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Exploring Downstream Changes in Channel Width Influenced by Engineered Structures

Caerwyn Hartten¹, Alex Powell¹, Brooke Safely¹, Weston Burcar¹, Hervé Piégay², Anne Chin¹

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I. Overview

As urbanization continues to increase along with human population growth, understanding how urbanizing river systems evolve remains important. Previous research has shown how urban channels typically enlarge due to greater runoff from impervious surfaces, with width, for example, 2-15 times larger than their natural counterparts. Many urban rivers are managed to some extent via engineered structures; however, few studies have examined the extent to which engineered structures may introduce variability in channel adjustments. This study follows the South Platte River in Colorado from its natural headwaters through the Denver area, which has experienced rapid urbanization in recent decades. We measure and calculate the rate of change in channel width with drainage area downstream. Within the urban area, we identify segments with engineered structures including concrete weirs, riprap, and rock and concrete walls. Engineered structures contribute towards the overall management of the urban river reach. We measured channel width in higher resolution increments to determine the influence of engineered structures on channel width. Findings suggest engineered structures support channel width confinement. However, channel width recovery occurs downstream of engineered structures, with enlargement up to 15 percent, 1000m downstream of such structures.

II. Study Sites - South Platte River Through Denver

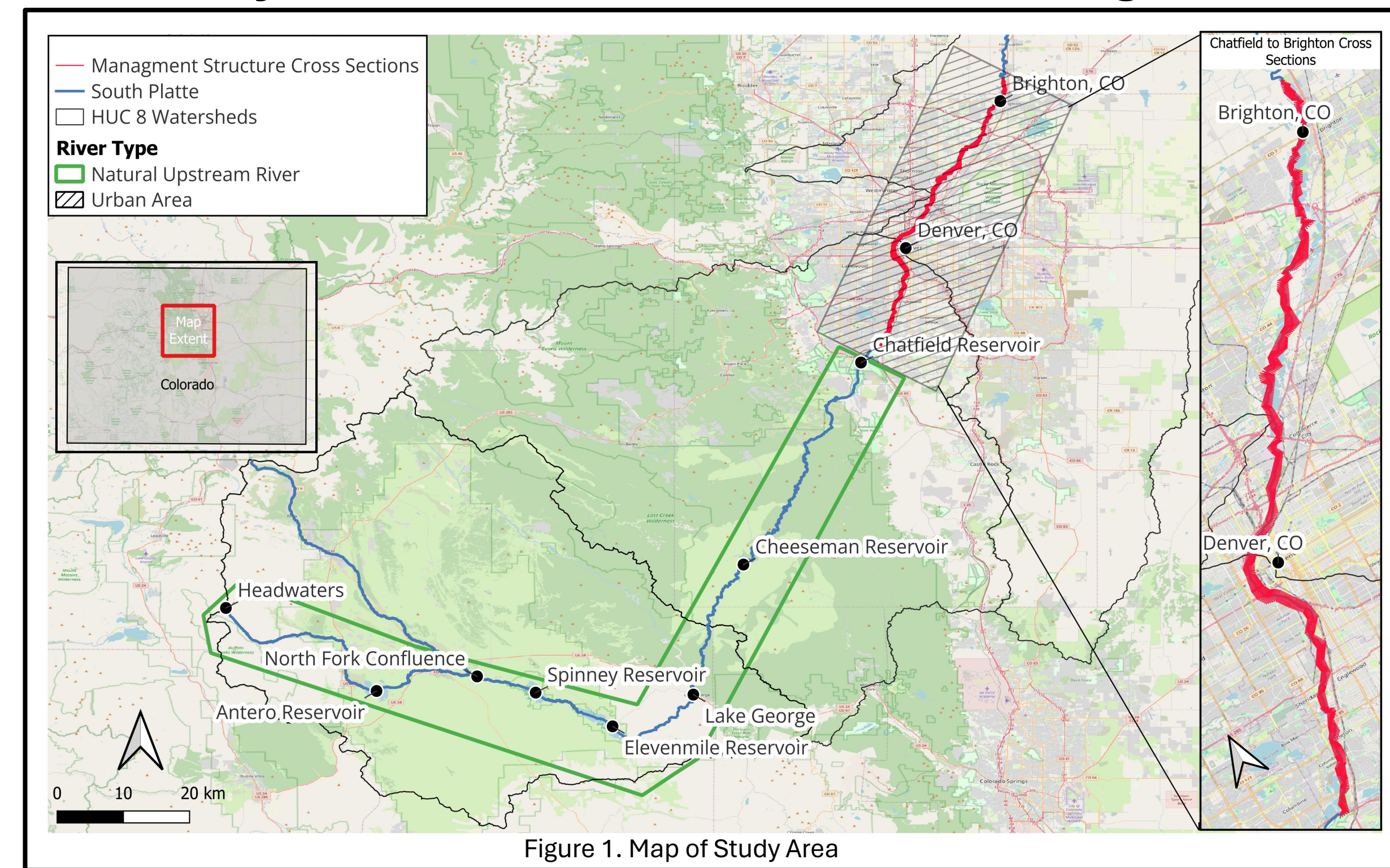


Figure 1. Map of Study Area

III. Research Questions

This research seeks to address two primary questions focusing on a) channel width adjustments and b) engineered structures:

- I. How does the channel width change through the Denver urban area?
- II. How do engineered structures influence adjustments in channel width within the urban reach?

