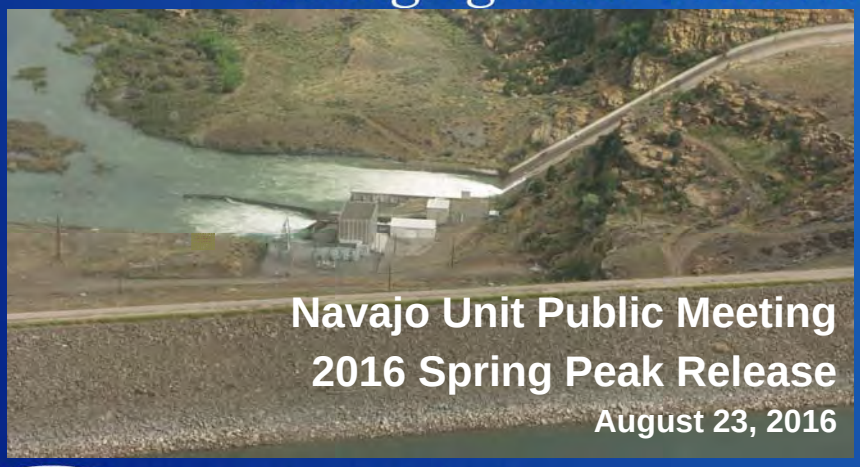
RECLAMATION

Managing Water in the West



Navajo Unit Public Meeting
2016 Spring Peak Release

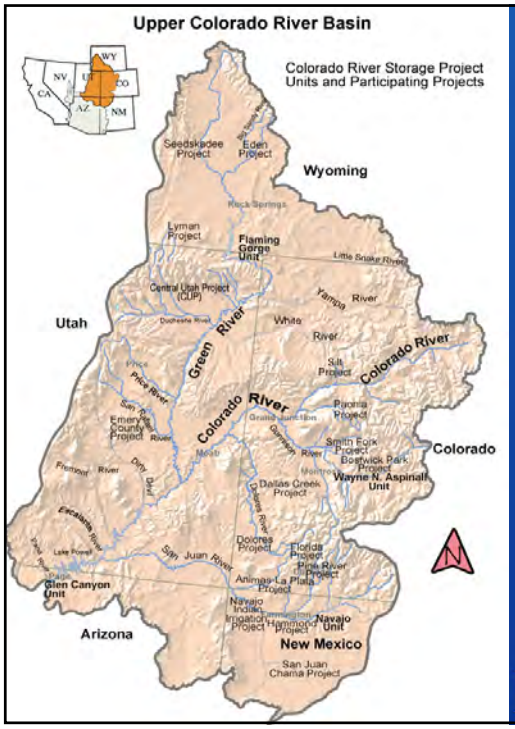
August 23, 2016

U.S. Department of the Interior
Bureau of Reclamation

AGENDA

- Review of 2016 Spring Peak Release Operations
  - -Susan Behery, Reclamation Western Colorado Area Office, Durango
- River Channel Processes and Flow Conveyance
  - -Tim Randle, Reclamation Technical Service Center, Denver
- Channel Capacity Downstream of Navajo Dam
  - -Ryan Gronewold, US Army Corps of Engineers, Albuquerque

RECLAMATION



Colorado River Storage Project

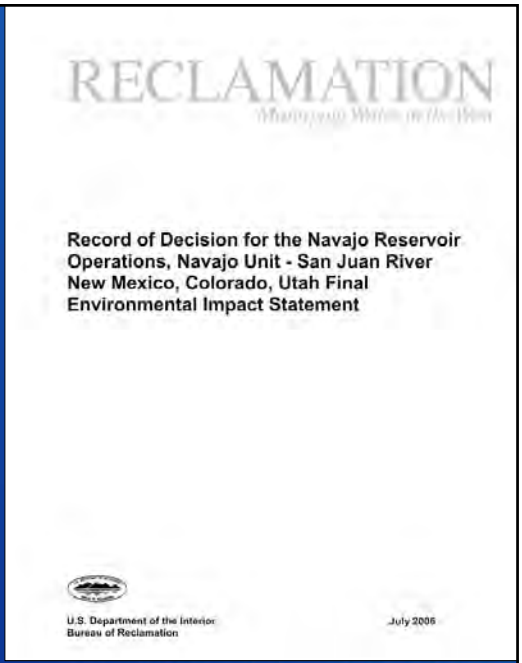
- Aspinall Unit
- Flaming Gorge
- Fontenelle
- Navajo
- Lake Powell

RECLAMATION

How is Navajo Reservoir Managed?

- Water Supply
- Flood Control
- Endangered Species Act

Releases range between 250-5000 cfs

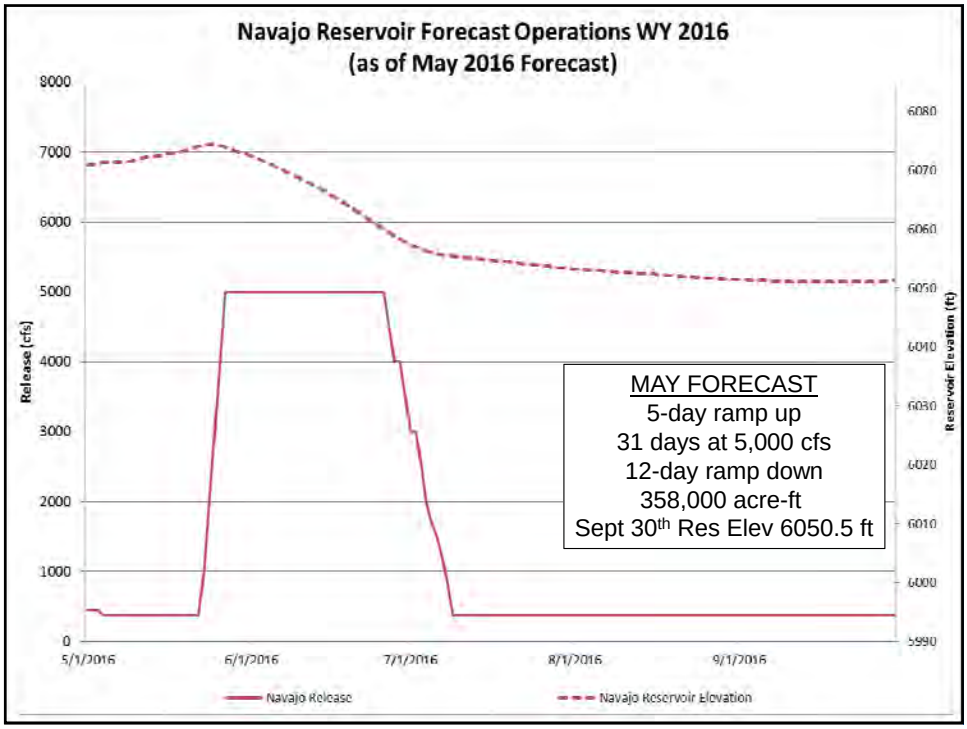

RECLAMATION
Managing Water in the West

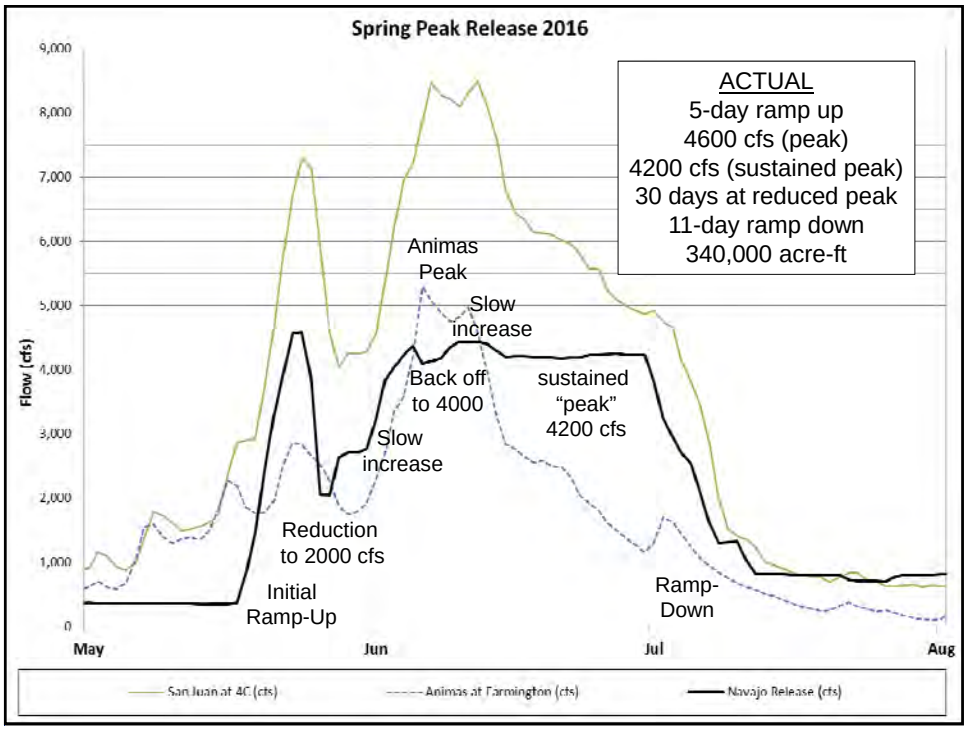
Record of Decision for the Navajo Reservoir Operations, Navajo Unit - San Juan River New Mexico, Colorado, Utah Final Environmental Impact Statement

