

## Sediment Transport in the Jordan River

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Why this study: The beautiful Michigan grayling that once thrived in the Jordan River is now extinct, which is perhaps due to sediment destroying the spawning grounds



### Talk Outline

- **Introduction**
- Research Questions, Approach and Tasks
- Expected results and Deliverables
- Discussion

### Background

#### Historical records:

- Grayling were reproducing in the Jordan River during the Civil War.
- This likely required a river with gravel bottom with little or no mobile sand.

#### Current situation:

*A significant amount of sandy bedload transport.*

#### Unknowns:

- Has sand been added in recent/historical time?
- Did the fish reproduce in an environment similar to the present?
- Do other factors play a role (e.g., species competition, shade)?

#### Hypothesis:

*The source of the sand in the Jordan River and its recent increase is a result of changes in land use (logging, farming, etc.) in the 1880's-1920's.*

### Scenarios for changing sediment load of a river:

- A. Landslides
- B. Forest fires
- C. Logging
- D. Land use
- E. Climate
- F. Groundwater level change
- G. Change of river gradient



### A. Landslides

*Landslides generally bring a large mass of sediment down steep slopes.*

*They may be caused by human intervention but also occur in pristine forests.*

#### Landslide triggers include:

- Steep slopes
- Forest fires
- Logging (land use change)



## Landslides in the Jordan River Basin

Research questions:

1. What is the evidence of landslides in the Jordan River drainage basin?
  - Channel form (braided vs. meandering)
  - Landslide trail
  - Trees in channel
2. Has landslide frequency increased as a result of land use changes?



## B. Forest Fires



Results of forest fires:

- Hydrophobic soils, which limit water infiltration
- Absence of vegetation, which reduces intercept and ET

Enhanced fluvial sediment transport through:

- Increased erosion rates
- Increased landslide potential

## Forest Fires in the Jordan River Basin

Research questions:

1. What is the evidence of forest fires in the Jordan River drainage basin?
  - Gravel pit
  - Records from offshore cores
2. Can we date specific events?
3. What are the effects on the river's sand budget?

Local evidence of a forest fire:

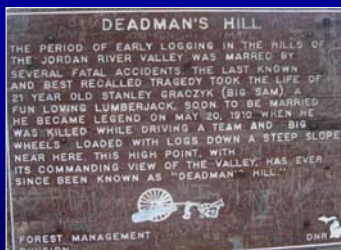


## C. Effects of Logging

- Logging increases erosion rates
- Increased landslide potential
- Enhance fluvial sediment transport



## Logging in the Jordan River Basin



Research question:

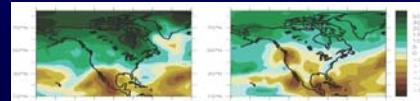
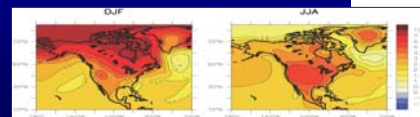
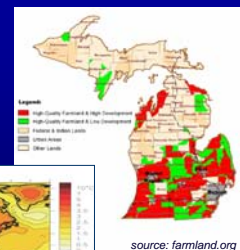
What can historical records tell us about logging-induced changes to the Jordan River?

## D/E. Effects of Land Use and Climate

Components of the hydrological cycle are controlled by:

- land use (forest - agricultural - urban)
- climatic conditions, and
- subsurface properties.

Changes have occurred in the past and are likely to occur again.



2080-2099  
Regional  
Projections  
IPCC 2007

## Important land use and climate changes in Jordan River Basin

### Late 1800's:

Widespread logging and fires

### Early 1900's:

Change to agricultural land use practices

### The Future:

Changes in dominant crop types

Warmer temperatures (+3° C) and Wetter winters (+12%)

Research questions:

1. Can we estimate the effects of past land use changes on river characteristics?
2. Can we predict changes as a result of future changes in land use and climate?

## F/G. Changes in Head and Gradient

Characteristics of a river and its drainage area directly influence its sediment load:

- For groundwater-fed streams, changes in the groundwater table (head) surface influences discharge.
- The gradient of a river influences its capability to transport sediment. Local changes in gradient (e.g., as a result of a landslide) will affect the sediment load.

