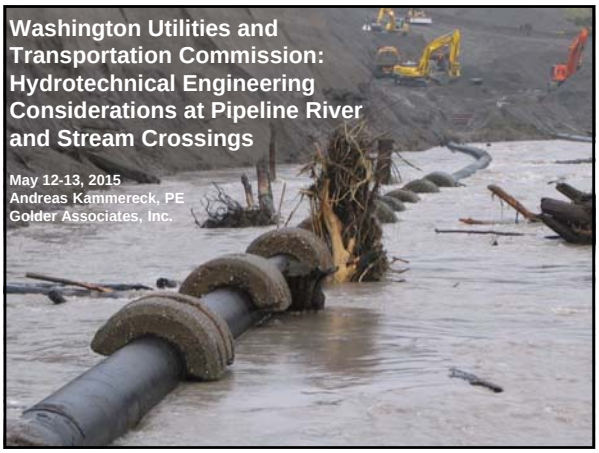


Washington Utilities and Transportation Commission: Hydrotechnical Engineering Considerations at Pipeline River and Stream Crossings

May 12-13, 2015
Andreas Kammereck, PE
Golder Associates, Inc.

Overview

- Regulatory Conditions
- Introduce types of hydrotechnical risks…with focus on horizontal and vertical processes (i.e. erosion and scour hazards)
- Think in terms of process based approaches, probabilities, and risk

Pipeline Safety, Regulatory Certainty, and Job Creation Act of 2011

"…we believe in a risk-based, data-driven approach to pipeline safety that focuses on private investment in pipeline safety on areas of higher risk…"

"…it is critically important that we must provide the regulatory certainty necessary for pipeline owners and operators to plan infrastructure investments…"

Senate Sub-Committee meeting review of the new law (May 20, 2014), by Chairman Jeff Dunham

The PROCESS:

HAZARDS:
- ❑Bank Erosion
- ❑Channel Scour
- ❑Lateral Meander
- ❑Channel Migration
- ❑Exposed Pipelines
- ❑Vortex Shedding
- ❑Mechanical Damage

The Hydrotechnical Components…

Includes: hydrology, hydraulics, and fluvial geomorphology

- Basin areas
- Precipitation
- Weather
- Snow
- Watersheds
- Run-off
- Urbanization
- Logging
- Climate change
- Geology
- Hydrogeology
- Soils
- etc.

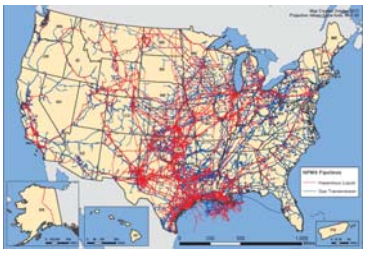
- Channel geometry
- Floodplain geometry
- Overbank areas ?
- Velocity
- Shear Stress
- Flow depth
- Area
- Elevations
- Froude Number
- Turbulence
- Gradient
- Groundwater
- etc.

- Scour
- Erosion
- Channel Migration
- Geomorphology
- Channel dynamics
- Trends
- Changes in channel or floodplain geometries
- Gaining reaches
- Loosing reaches
- Vegetation
- More geology
- etc.

Pipeline Footprint – Spatial and Temporal

- **Pipelines and the ROW are linear facilities, traversing rivers and streams (and other hazards)**
- **Pipelines built in the 1950's, 1970's, 1980's, 1990's, and 2000's…making them 50, 30, 10, <5 years old**
- **Rivers and streams change at decadal timescales…10-, 50-, 100- or more year recurrence internvals**

Large Scale - Crossings in the United States



- PHMSA Estimates:
  - 400,000 miles of transmission lines
  - 200,000 miles of gathering lines
  - 30,000 - 40,000 miles of liquid gathering lines
- Many River and Stream Crossings!!

