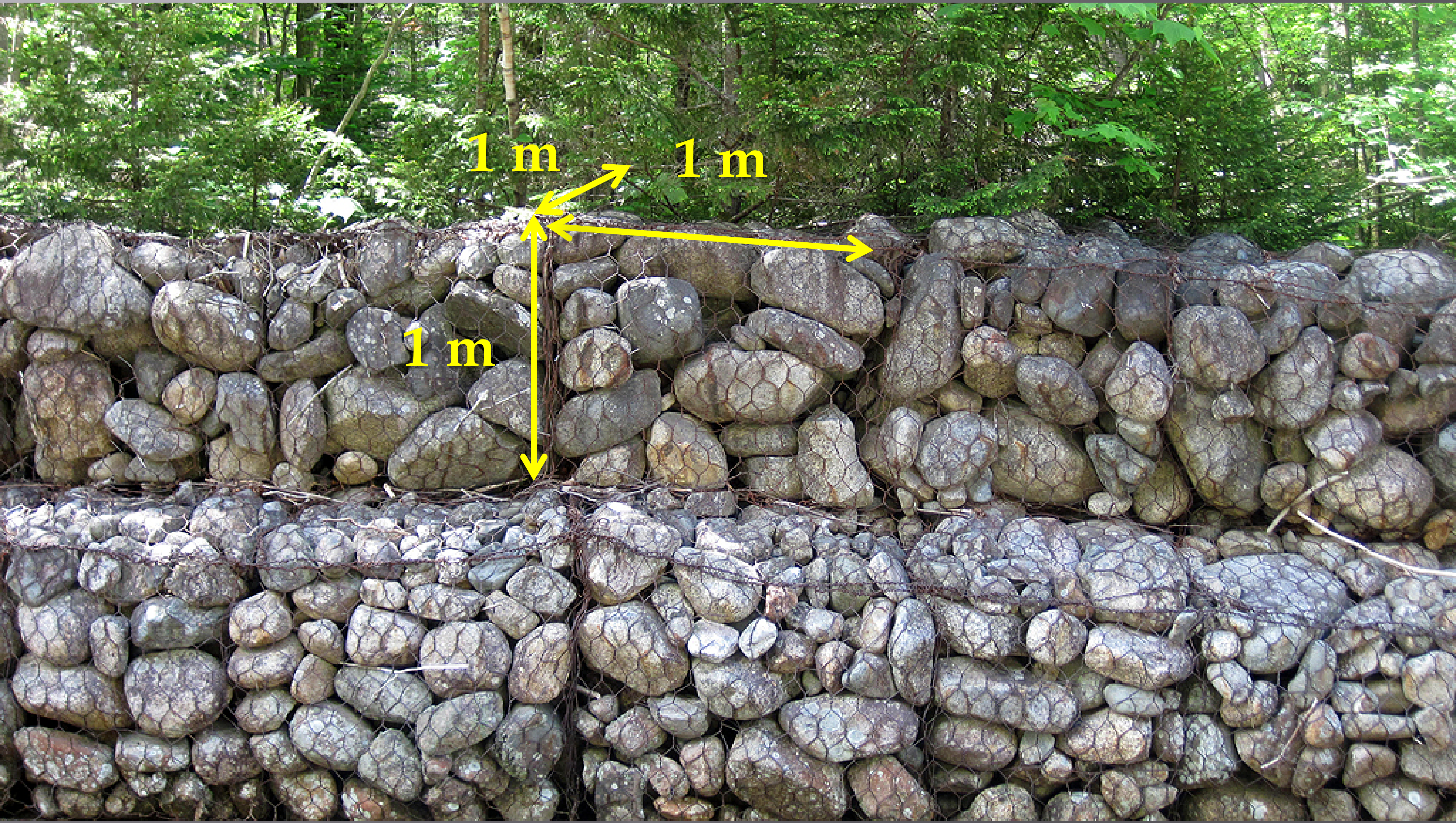
The Role of Channel Armoring with Gabions on Channel Adjustments on the Zealand River, New Hampshire

Douglas M. Thompson, Leah S. Puklin and Anna E. Marshall

Connecticut College

Gabion?

Rock-filled wire-mesh basket




Project Construction
1960-1963
Gabion walls
4.5 km long reach
1,724 m
4,870 m^3 of fill
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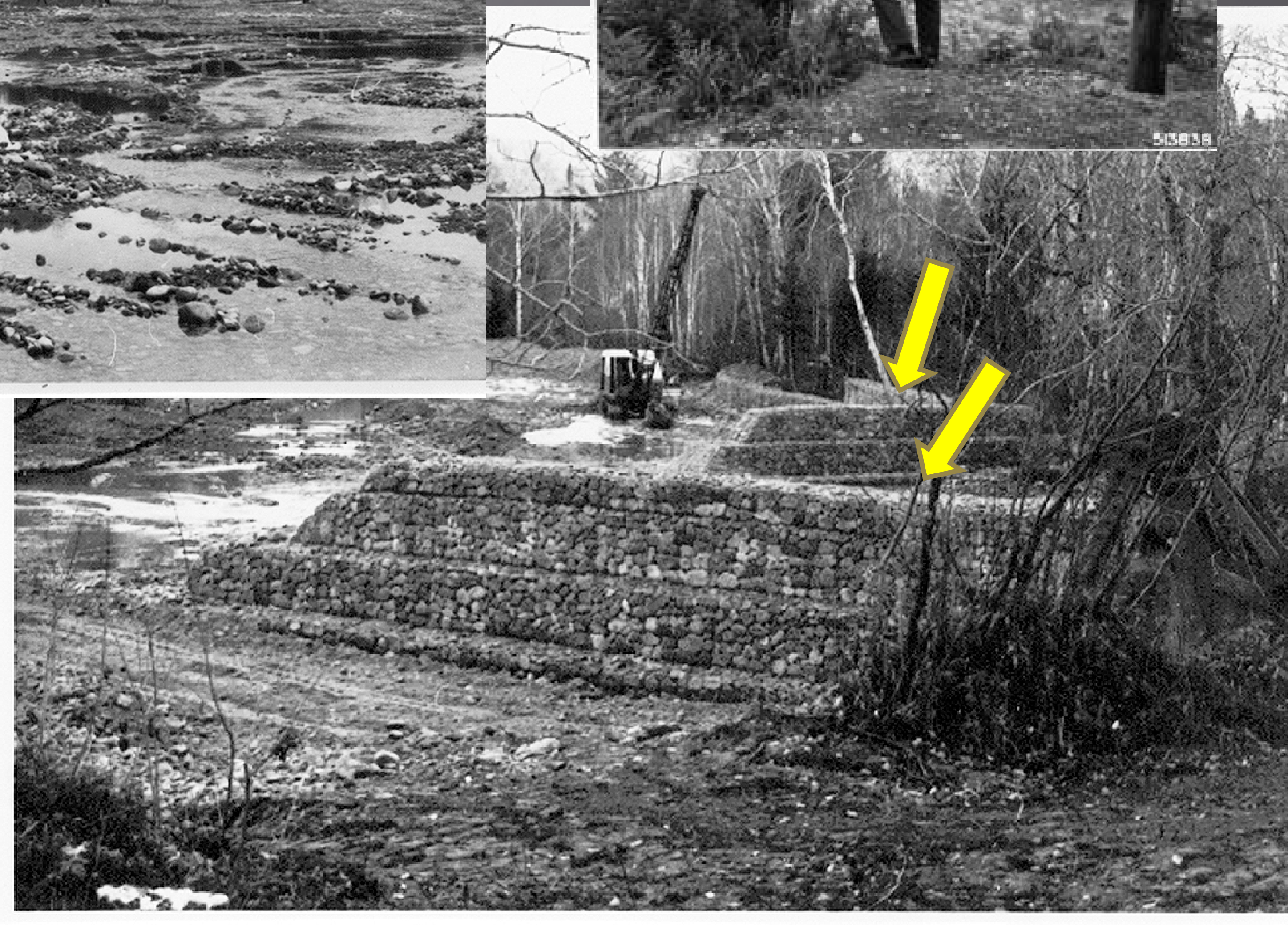
Gabion deflectors

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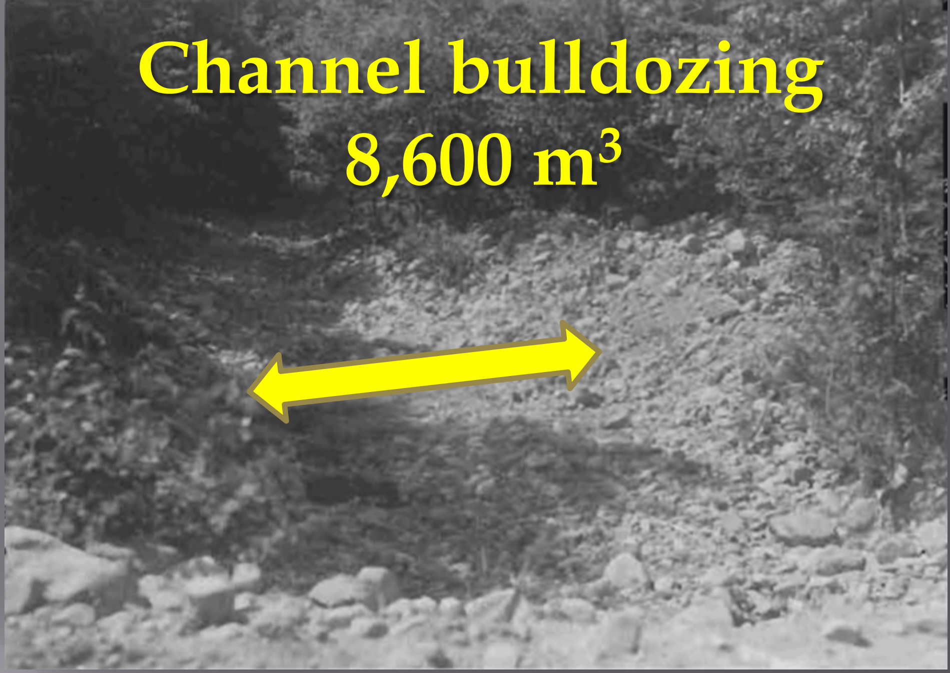
Gabion sills
405 m


Channel bulldozing
8,600 m^3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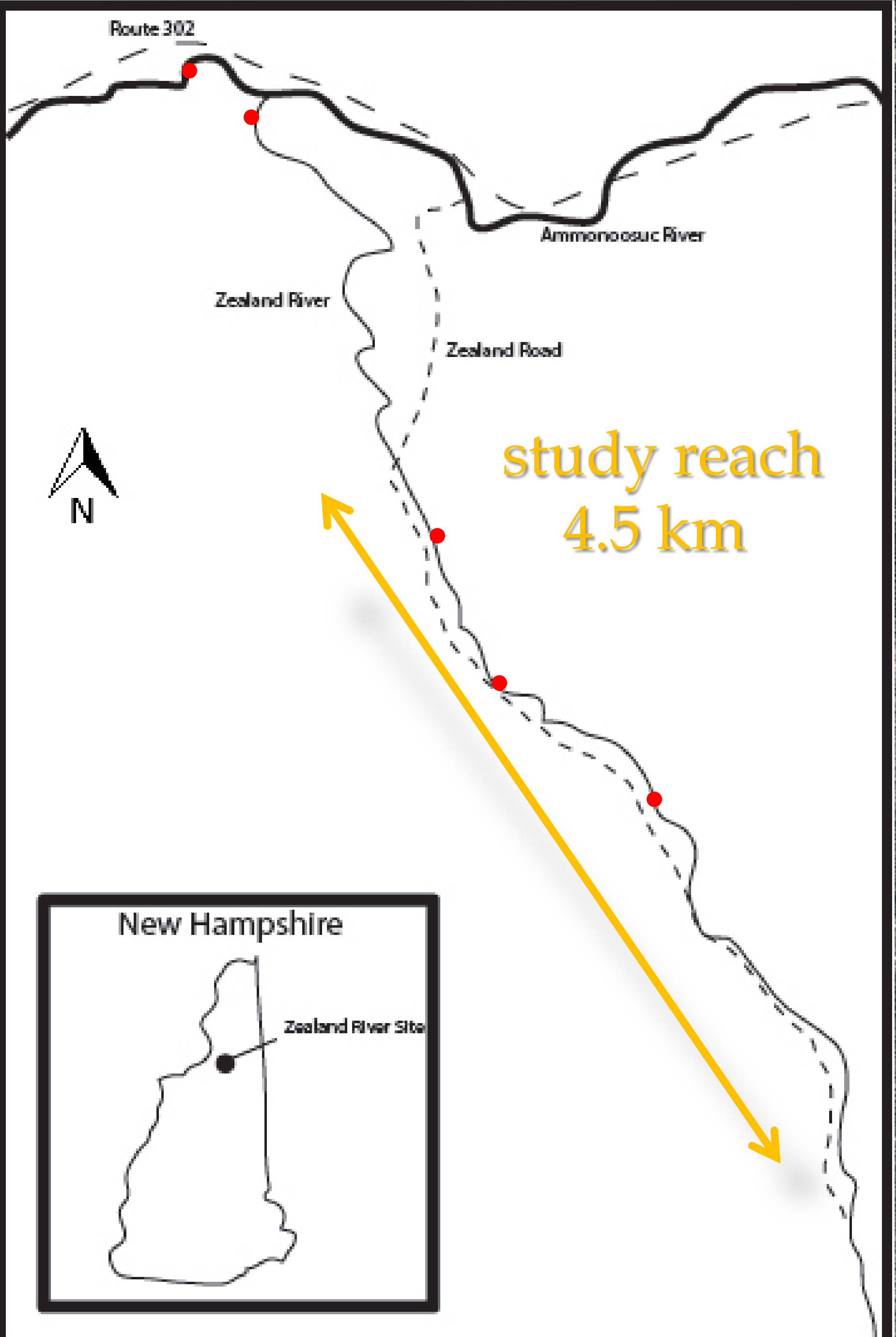
Project Evaluation 2014

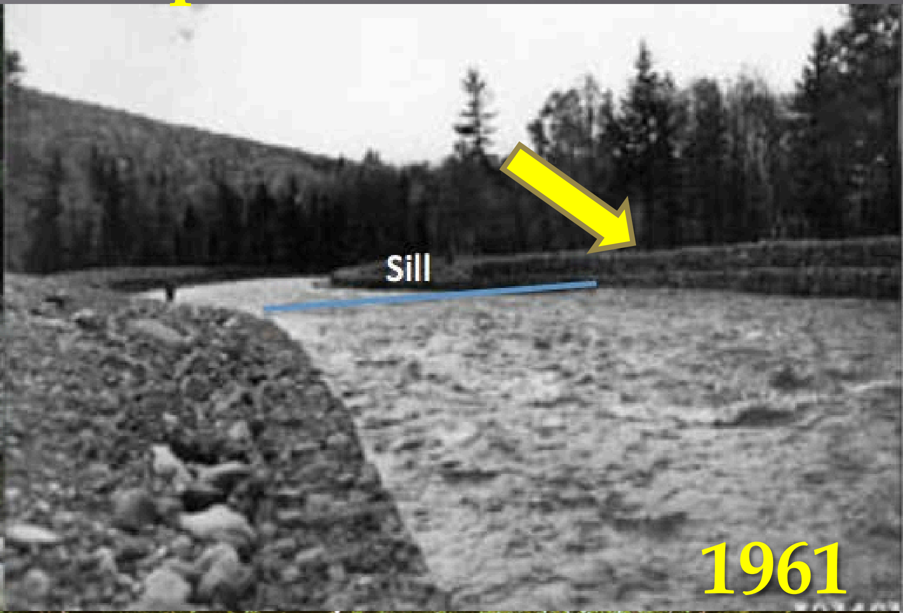
1,412.7 m of remaining gabion walls

What is the long-term impact (50 years) of extensive channel stabilization in an area with few other human impacts?

