River Mechanics and Stream Restoration Seminar

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Malaysia 2004

Objectives

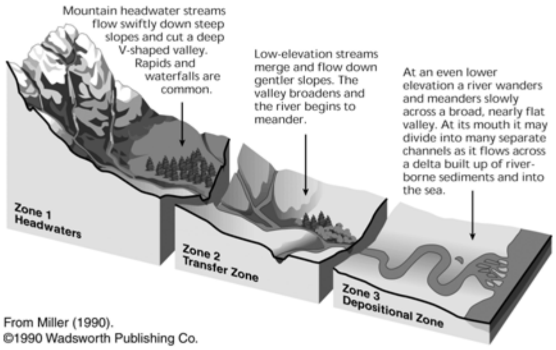
Part I – Equilibrium and Bank Protection

1. Concept of Equilibrium, environmental river mechanics and bank protection
2. Provide Three basic laws for Stream Restoration

Three Laws of Stream Restoration

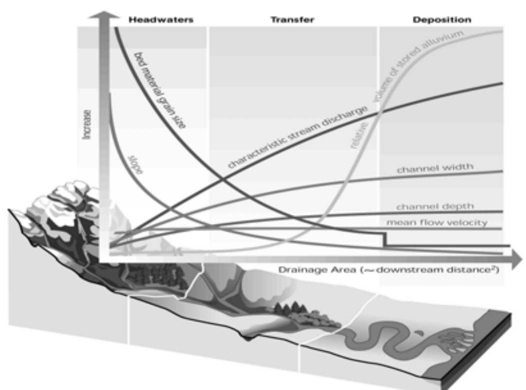
#1 There is no cookbook approach to stream restoration projects.

Concept of Equilibrium



From Miller (1990).

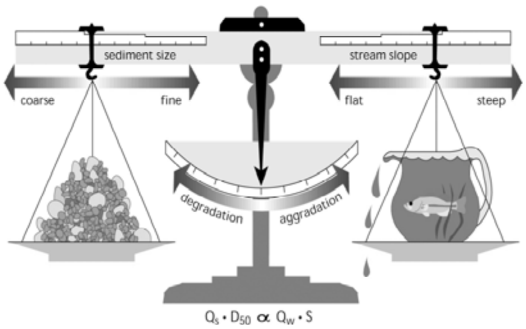
Fig. 1.27 – Three longitudinal profile zones.
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (15 Federal Agencies of the US).



Three Laws of Stream Restoration

#1 There is no cookbook approach to stream restoration projects.

#2 Solutions normally require **equilibrium** conditions between sediment regime and stream ecology.



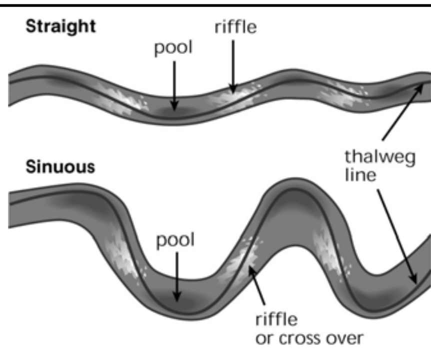
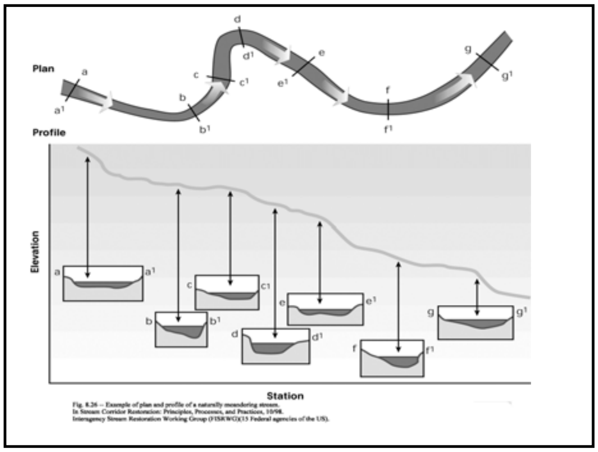
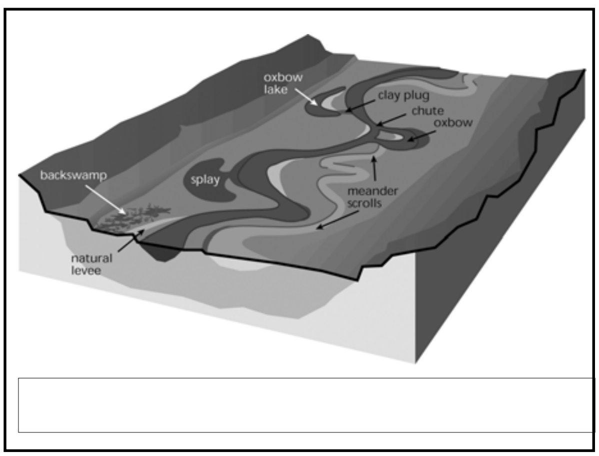


