Eastern Snake Plain Aquifer Model

Presentation to IWRB Advisory Group
23 August 2007

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Outline

- What is “equilibrium?”
- What is a model?
- What is calibration?
- What is the Eastern Snake Plain Aquifer Model (ESPAM 1.1) good for?
- What are its limitations?
- What are specific issues with the model?
- What is planned for the model?
- How can I find out more information?

What is Equilibrium?

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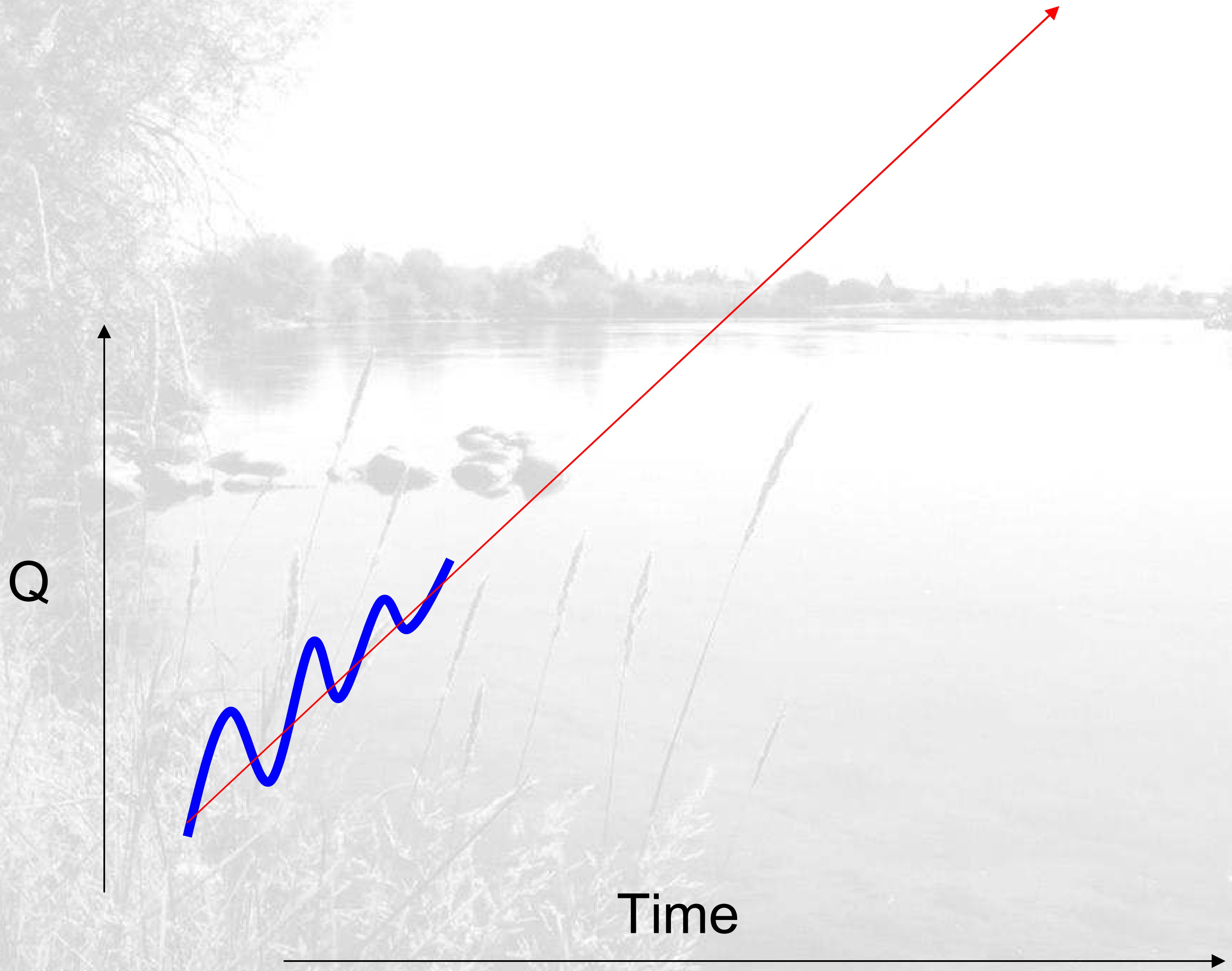

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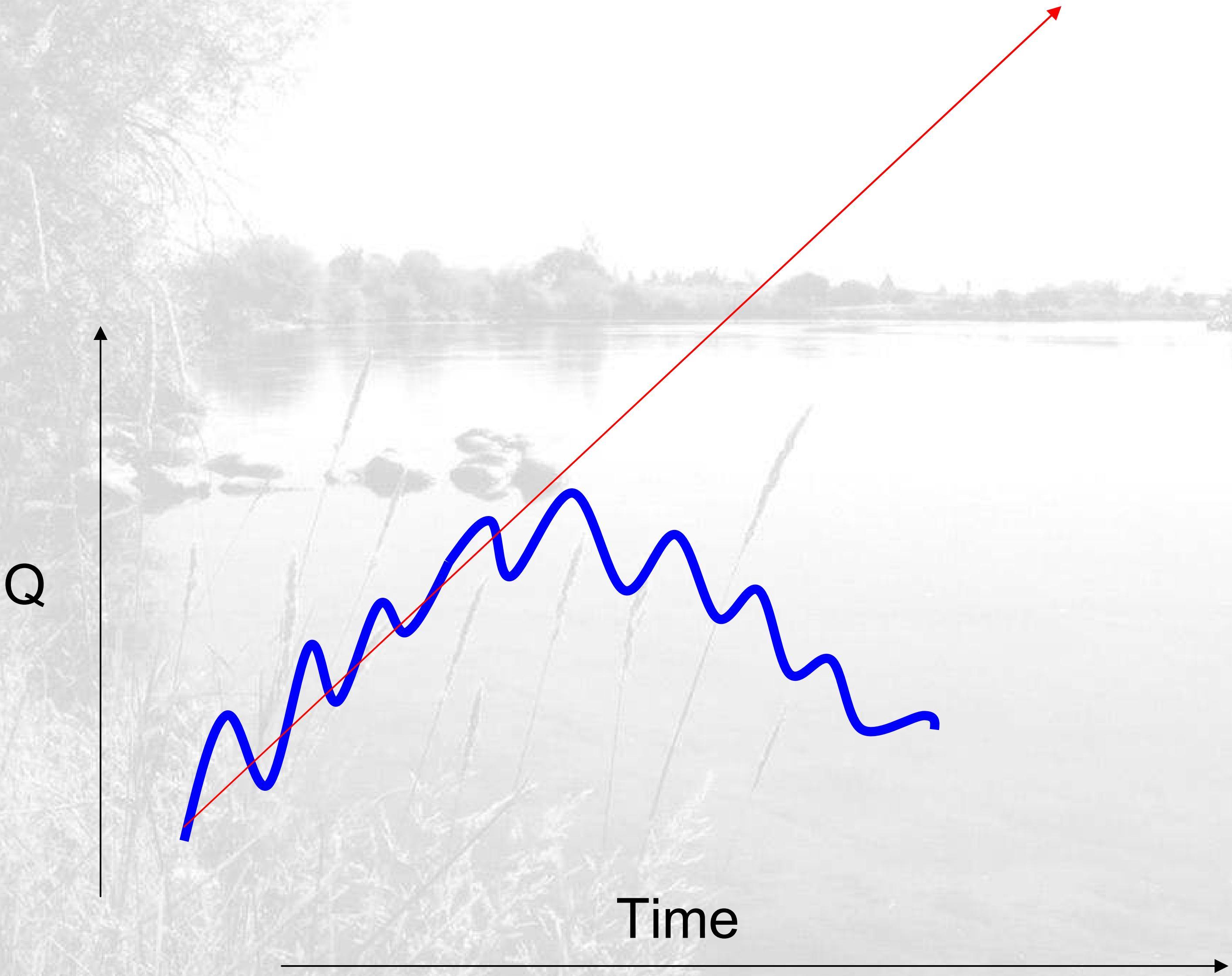

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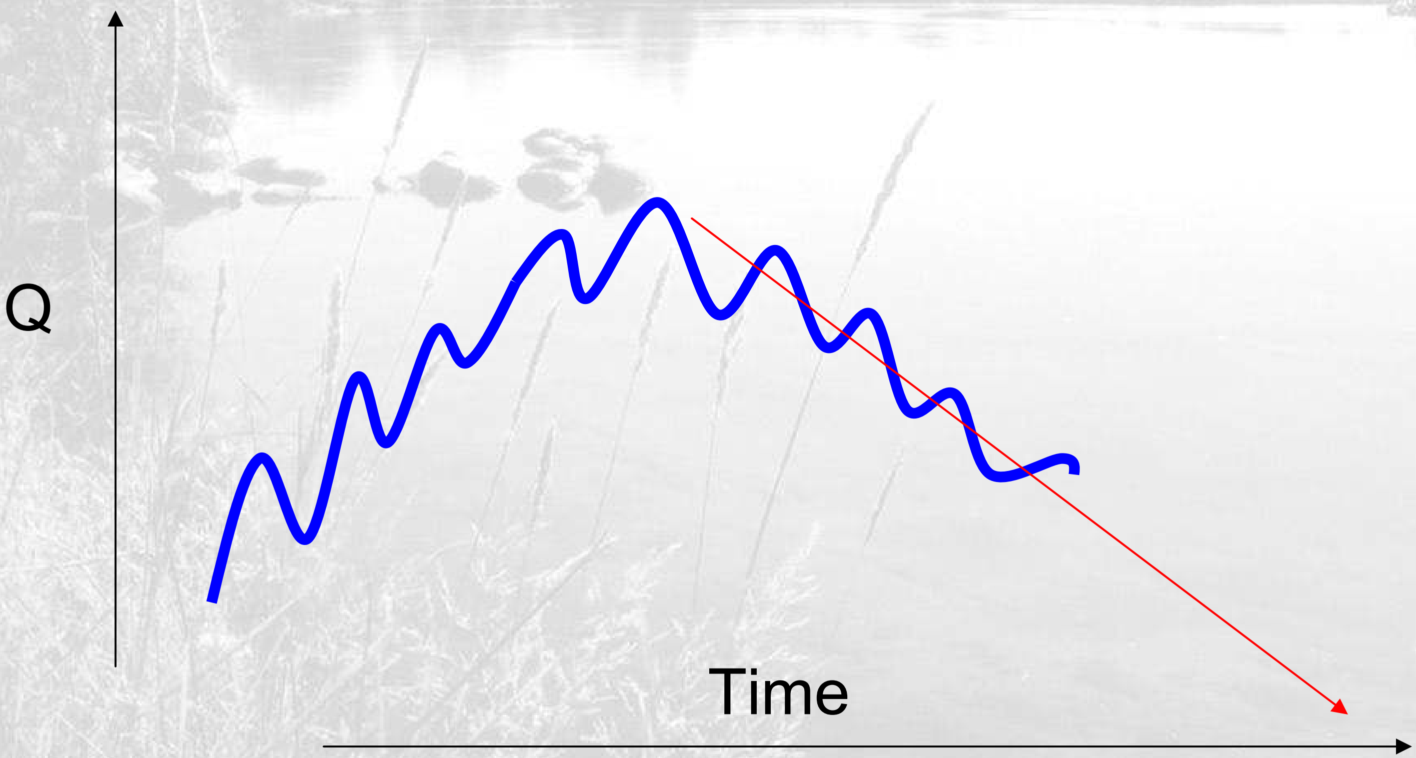