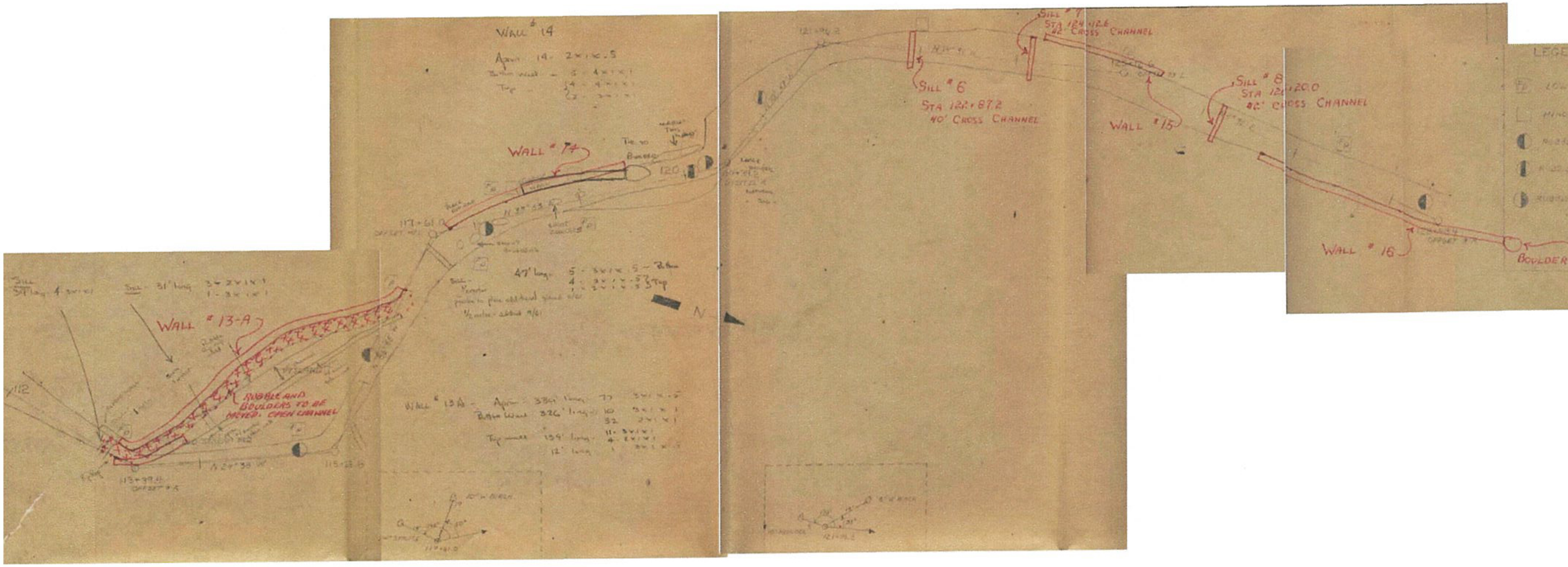

Route 302
Ammonoosuc River
Zealand River
Zealand Road
N
study reach
4.5 km
New Hampshire
Zealand River Site

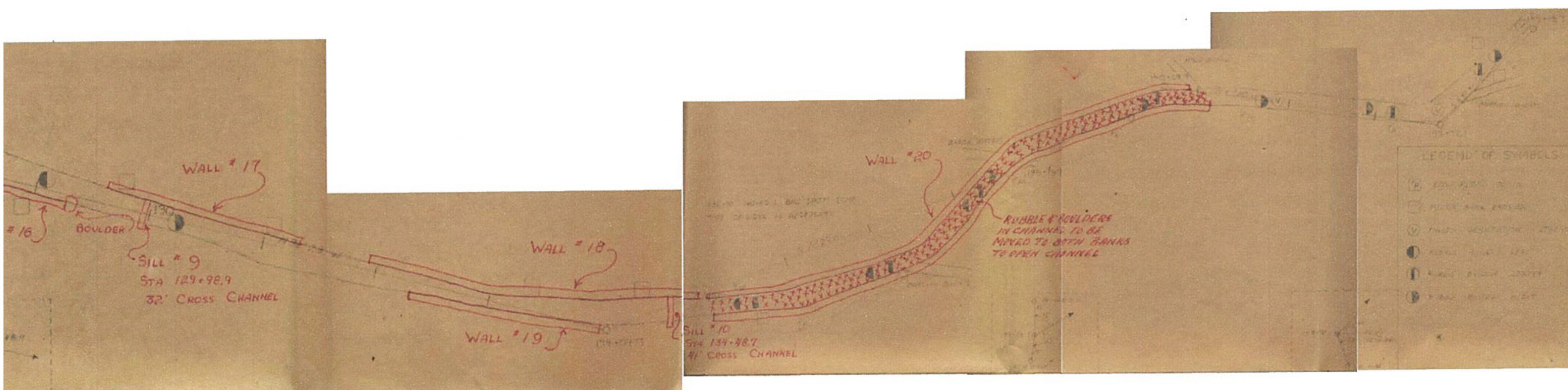

average slope
0.022
drainage area
35.7 km^2
White Mountains
National Forest, NH

Historic Photograph Replication



1960s Historic Survey





2014 Longitudinal Profile Resurvey

2014 Cross-sectional Surveys

Pebble Counts

1963 Damage Report

The general damage and recommendations for repair or improvement are as follows:

Walls #22 - 1 meter high wall on 2 x 1 x .5 apron. Water was 7' high at end of wall. Boulders left in the stream channel as "natural sill" were barriers to stream flow. The last 50' of the wall dropped. Height of wall should be increased to 2 meters high on 2 x 1 x .5 apron.

#23 - Water peaked over top of 2 meter high wall on 2 x 1 x .5 apron; water action on back and front side of wall scoured base, and 30' of wall sagged. Increase channel capacity and add 30' of ½ meter gabions to top of sagged portion. At end of Wall #23, an approximate 5 ton boulder, used as a key at end of wall was washed out. This will require placement of 20' of additional wall, tied to Sill #23a.

#24 - 2 meter high wall set on foundation of large boulders. Water was 2½' over top of this wall, and caused wash to slope and streambed. The wall sagged and will require additional height of 1 meter. Constriction above this wall should be removed. (This "point" of land was left for asthetics in 1962).

#26 - 1 meter high wall on 2 x 1 x .5 apron. Water peaked over top of wall; uprooted trees blocked the channel and caused subsequent damage to Wall #27. Increase height of wall, extend around point and place sill to reduce velocity.

#27 - 1 meter high wall on 3 x 1 x .5 apron. Due to uprooted trees, under - design, and flowage from old channel, this was the trouble spot on the river. Water peaked over wall, undermining back side. 60' of wall dropped into created "hole". This wall will have to be rebuilt and increased to 2 meter height; should be extended around curve in the river with allowance for flowage from old channel.

Fish-Improvements - Two "T" design hammers, using 2 x 1 x 1 meter gabions placed in center of stream to create fishing holes, were lost. Streams of this velocity should not be listed for any fish improvements of this type.

Sills #23a - East bank washed; needs 13 - 16' additional length, anchored securely into bank.

#25a - Same as above.

#25c - Add to height of wingwall; water washed over and behind present wingwall.

Relocation - 60' of Seattle gabions that were added in June 1963 to increase height of existing sill moved 15 - 20' downstream. The base of the sill (Maccaferi gabions) is still functional.

1974 Damage Report

Damages - Summary

Sills - From wall 11 downstream 14 sills were breached and of those remaining, most are worn to some degree. Some sills were breached before the June 30 storm and it is likely that annual floods would have eventually worn out these sills. The unstable cobble size rubble in the stream grates on the baskets during each storm. One 20year flood will breach most sills. For example, the State Highway Dept. installed sills in the Ammonoosuc River during 1971 and these were breached during the June 30 flood.

Walls

The total length of wall damaged is 963 feet. Past surveys indicate that some sections had been damaged before, but the June 30 flood did most of the present damage.

The most successful walls were those where the river had plenty of room or which blended into the river's present hydrologic configuration. Where walls were installed to channel flow away from a developing meander they were frequently undercut or overtopped. Many sections settled, but gabions are designed to do this without breaking up.

Walls 11 and 21 are the most heavily damaged. These walls were exposed to the full force of the river and its bedload of cobbles during storms. Gabion baskets do not have enough strength for this type of location. Deflectors could be used as a means of keeping the force of the river away from the wall, but these baskets would have to be rebuilt every ten years. A better choice may have been to place the baskets on a sloping wall and to have faced the wall with a more resistance material such as concrete or metal panels.

The flood water also went over wall 25 similar to wall 11 and 21, but the baskets are intact. The angle of impact was less here and perhaps this is why 25 did not break up.

Recommended Actions

The minimum repairs should be made as listed below. This is a pilot project and should be left to stand the test of time. There is no justification for restoring the project to its original condition. Gabions are designed to settle, therefore, appearance is not a criteria for repair. Furthermore, resource or facility values are not a significant factor. There are many natural areas of streambank erosion on the Forest which are not considered serious from a resource point. Eroding banks on the Zealand River do no more damage than eroding banks on the Swift River. Finally, no facilities are being threatened by the river.

1989 Research Article

Field Copy (2.6)

HEADWATERS HYDROLOGY
JUNE — AMERICAN WATER RESOURCES ASSOCIATION — 1989

EVALUATING A BANK STABILIZATION PROJECT 25 YEARS AFTER COMPLETION

Randy S. Ferrin and Janice W. Staats[1]

ABSTRACT: Zealand River, a headwater tributary to the Connecticut River, drains a steep basin in the White Mountain National Forest of northern New Hampshire. A severe flood in October, 1959 caused considerable bank damage, aggradation, and channel change. Following a stream condition survey in 1960, gabions and riprap were prescribed for restoration of the stream channel. Besides repairing bank damage, the objectives of the project were (1) to study techniques of gabion and riprap placement, and (2) to evaluate the effectiveness and durability of those techniques. Installation of riprap walls, gabion walls, and gabion sills in 2.5 miles of river was made from 1961 to 1963. In 1974 an assessment of the gabions was made because of the damages caused by the June, 1973 flood. In 1988, the gabions, riprap, and streambanks were inspected and mapped to ascertain their condition. The gabions walls failed at high energy points in the river or where the channel was too constricted. Gabion sills were obliterated by the river's massive beload movement. Even 25 years after placement, the remaining gabion walls still do not fit the character of the surrounding landscape, while the riprap is natural appearing. Effectiveness and durability of the gabions and riprap are evaluated. Recommendations for future management of the structures are made.
(KEY TERMS: gabions; riprap; bank stabilization; channel restoration)

INTRODUCTION

The Zealand River drains a 8810 acre watershed in the White Mountains of northern New Hampshire. Entirely within the White Mountain National Forest, the river joins the Ammonoosuc River, a Connecticut River tributary, near Twin Mountain, NH. Besides being a municipal watershed for the town of Bethlehem, NH, the Zealand River watershed provides a mix of resource opportunities including timber management, hiking trails, wildlife habitat, campgrounds, scenic driving, fishing, wading, and a backcountry hut. The Zealand Valley receives over 85000 recreation visitor days per year. The White Mountain National Forest itself is a popular and heavily visited area. Approximately 65 million people live within a day's drive of the Forest. Total yearly visits approach six million people. Scenery and the mix of recreational opportunities provide the attraction.

The area receives an average annual precipitation of 44 inches, well distributed throughout the year. The mean annual flow for the Zealand River is calculated to be 28 cubic feet per second (using the method described in Dingman, 1978). The 2, 10, and 100 year recurrence interval flood flows are predicted at 590, 1340, and 3265 cfs, respectively (using the method described in LeBlanc, 1978).

The Zealand River watershed resembles many of the watersheds of the White Mountain area with steep headwater streams (see Table 1) draining steep slopes with shallow soils. Elevations range from 4374 feet to 1460 feet at the mouth of the river. Soils are [illegible]

[1] Respectively, Forest Hydrologist, White Mountain National Forest, P.O. Box 638, Laconia, New Hampshire 03247; Hydrologist, Pemigewasset Ranger District, RFD #3, Box 15, Plymouth, New Hampshire 03264

The gabion walls suffered damage on 1561 feet of the total 5658 linear feet. This compares to 963 feet of wall showing damage in 1974. Damage ranged from undermining of aprons, loss of rocks from aprons, settling of walls, toppled walls, and obliteration. See Table 3 for a summary of damage to the gabion walls comparing 1973 to 1988. Table 3 also summarizes the effectiveness of the walls in both years. Of the original 24 gabion walls, only 14 were still effective. Seven had reduced effectiveness, for example, flow was going over or around the structures. In two locations, toppled gabion wall sections were obstructing flow and were threatening to pull more sections of wall into the river. The gabion structures continue to dominate the view in many segments of the project area, even though trees and shrubs have vegetated approximately 1100 linear feet of the top surface of the gabion walls and the rocks and wire of the gabion baskets have taken on a weathered appearance.