Golder Associates

R = f [P, C]

RISK

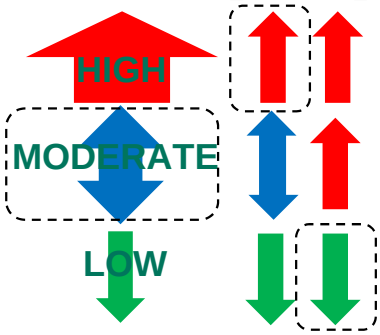
(P)ROBABILITY

(C)ONSEQUENCE

- ❑ EXPOSED PIPELINE AT CROSSINGS
- ❑ ROW EROSION
- ❑ INTEGRITY THREAT TO PIPELINE (RUPTURES)
- ❑ MAINTENANCE
- ❑ OFF-SITE IMPACTS-LANDOWNERS
- ❑ ENVIRONMENTAL IMPACTS
- ❑ PUBLIC HEALTH AND SAFETY
- ❑ REPUTATION/BUSINESS

Golder Associates

R = f [P, C]



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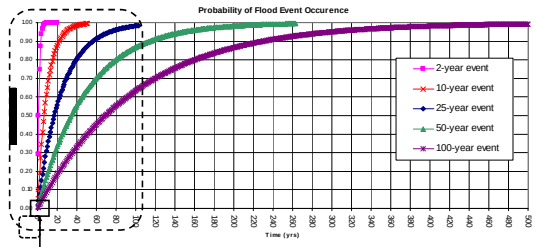
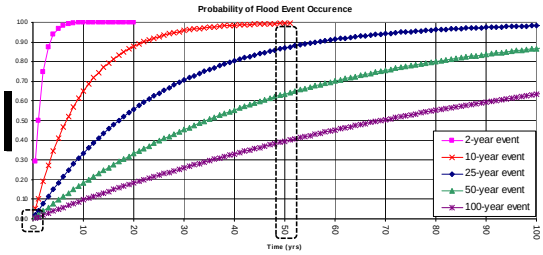
Frequency of Erosion as a Function of RI and P

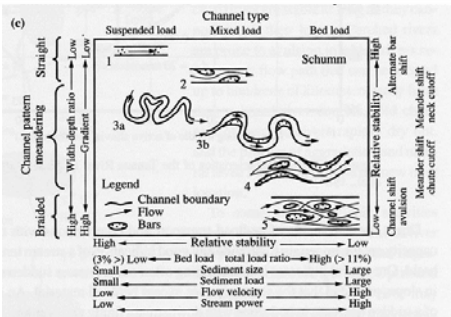


100-year Flood, P=0.01 in 1 Year

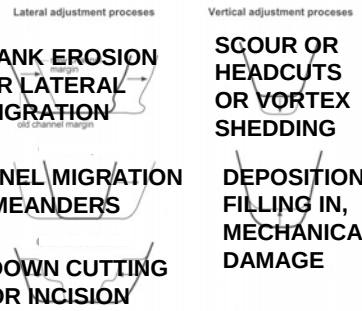
Frequency of Erosion as a Function of RI and P



Observed Conditions Help Describe Dynamics



Horizontal and Vertical Process



BANK EROSION OR LATERAL MIGRATION

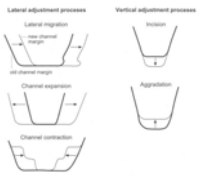
SCOUR OR HEADCUTS OR VORTEX SHEDDING

CHANNEL MIGRATION AND MEANDERS

DEPOSITION OR FILLING IN, MECHANICAL DAMAGE

DOWN CUTTING OR INCISION

Horizontal and Vertical Processes

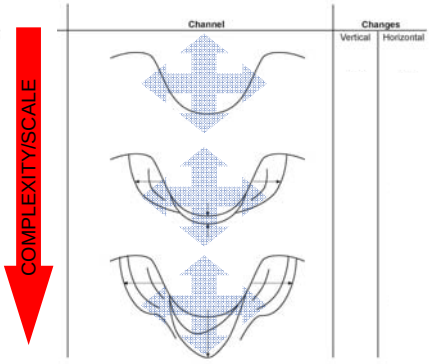


Inundation, Aggradation, Deposition

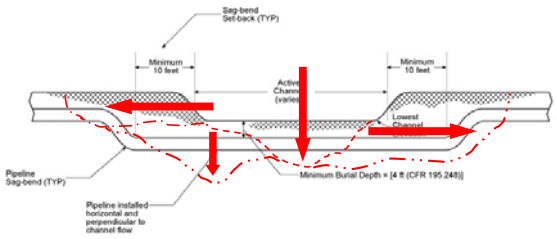
Channel Migration, Bank Erosion, Widening, Expansion, Contraction, Lateral changes

Scour, Degradation, Head-cut erosion, Incision

Increasing Complexity in Channels results in Increasing Complexity in Erosion and Scour

