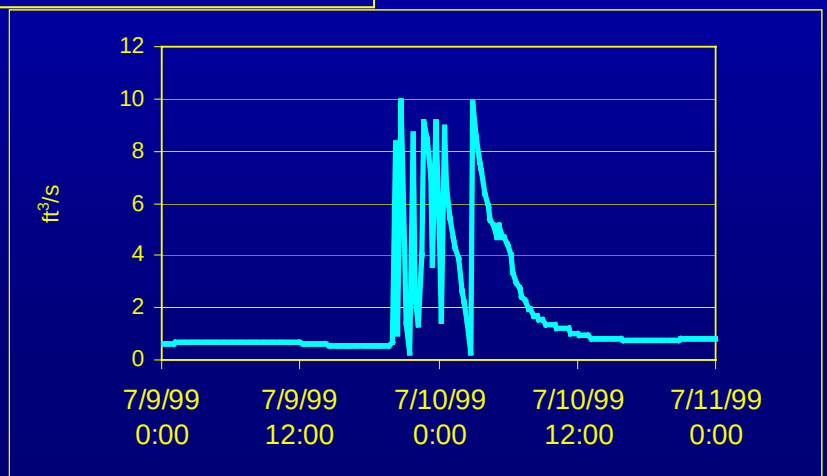


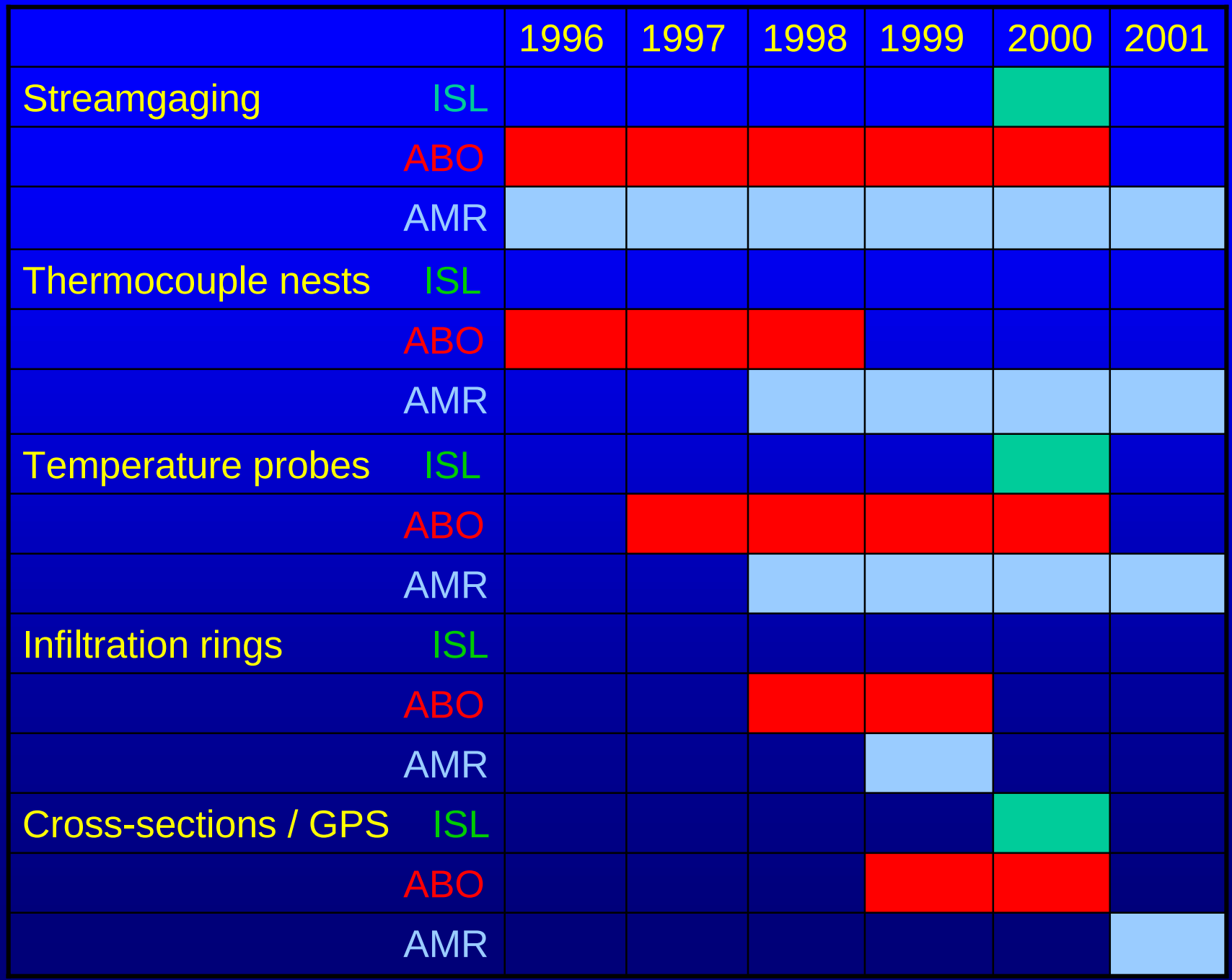
Isleta Arroyo



Abo Arroyo

Amargosa River




1996
1997
1998
1999
2000
2001
Streamgaging ISL
ABO
AMR
Thermocouple nests ISL
ABO
AMR
Temperature probes ISL
ABO
AMR
Infiltration rings ISL
ABO
AMR
Cross-sections / GPS ISL
ABO
AMR