U.S. Department of the Interior
Bureau of Reclamation

July 2006

RECLAMATION

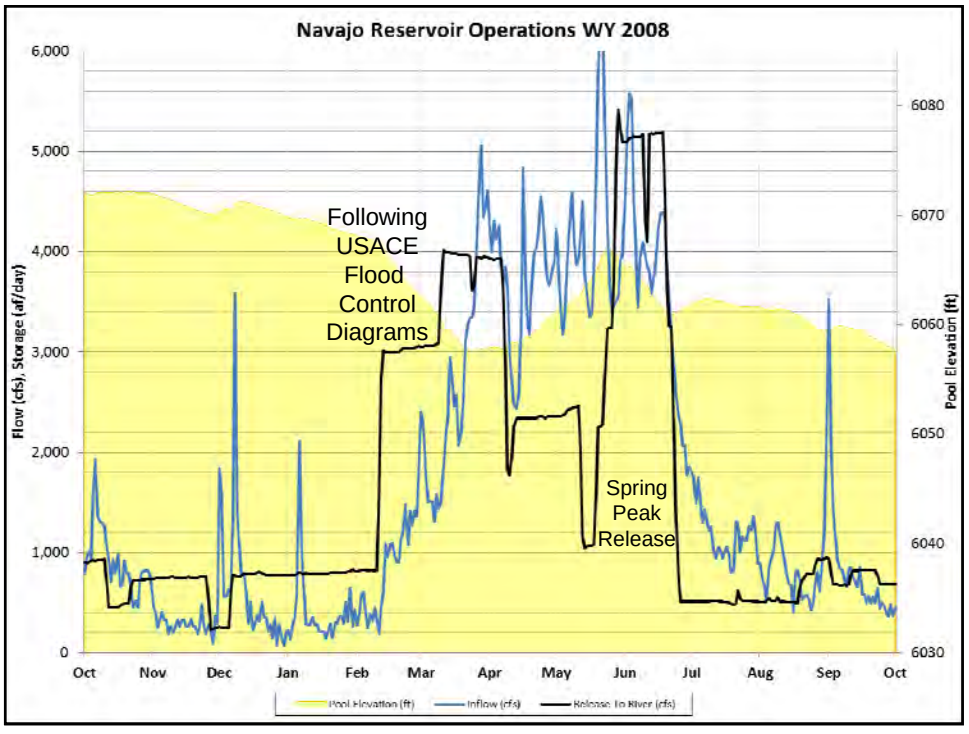

Navajo Reservoir Forecast Operations WY 2016
(as of May 2016 Forecast)
Release (cfs)
Reservoir Elevation (ft)
8000
7000
6000
5000
4000
3000
2000
1000
0
6080
6070
6060
6050
6040
6030
6020
6010
6000
5990
5/1/2016
6/1/2016
7/1/2016
8/1/2016
9/1/2016
Navajo Release
Navajo Reservoir Elevation
MAY FORECAST
5-day ramp up
31 days at 5,000 cfs
12-day ramp down
358,000 acre-ft
Sept 30th Res Elev 6050.5 ft

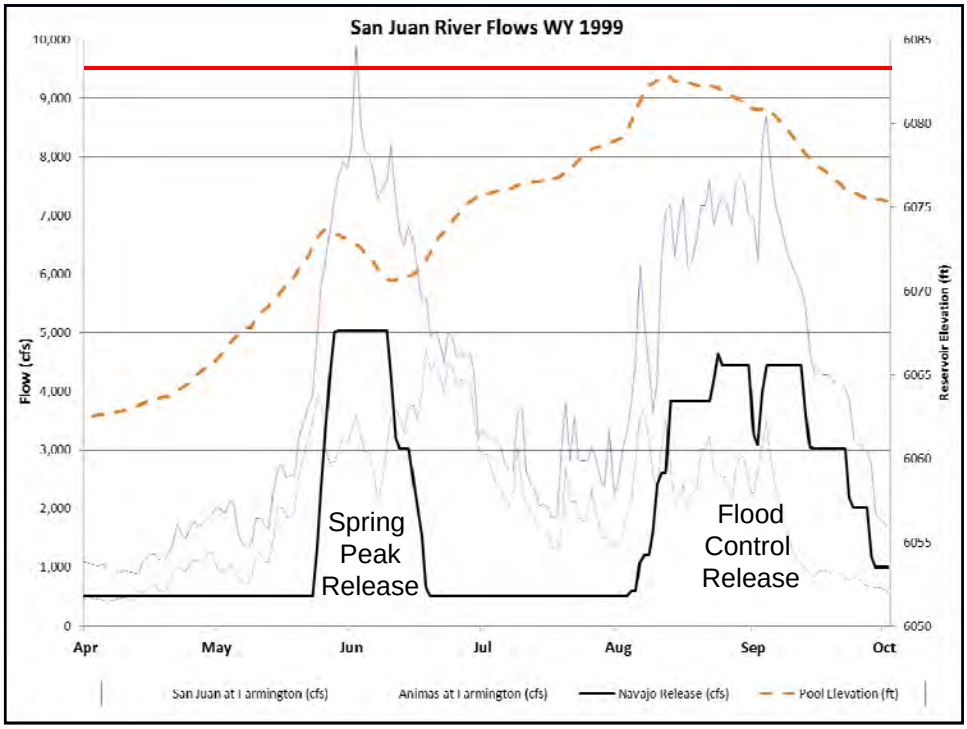

Spring Peak Release 2016
Flow (cfs)
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
May
Jun
Jul
Aug
ACTUAL
5-day ramp up
4600 cfs (peak)
4200 cfs (sustained peak)
30 days at reduced peak
11-day ramp down
340,000 acre-ft
Animas
Peak
Slow
increase
Back off
to 4000
sustained
"peak"
4200 cfs
Slow
increase
Reduction
to 2000 cfs
Initial
Ramp-Up
Ramp-
Down
San Juan at AC (cfs)
Animas at Farmington (cfs)
Navajo Release (cfs)

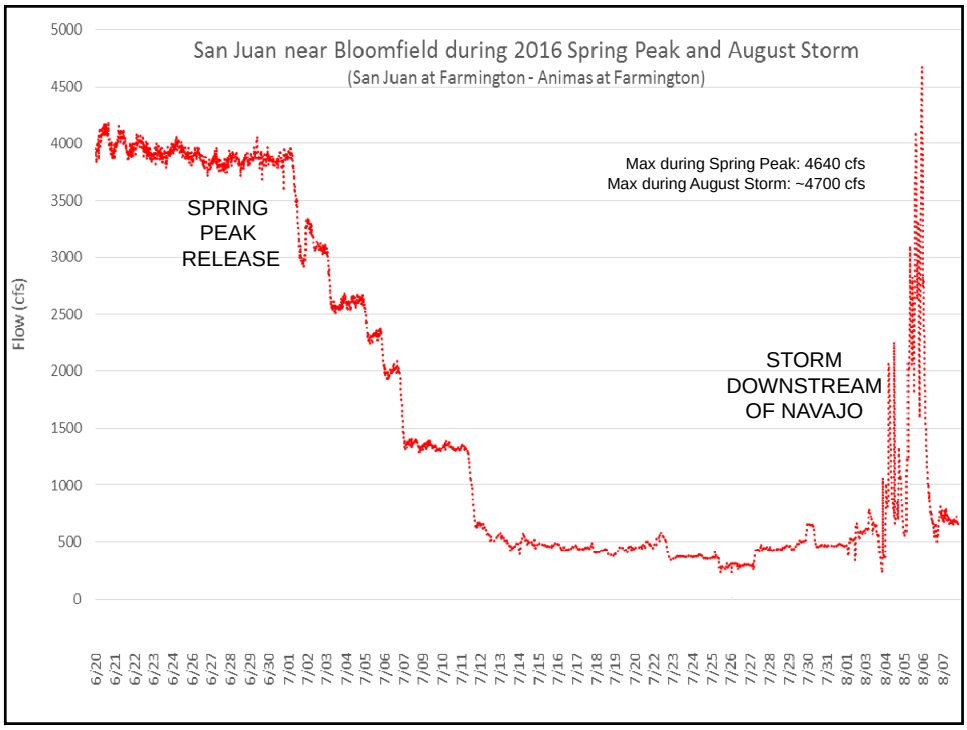
Reservoir Operations

- Water Supply (conserve)
  - target end of year storage of 1.2 – 1.4 million acre-ft
- Flood Control (release)
  - Storage Safety
  - Channel Maintenance
- Endangered Species Act (release)
  - Mimic of natural hydrograph
  - Maintain minimum flows throughout the year
  - System water timed to benefit endangered species

RECLAMATION




San Juan River Flows WY 1999
Flow (cfs)
Reservoir Elevation (ft)
Spring Peak Release
Flood Control Release
Apr
May
Jun
Jul
Aug
Sep
Oct
San Juan at Farmington (cfs)
Animas at Farmington (cfs)
Navajo Release (cfs)
Pool Elevation (ft)


San Juan near Bloomfield during 2016 Spring Peak and August Storm
(San Juan at Farmington - Animas at Farmington)
Flow (cfs)
Max during Spring Peak: 4640 cfs
Max during August Storm: ~4700 cfs
SPRING PEAK RELEASE
STORM DOWNSTREAM OF NAVAJO

Public Outreach

- ANNUAL COORDINATION MEETINGS
  - Jan-Apr-Aug
  - Open to the Public

- RELEASE NOTICES
  - Email list
    (to be added, email rswickard@usbr.gov)
  - Website
    (http://www.usbr.gov/uc/wcao/water/rsvrs/notice/nav_rel.html)
  - Contact Us Directly
    Susan Behery 970-385-6560 (sbehery@usbr.gov)
    WCAO Main Office 970-385-6500

RECLAMATION

RECLAMATION

Managing Water in the West

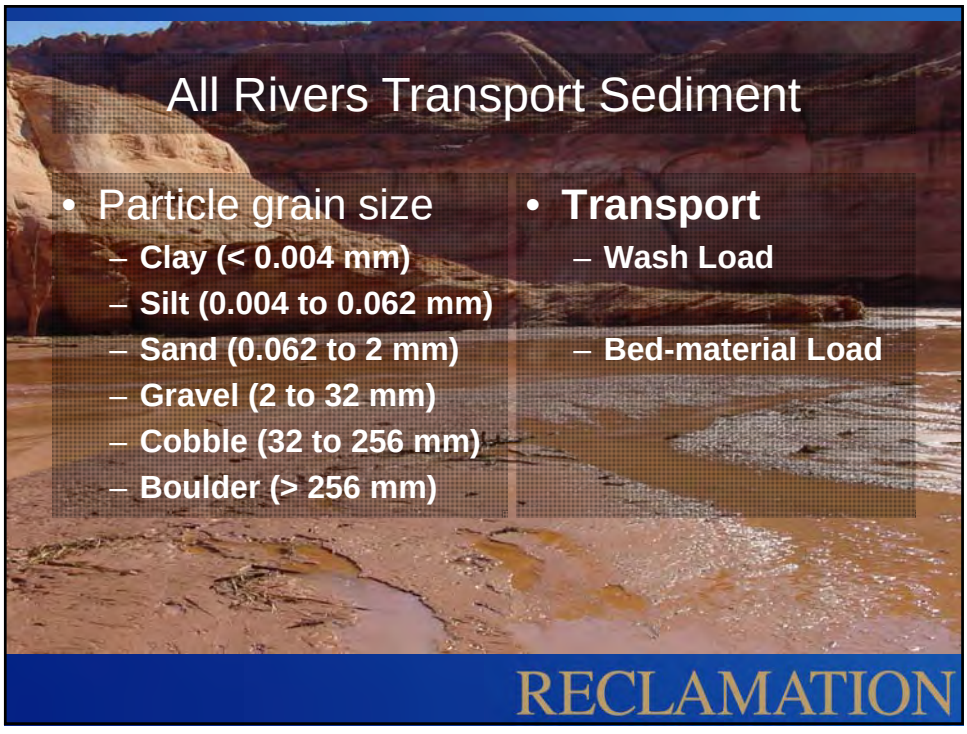
River Channel Processes and Flow Conveyance