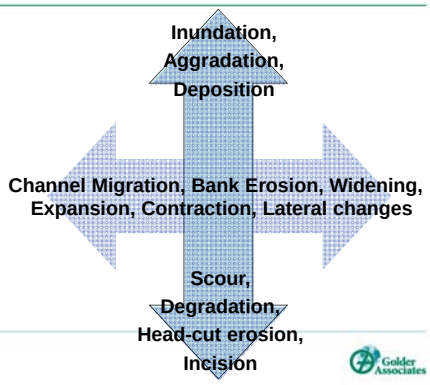


Erosion and Scour at Crossings

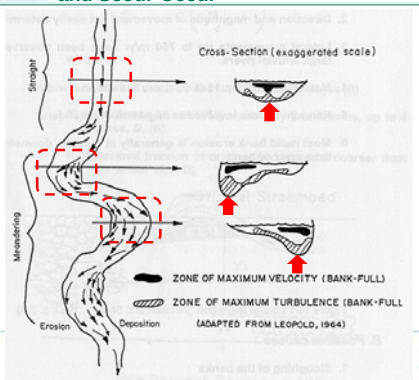


Vertical Processes

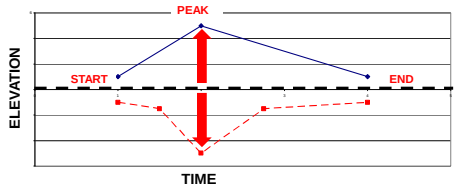
- Focus on the process
- Organize things into vertical and horizontal processes
- Everything is connected
- State-of-the-art engineering and science



High Velocity and Shear Zones where Erosion and Scour Occur



Change in Scour



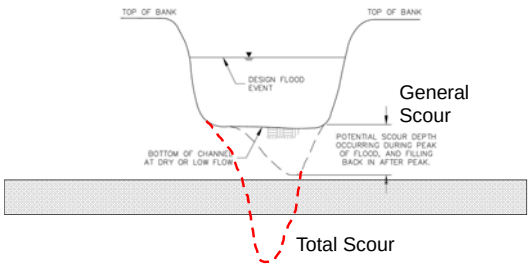
- Hydrograph tracks with scour
- Scour correlates to flow energy
- Max scour at peak, channel backfills as hydrograph drops off

Total Scour is Larger than General Scour

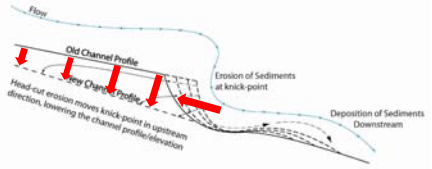
- Total Scour
  - Long-term Degradation
  - General Scour
  - Local Sour
  - Bend Scour/Contraction Scour
  - Bed Form Scour
  - Low-flow Incisement

$$y_{ts} = y_{lt} + y_{gs} + y_{ls} + y_{bs} + y_{bf} + y_{lf}$$

Total Scour

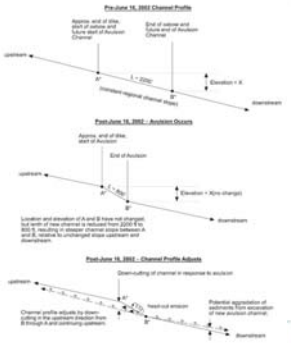


Headcut Erosion



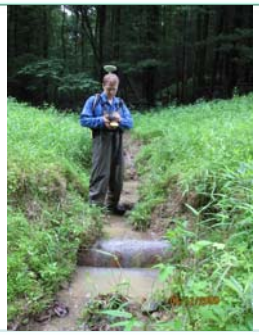
- Knick-points (man-made or natural)
- Erosion of sediments at knick-point, results in lowering of upstream channel profile (exposes pipe)
- Downstream deposition of eroded sediments changes channel dynamics (erosion, channel changes, etc.)
- Movement a function of flows…timescale is 10, 50, 100 years

Avulsions and Headcut Erosion



Example of Head-Cut Erosion

Example Head-Cut Exposed Pipeline



Example: Headcut Erosion

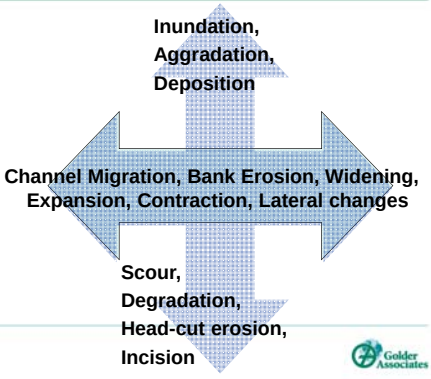
- Head-cut Erosion
- Heavy bedload damaging pipeline
- Flashy system