Fig. 1.33 – Sequence of pools and riffles in (a) straight and (b) sinuous streams.
In Stream Corridor Restoration: Principles, Processes, and Practices (10/98).
Interagency Stream Restoration Working Group (15 federal agencies)(FISRWG).


Plan
Profile
Elevation
Station
a
a1
b
b1
c
c1
d
d1
e
e1
f
f1
g
g1
Fig. 8.26 -- Example of plan and profile of a naturally meandering stream.
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).


oxbow lake
clay plug
chute
oxbow
backswamp
splay
meander scrolls
natural levee

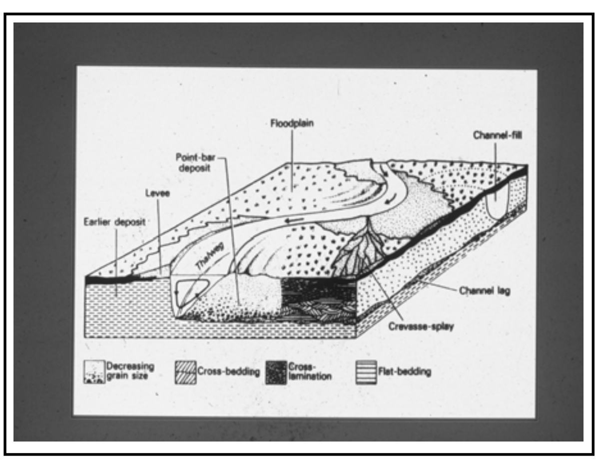
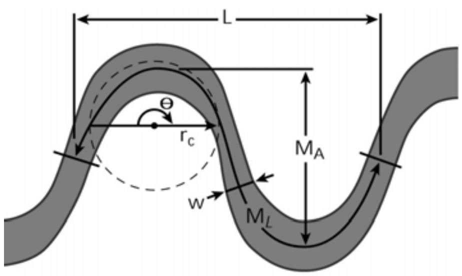
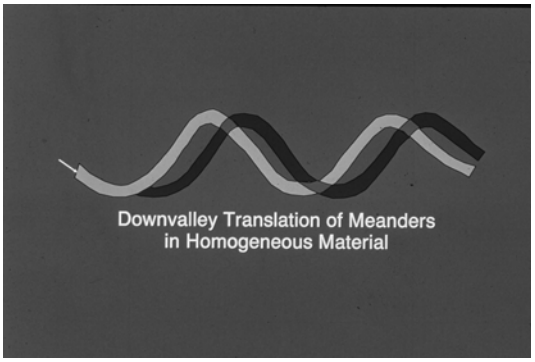

Floodplain
Channel-fill
Point-bar deposit
Levee
Earlier deposit
Thalweg
Channel lag
Crevasse-splay
Decreasing grain size
Cross-bedding
Cross-lamination
Flat-bedding

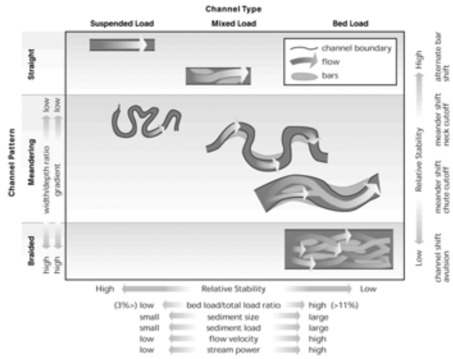
Figure 3.3 Typical Meandering River



- The system is dynamic
- A stable river is one in which, over a period of years, slope is delicately adjusted to provide just the velocity required to transport the available water & sediment supplied from the drainage basin.