IV. Methods

HEC-GeoRAS

Because of the areal extent and size of the study channel, we relied on geospatial tools to extract and analyze data. To create the dataset, we used HEC-GeoRAS (U.S. Army Corps of Engineers) to join 1-m resolution DEM raster data with river centerlines from the National Hydrography Dataset of the United States Geological Survey. This approach allowed interpolation and extraction of cross sections along the South Platte River by analyzing elevation profiles and bank to floodplain transition (Fig. 3). This cross-section data was then used to generate a shapefile in QGIS for spatial comparison.

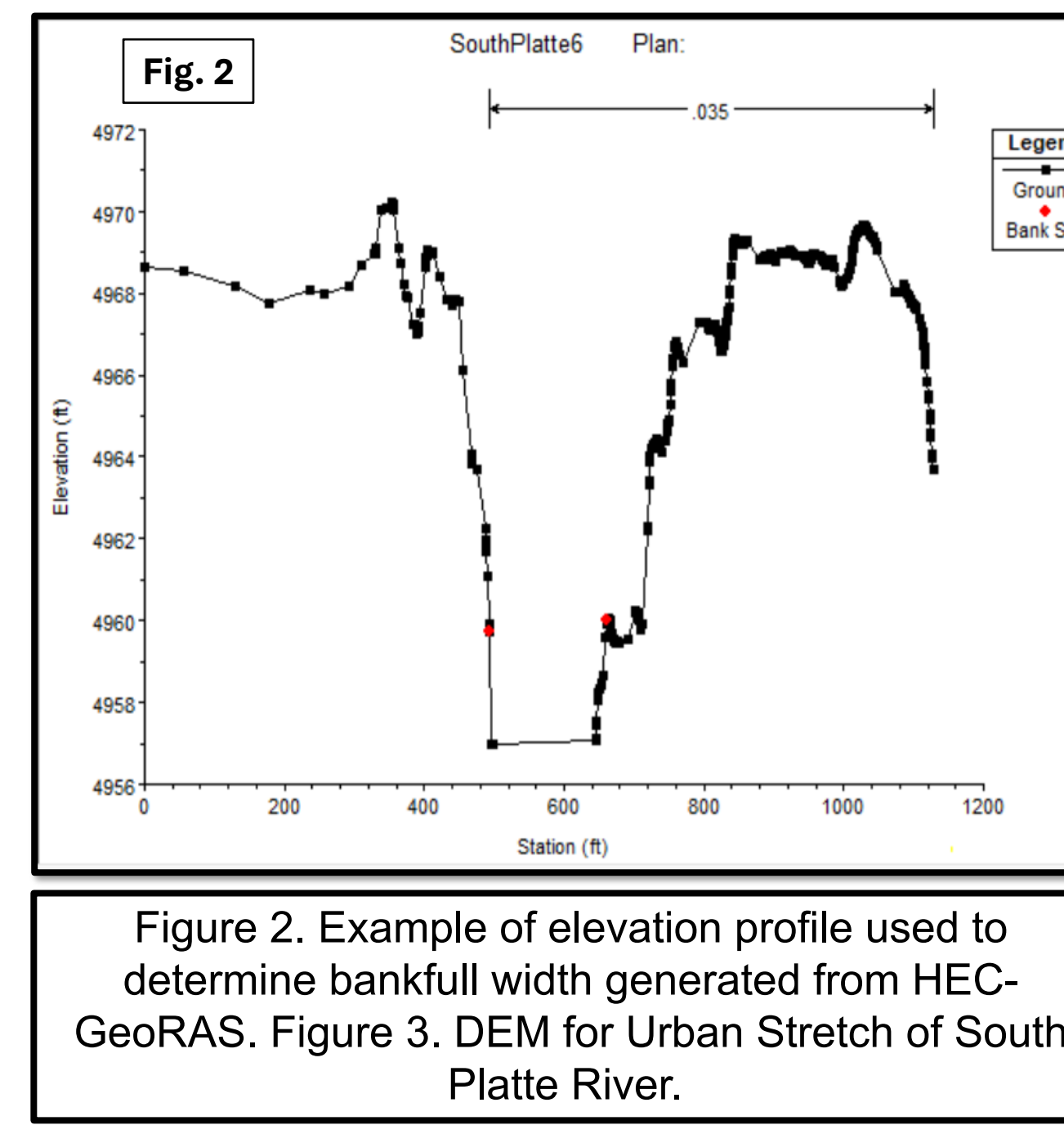
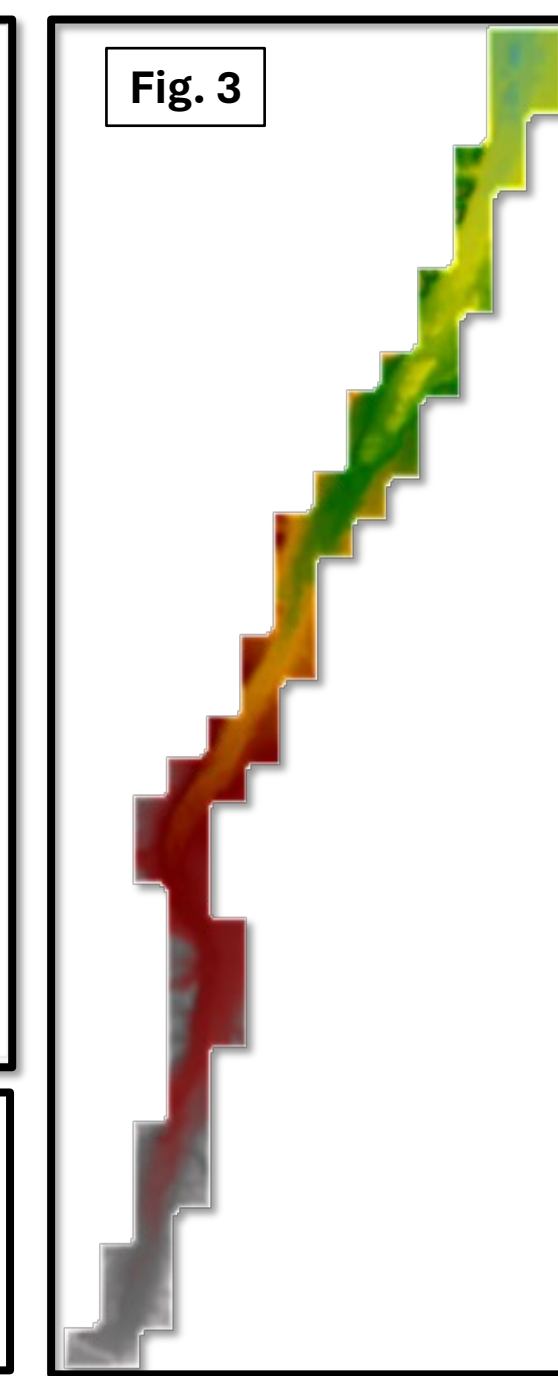