Subsurface thermocouple nests – Infiltration rates

Recording Streamgages and Crest-Stage Gages

Ring Infiltrometers

Surface temperature probes – presence or absence of streamflow

Cross-Sections

Precipitation Gages

Model Criteria

Realistic cross-sections

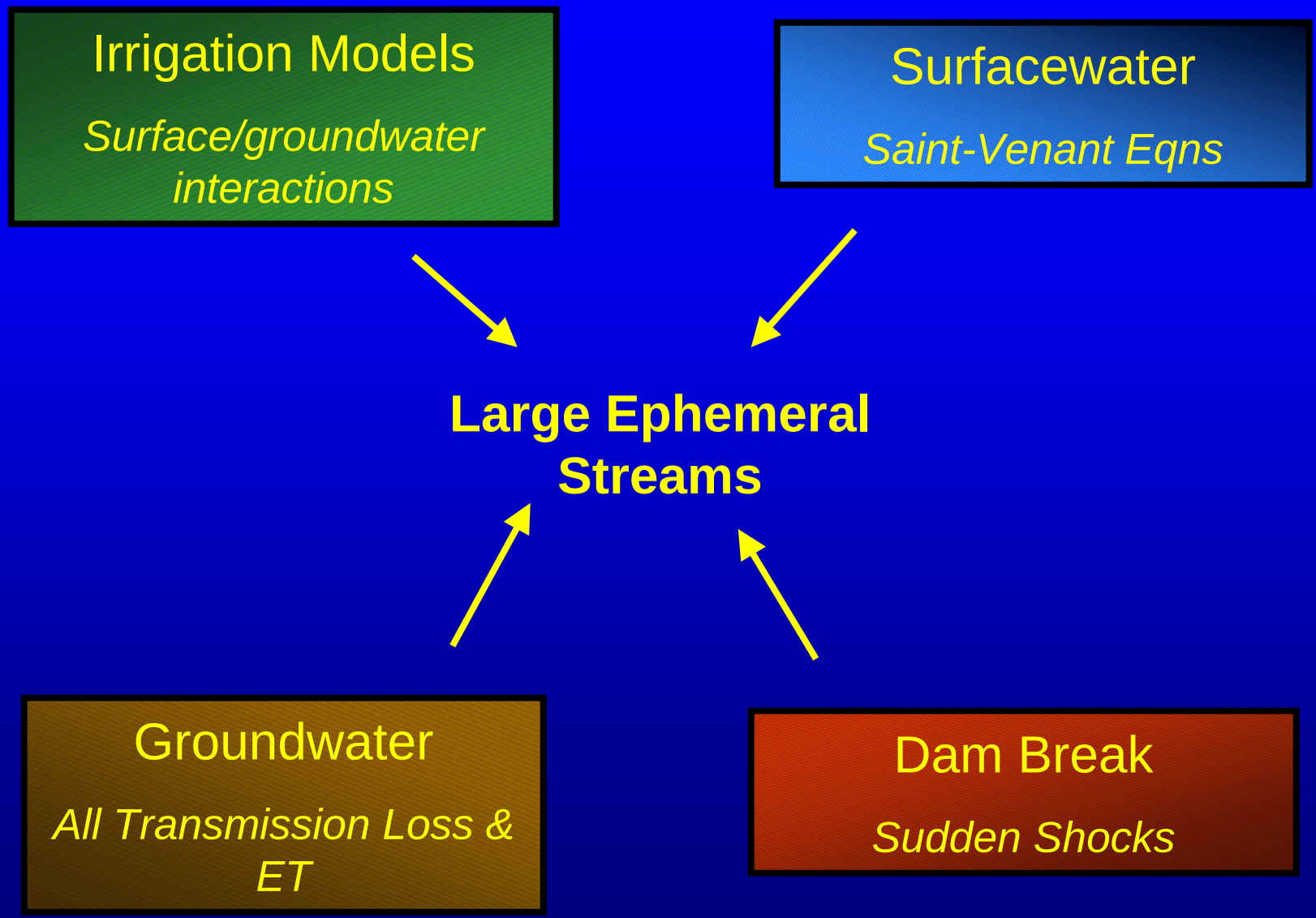
1-D channel flow – shallow water equations