  (… after Mackin, 1948)


Downvalley Translation of Meanders
in Homogeneous Material



Source: Schumm, The Fluvial System. © 1977. Reprinted by permission of John Wiley and Sons, Inc.

Fig. 7.10 – Classification of alluvial channels, per Schumm's classification system.
In Stream Corridor Restoration: Principles, Processes, and Practices, 10/98.
Interagency Stream Restoration Working Group (FISRWG)(15 Federal agencies of the US).

2. Bank Protection

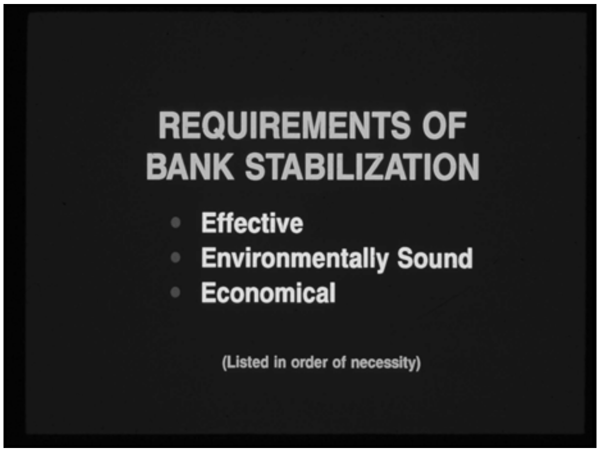

REQUIREMENTS OF
BANK STABILIZATION
Effective
Environmentally Sound
Economical
(Listed in order of necessity)

Figure 7.6 Launched Windrow Rock

Figure 7.10 Longitudinal Stone Fill Toe Protection Placed Adjacent to Bank With Tiebacks

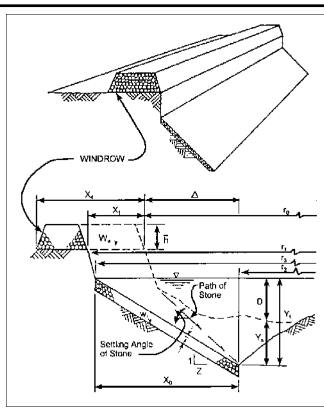
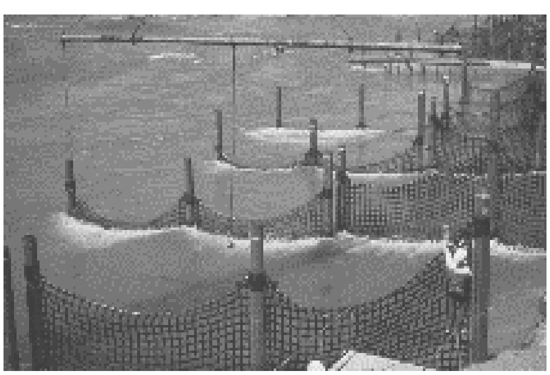


Figure 7.3 Schematic Diagram of Windrow Revetment

Figure 8.2 Typical Impermeable Dikes



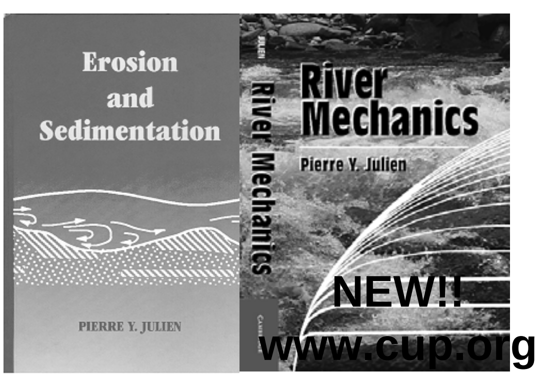
Three Laws of Stream Restoration

#1 There is no cookbook approach to stream restoration projects.