Figure 2. Example of elevation profile used to determine bankfull width generated from HEC-GeoRAS. Figure 3. DEM for Urban Stretch of South Platte River.



Downstream Changes in Channel Width

To examine downstream adjustments in channel width, we applied the spatial interpolation technique by comparing the widths of the channels upstream of the Denver urban areas with those downstream. Natural channel segments are defined as segments with little to no surrounding impervious surface and were divided into seven segments from Antero to Chatfield Reservoir (Fig. 1). The urban segment of the channel was that which was surrounded by a significant area of impervious surfaces, engineering structures, and buildings, and stretched one channel segment from Chatfield Reservoir to Brighton, CO (Fig. 1). Using drainage area as a surrogate for discharge, we first developed power functions relating drainage area to channel width for the upstream natural area. We then used this relationship to determine the expected channel width in the urban areas downstream. We also developed a regression relationship for the channels in the downstream urban section.

Channel Widths Through the Urban Engineered Structures

- We first identified the segment of the river populated by engineered structures, from Chatfield Reservoir to the city of Brighton (Figure 1)
- HEC-GeoRAS generated transects along the river every 100 meters (Figure 1)
- We identified and marked engineered structures on Google Maps and measured their lengths (where applicable). We then imported points and segments to QGIS to match the corresponding cross sections and river km.
- Categorizing managed and unmanaged transects and engineered structure types enabled comparisons of channel widths.
- Analysis of channel widths every 100m, 500m and 1000m downstream of engineered structure type provided insight on the influence of the engineered structures.

Engineered Structures Along the South Platte River



Rip Rap

Rip Rap and Concrete Weir

Concrete Wall

Rock Wall

V. Results

Downstream Changes in Channel Width

River Stretch (Figure 1)	Cross Section Count	Average Width (m)
Headwaters to Antero	n = 25	7.21
Antero to North Fork Confluence	n = 27	11.65
North Fork Confluence to Spinney	n = 11	13.27
Spinney to Elevenmile	n = 10	16.88
Elevenmile to Lake George	n = 18	20.35
Lake George to Cheeseman	n = 34	17.39
Cheeseman to Chatfield Res.	n = 58	19.9
Chatfield Reservoir to Brighton	n = 31	38.1

