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2015 Pre-San Clemente Dam Removal Morphological Monitoring of the Carmel River Channel in Monterey County, California

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Publication No. WI-2016-01

28 January 2016

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Executive Summary

San Clemente Dam was removed from the Carmel River in fall 2015. A study of dam-removal impacts on the Carmel River will compare channel shape and substrate measurements from before-and-after dam removal. In 2013 several sites were selected for monitoring, both downstream of the dam (impact sites) and upstream of the dam (control sites). Subsets of the study sites were established by CSUMB and collaborating partners with the USGS and NOAA. This report presents a resurvey of the 2013 sites that were established by CSUMB. It also presents the first measurements of a new impact site and a new control site.

The resurvey of previous sites indicates that we will be able to determine vertical geomorphic changes greater than approximately 3 cm in the future before-after survey comparisons. The resurveys also showed that there has no substantial geomorphic change between 2013 and 2015. Substrate grain size analysis shows considerable change in sample percentiles during the span from 2013 to 2015 at some sites. The presence of high variability in the "before removal" era, suggests that only large changes will be detectable in the "before-after" comparison, to be attempted in future studies. The lack of geomorphically altering flows between 2013 and 2015 shows that grain size distributions can change with little forcing.

This report can be cited as:

Chow K., Luna L., Delforge A. and Smith D. 2016. 2015 Pre-San Clemente Dam Removal Morphological Monitoring of the Carmel River Channel in Monterey County, California. The Watershed Institute, California State University Monterey Bay, Publication No. WI-2016-01, 50 pp.

Acknowledgements

Funding and support for this project was provided by U.C. Santa Cruz and NOAA Fisheries Service's Southwest Fisheries Science Center and by CSUMB Undergraduate Research Opportunity Center.

We are grateful for the assistance and collaboration of:

- David Boughton, Lee Harrison, Colin Nicol, and Lea Bond (NOAA Fisheries)
- Amy East and Josh Logan (USGS)
- John Silveus, Alana Kleven, Steve Flores, and Leah MacCarter (CSUMB)

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1 Introduction

The 32 m tall San Clemente Dam, located in the northern Santa Lucia Mountains of Central California, was removed from the Carmel River in fall of 2015 (Figure 1). The dam was decommissioned because the 1425 acre feet reservoir was more than 95% filled with sediment, the dam was located near a seismically active fault zone, and there was uncertainty about the dam's ability to withstand a major flood (CCOWS 2012 for summary). Unlike all previous dam removal projects, this project was designed to minimize downstream impacts to fish habitat and flood frequency by sequestering all the stored sediment on site (SCDRP 2015). Sediment transport modeling of the dam removal project indicated that the river would not be significantly altered by the project (Mussetter 2005).

In collaboration with the U.S. Geological Survey and NOAA Fisheries Service, we established several study reaches in 2013 to monitor the actual downstream impacts of the dam removal project (Leiker et al. 2014). The study reaches include "impact" reaches located downstream of the dam, and "control" reaches located upstream of the dam. At each study reach surveyed in 2013, Leiker et al. (2014), or collaborators, surveyed benchmarked channel cross sections and performed particle counts to establish a baseline for documenting changes related to the dam removal. Our study resurveyed the Leiker et al. (2014) reaches to document between-survey precision, investigate natural annual variability, and to create a "before dam removal" data set that immediately preceded dam removal. We also added another "impact" study reach downstream of the dam and a "control" reach upstream of the dam removal project.

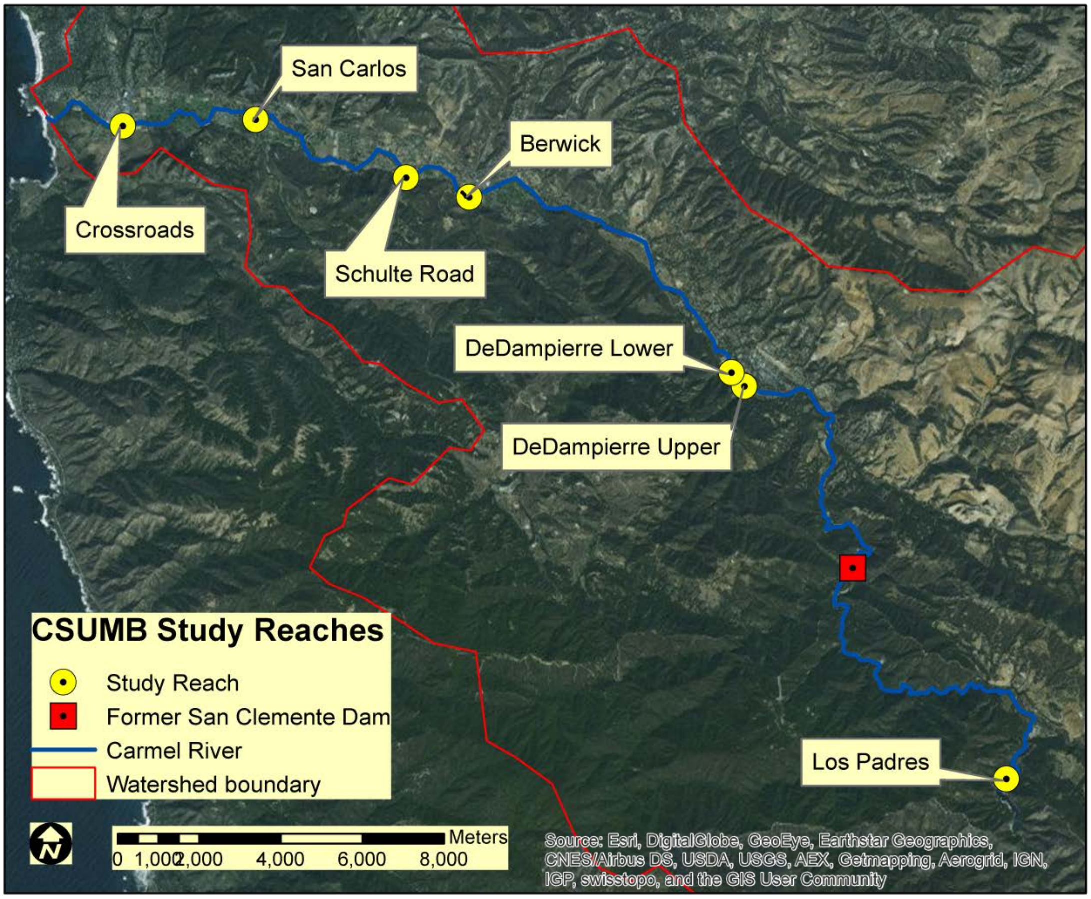


Figure 1. Location of study reaches upstream and downstream of the San Clemente Dam on the Carmel River.

2 Methods

Following the methods of the initial 2013 study (Leiker et al. 2014), we conducted geomorphic measurements of the Carmel River before the San Clemente Dam (SCD) reroute and removal at six diverse and representative reaches of the river that could change character following dam removal. The geomorphology of each reach was studied in the dry season when there were low flows and easy access to the channel. Data were collected in the fall of 2015. Five reaches established in 2013 were resurveyed and an additional "impact" reach was added downstream of the dam

(Berwick in Figure 1). An additional “control” reach was added to the study upstream of the San Clemente dam to better understand morphological change that was not influenced by the dam removal (Las Padres in Figure 1). Each study reach is described below:

- **Los Padres (LP)**: Located directly downstream from the Los Padres Dam, this reach is the most upstream reach established in 2015.
- **DeDampierre Upper (DDU)**: Located in the upper portion DeDampierre Park, the reach extends from the footbridge past the baseball fields. This reach contains several pieces of large wood installed for a restoration project by the Monterey Peninsula Water Management district (MPWMD).
- **DeDampierre Lower (DDL)**: This reach begins at the lower end of DeDampierre park and extends to the Carmel Valley Trail and Saddle Club downstream of the park.
- **Berwick (BW)**: Established in 2015, this reach is located on California American Water (CalAm) property.
- **Schulte Road (SR)**: Located upstream of the Schulte Road Bridge. This reach begins in land owned by the Big Sur Land Trust and extends to 100m upstream of the Schulte Bridge.
- **San Carlos (SC)**: Located just downstream of the San Carlos Road Bridge. The reach extends from the bridge to the California American Water (CalAm) San Carlos production well.
- **Crossroads (CR)**: Located adjacent to the Crossroads Shopping Center at the mouth of Carmel Valley. This is the most downstream reach included in this study.

Each reach was approximately 300 m in length and contained four to six transects evenly spaced at 60 m. Cross sections occurred in a variety of hydraulic settings, including riffles, glides, runs, and pools. Using the previous benchmarks established in 2013, we resurveyed each cross section using an autolevel, leveling rod, and 30 meter tape (Harrelson et al. 1994). At each cross section, a taut tape was set between the left and right benchmarks to facilitate a precise resurvey of each transect and guide shot distances. Points along transect were shot at one meter increments with additional shots to record breaks in slope. Surveys were closed at the end of every cross section using the left benchmark. Cross section data were plotted and visually compared with the 2013 surveys. At the two new reaches (Los Padres and Berwick), new cross section benchmarks were set and georeferenced using methods similar to those of Leiker et al. (2014) before autolevel surveys were performed.

In addition to topographic surveys, pebble counts were performed along each cross section to determine average particle size distribution. Pebble counts included only particles within the active low flow channel as indicated by recent substrate activity. We employed a sampling technique from Bunte and Abt (2001) that uses a 60 x 60 cm sampling quadrat. This method reduces serial correlation by adjusting the spacing between intersections on the frame to equal the dominant large particle size (≈D95). The 60 x 60 cm square sampling frame was constructed from 1" PVC pipe with notches every 10 cm. Elastic bands were then attached to notches according to the dominant large particle size of each transect.

The sampling grid was moved repeatedly across the estimated low flow channel at fixed intervals to achieve a sample size of ≥ 100. A gravelometer was used to measure particle sizes for pebble counts. Particle size percentiles were determined in R

(R Core Team, 2012). Particle size histograms and cumulative frequency graphs were generated for each cross section for comparison with the 2013 measurements.

3 Results

3.1 Los Padres Reach

The Los Padres reach is located directly downstream of the Los Padres Dam (Figure 1). This reach is upstream of the San Clemente Dam reroute site and serves as a control reach to be compared with the downstream reaches (Figure 2).

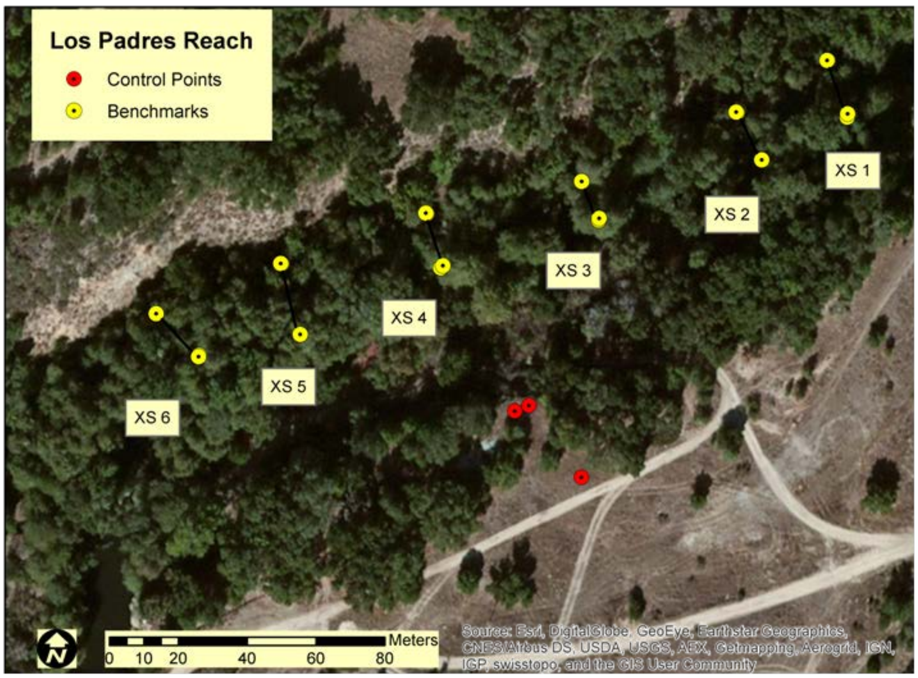


Figure 2. Location of georeferenced control points and cross sections within the Los Padres Reach.

The median grain size of this reach (D50) ranged from coarse pebbles to boulders (22.6 – 300 mm) among transects (Table 1). The 84th and 90th percentiles (D84 and D90) were mostly boulders with the exception of transect 1 (LP 1) which ranged from very coarse pebbles to cobbles (Figure 3). Cross sections located in pools tended to have smaller particle sizes while riffles tended to have larger particle sizes. Grain size distribution analysis revealed similar distributions of smaller particles, but higher variability in the larger particles between transects where large boulders were present. The width of cross sections in this reach covered the active channel and potions of floodplain when possible. Cross section widths ranged from 12 – 22 m and the average low-flow active channel observed in the field was between 10 – 12 m. The channel geometry and pebble count distribution of each surveyed cross section is in the Appendix.

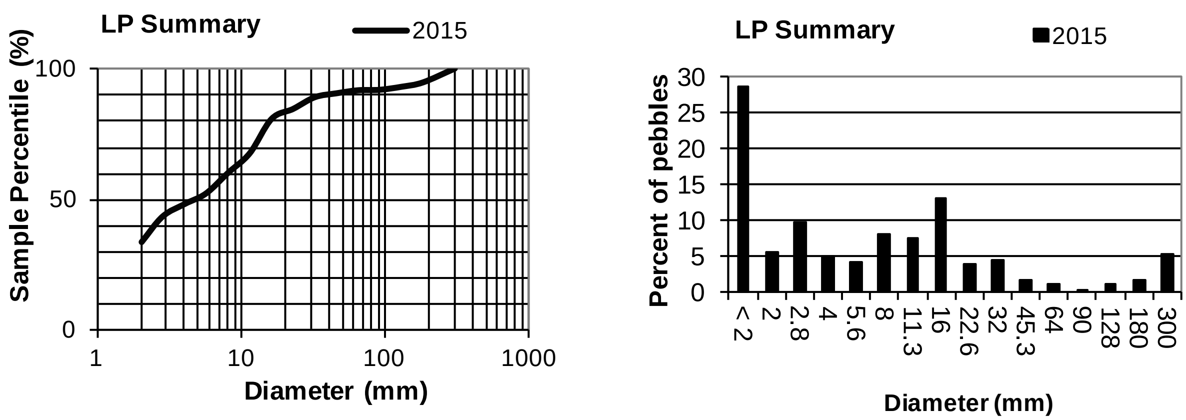


Figure 3. Summary pebble count distribution (LP 1 – LP 6) for the Los Padres reach displayed as cumulative percentiles (left) and individual bins (right) for 2015.

Table 1. Grain size distribution and cumulative finer than graphs among cross-sectional transects within the Los Padres Reach for 2013 & 2015. Runs like LP6 tended to have smaller particles.

	2015				
Los Padres	**D_{16}**	**D_{35}**	**D_{50}**	**D_{84}**	**D_{95}**
LP 1	16.0	32.0	64.0	300.0	300.0
LP 2	22.6	32.0	45.3	300.0	300.0
LP 3	11.3	38.7	90.0	300.0	300.0
LP 4	64.0	180.0	300.0	300.0	300.0
LP 5	13.7	45.3	128.0	300.0	300.0
LP 6	2.0	11.3	22.6	45.3	90.0

3.2 DeDampierre Upper Reach

The DeDampierre Upper Reach (Figure 4) is the most upstream reach monitored by CSUMB that will see impacts of the San Clemente Dam reroute. This reach included four large wood installments constructed by MPWMD. The large wood installments have created large, deep scour pools.

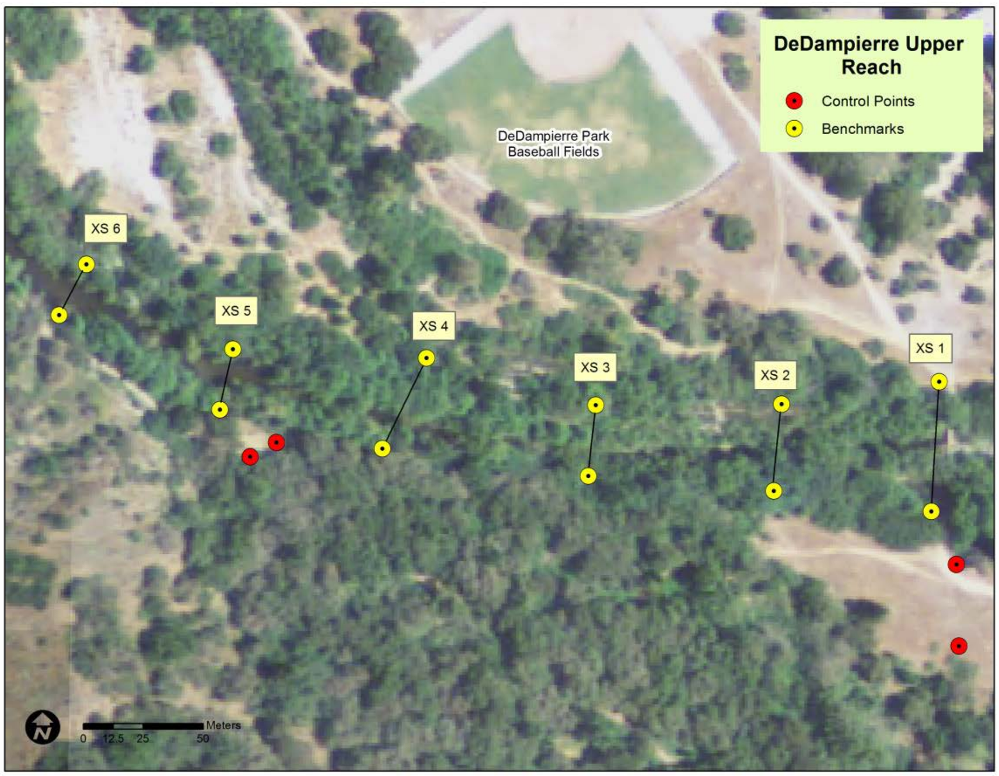
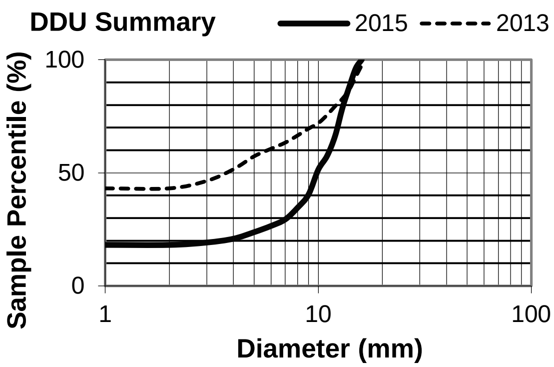


Figure 4. Location of georeferenced control points and cross sections within the DeDampierre Upper Reach.

The D50 of this reach ranged from fine pebbles to cobbles (5.6 – 90 mm) among transects (Table 2). Since 2013, grain size has increased overall, in large part because the < 2 mm fraction was removed (Figure 5). The 85th and 90th percentiles (D85 and D90) included a range of particle sizes from medium gravel and to small boulders (Table 2). Cross sections located in pools tended to have smaller particle sizes while riffles tended to have larger particle sizes. The pools formed by the large wood installments in this reach had much smaller particle sizes than other sections of the reach. The width of cross sections in this reach covered the active channel and potions of floodplain when possible. Two of the six cross sections (DDU2 & 3) were extended in 2015 by approximately 10 m. There are no noteworthy changes in channel shape at this reach.



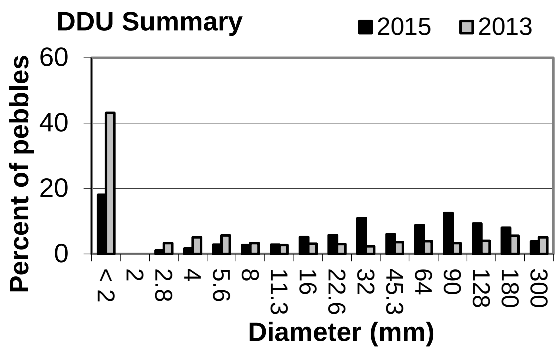


Figure 5. Summary pebble count distribution (DDU 1 – DDU 6) for the DeDampierre Upper reach displayed as cumulative percentiles (left) and individual bins (right) for 2015 and 2013.

Table 2. Grain size distribution and cumulative finer than graph among cross-sectional transects within the DeDampierre Upper Reach. Riffles such as DDU 3, tended to have larger particles than pools, such as DDU 1.

	2013					**2015**				
DeDampierre Upper	D_{16}	D_{35}	D_{50}	D_{84}	D_{95}	D_{16}	D_{35}	D_{50}	D_{84}	D_{95}
DDU 1	2.0	2.0	2.0	16.0	54.7	2.0	2.0	5.6	16.0	32.0
DDU 2	2.0	2.0	2.0	64.0	300.0	2.0	2.5	32.0	128.0	180.0
DDU 3	2.0	2.0	8.0	128.0	300.0	22.6	64.0	90.0	180.0	300.0
DDU 4	2.0	2.0	19.3	240.0	300.0	22.6	45.3	64.0	128.0	300.0
DDU 5	2.0	2.0	4.0	180.0	240.0	2.0	16.0	32.0	90.0	128.0
DDU 6	2.0	4.0	4.0	32.0	300.0	11.3	54.7	64.0	128.0	180.0

3.3 DeDampierre Lower Reach

This reach is located directly downstream of the DeDampierre Upper Reach. The upstream portion of the reach is a wide and open channel with a pool and long run. The reach narrows after cross section 3 (XS 3 of Figure 6) and has a steeper gradient than Upper DeDampierre.

