WSDOT
Scour Workshop

Module 6
Long-Term Degradation and Stream Stability

May 31st, 2023

Robert Humphries

Geomorphologist, LEG.

HQ Development Division
WSDOT

Current Duties

- Chronic Environmental Deficiencies Program
- Fish Passage: design, management, and review Section
- Emergency Repair: design and construction

Background and Experience

- 14 years as a consulting geologist / engineering geologist / geomorphologist
- ~1.5 years at WSDOT

Education

- B.S. in Geology from UGA
- M.S. Applied Geosciences from SFSU

Personal Interests

- My family and friends
- Fly Fishing
- Camping
- Travel

Gabriel Taylor

Assistant State Engineering Geologist, LEG.

HQ State Geotechnical Office
WSDOT

Current Duties

- Landslide and Rockfall Response
- Unstable Slope Mitigation
- Earthwork/Widening Projects
- Geotechnical Fish Passage Scoping
- Scour Research!

Background and Experience

- 18 years at WSDOT
- Licensed Engineering Geologist since 2010
- AEG Nisqually past-Chair

Education

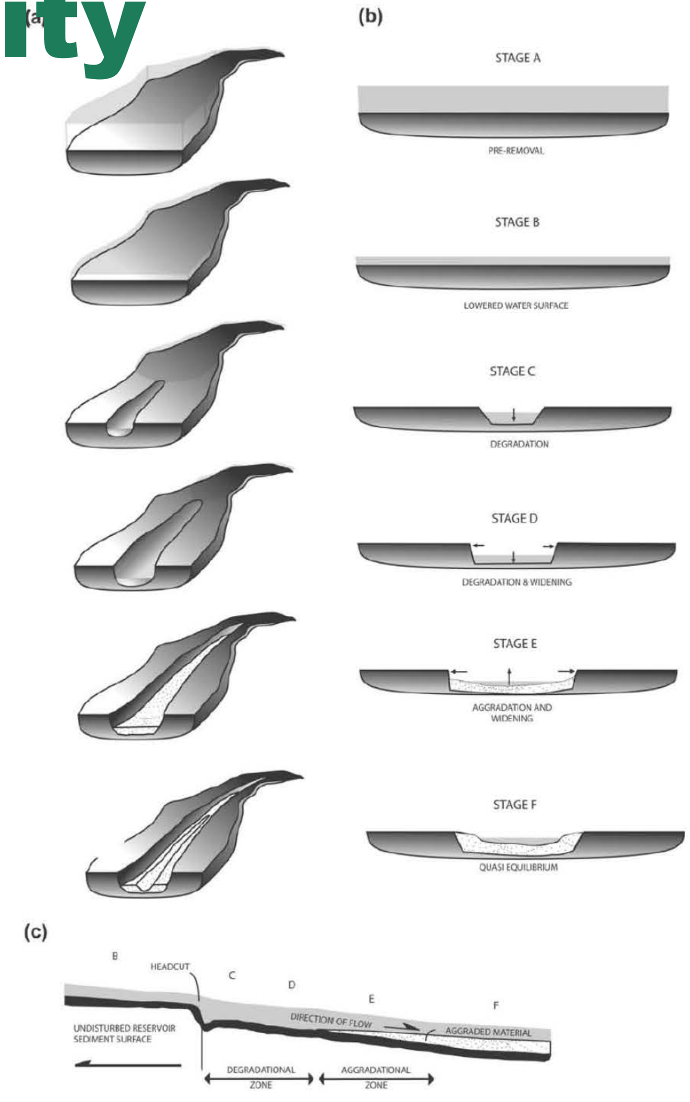
- B.S. Geology (WWU 2004)

Personal Interests

- Mountains (biking and climbing)
- Music (various stringed instruments)
- History & Astronomy
- Camping with friends and family

Overview: Long-Term Degradation and Stream Stability

- Interdisciplinary: Driving Forces v Resisting Forces
- Time Scale: Life of the Structure
- Factors that affect Long Term Degradation (LTD) and Stream Stability
  - Driving Forces: Hydraulic Forces
  - Resisting Forces: Geotechnical Properties
    - Geotechnical properties of these deposits
      - Cohesionless
      - Cohesive
      - Rock
- Channel Migration Zone (CMZ), Lateral Migration, and LTD
  - Characteristic Processes
  - Widening due to vertical incision
- Geotechnical and Hydraulic coordination example
- Future Research



Doyle 2003

Aligning Scour Analysis Methods with Scour Processes

- **Total Scour Analysis**
  - Contraction Scour **(Module 7)**
  - Local Scour **(Module 8 and 9)**
  - Lateral Migration **(Module 6)**
    - Stream Instability
    - Geomorphic Assessment: Site, Reach, and Watershed
  - Long-Term Degradation **(Module 6)**
    - Stream Instability
    - Geomorphic Assessment: Site, Reach, and Watershed
- **Hydraulic Modeling**
- **Foundation Design**
- **Slope/Global Stability**
- **Stream Instability**
- **Geomorphic Assessment: Site, Reach, and Watershed**
- **Etc.**

- **Data for Scour Analysis (Module 5)**
  - Bed Material Samples
    - Surface (Wolman Pebble Count)
    - Subsurface
  - Geotechnical Samples
    - Cohesionless
    - Cohesive
    - Rock

Fundamentally Interdisciplinary

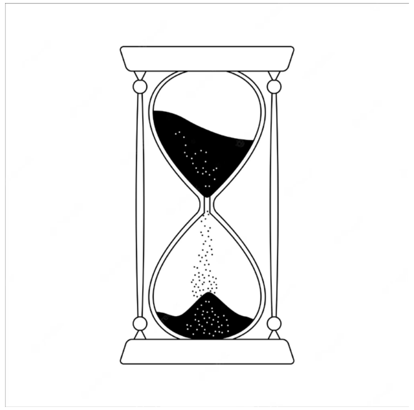
Driving Forces:
Hydrology & Hydraulics

Resisting Forces:
Geology & Geotech.

Scour
Calculation

Time Scale of Interest

- Life of the Structure
  - Limit by corrosion rate of steel with the crossing structure to ~75 years
- Time Scale of the Design Discharges
  - Q100 for channel hydraulics
- Scour Processes and Rates



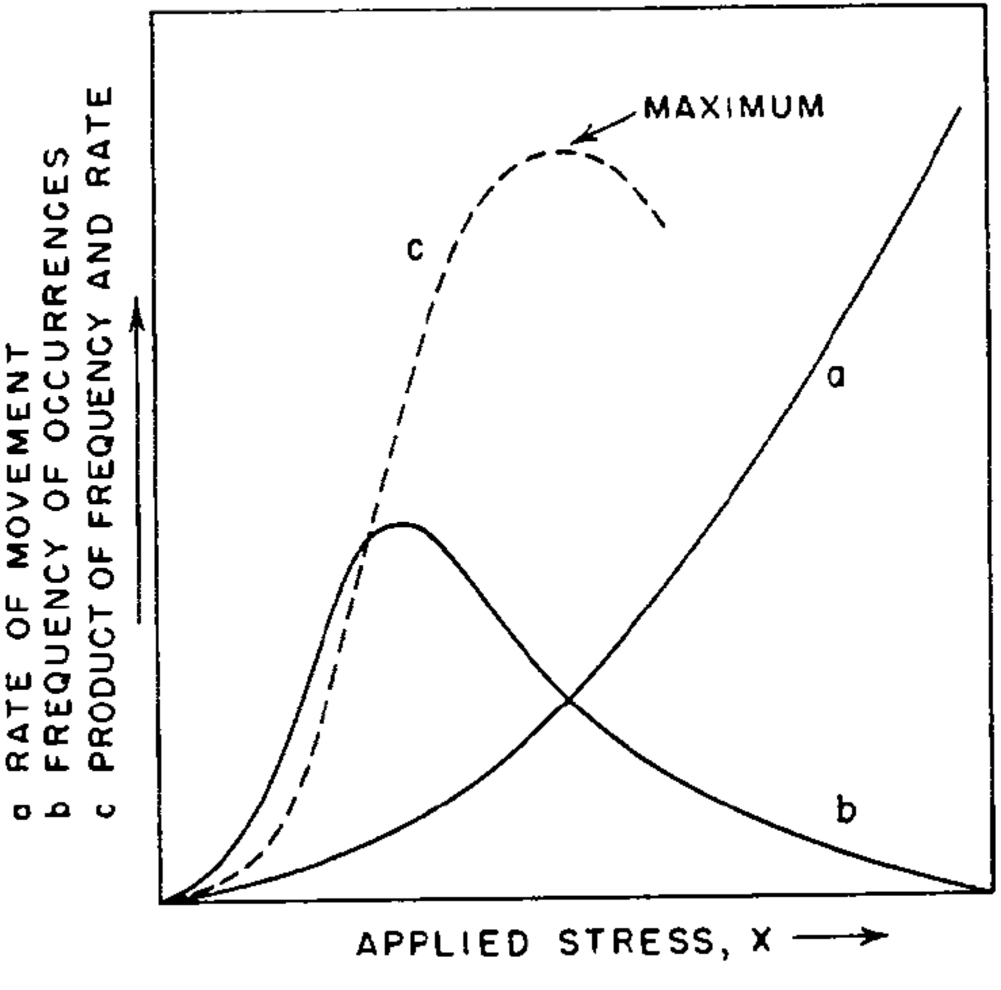
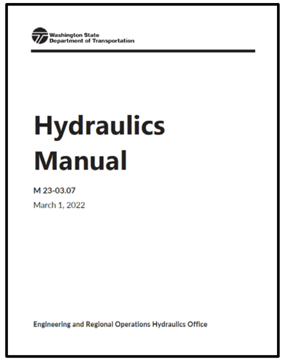


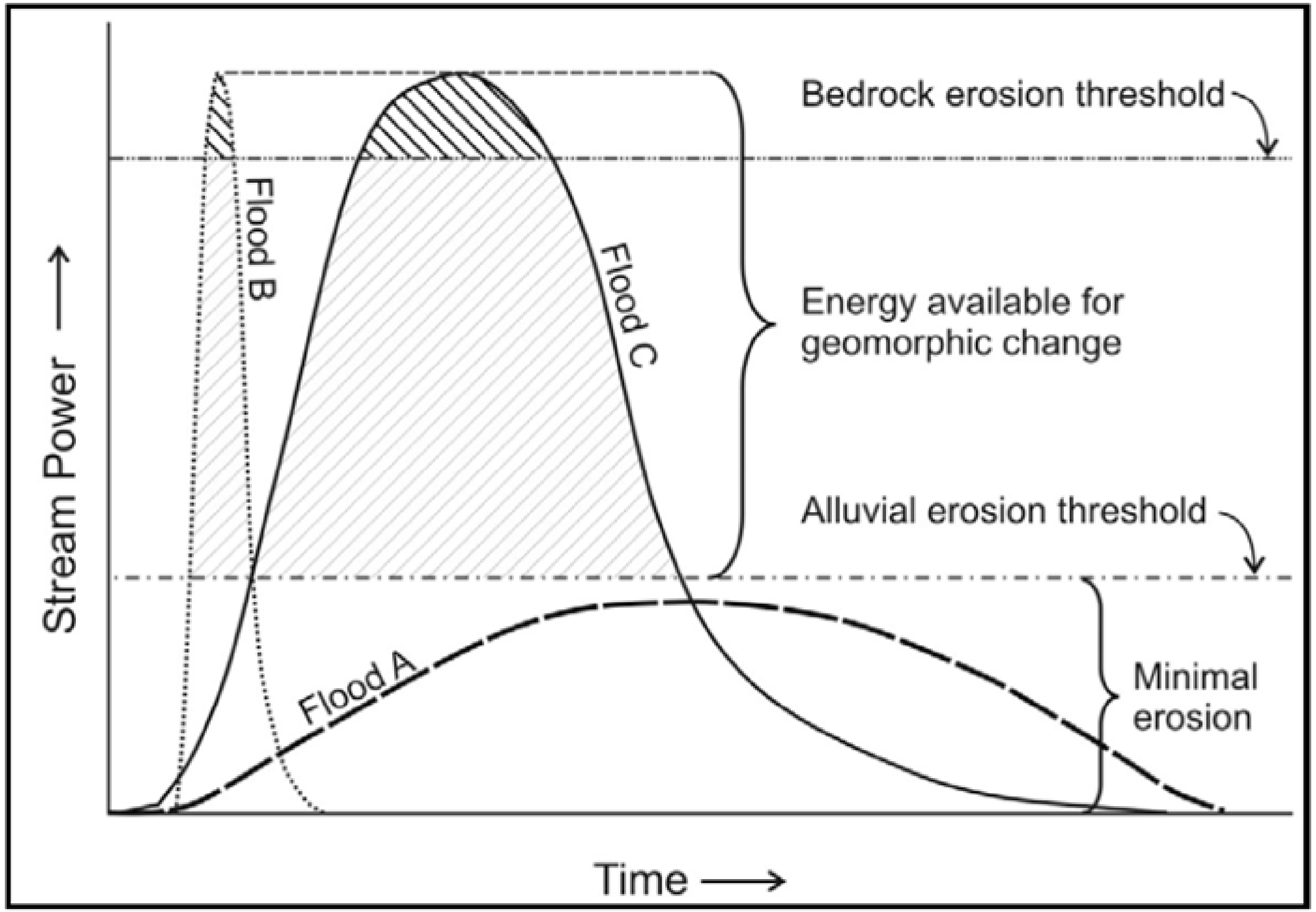
FIG. 1.—Relations between rate of transport, applied stress, and frequency of stress application.

Wolman and Miller 1959

Driving Forces: Hydrology

- Hydrology:
  - Hydraulics Manual Chapter 2
    - WSDOT Hydraulics Training Website
  - Data Availability
  - Bankfull Flow
    - Varies by region (Castro and Jackson, 2001)
      - Western WA: 1.2 year
      - Eastern WA: 1.4 to 1.5 year
  - Recurrence Interval
  - Flow Duration Curve

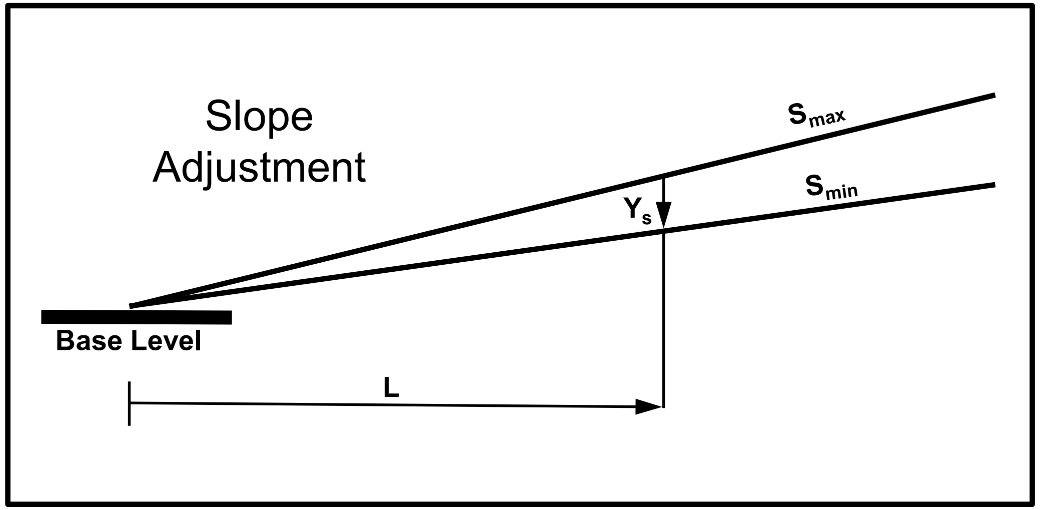


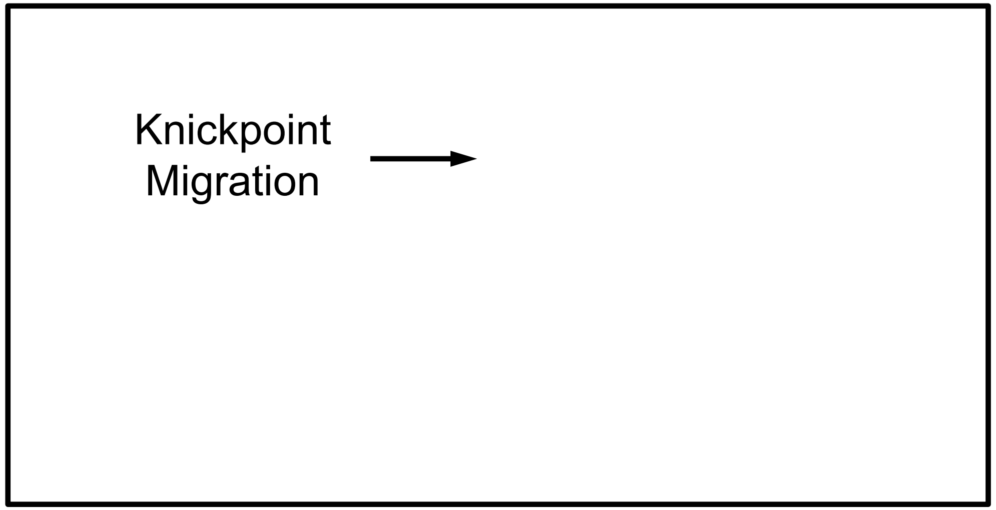


HEC 20 (2012)

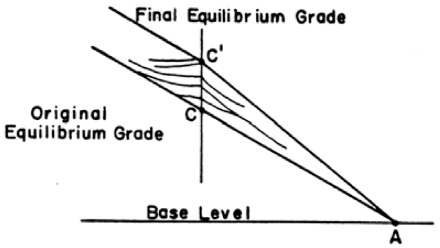
Driving Forces: Vertical Incision

- Slope Adjustment Relative to Base Level
  - Aggradation – Degradation
  - Sediment Supply and Transport Capacity
- Knickpoint Migration
  - Maintain vertical offset while propagating upstream