Example: Headcut Erosion

Example Head-Cut Exposed Pipeline

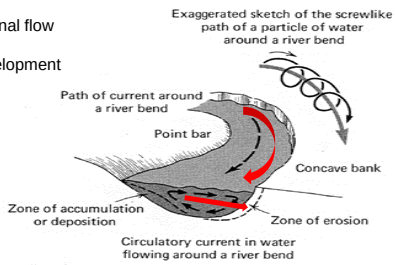
Horizontal Processes

- Focus on the process
- Organize things into vertical and horizontal processes
- Everything is connected
- State-of-the-art engineering and science

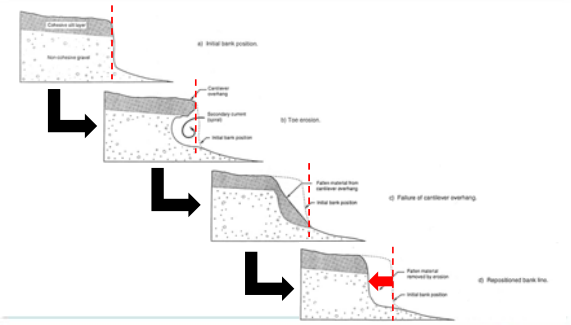


Bank Erosion along Outside of Bend

- Lateral channel migration
- Vertical scour
- Helical latitudinal flow conditions
- Point bar development



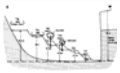
What does Bank Erosion Look Like?



Example Exposed Sagbend

Channel Migration - White River, WA

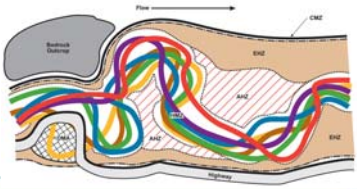
Example: Bank Erosion



Bank Erosion/Channel Migration

- **CMZ** = Channel Migration Zone
  - **HMZ** = Historical Migration Zone
  - **AHZ** = Avulsion Hazard Zone
  - **EHZ** = Erosion Hazard Zone
  - **DMA** = Disconnected Migration Area

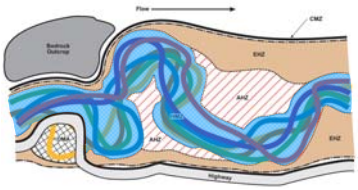
- **CMZ organized into components**
- **Components define hazards and risk**
- **Results support:**
  - **Planning**
  - **Permitting**
  - **Design**
  - **Construction**



WSDOE,, Ecology Publication #03-06-027, "A Framework for Delineating Channel Migration Zones", November 2003

Channel Migration Zone Pieces

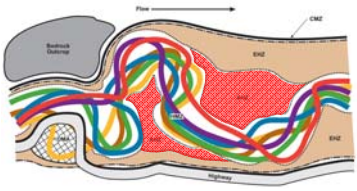
- **Historical Migration Zone (HMZ)**
  - Historical aerial photos
  - Fieldwork
  - GLO Maps
  - USGS Maps
  - Surveys
  - GIS analysis



WSDOE, Ecology Publication #03-06-027, "A Framework for Delineating Channel Migration Zones", November 2003

Channel Migration Zone Pieces

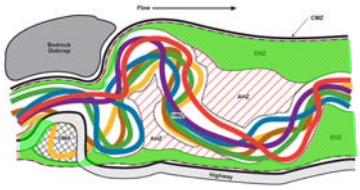
- **Avulsion Hazard Zone (AHZ)**
  - Secondary channels
  - Relic channels
  - Swales
  - Gradient changes/
  - Head-cut erosion
  - Erodible banks
  - Cut-offs



WSDOE, Ecology Publication #03-06-027, "A Framework for Delineating Channel Migration Zones", November 2003