Heterogeneity

Upstream hydrograph, downstream stage BC

Potential Problems

- groundwater and surfacewater
- initially dry channel
- steep rising limb of hydrograph


Irrigation Models
Surface/groundwater interactions
Surfacewater
Saint-Venant Eqns
Large Ephemeral Streams
Groundwater
All Transmission Loss & ET
Dam Break
Sudden Shocks

FLDWAV

- Developed by the National Weather Service (D.L. Fread & J.M Lewis), 1998 - updated in 2000

  (replaces DWOPER and DAMBRK)

- Fortran, finite-difference

- Flood routing model – complete 1-D Saint-Venant equations for unsteady flow (dynamic-implicit/explicit, diffusion, level-pool).

  internal boundaries – dams (breaches), bridges, ponds

  lateral inflow/outflow – multiple interconnected waterways, levee overtopping

  Kalman filter estimator for updating real-time predictions of flow

  cross-sectional interpolation

FLDWAV - Equations

Saint-Venant equations with additional terms for expansion/contractions, channel sinuosity, wind resistance and non-Newtonian flow

Continuity:

$$\frac{\partial Q}{\partial x} + \frac{\partial s_{co}(A + A_o)}{\partial t} - q = 0$$

Momentum:

$$\frac{\partial (s_m Q)}{\partial t} + \frac{\partial (m_{cv} Q^2 / A)}{\partial x} + gA\left(\frac{\partial h}{\partial x} + S_f + S_e + S_i\right) + L + W_f B = 0$$