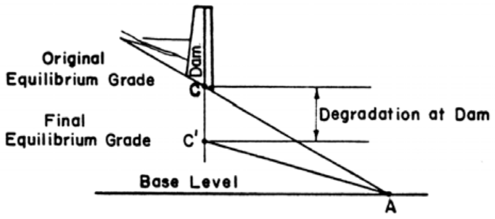


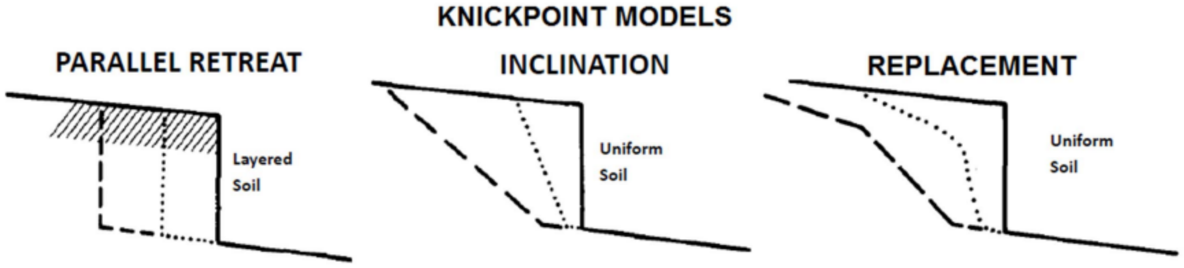


Aggradation

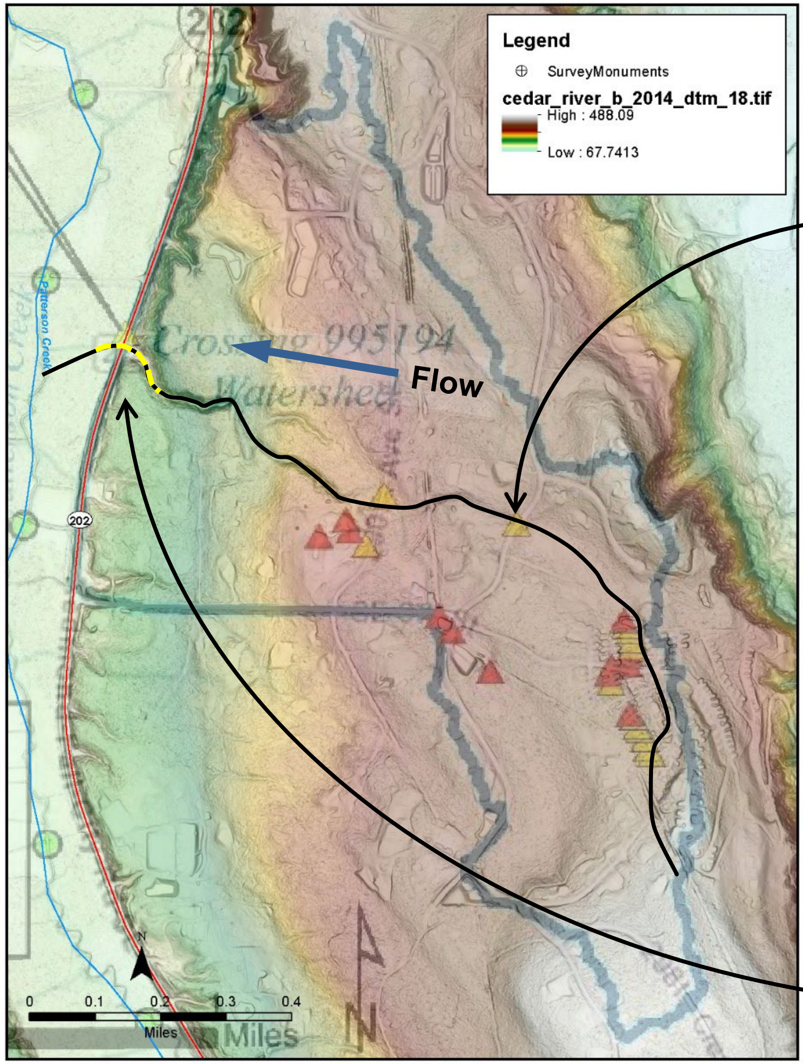


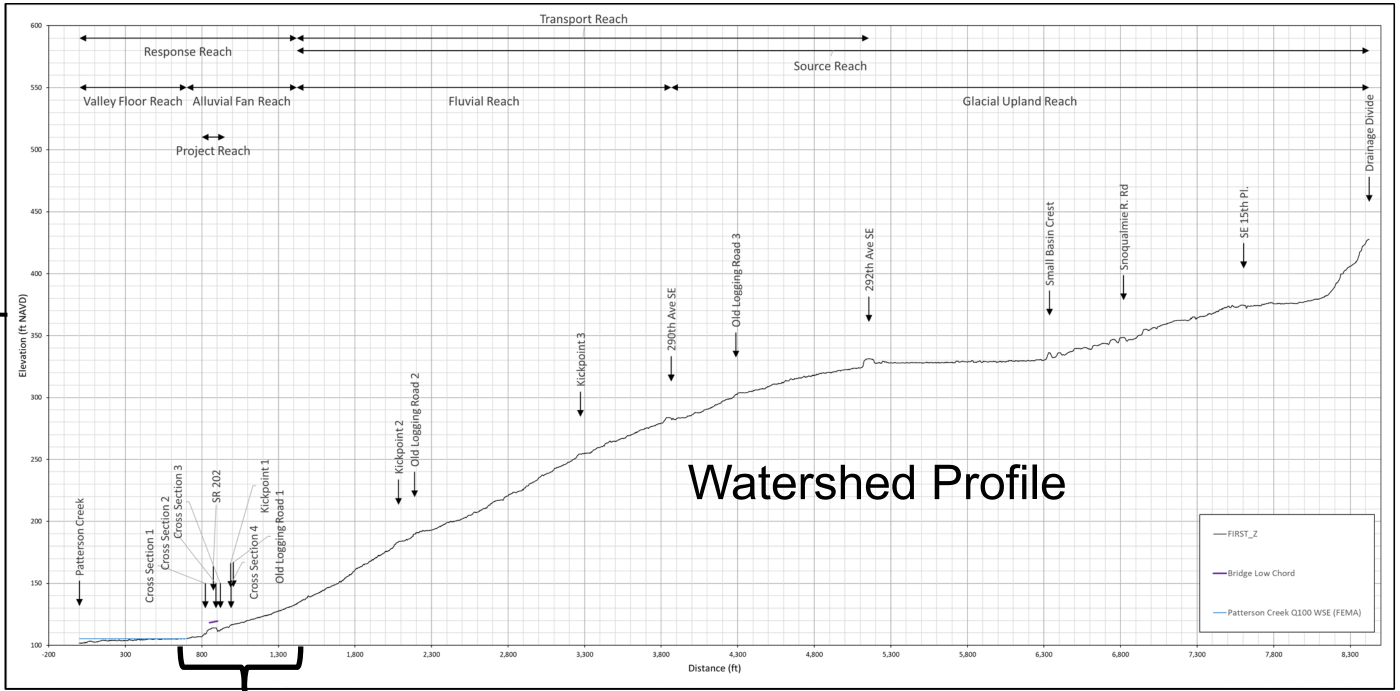
Degradation

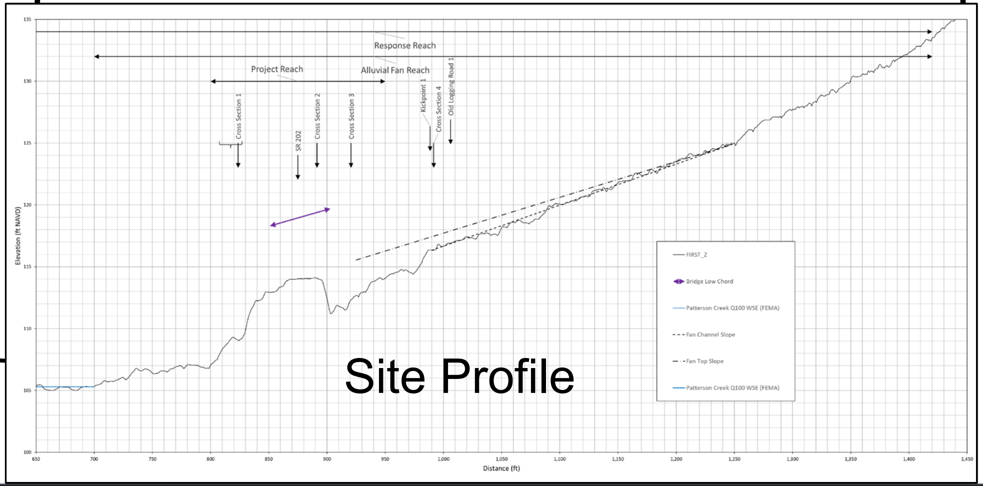




Driving Forces: Watershed Scale Processes

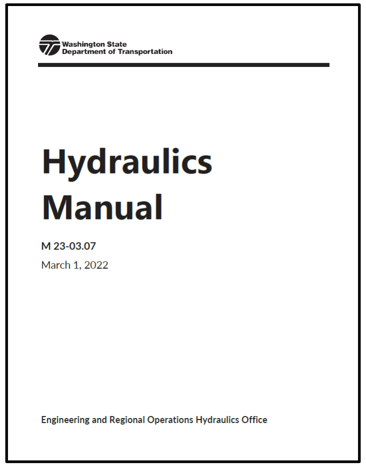






Driving Forces: Hydraulics

- Hydraulics
  - Boundary Shear Stress and Applied Stream Power
  - Fish Passage Module 6: Modeling with SRH-2D
    - by Ryan Barkie (Video)
  - Hydraulics Manual Chapter 7
  - SRH-2D
    - Aquaveo
    - FHWA webinars
    - WSDOT 2D user's forum
    - FHWA Two-Dimensional Hydraulic Modeling for Highways in the River Environment

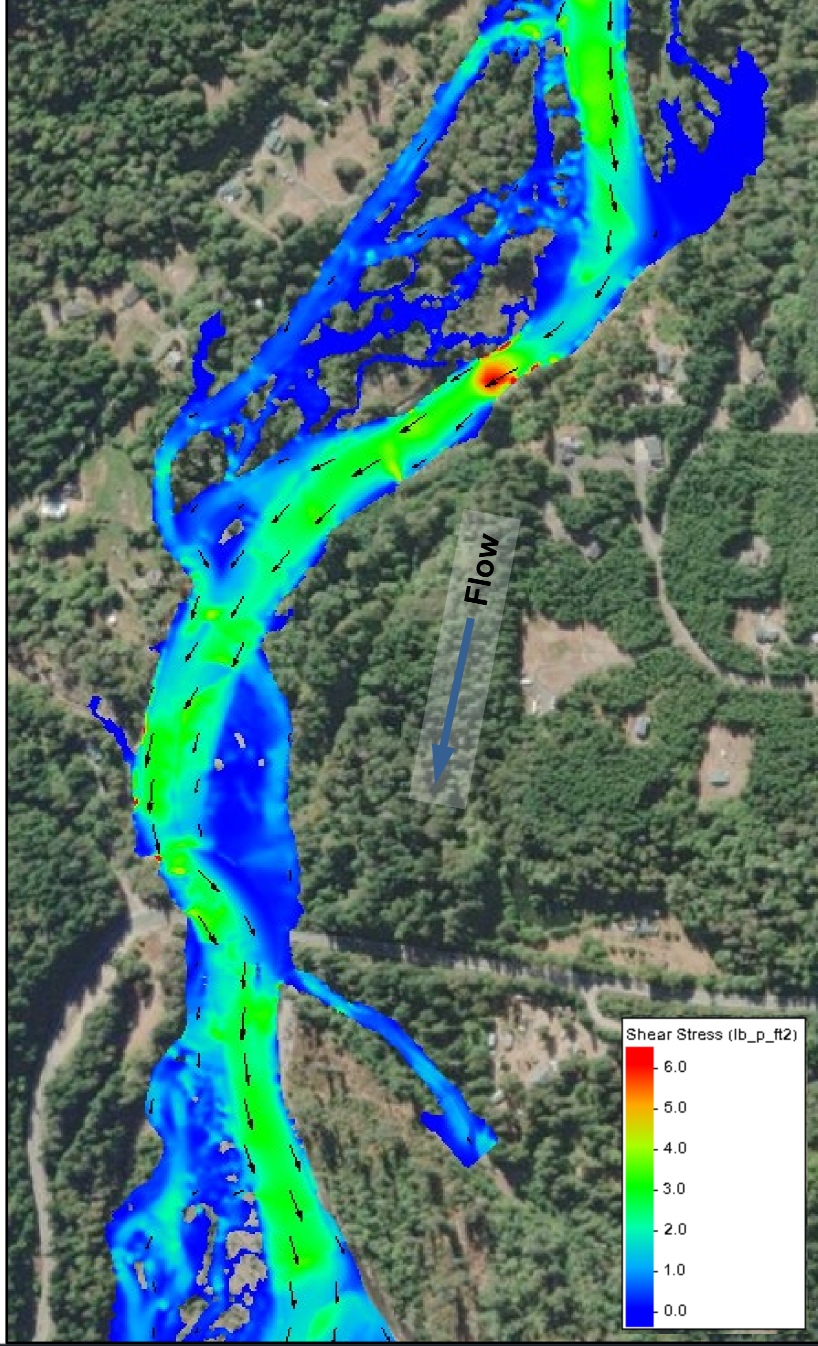

Washington State Department of Transportation

Hydraulics Manual

M 23-03.07

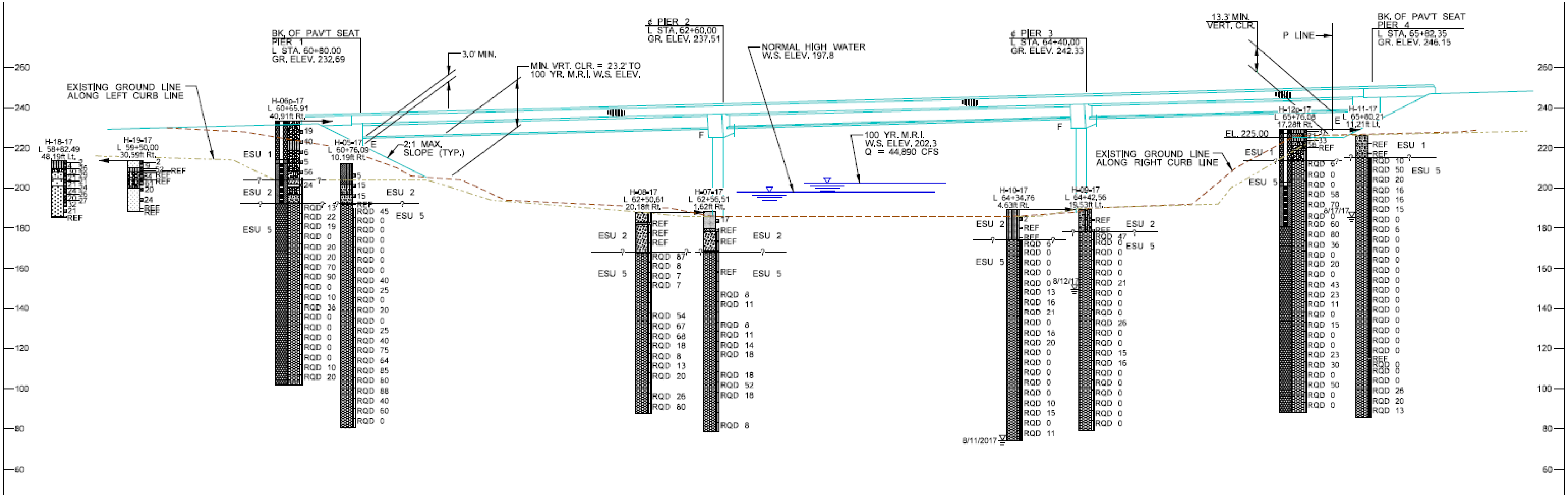
March 1, 2022

Engineering and Regional Operations Hydraulics Office



Resisting Forces

US 101 / Elwha River Bridge
Subsurface Profile

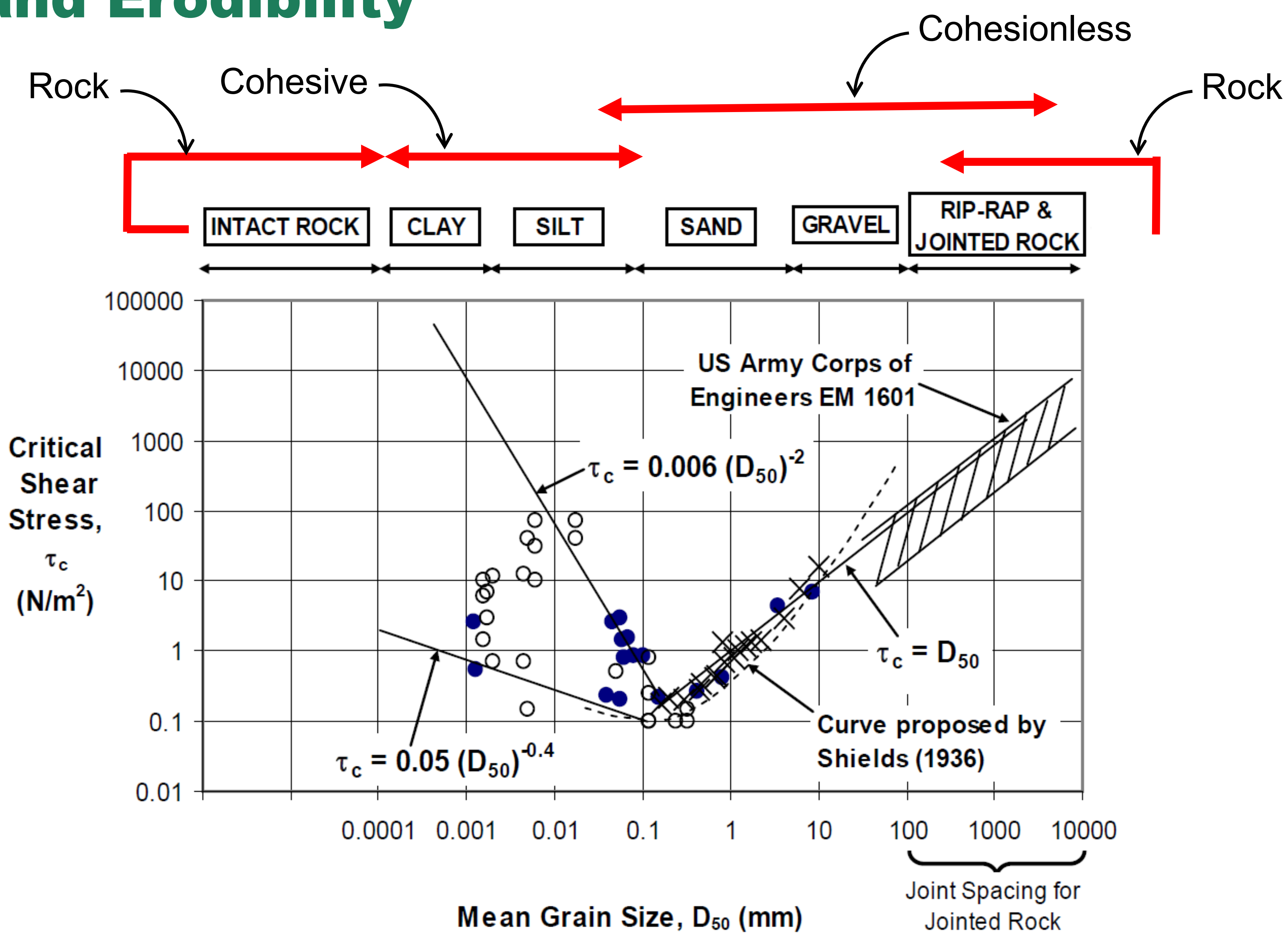


ESU 1 - Existing Fill: ESU 1 was observed in drilled borings H-6p-17, H-13-17, and H-14p-17, H-15-17, H-16p-17, and H-17p-17 from the current ground surface to a depth of 6 to 47 feet below the ground surface. ESU 1 is characterized primarily as very loose to medium dense well graded gravel with sand, well graded sand with gravel, silty sand with gravel, and silty gravel with sand.