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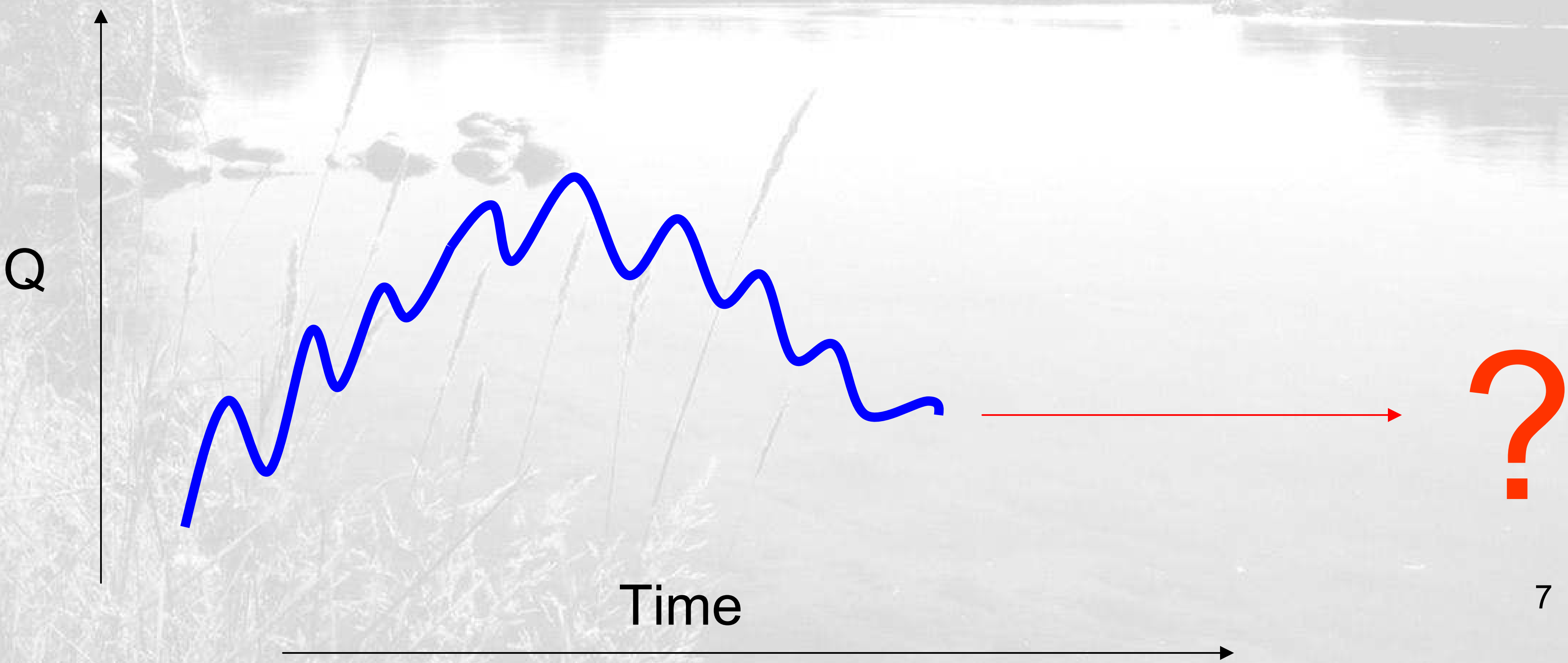

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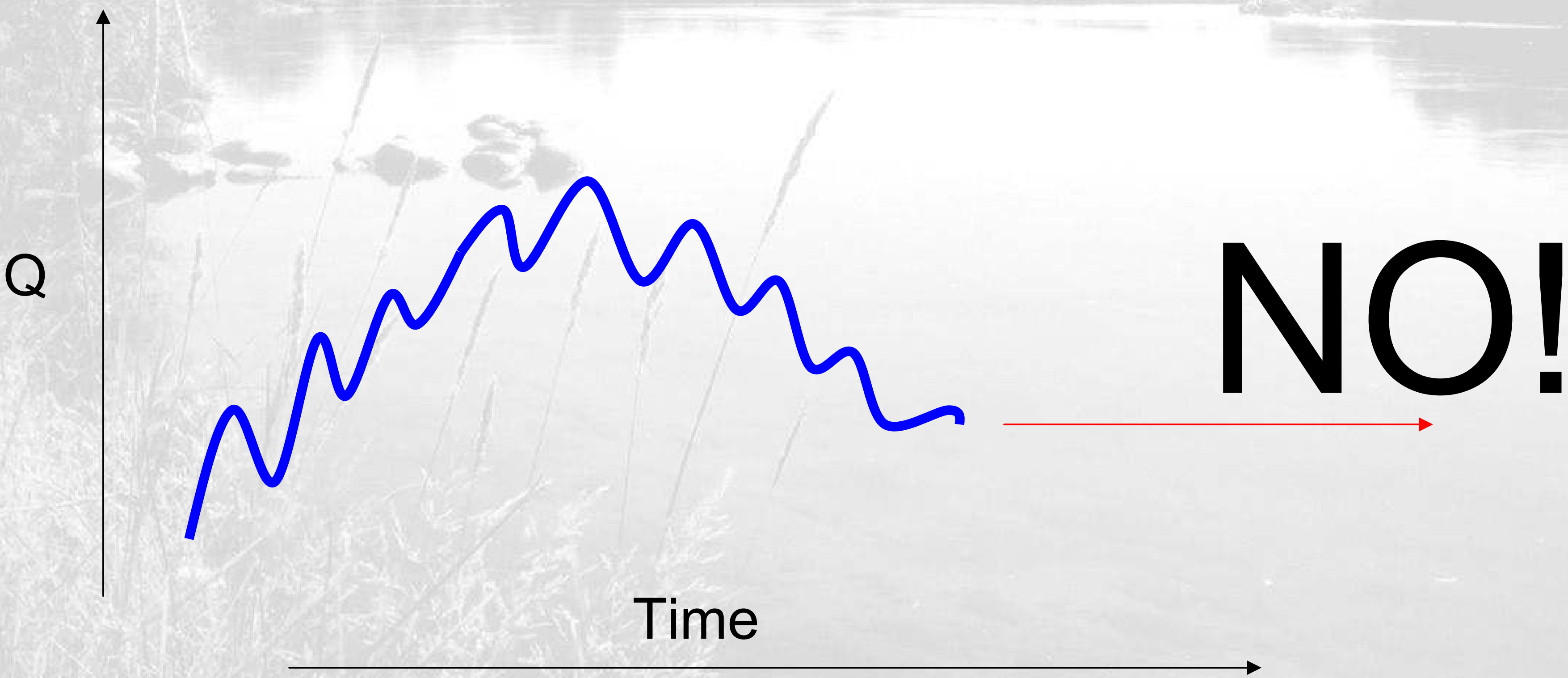
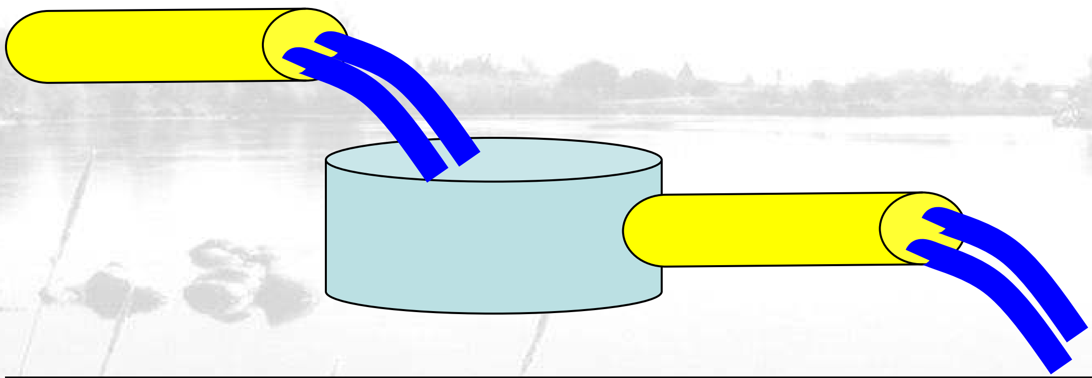


What is Equilibrium?