Figure 4. River width by channel segment

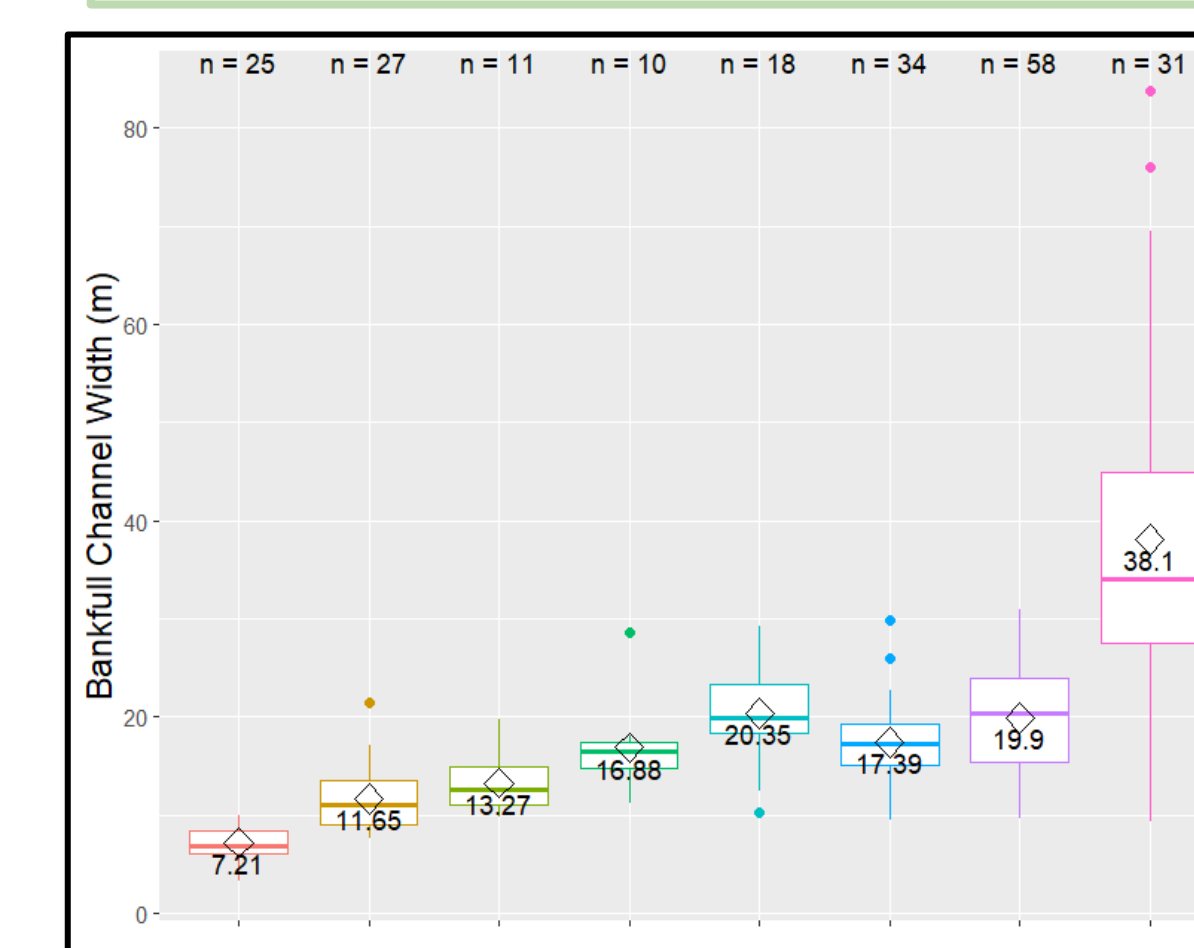


Figure 5. Relation between channel width and drainage area

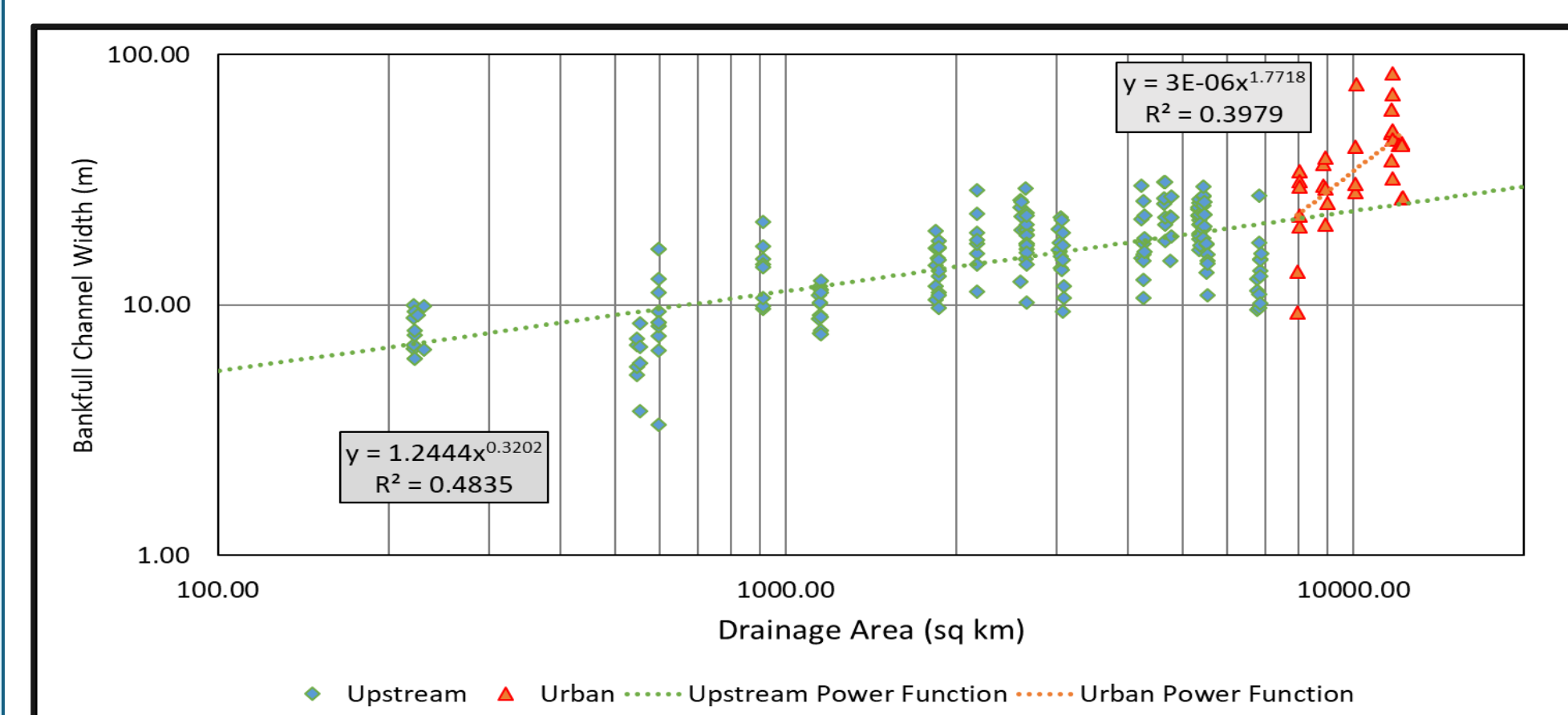


Table 1 presents the cross section count and average width breakdown for the natural river stretches (green) to the urban river stretch (blue). The urban stretch of the river shows an average increase to 38.1 m from an average 15.2 m across the natural stretch. Figure 4 shows the evolution of river width as the river moves downstream and flows towards the Denver Metropolitan Area, as represented in Table 1. Table 2 (right) outlines the observed vs predicted width measurements for the urban channel segment. The change ratio was calculated for each segment with an average width change of 1.58 m between the observed vs predicted channel widths (green box, left).