ESU 2 - Delta Deposits: ESU 2 was observed in borings H-5-17, H-7-17, H-8-17, H-9-17, and H-10-17 from the existing ground surface or mudline in the river to a depth of 11 to 22 feet. ESU 2 was also observed in boring H-6p-17 below ESU 1 to a depth of 41 feet below the ground surface. ESU 2 is characterized primarily as very loose to medium dense well graded gravel with sand, poorly graded sand, and silty sand with gravel. Intermittent cobble and boulder sized particles are also present throughout ESU 2.

ESU 5 - Basalt Bedrock: ESU 5 was observed in all borings except H-17p17 below ESU 2, ESU 3, and ESU 4 to the final depth of the borings. ESU 5 is characterized primarily as very weak to moderately strong basalt rock.. Discontinuities are moderately spaced and in fair condition. Discontinuities are generally close to very widely spaced and in poor to good condition.

Grain Size and Erodibility



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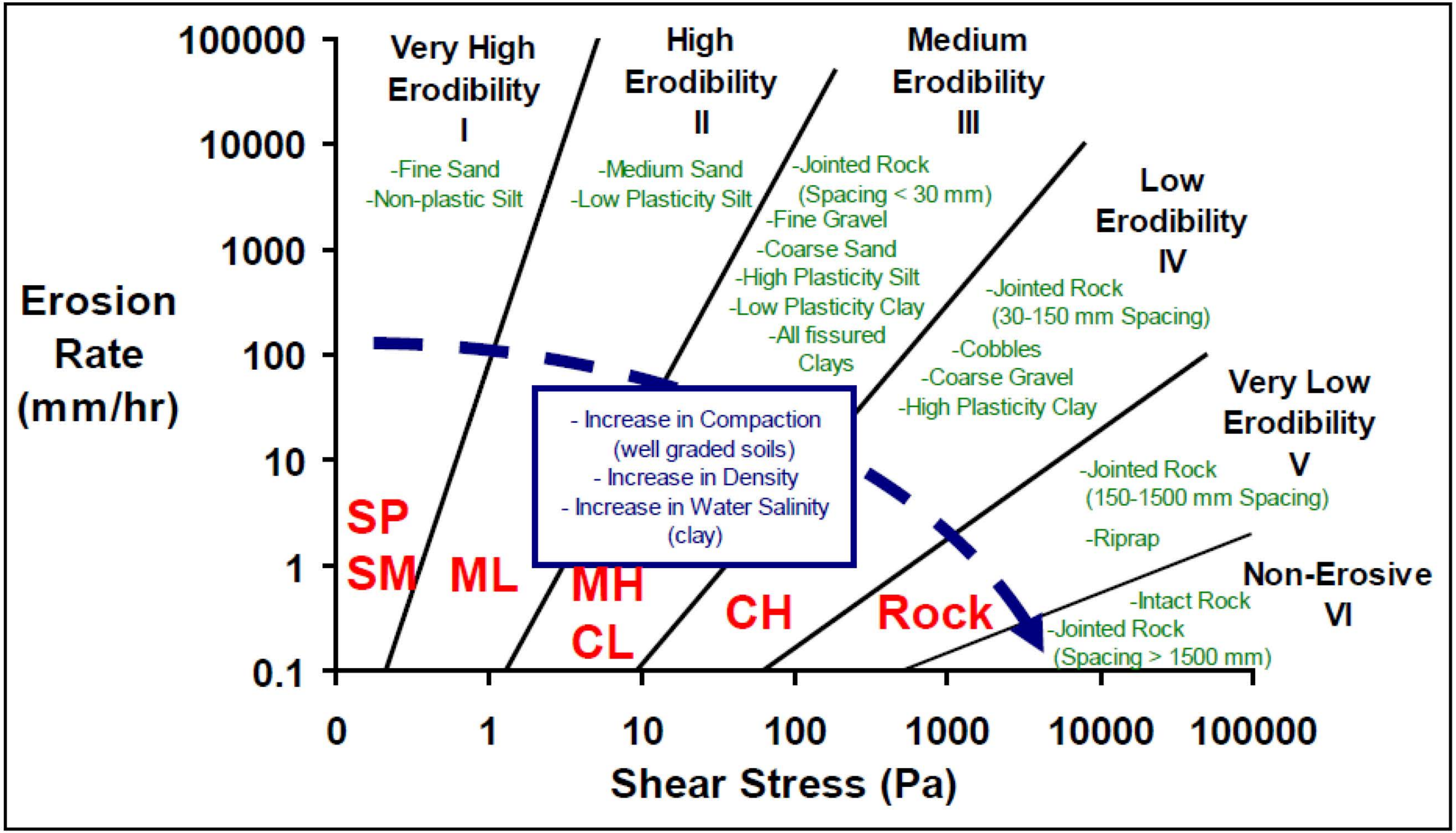
USCS Classification and Erodibility



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Scour in Rock – Erodibility Index

$$K = (M_s)(K_b)(K_d)(J_s)$$

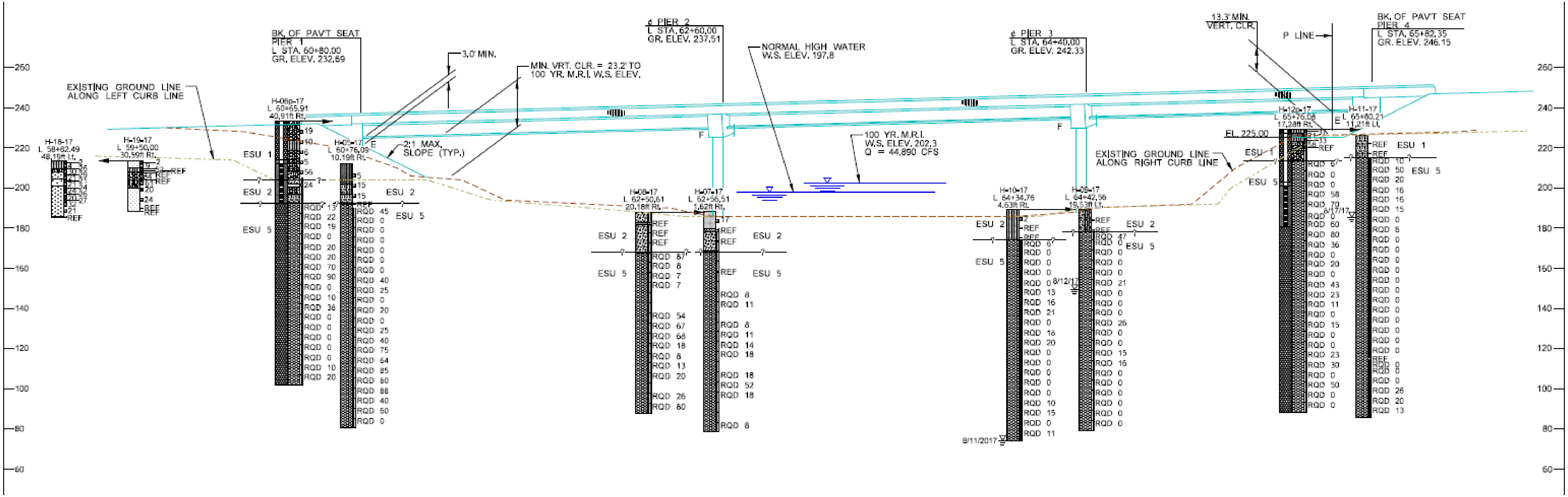
where:

K	=	Erodibility Index
M_s	=	Intact rock mass strength parameter
K_b	=	Block size parameter
K_d	=	Shear strength parameter
J_s	=	Relative orientation parameter

HEC 18 2012

Resisting Forces

US 101 / Elwha River Bridge
Subsurface Profile



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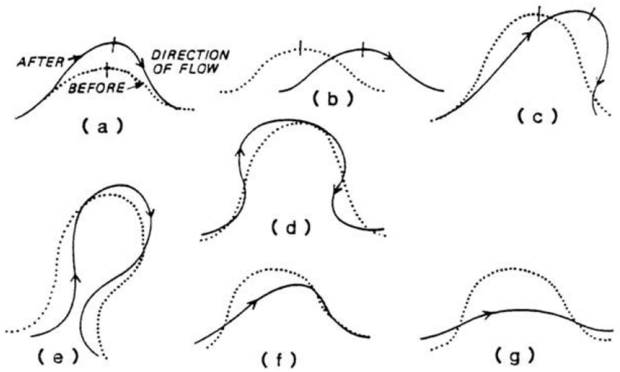
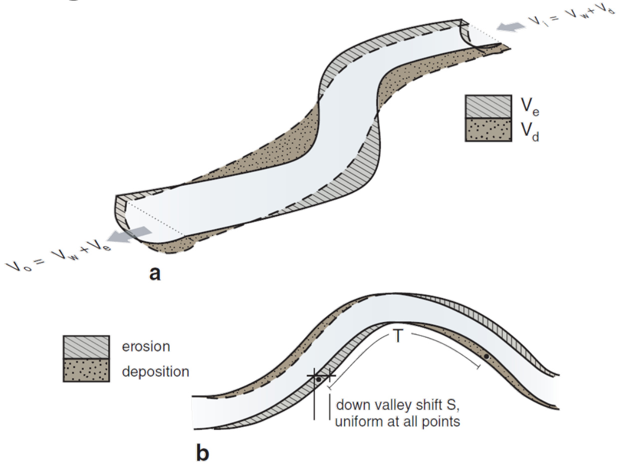
CMZ versus Lateral Migration

Lateral Migration



Brice 1977



Church 2006

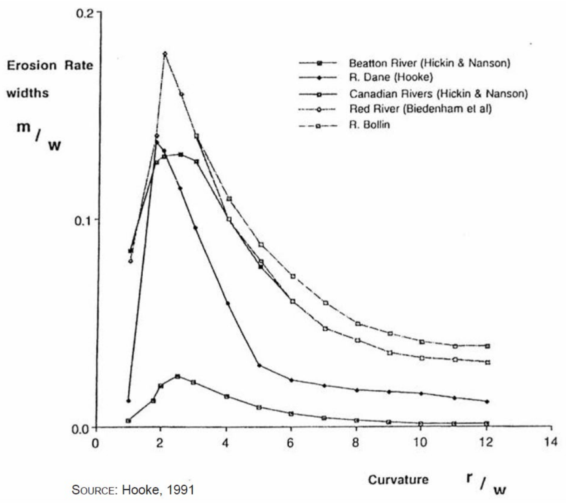
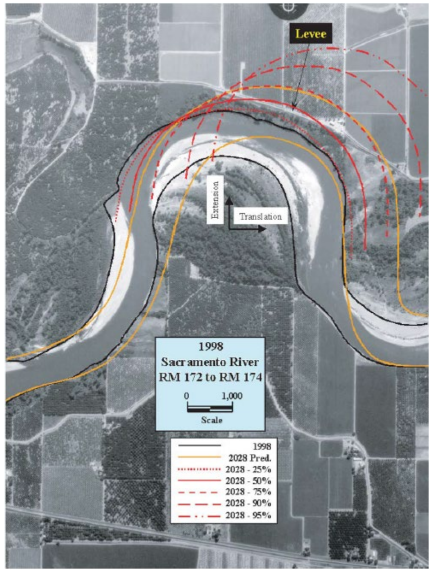


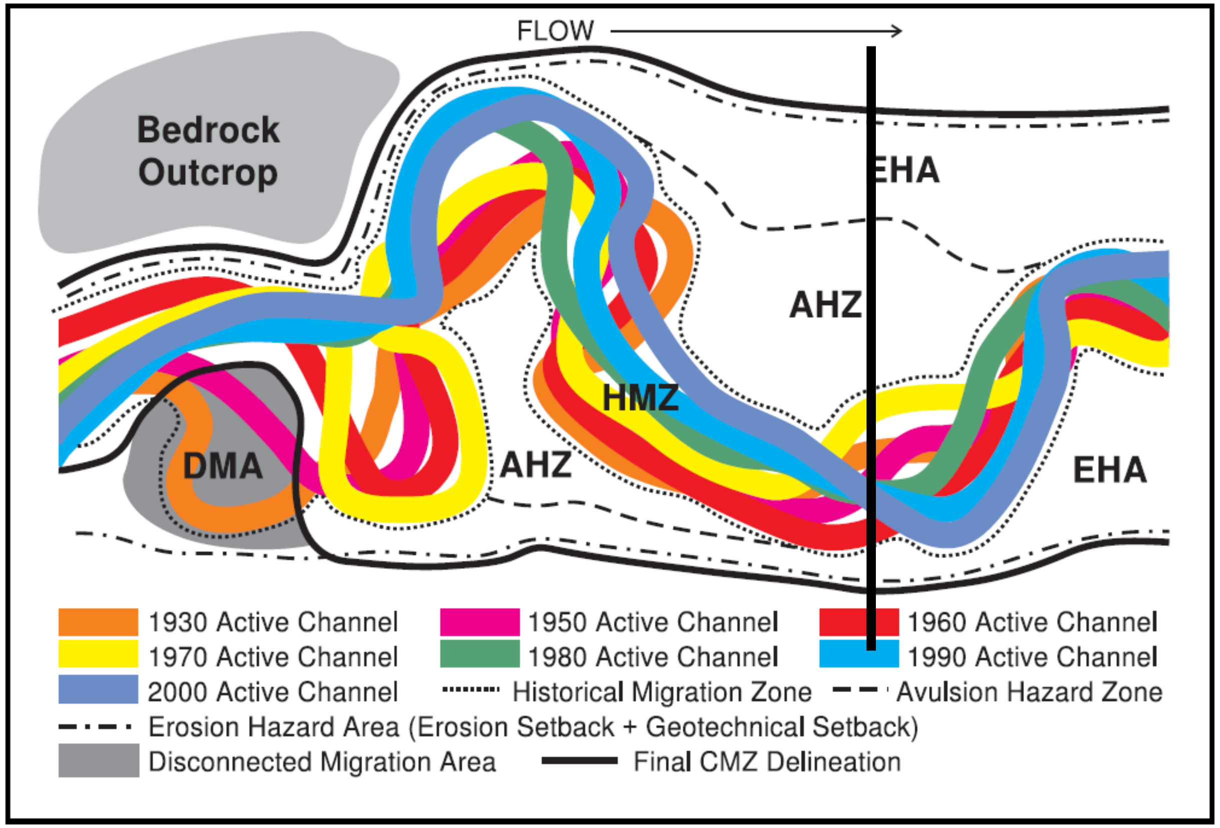
Figure 2.4. Relationship between erosion (migration) rate and bend curvature.