#2 Solutions normally require equilibrium conditions between sediment regime and stream ecology.

#3 Solutions need to be effective, environmentally acceptable and economical.

Erosion and River Mechanics Textbooks

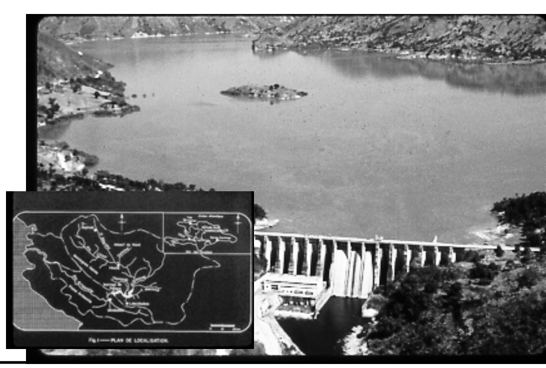


Objectives

Part II – River Dynamics and Response

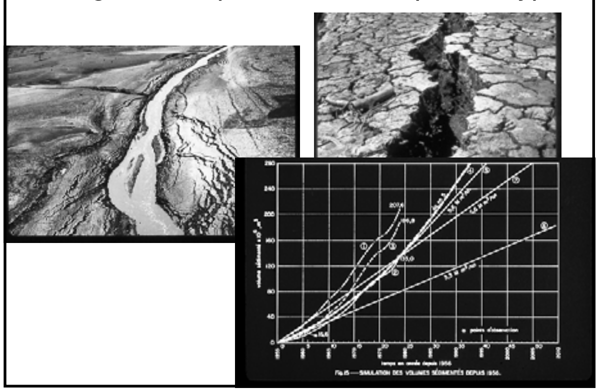
1. Deforestation impact on rivers
2. The concept of time scales
3. Headcutting and degradation

Peligre Dam in Haiti (deforestation)



Peligre Dam (sedimentation)

Peligre Dam (reduced life expectancy)



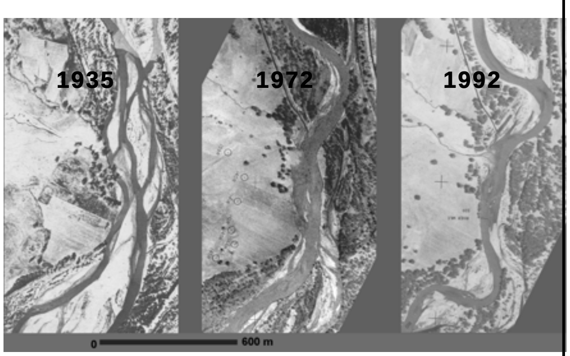
River Dynamics

#1 Deforestation may impact river equilibrium for a very long time.

Time Scale

- Geological ~ 1,000,000 years
- Engineering ~ 100 years
- Aquatic life ~ 1 year

Hydraulic geometry of the Rio Grande



Restoration vs Rehabilitation

Restoration

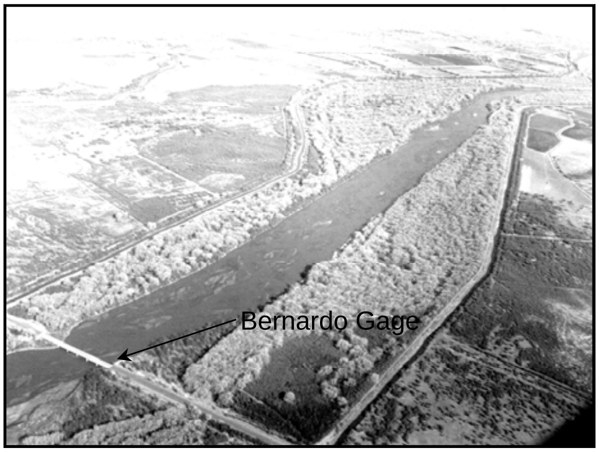
•returning a resource to some former condition.

Rehabilitation

•maximize the potential beneficial uses of a resource to some reasonable and practical level.