Tim Randle, Ph.D., P.E., D.WRE, Civil Engineer and Group Manager

David Varyu, M.S., P.E., Civil Engineer

Sedimentation and River Hydraulics Group

U.S. Department of the Interior
Bureau of Reclamation



VDR1

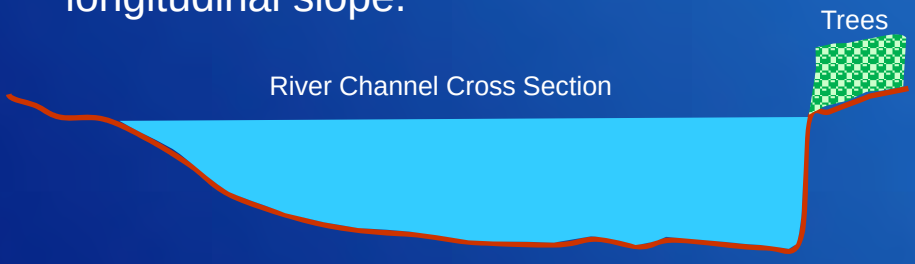
River Flow Conveyance

- Channel conveyance capacity is the maximum flow rate that can pass without overtopping the channel banks.

RECLAMATION

River Flow Conveyance

- River stage is a function of the flow rate, channel geometry, roughness, and the longitudinal slope.



Flow rate = (Flow Velocity) × (Cross-Sectional Flow Area)

RECLAMATION

River Flow Conveyance

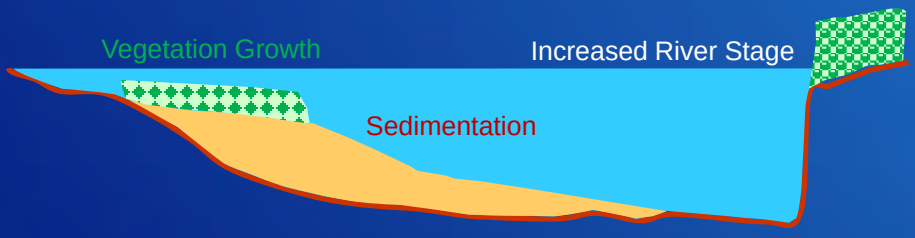
- River stage is a function of the flow rate, channel geometry, roughness, and the longitudinal slope.

Flow rate = (Flow Velocity) × (Cross-Sectional Flow Area)

RECLAMATION

River Flow Conveyance

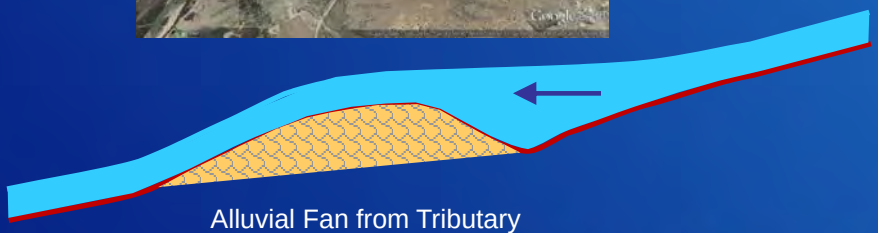
- River stage is a function of the flow rate, channel geometry, roughness, and the longitudinal slope.



Flow rate = (Flow Velocity) × (Cross-Sectional Flow Area)

RECLAMATION

Coarse sediments from tributaries can locally increase water surface.



Alluvial Fan from Tributary

RECLAMATION

VDR2

Changes in channel alignment will affect the longitudinal slope.

RECLAMATION

River Flow Conveyance (continued)

- Even for a given flow rate, river stage will change with changes in channel geometry, roughness, and the longitudinal slope.
  - Sediment deposits on the channel bottom, bars, and the floodplain will increase river stage.
  - Increased roughness from vegetation will increase river stage and promote sediment deposition.

RECLAMATION

River Flow Conveyance (continued)

- Even for a given flow rate, river stage will change with changes in channel geometry, roughness, and the longitudinal slope.
  - Longer flow paths from river meandering will slow velocity and increase river stage.

RECLAMATION

VDR5

River Width, Depth, and Flow Alignment

- The width, depth, and alignment of a river are a function of the water flow, sediment load, vegetation, and geologic and human-built constraints.
- Rivers are naturally dynamic and change with time, especially during floods.