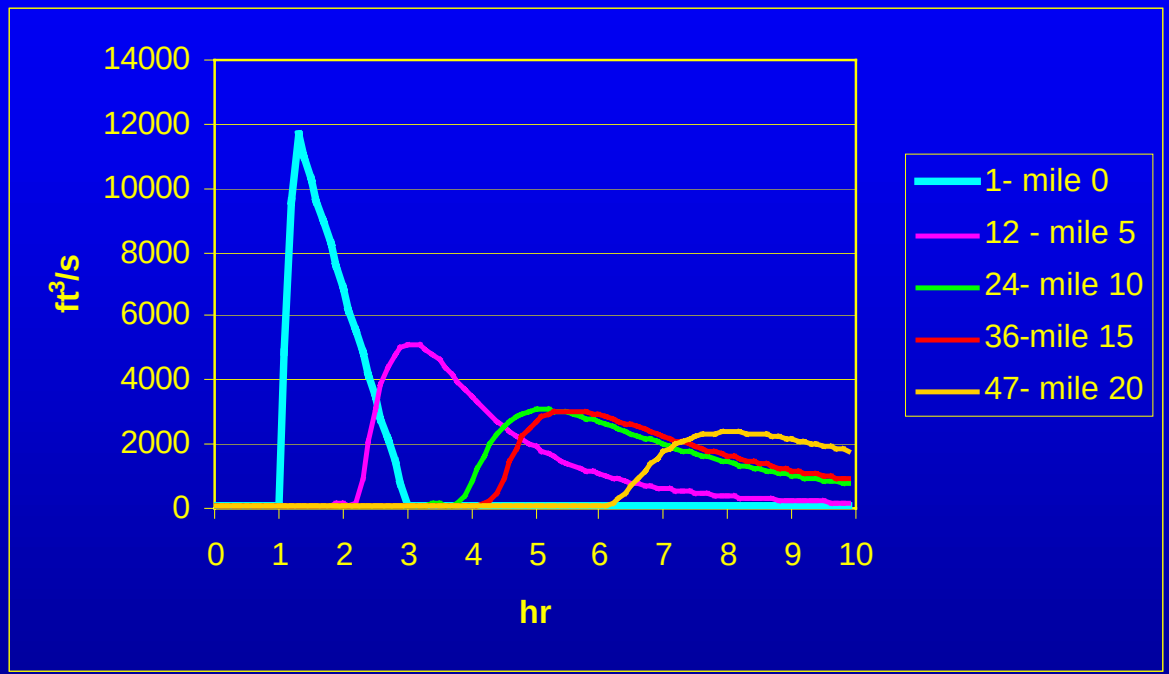
Volumetric Losses

Loss (q) not dependant on head – user specified parameters

Assumes that loss is proportional with the local flowrate

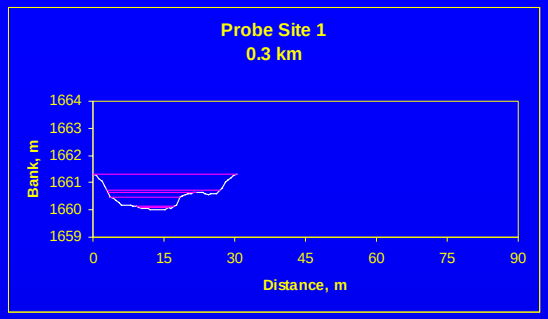
$$q = \frac{e'\left((x - x_{up})/(x_{down} - x_{up})\right)^{e'-1}\alpha(Q - Q_o)}{\left(1 + (x - x_{up})/(x_{down} - x_{up})^{e'}\alpha(x_{down} - x_{up})\right)}$$

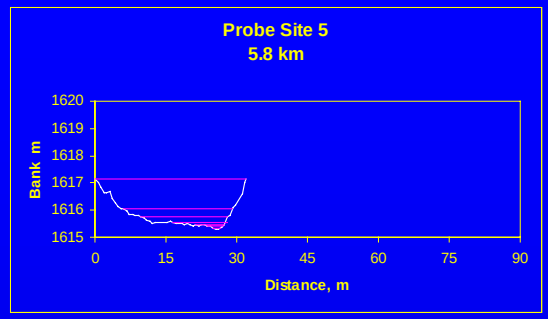
Event Simulation

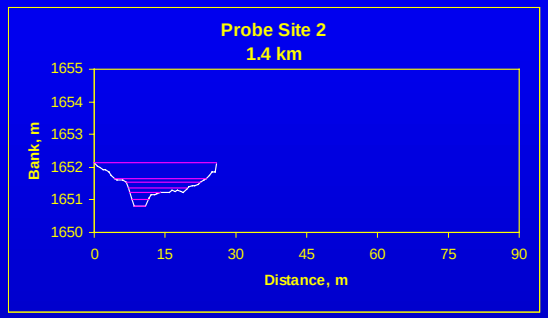


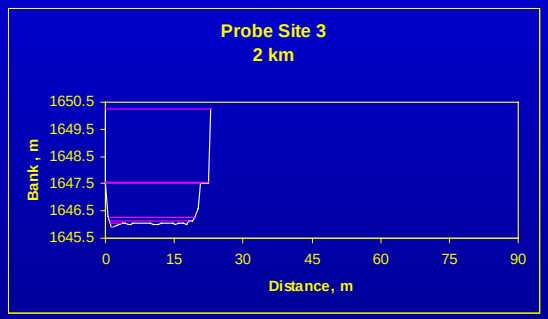
- Trapezoidal Channel
- Upstream Hydrograph, Downstream Stage
- Steepening of Rising Limb
- Decrease Baseflow