Hickin and Nanson 1975



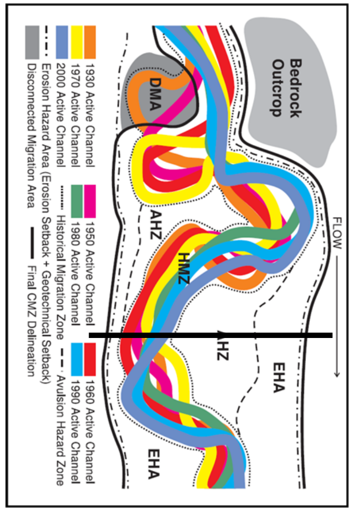
NCHRP 2004

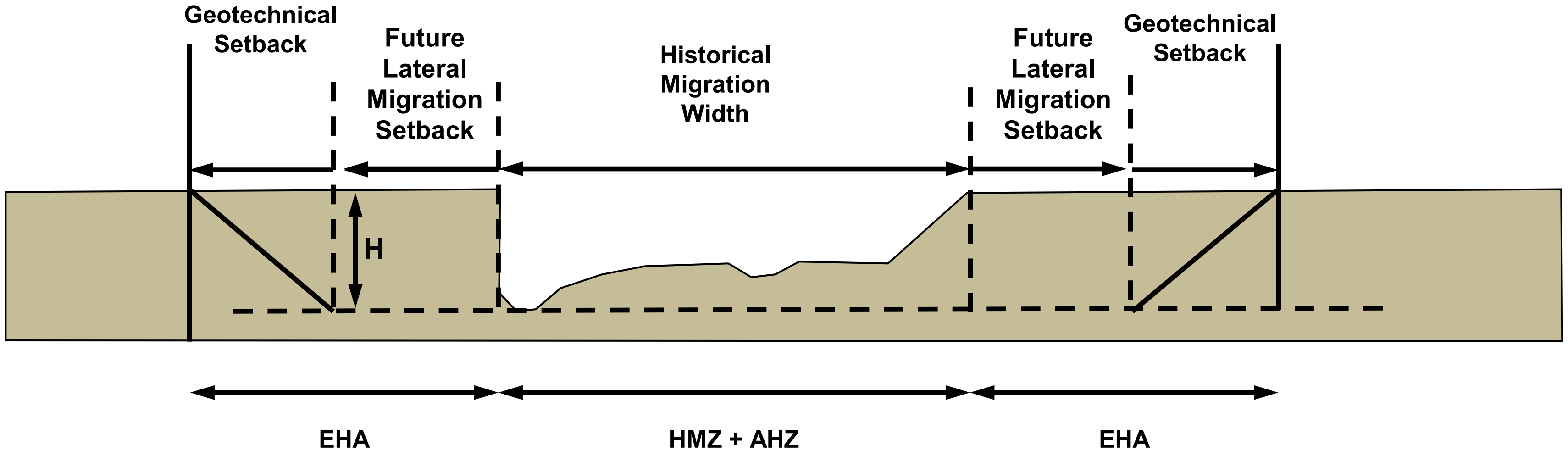
Channel Hazard Migration Zone



Rapp and Abbe 2003

CMZ Lateral Migration Framework



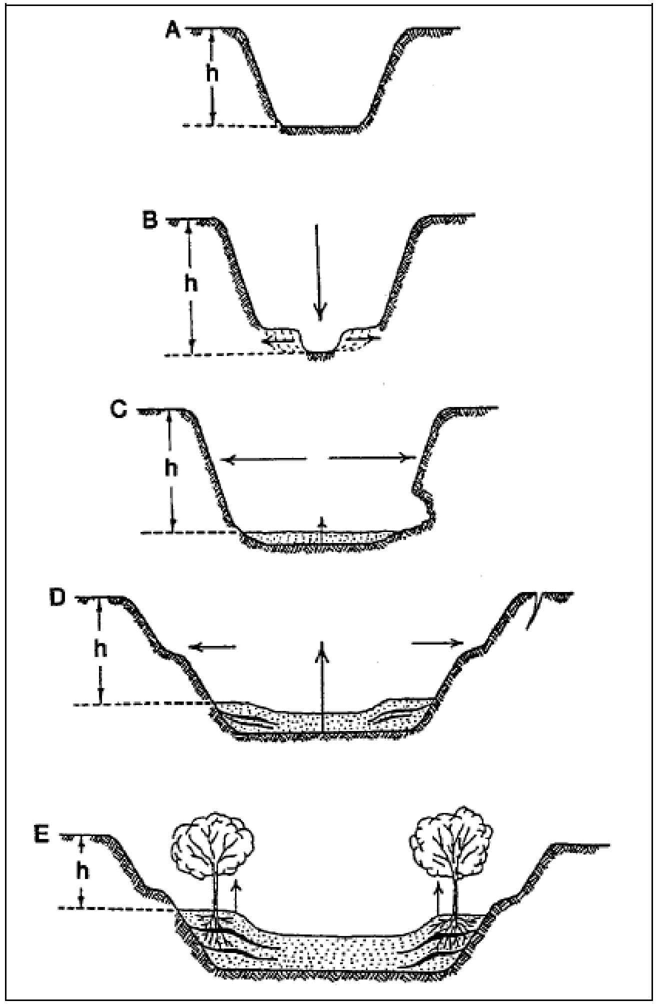


EHA = Erosion Hazard Area
HMZ = Historic Migration Zone
AHZ = Avulsion Hazard Zone

Alluvial material

Lateral Migration Within Structure

Vertical Incision can result in channel widening



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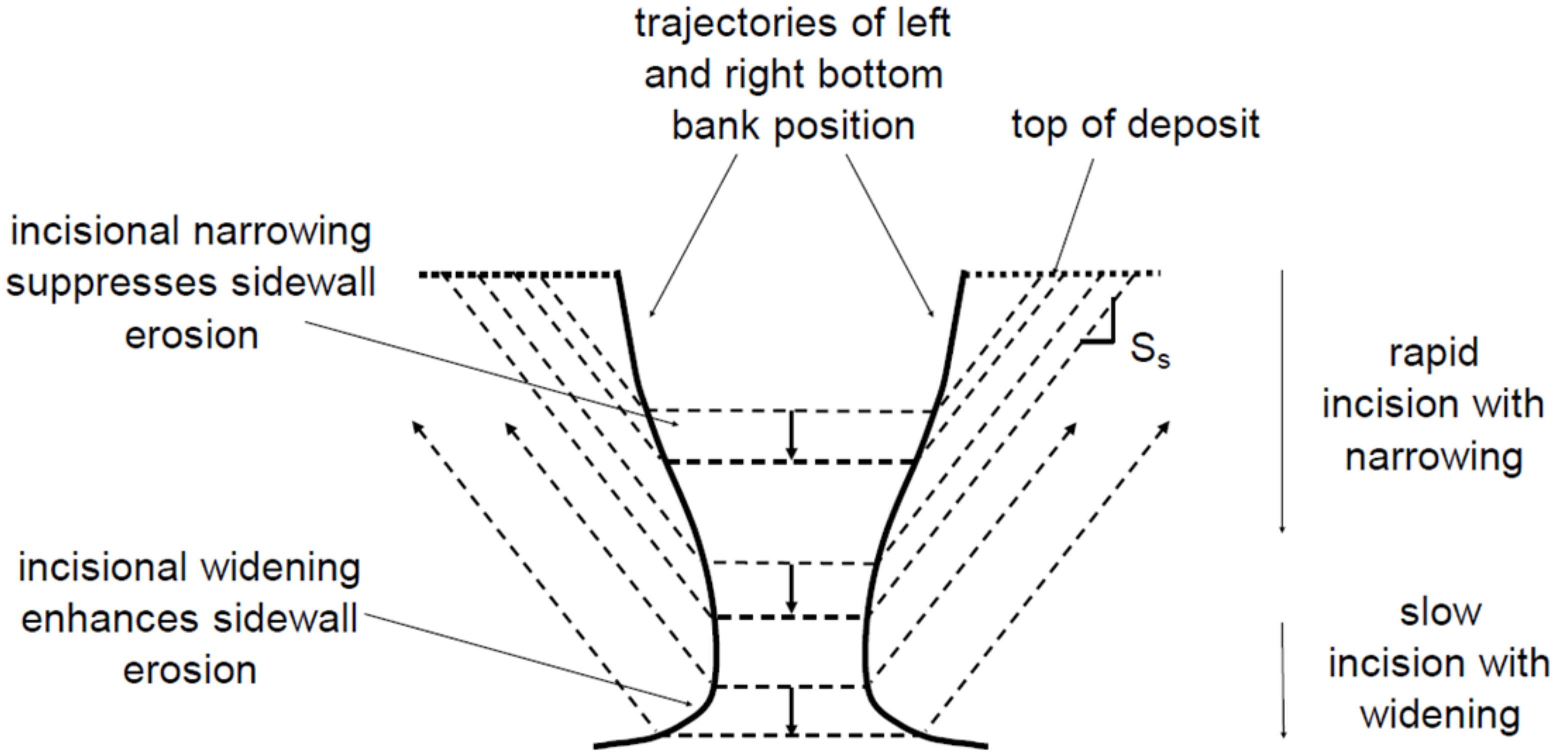
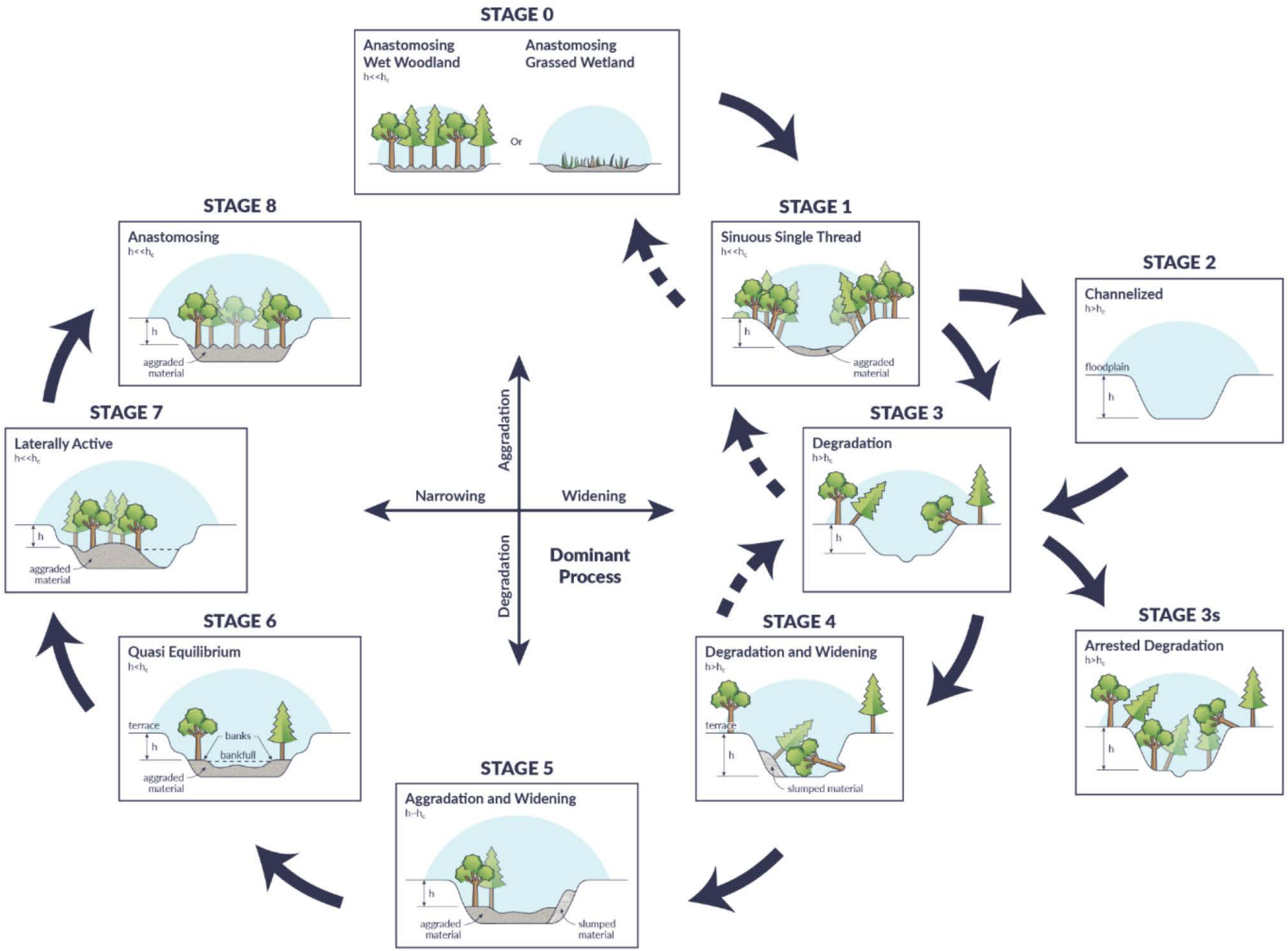