Table 3. SUMMARY OF DAMAGE TO GABION WALLS

DAMAGE CATEGORY	YEAR 1973	YEAR 1988
Major Damage	4	6
Apron Damage	2	7
Toppled	1	1
Settled	7	7
No Damage	10	3
EFFECTIVENESS CATEGORY		
No Longer Functioning	2	3
Effectiveness Reduced	3	7
Still Functioning	19	14

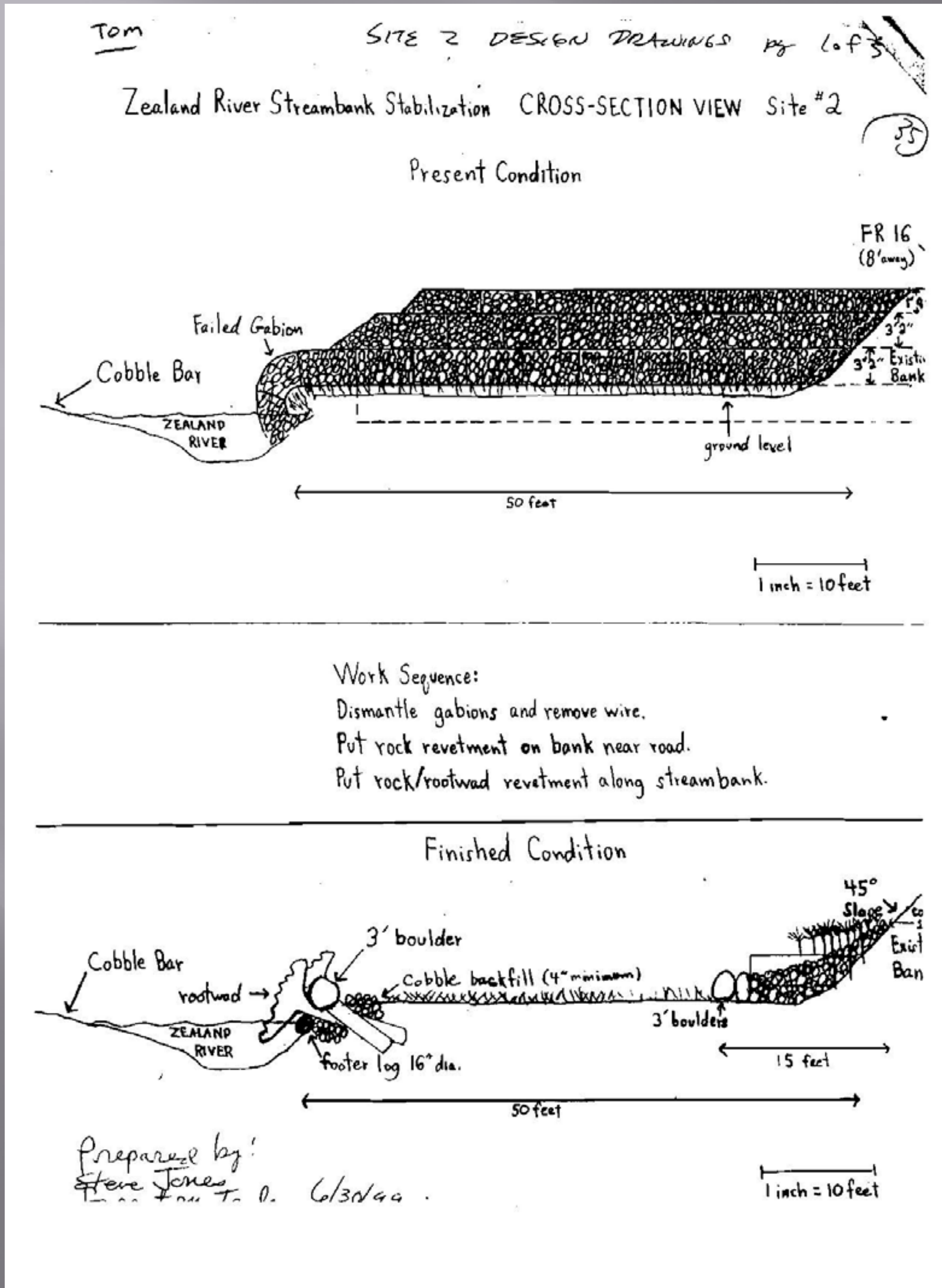
CONCLUSIONS

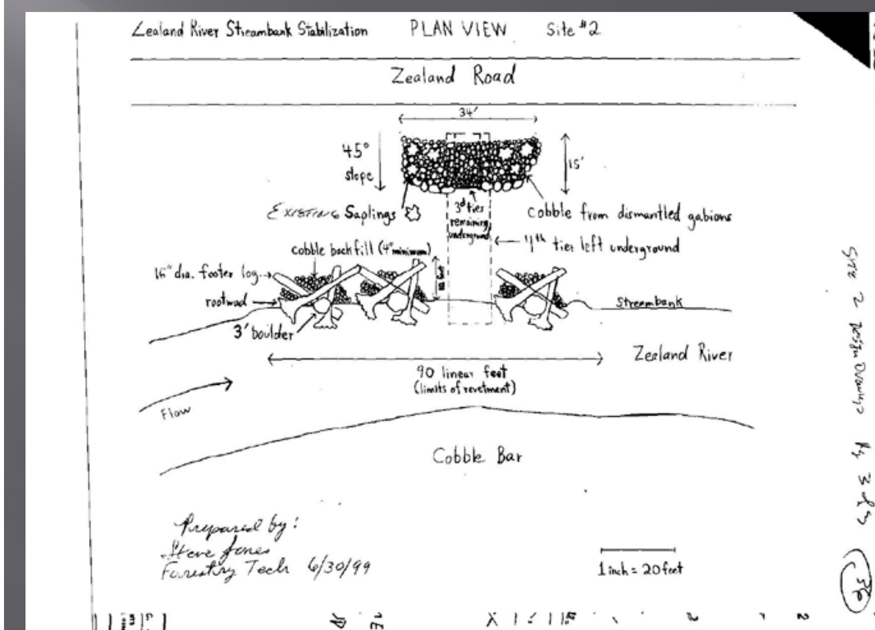
As Stuart (1974) observed, gabion walls which were installed to redirect flow away from a developing meander were frequently undercut or overtopped. The most successful walls were those in relatively straight stretches where the channel capacity was not constrained. A river with such a large bedload is difficult to tame with gabion structures. In the early years of this project, damage to structures was usually inflicted on those structures exposed to the full force of the river at bends. Now, even in some straight channel sections, damage is occurring due to constantly shifting rubble bars which direct the flow into the walls. Settling or toppling of structures was nearly always initiated with some type of damage to the apron. Settling did not significantly reduce the effectiveness of the structures but toppling nearly always reduced their effectiveness.

Sills were effective for only a short time on a stream system with such a large amount of bedload movement. It would be difficult to justify their use again in a similiar situation. Groins are massive and obtrusive and likewise would be difficult to justify again on a scenic mountainous stream. Riprap proved to be effective in protecting banks from further damage while maintaining a natural appearance. However, banks upstream that were not treated with riprap had healed naturally over the life of the project.

As stated in the introduction, the overall objective of the project was to contain ɔod flows, trap bedload, and minimize further bank damage. The project was successful ɹn protecting streambanks and reducing the number of high water channels but failed in

1999 Revetment Design





2014 Gabion Assessment

Doug Thompson Connecticut College 860-439-5016 Zealand River, NH

Date:	DS Distance:
1960's Label:	LB Center RB
Our Label:	Distance to Bank:

Length (m)		Trees on Top	#
Height (#/m)		None	
Width (#)		5-10 cm	
Missing		>10 cm	

Way Point #	Details

Photos #	Details

Diagram:

Failed

Damaged

Intact

Failed

<50% Full

>50% Broken Wires


Failed
Tilting >30º

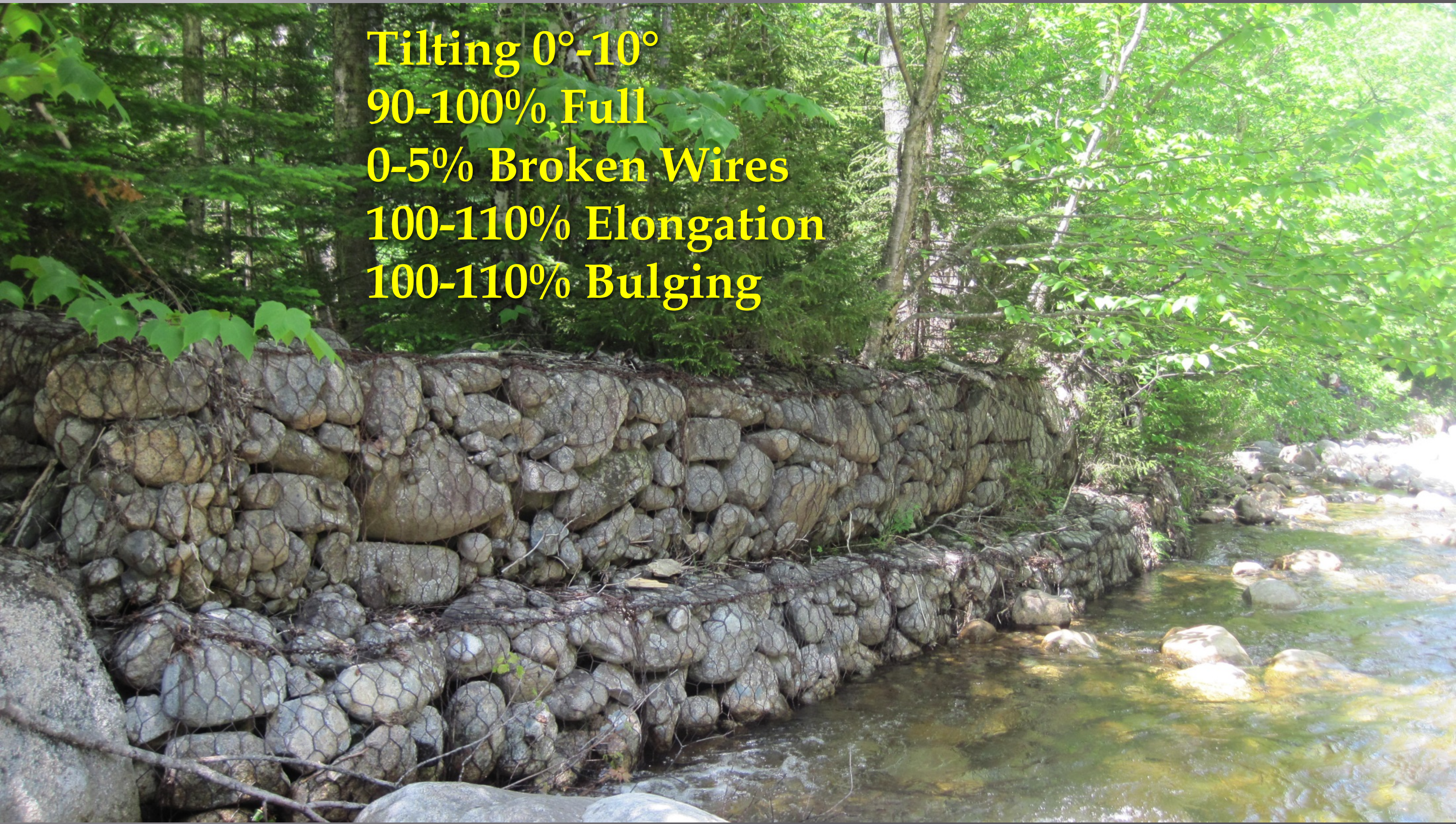

Failed
>150% Elongation

Failed
Tilting >30º
>150% Bulging

Failed Damaged

Damaged

Intact



57.6% of the full length of remaining walls were intact

Gabion Wall Classification

	1963	1973	1988	2014
No Damage	**-**	**10**	**3**	**1**
Apron	**-**	**2**	**7**	**2**
Settled	**4**	**7**	**7**	**3**
Major	**-**	**4**	**6**	**2**
Toppled	**-**	**1**	**1**	**15**
Total	**-**	**24**	**24**	**23**
Still Functioning	**-**	**19**	**14**	**3**
Effectiveness Reduced	**-**	**3**	**7**	**10**
No longer functioning	**-**	**2**	**3**	**10**
Toppled if any portion = no longer functioning				