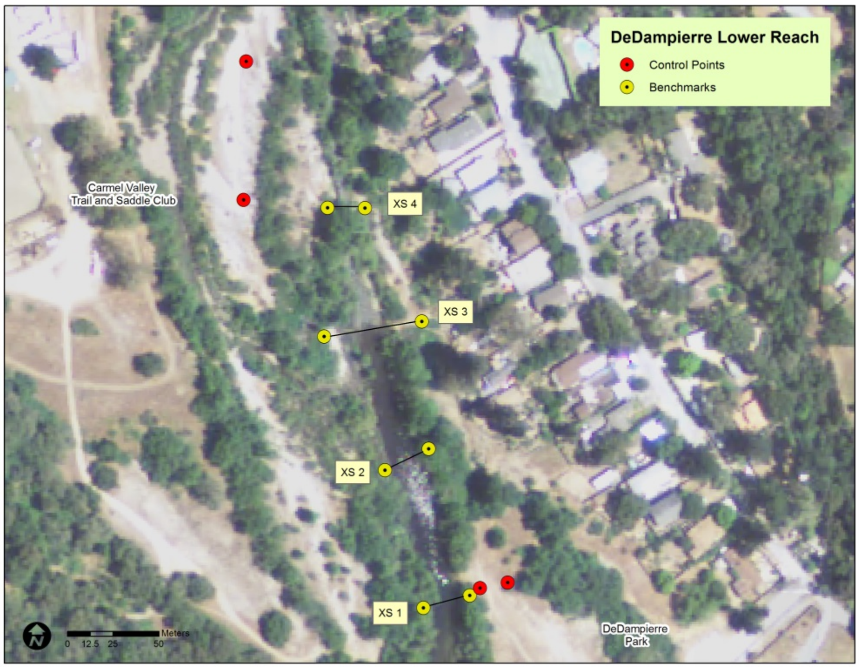
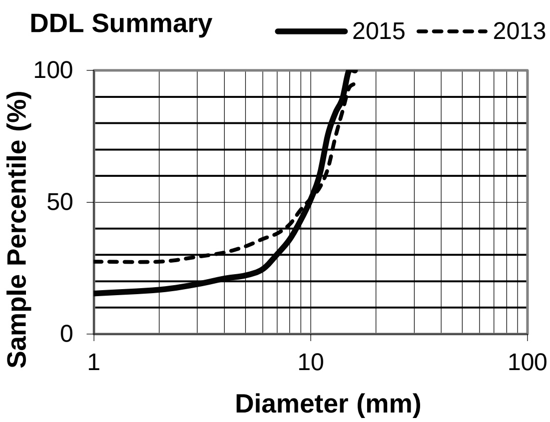


Figure 6. Location of georeferenced control points and cross sections within the DeDampierre Lower Reach.

The D50 ranged from medium- to very coarse-pebbles. (13.65 – 64 mm) among transects (Table 3). The D84 and D90 contained only cobbles. 2015 results reveal a less diverse distribution of particles and an increase in fine to very coarse pebbles (Figure 7). The width of cross sections in this reach covered the active channel and portions of floodplain when possible. Cross section widths ranged from 16 – 44 m and the average low-flow active channel observed in the field was between 10 – 20 m.

There has been no topographic change over all cross sections within this reach (Appendix).



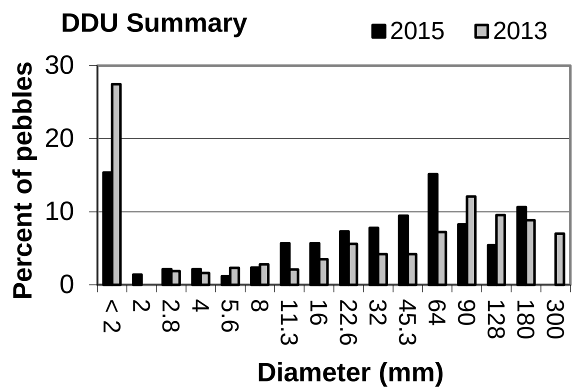


Figure 7. Summary pebble count distribution (DDL 1 – DDL 4) for the DeDampierre Lower reach displayed as cumulative percentiles (left) and individual bins (right) for 2015 and 2013.

Table 3. Grain size distribution and cumulative finer than graph among cross-sectional transects within the DeDampierre Lower Reach. DDL 1 has the largest pool (Appendix) and the largest decrease in grain size between 2013 and 2015.

	2013					2015				
DeDampierre Lower	D_{16}	D_{35}	D_{50}	D_{84}	D_{95}	D_{16}	D_{35}	D_{50}	D_{84}	D_{95}
DDL 1	2.0	2.0	11.3	180.0	300.0	2.0	2.0	13.7	90.0	180.0
DDL 2	2.0	8.0	45.3	128.0	180.0	9.7	32.0	45.3	90.0	128.0
DDL 3	2.0	11.3	22.6	128.0	300.0	8.0	16.0	22.6	64.0	128.0
DDL 4	2.0	22.6	64.0	180.0	300.0	2.0	32.0	64.0	180.0	180.0

3.4 Berwick Reach

Established in 2015, this site is located on California American Water (CalAm) property (Figure 8).

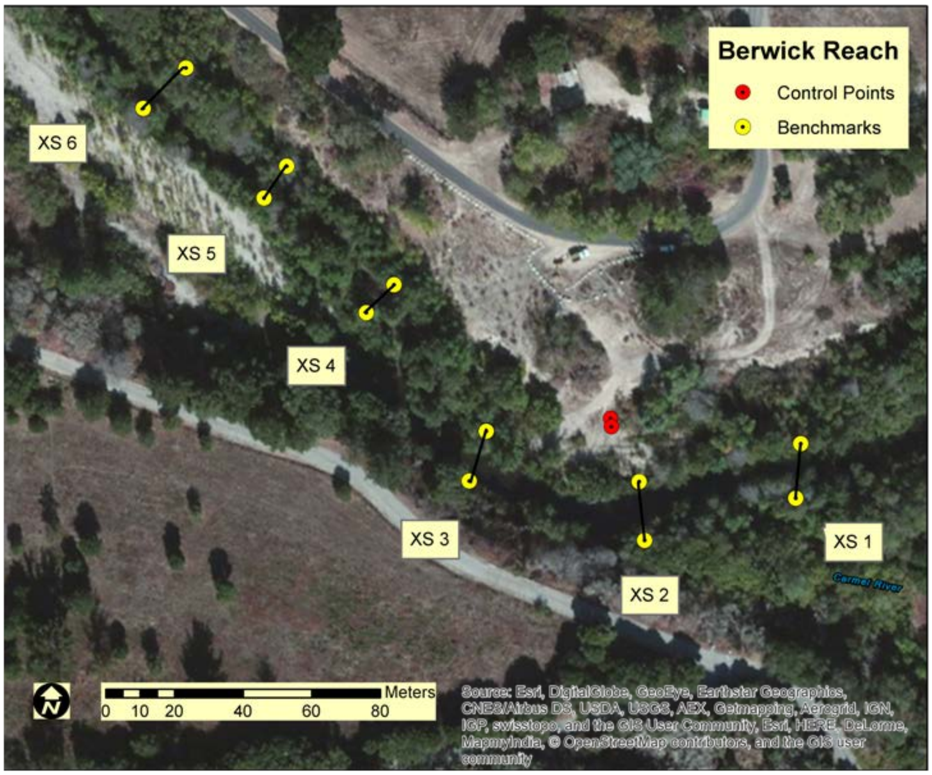


Figure 8. Location of georeferenced control points and cross sections within the Berwick Reach.

The median D50 ranged from coarse sand to very coarse pebbles (1-64 mm) (Table 4). The D84 and D90 contained coarse pebbles to boulders (Figure 9). The cross sections in this reach continue the trend of pools having a smaller particle size, such as BW 4 & BW 5. Cross section widths ranged from 11 to 16 m and the average low-flow active channel observed in the field was between 5-15 m (Appendix).

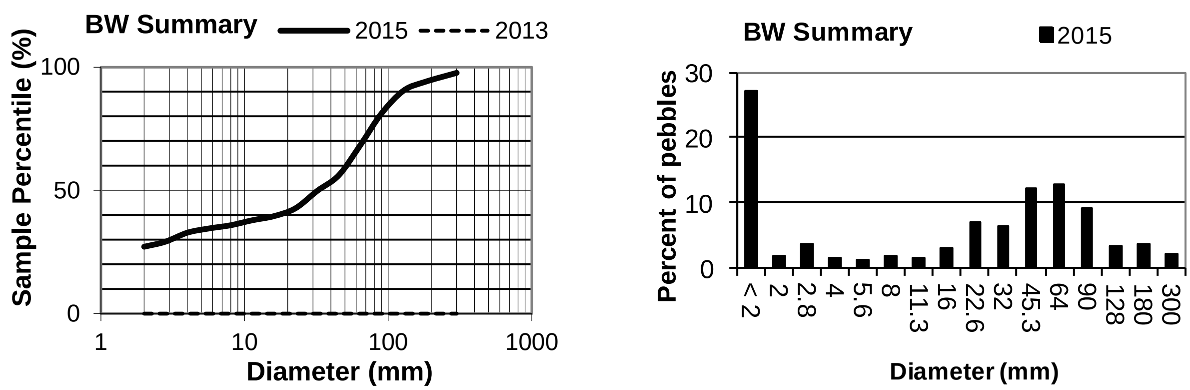


Figure 9. Summary pebble count distribution (BW 1 – BW 6) for the Berwick reach displayed as cumulative percentiles (left) and individual bins (right) for 2015.

Table 4. Grain size distribution and cumulative finer than graph among cross sectional transects within the Berwick Reach.

	2015				
Berwick	D_{16}	D_{35}	D_{50}	D_{84}	D_{95}
BW 1	19.3	32.0	64.0	90.0	128.0
BW 2	2.0	45.3	64.0	180.0	300.0
BW 3	2.0	4.0	22.6	64.0	90.0
BW 4	2.0	2.0	2.0	22.6	45.3
BW 5	2.0	5.6	22.6	64.0	64.0
BW 6	2.0	4.0	32.0	90.0	180.0

3.5 Schulte Reach

The Schulte reach is located approximately 200 m upstream of the Schulte Bridge and extends above the 'Steinbeck Pool' which is located between cross sections 2 and 3 (Figure 10).

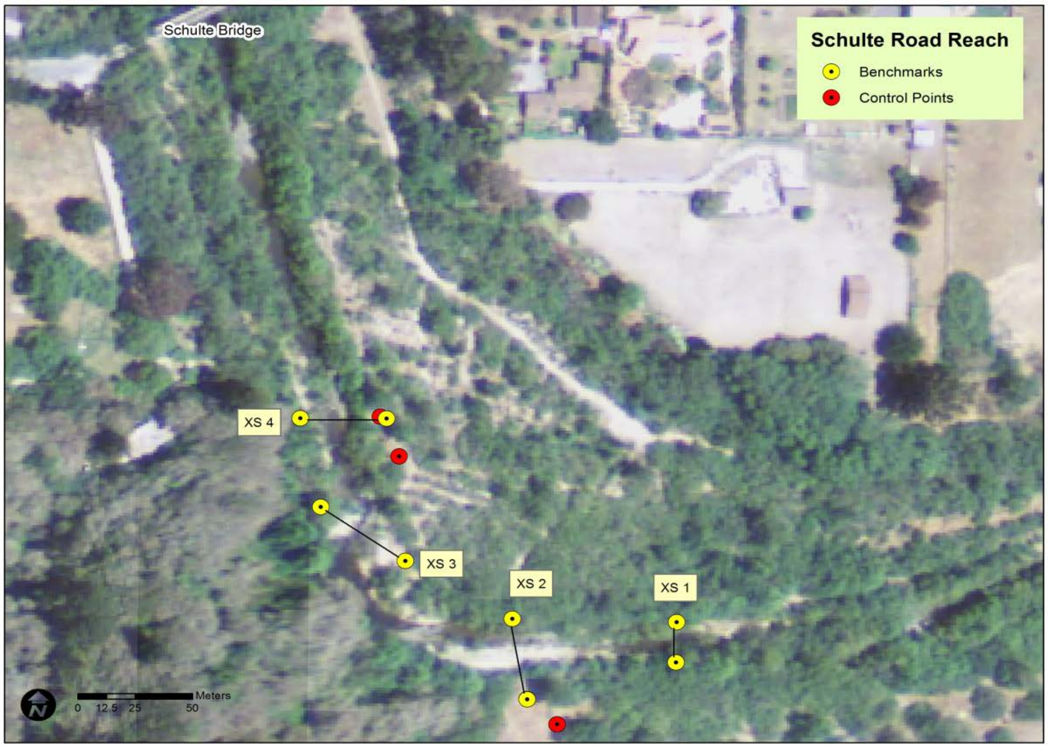
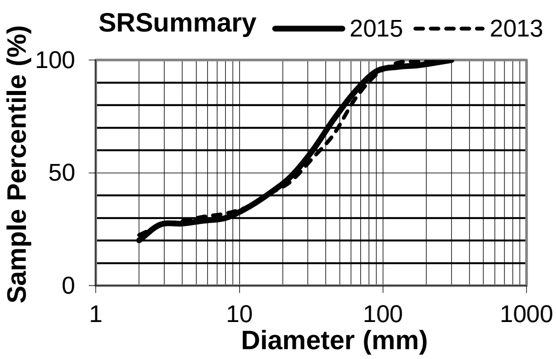


Figure 10. Locations of georeferenced control points and cross sections within the Schulte Road Reach.

The D50 ranged from granules to coarse pebbles (2-32 mm) among transects approximately the same as 2013 (Table 5). The D84 and D90 contained a wide range of particle sizes from coarse pebbles to boulders. The variability of sand and granules to cobbles and boulders is highest in pools, evident by cross section 1 (D50= 2 mm, D84= 45.3 mm).

Particle size distribution has not changed since 2013 (Figure 11). The channel width of cross sections in this reach covered the active channel and portions of floodplain when possible. Cross section widths ranged from 15-35 m and the average low-flow active channel observed in the field was between 10-15 m (Appendix).



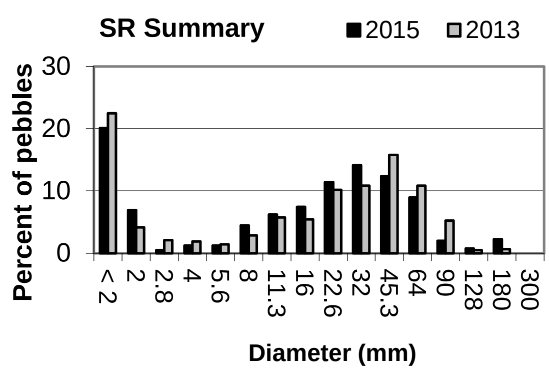


Figure 11. Summary pebble count distribution (SR 1 - SR 4) for the Schulte Road reach displayed as cumulative percentiles (left) and individual bins (right) for 2015 and 2013.

Table 5. Grain size distribution and cumulative finer than graph among cross-sectional transects within the Schulte Road Reach. SR1 has the deepest pool and smallest grain size.

	2013					2015				
Schulte Road	D_{16}	D_{35}	D_{50}	D_{84}	D_{95}	D_{16}	D_{35}	D_{50}	D_{84}	D_{95}
SR 1	2.0	2.0	2.0	45.3	180.0	2.0	2.0	2.0	45.3	180.0
SR 2	8.0	16.0	22.6	45.3	64.0	8.0	16.0	22.6	45.3	64.0
SR 3	16.0	22.6	32.0	45.3	64.0	16.0	22.6	32.0	45.3	64.0
SR 4	2.0	8.0	27.3	64.0	64.0	2.0	8.0	27.3	64.0	64.0

3.6 San Carlos Reach

The D50 ranged from very coarse sand to coarse pebbles (1.9-32 mm) among transects with a more frequent occurrence of sand and fine pebbles (Table 6). The D84 and D90 ranged from very coarse pebbles to boulders with not much variation. Not much changed since 2013 (Figure 12). Large boulders were less frequent this far downstream. The channel width of cross sections in this reach covered the active channel and portions of floodplain when possible (Figure 13). Cross section widths ranged from 19-47 m and the average low-flow active channel observed in the field was between 10-15 m. Channel shape also has not significantly changed since 2013 (Appendix).

Table 6. Grain size distribution and cumulative finer than graph among cross-sectional transects within the San Carlos Reach.

	2013					2015				
San Carlos	D_{16}	D_{35}	D_{50}	D_{84}	D_{95}	D_{16}	D_{35}	D_{50}	D_{84}	D_{95}
SC 1	9.7	16.0	16.0	45.3	122.0	5.6	27.3	45.3	90.0	128.0
SC 2	11.3	22.6	32.0	45.3	64.0	11.3	32.0	45.3	90.0	109.0
SC 3	2.0	5.6	11.3	32.0	45.3	2.0	2.0	2.8	45.3	300.0
SC 4	2.0	2.0	2.8	45.3	64.0	2.0	2.0	2.0	45.3	90.0
SC 5	2.0	5.6	11.3	32.0	45.3	2.0	16.0	32.0	54.7	64.0
SC 6	2.0	2.0	1.9	32.0	45.3	2.0	2.0	2.8	32.0	64.0

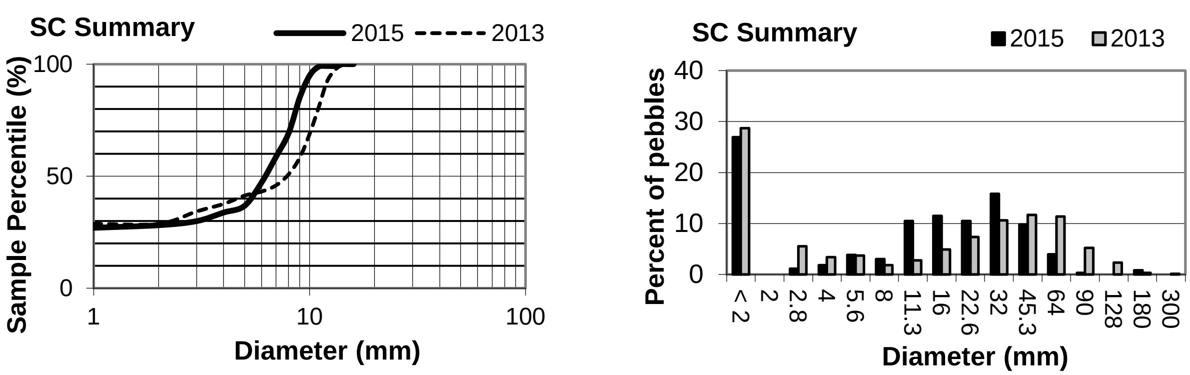


Figure 12. Summary pebble count distribution (SC 1 - SC 6) for the San Carlos reach displayed as cumulative percentiles (left) and individual bins (right) for 2015 and 2013.

Figure 13. Locations of georeferenced control points and cross sections within the San Carlos Reach.

3.7 Crossroads Reach

Crossroads is the lowermost reach monitored, and is located adjacent to the Crossroads shopping center near the mouth of Carmel Valley (Figure 14). The D50 ranged from medium pebbles to coarse pebbles (11.3-22.6 mm) among transects (Table 7). The D84 and D90 contained coarse to very coarse pebbles. Particle size distributions between cross sections were very consistent (Figure 15). The channel width of cross sections in this reach covered the active channel and portions of floodplain when possible. Cross section widths ranged from approximately 16 - 25 m and the average low-flow active channel observed in the field was between 10 - 15 m. There has not been significant topographic change at this reach since 2013 (Appendix).