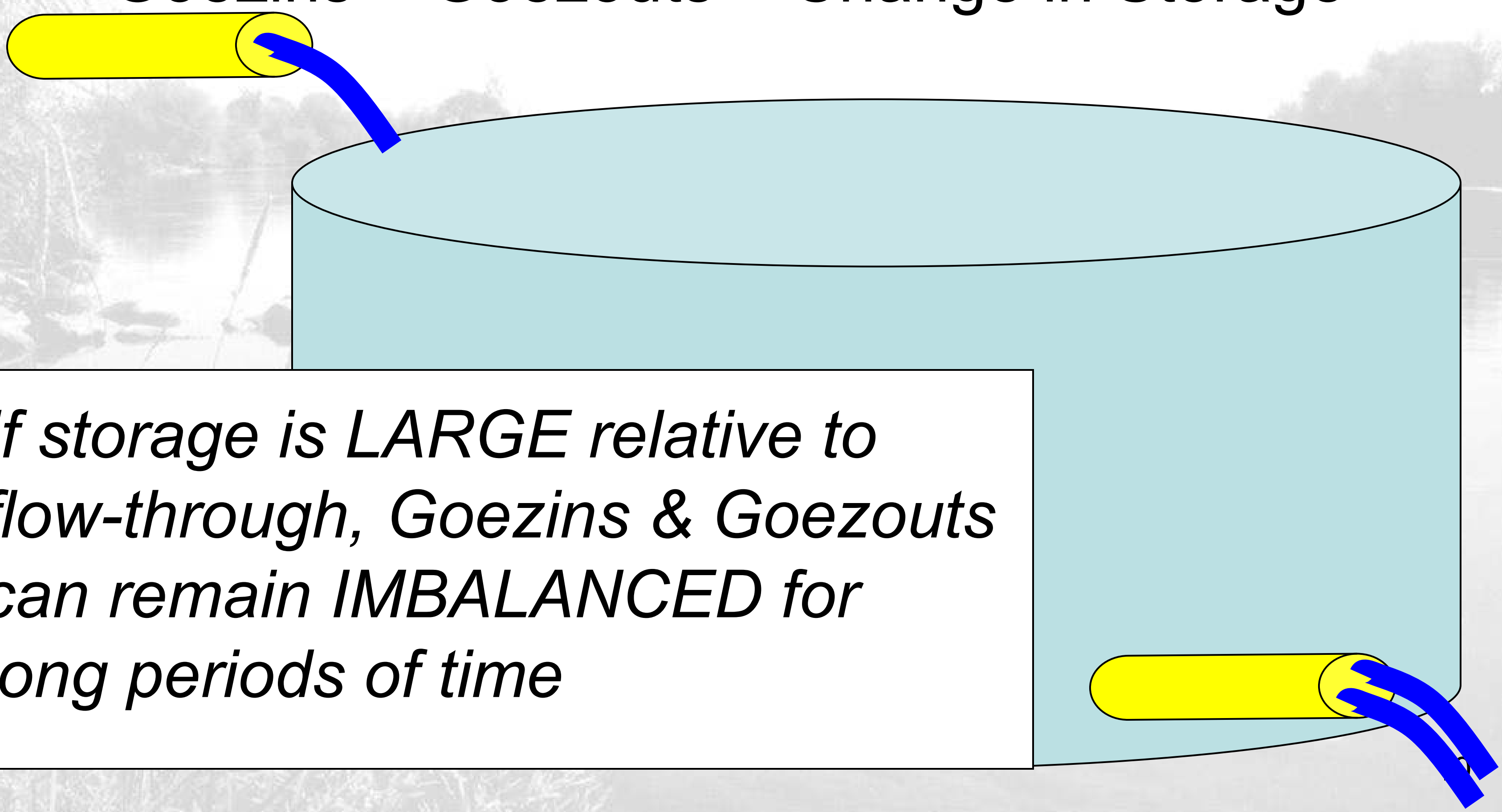
Goezins + Goezouts = Change in Storage



If storage is SMALL relative to flow-through, Goezins & Goezouts generally BALANCE within a short period of time.

What is Equilibrium?

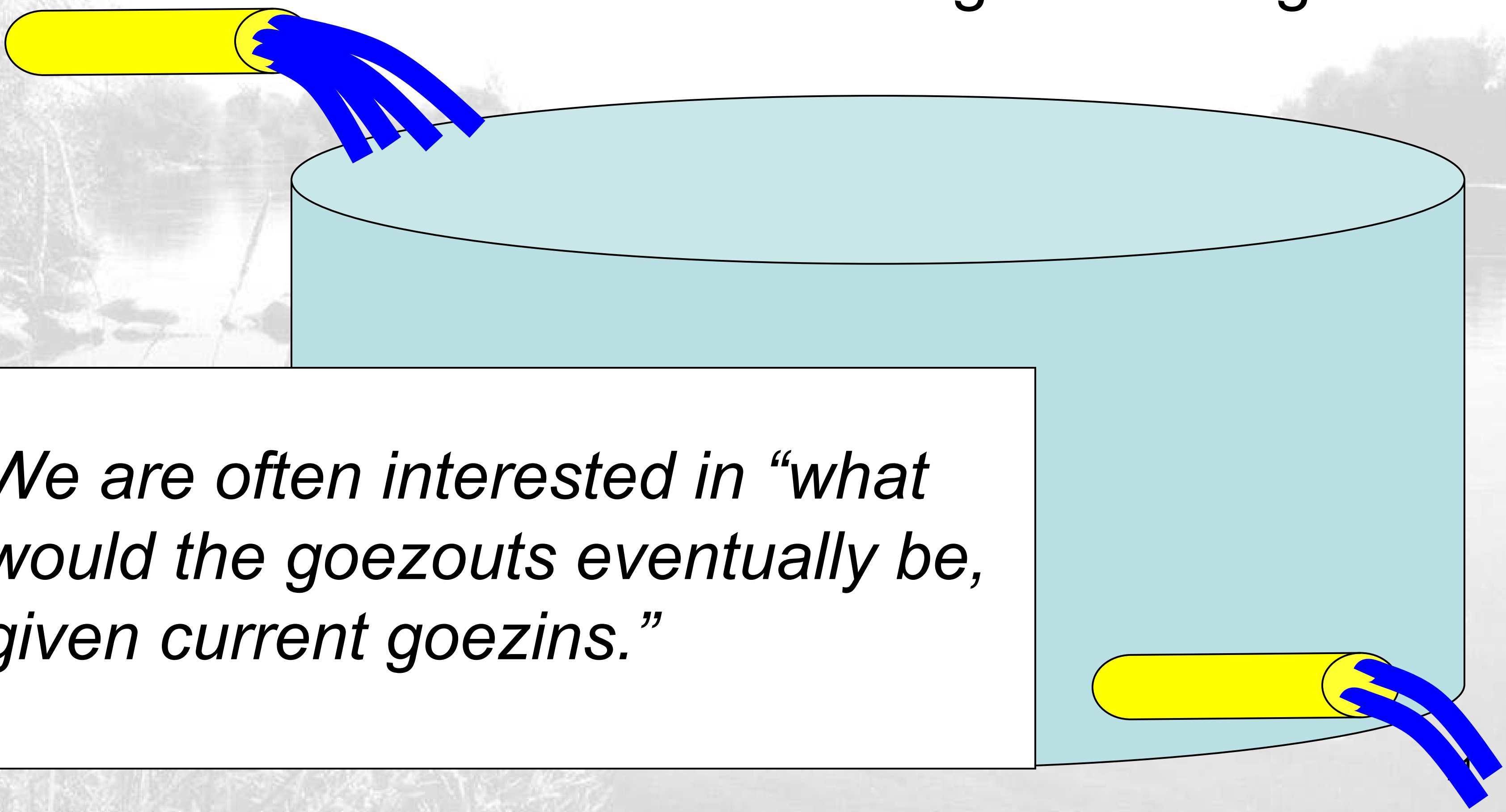
Goezins + Goezouts = Change in Storage



If storage is LARGE relative to flow-through, Goezins & Goezouts can remain IMBALANCED for long periods of time

What is Equilibrium?

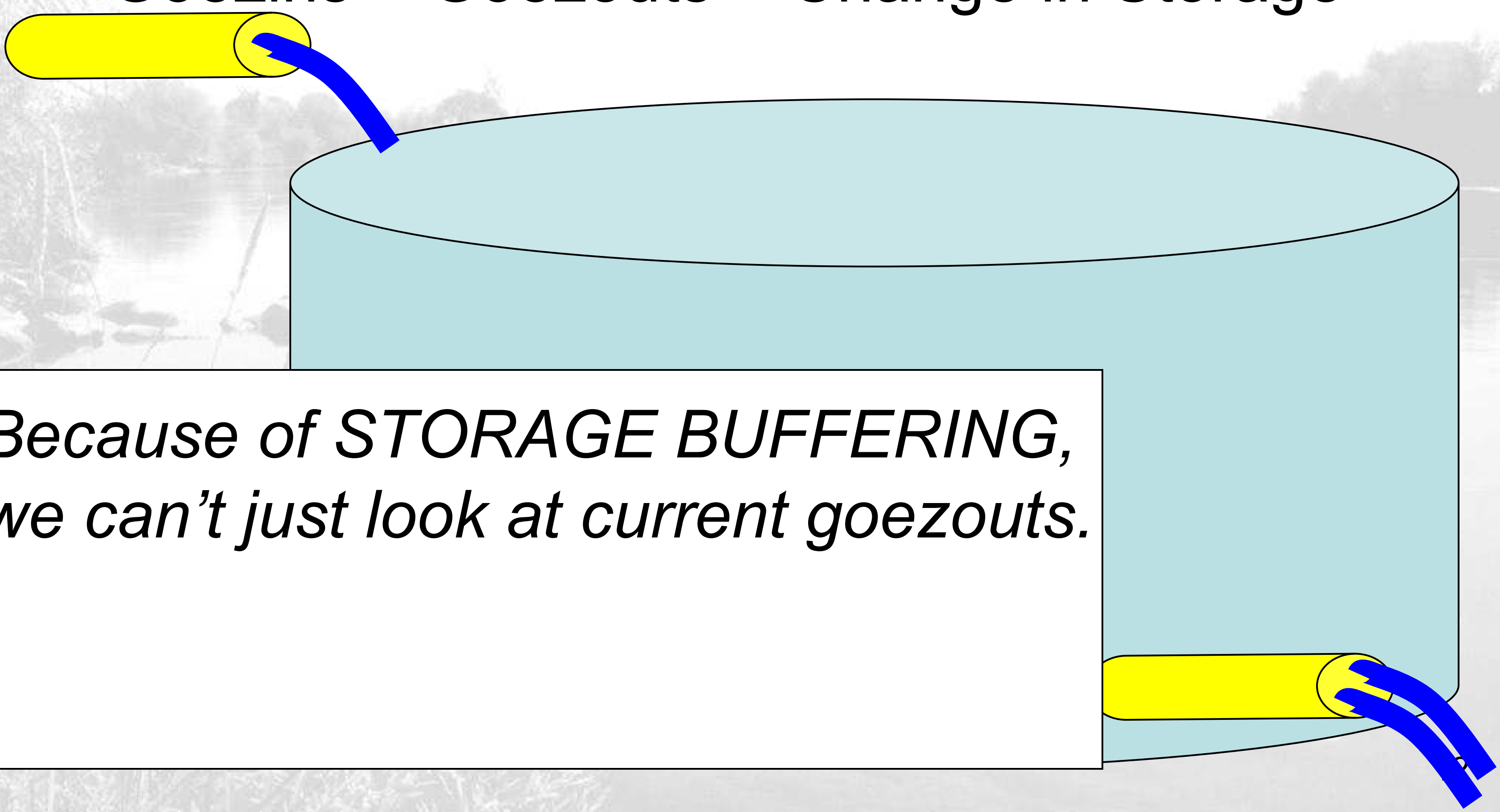
Goezins + Goezouts = Change in Storage



We are often interested in "what would the goezouts eventually be, given current goezins."