Approx. Distance (km)	Width (m)		Difference (Pred. - Obs.)	Change Ratio
	Observed	Predicted		
1	9.36	22.09	-12.73	0.42
2	13.56	22.09	-8.53	0.61
3	34.06	22.15	11.91	1.54
4	31.27	22.16	9.11	1.41
5	20.63	22.16	-1.53	0.93
6	22.72	22.16	0.56	1.03
7	29.80	22.16	7.64	1.34
8	36.42	22.86	13.56	1.59
9	29.98	22.87	7.11	1.31
10	38.74	22.91	15.83	1.69
11	20.98	22.91	-1.93	0.92
12	29.13	22.92	6.21	1.27
13	25.64	22.99	2.65	1.12
14	28.20	23.83	4.37	1.18
15	42.94	23.83	19.11	1.80
16	30.38	23.83	6.55	1.27
17	75.97	23.85	52.12	3.18
18	48.96	24.96	24.00	1.96
19	37.73	24.96	12.77	1.51
20	48.41	24.96	23.45	1.94
21	60.32	24.96	35.36	2.42
22	49.72	25.01	24.71	1.99
23	31.99	25.01	6.98	1.28
24	45.58	25.01	20.57	1.82
25	69.56	25.01	44.55	2.78
26	83.86	25.01	58.85	3.35
27	43.69	25.20	18.49	1.73
28	44.41	25.30	19.11	1.76
29	26.71	25.30	1.41	1.06
30	43.62	25.30	18.32	1.72
31	26.80	25.33	1.47	1.06