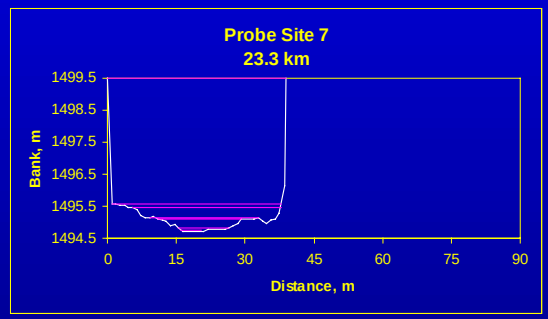
Abo Arroyo Cross-Sections

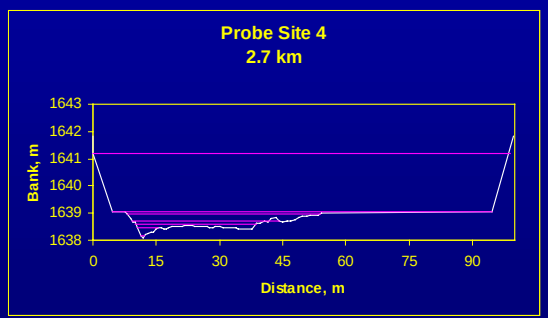


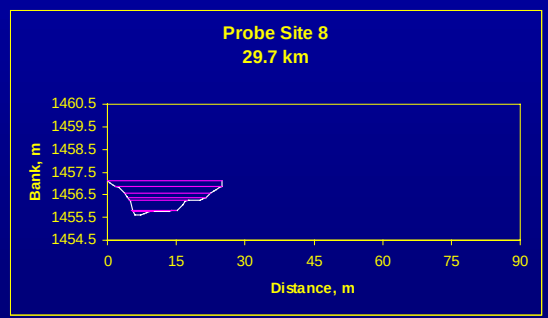




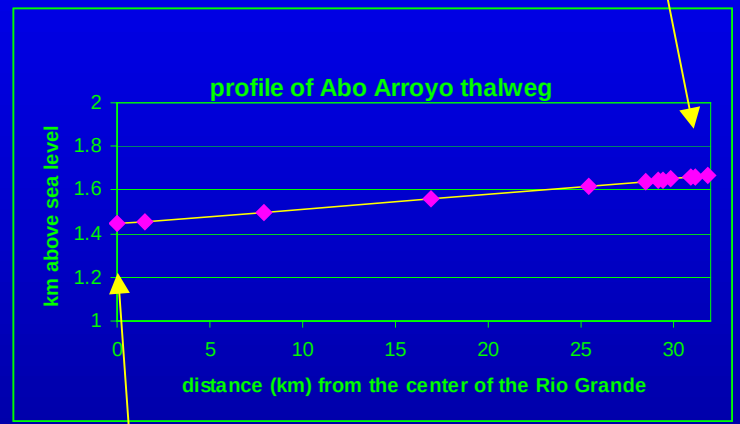








Upstream: USGS Streamgage



Downstream: Rio Grande

In Progress:

Simulations – Matching with Data

- Abo Arroyo
- Amargosa River
- Isleta Arroyo

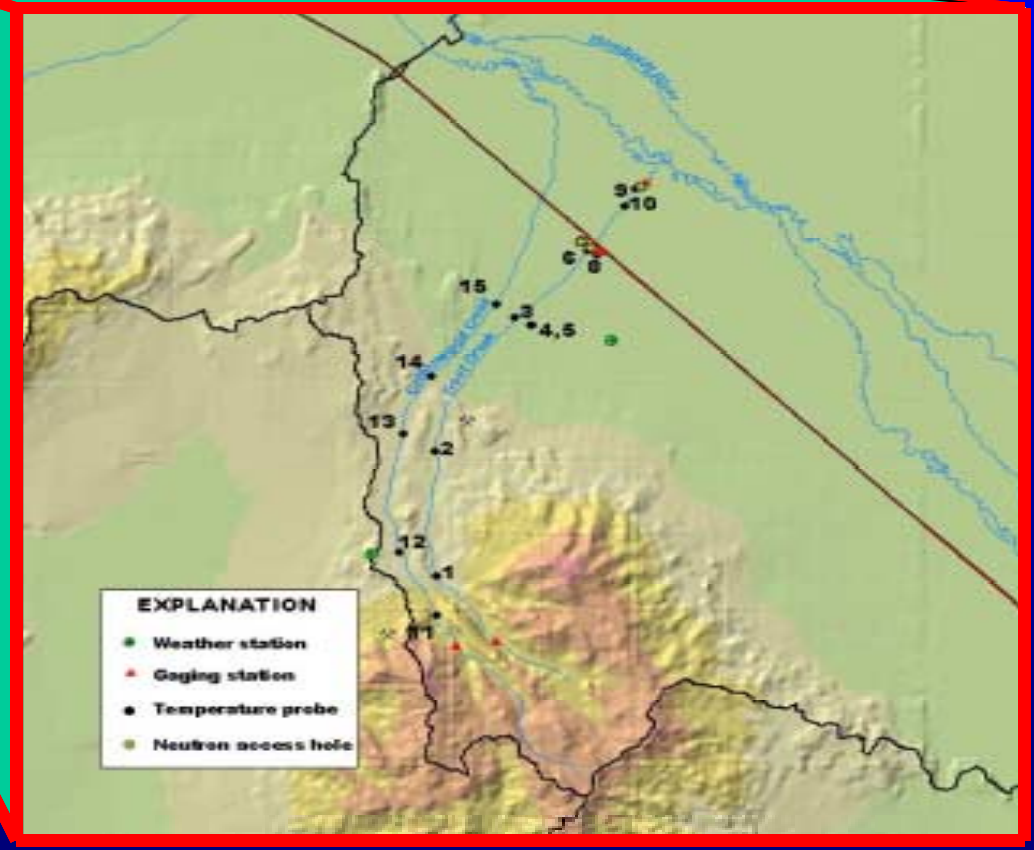
Addition of spatially variable enhanced Loss Function