What is Equilibrium?

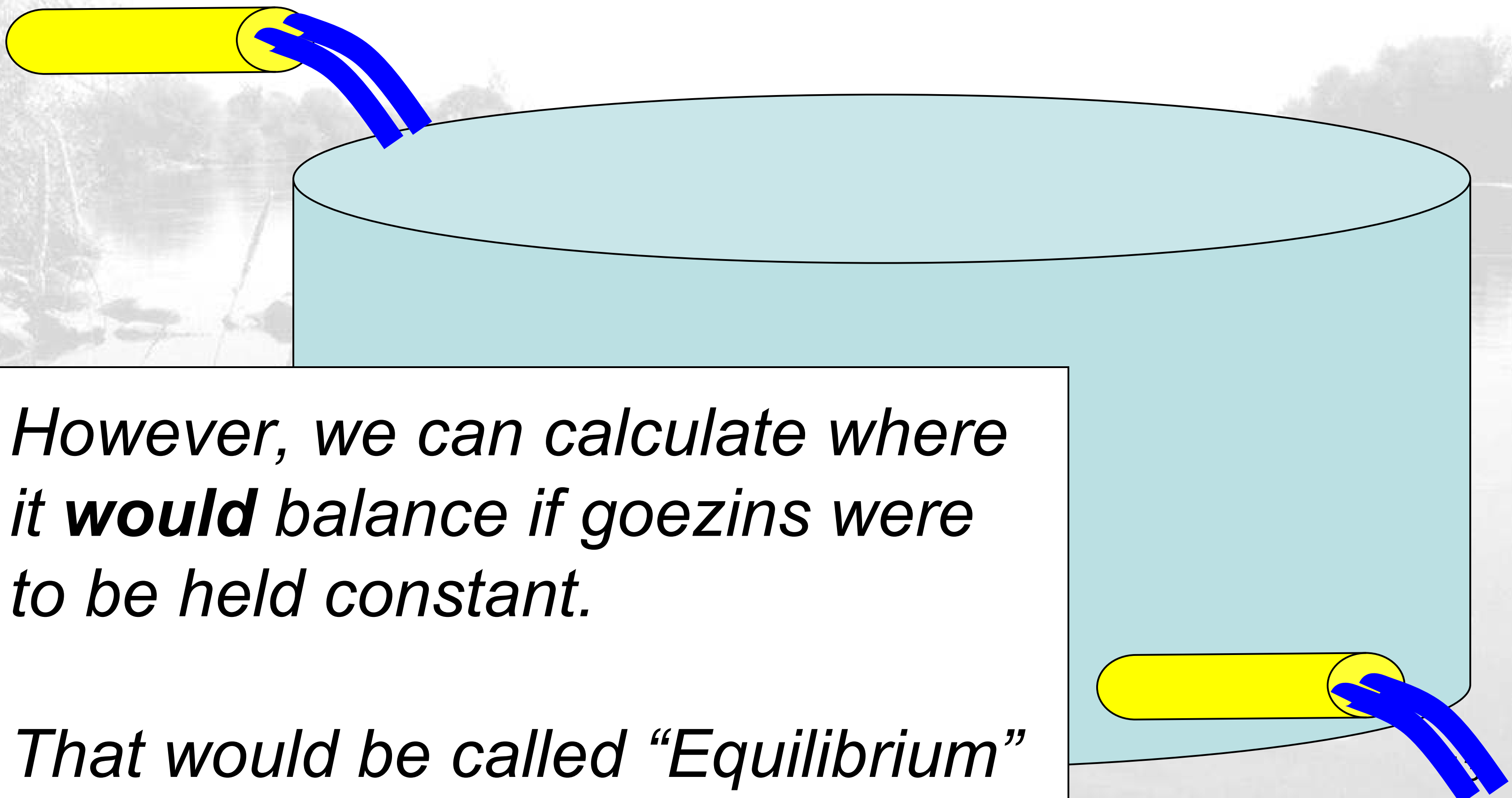
Goezins + Goezouts = Change in Storage



Because of STORAGE BUFFERING, we can't just look at current goezouts.

What is Equilibrium?

Goezins + Goezouts = Change in Storage

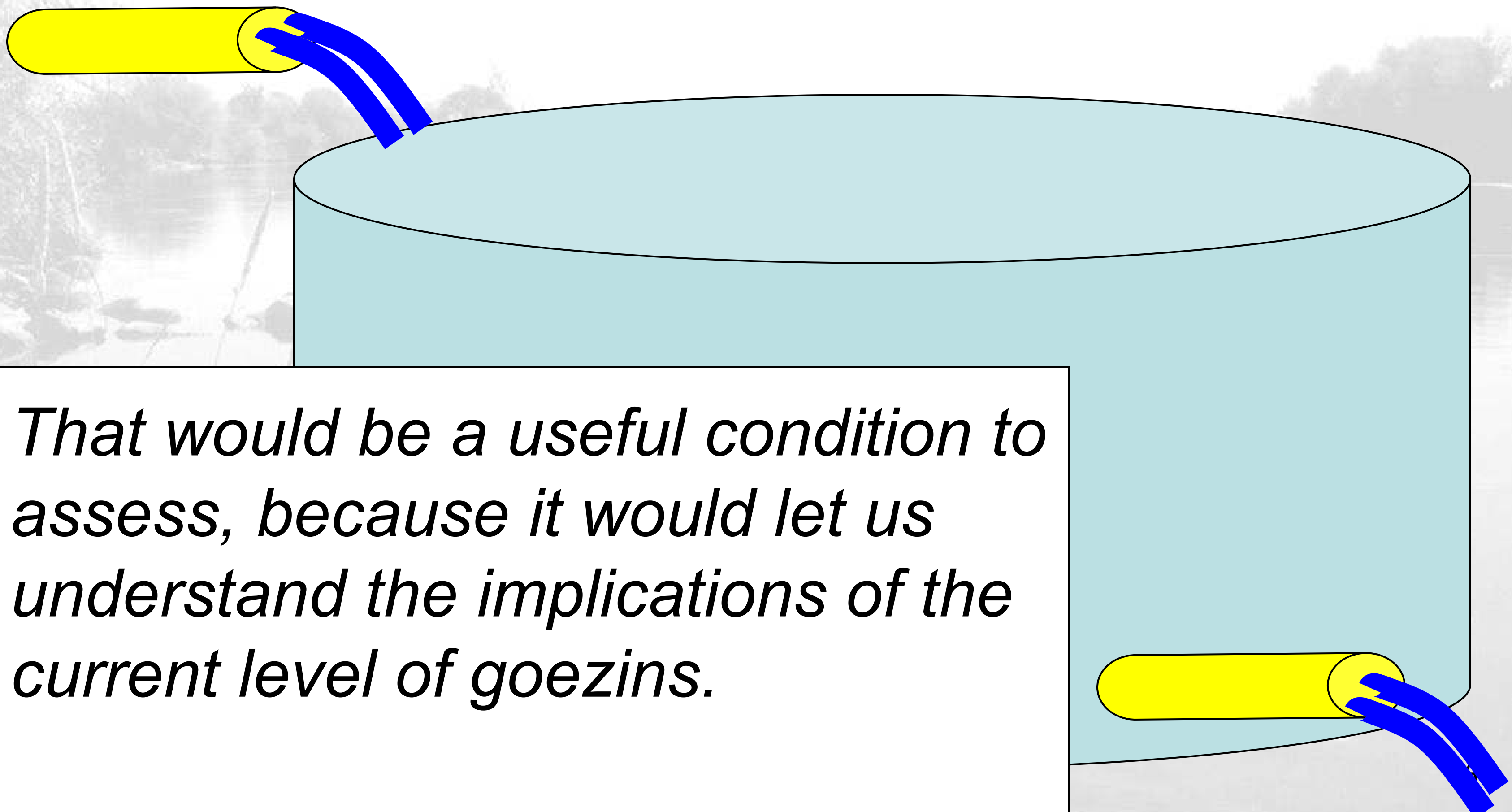


*However, we can calculate where it **would** balance if goezins were to be held constant.*

That would be called "Equilibrium"

What is Equilibrium?