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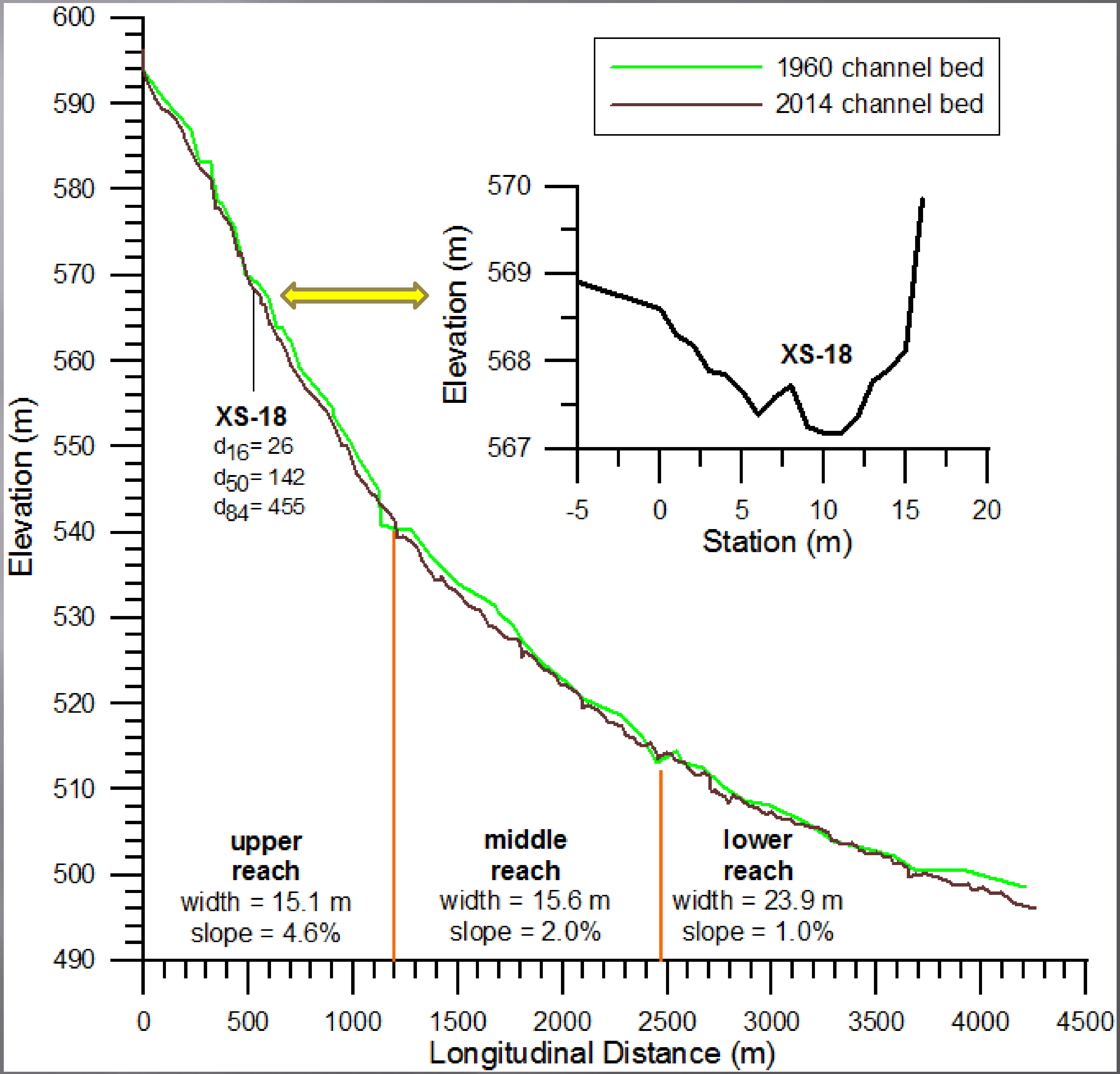
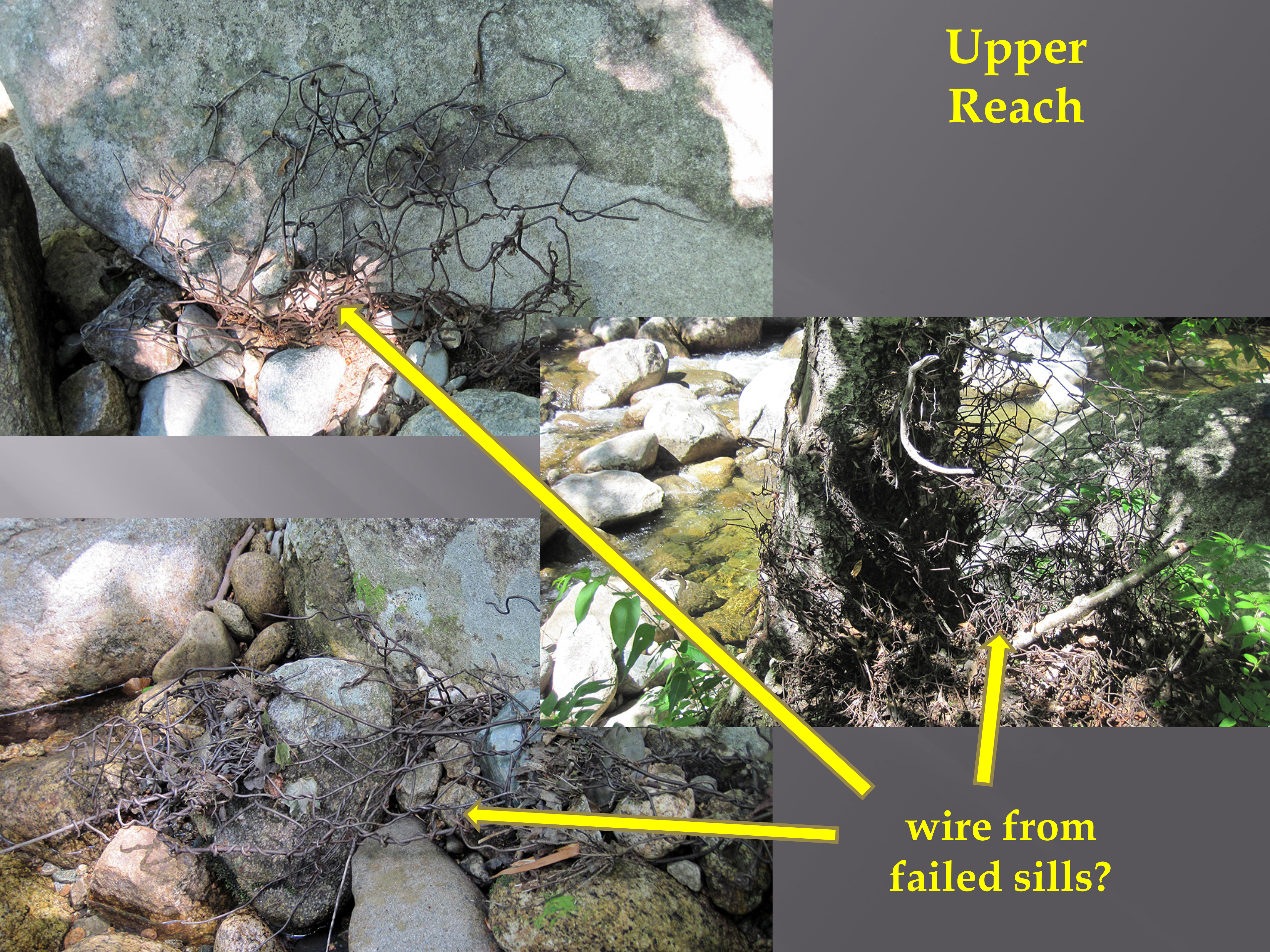
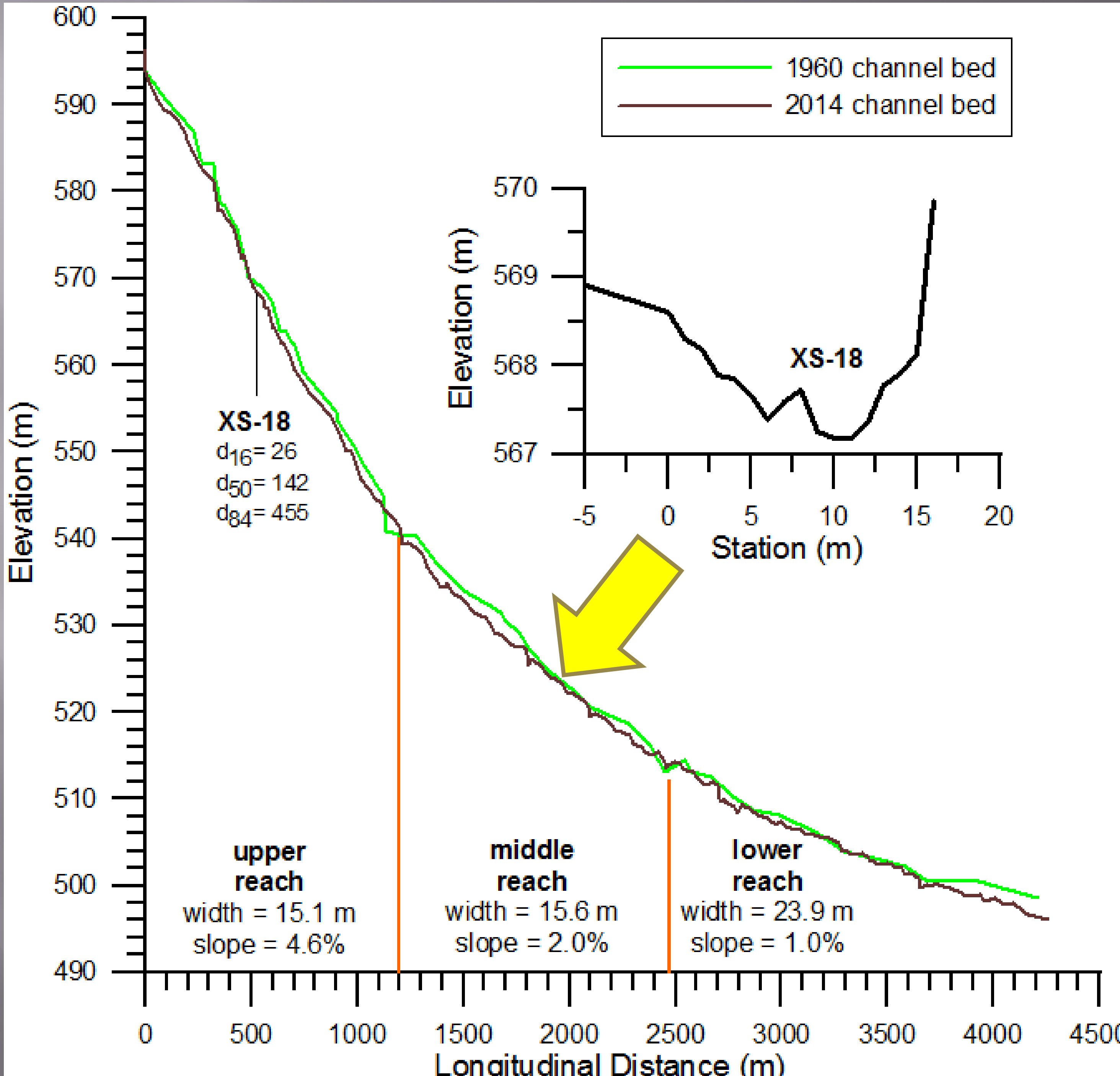


1960 channel bed
2014 channel bed
Elevation (m)
Longitudinal Distance (m)
XS-18
d16= 26
d50= 142
d84= 455
Station (m)
upper reach
width = 15.1 m
slope = 4.6%
middle reach
width = 15.6 m
slope = 2.0%
lower reach
width = 23.9 m
slope = 1.0%

Upper Reach

Upper Reach





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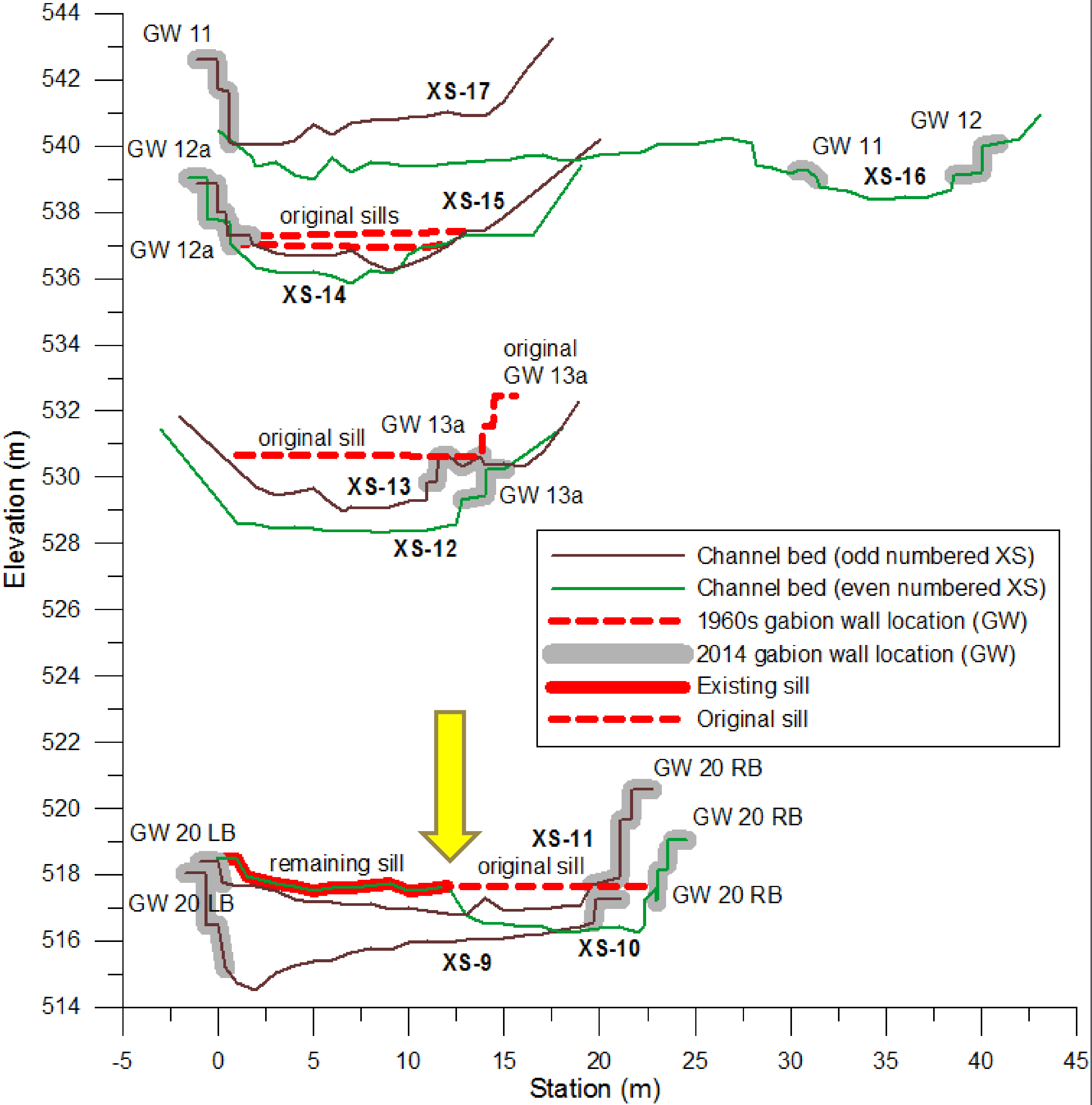
slope = 1.0%
Station (m)