RECLAMATION

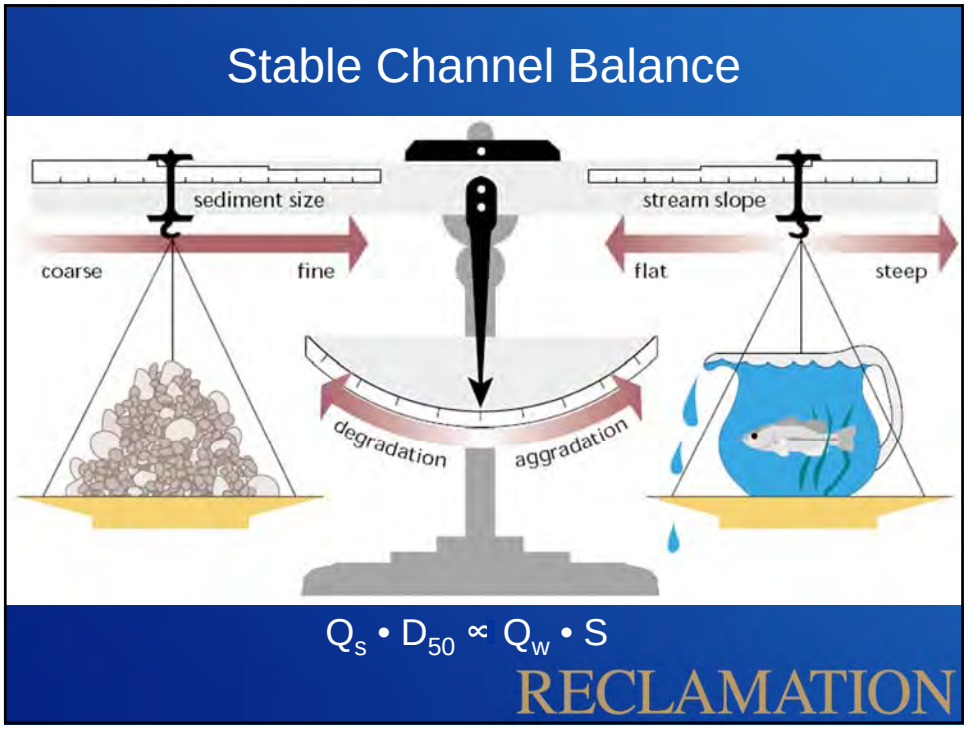
Rio Grande Example

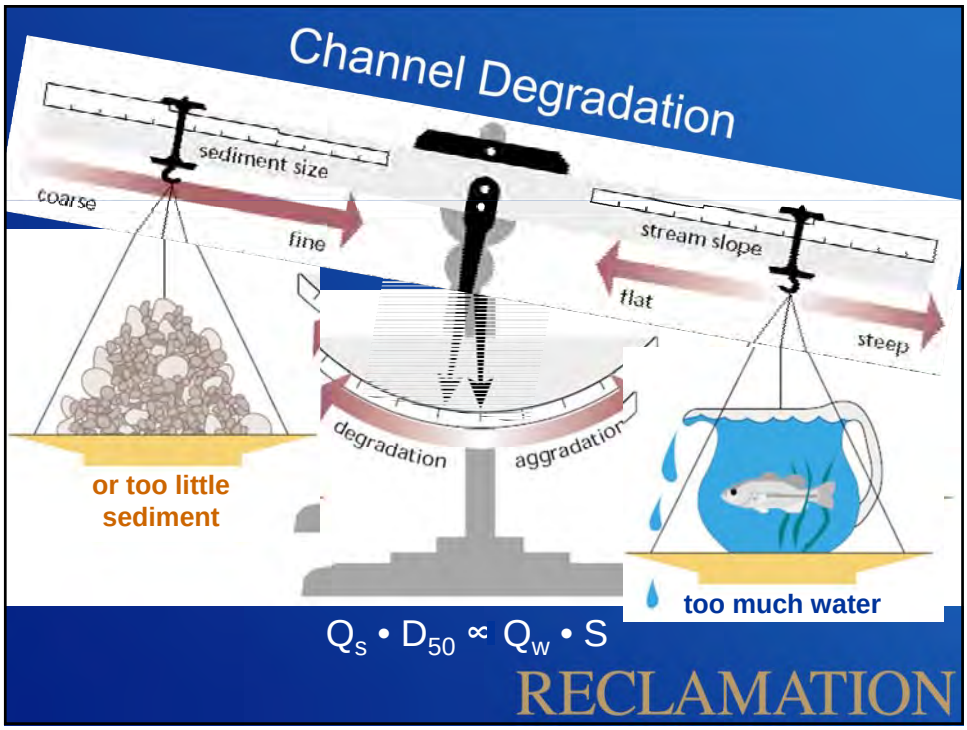
1953

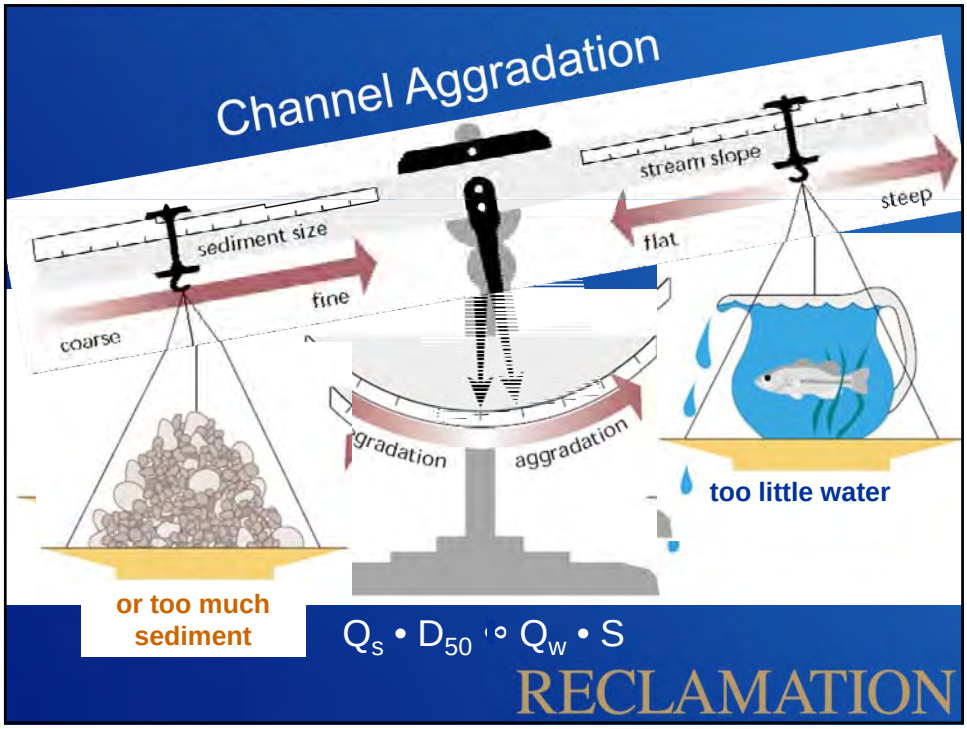
2013

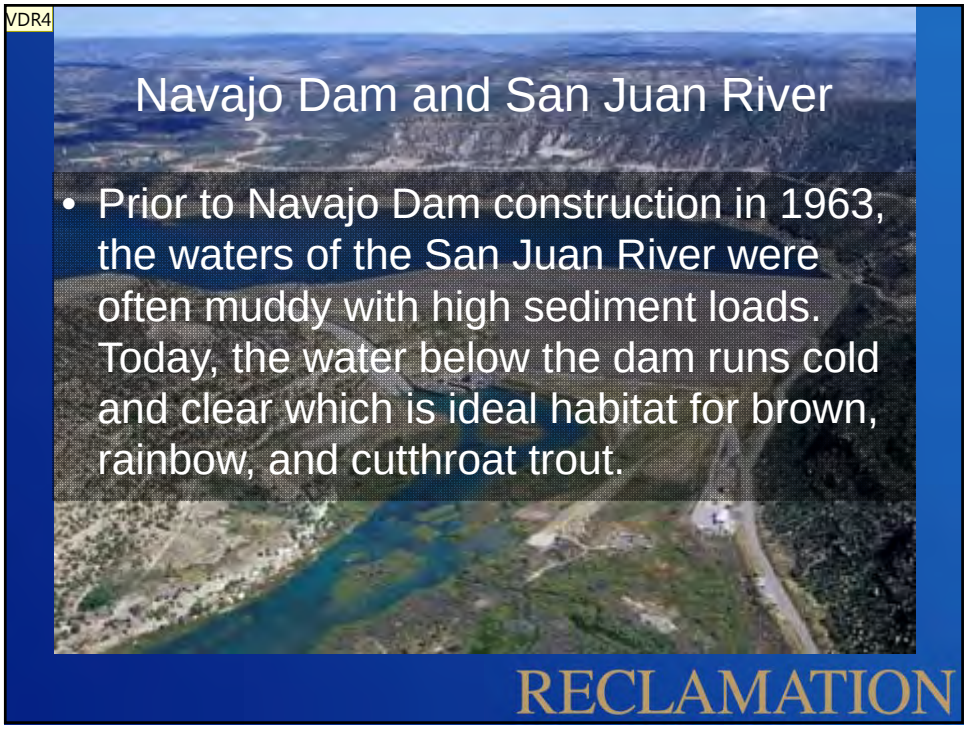
RM 101 (looking downstream)

RECLAMATION

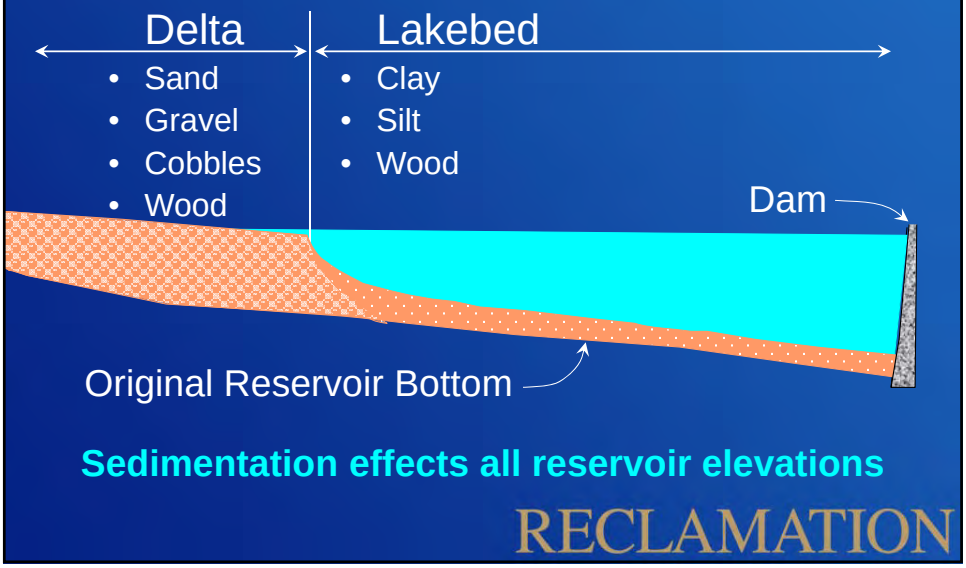

Stable Channel Balance
sediment size
coarse
fine
stream slope
flat
steep
degradation
aggradation
$Q_s \bullet D_{50} \propto Q_w \bullet S$
RECLAMATION


Channel Degradation
sediment size
coarse
fine
stream slope
flat
steep
degradation
aggradation
or too little sediment
too much water
$Q_s \bullet D_{50} \propto Q_w \bullet S$
RECLAMATION


Channel Aggradation
sediment size
fine
coarse
stream slope
steep
flat
gradation
aggradation
too little water
or too much sediment
$Q_s \bullet D_{50} \propto Q_w \bullet S$
RECLAMATION


VDR4
Navajo Dam and San Juan River
• Prior to Navajo Dam construction in 1963, the waters of the San Juan River were often muddy with high sediment loads. Today, the water below the dam runs cold and clear which is ideal habitat for brown, rainbow, and cutthroat trout.
RECLAMATION

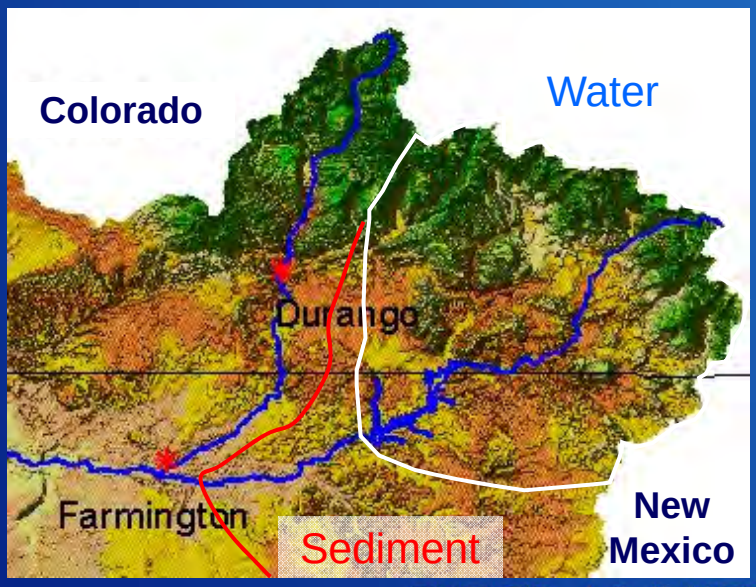
Reservoir Sediment Profile



Sedimentation effects all reservoir elevations

RECLAMATION

Watershed Sources of Water & Sediment



RECLAMATION

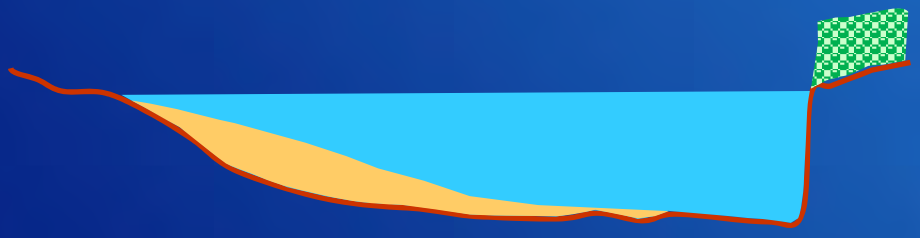
Seasonal Channel Changes

- Initial conditions.

RECLAMATION

Seasonal Channel Changes

- High flow releases from Navajo Dam.



RECLAMATION

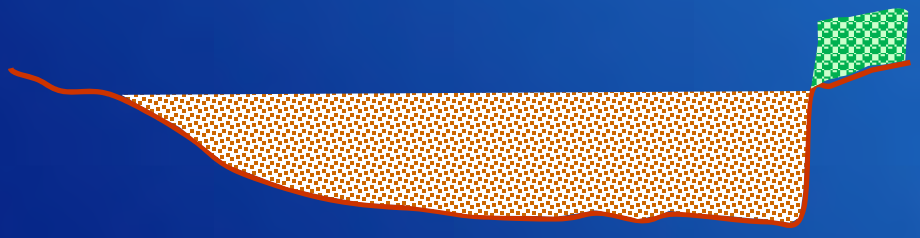
Seasonal Channel Changes

- After high flow releases.