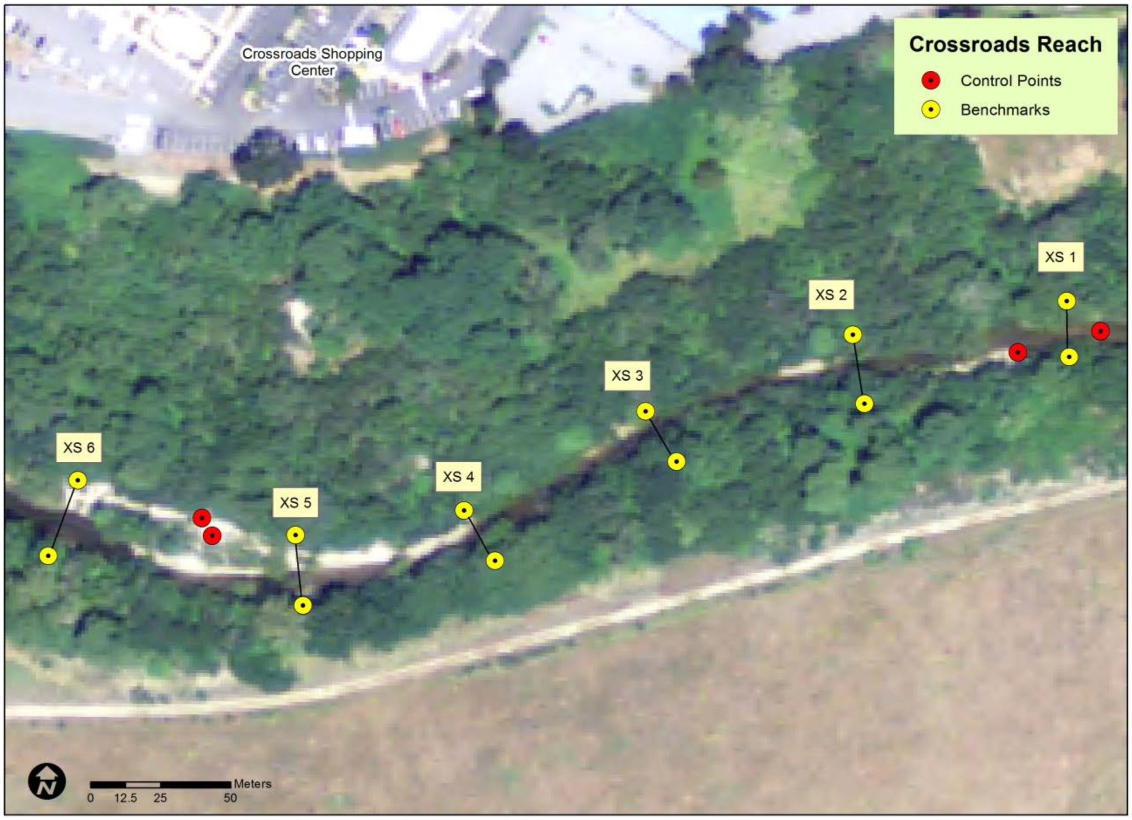


Figure 14. Locations of georeferenced control points and cross sections within the Crossroads Reach.

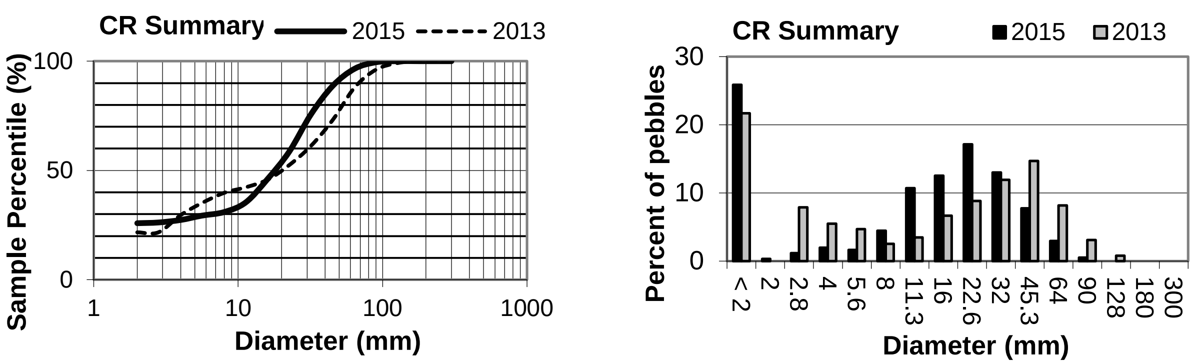


Figure 15. Summary pebble count distribution (CR 1 – CR 6) for the Crossroads reach displayed as cumulative percentiles (left) and individual bins (right) for 2015 and 2013.

Table 7. Grain size distribution and cumulative finer than graph among cross-sectional transects within the Crossroads Reach. This reach is dominated by sand. It is the furthest downstream and has the smallest average grain size.

	2013					2015				
Crossroads	D_{16}	D_{35}	D_{50}	D_{84}	D_{95}	D_{16}	D_{35}	D_{50}	D_{84}	D_{95}
CR 1	8.0	16.0	16.0	32.0	45.3	3.4	16.0	22.6	38.7	45.3
CR 2	2.0	2.0	11.3	32.0	45.3	2.0	2.8	9.7	32.0	45.3
CR 3	2.0	2.0	11.3	32.0	45.3	2.0	2.0	2.8	32.0	45.3
CR 4	2.0	8.0	16.0	32.0	64.0	2.0	4.0	11.3	32.0	54.7
CR 5	6.8	16.0	22.6	32.0	54.7	2.0	11.3	16.0	45.3	64.0
CR 6	1.5	8.0	11.3	32.0	45.3	2.0	4.0	8.0	32.0	45.3

4 Discussion

The cross section plots indicate little geomorphic change has occurred between the 2013 and 2015 surveys (Appendix), despite flows of 700 cfs and 1000 cfs during that time span. Likewise, the plots indicate that between-survey error is acceptably low, giving confidence in our ability to document even minor geomorphic changes in the post-dam removal era. In general, future surveys should be able to capture vertical changes in the bed exceeding approximately 3 cm.

Particle distribution appears to be bimodal with a large amount of sand and cobbles, but sparse intermediate sizes (Appendix). Upstream reaches have a larger abundance of small cobbles, coarse gravel and sand this year (Figure 16).

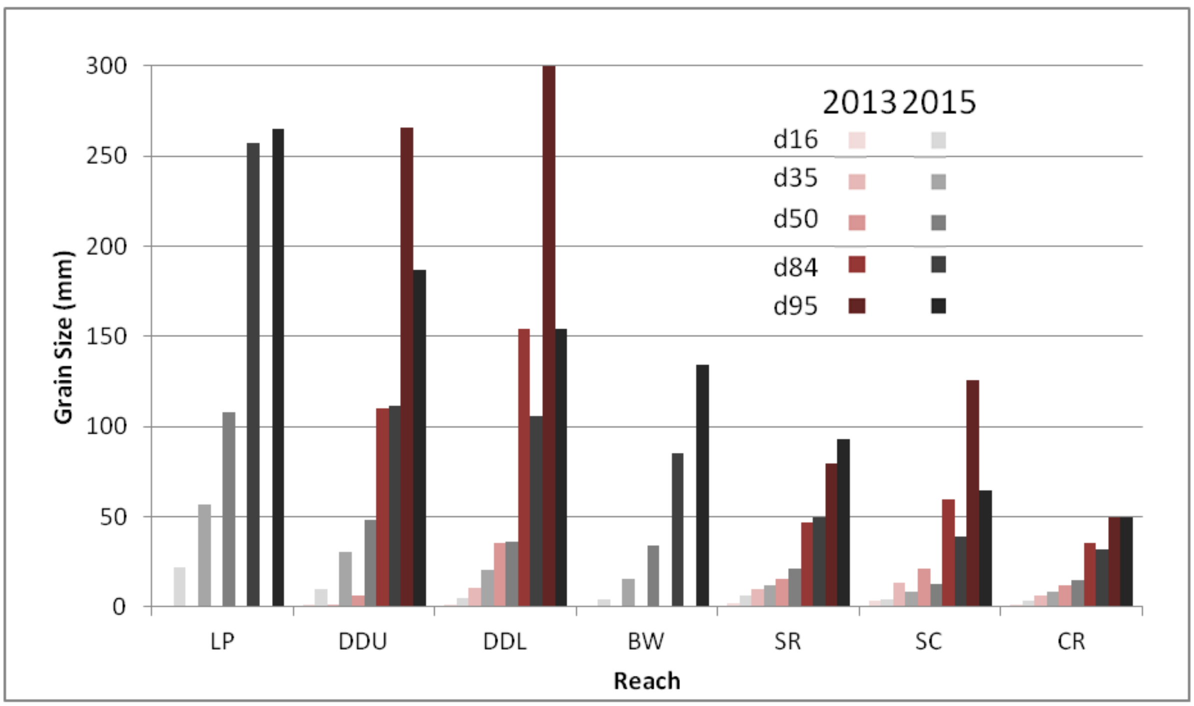


Figure 16. Particle size percentiles averaged within reaches and arranged by year from upstream (LP) to downstream (CR). Symbols are Los Padres (LP), upper DeDampierre (DDU), lower DeDampierre (DDL), San Carlos Road (SC), and Crossroads (CR). 2013 data from Leiker et al. (2014). Locations in Figure 1.

Particle size percentiles monotonically decreased downstream in 2015, as expected for a river system with downstream decreasing slope (Figure 16). Grain size percentiles in upstream sites (DDU and DDL) have decreased in size and variation between 2013 and 2015. Downstream reaches (SR, SC, and CR) did not show as much change (Figure 16). Given the considerable grain size changes that occurred between 2013 and 2015 in the “before” dam removal era, future studies that compare “before” and “after” dam conditions will only be able to assign very large changes in grain size distribution to the dam removal impact.

5 References

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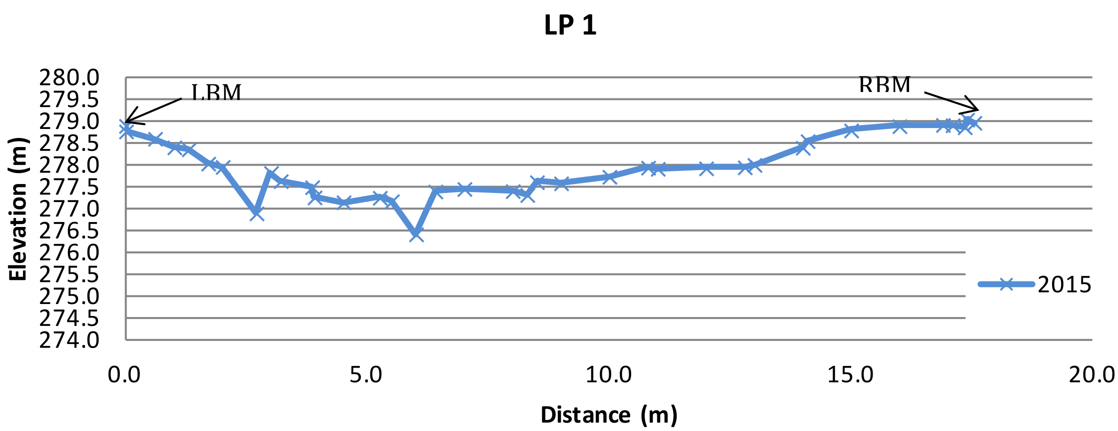
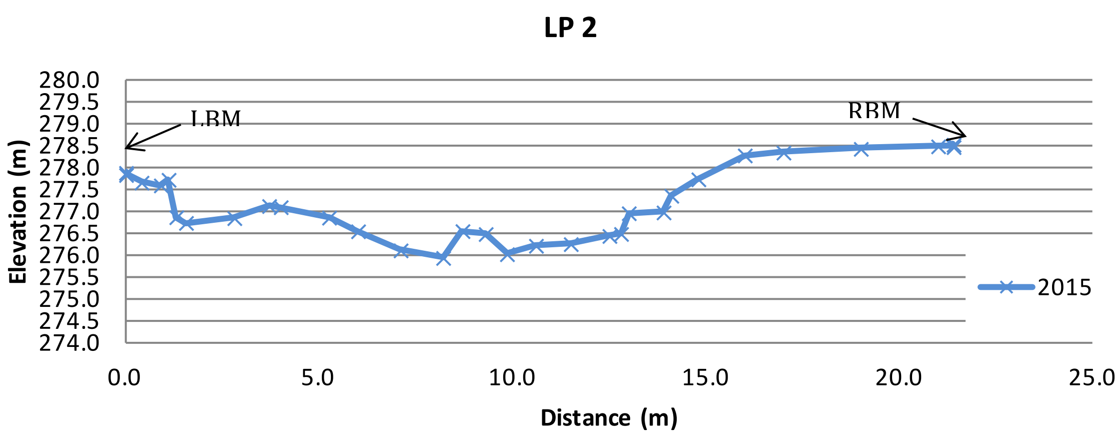
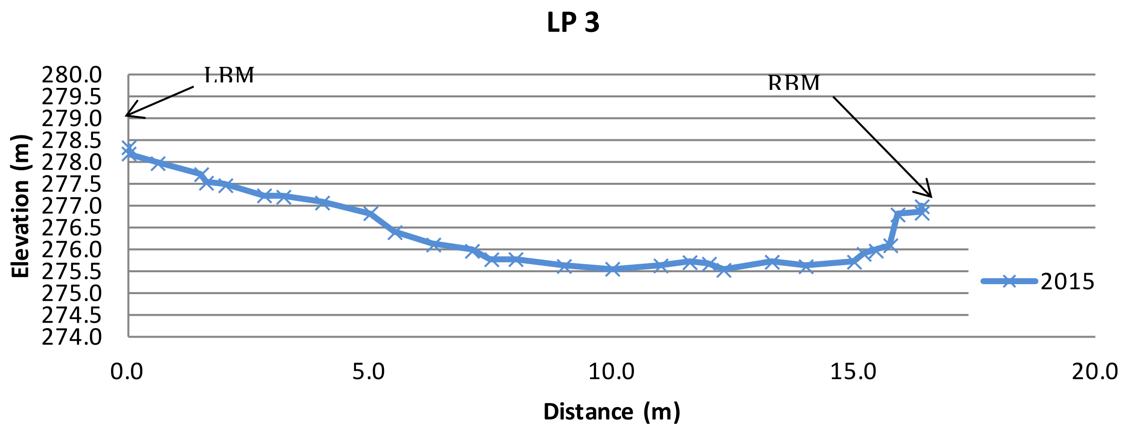
6 Appendix

6.1 Cross sections

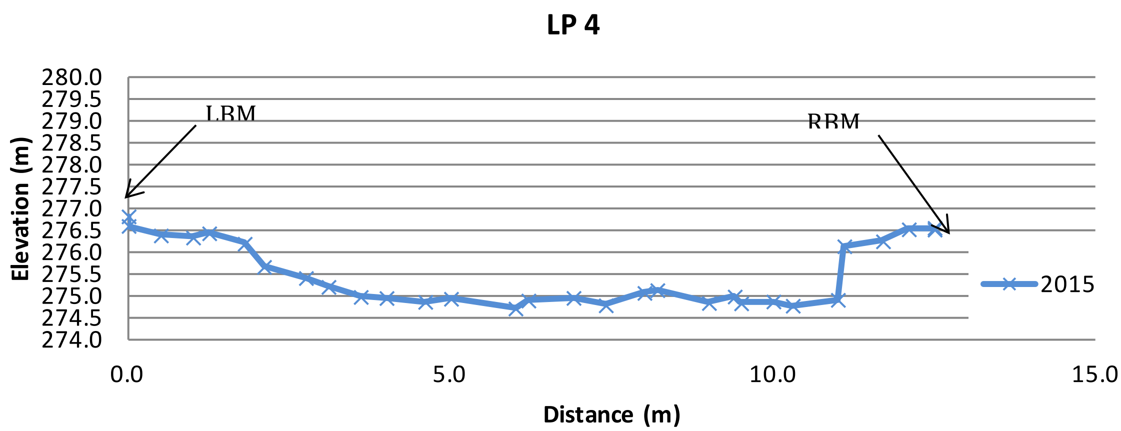
Channel geometry for each cross section surveyed within each reach. Cross sections are denoted by their reach abbreviation (LP, DDU, DDL, BW, SR, SC, and CR) and transect number descending from upstream to downstream (1 to 4 or 6).



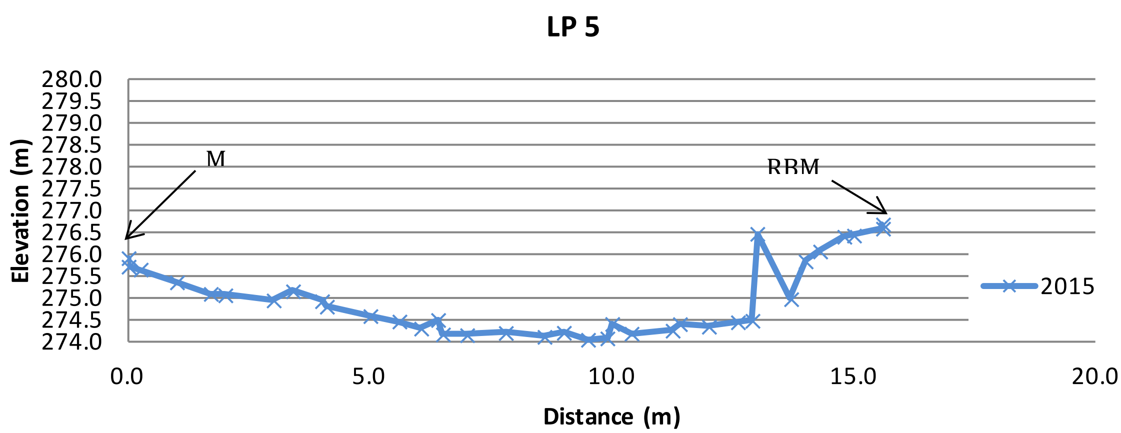




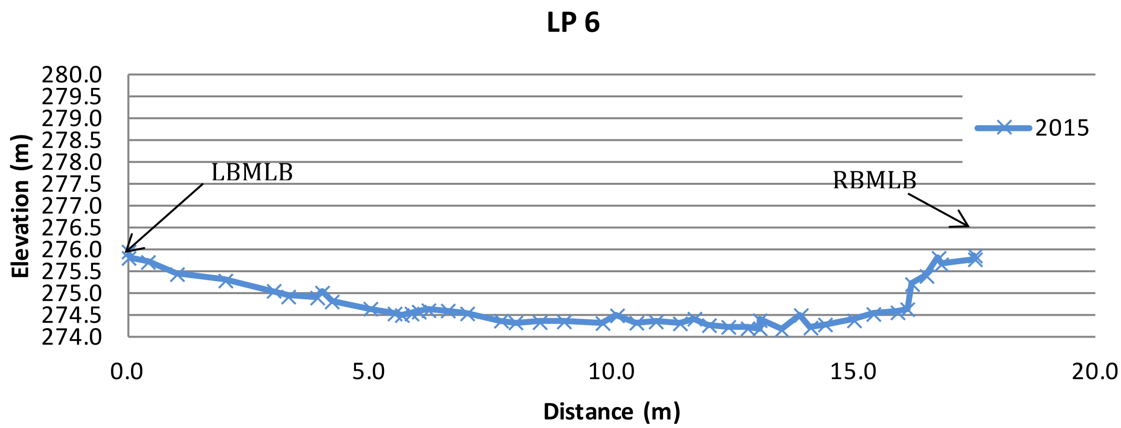
LP 3
LBM
RBM
Elevation (m)
Distance (m)
2015

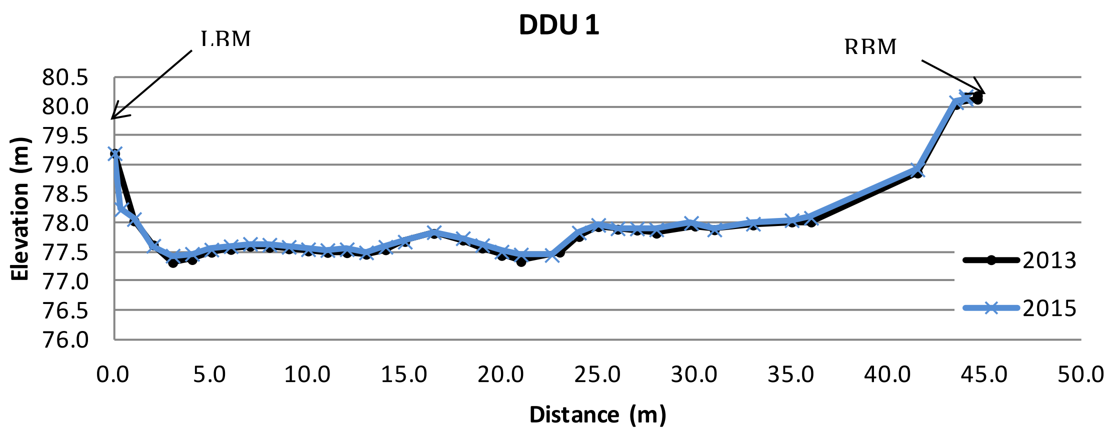


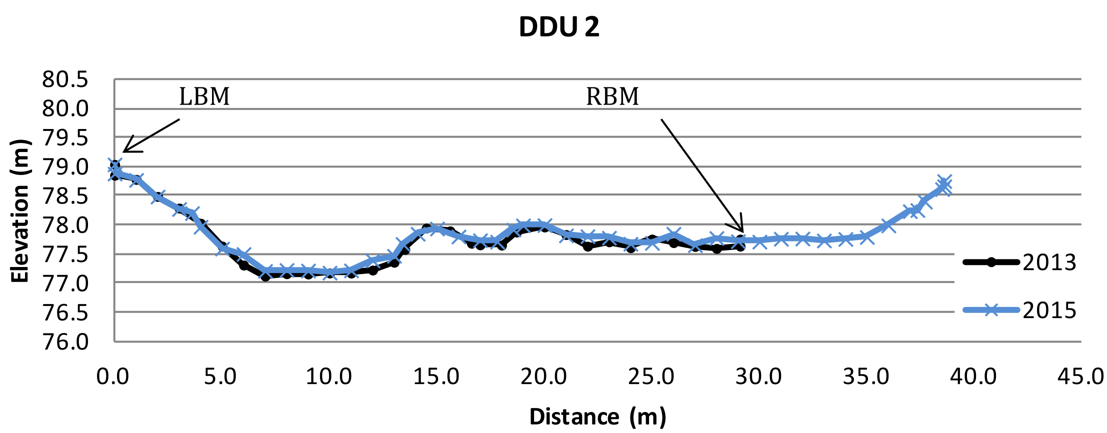
LP 4
LBM
RBM
Elevation (m)
Distance (m)
2015