Middle Reach

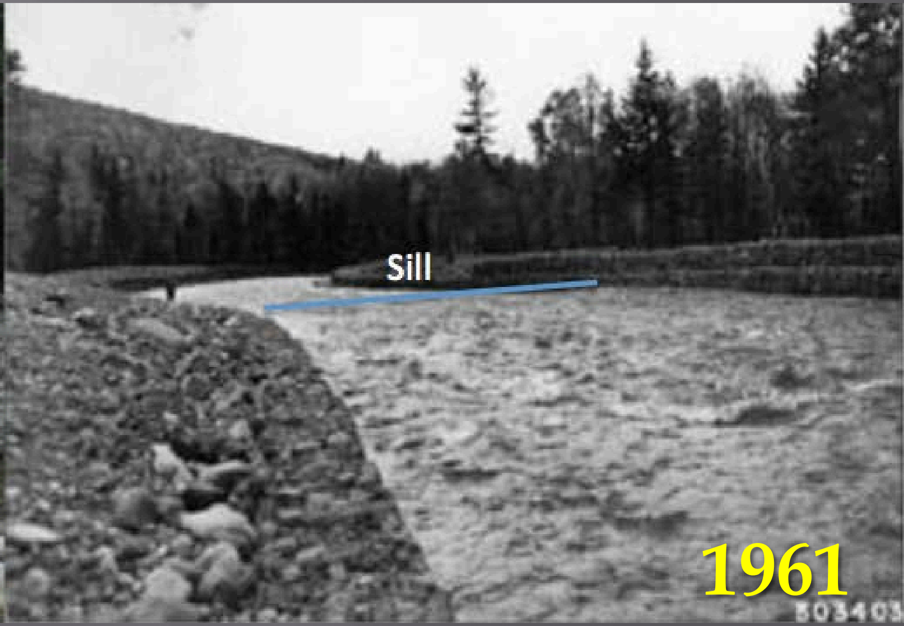
Middle Reach



Middle Reach

damaged sills

Historic Photograph Replication



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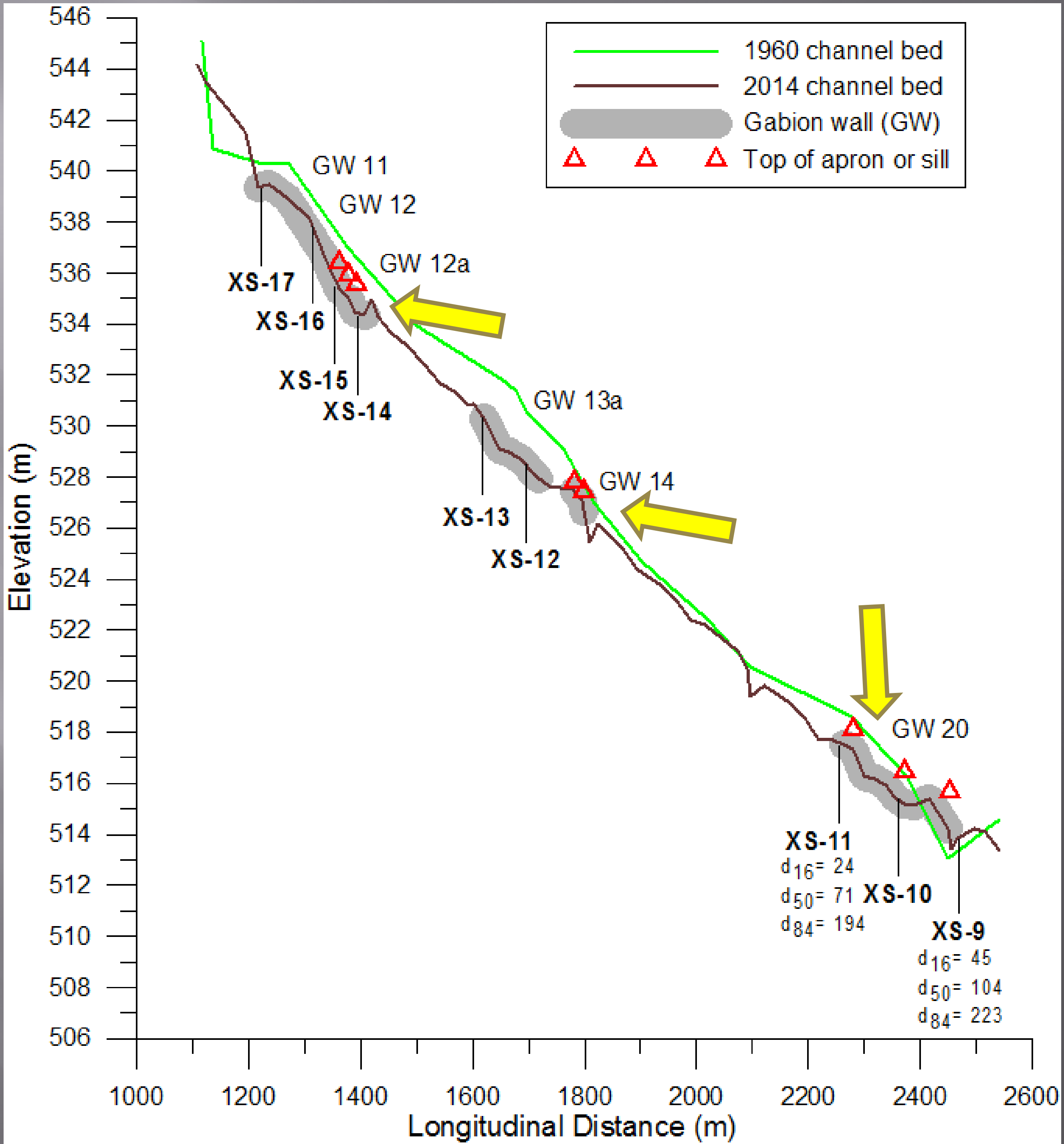
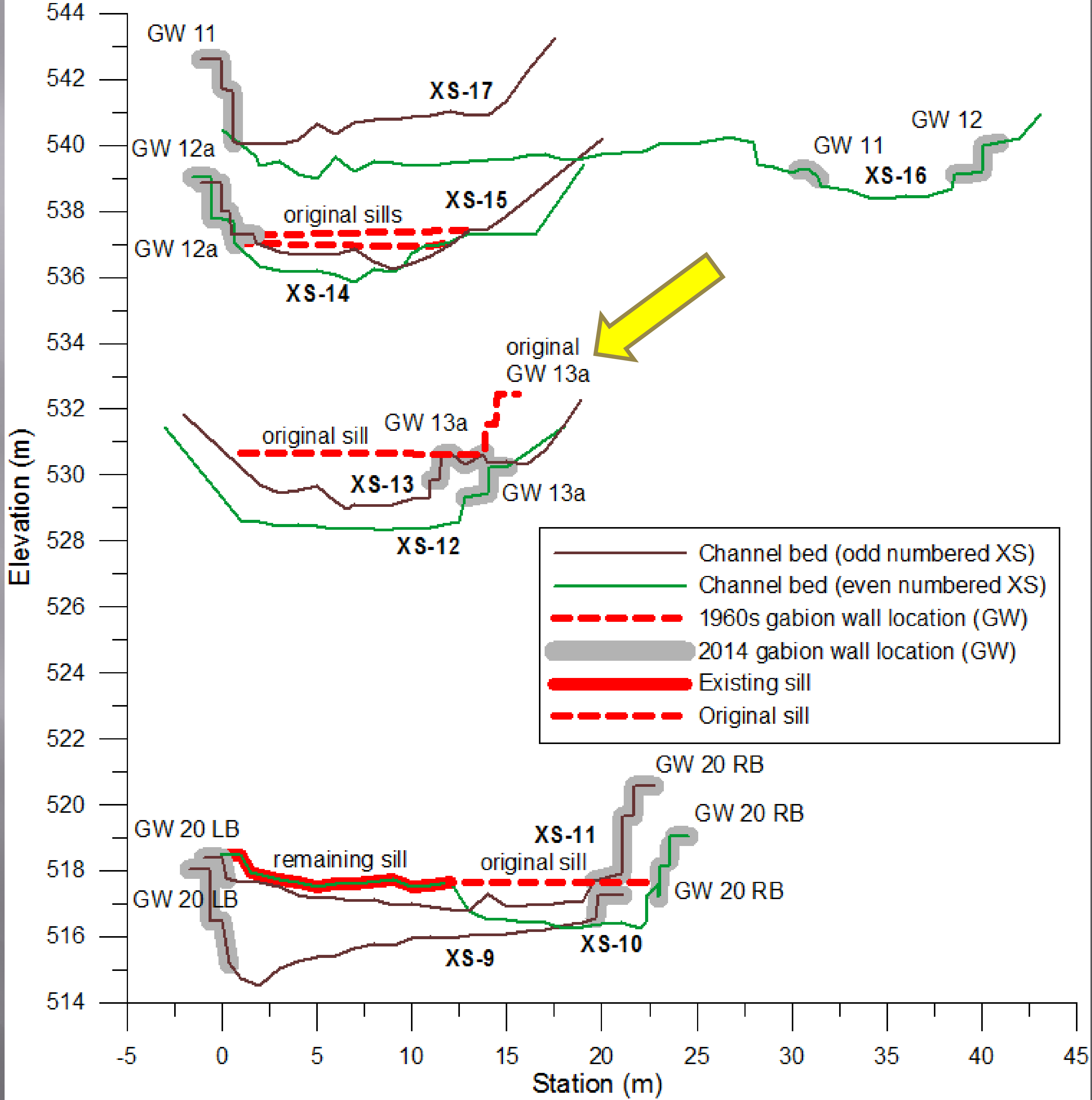


Middle Reach

exposed aprons

Middle Reach



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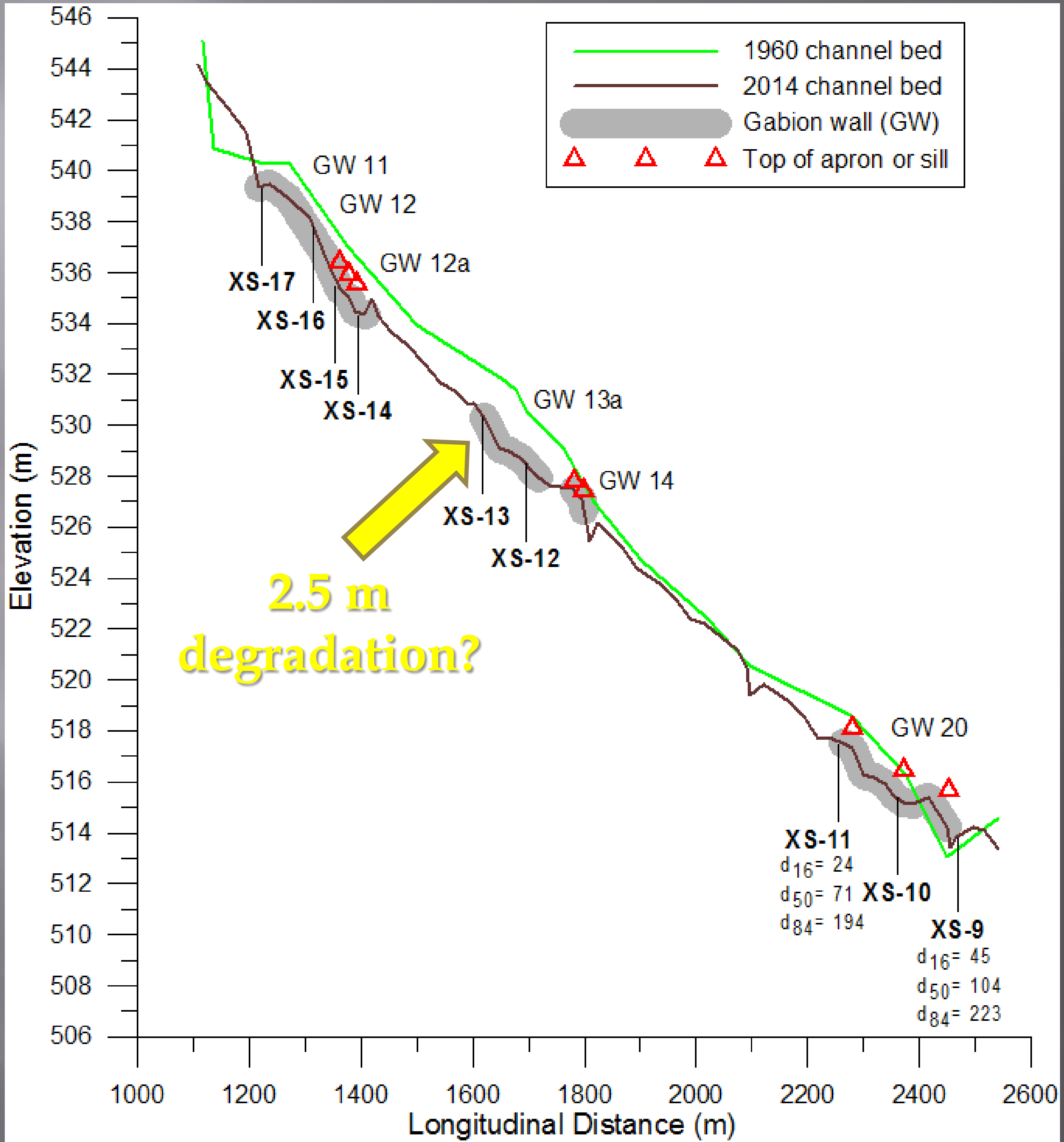