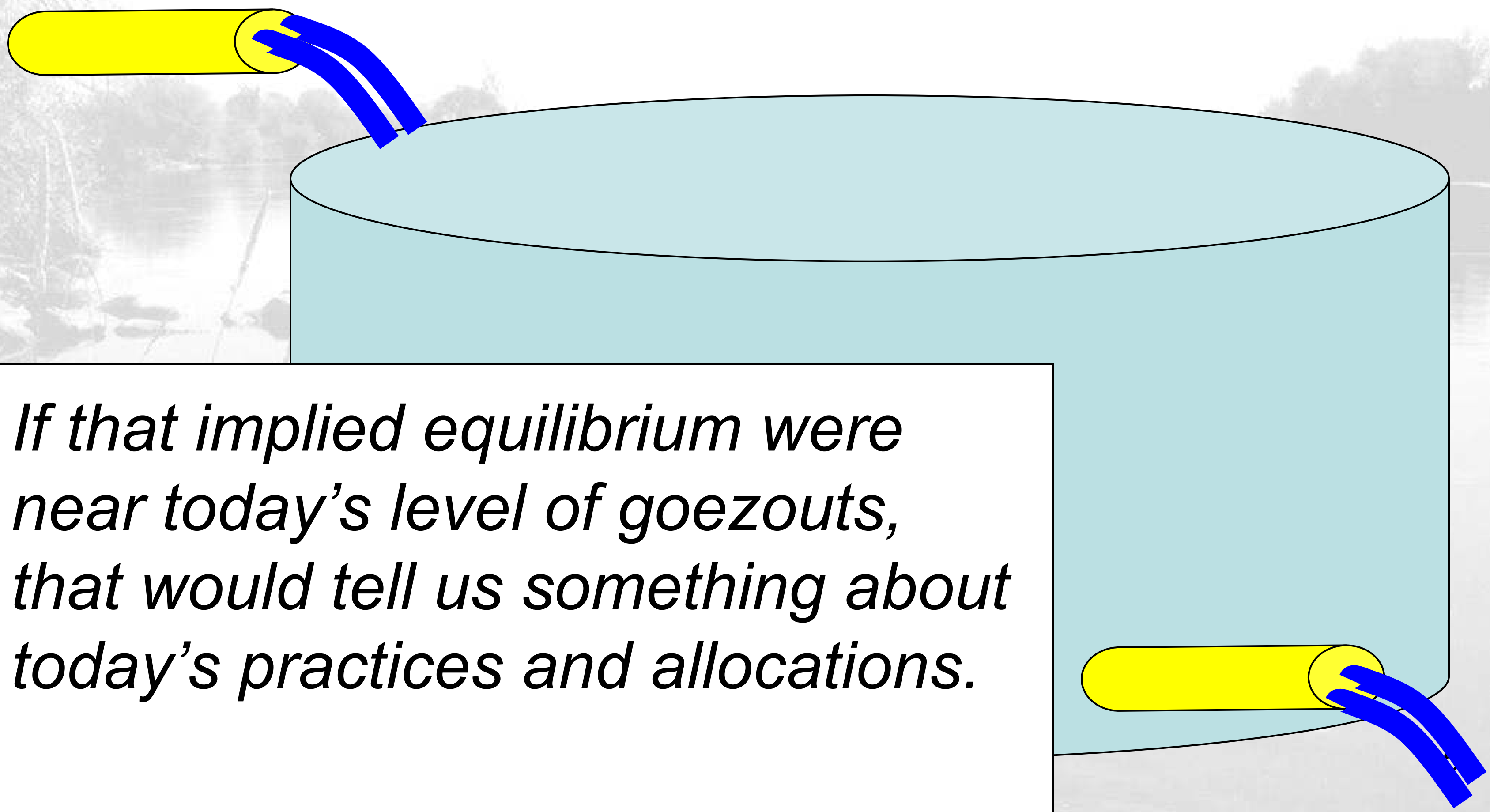
Goezins + Goezouts = Change in Storage



That would be a useful condition to assess, because it would let us understand the implications of the current level of goezins.

What is Equilibrium?

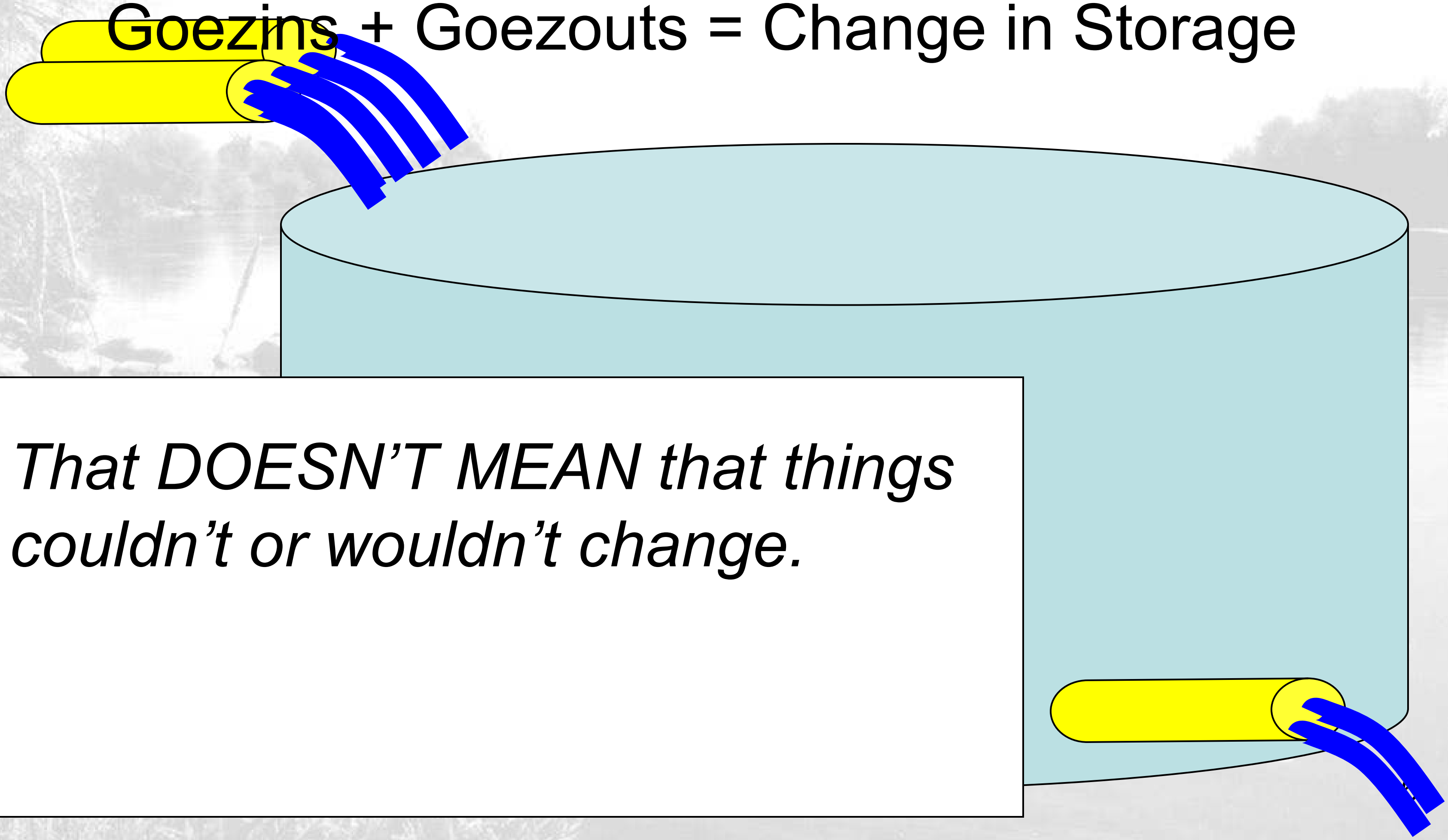
Goezins + Goezouts = Change in Storage



If that implied equilibrium were near today's level of goezouts, that would tell us something about today's practices and allocations.

What is Equilibrium?

Goezins + Goezouts = Change in Storage



That DOESN’T MEAN that things couldn’t or wouldn’t change.

What is Equilibrium?

Here's another way to think about it:

Tomorrow's flows depend on what happened yesterday, what happens today, and what will happen tomorrow.

If the system is currently "near equilibrium" it means there are no surprises coming ***because of what happened yesterday and today.*** *But tomorrow could still bring something new!*

What is a Model?

- Conceptual Model
- Mathematical Representation
- Parameters

- Input data?
- Use of the model?

Conceptual Model

- Gas consumption
  - Fuel used depends on a whole bunch of things; time of year, brand of fuel, road conditions, tire inflation, gender of driver….
- Eastern Snake Plain Aquifer
  - Flow at springs depends on the hydraulic properties of every cubic inch of the aquifer and upon all hydrologic impacts from time immemorial through the present. Flow is governed by many physical processes (laminar flow, turbulent flow, unsaturated flow, tidal effects, barometric effects, temperature and viscosity...) which vary over space and time

Conceptual Model includes "simplifying assumptions"

- Gas consumption
  - Fuel used depends on gas mileage & distance traveled
- Eastern Snake Plain Aquifer
  - Single-layer porous medium with recharge and discharge along the boundaries and from land surface, with hydraulic connection to springs and to the Snake River defined by laminar flow

"The best maps are at a scale of one-to-one but they are hard to fold"

- Mark Twain ?

Mathematical Representation

- Gas consumption: one equation
  - Gallons = miles / MPG
- Eastern Snake Plain Aquifer: two equations
  - Darcys Law
  - Continuity Equation

Parameters

- Gas consumption
  - Miles per gallon
- Eastern Snake Plain Aquifer
  - Table of hydraulic properties
    - transmissivity
    - storage coefficient
    - spring/riverbed conductance
    - spring/riverbed elevation
  - Table of aquifer, river and spring geometry

Input Data

- Gas consumption
  - Miles driven
- Eastern Snake Plain Aquifer
  - starting heads*
  - recharge & discharge across land surface & along borders
  - locations of all inputs

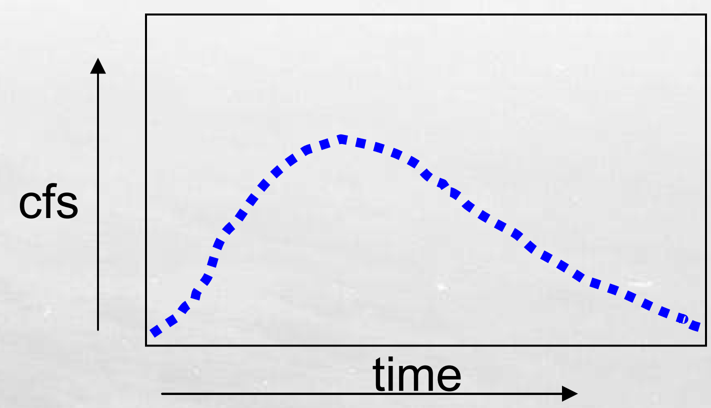
*sometimes

Example use of model

- Gas consumption
  - I drove 341.5 miles:

    341.5 miles /30 mpg =
    11.4 gallons

- Eastern Snake Plain Aquifer
  - Recharge of 10,000 acre feet at site X in 2007 produces the following time series of benefits to My Favorite Reach:



Models **DO NOT** give "PREDICTIONS"

(as the term is commonly used)

- "Prediction:"
  - "You will burn 543.21 gallons of gas next year"
  - "Spring discharge in My Favorite Reach will be 1234.567 cfs next year"
- **Conditional** estimate:
  - "**If** you drive 15,000 miles next year, you will burn about 500 gallons of gas"
  - "**If** you recharge X acre feet/year at Wendell, spring discharge in My Favorite Reach will increase by about 12 cfs

What is Calibration?