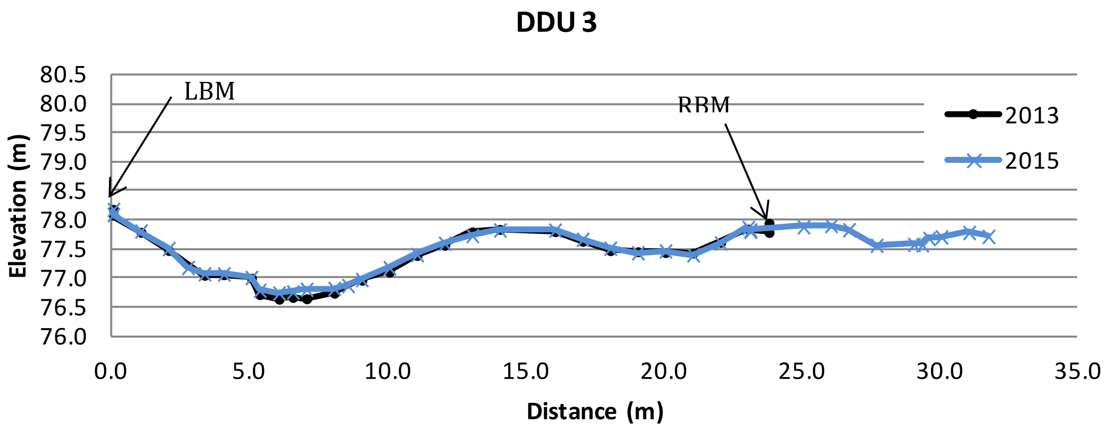


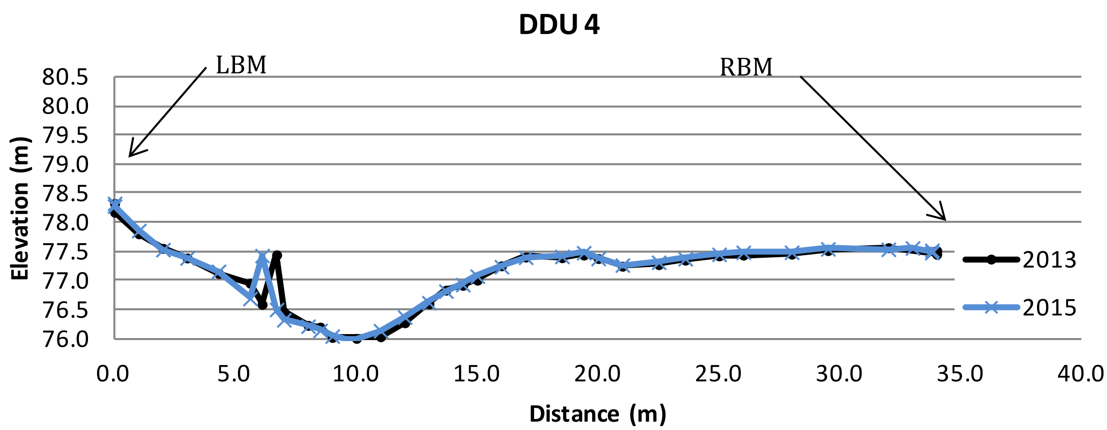
LP 5
M
RBM
Elevation (m)
Distance (m)
2015

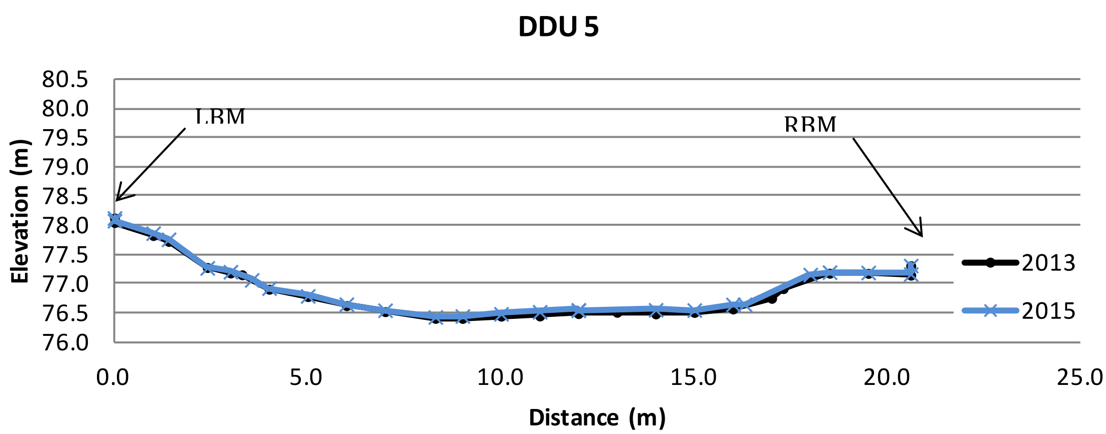

LP 6
280.0
279.5
279.0
278.5
278.0
277.5
277.0
276.5
276.0
275.5
275.0
274.5
274.0
Elevation (m)
LBMLB
RBMLB
2015
0.0
5.0
10.0
15.0
20.0
Distance (m)

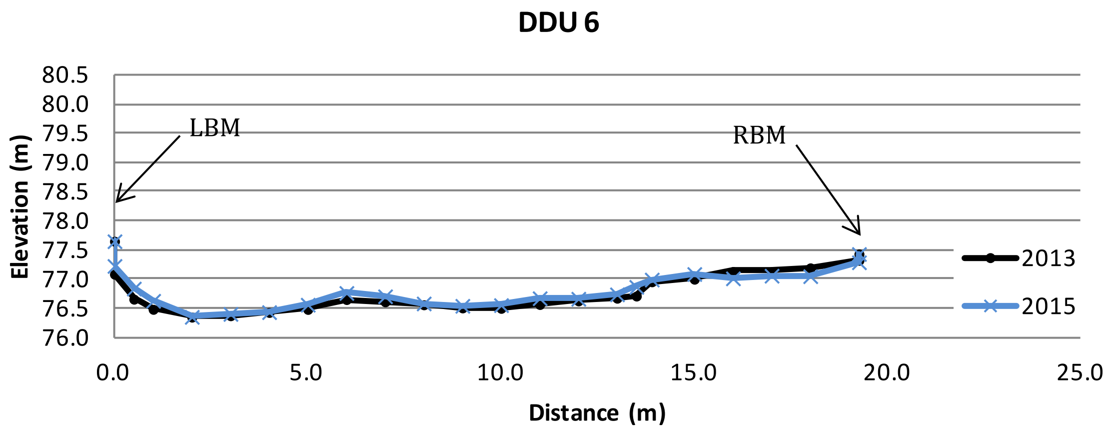

DDU 1
LBM
RBM
80.5
80.0
79.5
79.0
78.5
78.0
77.5
77.0
76.5
76.0
Elevation (m)
2013
2015
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
Distance (m)

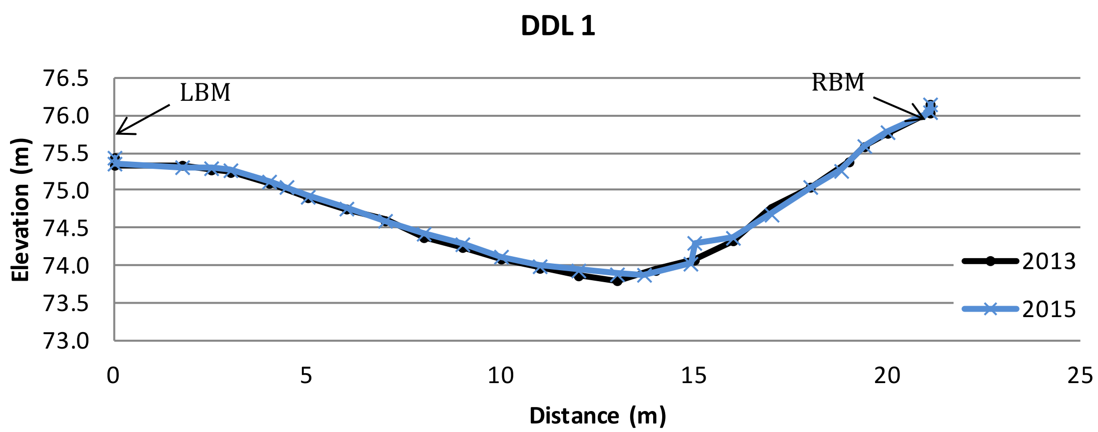

DDU 2
80.5
80.0
79.5
79.0
78.5
78.0
77.5
77.0
76.5
76.0
Elevation (m)
LBM
RBM
2013
2015
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
Distance (m)

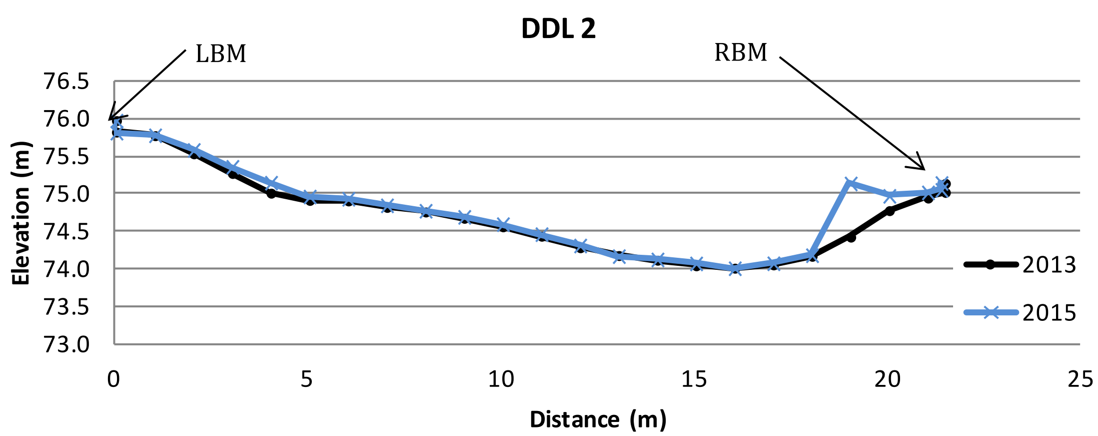

DDU 3
LBM
RBM
2013
2015
Elevation (m)
Distance (m)

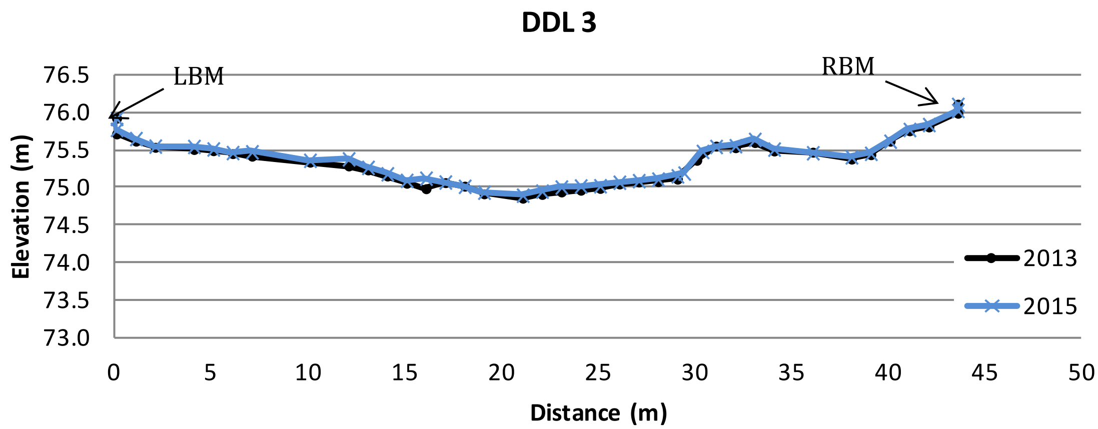

DDU 4
LBM
RBM
2013
2015
Elevation (m)
Distance (m)

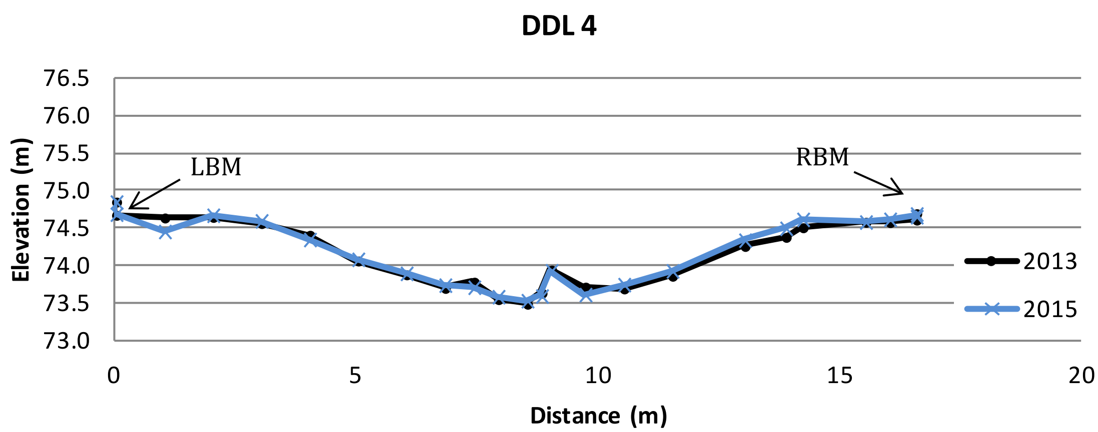

DDU 5
LBM
RBM
2013
2015
Elevation (m)
Distance (m)

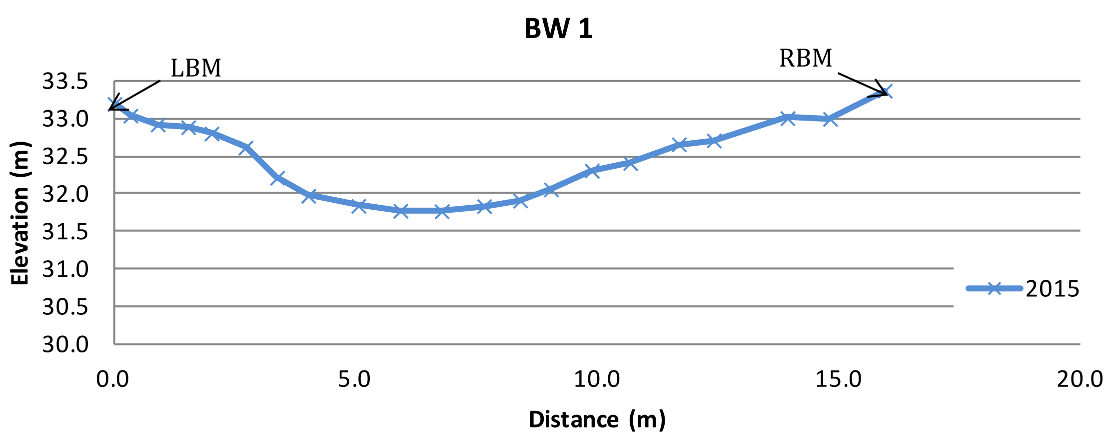

DDU 6
80.5
80.0
79.5
79.0
78.5
78.0
77.5
77.0
76.5
76.0
Elevation (m)
LBM
RBM
0.0
5.0
10.0
15.0
20.0
25.0
Distance (m)
2013
2015

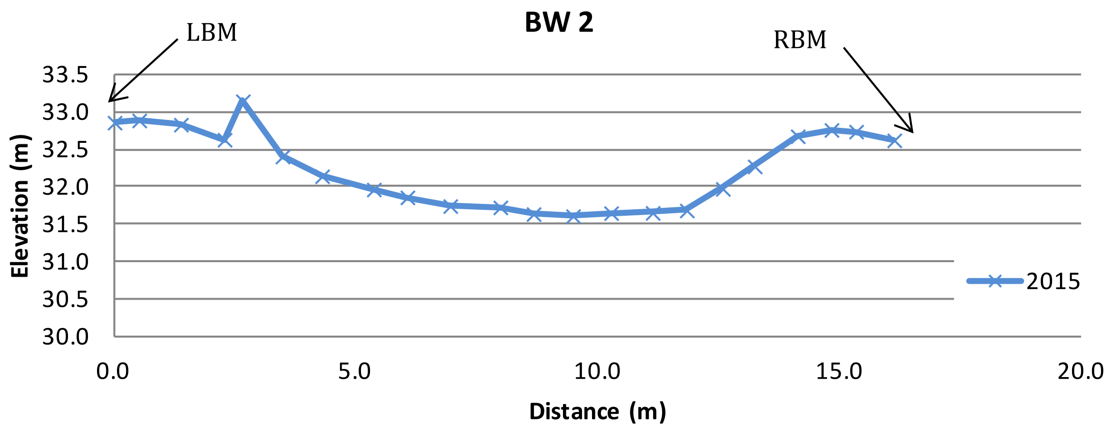

DDL 1
76.5
76.0
75.5
75.0
74.5
74.0
73.5
73.0
Elevation (m)
LBM
RBM
0
5
10
15
20
25
Distance (m)
2013
2015

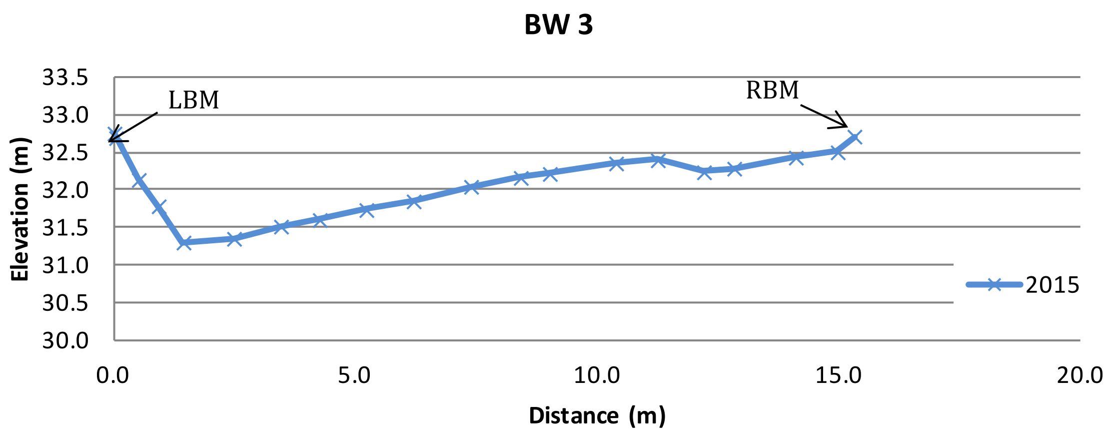

DDL 2
76.5
76.0
75.5
75.0
74.5
74.0
73.5
73.0
Elevation (m)
LBM
RBM
0
5
10
15
20
25
Distance (m)
2013
2015

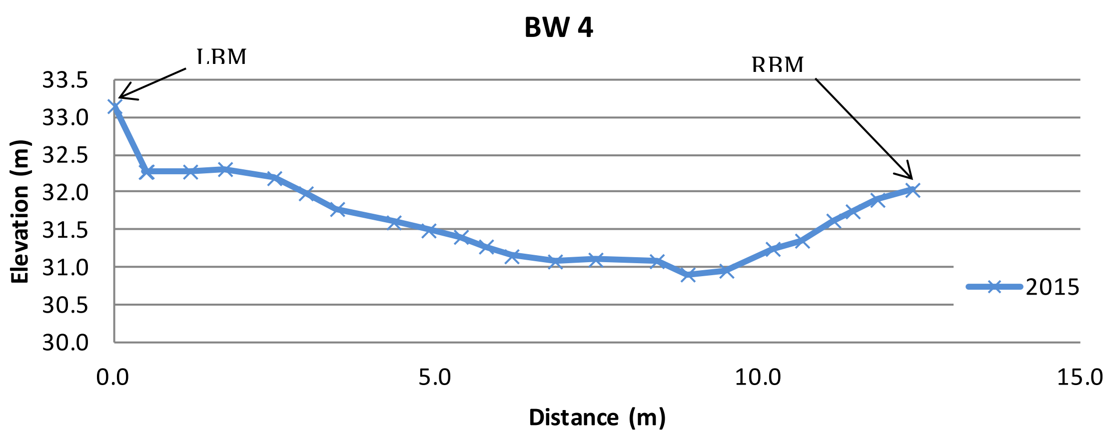

DDL 3
LBM
RBM
Elevation (m)
Distance (m)
76.5
76.0
75.5
75.0
74.5
74.0
73.5
73.0
0
5
10
15
20
25
30
35
40
45
50
2013
2015