RECLAMATION

Seasonal Channel Changes

- Tributary monsoon floods bring sediment.



RECLAMATION

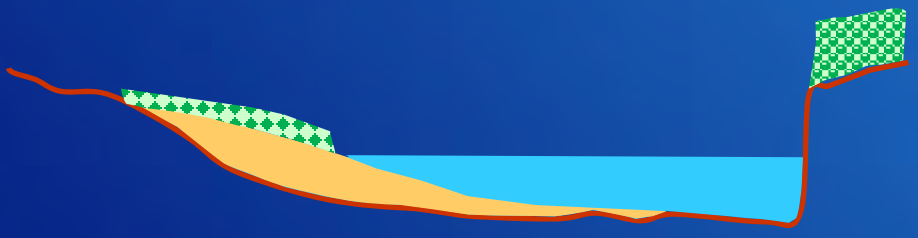
Seasonal Channel Changes

- End of year conditions.

RECLAMATION

Seasonal Channel Changes

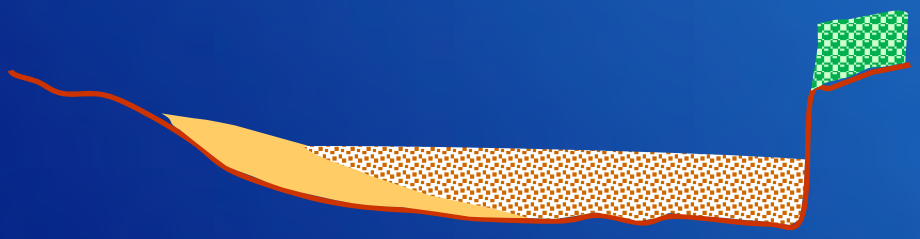
- If there were no high flow releases from Navajo Dam.



RECLAMATION

Seasonal Channel Changes

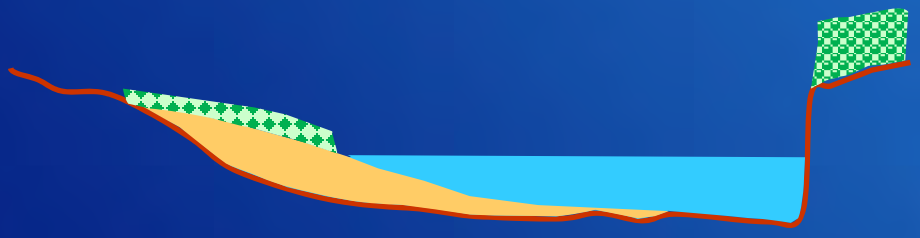
- and only small tributary monsoon flows.



RECLAMATION

Seasonal Channel Changes

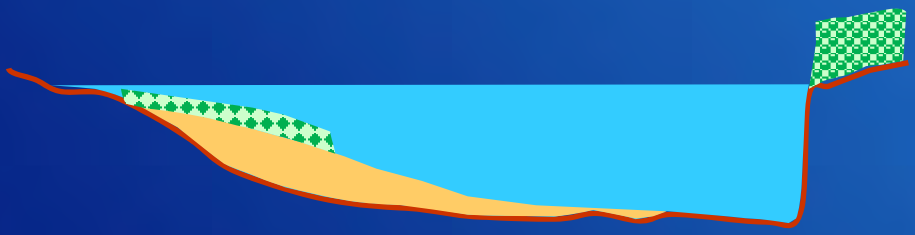
- End of year conditions.



RECLAMATION

Seasonal Channel Changes

- Next year high flow releases from Navajo Dam with a small reduction in safe channel capacity.



RECLAMATION

Seasonal Channel Changes

- After high flow releases.

RECLAMATION

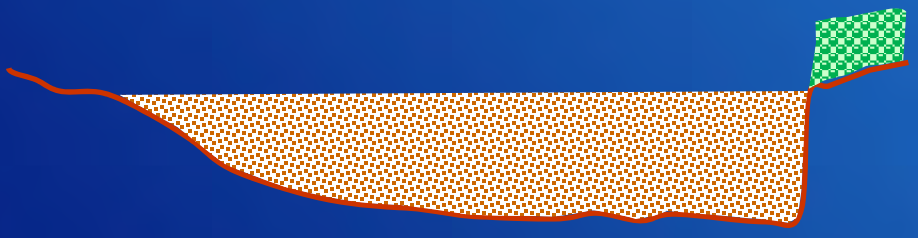
Seasonal Channel Changes

- If there were no high flow releases from Navajo Dam.

RECLAMATION

Seasonal Channel Changes

- and tributary monsoon floods bring a lot of sediment.



RECLAMATION

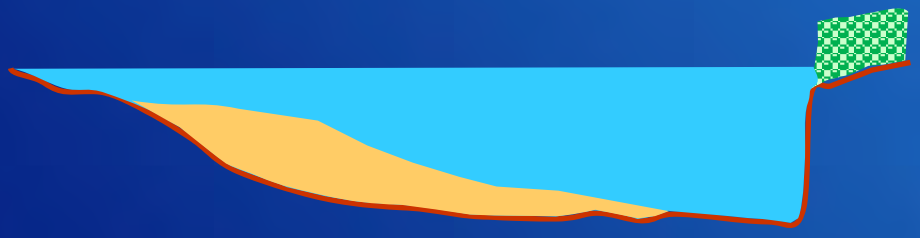
Seasonal Channel Changes

- End of year conditions with more sediment deposition.

RECLAMATION

Seasonal Channel Changes

- Subsequent year high flow releases from Navajo Dam could begin to exceed the channel capacity.



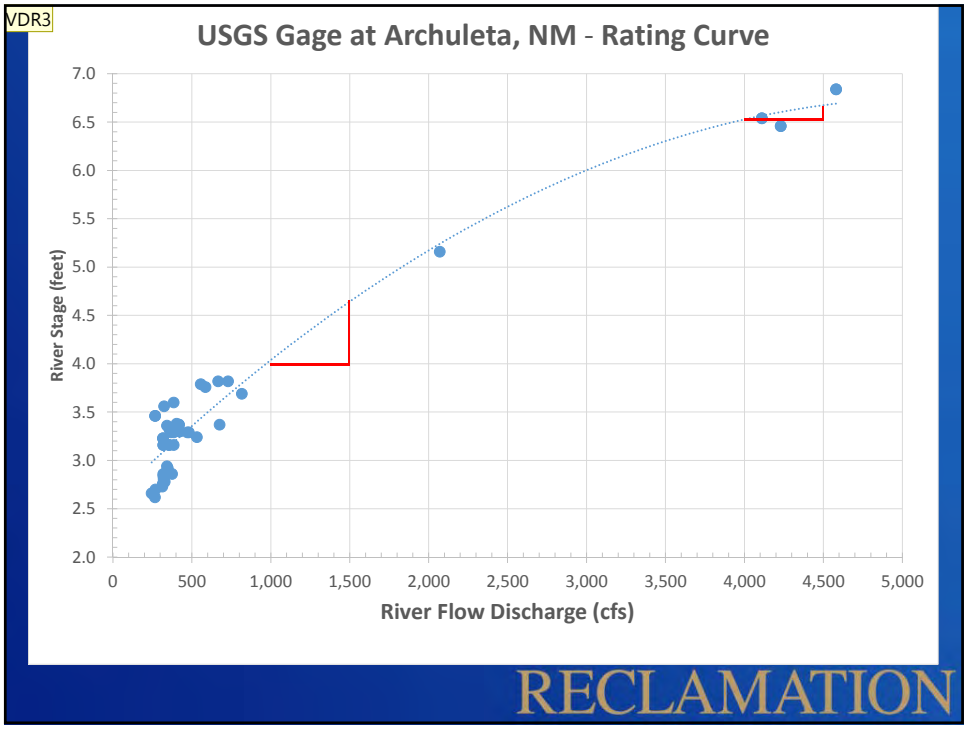
RECLAMATION

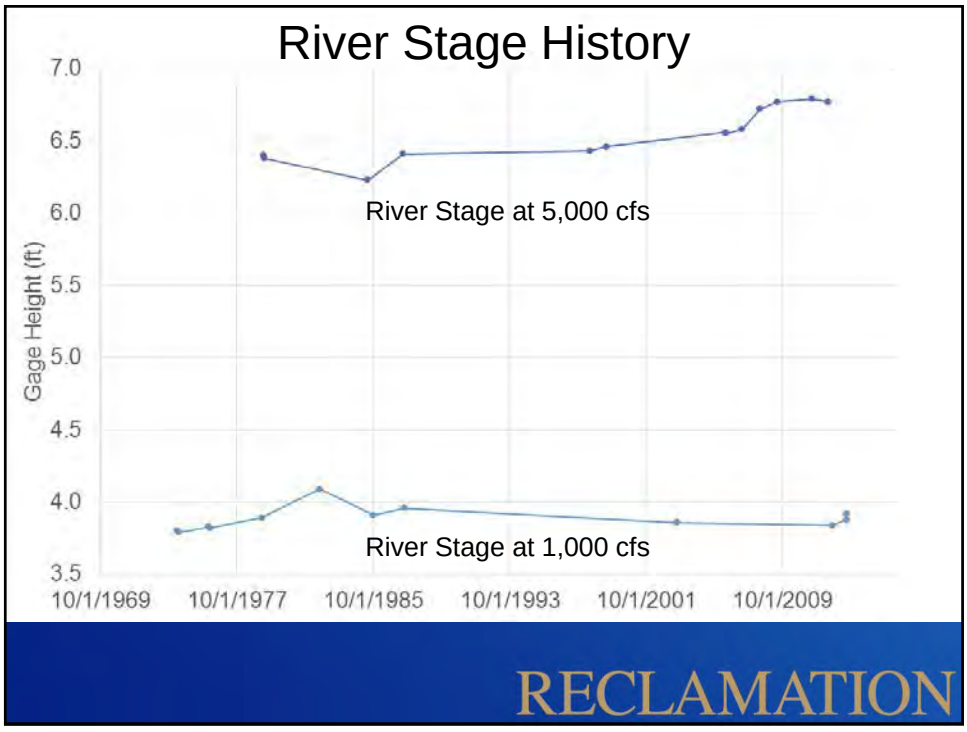
Tributaries Between Navajo Dam and USGS Stream Gage at Archuleta