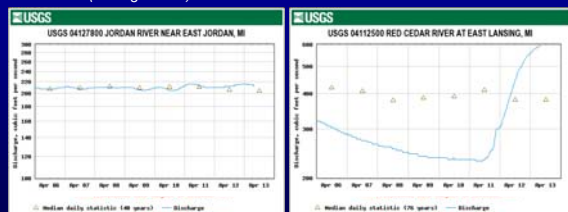
## Jordan River is a groundwater-dominated stream

USGS stream gauge data show that the Jordan is an amazing river!

- Drainage area: 67.9 square miles.
- Average flow: ~187 cfs; little variation.
- Cold water (average 45 °F).

Red Cedar River on MSU campus for comparison:

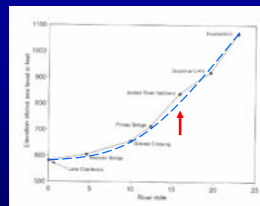
- Drainage area: 355 square miles.
- Average flow: 213 cfs.



How can a river with 1/5<sup>th</sup> the drainage area have similar average annual flow?

Very high **ground-water base-flow** in the Jordan.

## Gradient of the Jordan River



This graph suggests that the Jordan River is currently not in equilibrium state.

Research questions:

1. Which sections of the river show evidence of disturbance?
2. Can river terraces be used to study the state of equilibrium pre-1900?

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## Michigan State University Study 2007-2010

### Research Questions

What is the **rate of sediment movement** through this system (upper vs. lower)? How much is transported at different flow rates?

What are the **origin(s) of the sediments** (boiling springs, road development, agriculture, deforestation, forest fire, landslides, Great Lakes levels, etc...)?

What can the **deltaic deposits** tell us about past conditions?

**Did a gravel bottom river exist** some time period pre-1900's? Can human influence be reversed?

What are possible **scenarios for future** state of this system?

### Approach & Tasks

1. Search and study of scientific literature and historical records.
2. **Characterization and measurement** (flow & river stage measurements, sediment trap monitoring, deltaic deposition, age dating).
3. Combine all components of the hydrological cycle in the **Integrated Landscape Hydrology Model** to predict stream discharge under current conditions, and as affected by change (e.g., fire, logging, land use).
4. Integration of all data sources to improve understanding of **current, historical, and future flow and sediment transport** conditions in the Jordan River Basin.
5. Develop a **comprehensive management strategy** for the Jordan River Basin, based on the findings of our research.

### Task 1. Literature search and historical records

Topics for literature search include:

- Human occupation
- Land use change (logging, agriculture)
- Engineering structures  
(Pine River connection / East Jordan Bridge)
- Lake Michigan level
- Glacial history
- ...

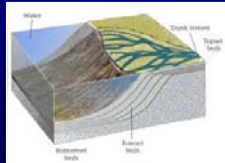


### Task 2a. Characterization and measurement - Delta

Sedimentation history of the Jordan River delta.

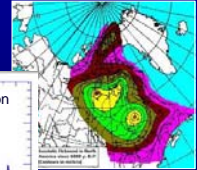
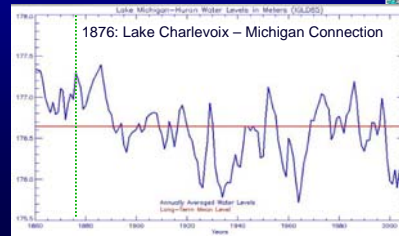
By dating a series of beds and determining their volume, we will reconstruct the transport conditions.

Research methods will be geophysics (ground penetrating radar), cores (hand augers and vibracores), and age dating ( $^{14}\text{C}$  and OSL)



Factors controlling deltaic deposition:

- River sediment load
- Isostatic rebound (~ 0.3 m in last 150 years)
- Lake level variations
- Engineering structures

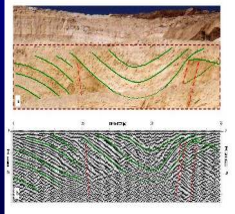


Geophysical methods:

To evaluate the volume of the sediment we will use ground penetrating radar (GPR).

GPR forms an image of the subsurface by transmitting and receiving electromagnetic (radio frequency) energy.

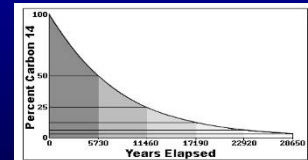
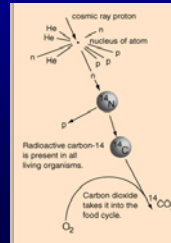
Reflections occur at interfaces between different materials (i.e. sand, clay, peat, gravel etc.).