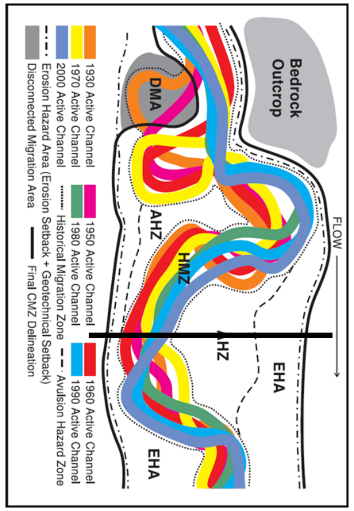
Parker ebook

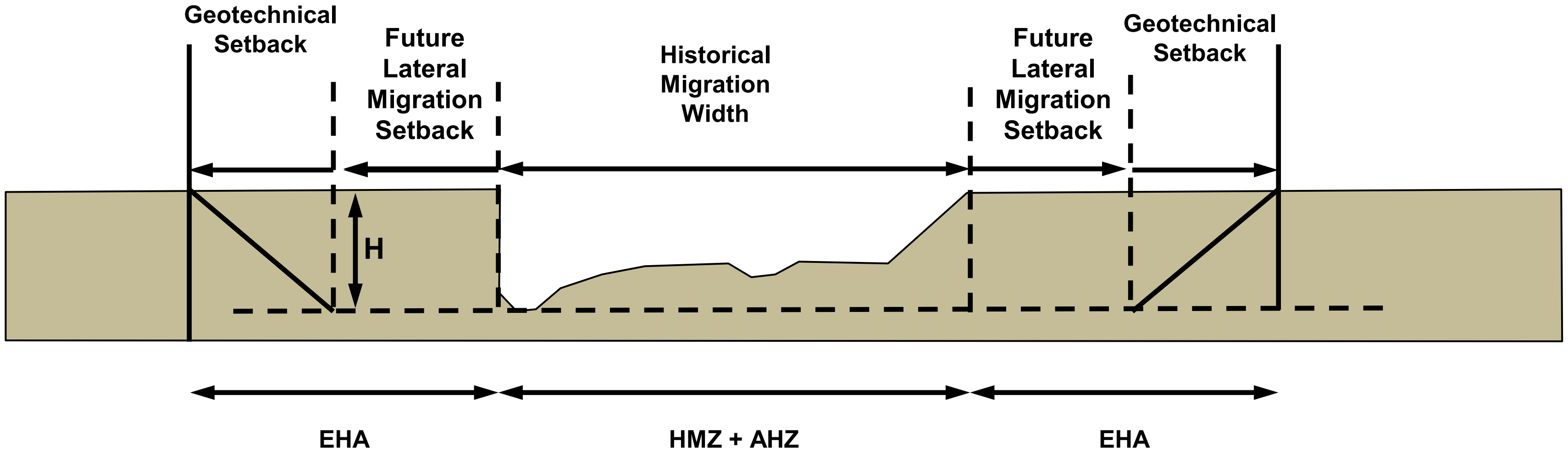
Stream Evolution Models



Cluer and Thorne 2014

CMZ Lateral Migration Model





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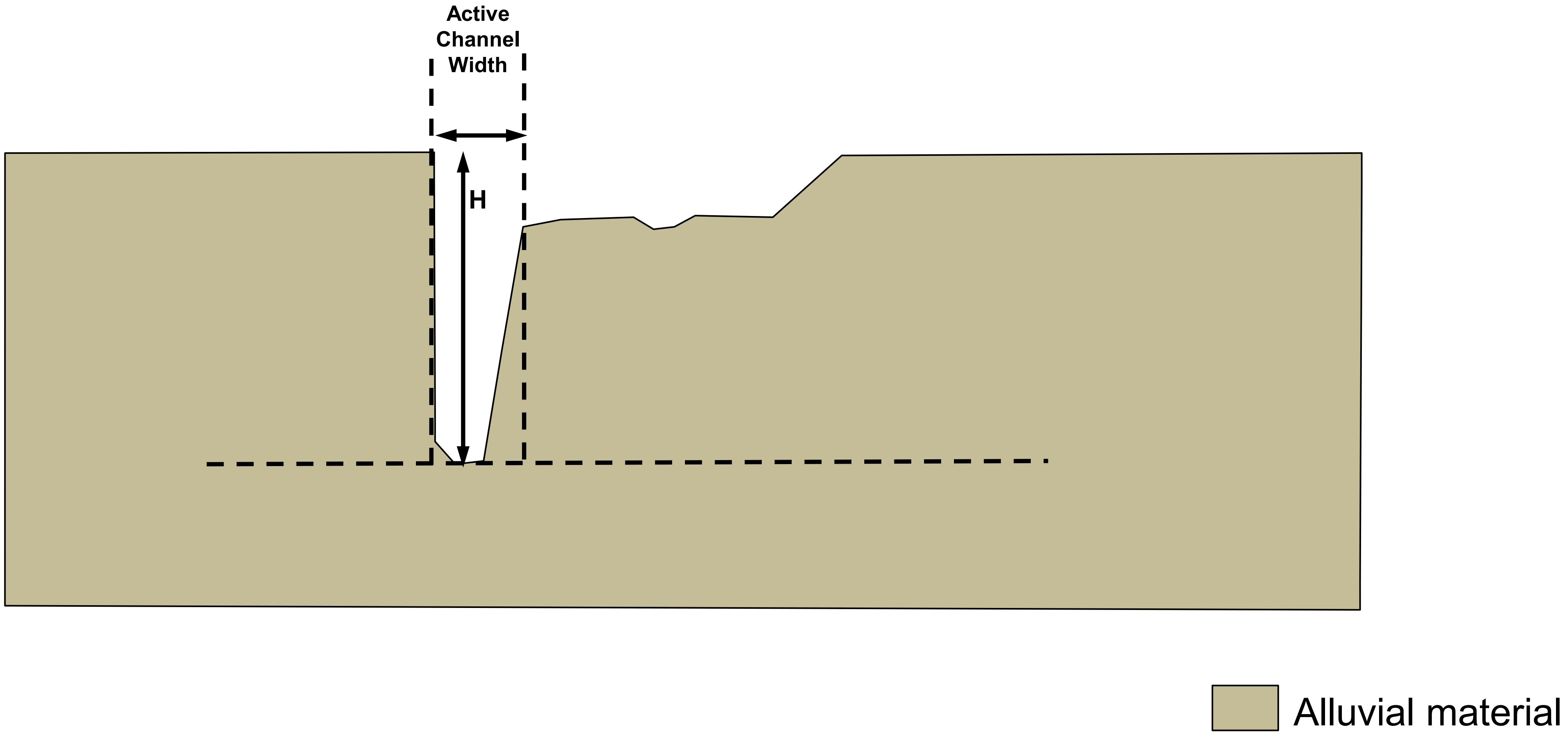
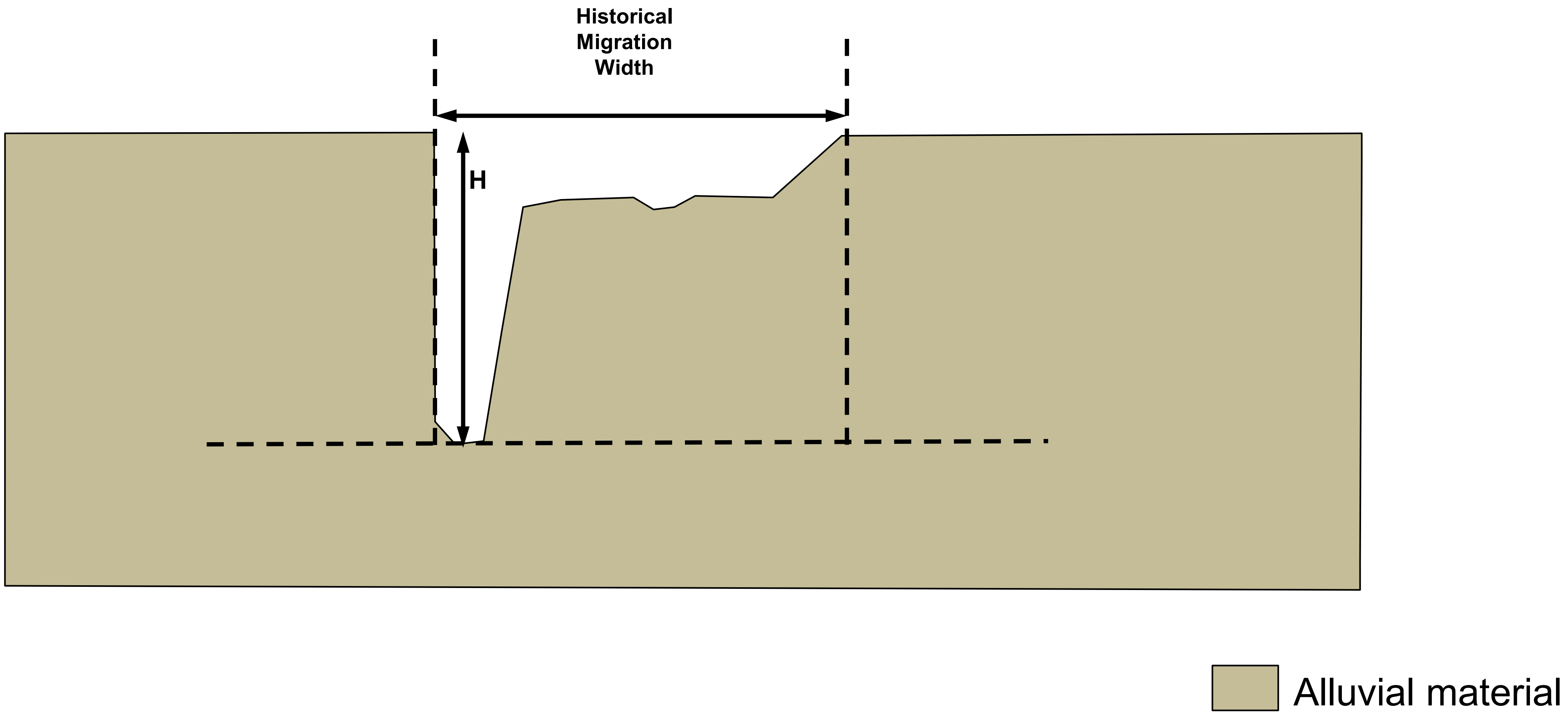
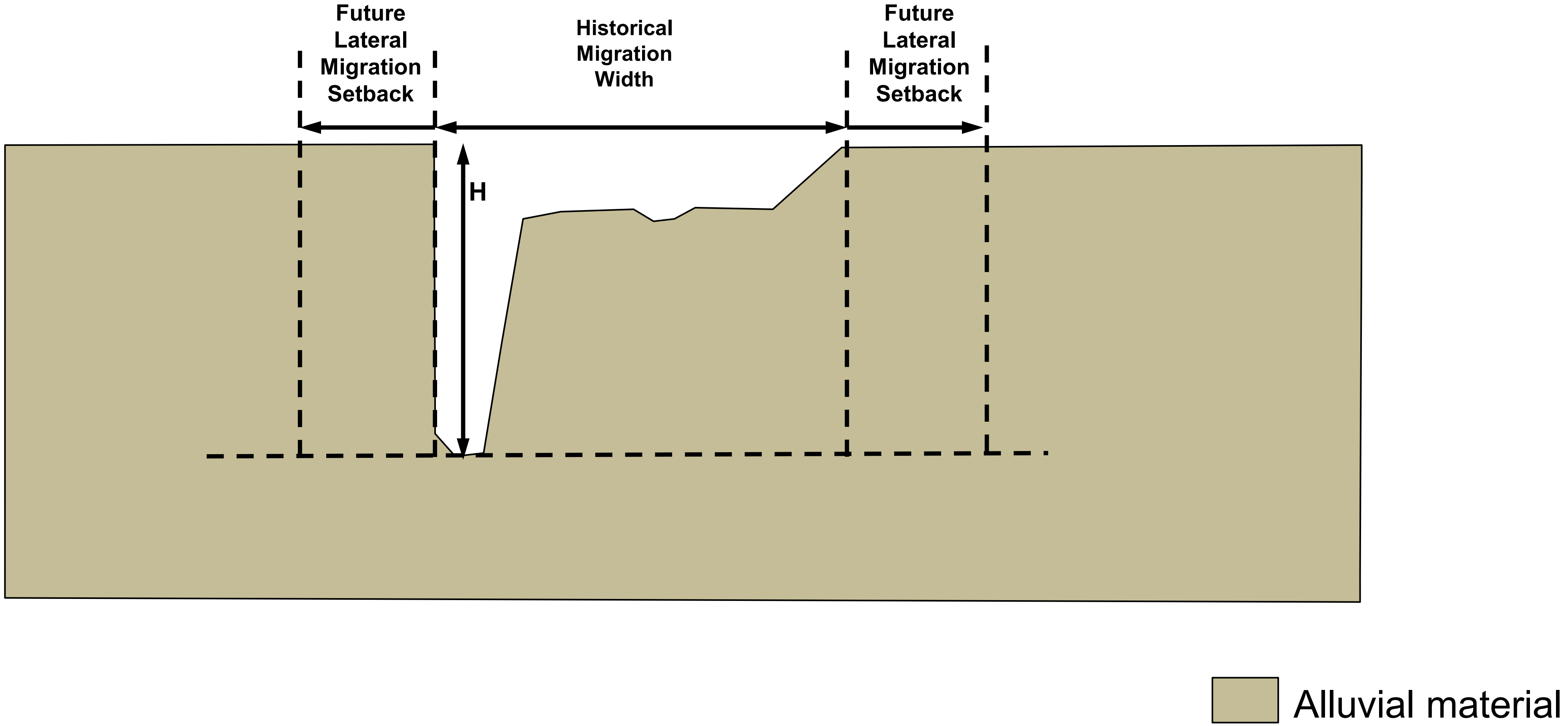
Vertical Incision



Vertical Incision Plus Historical Migration Zone



Vertical Incision Plus Historical Migration Zone Plus Future Lateral Migration



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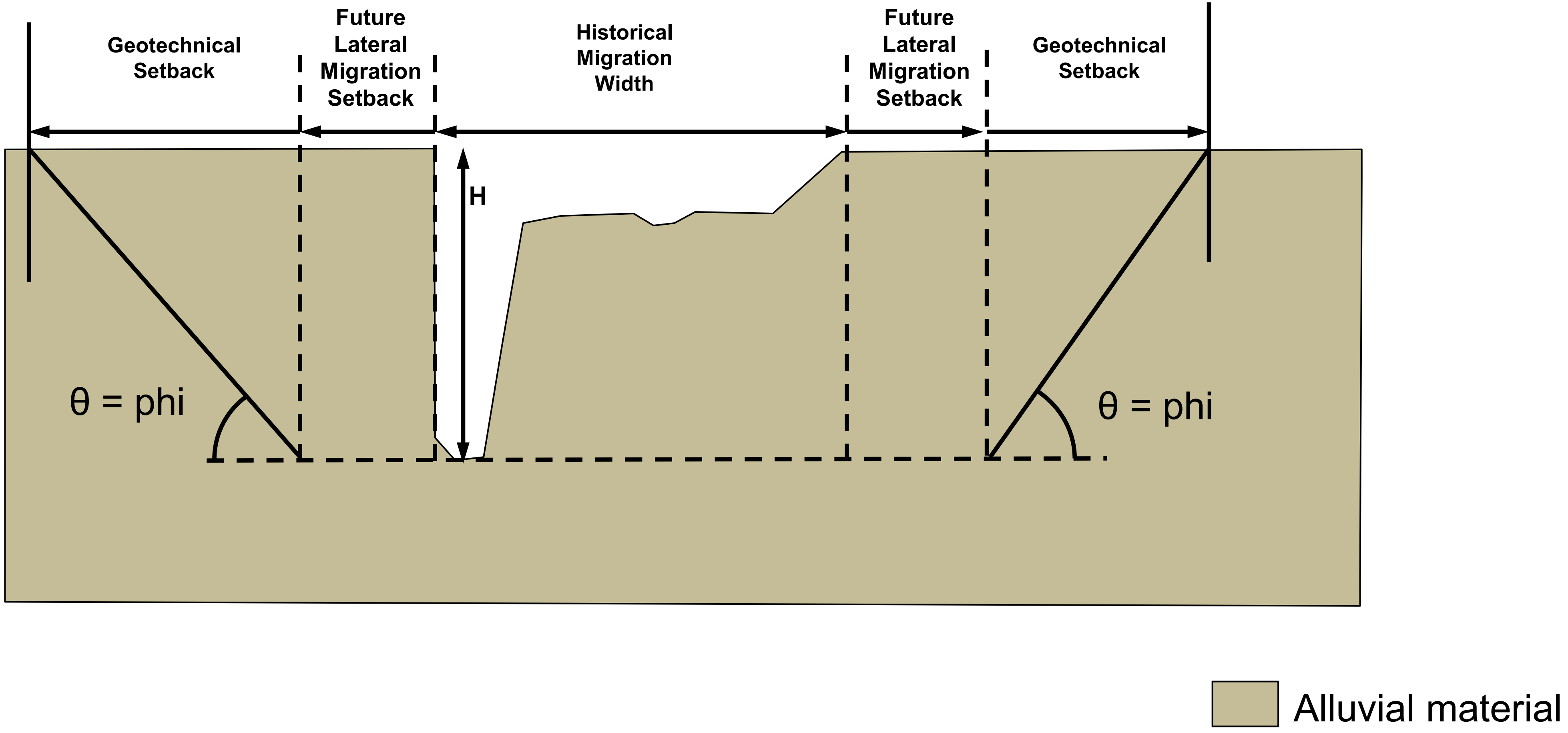

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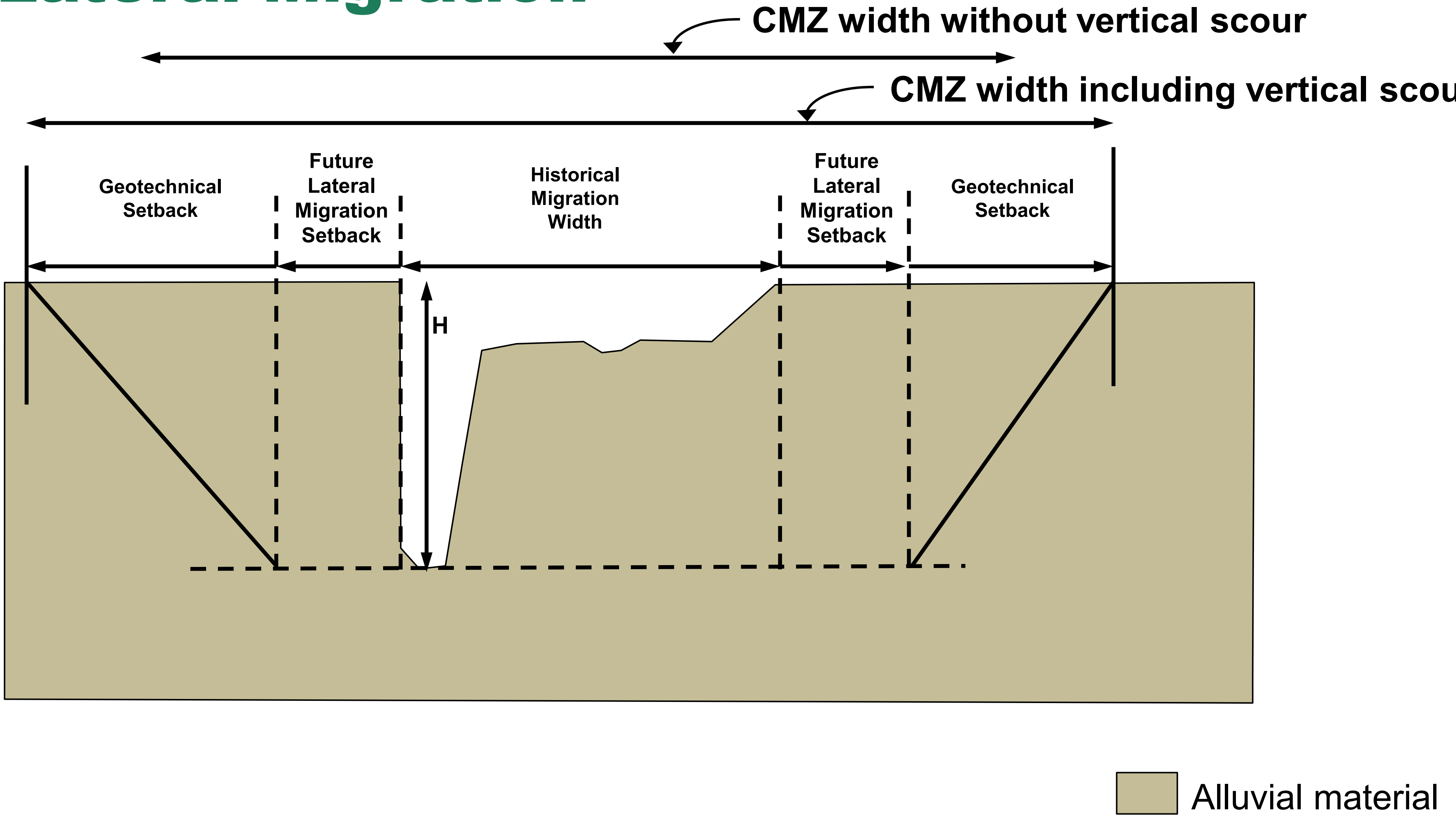
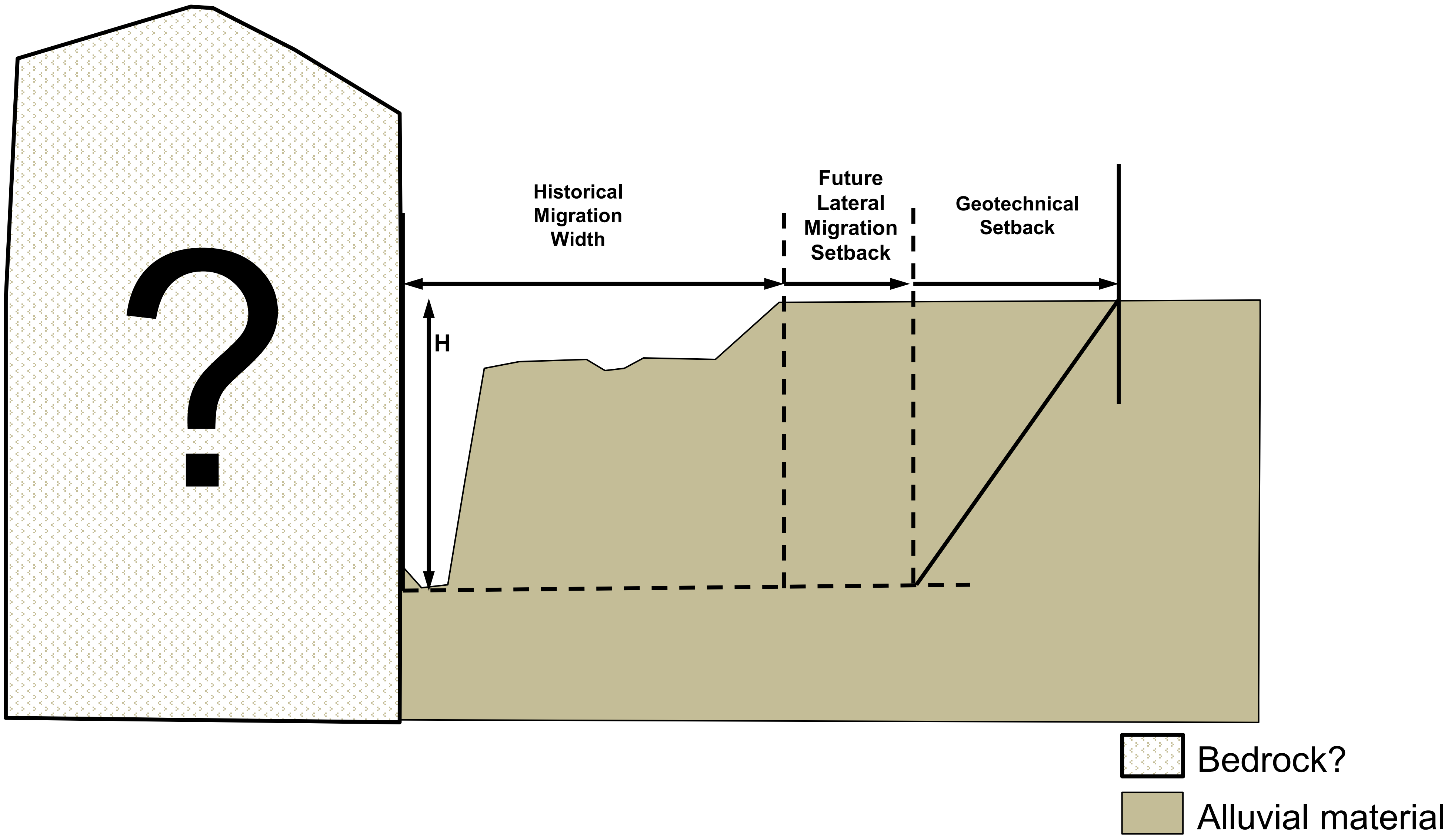


Vertical Incision plus Bedrock?