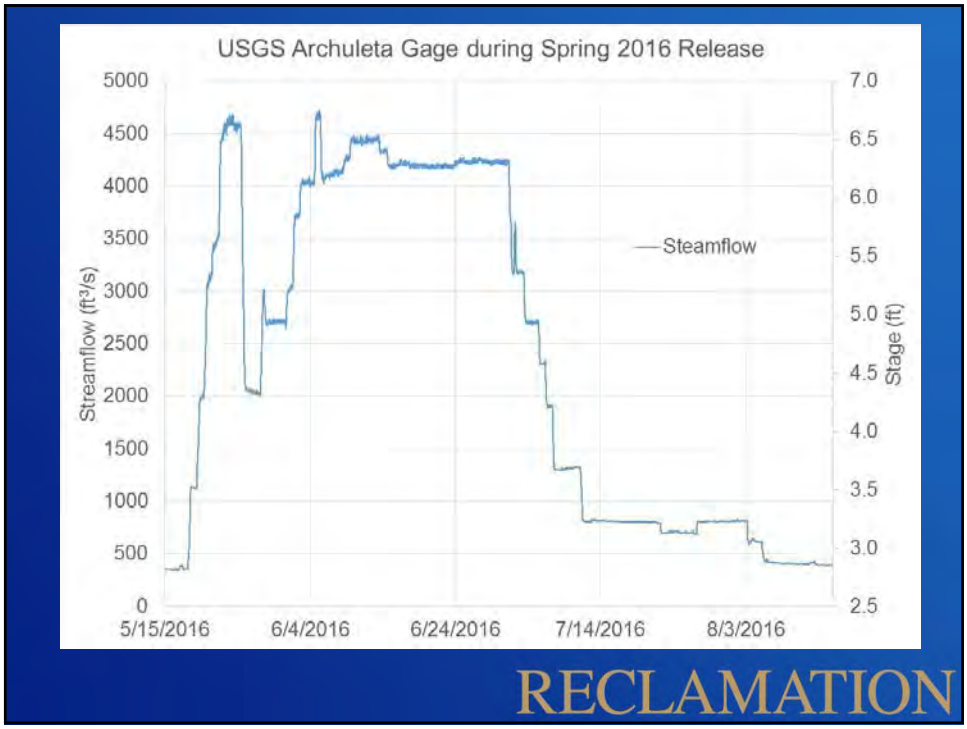
RECLAMATION

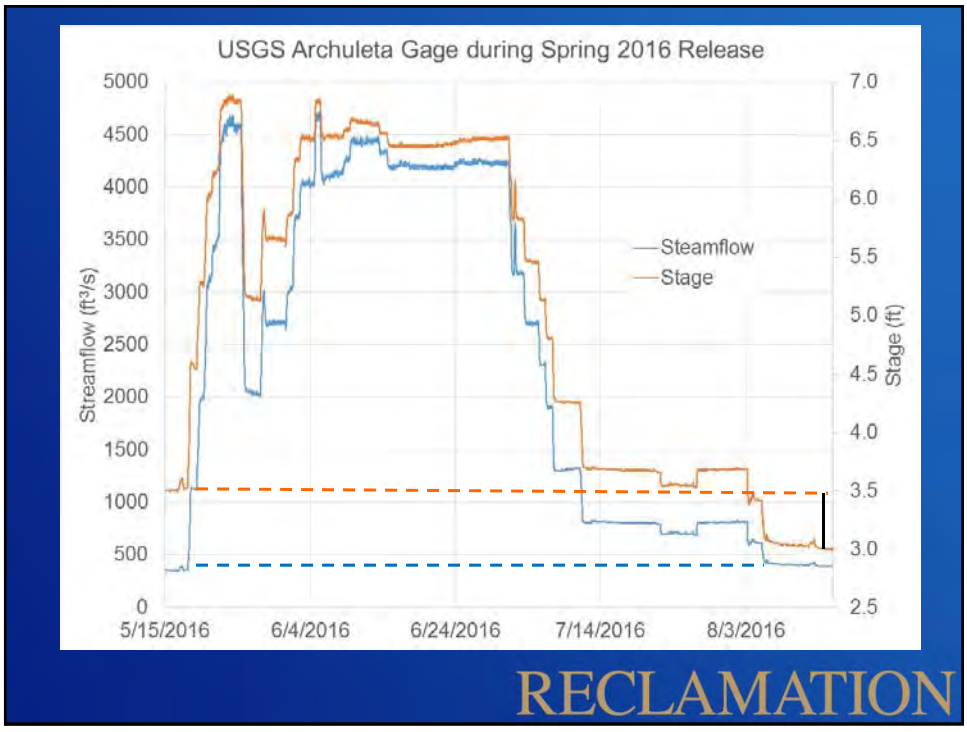
USGS Stream Gage at Archuleta

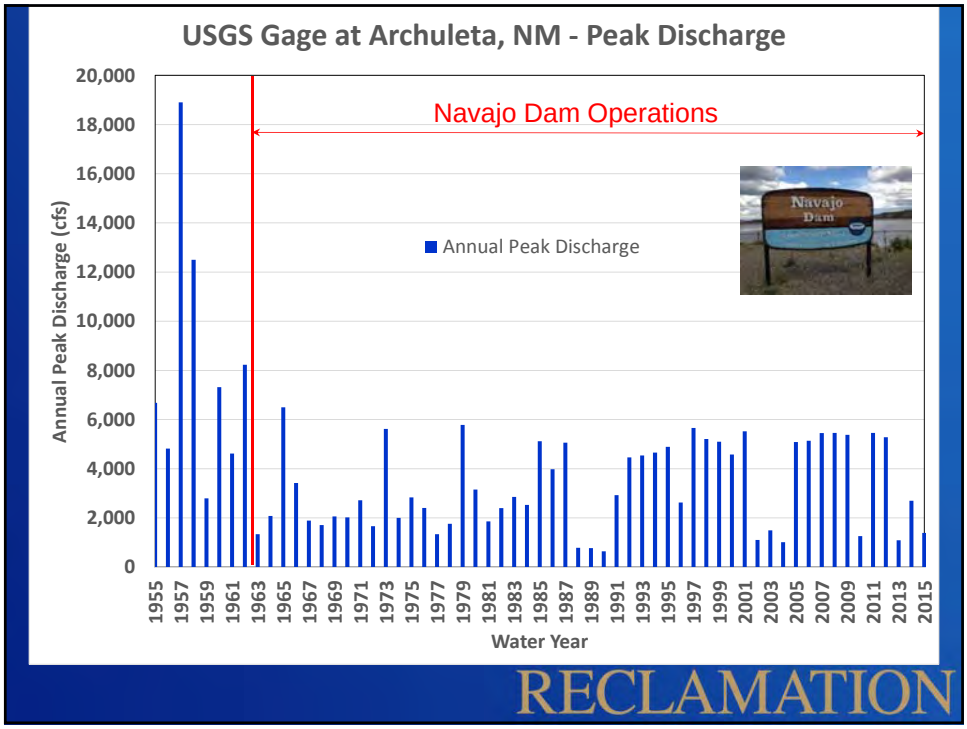
RECLAMATION

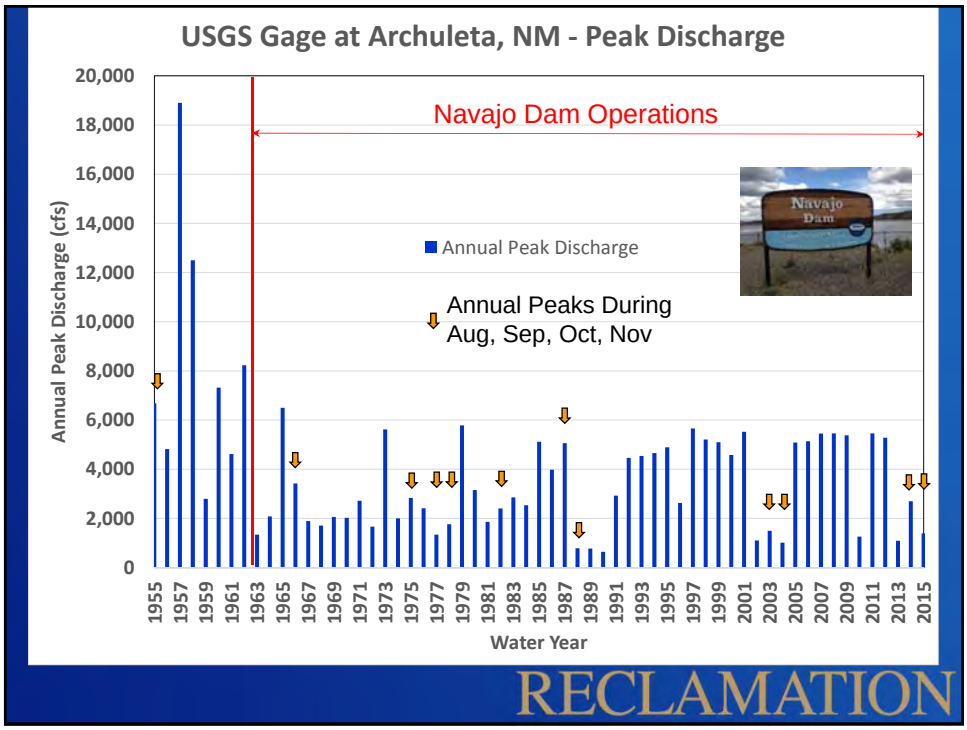

VDR3
USGS Gage at Archuleta, NM - Rating Curve
River Stage (feet)
River Flow Discharge (cfs)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
RECLAMATION


River Stage History
Gage Height (ft)
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
River Stage at 5,000 cfs
River Stage at 1,000 cfs
10/1/1969
10/1/1977
10/1/1985
10/1/1993
10/1/2001
10/1/2009
RECLAMATION


USGS Archuleta Gage during Spring 2016 Release
Streamflow (ft³/s)
Stage (ft)
Steamflow
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
5/15/2016
6/4/2016
6/24/2016
7/14/2016
8/3/2016
RECLAMATION