Average 1.58

Channel Widths Through the Urban Engineered Structures

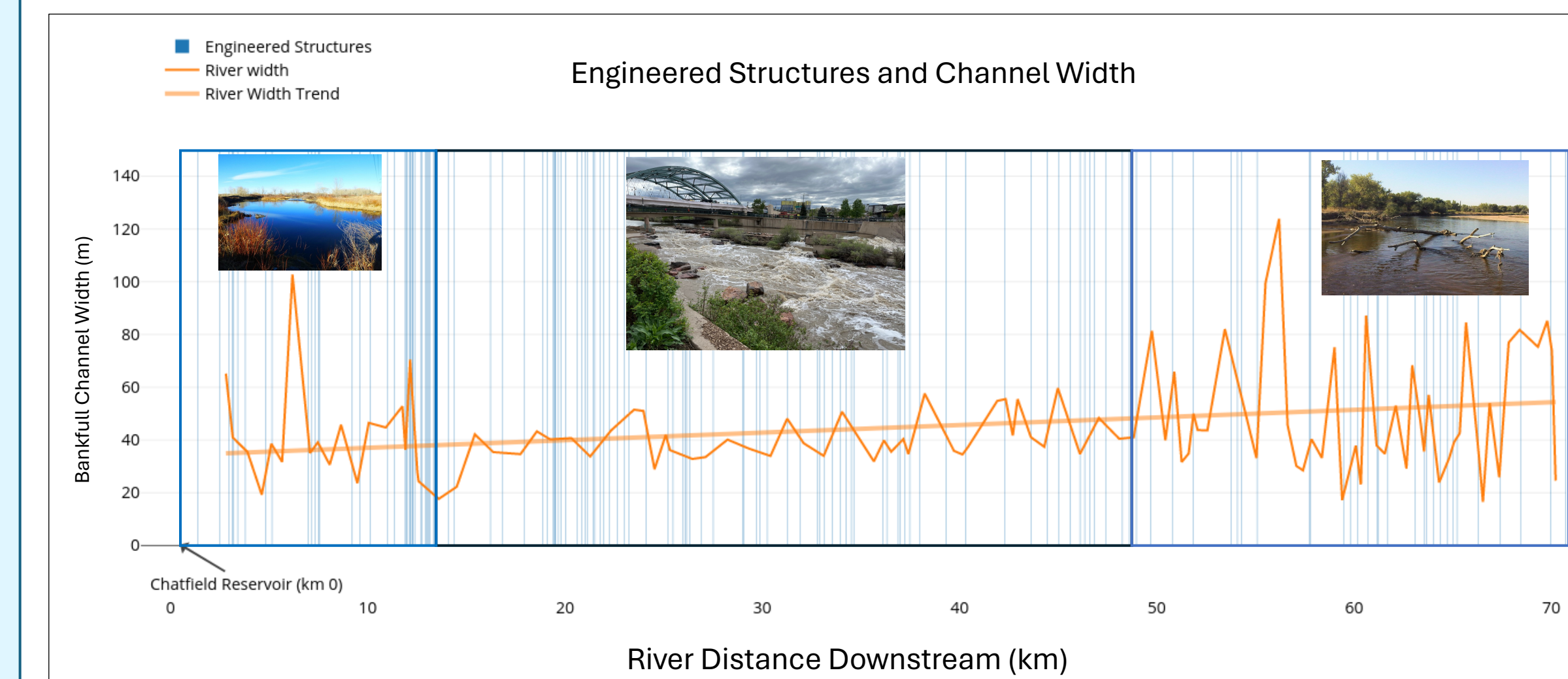


Figure 6 displays the channel width, in orange, to the appearance of engineered structure along the South Platte River (blue). Engineered structures were found in 36.4% of the transects taken from the Chatfield Reservoirs to Brighton (Figure 7). Of the five types of engineered structures, the average width ranged from 38.37 m to 43.56 m. However, there was variability in the channel widths confined by the engineered structures (Figure 8). Engineered structures also influences channel width downstream of the structures, with a 14% increase in width downstream of the structure in 24 cases (Figure 9).