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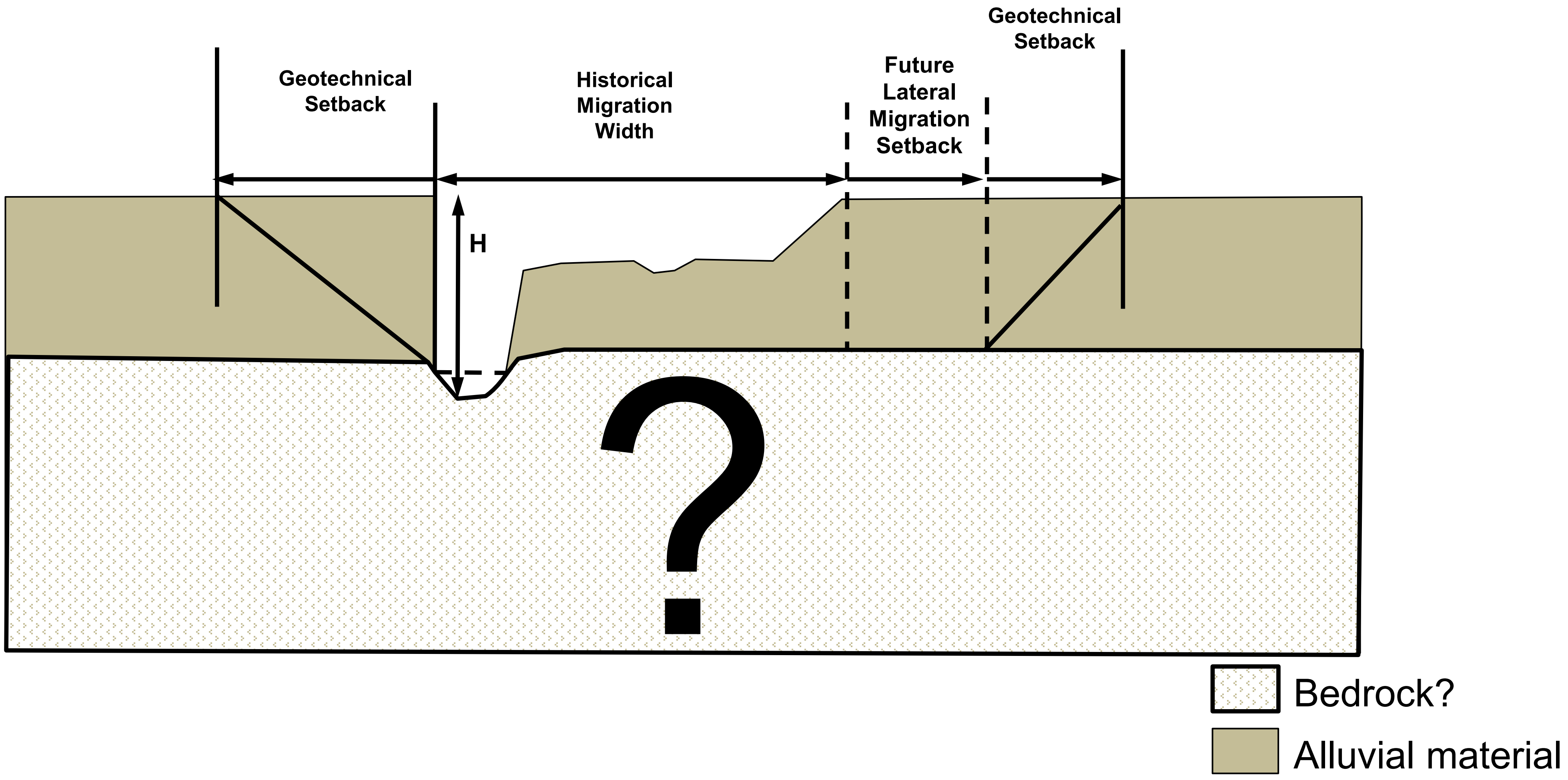

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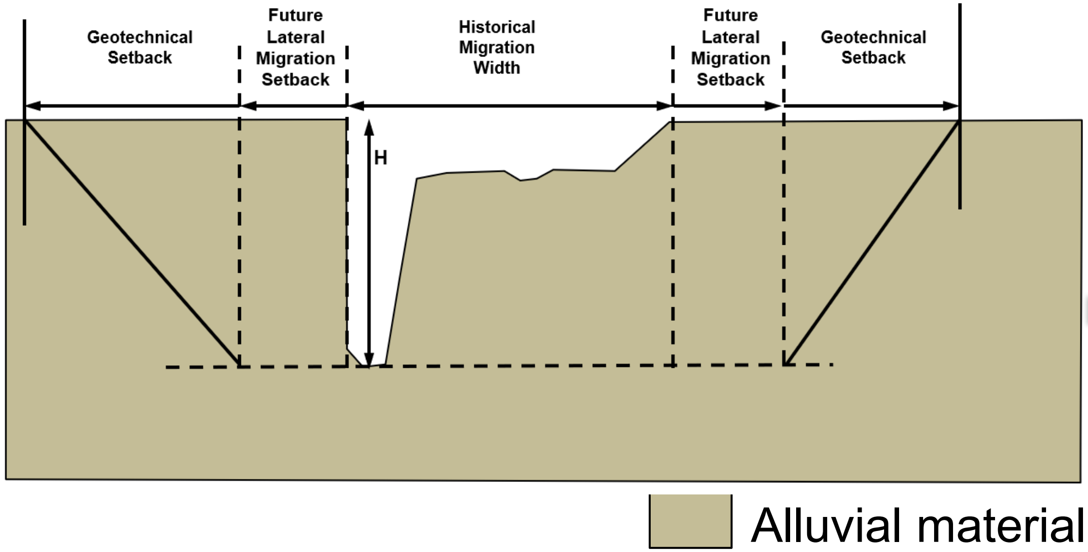
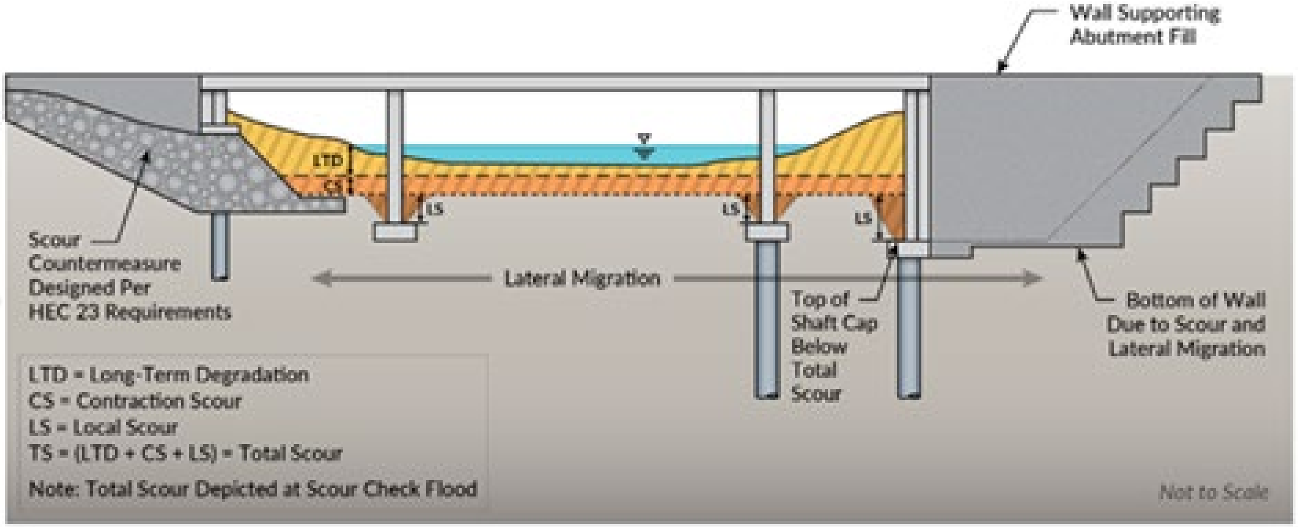


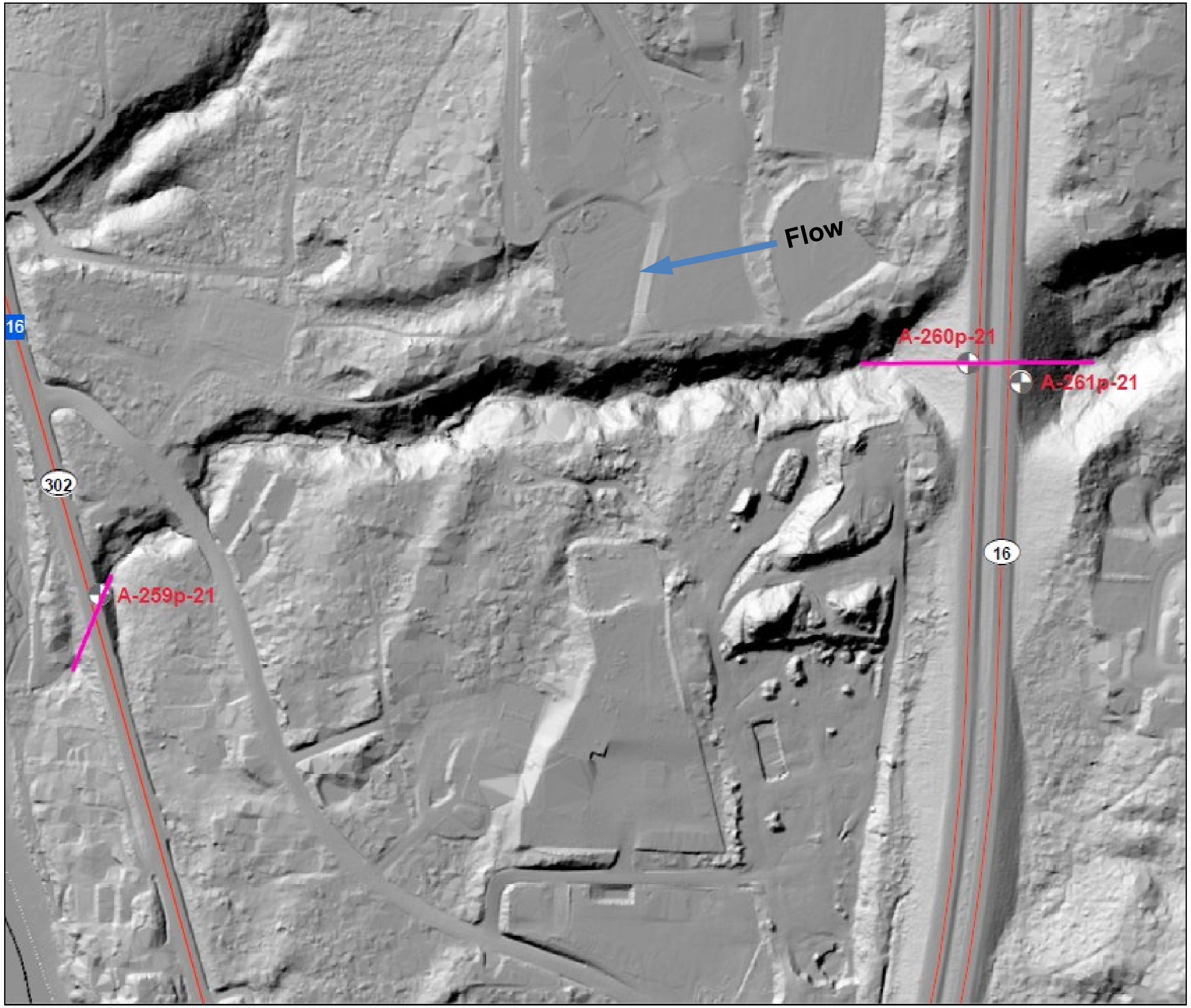


Subsurface Characterization

- Review Geologic Maps and Literature
- Incorporate Subsurface Data
- Develop Geologic Interpretation
- Develop Long Stream Profile

<u>Example:</u>

Goodnough Creek (SR 16 & SR 302)



Geologic Mapping and Literature

Geologic Units 24k

Holocene

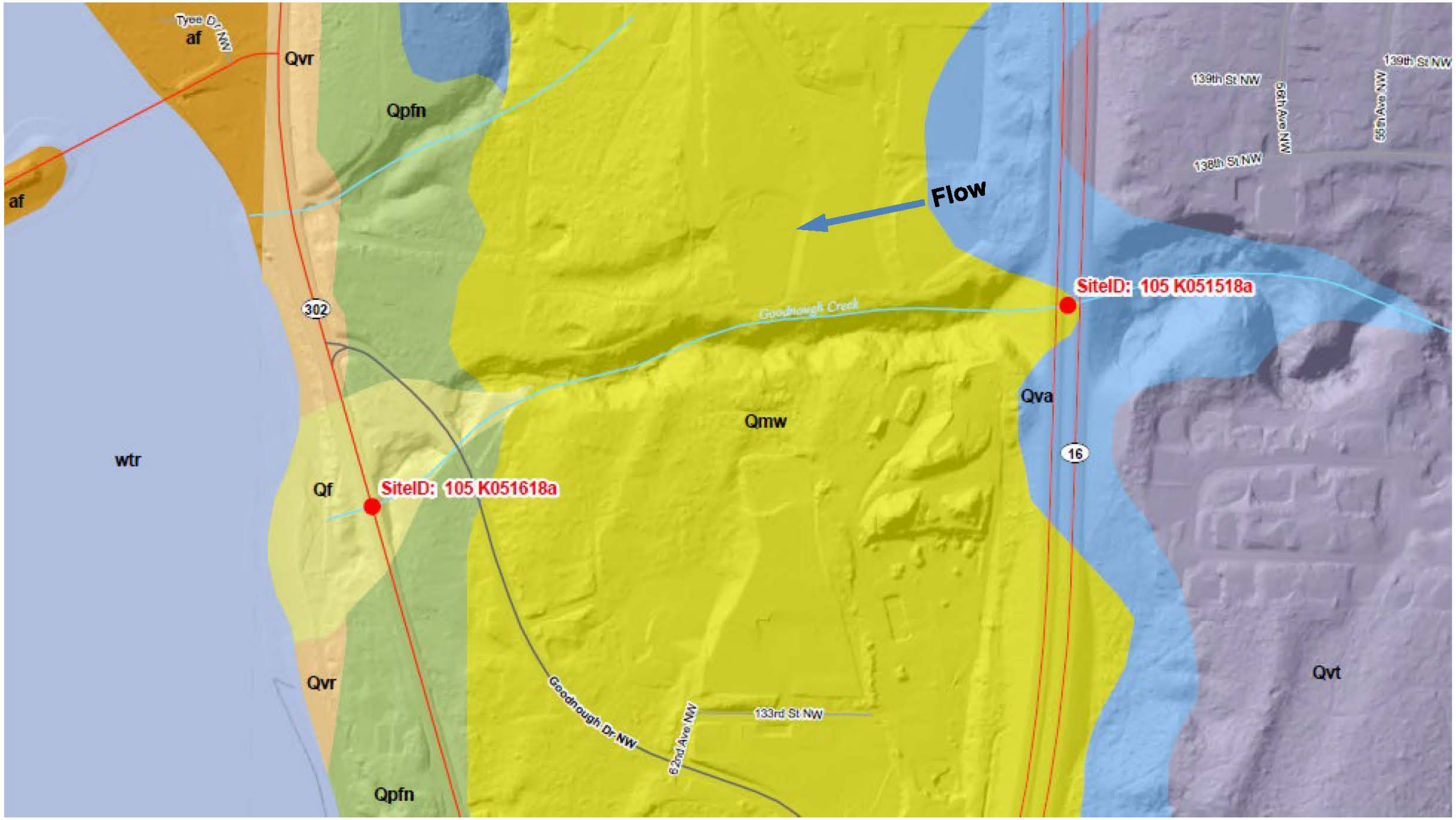
- af - Artificial fill
- Qmw - Mass-wastage deposits
- Qf - Fan deposits