Jetty fields and vegetation of the Rio Grande

Jetty System (near Bernardo), USACE 1963



Debris Deposition

Debris Deposition

River Dynamics

#1 Deforestation may impact river equilibrium for a very long time.

#2 Stream restoration/rehabilitation may be effective only after a long period of time

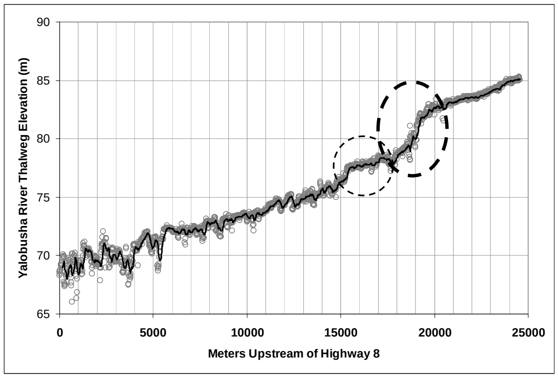
Bank Caving

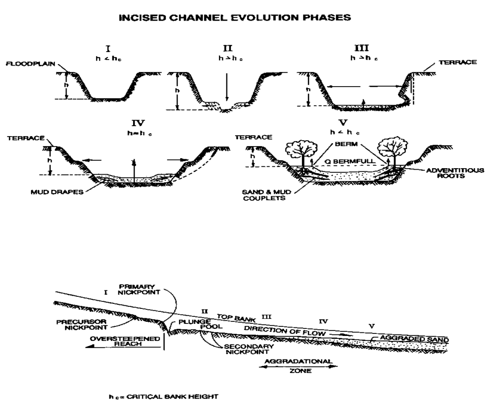
Bank Caving

Bank Caving

Headcutting

Headcutting

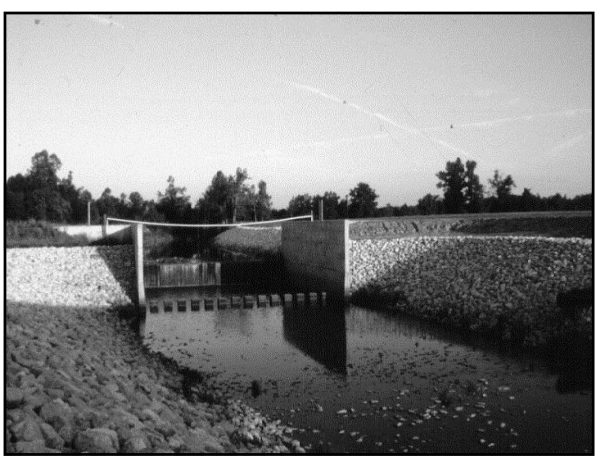


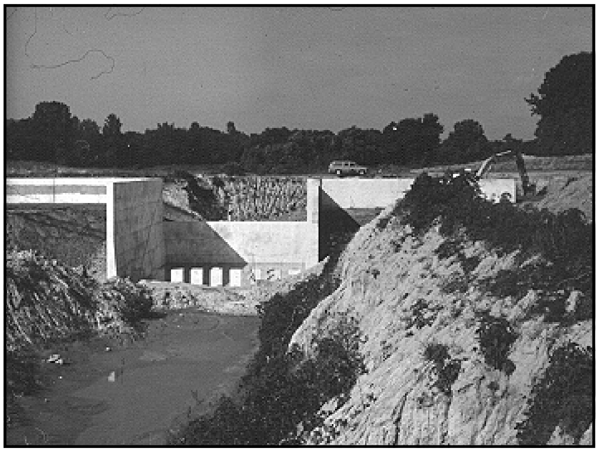


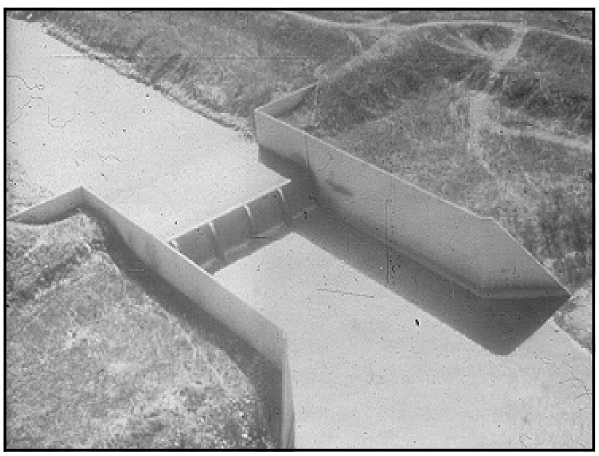
Vertical Degradation

Headcutting

Vertical Degradation







River Dynamics

#1 Deforestation may impact river equilibrium for a very long time.