Analysis of spatially and temporally varying streamflow patterns and losses

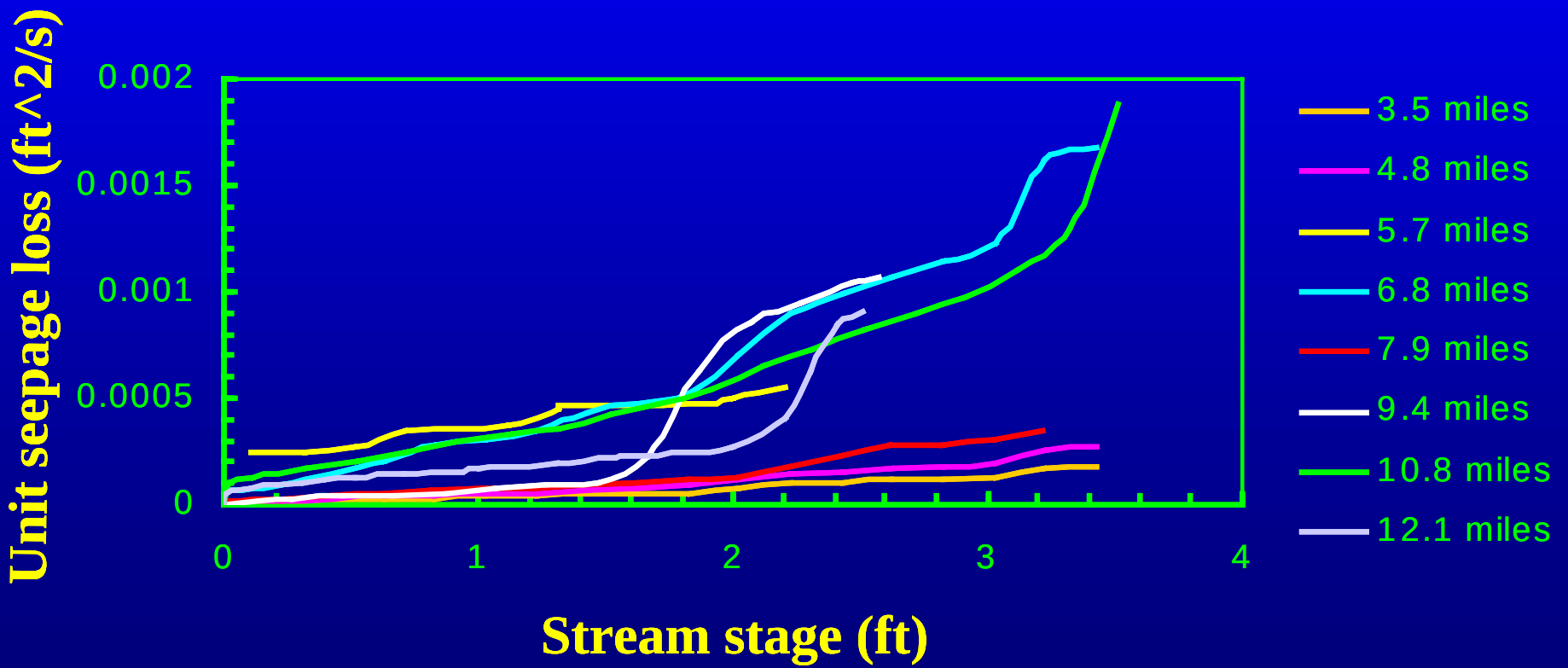
Predictive Use for these and other SWGWR sites and other large ephemeral streams

Simulating streamflow and transmission losses for Intermittent Streams

Map of Trout Creek
Battle Mountain, NV.