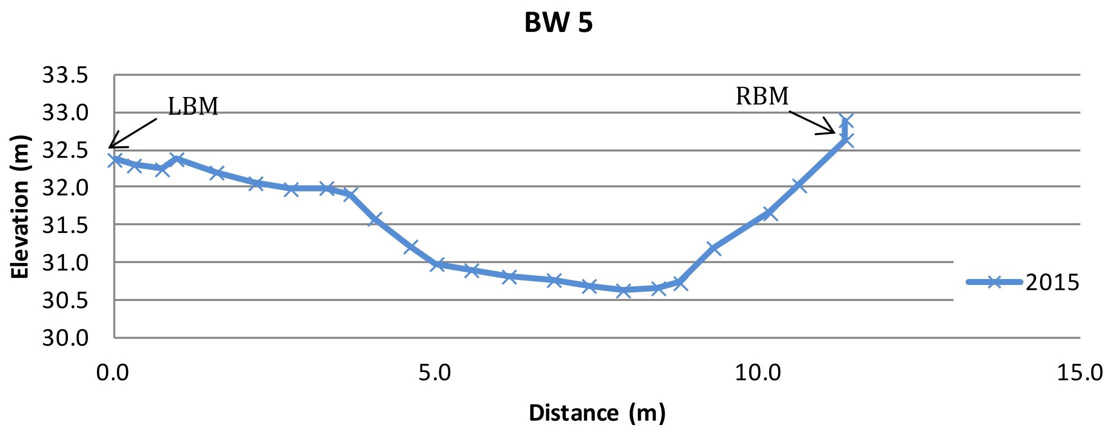

DDL 4
LBM
RBM
Elevation (m)
Distance (m)
76.5
76.0
75.5
75.0
74.5
74.0
73.5
73.0
0
5
10
15
20
2013
2015

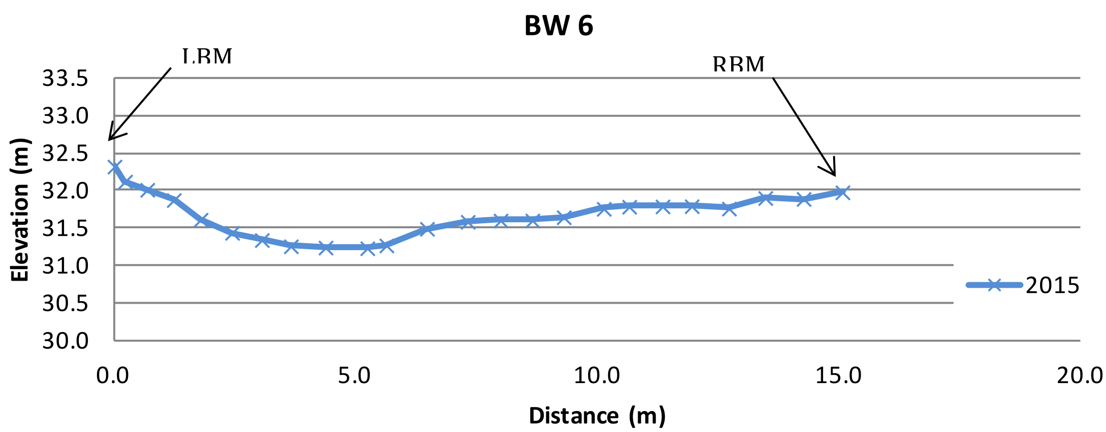

BW 1
LBM
RBM
Elevation (m)
Distance (m)
33.5
33.0
32.5
32.0
31.5
31.0
30.5
30.0
0.0
5.0
10.0
15.0
20.0
2015

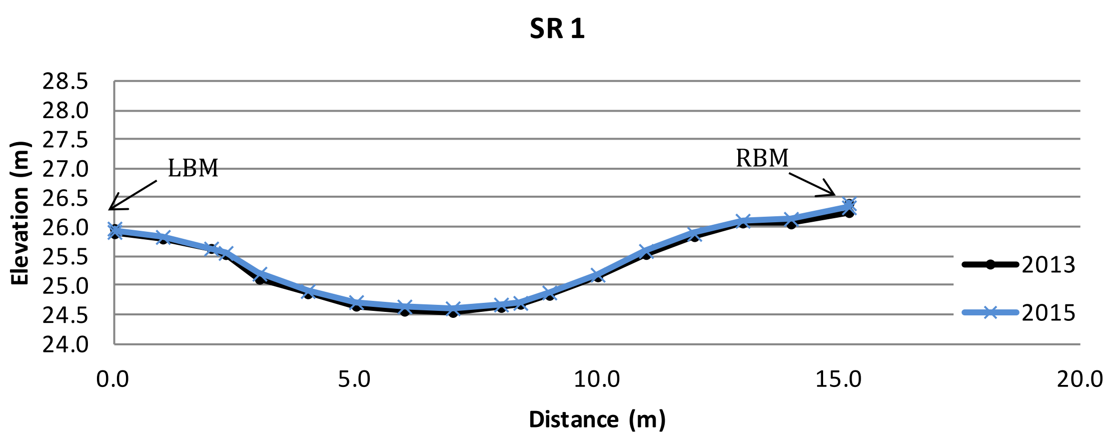

BW 2
LBM
RBM
33.5
33.0
32.5
32.0
31.5
31.0
30.5
30.0
Elevation (m)
0.0
5.0
10.0
15.0
20.0
Distance (m)
2015

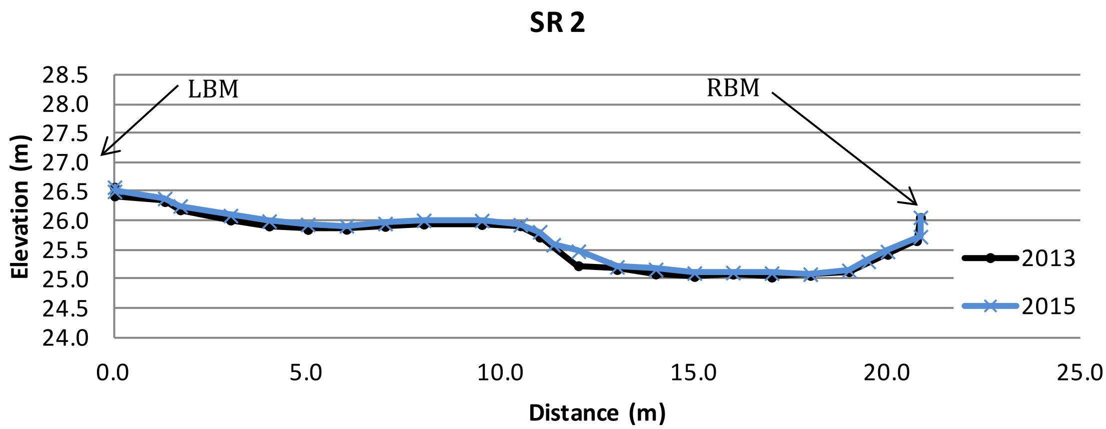

BW 3
LBM
RBM
33.5
33.0
32.5
32.0
31.5
31.0
30.5
30.0
Elevation (m)
0.0
5.0
10.0
15.0
20.0
Distance (m)
2015

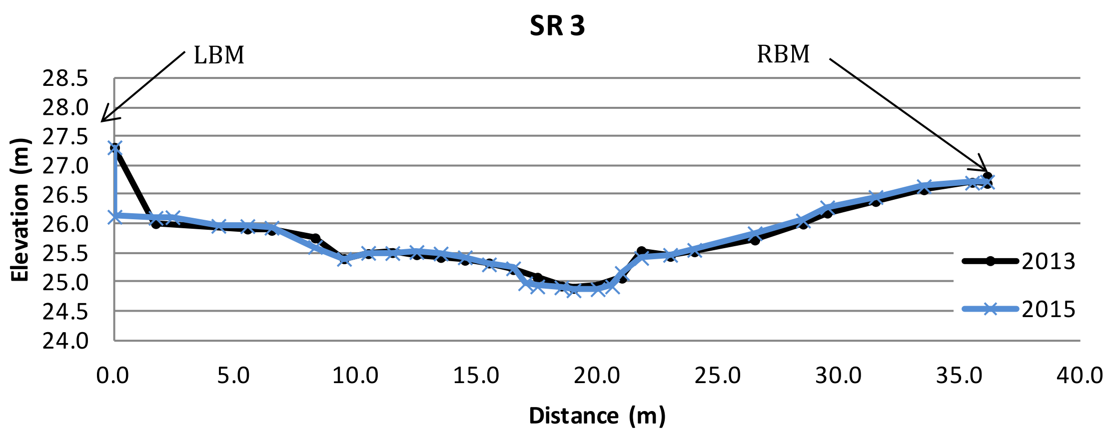

BW 4
LBM
RBM
33.5
33.0
32.5
32.0
31.5
31.0
30.5
30.0
Elevation (m)
0.0
5.0
10.0
15.0
Distance (m)
2015

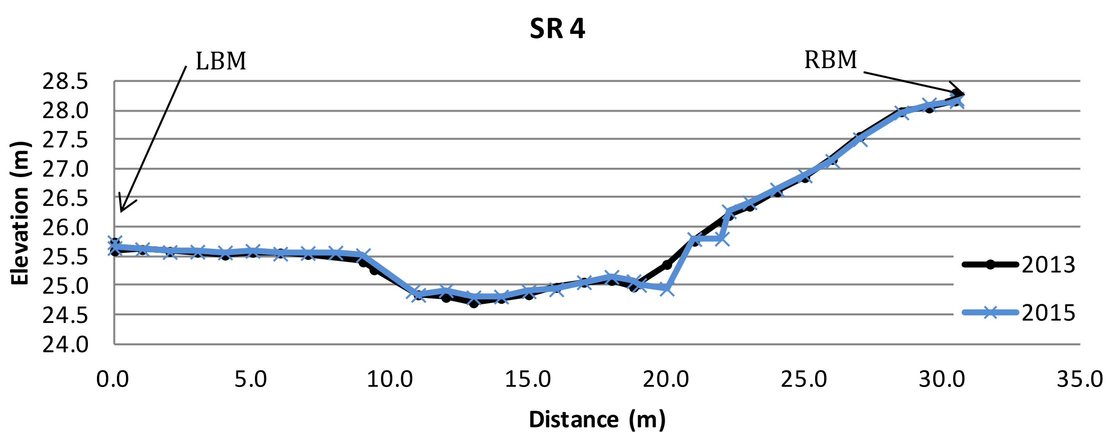

BW 5
LBM
RBM
Elevation (m)
33.5
33.0
32.5
32.0
31.5
31.0
30.5
30.0
0.0
5.0
10.0
15.0
Distance (m)
2015

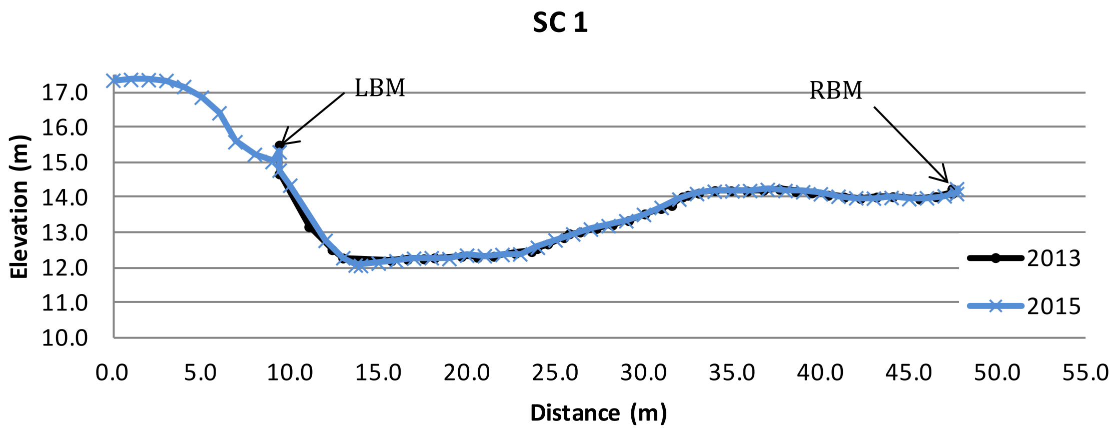

BW 6
LBM
RBM
Elevation (m)
33.5
33.0
32.5
32.0
31.5
31.0
30.5
30.0
0.0
5.0
10.0
15.0
20.0
Distance (m)
2015

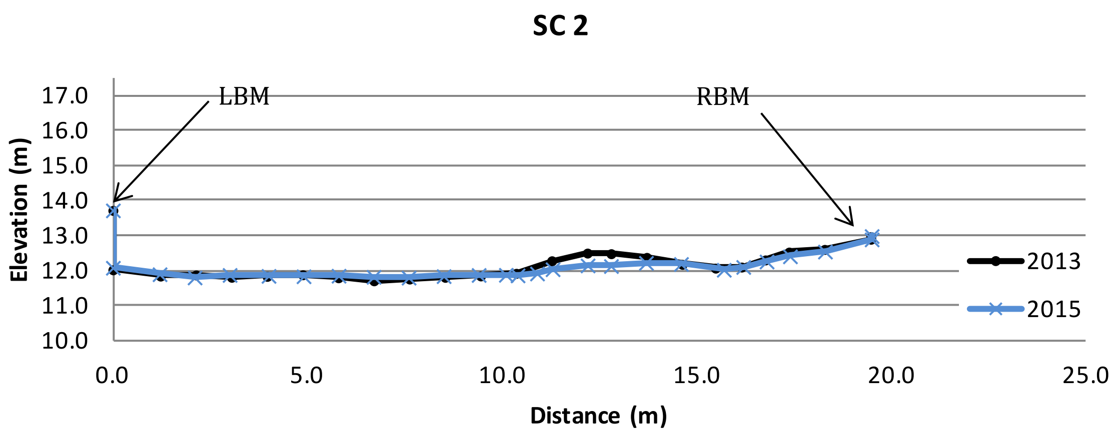

SR 1
LBM
RBM
Elevation (m)
28.5
28.0
27.5
27.0
26.5
26.0
25.5
25.0
24.5
24.0
0.0
5.0
10.0
15.0
20.0
Distance (m)
2013
2015

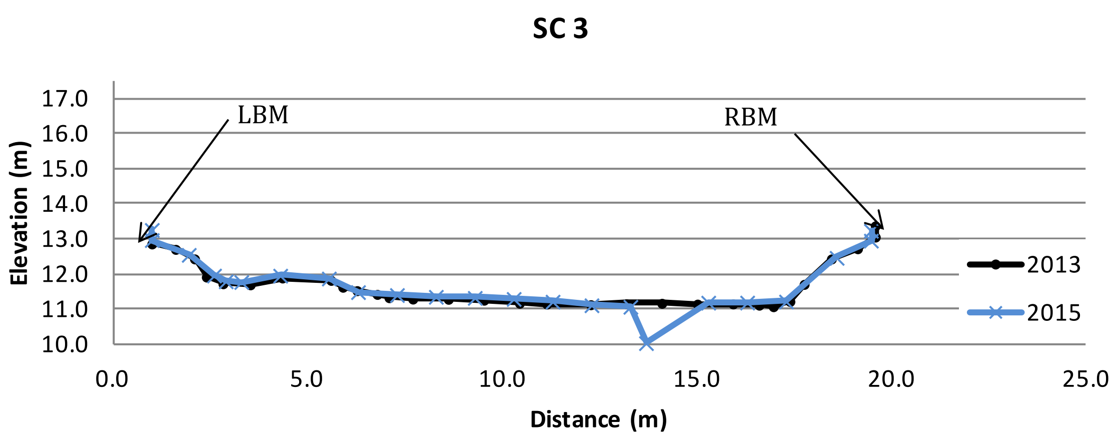

SR 2
LBM
RBM
28.5
28.0
27.5
27.0
26.5
26.0
25.5
25.0
24.5
24.0
Elevation (m)
0.0
5.0
10.0
15.0
20.0
25.0
Distance (m)
2013
2015

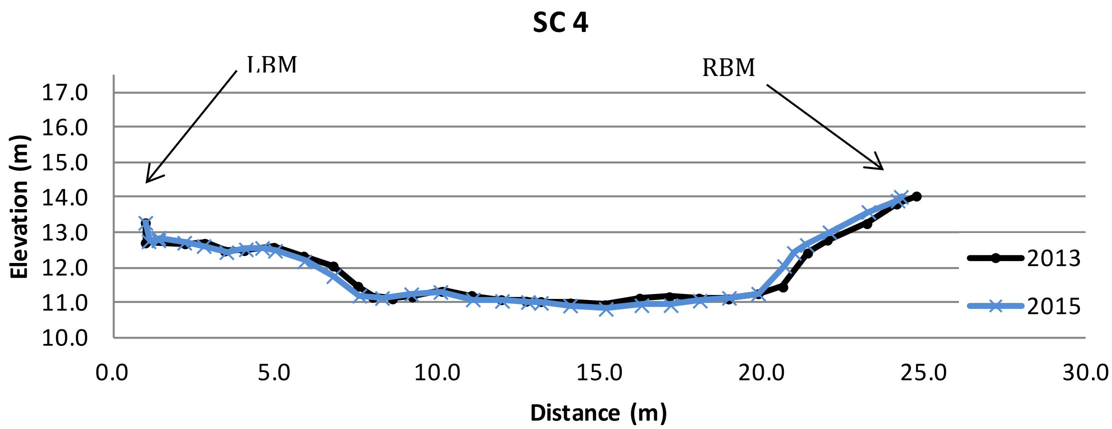

SR 3
LBM
RBM
28.5
28.0
27.5
27.0
26.5
26.0
25.5
25.0
24.5
24.0
Elevation (m)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
Distance (m)
2013
2015

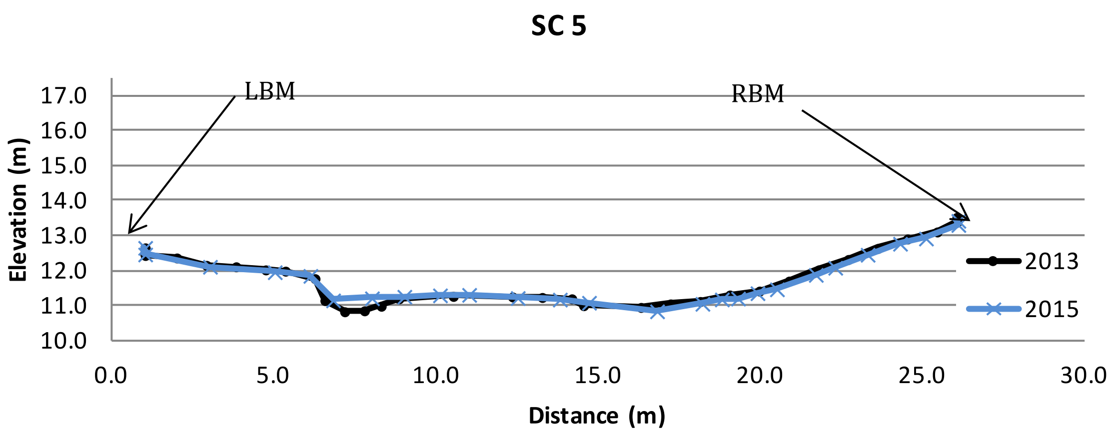

SR 4
LBM
RBM
28.5
28.0
27.5
27.0
26.5
26.0
25.5
25.0
24.5
24.0
Elevation (m)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
Distance (m)
2013
2015

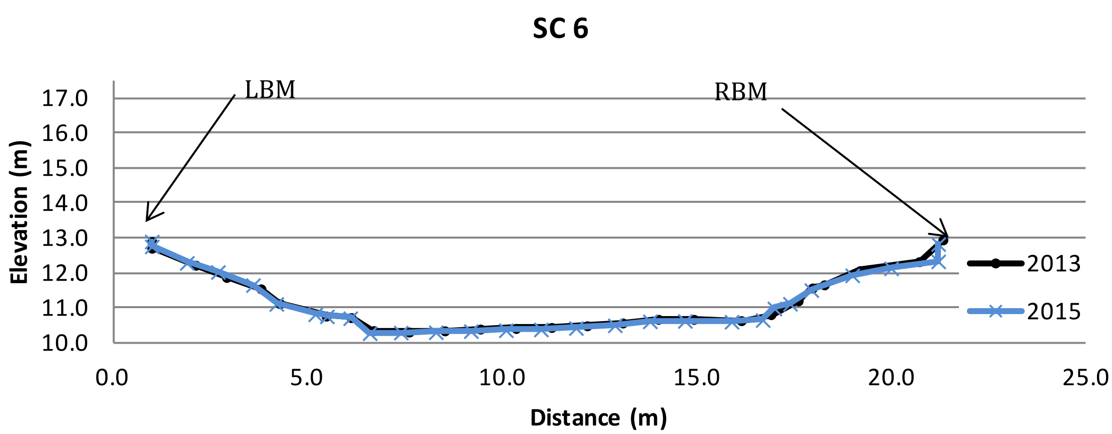

SC 1
LBM
RBM
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
Elevation (m)
0.0
5.0
10.0
15.0
20.0
25.0
30.0
35.0
40.0
45.0
50.0
55.0
Distance (m)
2013
2015