Using *Input Data* and *Known Targets*, we adjust *Parameters* to try to match the targets

	Input Data	**Target**
Trip 1	300 miles	11 gallons
Trip 2	400 miles	12 gallons
Trip 3	270 miles	9 gallons

Iteration 1: Parameter “20 miles per gallon”

	Input Data	Model Result	Target
Trip 1	300 miles	15 gallons	11 gallons
Trip 2	400 miles	20 gallons	12 gallons
Trip 3	270 miles	13.5 gallons	9 gallons

Iteration 2: Parameter "40 miles per gallon"

	Input Data	Model Result	Target
Trip 1	300 miles	7.5 gallons	11 gallons
Trip 2	400 miles	10 gallons	12 gallons
Trip 3	270 miles	6.8 gallons	9 gallons

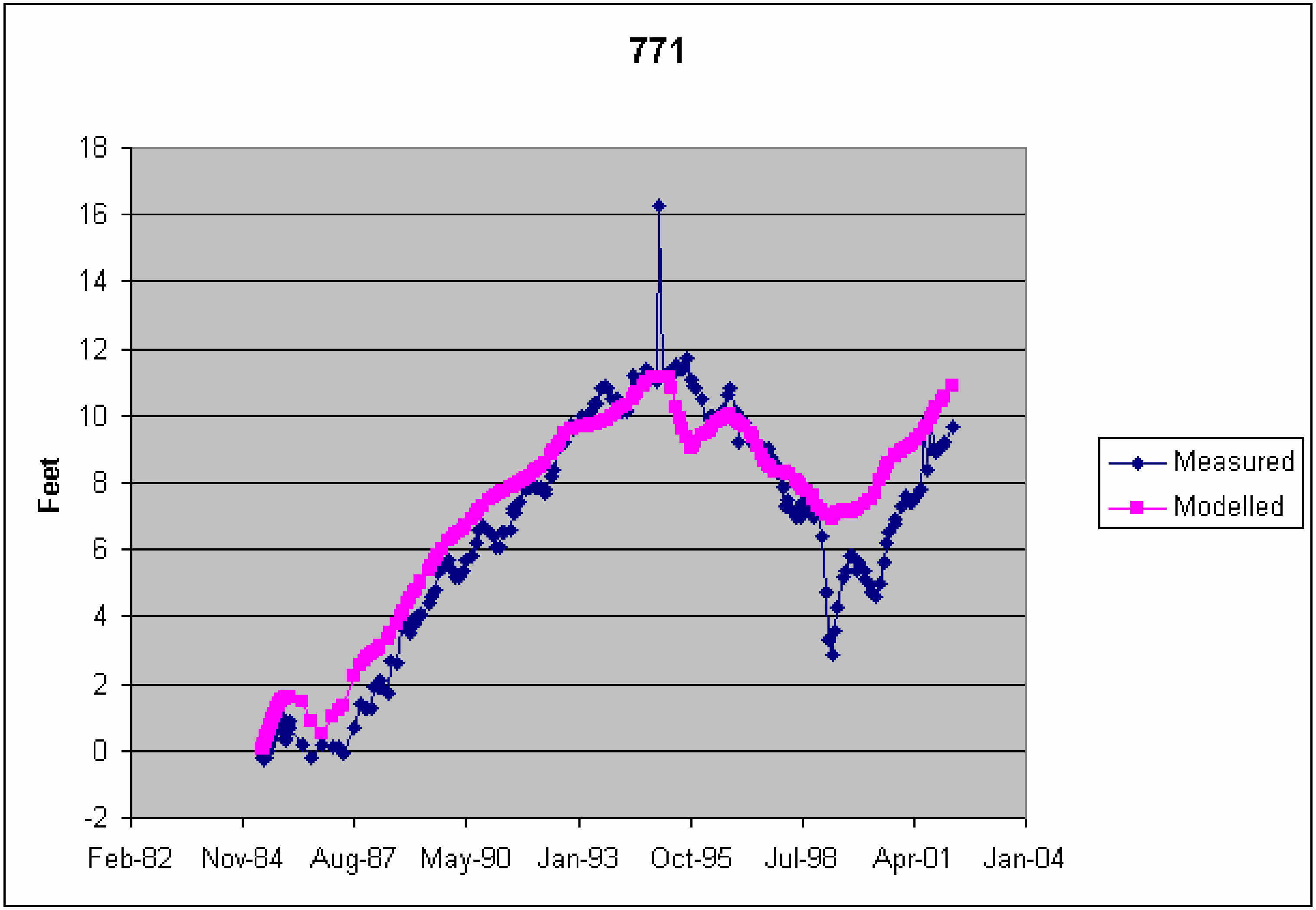
Iteration 3: Parameter "30 miles per gallon"

	Input Data	Model Result	Target
Trip 1	300 miles	10 gallons	11 gallons
Trip 2	400 miles	13 gallons	12 gallons
Trip 3	270 miles	9 gallons	9 gallons

ESPAM 1.1 calibration: Match to ~ 15,000 data points

- Inputs varied every six months; output calculated every 18 days
- Head values interpolated to exact date of target
- Gains & discharges compared to filtered (smoothed) data
- A few hundred parameters were adjusted
- Sophisticated software was used to make the adjustments, over tens of thousands of model runs

Sample comparison



What is ESPAM 1.1 Good For?

(These are opinions from the “White Paper” presented without comment or evaluation. They represent individual views and not consensus.)

- “The model can be used to [help determine] how [aquifer] water use… will impact gains or losses to the river in specified reaches…. The ESPAM was designed to make broad-scale predictions.”

IDWR

- “The model has great potential as a planning tool and for the evaluation of... alternative… management plans... provided that [the following suggestions are followed]*…”

Leonard Rice Engineers

*The suggestions revealed a high level of discomfort with the model calibration and data sets

- “The model … can be used for…
  - [evaluation of] the aquifer response and effect on aggregated river reaches from changes in net aquifer recharge across wide areas…
  - [evaluation of] specific ground-water levels and aggregated river reach gains…
  - [development of] an aquifer management plan…
  - support[ing] administrative actions”

HDR Engineering
Brockway Engineering
Idaho Power
Principia Mathematica

- “[The model] presents a coherent and reasonably accurate picture of the aquifer-river interactions that occur in the ESP.”

Bureau of Reclamation

- “The ESPAM is suitable for use in performing regional-scale analyses of the effects of [aquifer] water management and administration… and is an appropriate tool for the IWRB to use in its effort to develop an ESPA management plan.”

Hydrosphere

- “The model is most useful and suited for predicting regional water level [and] reach gains [changes] over relatively long periods.”

Spronk Water Engineers

IWRRI statement, Appropriate Uses of ESPAM 1.1

- The ESPAM is a regional model
  - Estimate effects on aggregated river reaches or groups of springs.
  - Estimate regional water-level impacts.
- Suited for 6-month or longer evaluations.
- The best use of the model is to evaluate *changes* expected from a particular practice or event.

What are ESPAM's limitations?

(These are opinions from the "White Paper" presented without comment or evaluation. They represent individual views and not consensus.)

- “[ESPAM] was not designed to assess localized phenomena such as the impact from pumping a specific well on a specific spring.”

IDWR

- “The current model has no technical credibility as a tool for water rights administration.”

Leonard Rice Engineers

- “The model needs to include a high[er] degree of spatial and temporal accuracy [than it currently exhibits].”

HDR Engineering
Brockway Engineering
Idaho Power
Principia Mathematica

- “To the extent that [pre-1980] legacy effects are unaccounted for in the model, they can influence model calibration and… (thereby) model predictions of river response.”

Bureau of Reclamation

- "[ESPAM] cannot be used reliably to determine the absolute effects of localized water management activities on specific springs."

  "Model scenarios constructed to simulate more extreme stresses [than included in calibration data] should be viewed with great circumspection."

Hydrosphere

- “The model should not be used to evaluate changes in water levels, reach gains, spring flows, etc. over periods of shorter duration [than six months to one year].”

Spronk Water Engineers

IWRRI Statement, Limitations of ESPAM 1.1

- Less reliable for analysis of impacts close to springs (~ 10 miles) and river (~ 5 miles).
- Less reliable for analysis of short-term effects.
- Not intended to evaluate impacts of an individual well upon an individual spring.
- Estimates of *absolute* values are not as reliable as estimates of *expected changes.*

What are specific issues with the model?

- Desired improvements to the conceptual model
  - finer spatial resolution
  - finer temporal resolution
  - more layers in the conceptualization
  - ability to predict impacts at individual springs
  - representation of specific water-budget components
    - return flows
    - tributary-valley underflow
    - fraction of ground-water supply on mixed-source lands
    - recharge from precipitation on non-irrigated lands

- Issues with some past scenarios & results
  - what did the scenario represent?
  - what did we *think* it represented?
  - what do we *wish* it represented?
  - how was it interpreted by the authors?
  - how is it interpreted by the public?
  - How would we *like* it to be interpreted?

"The model says it takes 10 gallons of gas to drive to Salt Lake. I drove to Seattle and used 40 gallons. *The model is wrong."*

- Desire for better calibration results
  - variability of modeled spring discharges
  - matches to reach gains
- Differences of opinion over technical matters
  - pre-1980s data vs starting heads
  - role of superposition
  - modeling principle of “parsimony”
  - need for data to support model detail

- Need for better characterization of uncertainty
- Stakes (and emotions) are very high

What is planned for the model?

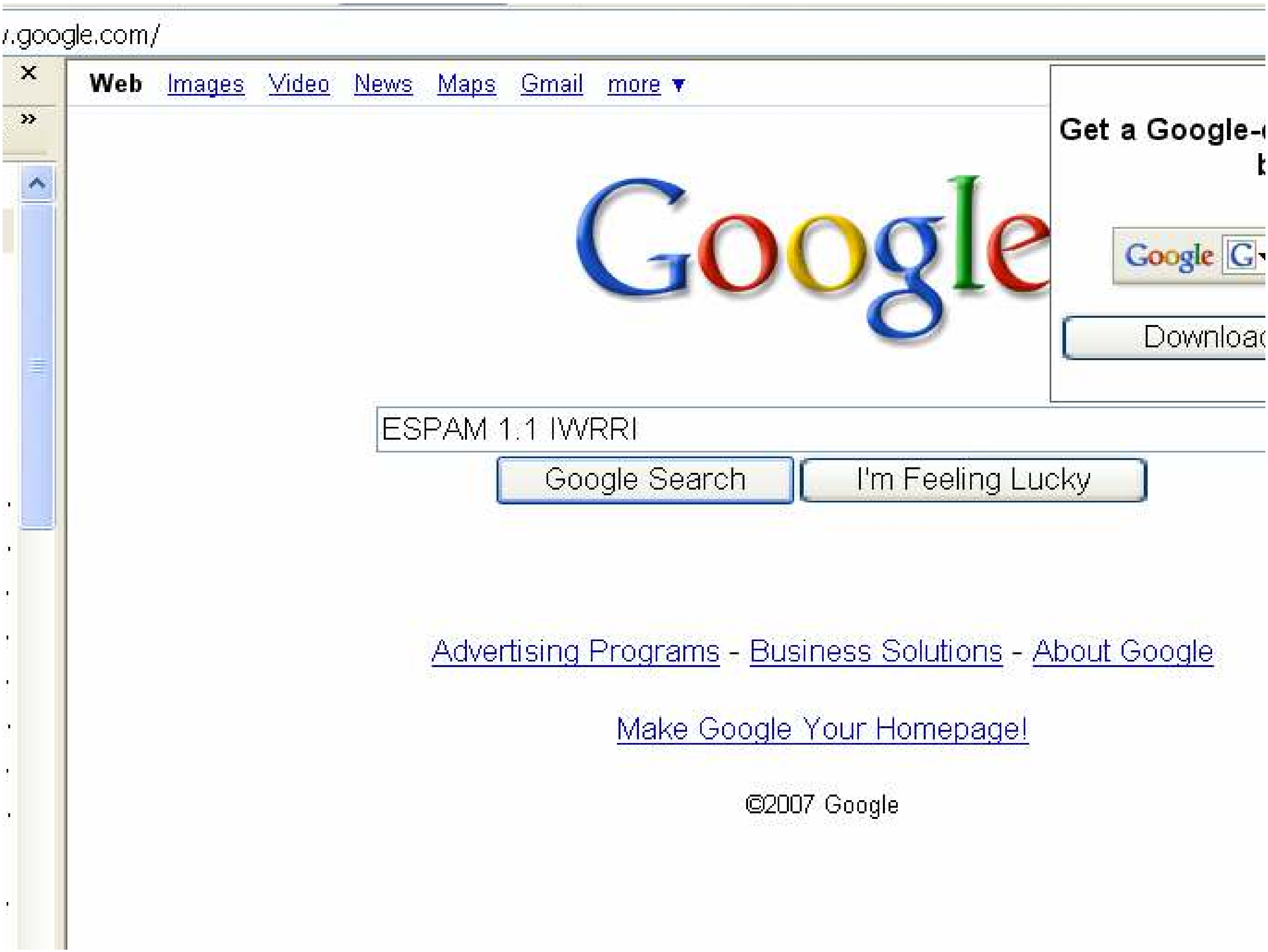
- Calibration of ESPAM 2.0 in 2008 or 2009
- ESHMC is carefully considering what conceptual model changes we can and should make
  - can we get the data?
  - do we have the time?
  - do we have the money?
- Data gathering will commence in September 2007
- IDWR has funded investigation of improvements in methods