#2 Stream restoration/rehabilitation may be effective only after a long period of time

#3 Looking downstream may prevent headcutting and severe degradation problems

ASCE Journal of Hydraulic Engineering

Erosion and River Mechanics Textbooks

Objectives

Part III – Guidelines and Case Study

1. Guidelines for Stream Restoration Projects
2. Case-study on the Rio Grande

Stream Restoration Guidelines

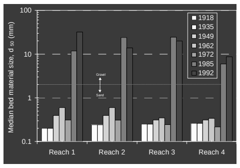
1. **OBJECTIVES -** Clearly define the engineering and ecological objectives. Restoration vs rehabilitation.
2. **PAST, PRESENT and FUTURE – **Consider present conditions in the perspective of past events and examine future changes.

Rio Grande Restoration– Santa Ana

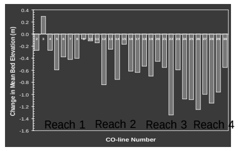
Project Goals

- **Protect Levee**
- **Create a Functioning Floodplain**
- **Improve Wildlife Habitat**

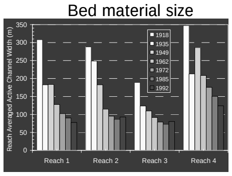
Hydraulic geometry of the Rio Grande



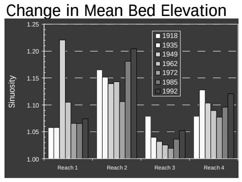
Bed material size



Change in Mean Bed Elevation



Active channel width



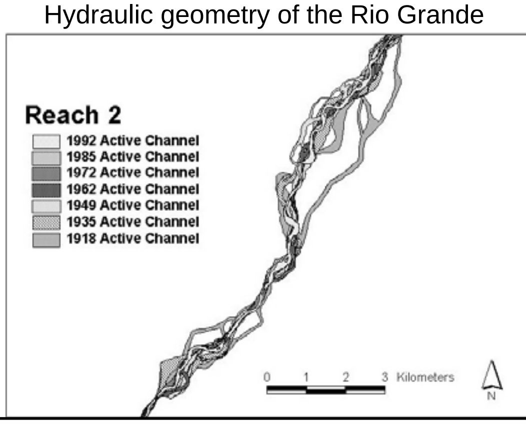
Sinuosity

Stream Restoration Guidelines

3. **UPPER WATERSHED** – Look at the geology, deforestation, land use changes, urbanization, climate and extreme events. Examine water and sediment supply, flood frequency curves, sediment mass curves sediment concentrations, water quality, etc.

4. **DOWNSTREAM REACH** – Look at possible changes in the downstream reach that may affect current conditions – like reservoirs, base level changes, headcutting, etc.

Hydraulic geometry of the Rio Grande



Stream Restoration Guidelines

5. **CHANNEL GEOMETRY** – Determine equilibrium downstream hydraulic geometry in terms of width, depth, velocity, slope, discharge and morphology.

6. **AQUATIC HABITAT**– determine appropriate aquatic habitat conditions including low and high flow periods, pools, riffles, spawning grounds, shade, aeration, migration, etc.

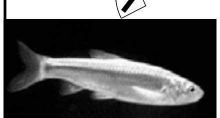
Rio Grande Restoration– Floodplain restoration

Santa Ana Reach - Mid 80's

Santa Ana Reach – Mid 90's

Rio Grande Restoration– Endangered Species

- **Bimodal sand / gravel bed**
- **Deep water h ~ 1.20 m**
- **Water velocities 1.4 m / s**



Restoration

- **Create wider channels**

- **Sandy / silty substrate**
- **Shallow water h < 0.4 m**
- **Water velocities $0.1\ m/s < V < 0.5\ m/s$**

Stream Restoration Guidelines

7. **EXAMINE ALTERNATIVES** – Identify several different stream rehabilitation schemes that would suit the engineering and environmental needs.