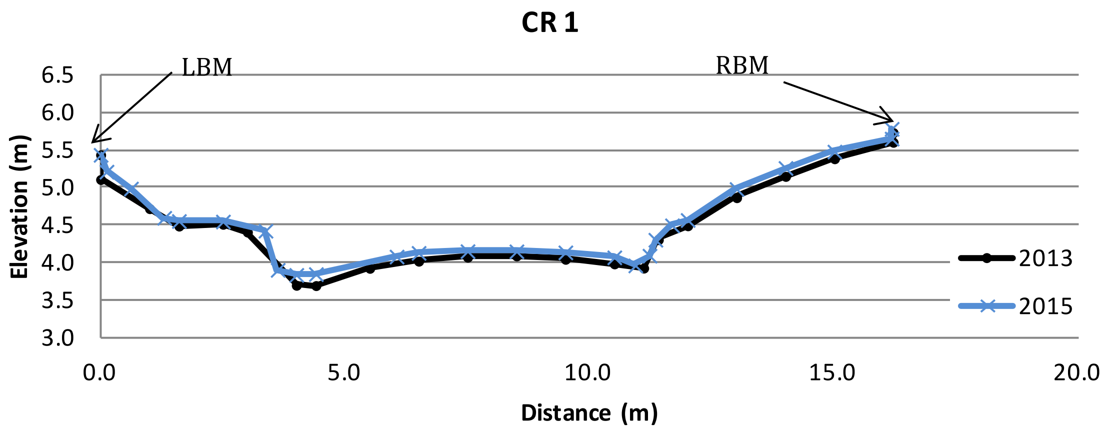

SC 2
LBM
RBM
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
Elevation (m)
0.0
5.0
10.0
15.0
20.0
25.0
Distance (m)
2013
2015

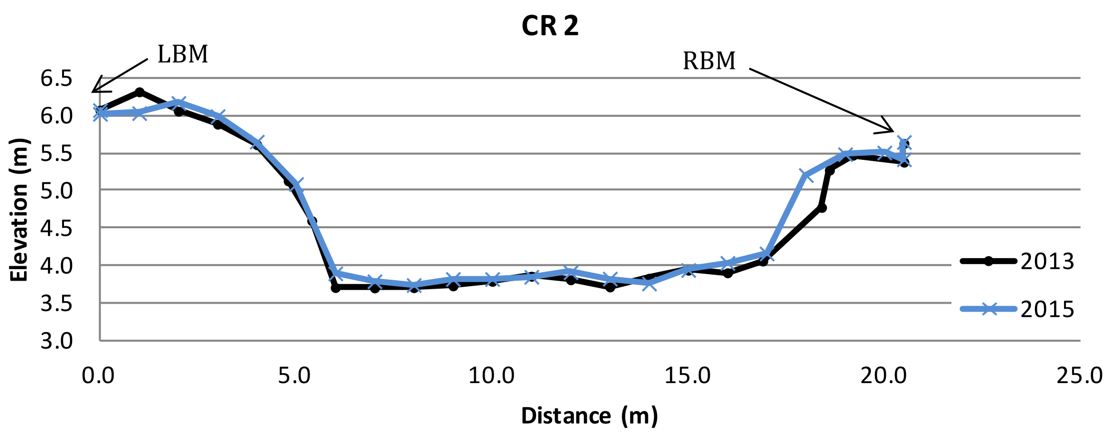

SC 3
LBM
RBM
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
Elevation (m)
0.0
5.0
10.0
15.0
20.0
25.0
Distance (m)
2013
2015

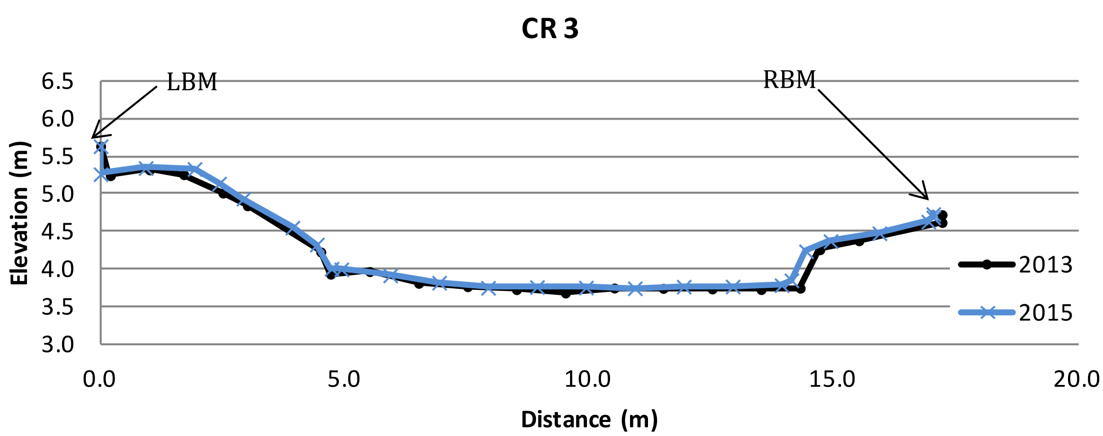

SC 4
LBM
RBM
Elevation (m)
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
Distance (m)
2013
2015

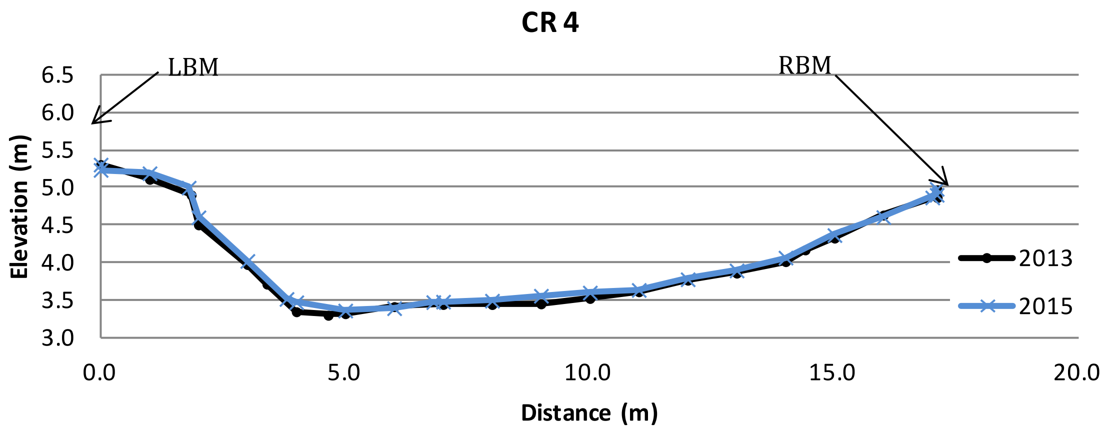

SC 5
LBM
RBM
Elevation (m)
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
0.0
5.0
10.0
15.0
20.0
25.0
30.0
Distance (m)
2013
2015

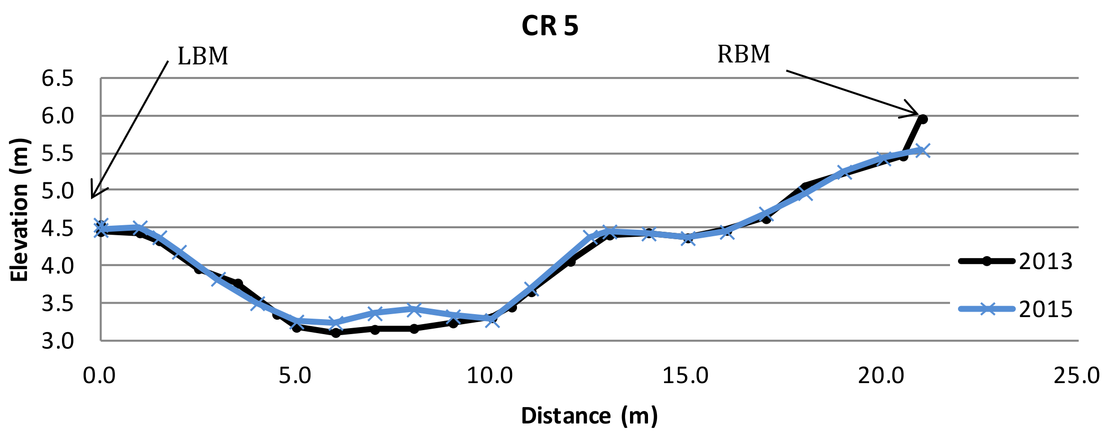

SC 6
LBM
RBM
Elevation (m)
17.0
16.0
15.0
14.0
13.0
12.0
11.0
10.0
0.0
5.0
10.0
15.0
20.0
25.0
Distance (m)
2013
2015

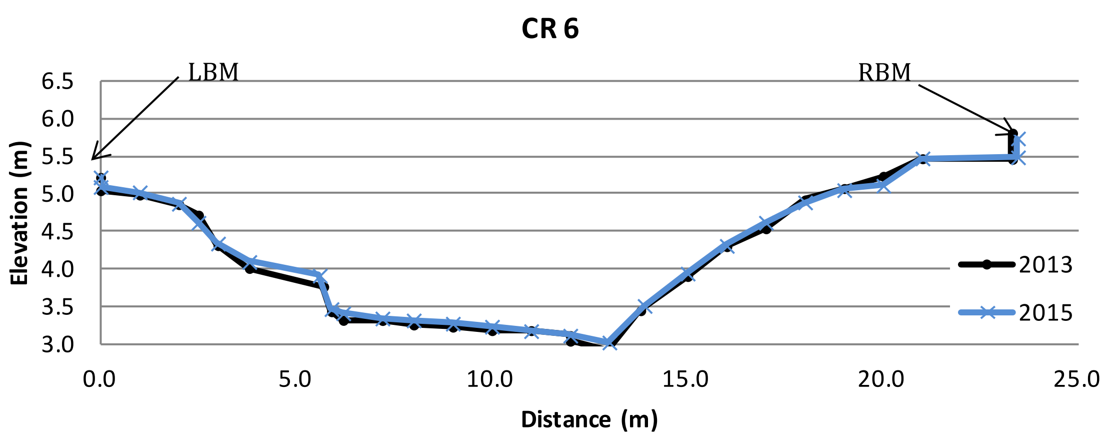

CR 1
LBM
RBM
Elevation (m)
Distance (m)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
0.0
5.0
10.0
15.0
20.0
2013
2015


CR 2
LBM
RBM
Elevation (m)
Distance (m)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
0.0
5.0
10.0
15.0
20.0
25.0
2013
2015


CR 3
LBM
RBM
Elevation (m)
Distance (m)
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
0.0
5.0
10.0
15.0
20.0
2013
2015

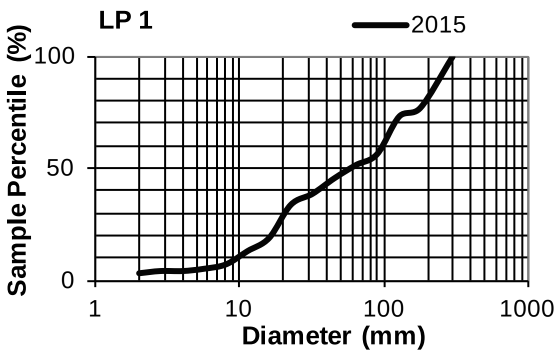

CR 4
LBM
RBM
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
Elevation (m)
0.0
5.0
10.0
15.0
20.0
Distance (m)
2013
2015

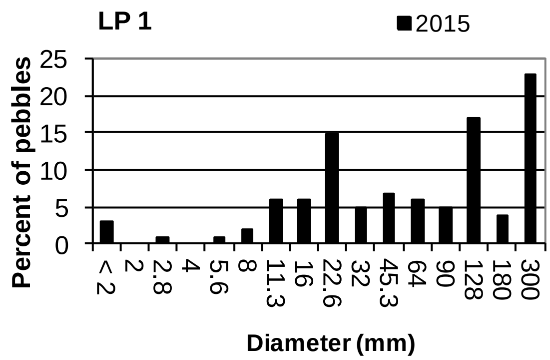

CR 5
LBM
RBM
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
Elevation (m)
0.0
5.0
10.0
15.0
20.0
25.0
Distance (m)
2013
2015

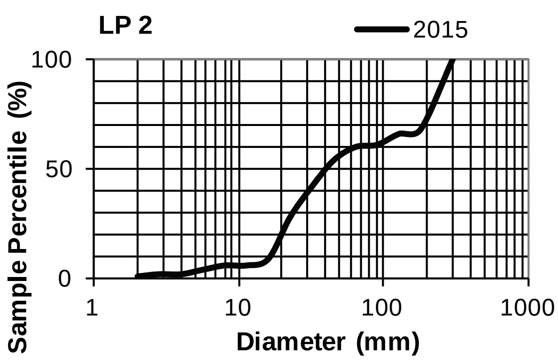

CR 6
LBM
RBM
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
Elevation (m)
0.0
5.0
10.0
15.0
20.0
25.0
Distance (m)
2013
2015

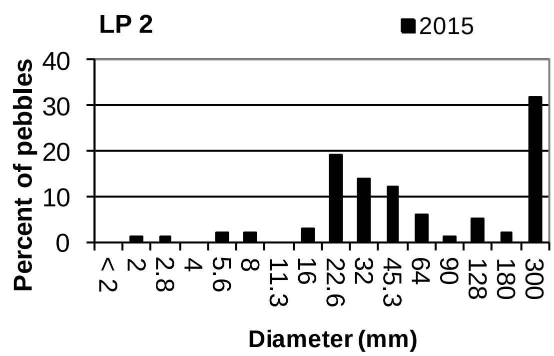
6.2 Pebble Counts

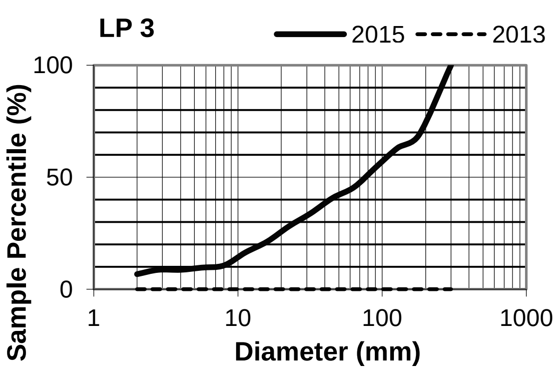
Channel pebble counts for each cross section within each reach. Reaches are denoted by their reach abbreviation (LP, DDU, DDL, BW, SR, SC, and CR) and transect number descending from upstream to downstream (1 to 4 or 6).

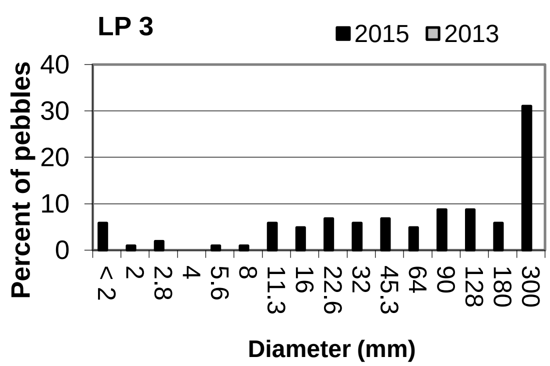


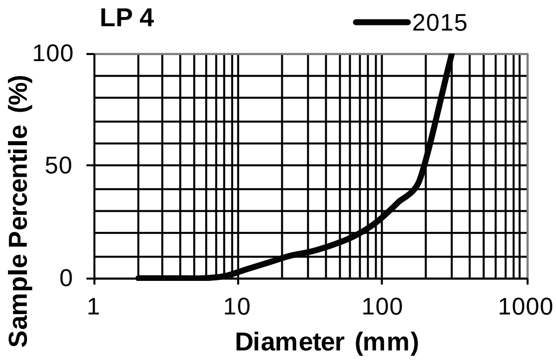


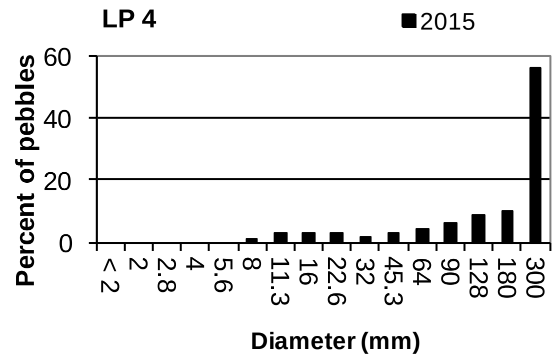


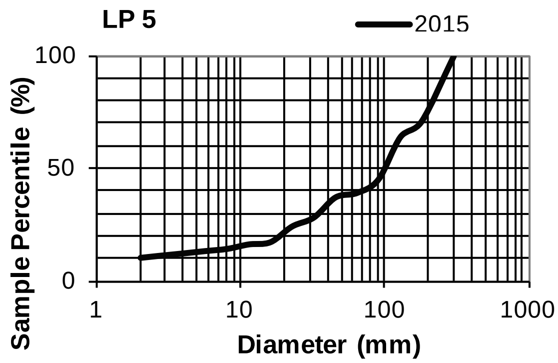


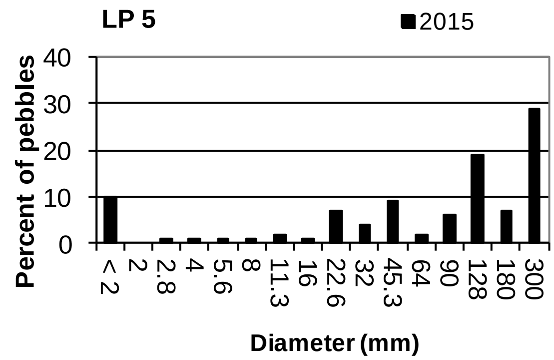


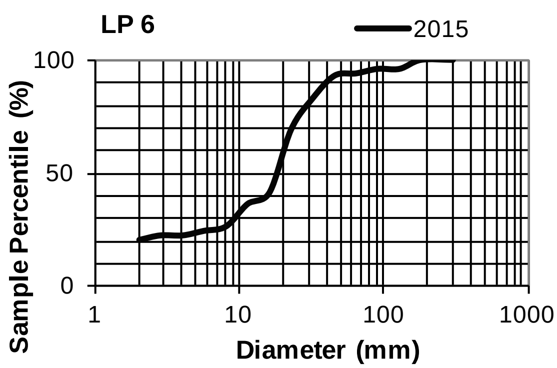


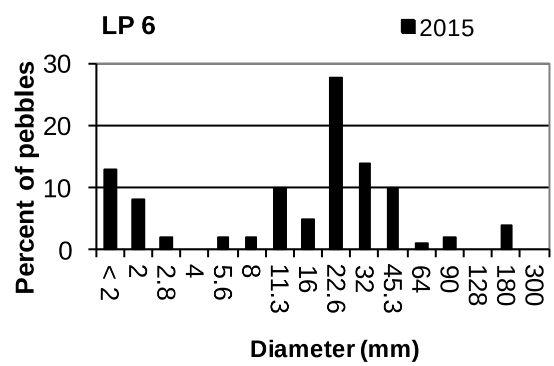

LP 4
2015
Sample Percentile (%)
100
50
0
1
10
100
1000
Diameter (mm)

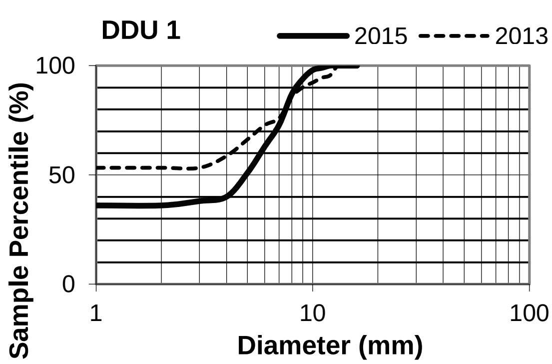

LP 4
2015
Percent of pebbles
60
40
20
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)

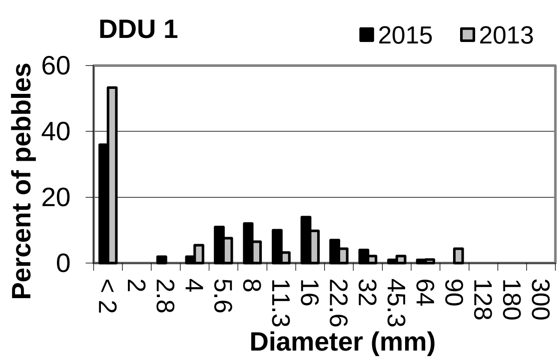

LP 5
2015
Sample Percentile (%)
100
50
0
1
10
100
1000
Diameter (mm)

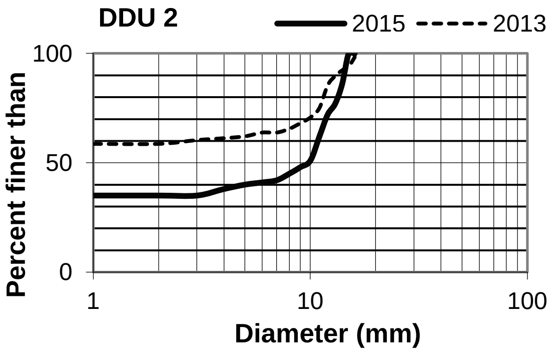

LP 5
2015
Percent of pebbles
40
30
20
10
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)