Middle Reach
Gabion Wall 13a

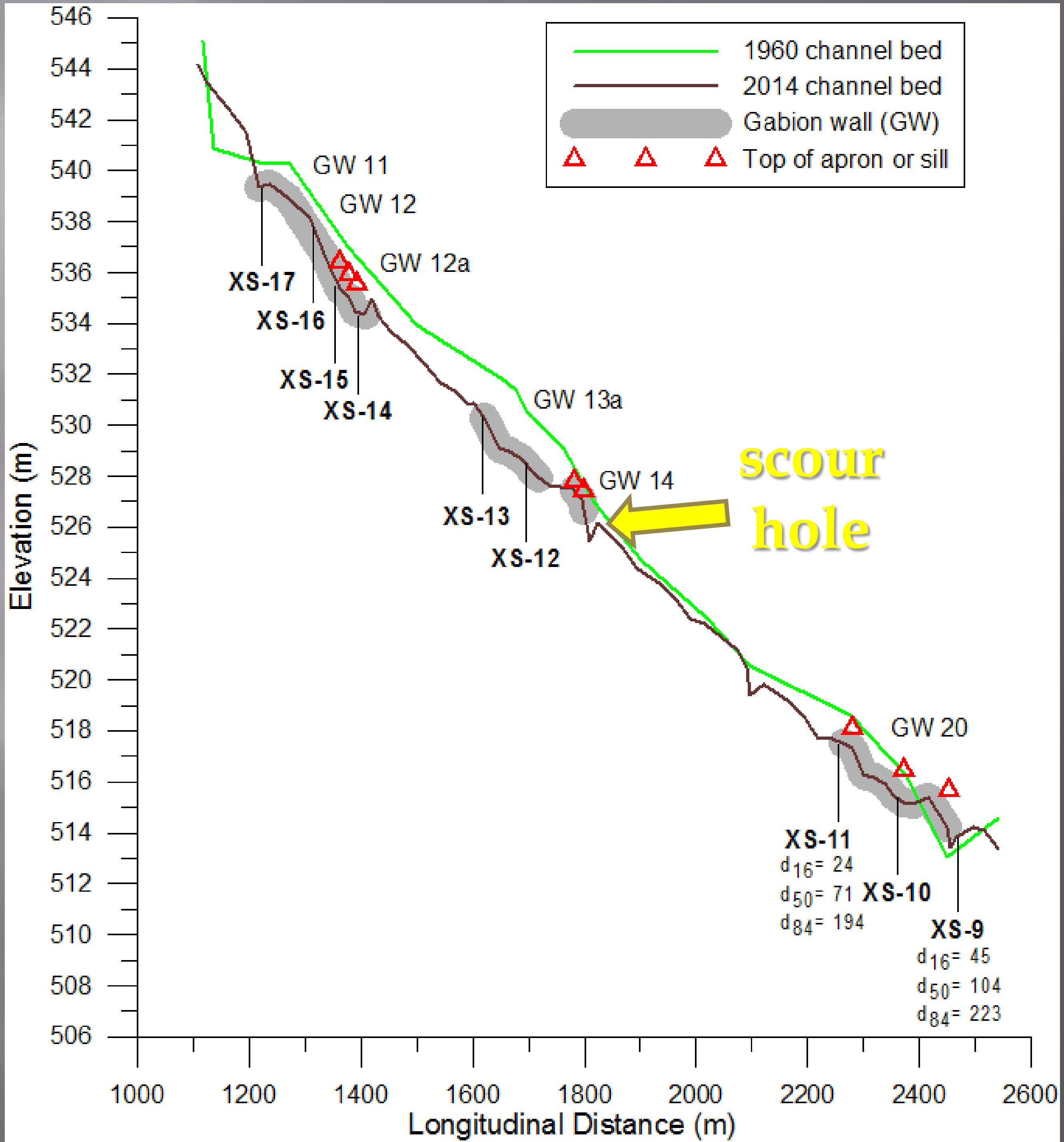
Middle Reach
Gabion Wall 13a

standing
waves

Channel Narrowing = Increased Stream Power

Middle Reach
Gabion Wall 13a

Middle Reach



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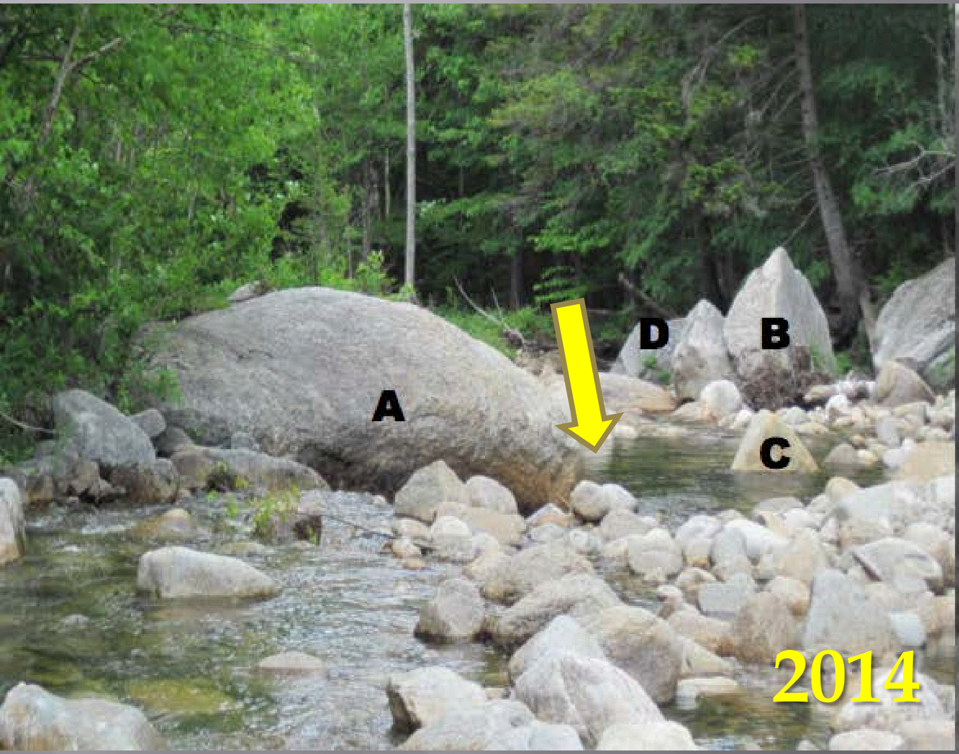
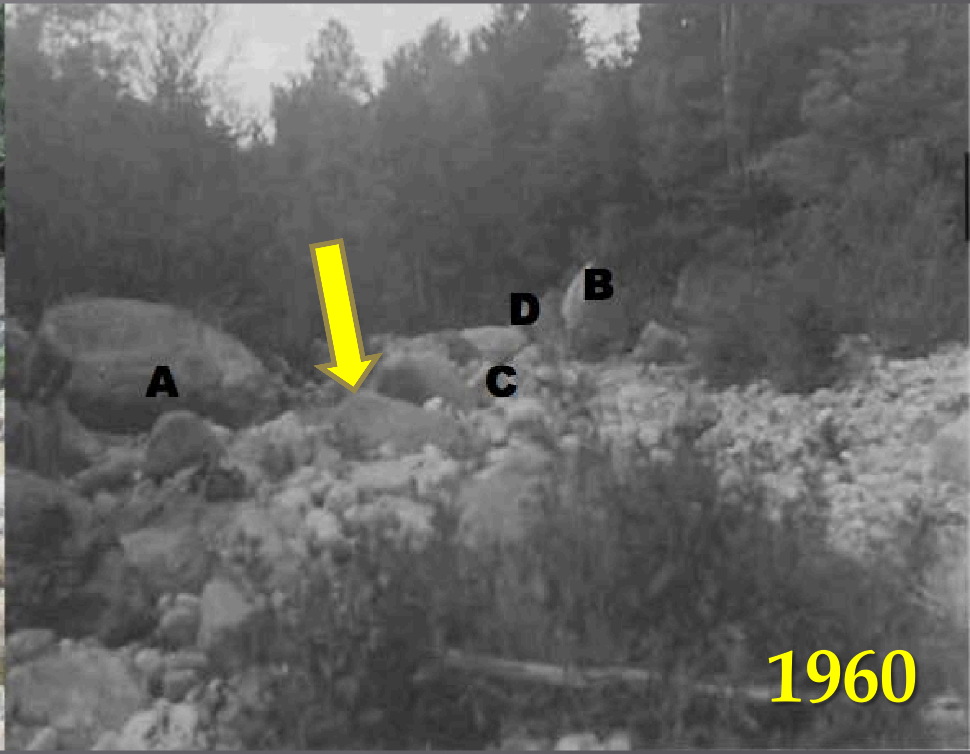
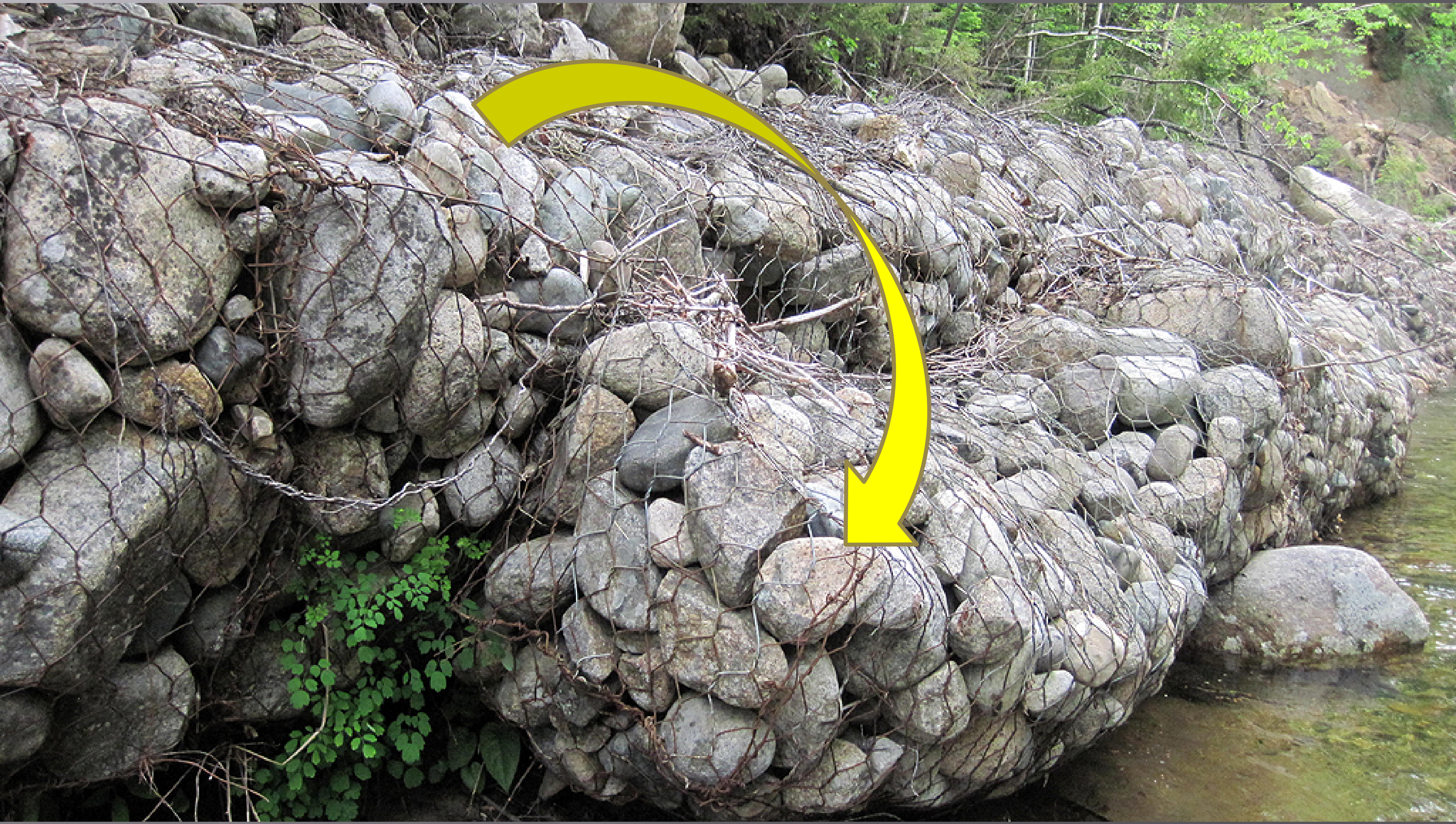