Pleistocene

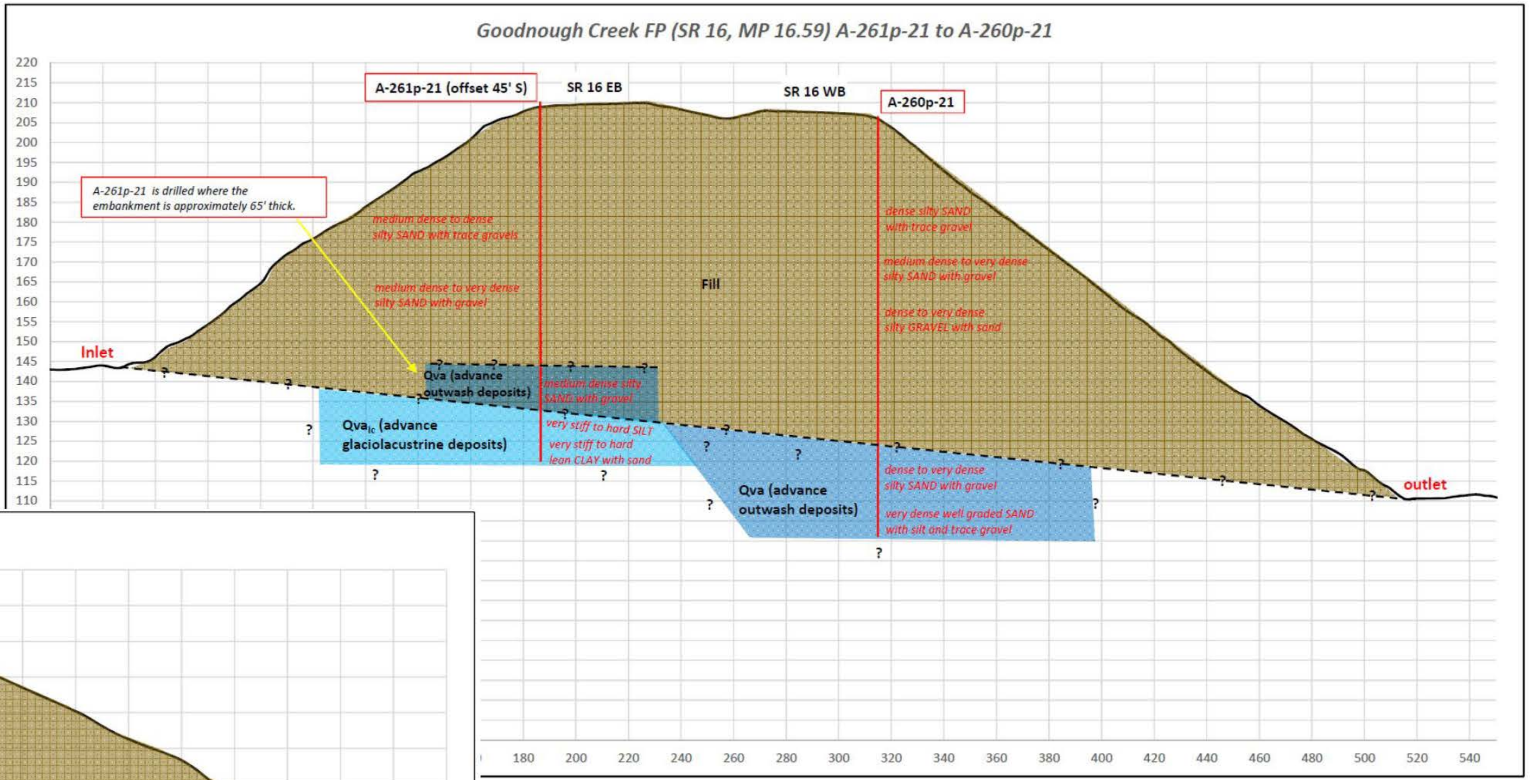
- Qvr - Recessional outwash deposits
- Qvi - Ice-contact deposits
- Qvt - Till
- Qva - Advance outwash deposits
- Qpfn - Nonglacial deposits
- Qob - Beach Deposits
- Qpog - Glacial deposits

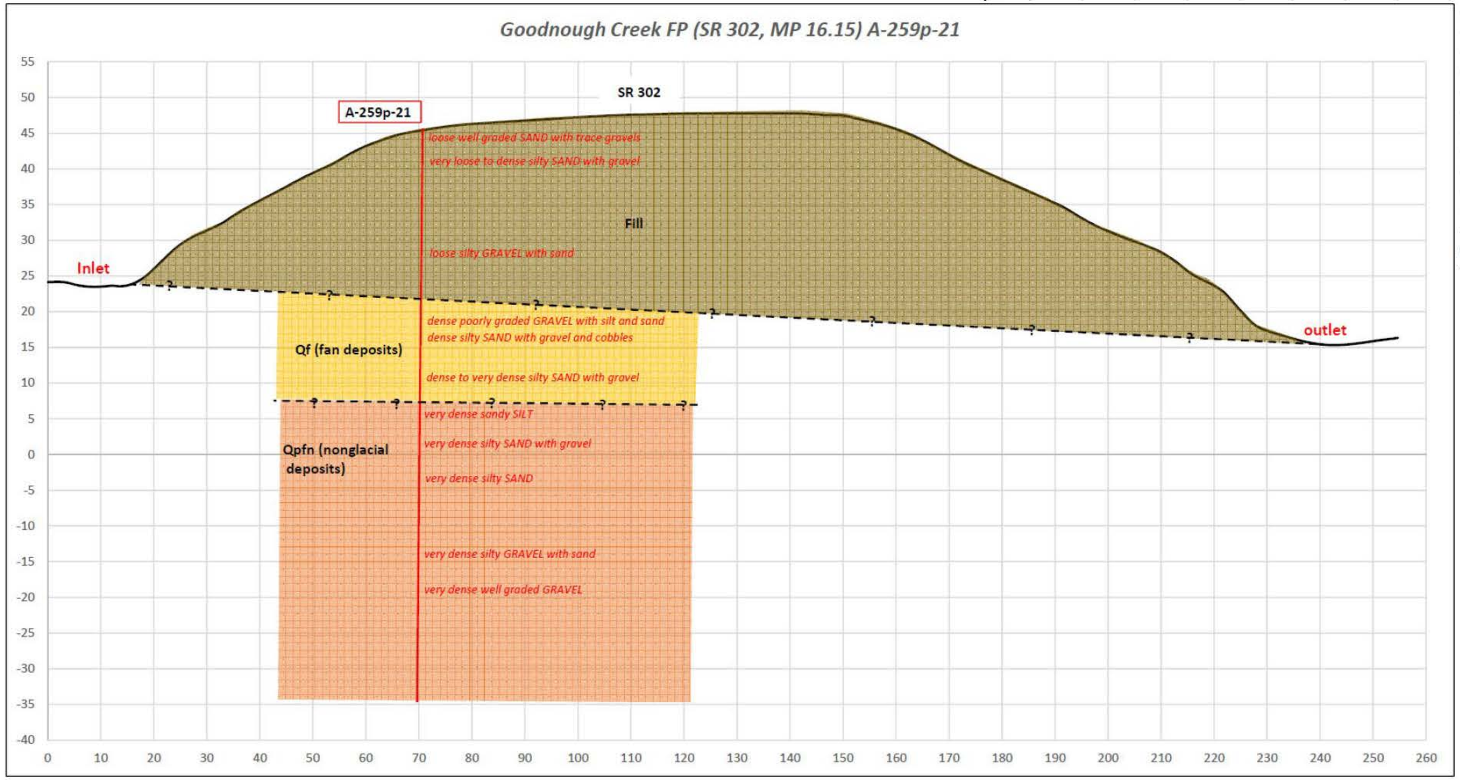
Other

- wtr - Water



Subsurface Data





Subsurface Data

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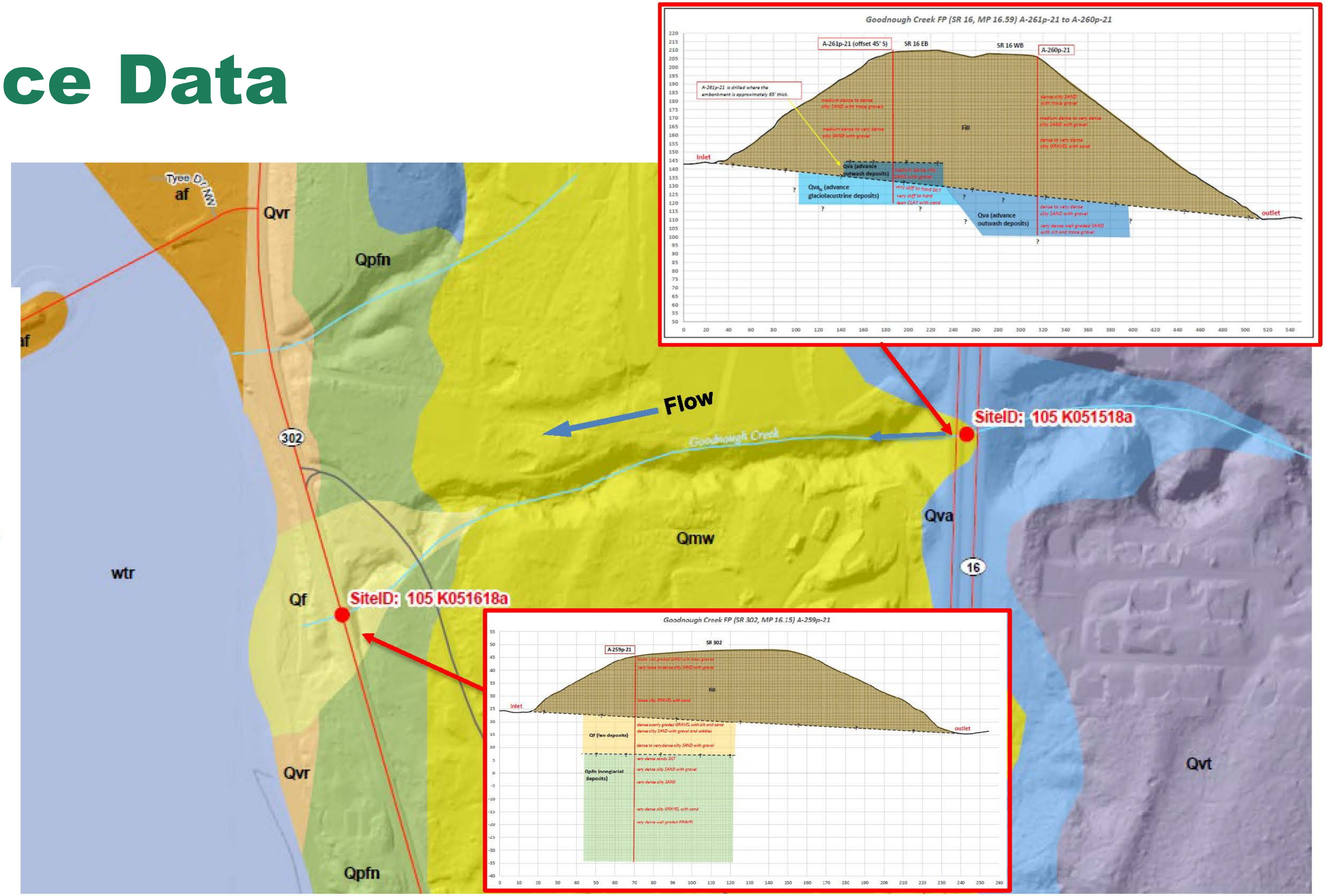
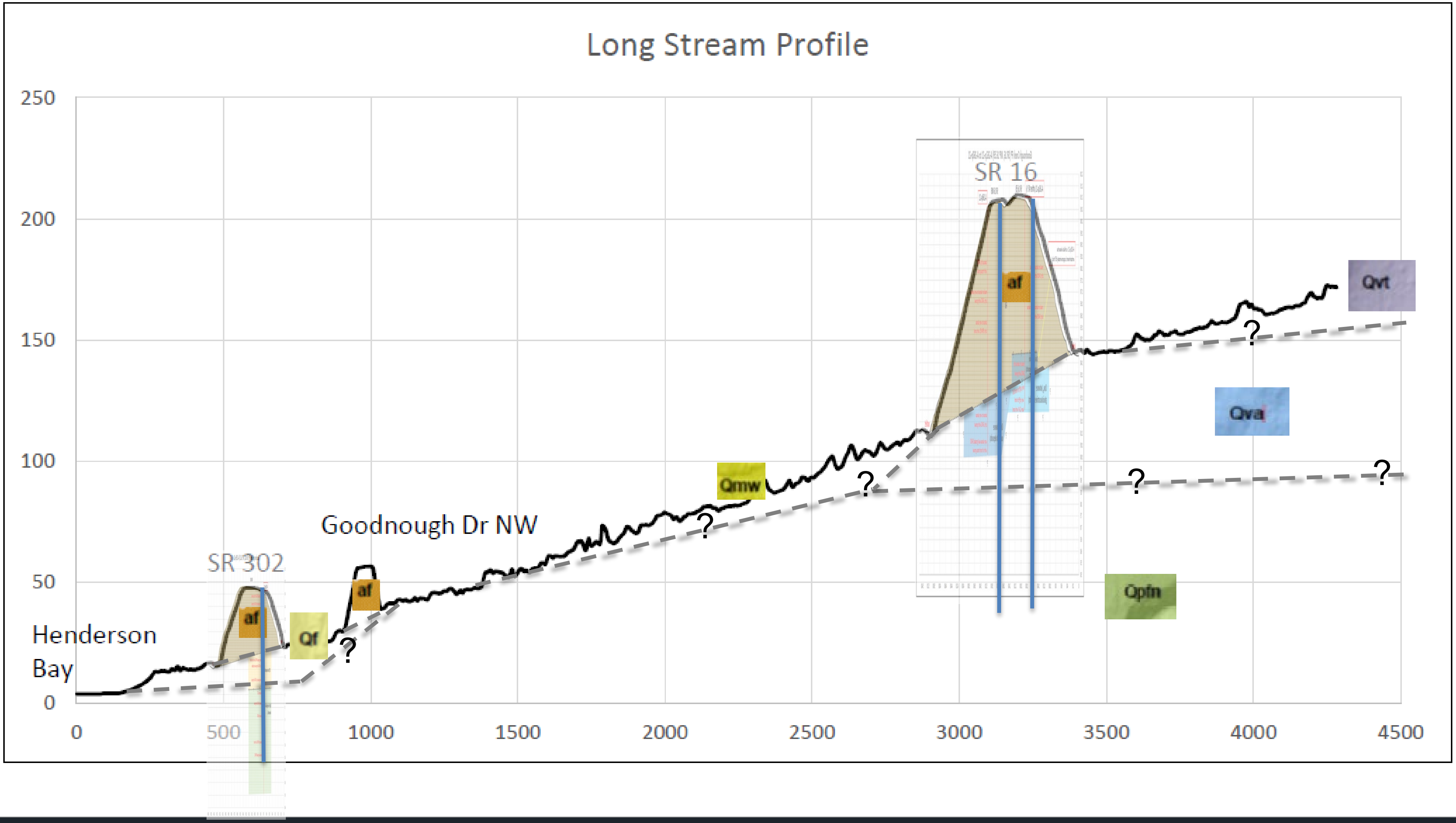


Long Stream Profile and Interpretation



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Long Stream Profile and Interpretation