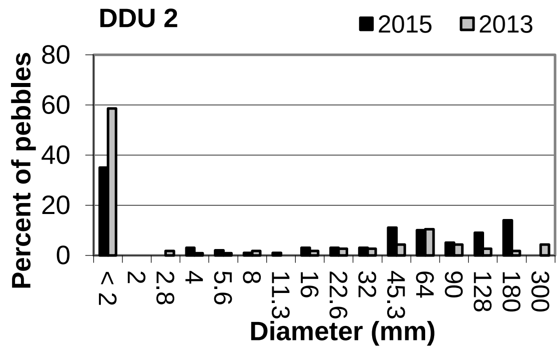

LP 6
2015
Sample Percentile (%)
100
50
0
1
10
100
1000
Diameter (mm)

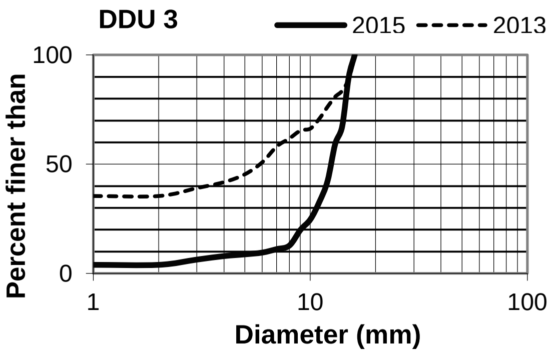

LP 6
2015
Percent of pebbles
30
20
10
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)

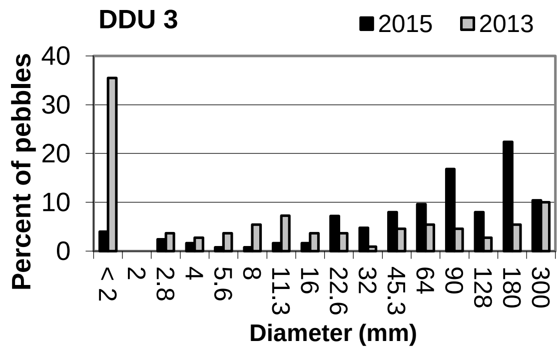

DDU 1
2015
2013
Sample Percentile (%)
100
50
0
1
10
100
Diameter (mm)

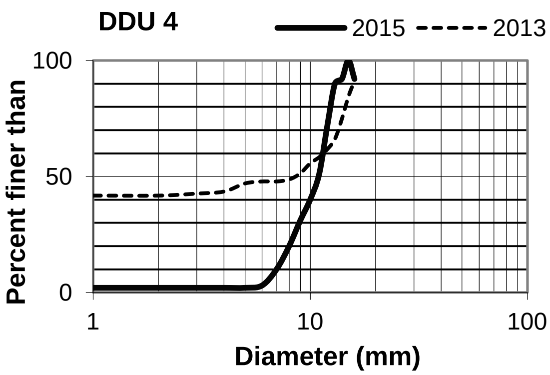

DDU 1
2015
2013
Percent of pebbles
60
40
20
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)

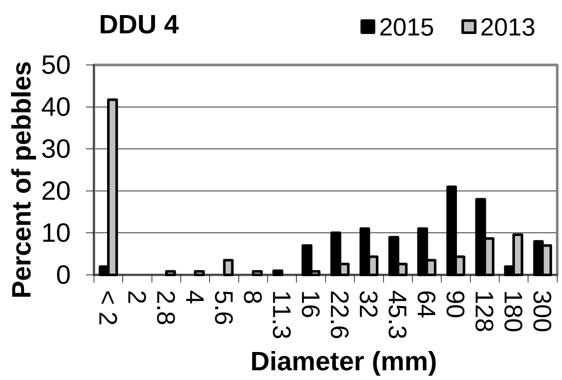

DDU 2
2015
2013
Percent finer than
100
50
0
1
10
100
Diameter (mm)

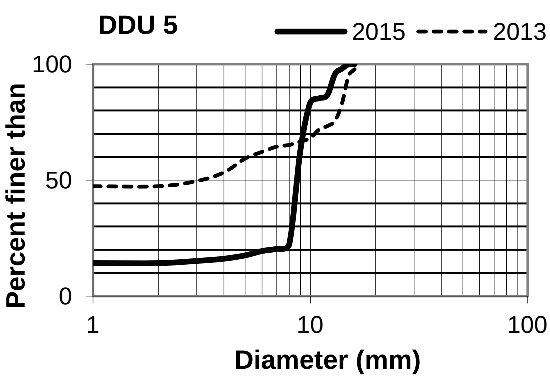

DDU 2
2015
2013
Percent of pebbles
80
60
40
20
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)

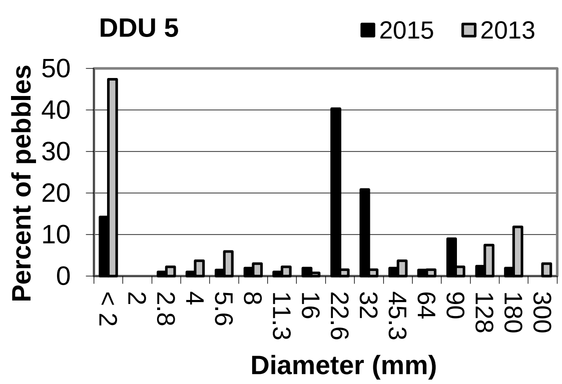

DDU 3
2015
2013
Percent finer than
100
50
0
1
10
100
Diameter (mm)

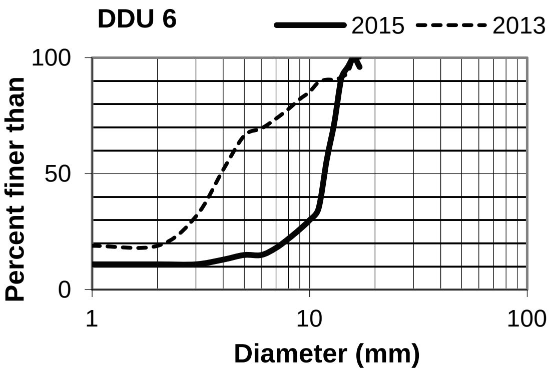

DDU 3
2015
2013
Percent of pebbles
40
30
20
10
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)

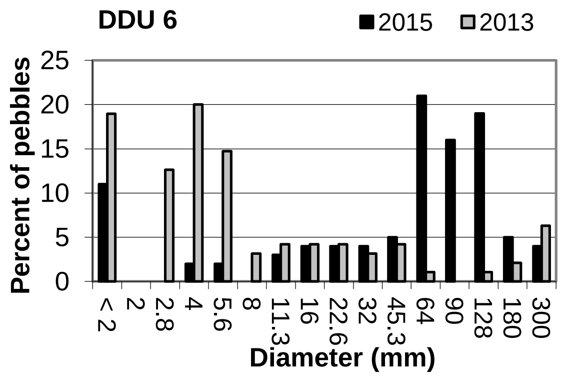

DDU 4
2015
2013
Percent finer than
100
50
0
1
10
100
Diameter (mm)

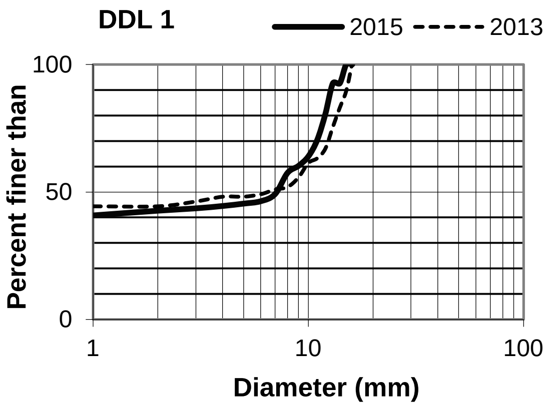

DDU 4
2015
2013
Percent of pebbles
50
40
30
20
10
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)

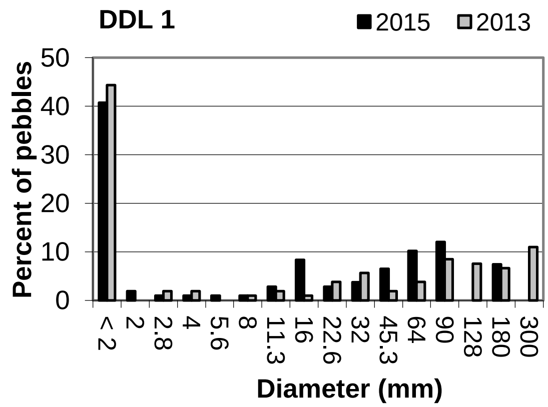

DDU 5
2015
2013
Percent finer than
100
50
0
1
10
100
Diameter (mm)

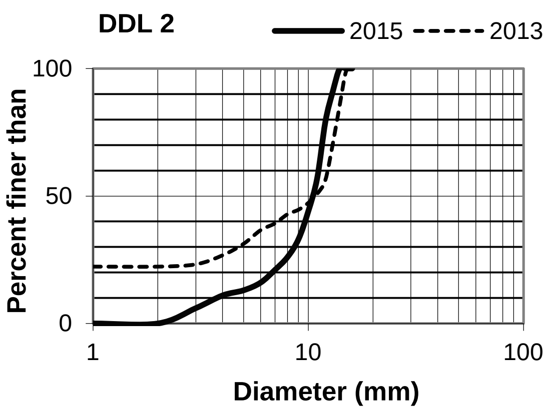

DDU 5
2015
2013
Percent of pebbles
50
40
30
20
10
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)

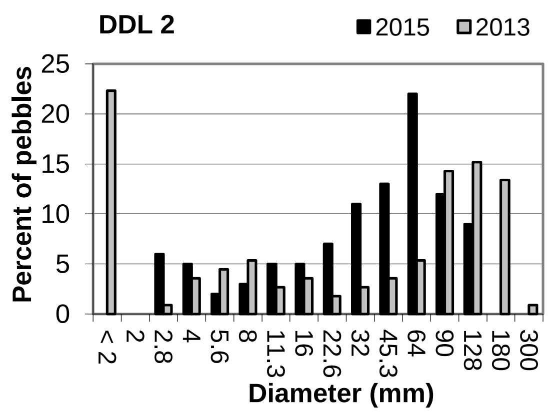

DDU 6
2015
2013
Percent finer than
100
50
0
1
10
100
Diameter (mm)

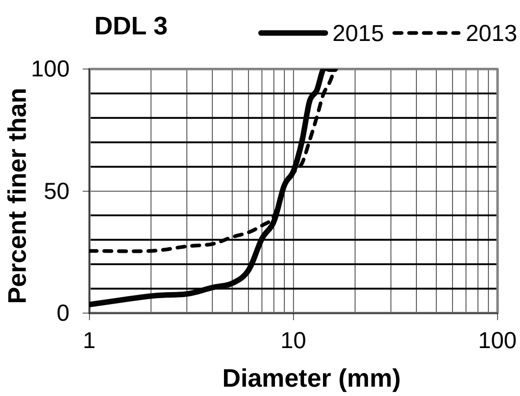

DDU 6
2015
2013
Percent of pebbles
25
20
15
10
5
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)

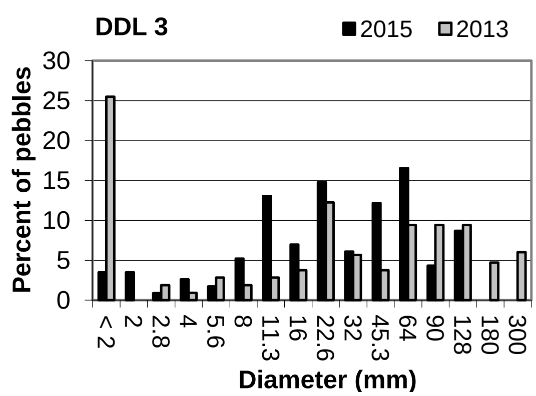

DDL 1
2015
2013
Percent finer than
100
50
0
1
10
100
Diameter (mm)

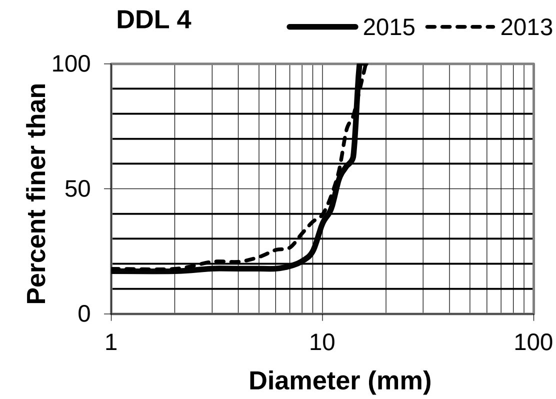

DDL 1
2015
2013
Percent of pebbles
50
40
30
20
10
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)

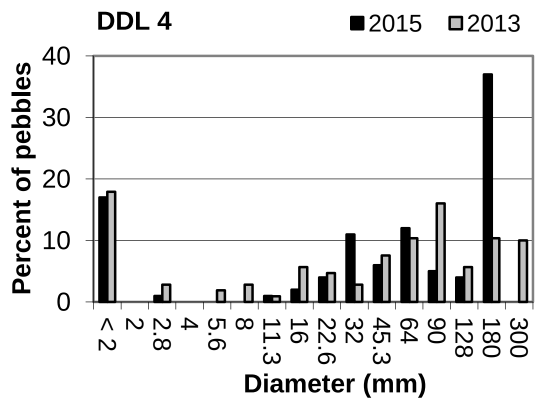

DDL 2
2015
2013
Percent finer than
100
50
0
1
10
100
Diameter (mm)

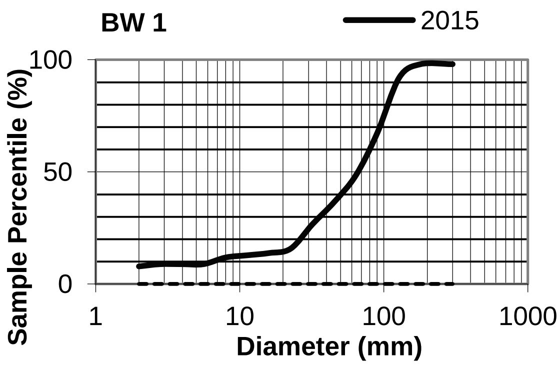

DDL 2
2015
2013
Percent of pebbles
25
20
15
10
5
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)

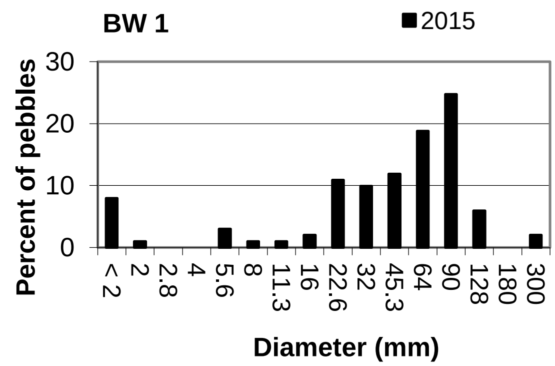

DDL 3
2015
2013
Percent finer than
100
50
0
1
10
100
Diameter (mm)

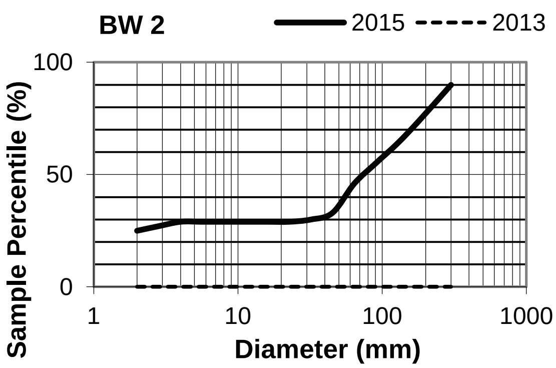

DDL 3
2015
2013
Percent of pebbles
30
25
20
15
10
5
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)

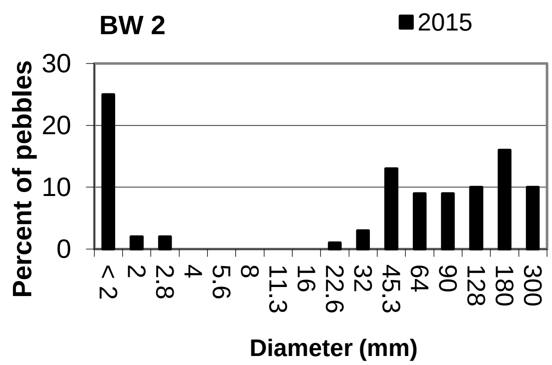

DDL 4
2015
2013
Percent finer than
100
50
0
1
10
100
Diameter (mm)

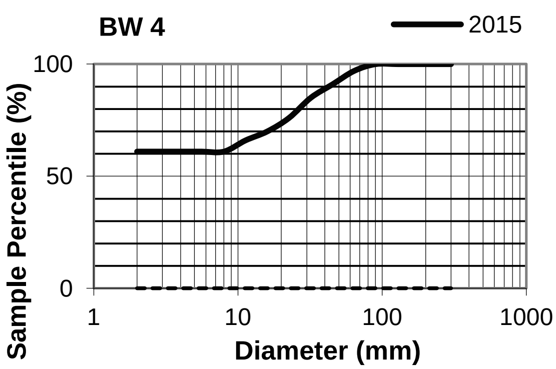

DDL 4
2015
2013
Percent of pebbles
40
30
20
10
0
< 2 2 2.8 4 5.6 8 11.3 16 22.6 32 45.3 64 90 128 180 300
Diameter (mm)

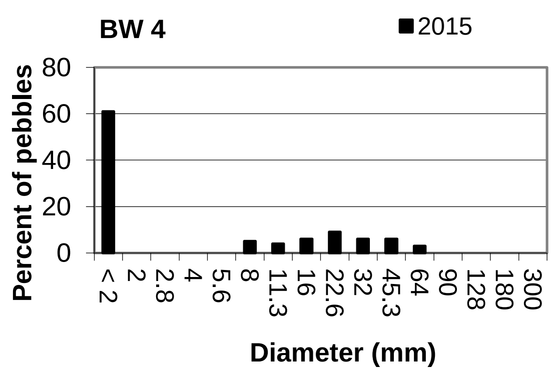

BW 1
2015
Sample Percentile (%)
100
50
0
1
10
100
1000
Diameter (mm)

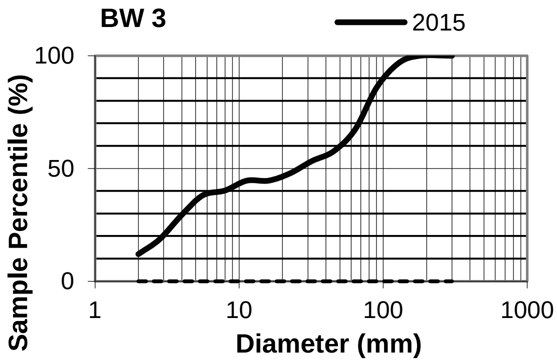

BW 1
2015
Percent of pebbles
30
20
10
0
< 2 2 2.8 4 5.6 8 11.3 16 22.6 32 45.3 64 90 128 180 300
Diameter (mm)

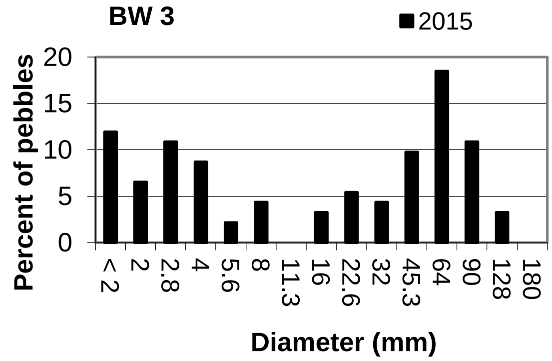

BW 2
2015
2013
Sample Percentile (%)
100
50
0
1
10
100
1000
Diameter (mm)

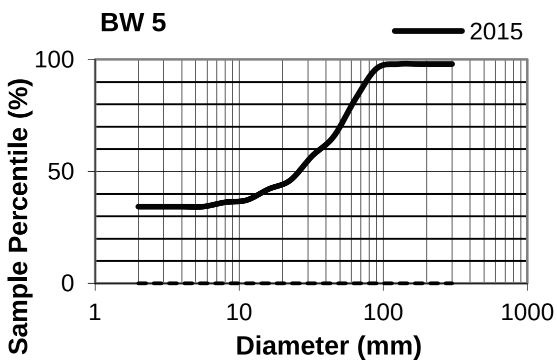

BW 2
2015
Percent of pebbles
30
20
10
0
< 2 2 2.8 4 5.6 8 11.3 16 22.6 32 45.3 64 90 128 180 300
Diameter (mm)

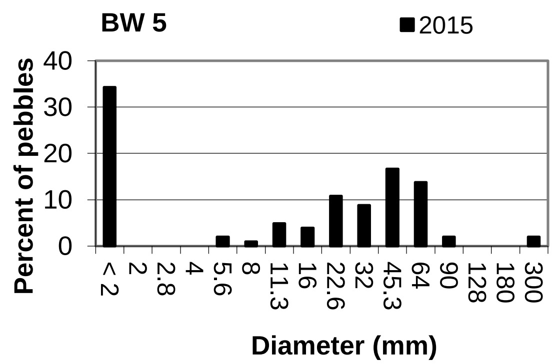

BW 4
2015
Sample Percentile (%)
100
50
0
1
10
100
1000
Diameter (mm)