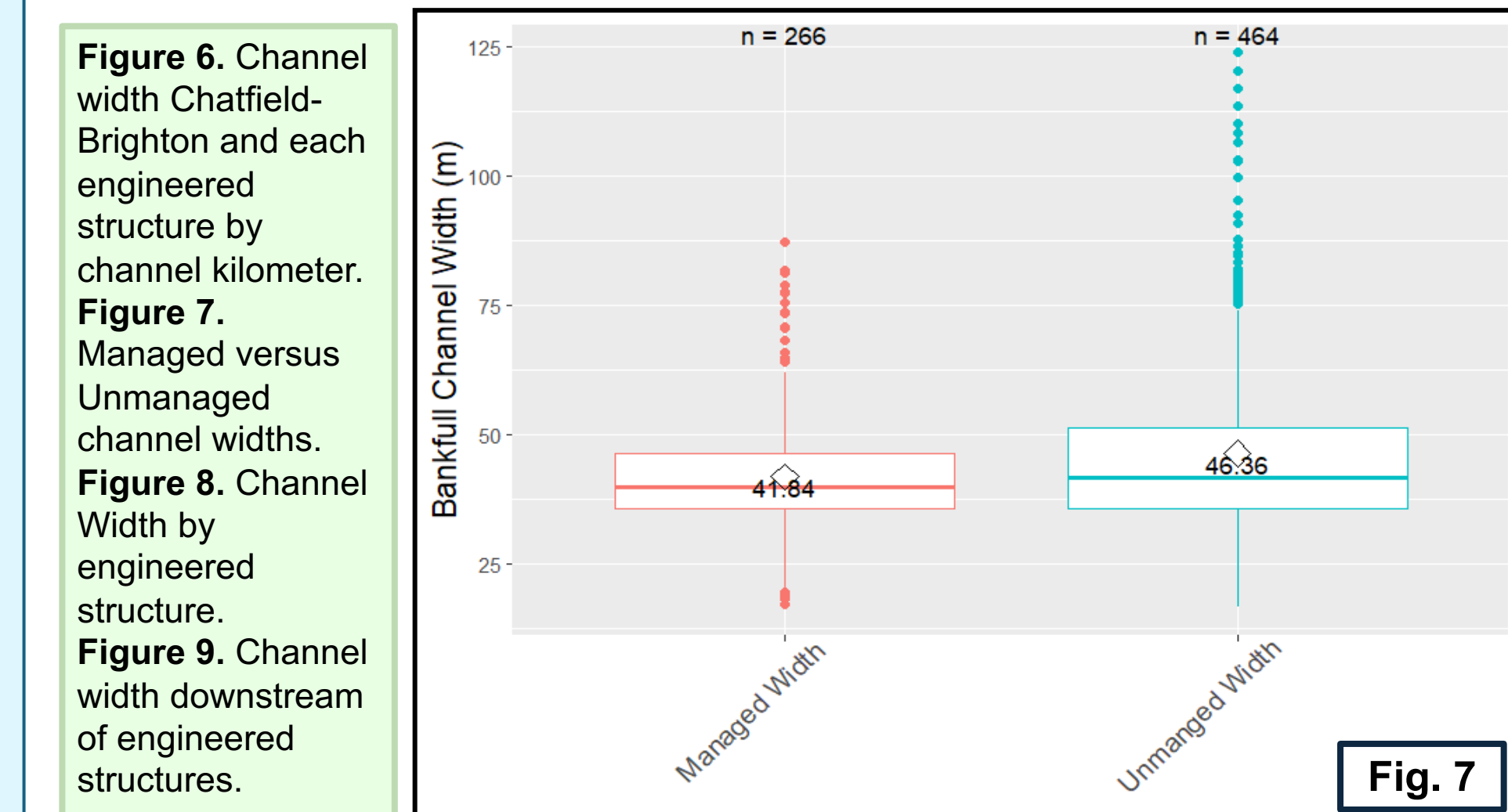


Figure 6. Channel width Chatfield-Brighton and each engineered structure by channel kilometer. Figure 7. Managed versus Unmanaged channel widths. Figure 8. Channel Width by engineered structure. Figure 9. Channel width downstream of engineered structures.

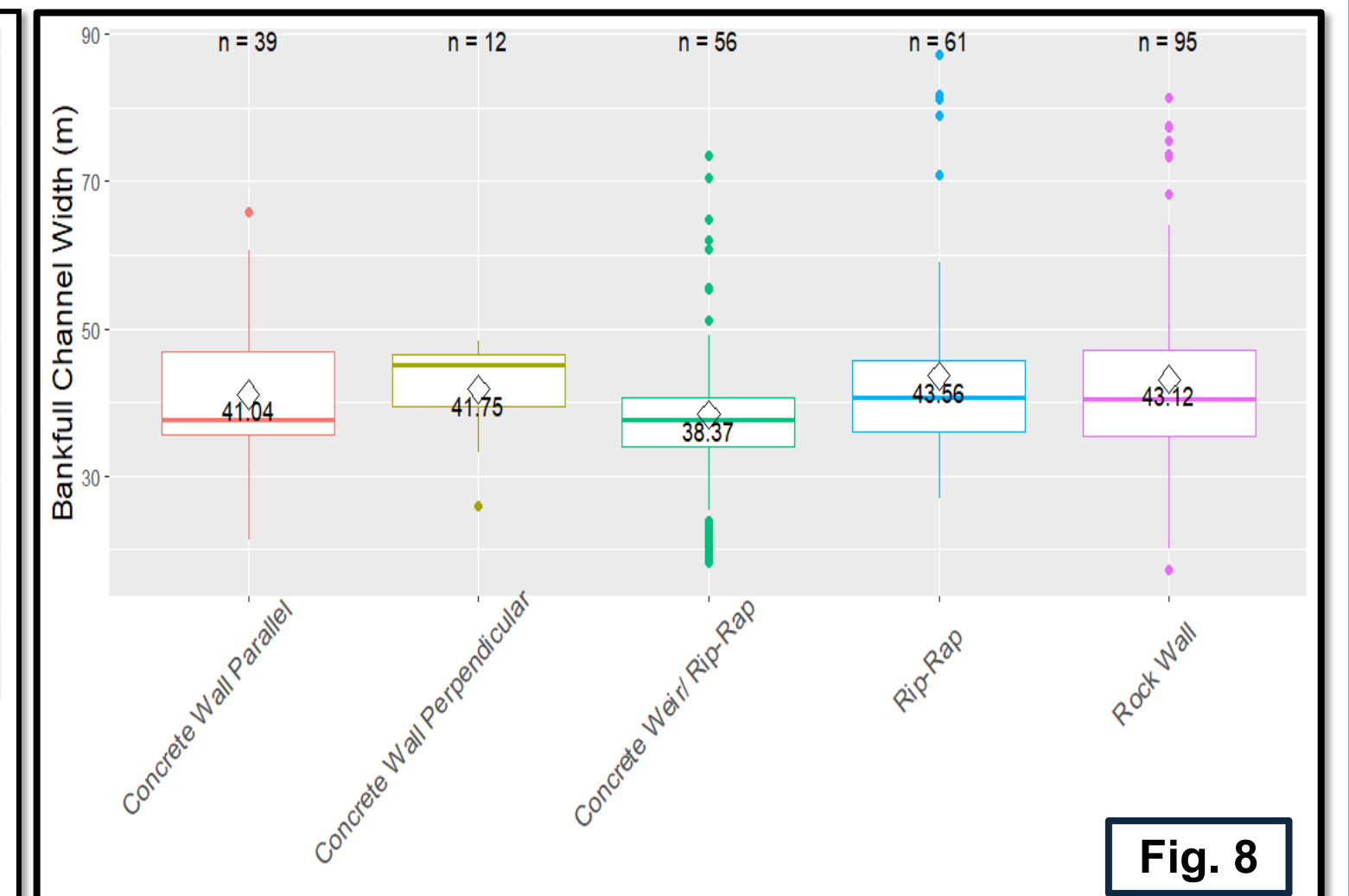


Figure 7. Managed versus Unmanaged channel widths. Figure 8. Channel Width by engineered structure. Figure 9. Channel width downstream of engineered structures.