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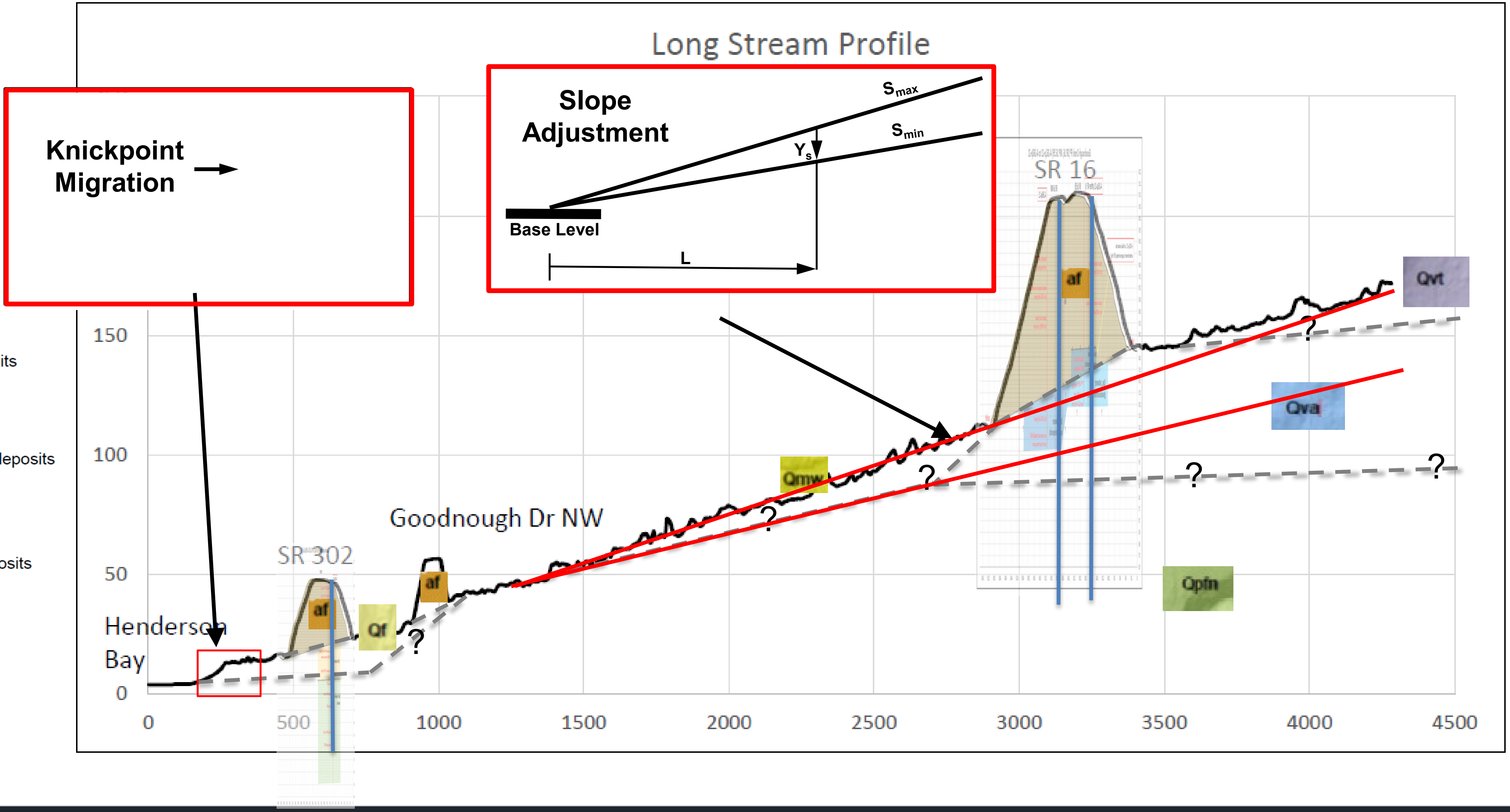
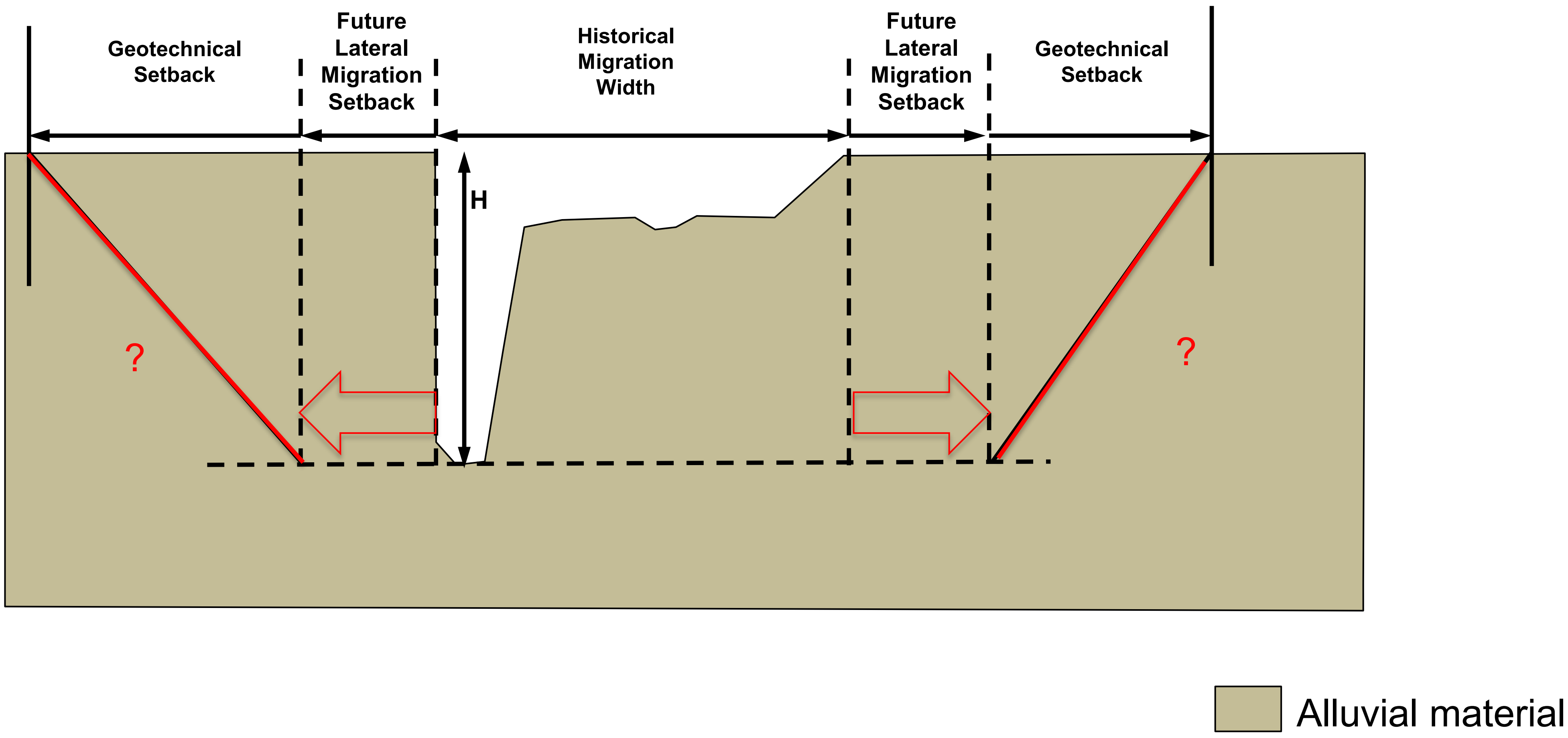
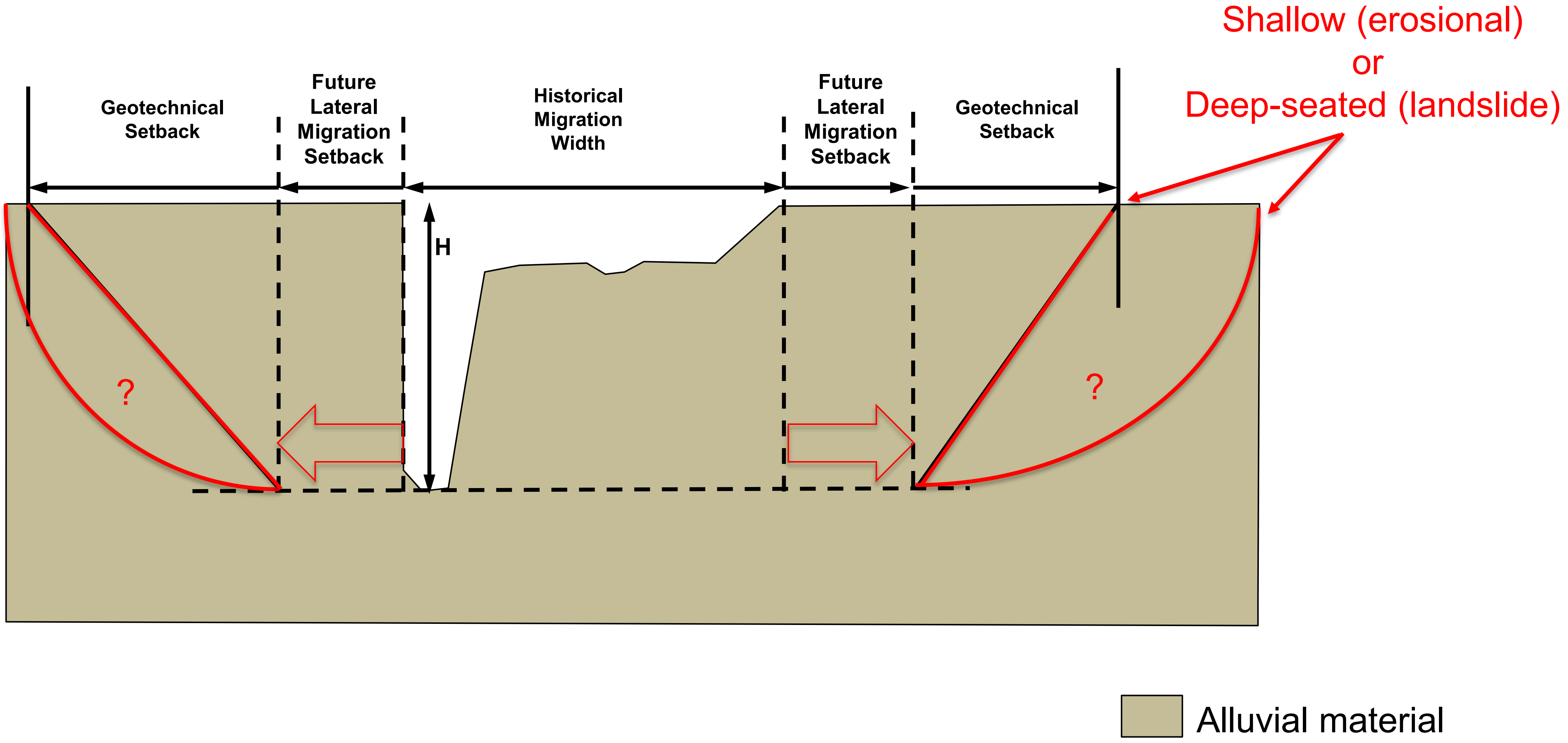


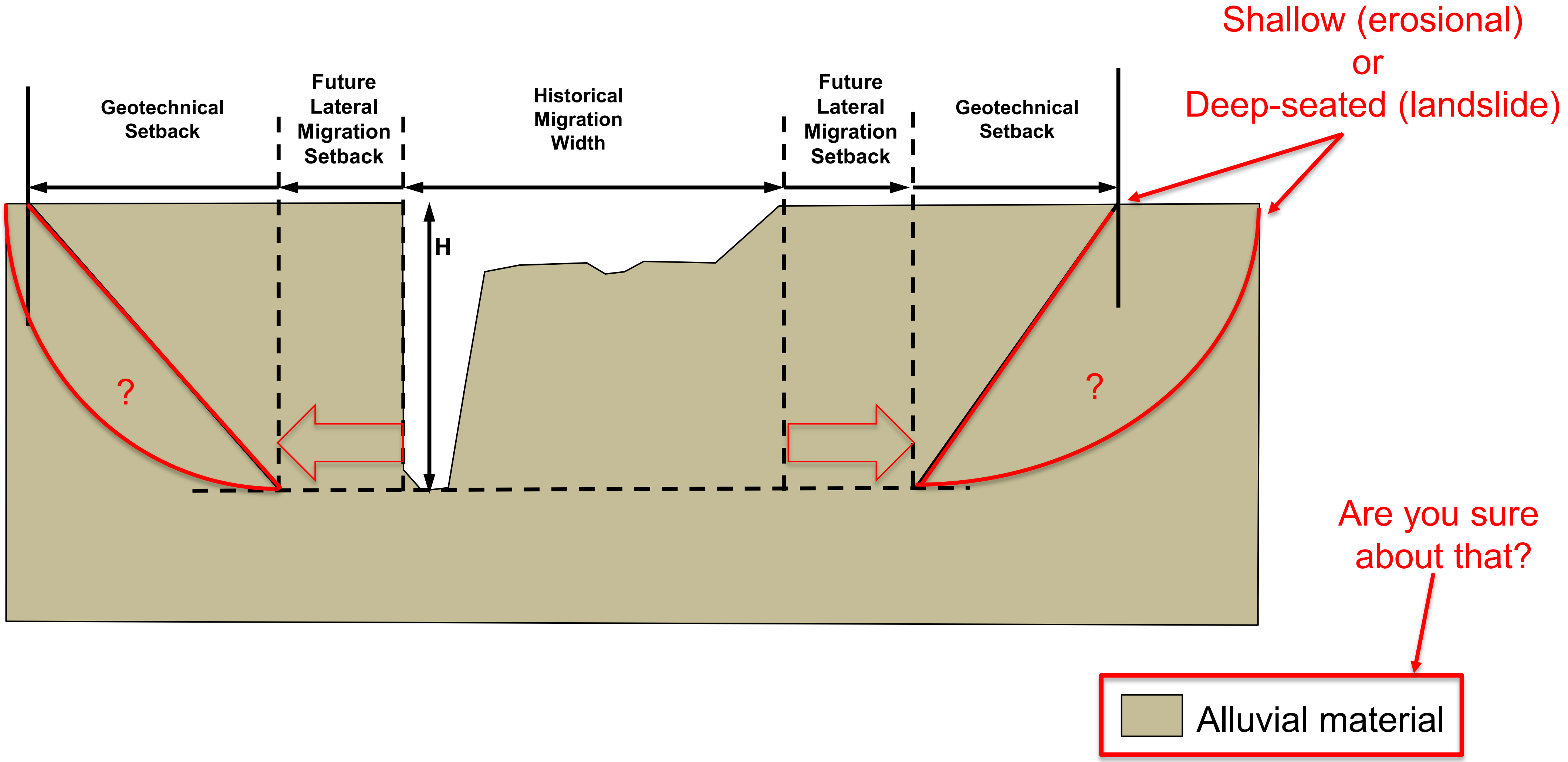
Vertical Incision Plus Historical Migration Zone Plus Future Lateral Migration



Vertical Incision Plus Historical Migration Zone Plus Future Lateral Migration



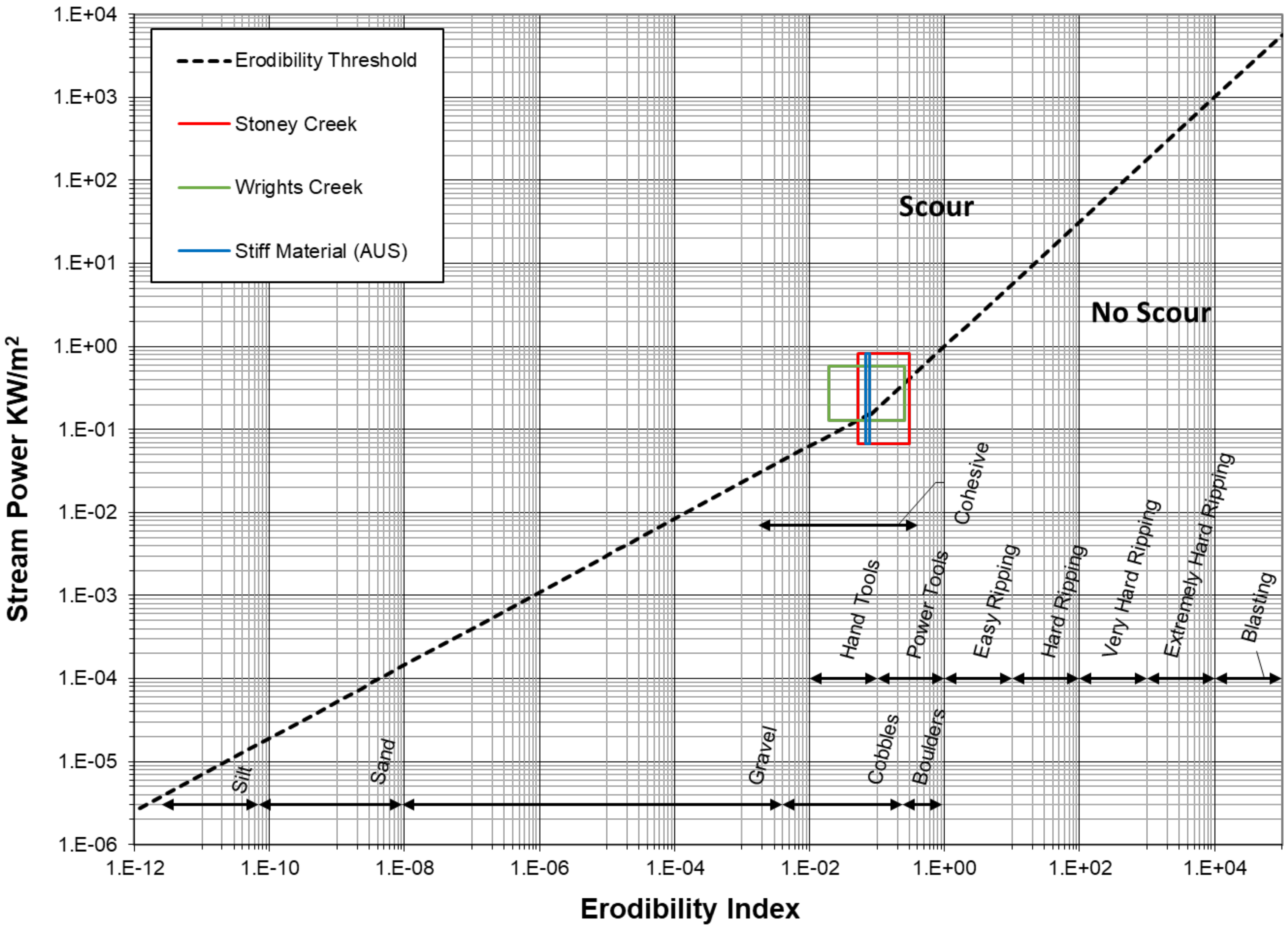
Vertical Incision Plus Historical Migration Zone Plus Future Lateral Migration



Future Developments

WSDOT is currently engaged in a multi-disciplinary effort to adapt the Erodibility Index for all geomaterials, including the 'IGMs' that are common in Washington State.

This will result in some new guidance around erosion rates and scour potential in various geomaterials.



The end.

Thank you.

Questions?

References: Module 6

WSDOT Resources

- WSDOT Hydraulics Manual:
  - https://wsdot.wa.gov/engineering-standards/all-manuals-and-standards/manuals/hydraulics-manual
- WSDOT Geotechnical Design Manual
  - https://wsdot.wa.gov/engineering-standards/all-manuals-and-standards/manuals/geotechnical-design-manual
- Hydrology and Hydraulics training website:
  - https://wsdot.wa.gov/engineering-standards/project-management-training/training/hydraulics-hydrology-training
- Fish Passage and Stream Restoration Design Training Slides:
  - Module 6: Modeling with SRH-2D by Ryan Barkie
    - https://wsdot.wa.gov/publications/fulltext/Hydraulics/hhtraining/FishPassageTraining/6-Modeling-with-SRH-2D.pdf
  - Module 8: Geomorphic Assessment for Stream Crossings by Cygnia Rapp
    - https://wsdot.wa.gov/publications/fulltext/Hydraulics/hhtraining/FishPassageTraining/8-Geomorphic-Assessment-of-Stream-Crossings.pdf
  - Module 9: Site and Reach Assessments and Reference Reaches by Garrett Jackson and Cygnia Rapp
    - https://wsdot.wa.gov/publications/fulltext/Hydraulics/hhtraining/FishPassageTraining/9-Site-and-Reach-Assessments.pdf

Other Resources

- HEC 18: https://www.fhwa.dot.gov/engineering/hydraulics/library_arc.cfm?pub_number=17&id=151
- HEC 20: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/hif12004.pdf
- HEC 23
  - Volume 1: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/09111/09111.pdf
  - Volume 2: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/09111/09112.pdf
- HDS 6: https://www.fhwa.dot.gov/engineering/hydraulics/pubs/nhi01004.pdf
- FHWA 2005. Field Observations and Evaluations of Streambed Scour at Bridges: https://www.fhwa.dot.gov/publications/research/infrastructure/hydraulics/03052/index.cfm
- Rapp, Cygnia F., and Timothy B. Abbe. A framework for delineating channel migration zones. No. Ecology Publication# 30-06-027. 2003.
- Annandale, George. Scour Technology: Mechanics and Engineering Practice (New York: McGraw-Hill, 2006).
- Annandale, G. W. "Erodibility." Journal of hydraulic research 33, no. 4 (1995): 471-494.
- Doyle MW, Stanley EH and Harbor JM (2003) Channel adjustments following two dam removals in Wisconsin. Water Resources Research 39(1).
- Wolman, M. Gordon, and John P. Miller. "Magnitude and frequency of forces in geomorphic processes." The Journal of Geology 68, no. 1 (1960): 54-74.
- ISRM Rock Mass Characterization