Channel Migration Zone Pieces

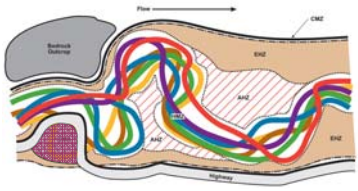
- **Erosion Hazard Zone (EHZ)**
  - Erosion Setbacks (ES)
    - Area at risk from erosion by stream flow
    - Polygon/Point Analysis
  - Geotechnical Setback (GS)
    - Channel and terrace banks at risk of mass wasting (due to erosion at the toe)



WSDOE, Ecology Publication #03-06-027, "A Framework for Delineating Channel Migration Zones", November 2003

Channel Migration Zone Pieces

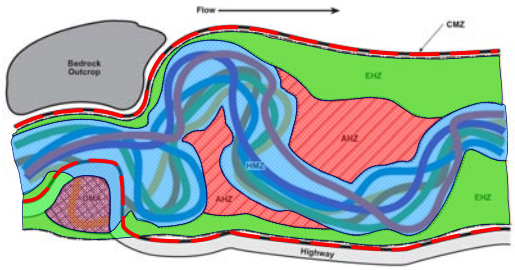
- **Disconnected Migration Areas (DMZ)**
  - Roads
  - Critical facilities
  - Levees
  - Bedrock/Geology
  - Terraces



WSDOE, Ecology Publication #03-06-027, "A Framework for Delineating Channel Migration Zones", November 2003

Bank Erosion/Channel Migration

HMZ + AHZ + EHZ – DMA = CMZ



WSDOE, Ecology Publication #03-06-027, "A Framework for Delineating Channel Migration Zones", November 2003

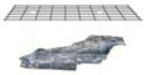
Example: Channel Migration

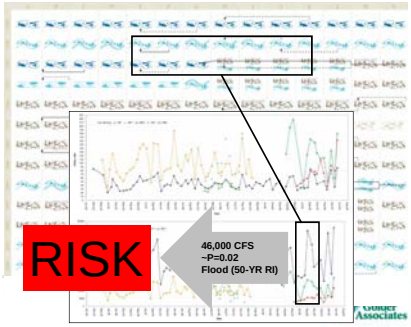
Example: Channel Migration

Go here.
See Master
Slide

Assessing the Hazard Relative to Risk

Geomorphic Changes ~ Flow Histories





Advisory Bulletin (PHMSA-2015-0105), April 9, 2015

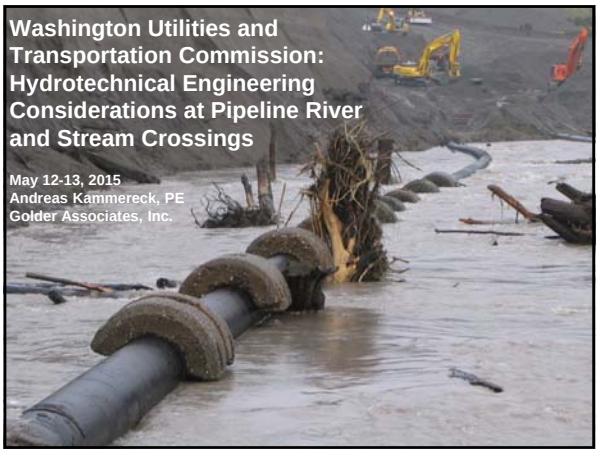
Pipeline Safety: Potential for Damage to Pipeline Facilities Caused by Flooding, River scour, and River Channel Migration

1. Engage Hydrotechnical Subject Matter Experts (SME's)
2. Evaluate Crossing Method/Conditions relative to Risks
3. Evaluate Hydrotechnical conditions/risks, scour and erosion potential
4. Access to crossing, valves, shutting in
5. Extend facilities (vents and stacks) above flood levels
6. Coordinate with Public Emergency Responders
7. Coordinate with other Operators (where applicable)
8. Deploy Resources for Response
9. Mark Facilities that get flooded (debris and vessels)
10. Regular Inspections and patrols
11. Open Communications with Local and State Officials
12. Track Flooding Conditions, Perform Surveys ASAP
13. Complete Regular Depth of Cover Surveys (Divers, instruments)
14. Maintain Line Markers

Wrap-up

- **Think in terms of Risk**
- **Use a process-based approach for assessing hazards and solving problems**
- **Start simple with hydrotechnical topics…remember the cross**
- **Look for public data, supplement with site specific data**
- **Consider scour at the crossing AND channel migration approaching/departing the crossing**

$$R = f\,[\,P, C\,]$$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