USGS Archuleta Gage during Spring 2016 Release
Streamflow (ft³/s)
Stage (ft)
Steamflow
Stage
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
5/15/2016
6/4/2016
6/24/2016
7/14/2016
8/3/2016
RECLAMATION


USGS Gage at Archuleta, NM - Peak Discharge
Navajo Dam Operations
Annual Peak Discharge
Annual Peak Discharge (cfs)
Water Year
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1955 1957 1959 1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
RECLAMATION


USGS Gage at Archuleta, NM - Peak Discharge
Navajo Dam Operations
Annual Peak Discharge
Annual Peaks During
Aug, Sep, Oct, Nov
Annual Peak Discharge (cfs)
Water Year
20,000
18,000
16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
1955 1957 1959 1961 1963 1965 1967 1969 1971 1973 1975 1977 1979 1981 1983 1985 1987 1989 1991 1993 1995 1997 1999 2001 2003 2005 2007 2009 2011 2013 2015
RECLAMATION

Recent San Juan River Observations

RECLAMATION

Recent San Juan River Observations

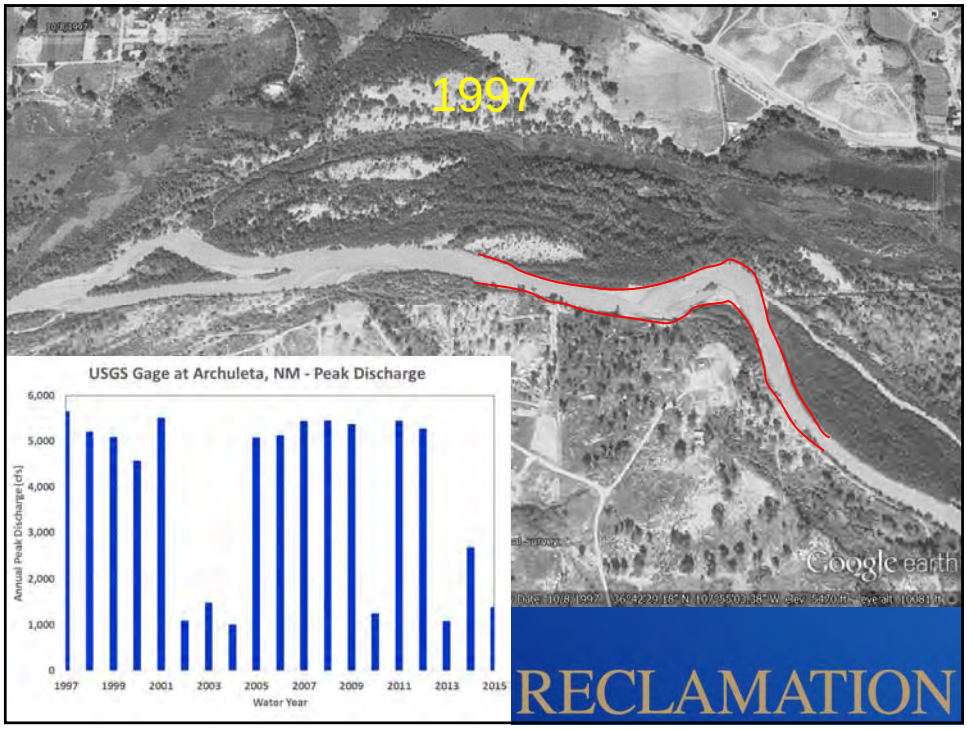
RECLAMATION

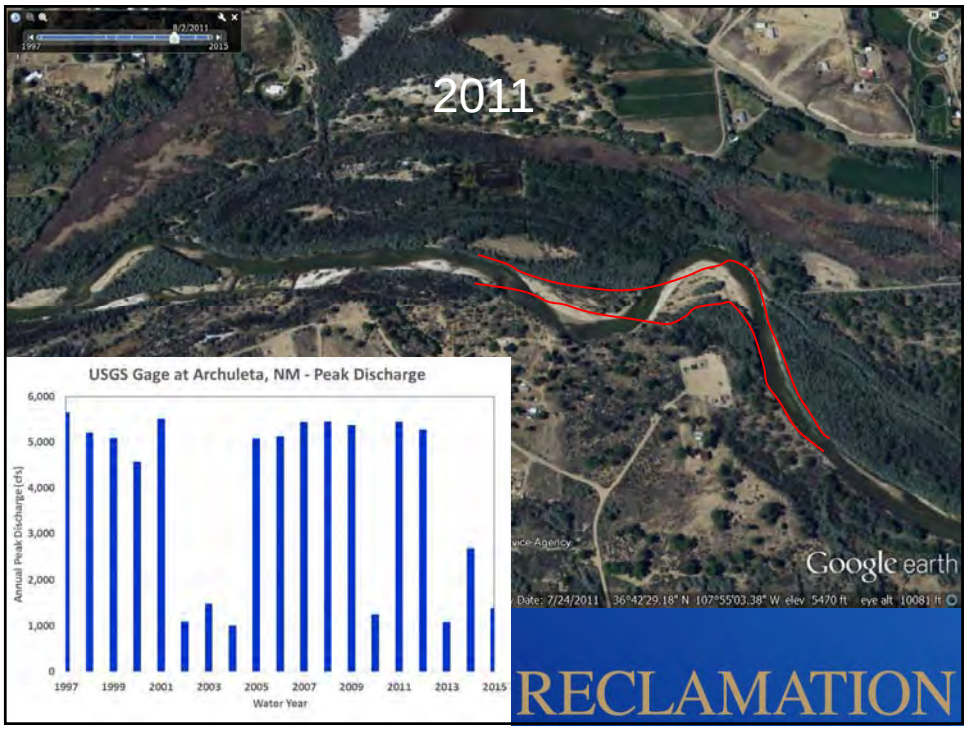
Recent San Juan River Observations

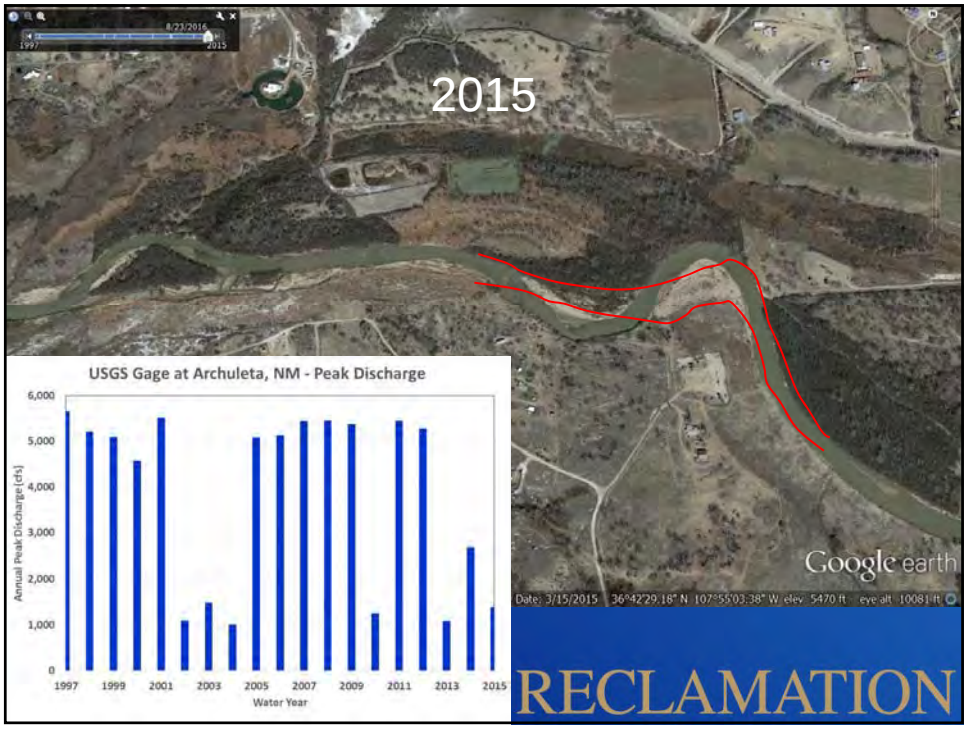
RECLAMATION

Recent San Juan River Observations

RECLAMATION


1997
USGS Gage at Archuleta, NM - Peak Discharge
Annual Peak Discharge (cfs)
6,000
5,000
4,000
3,000
2,000
1,000
0
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Water Year
Google earth
RECLAMATION


2011
USGS Gage at Archuleta, NM - Peak Discharge
Annual Peak Discharge (cfs)
6,000
5,000
4,000
3,000
2,000
1,000
0
1997
1999
2001
2003
2005
2007
2009
2011
2013
2015
Water Year
Google earth
RECLAMATION



Recent San Juan River Observations

RECLAMATION

Recent San Juan River Observations

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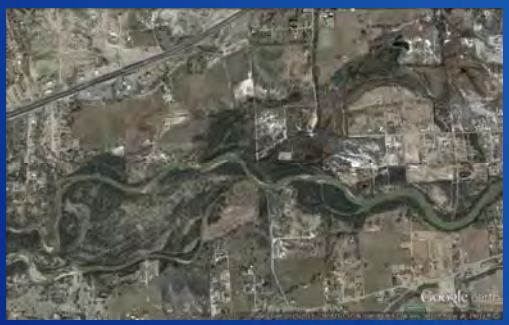
Conclusions

- Long-term maintenance of the channel capacity means that sediment loads from downstream tributaries be balanced with Navajo Dam flow releases.
- Stream bank erosion and channel migration are natural processes. Rates of channel migration can be accelerated by woody vegetation removal.

RECLAMATION

Conclusions

- Structures built in the floodplain are subject to flood inundation, erosion, and sediment deposition, even from tributary floods.