Dating techniques -  $^{14}\text{C}$ :

To date organic material that is buried with the sediment we measure the amount of radioactive carbon 14. This gives us the number of years since the organic material died and thus, presumably a date when it was buried.

This method allows us to date the age of abandoned channels, peat bogs, burnt plant material, etc. up to ages of 50 thousand years.



$^{14}\text{C}$  is generated by cosmic ray neutron striking an atom of  $^{14}\text{N}$  in the atmosphere.  $^{14}\text{C}$  is then incorporated in living things.

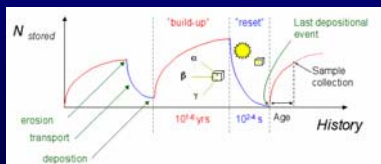
### Dating techniques - OSL:

Uses natural sedimentary processes of **erosion**, **transport**, and **deposition**.

Interaction of Quartz and Feldspar mineral grains with ionizing radiation results in the trapping of electron charges in crystal defects ("**build up**").

However, the crystals are bleached ("**reset**") and the electrons are removed from their traps each time they are exposed to the sun.

The OSL method counts the number of electrons trapped in crystal defects, which is a measure for the length of time since it was last exposed to sunlight (i.e., **time of deposition**). Datable age range: from 10's to 100,000's of years.



### Task 2b. Characterization and measurement – River

- Install pressure transducers in key reaches of the Jordan River.
- Measure flow using standard USGS measurement methods.
- Combine river level and flow data into stage-discharge relationships.
- Monitor sediment transport in different reaches of the river.



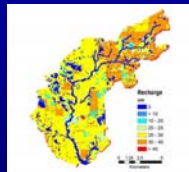
### Task 3. The Integrated Landscape Hydrology Model (ILHM)

The ILHM is a fully process-based model that integrates all components of the hydrological cycle to reconstruct and predict river discharge.

Input for the model is derived from publicly accessible GIS datasets, and is calibrated using field measurements.

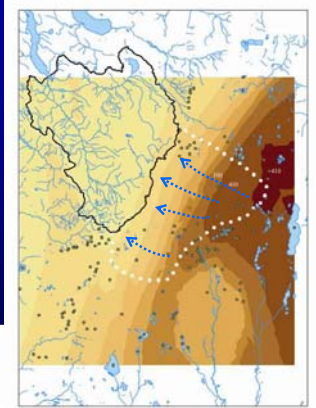
The model has been successfully tested for several Michigan Watersheds.

We have started to build this model for the Jordan River watershed; the next slides show some examples of input.

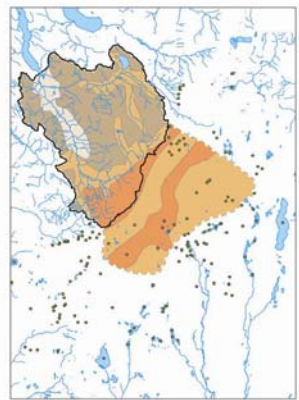


*Hyndman, D.W., A.D. Kendall, and N.R.H. Welty, (in press) Evaluating Temporal and Spatial Variations in Recharge and Streamflow Using the Integrated Landscape Hydrology Model (ILHM), AGU Monograph, Data Integration in Subsurface Hydrology.*

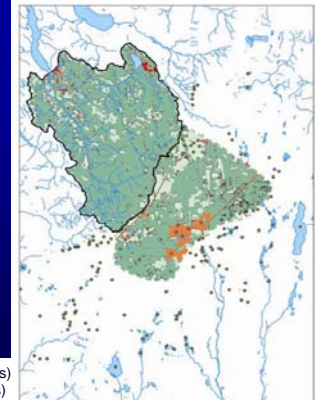
### Ground water surface



### Geology



### Land use



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### Expected results, products and deliverables

- *Yearly progress report*
- *Annual presentation of results to advisory committee*
- *M.Sc. Thesis Chris May*
- *Scientific publications and conference abstracts*

### Proposed Timeline for Research

- *Literature review and historic materials search (Year 1)*
- *Installation of monitoring equipment at key stretches of the river (Year 1)*
- *Characterization of Delta sediments with limited dating (Year 1&2)*
- *Development of the Integrated Landscape Hydrology Model (Year 1&2)*
- *Data analysis and integration (Year 2&3)*

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- **Discussion?**