8. **DESIGN SELECTION –** examine the various alternatives and select the best possible alternative and proceed with the design. Solution must be effective, environmentally sound and economical.


River Realignment
• Construct Bio-engineering Bankline
3 29 01


Floodplain Maintenance
• Lower Terraces with Heavy Equipment

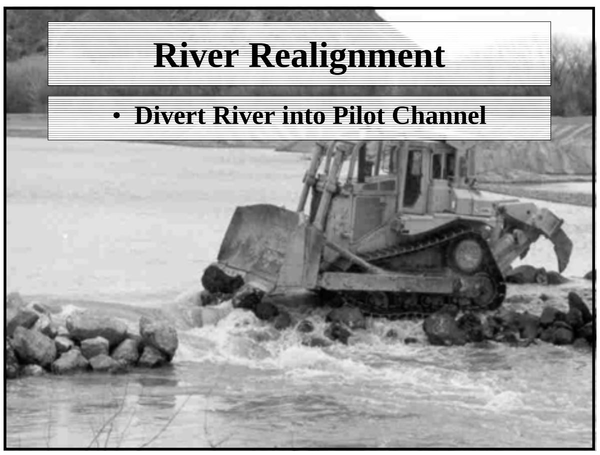

Floodplain Restoration
• Excavated Sediment Placed near Pilot Channel
1 18 '01

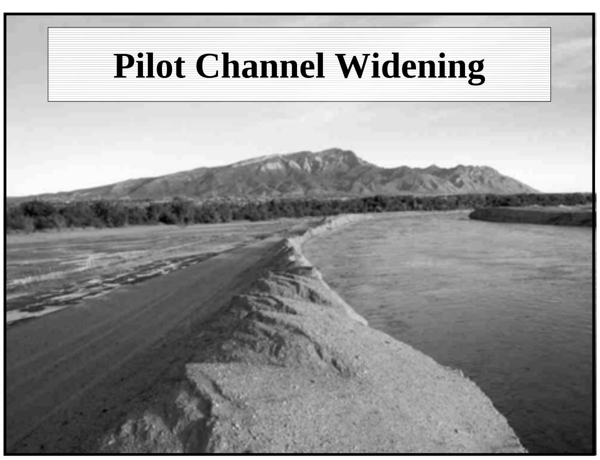
Stream Restoration Guidelines

9. **CONSTRUCTION** – Carefully plan the construction and consider the possible impact of possible extreme events during the construction period.

10. **MONITORING** – Things may not work as planned. A post-construction analysis and monitoring should be carried out until the objectives have been met.


Opening Pilot Channel


River Realignment
• Divert River into Pilot Channel


Pilot Channel Widening

Spring Runoff - 2001

Post-Runoff Assessment

- More Gravel than Anticipated
- Mean Bed Elevation 2 ft Higher than Anticipated
- Pilot Channel 50-100 ft Narrower than Desired

Effects on Bio-engineering

- Most Willows in Fabric Encapsulated Soil (FES) Completely Submerged
- Sections of Bio-engineering Covered in Sediment

Rio Grande Conclusions

- **Thoroughly study river mechanics and apply finding to the design process.**
- **Understand the evolution of the project and consider intermediate conditions.**
- **Be Flexible…Apply adaptive management techniques.**

Stream Restoration Guidelines

1. Clearly define the **OBJECTIVES**
2. **PAST,** Present and **FUTURE**
3. Look at the **UPPER WATERSHED**
4. Look **DOWNSTREAM** for degradation
5. **EQUILIBRIUM** Hydraulic Geometry
6. Appropriate **AQUATIC HABITAT**
7. Examine various design **ALTERNATIVES**
8. **DESIGN** must be Effective, Environmentally sound and Economical
9. Plan **CONSTRUCTION** for the unexpected
10. Post-construction **MONITORING**

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THANK YOU for your Attention!