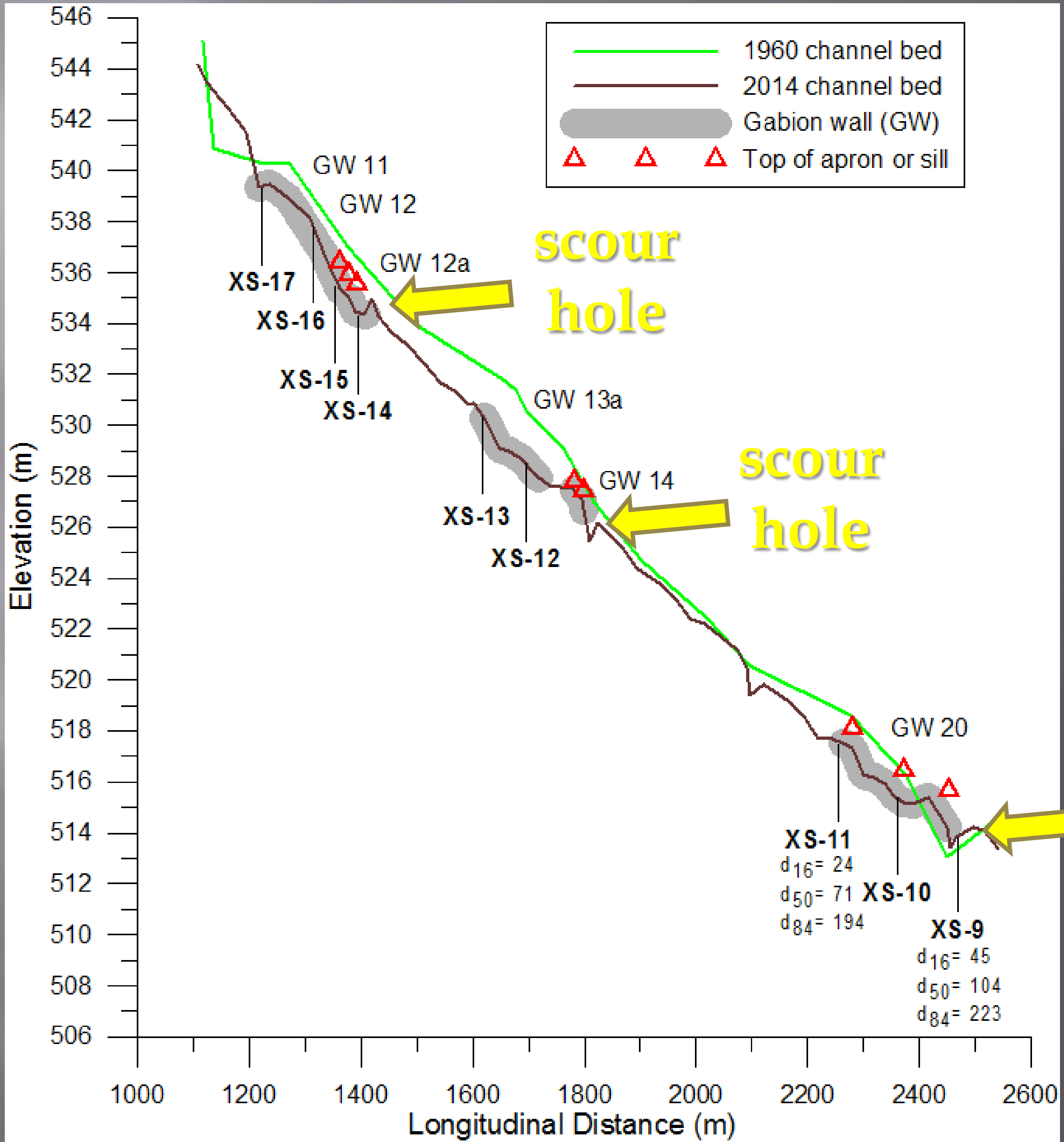
Middle Reach
Gabion Wall 13a



Middle Reach
Gabion Wall 13a

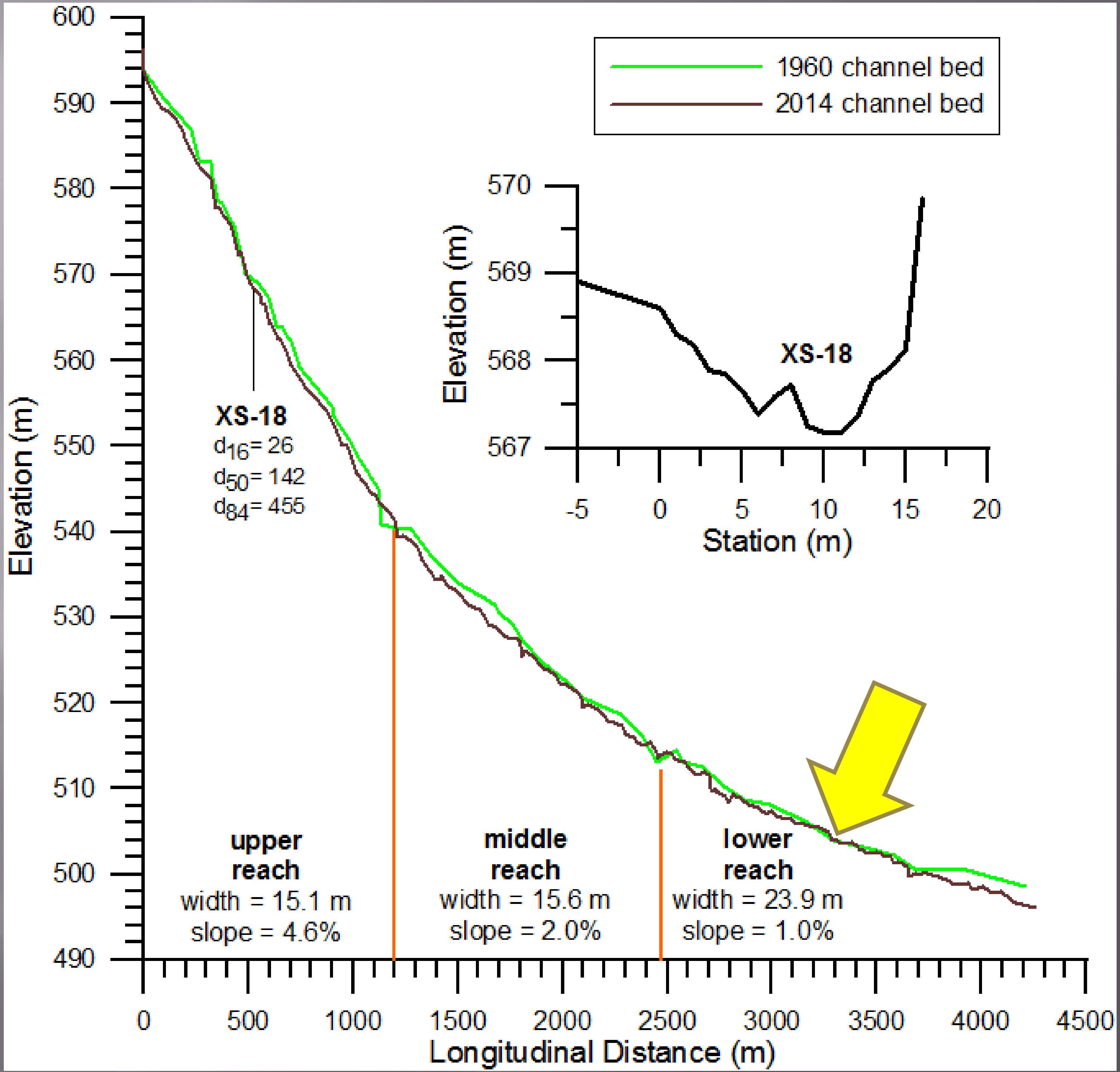
2014 | **1961**

Middle Reach



Middle Reach

Gabion Wall 20


1960 channel bed
2014 channel bed
Elevation (m)
570
569
568
567
XS-18
-5
0
5
10
15
20
Station (m)
600
590
580
570
560
550
540
530
520
510
500
490
XS-18
d16= 26
d50= 142
d84= 455
upper reach
width = 15.1 m
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middle reach
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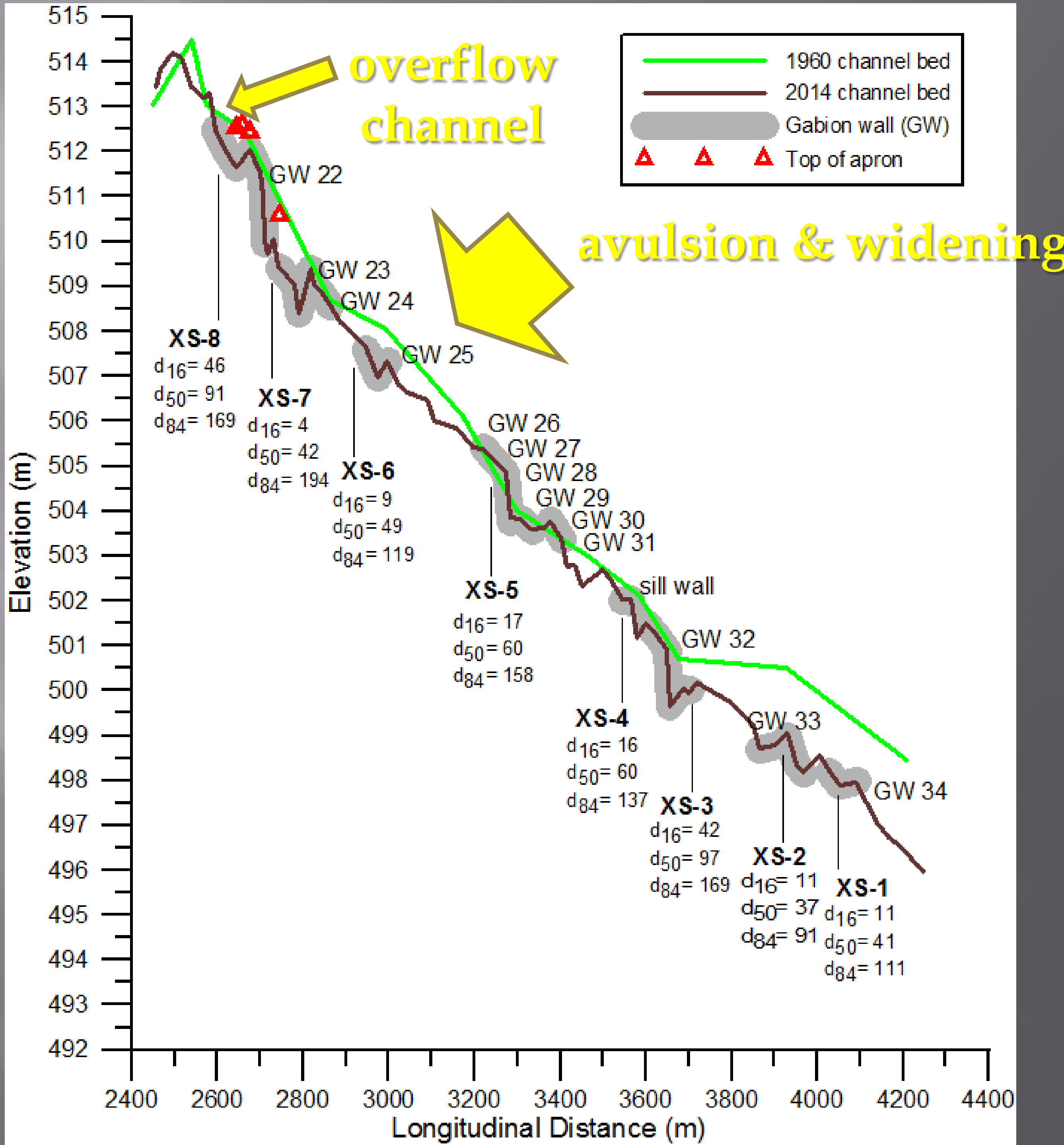
slope = 2.0%
lower reach
width = 23.9 m
slope = 1.0%
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Longitudinal Distance (m)