Take-Home Message

- The model is a tool. Not a perfect tool, but a useful tool.
- Some things don't need a model.
- Some things are not uncertain.

"If I take a bucket of water from the aquifer, it WILL come from the river or springs eventually."

How do I get more information?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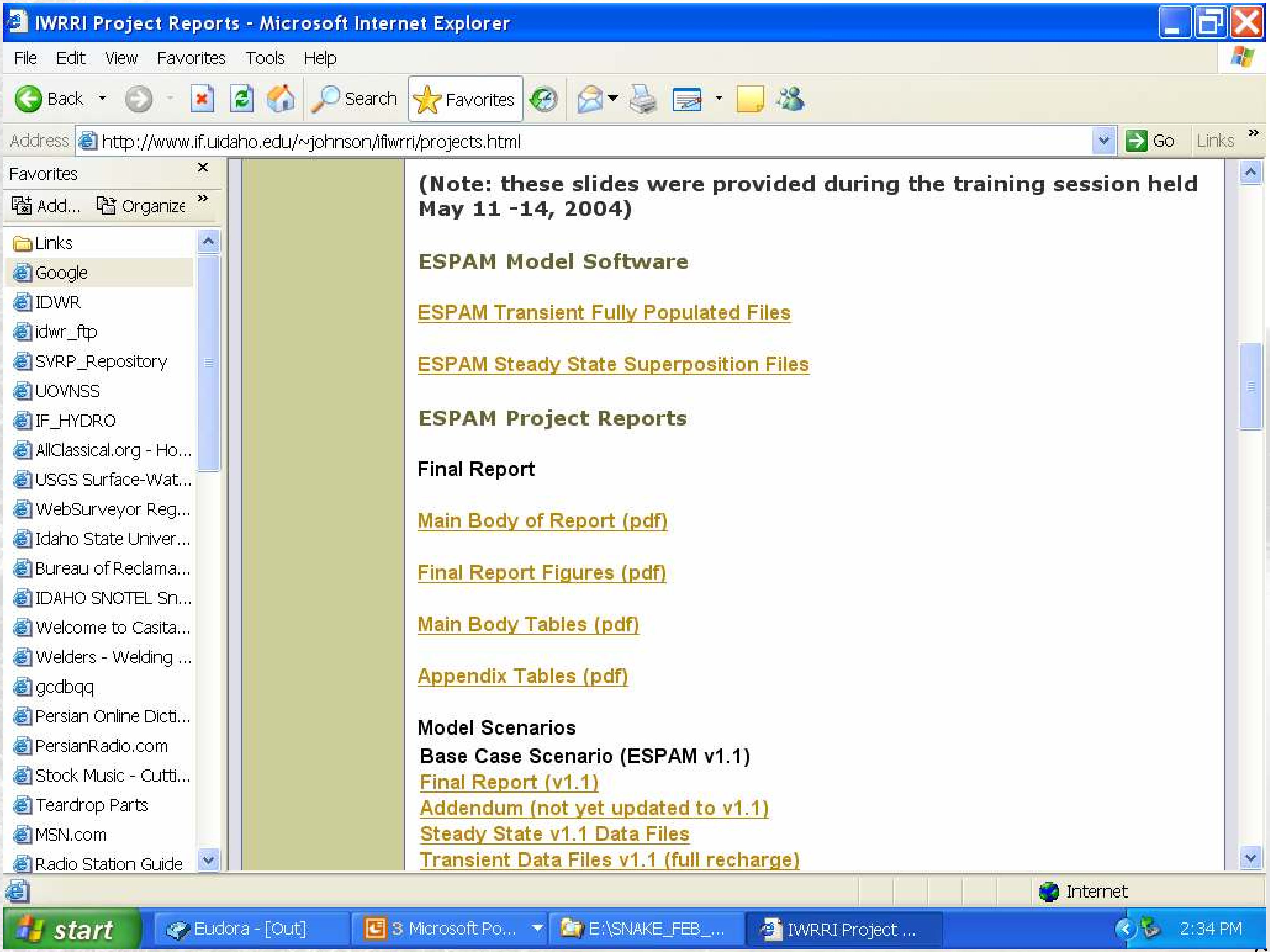
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Teardrop Parts
MSN.com
Radio Station Guide
(Note: these slides were provided during the training session held May 11 -14, 2004)
ESPAM Model Software
ESPAM Transient Fully Populated Files
ESPAM Steady State Superposition Files
ESPAM Project Reports
Final Report
Main Body of Report (pdf)
Final Report Figures (pdf)
Main Body Tables (pdf)
Appendix Tables (pdf)
Model Scenarios
Base Case Scenario (ESPAM v1.1)
Final Report (v1.1)
Addendum (not yet updated to v1.1)
Steady State v1.1 Data Files
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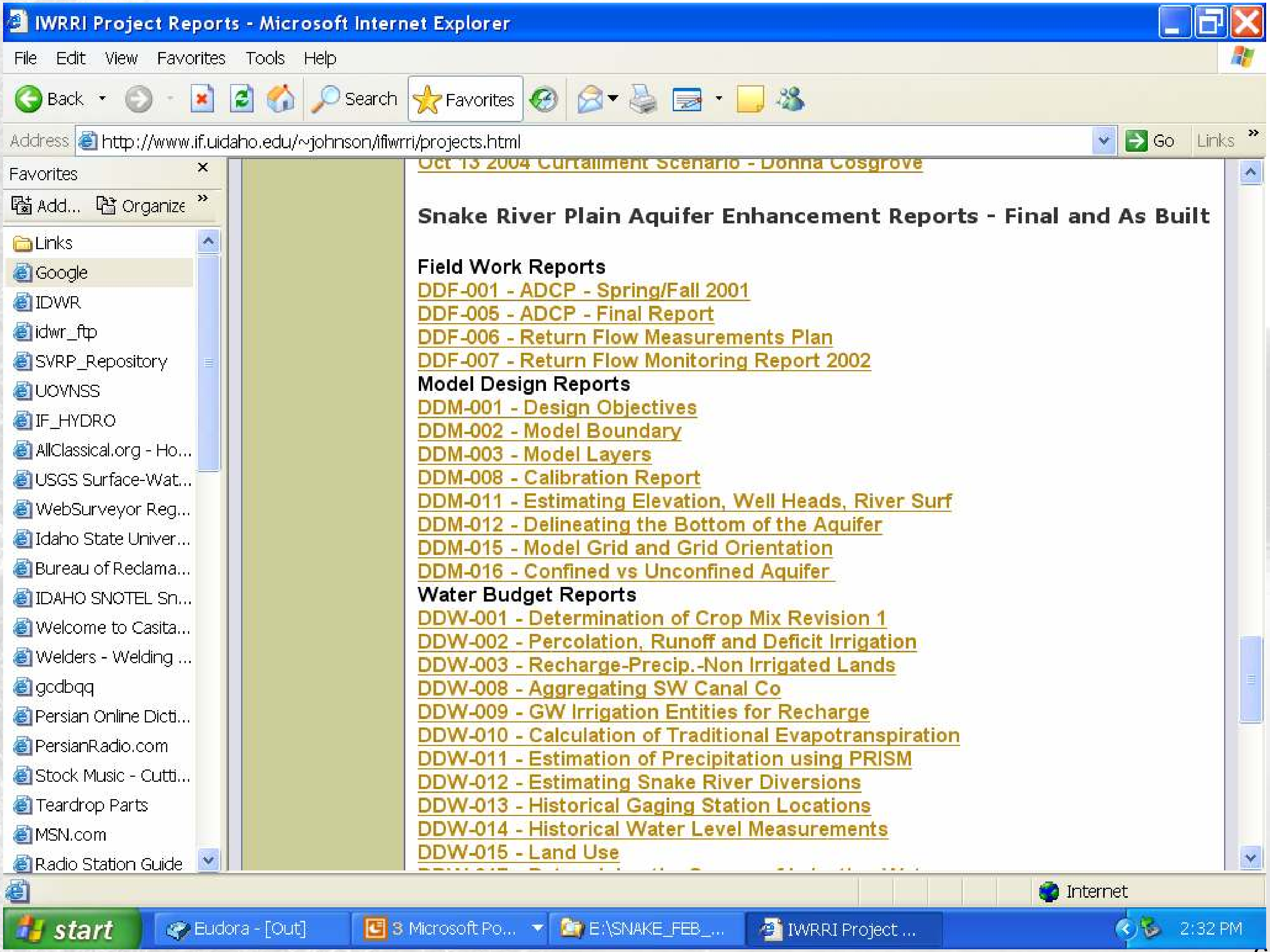
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MSN.com
Radio Station Guide
Oct 13 2004 Curtailment Scenario - Donna Cosgrove
Snake River Plain Aquifer Enhancement Reports - Final and As Built
Field Work Reports
DDF-001 - ADCP - Spring/Fall 2001
DDF-005 - ADCP - Final Report
DDF-006 - Return Flow Measurements Plan
DDF-007 - Return Flow Monitoring Report 2002
Model Design Reports
DDM-001 - Design Objectives
DDM-002 - Model Boundary
DDM-003 - Model Layers
DDM-008 - Calibration Report
DDM-011 - Estimating Elevation, Well Heads, River Surf
DDM-012 - Delineating the Bottom of the Aquifer
DDM-015 - Model Grid and Grid Orientation
DDM-016 - Confined vs Unconfined Aquifer
Water Budget Reports
DDW-001 - Determination of Crop Mix Revision 1
DDW-002 - Percolation, Runoff and Deficit Irrigation
DDW-003 - Recharge-Precip.-Non Irrigated Lands