Determination of seepage loss cont.



Assumptions in model linkage:

- changes on GW storage don't effect seepage rate
- Ignore wetting-for now
- Gravity seepage

Surface water model development Cont.

Staggered finite difference approximations

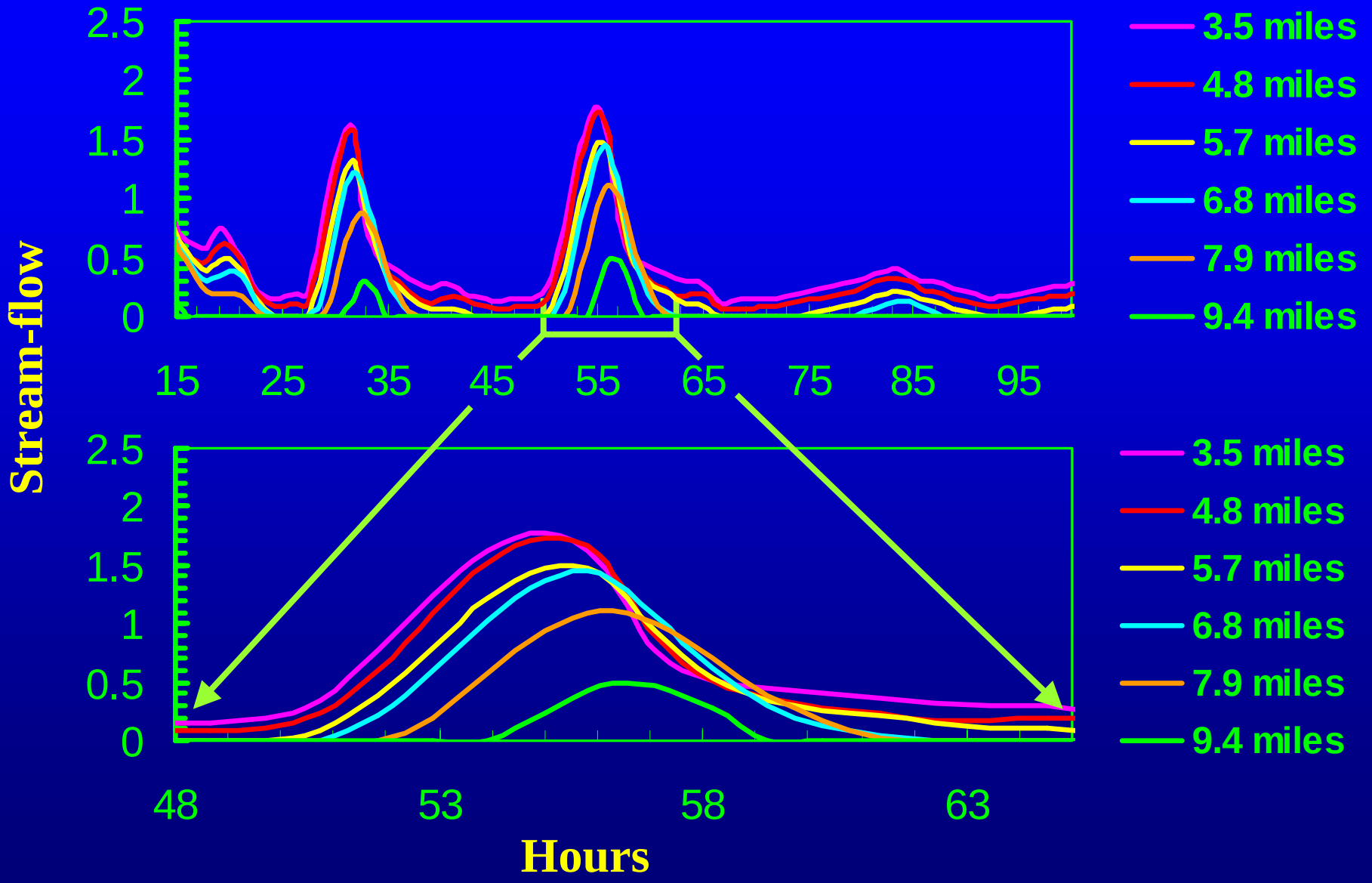
-Stage calculated at nodes

-Flow calculated between nodes (Mckee, 97)-reduces non-linearity

Surface water model-Results

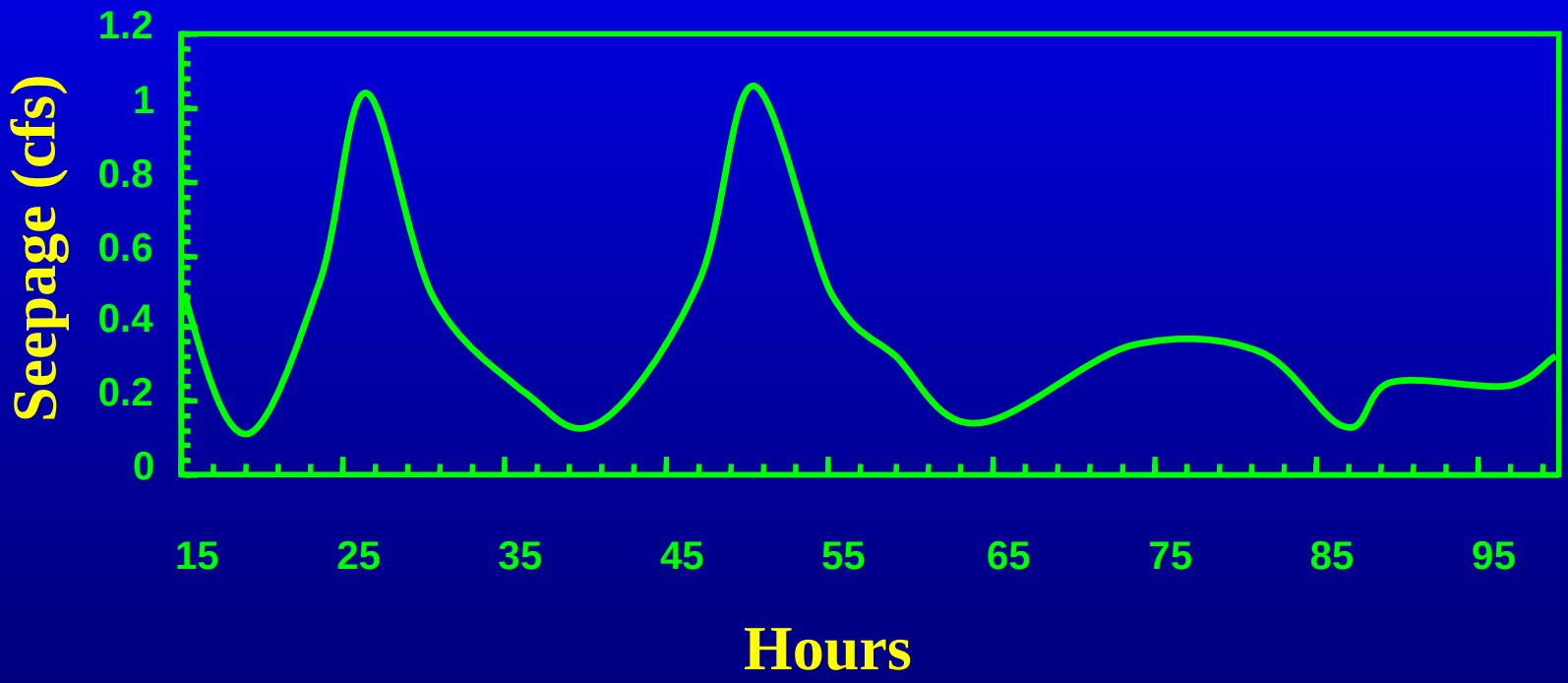
Comparison between measured stream-flow to simulated stream-flow accounting for Seepage loss.

Surface water model-Results



Surface water model-Results

Total Seepage loss for Trout Creek snow melt flow event.



Conclusions

1. The relative contribution of floods compared with inter-flood streamflows may vary geographically throughout the Southwest

2. Field measurements coupled with simulation models designed to predict streamflow and transmission-loss patterns will aid in quantifying the relative contributions of these two distinct flow patterns in the Southwest