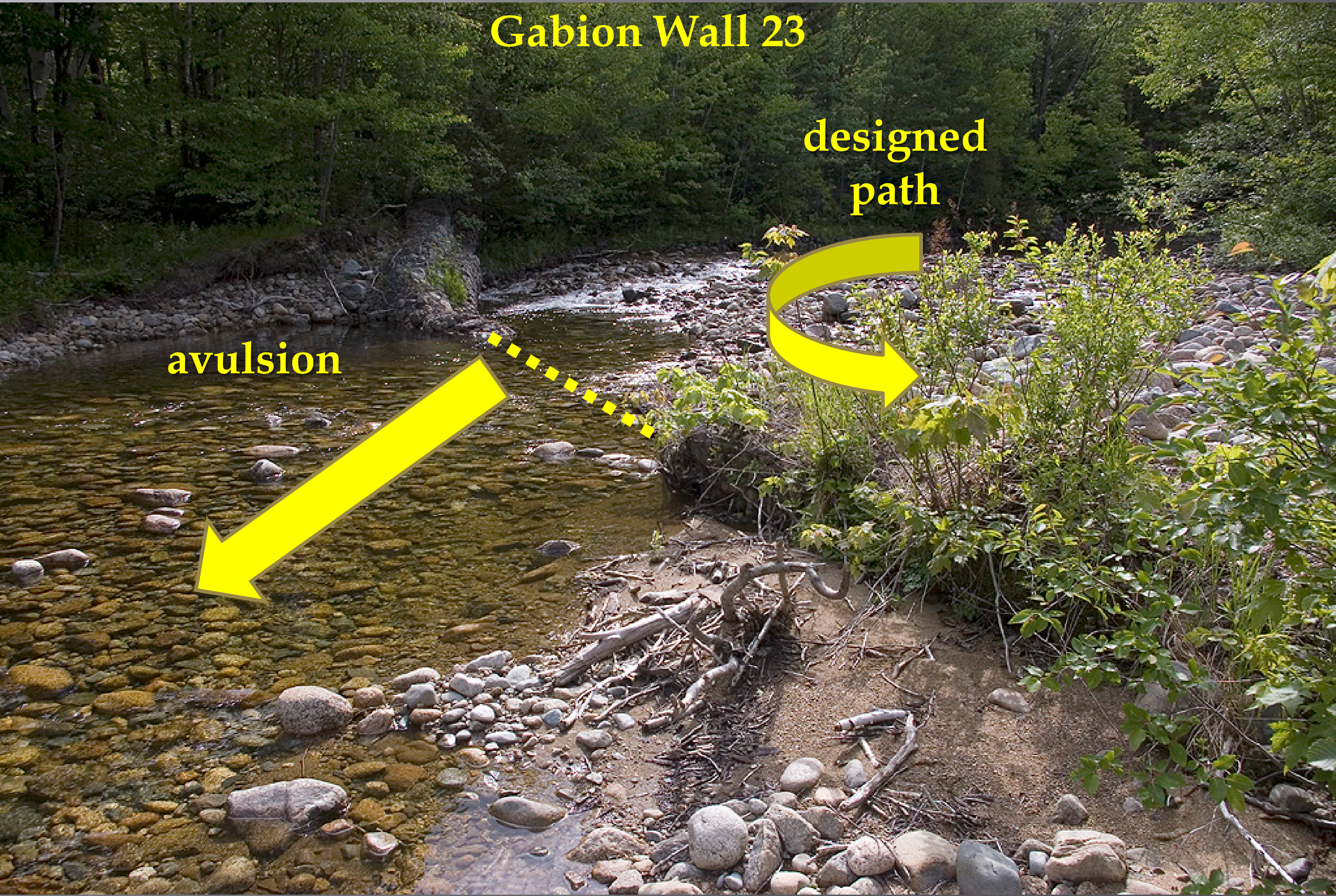
Lower Reach

Lower Reach

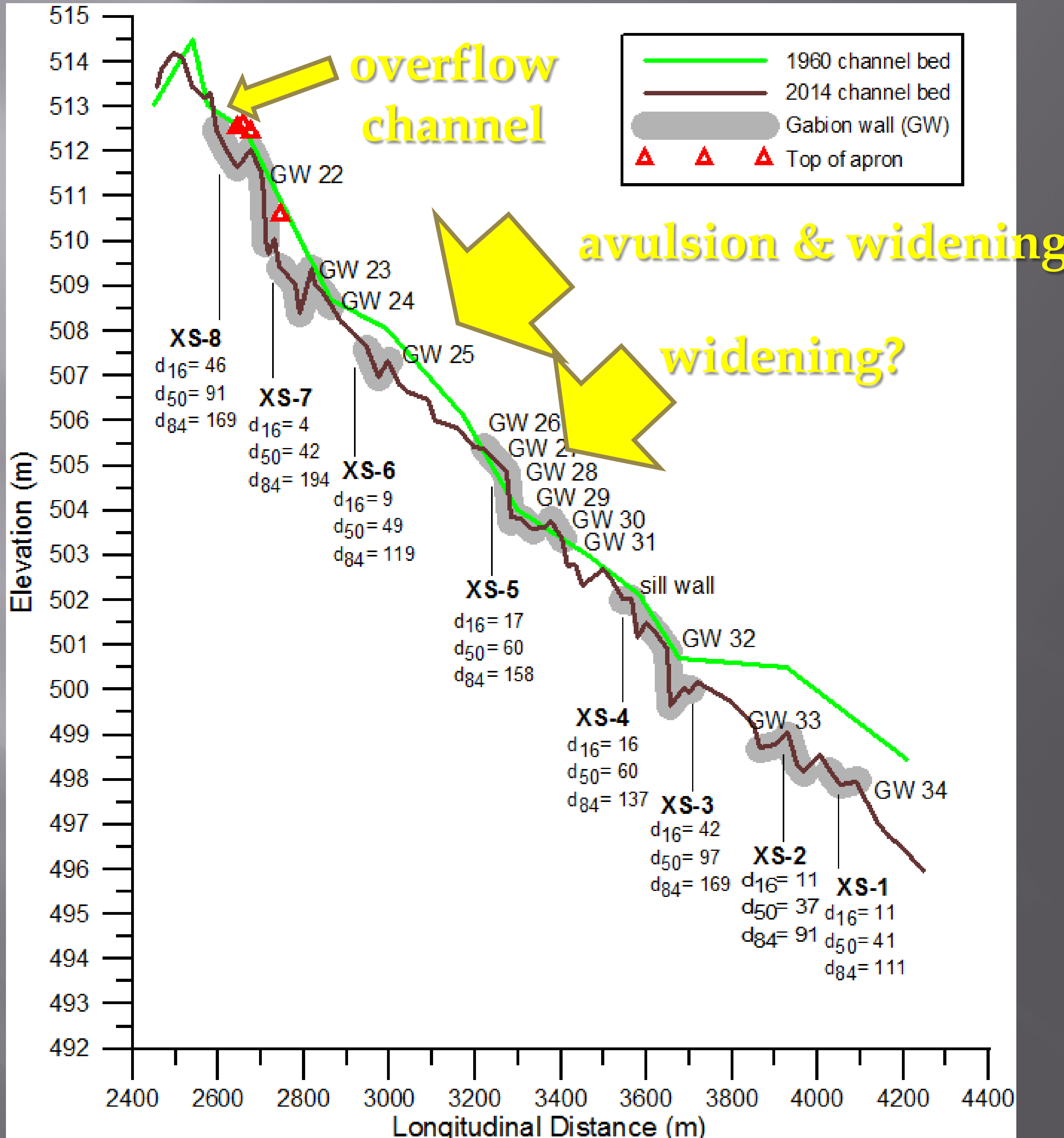


overflow channel
avulsion & widening
1960 channel bed
2014 channel bed
Gabion wall (GW)
Top of apron
GW 22
GW 23
GW 24
GW 25
GW 26
GW 27
GW 28
GW 29
GW 30
GW 31
sill wall
GW 32
GW 33
GW 34
XS-8
d16= 46
d50= 91
d84= 169
XS-7
d16= 4
d50= 42
d84= 194
XS-6
d16= 9
d50= 49
d84= 119
XS-5
d16= 17
d50= 60
d84= 158
XS-4
d16= 16
d50= 60
d84= 137
XS-3
d16= 42
d50= 97
d84= 169
XS-2
d16= 11
d50= 37
d84= 91
XS-1
d16= 11
d50= 41
d84= 111
Elevation (m)
Longitudinal Distance (m)

Lower Reach



Lower Reach

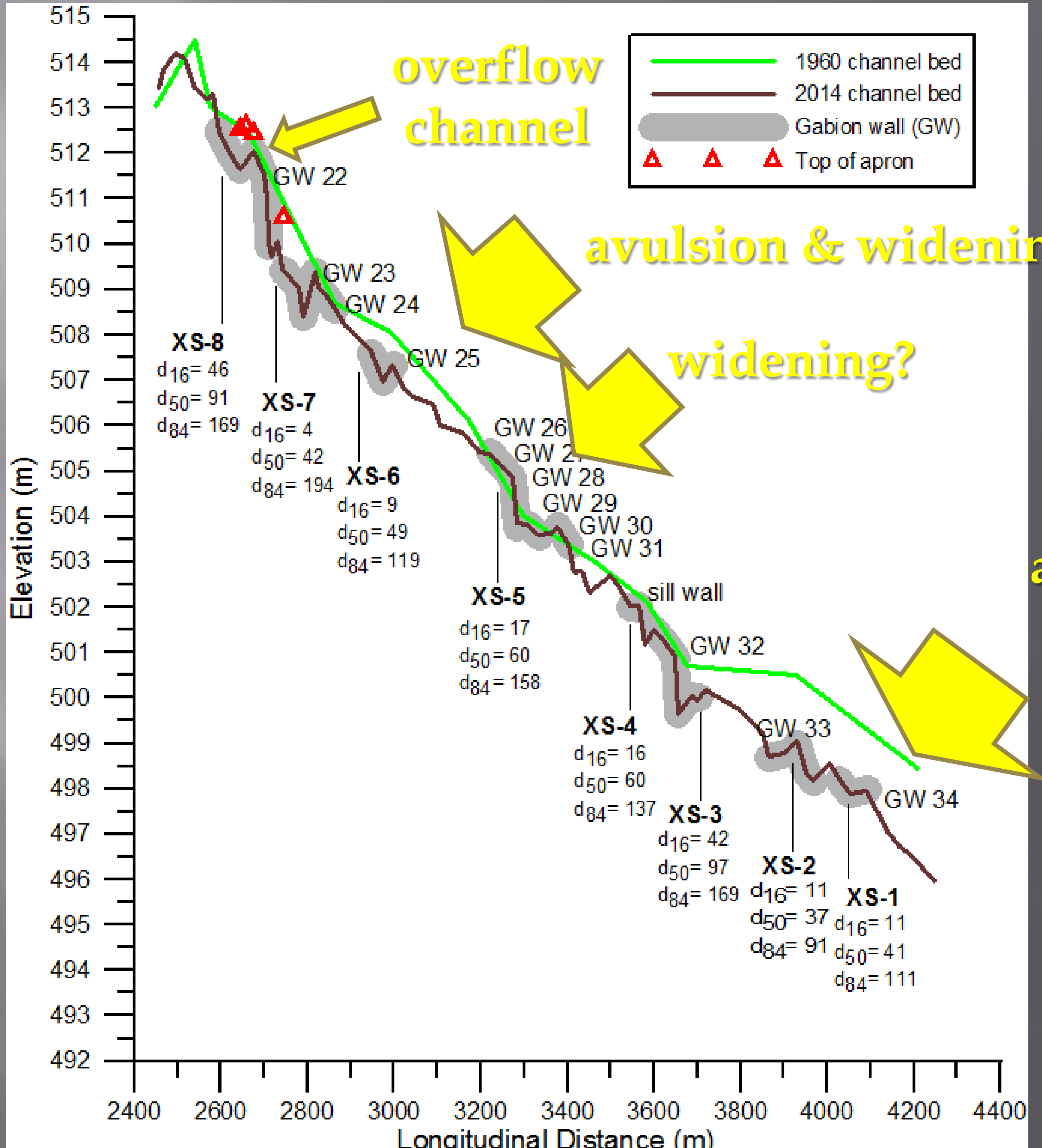


overflow channel
avulsion & widening
widening?
1960 channel bed
2014 channel bed
Gabion wall (GW)
Top of apron
Elevation (m)
Longitudinal Distance (m)
GW 22
GW 23
GW 24
GW 25
GW 26
GW 27
GW 28
GW 29
GW 30
GW 31
sill wall
GW 32
GW 33
GW 34
XS-8 d_{16}= 46 d_{50}= 91 d_{84}= 169
XS-7 d_{16}= 4 d_{50}= 42 d_{84}= 194
XS-6 d_{16}= 9 d_{50}= 49 d_{84}= 119
XS-5 d_{16}= 17 d_{50}= 60 d_{84}= 158
XS-4 d_{16}= 16 d_{50}= 60 d_{84}= 137
XS-3 d_{16}= 42 d_{50}= 97 d_{84}= 169
XS-2 d_{16}= 11 d_{50}= 37 d_{84}= 91
XS-1 d_{16}= 11 d_{50}= 41 d_{84}= 111


1964


2011

Lower Reach



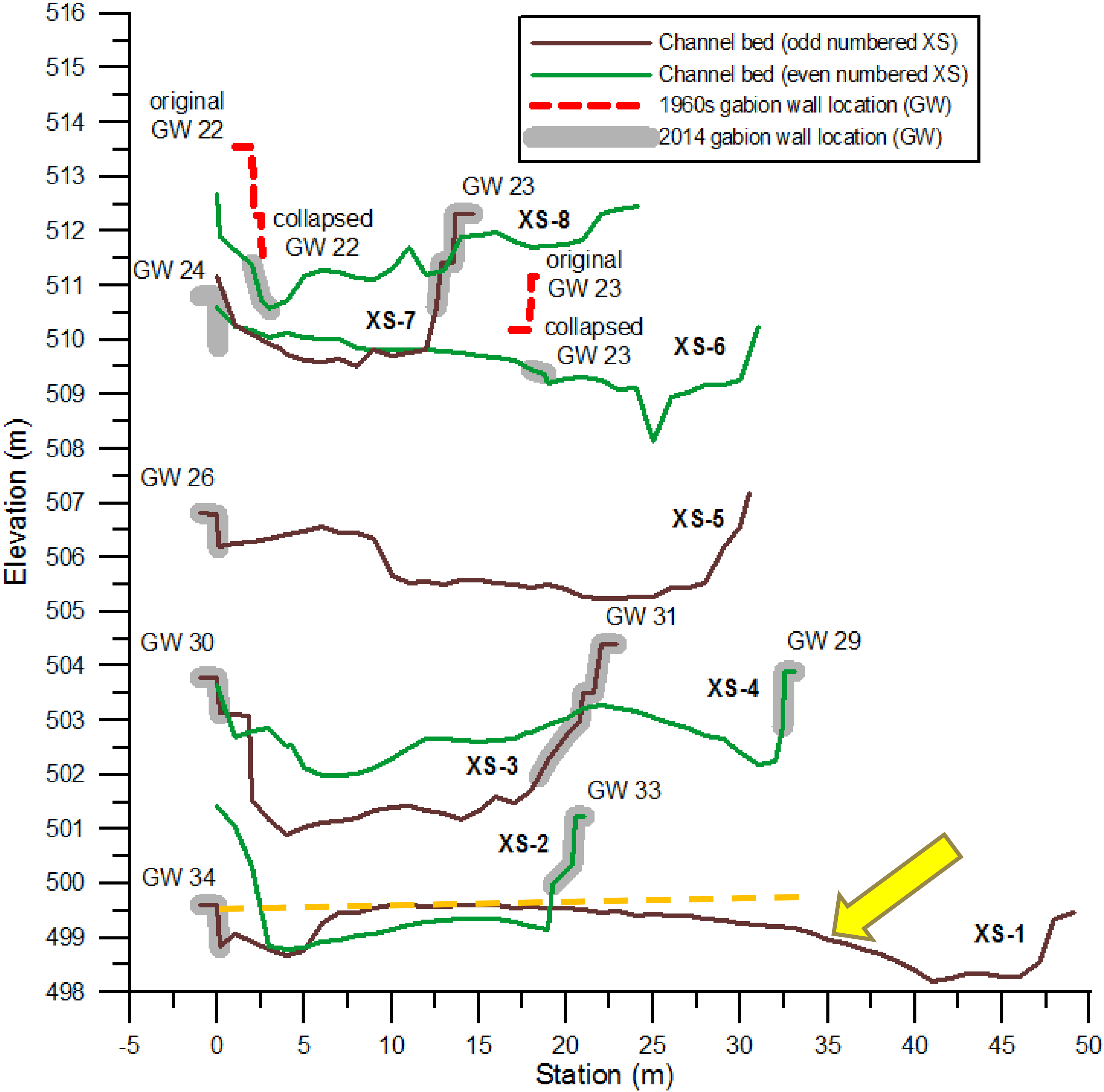
avulsion & widening


1964


2011
widening &
aggradation


aggradation

Lower Reach



Channel bed (odd numbered XS)
Channel bed (even numbered XS)
1960s gabion wall location (GW)
2014 gabion wall location (GW)
original GW 22
collapsed GW 22
GW 23
XS-8
original GW 23
collapsed GW 23
GW 24
XS-7
XS-6
GW 26
XS-5
GW 31
GW 30
GW 29
XS-4
XS-3
GW 33
XS-2
GW 34
XS-1
Elevation (m)
Station (m)
516
515
514
513
512
511
510
509
508
507
506
505
504
503
502
501
500
499
498
-5
0
5
10
15
20
25
30
35
40
45
50

Continuing Concerns

Increased Stream Power


tree growth
on wall


tree growth
on apron

Lower Reach

Conclusions

- All gabion sills failed, increasing chance of degradation
- Gabion walls narrowed flow and increased localized sediment transport capacity
- Bed scour undermined walls, toppling walls into channel and increasing channel narrowing and shear stress
- Increased sediment supply created local avulsions and channel widening, especially in the lower reach
- Channel has little chance for stabilizing in the near future

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