RECLAMATION

The End

Navajo Dam & Reservoir

RECLAMATION

Channel Capacity Downstream of Navajo Dam

Presented to

Navajo Operations Coordination Meeting

23 August 2016

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San Juan Basin Coordinator

US Army Corps of Engineers
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Channel Capacity Downstream of Navajo Dam

- Navajo Dam and Reservoir
- Channel Capacities San Juan
  - Historical Channel Capacities
- Water Operations of Navajo Reservoir (1977-2016)
- Flood Risk Management

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Navajo Dam and Reservoir

Reclamation Owned and Operated

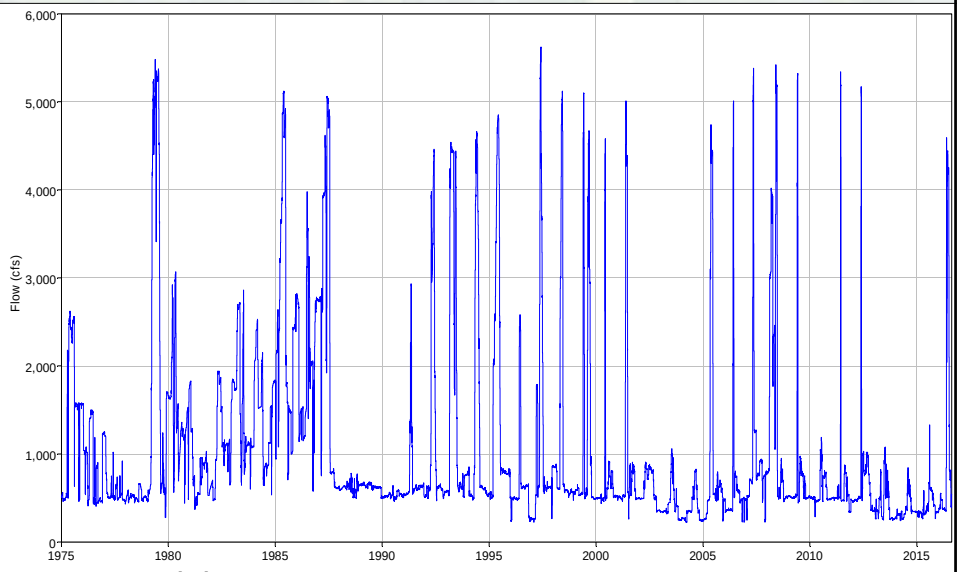
- Authorized for
  - Irrigation
  - Municipal & Industrial
  - Flood Control
  - Hydropower
  - Sediment Control
- USACE responsibilities
  - Flood Control Operation according to Section 7 of the Flood Control Act of 1944
  - Established Channel Capacities and Flood Control Plan for San Juan River

Navajo Dam

Historical Channel Capacities of San Juan River

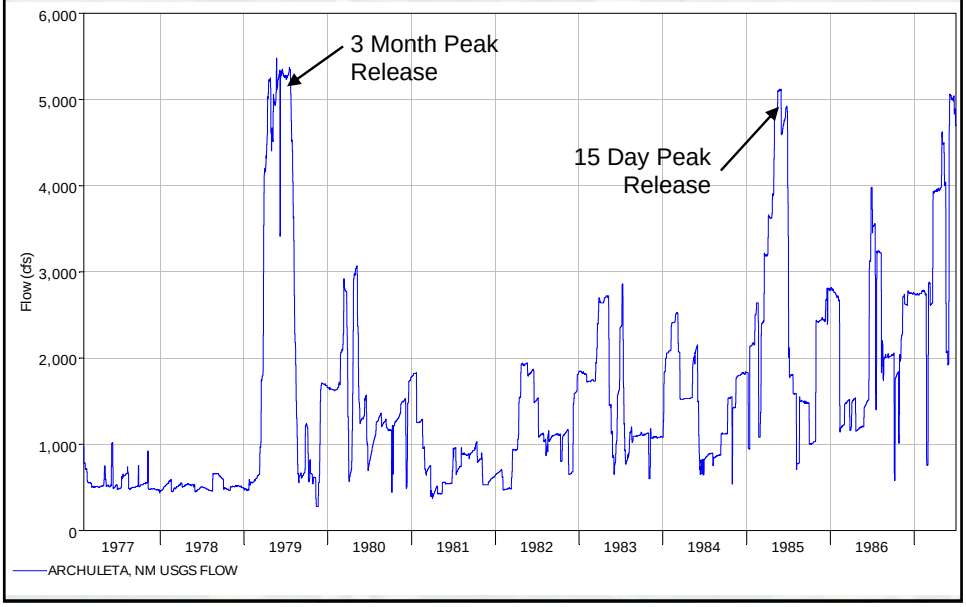
Date	River Locations Blanco (cfs)	Farmington (cfs)	Shiprock (cfs)
1958 (Benefits of Flood Control)	20,000	21,000	22,000
1970 (USACE WCM)	16,000	16,800	17,600
1984 (USACE Feasibility Study)	-	14,000	-
1985 (USBR Navajo SOP)	5,000	12,000	12,000

Navajo Reservoir Water Operations (1975-2016)

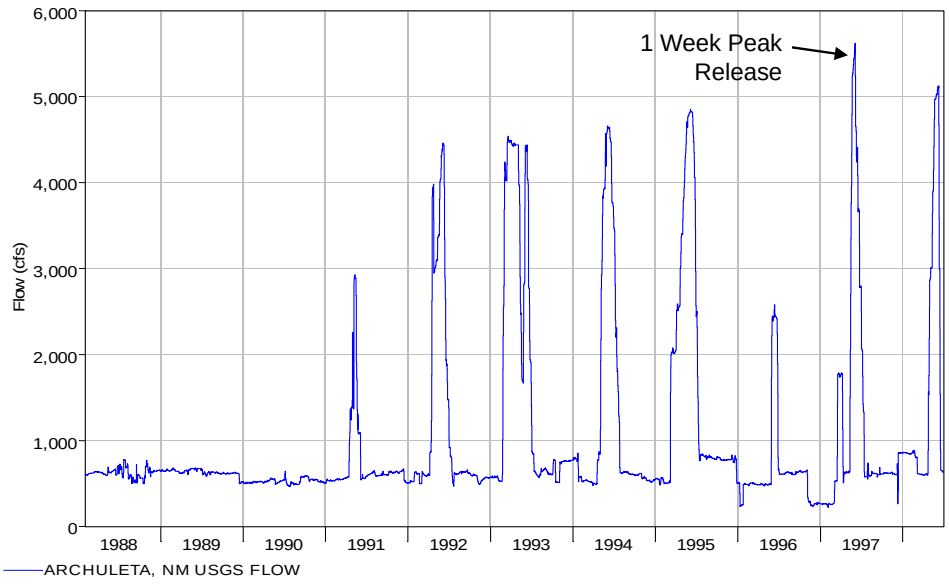


- **Per USGS Archuleta Gage**

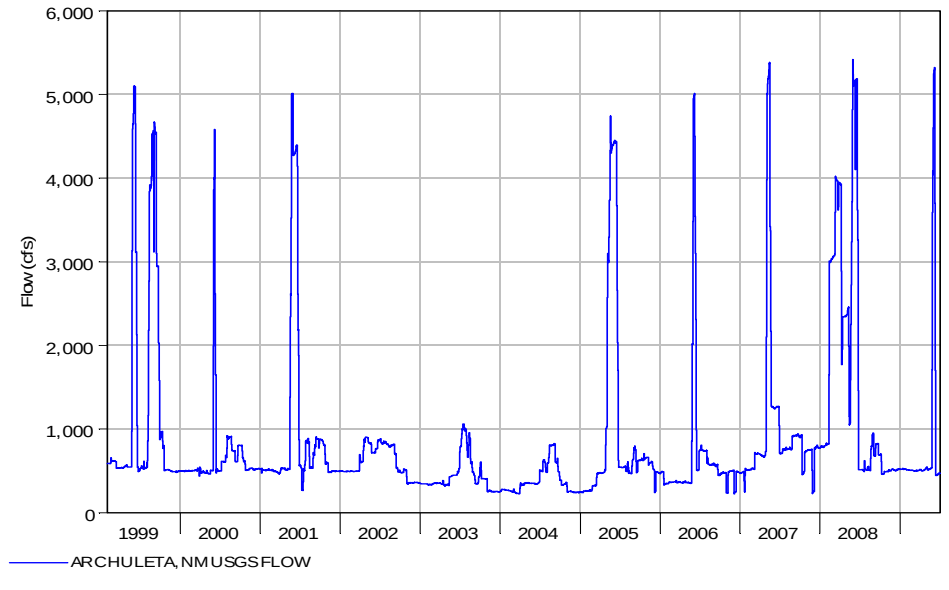
Navajo Reservoir Water Operations (1977-1987)



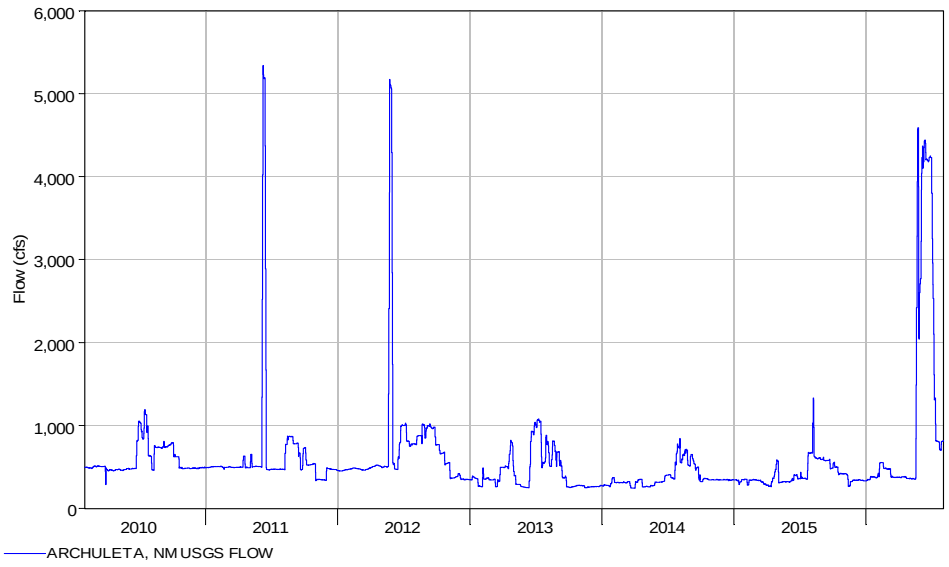
Navajo Reservoir Water Operations (1988-1998)



Navajo Reservoir Water Operations (1999-2009)



Navajo Reservoir Water Operations (2010-2016)



Flood Risk Management and Channel Capacity

- Current Water Control Plan requires 5,000cfs releases
- Channel Capacity needed to avoid uncontrolled spill
- Reduced Channel Capacity and Dam Safety

Navajo Dam Flood Control Diagram