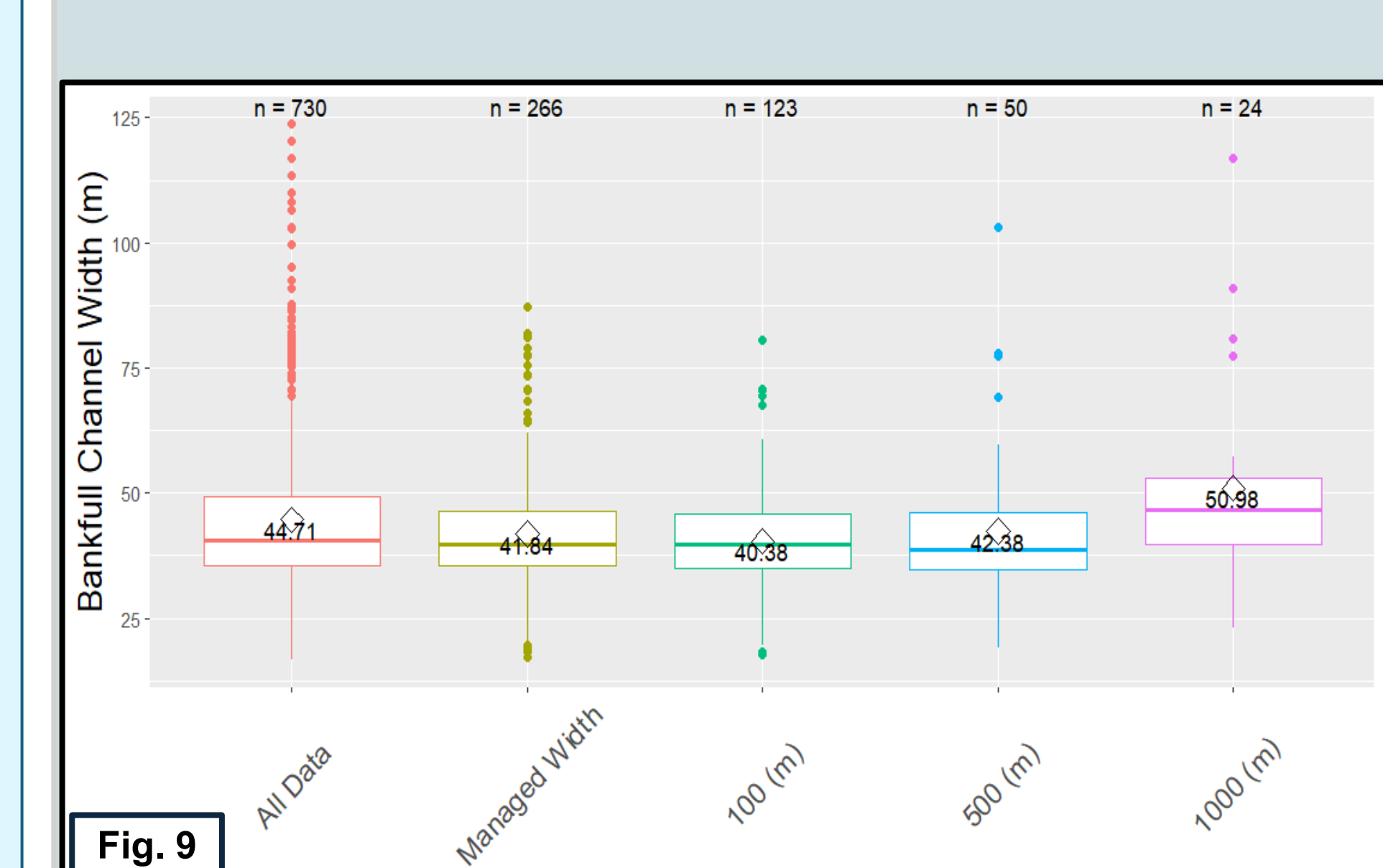


Figure 9. Channel width downstream of management structures.

Segment Type	Cross Section Count	Average Width (m)
Managed	n = 266	41.84
Unmanaged	n = 464	46.36

Management Type	Cross Section Count	Average Width (m)
Rock Wall	n = 95	43.12
Rip Rap	n = 61	43.66
Rip Rap/Concrete Weir	n = 56	38.37
Concrete Wall (Parallel)	n = 39	41.04
Concrete Wall (Perpendicular)	n = 12	41.75

Downstream Segment	Cross Section Count	Average Width (m)
All data	N = 730	44.71
All Managed Width data	n = 266	41.84
100 m	n = 123	40.38
500 m	n = 50	42.38
1000 m	n = 24	50.98

VI. Summary and Conclusions

Exploration of the downstream channel width through the Denver urban area along the South Platte River in Colorado produced several key points.

Q1: How does the river width change through the Denver urban area?

- Results show that channel width in the urban area is 1.58 times larger on average than their natural counterparts upstream. These results are slightly below previous research which outlines enlargement between 2-15 times. However, this may reflect the influence of engineered channel structures.

Q2: How do engineered structures influence adjustments in channel width within the urban reach?

- Channel width exhibits greater variability in managed sections with a range nearly four times higher than upstream natural sections.
- On average managed sections are 10.8% narrower than unmanaged sections. However, the narrower effects from the engineered structures extend downstream.
- Channel cross sections 1000 m downstream of engineered structures were on average 14% wider than the overall average width.

Future work includes testing difference in channel width and density of engineered structures per homogenous channel reach.

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