DDW-008 - Aggregating SW Canal Co
DDW-009 - GW Irrigation Entities for Recharge
DDW-010 - Calculation of Traditional Evapotranspiration
DDW-011 - Estimation of Precipitation using PRISM
DDW-012 - Estimating Snake River Diversions
DDW-013 - Historical Gaging Station Locations
DDW-014 - Historical Water Level Measurements
DDW-015 - Land Use
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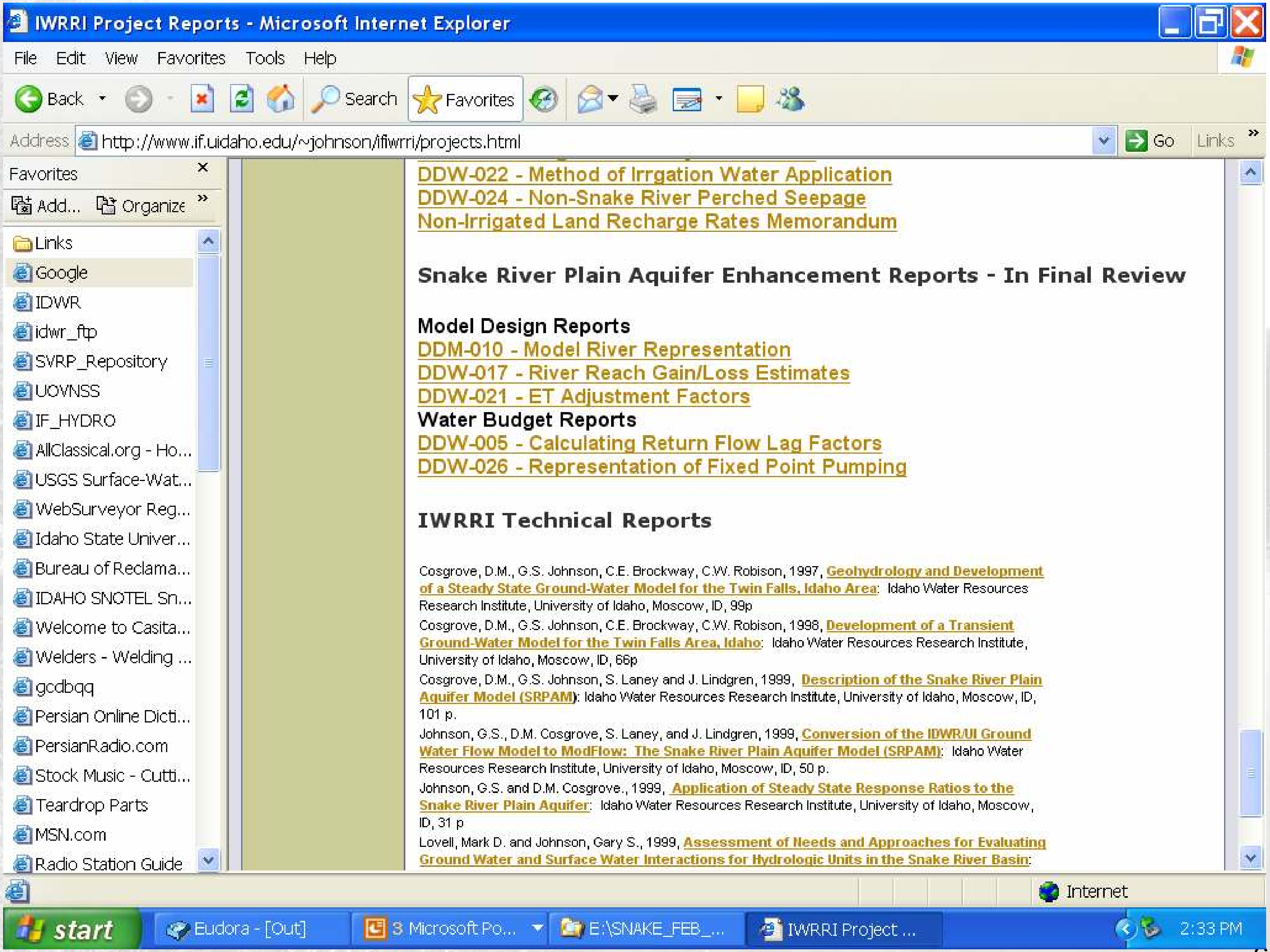
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DDW-022 - Method of Irrgation Water Application
DDW-024 - Non-Snake River Perched Seepage
Non-Irrigated Land Recharge Rates Memorandum
Snake River Plain Aquifer Enhancement Reports - In Final Review
Model Design Reports
DDM-010 - Model River Representation
DDW-017 - River Reach Gain/Loss Estimates
DDW-021 - ET Adjustment Factors
Water Budget Reports
DDW-005 - Calculating Return Flow Lag Factors
DDW-026 - Representation of Fixed Point Pumping
IWRRI Technical Reports
Cosgrove, D.M., G.S. Johnson, C.E. Brockway, C.W. Robison, 1997, Geohydrology and Development of a Steady State Ground-Water Model for the Twin Falls, Idaho Area: Idaho Water Resources Research Institute, University of Idaho, Moscow, ID, 99p
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Johnson, G.S., D.M. Cosgrove, S. Laney, and J. Lindgren, 1999, Conversion of the IDWR/UI Ground Water Flow Model to ModFlow: The Snake River Plain Aquifer Model (SRPAM): Idaho Water Resources Research Institute, University of Idaho, Moscow, ID, 50 p.
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Lovell, Mark D. and Johnson, Gary S., 1999, Assessment of Needs and Approaches for Evaluating Ground Water and Surface Water Interactions for Hydrologic Units in the Snake River Basin:
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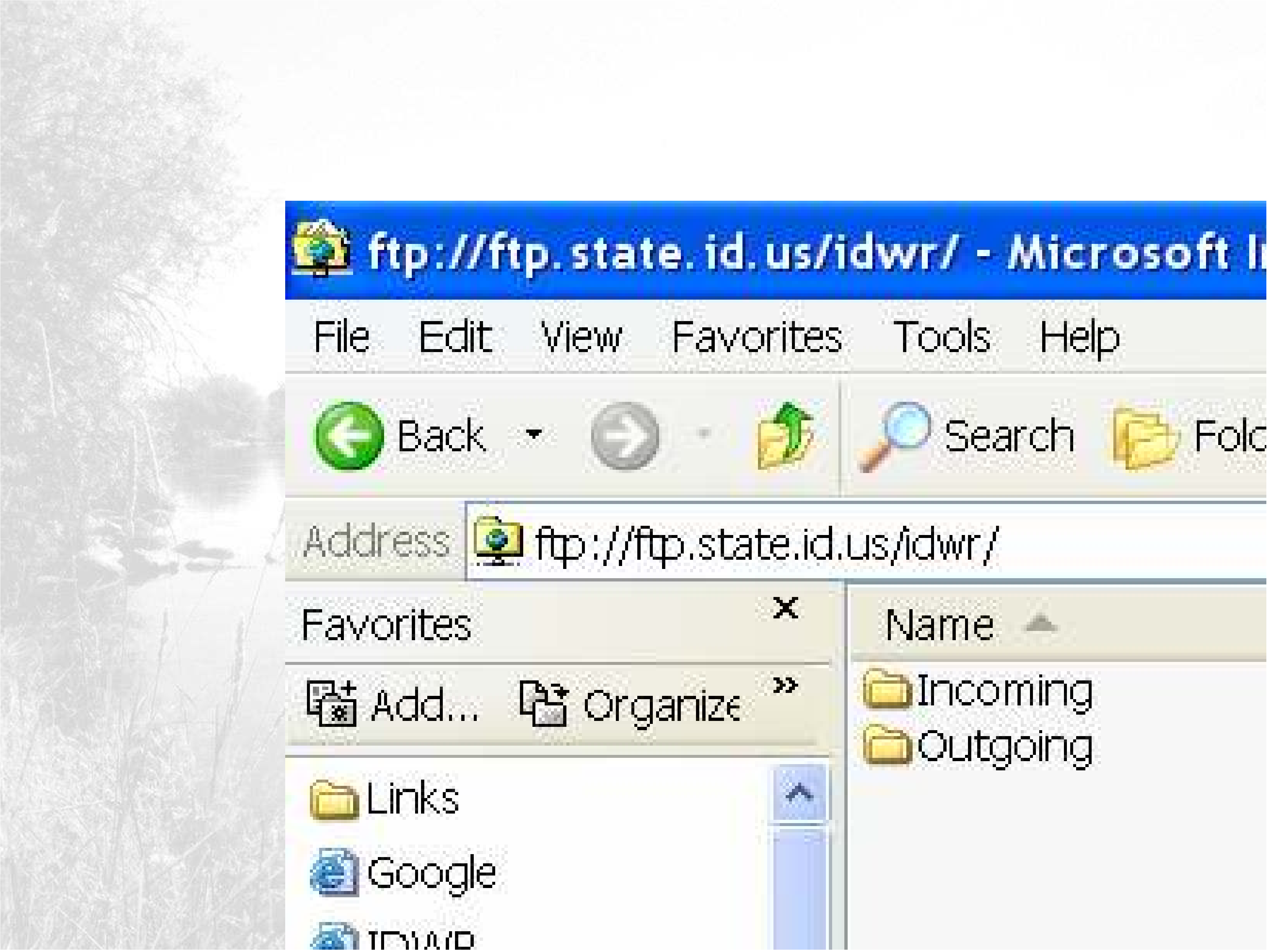
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