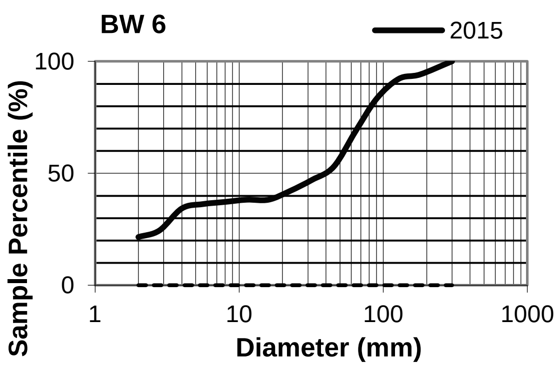

BW 4
2015
Percent of pebbles
80
60
40
20
0
< 2 2 2.8 4 5.6 8 11.3 16 22.6 32 45.3 64 90 128 180 300
Diameter (mm)

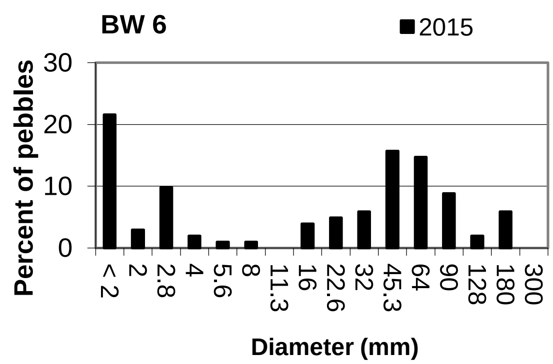

BW 3
2015
Sample Percentile (%)
100
50
0
1
10
100
1000
Diameter (mm)

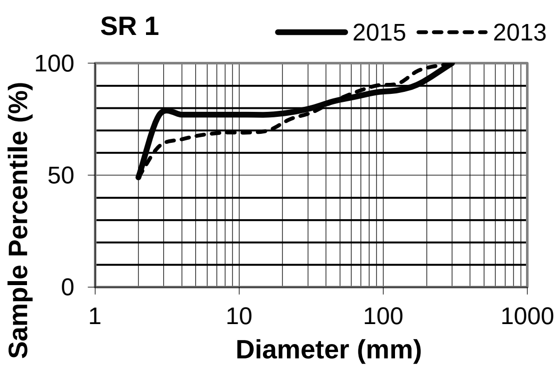

BW 3
2015
Percent of pebbles
20
15
10
5
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
Diameter (mm)

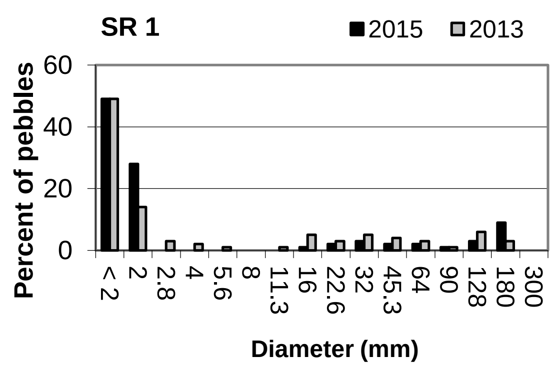

BW 5
2015
Sample Percentile (%)
100
50
0
1
10
100
1000
Diameter (mm)

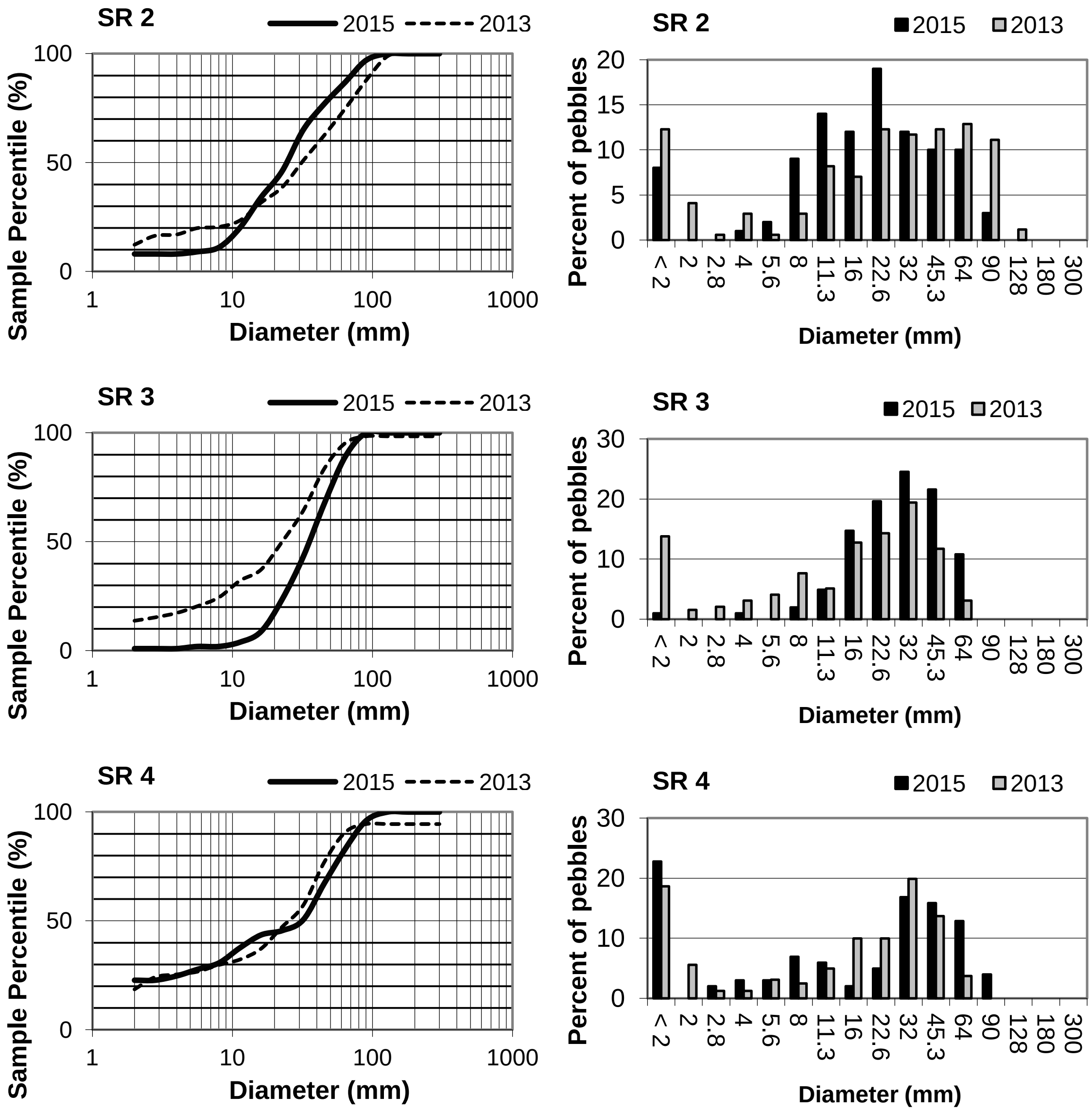

BW 5
2015
Percent of pebbles
40
30
20
10
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)


BW 6
2015
Sample Percentile (%)
100
50
0
1
10
100
1000
Diameter (mm)


BW 6
2015
Percent of pebbles
30
20
10
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)


SR 1
2015
2013
Sample Percentile (%)
100
50
0
1
10
100
1000
Diameter (mm)


SR 1
2015
2013
Percent of pebbles
60
40
20
0
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300
Diameter (mm)


SR 2
2015
2013
Sample Percentile (%)
Diameter (mm)
Percent of pebbles
SR 3
SR 4
< 2
2
2.8
4
5.6
8
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16
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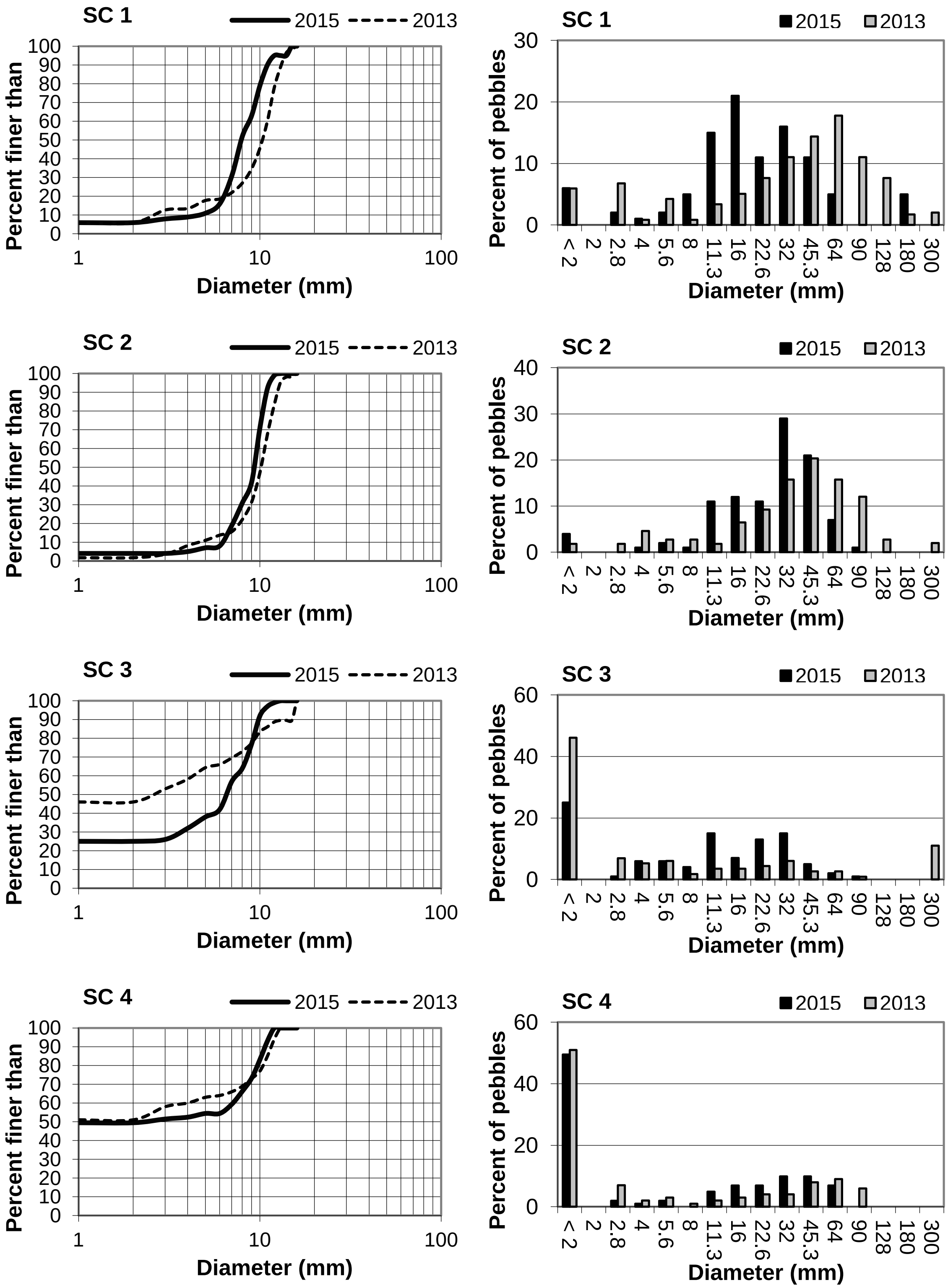
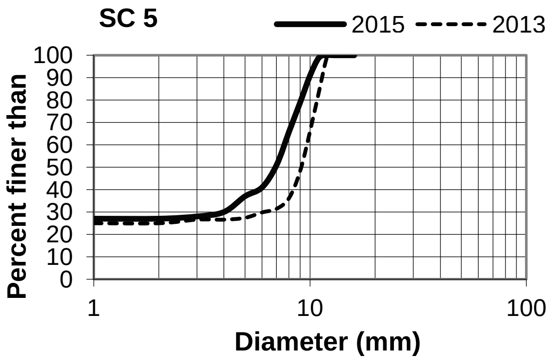
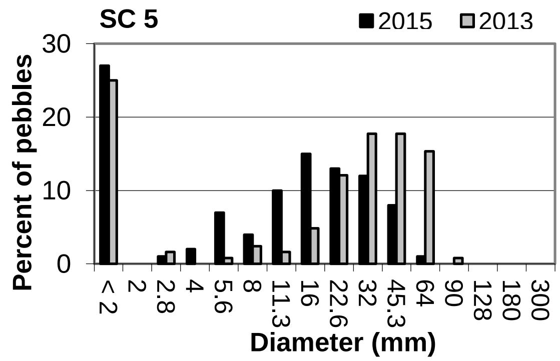
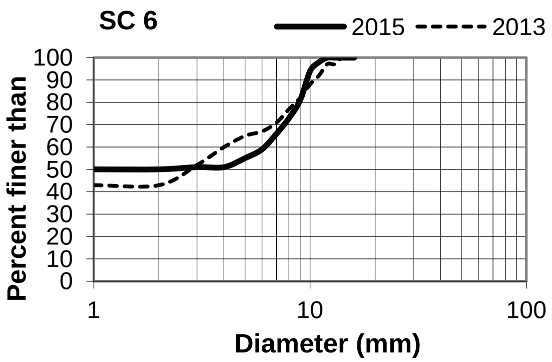
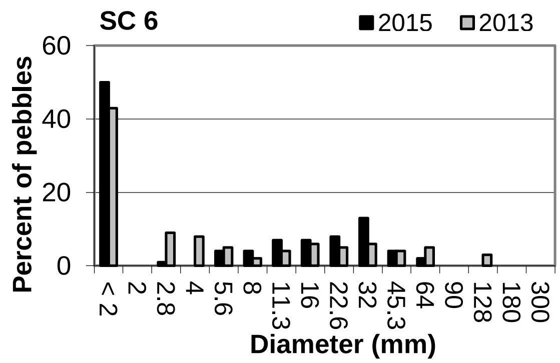
64
90
128
180
300

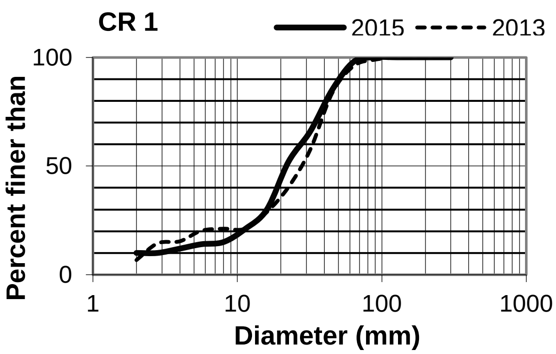

SC 1
2015
2013
Percent finer than
Diameter (mm)
Percent of pebbles
SC 2
SC 3
SC 4
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300

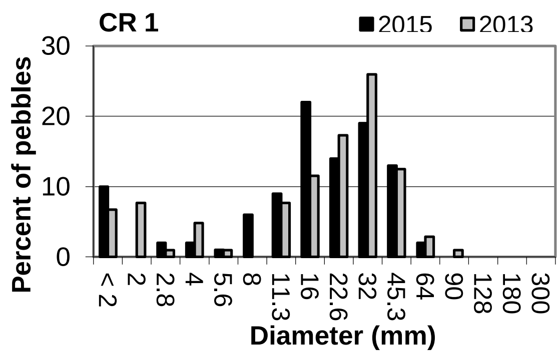

SC 5
2015
2013
Percent finer than
Diameter (mm)
0 10 20 30 40 50 60 70 80 90 100
1 10 100

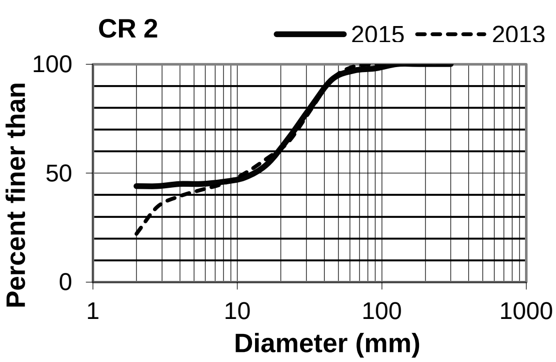

SC 5
2015
2013
Percent of pebbles
Diameter (mm)
0 10 20 30
< 2 2 2.8 4 5.6 8 11.3 16 22.6 32 45.3 64 90 128 180 300

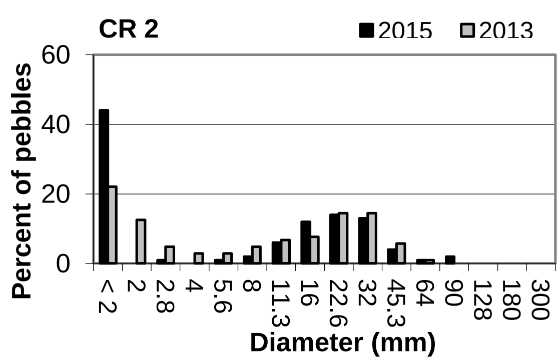

SC 6
2015
2013
Percent finer than
Diameter (mm)
0 10 20 30 40 50 60 70 80 90 100
1 10 100

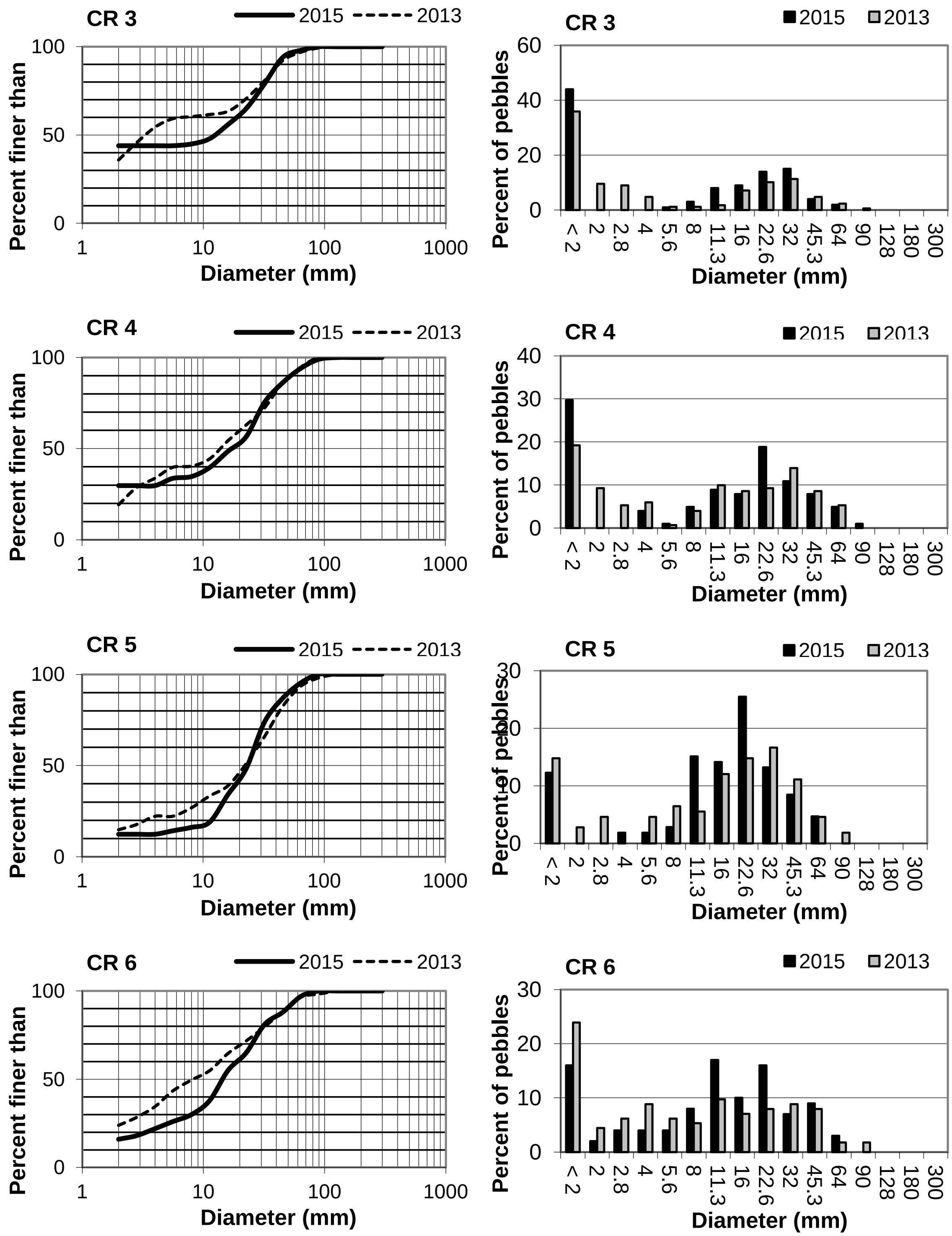

SC 6
2015
2013
Percent of pebbles
Diameter (mm)
0 20 40 60
< 2 2 2.8 4 5.6 8 11.3 16 22.6 32 45.3 64 90 128 180 300


CR 1
2015
2013
Percent finer than
Diameter (mm)
0 50 100
1 10 100 1000


CR 1
2015
2013
Percent of pebbles
Diameter (mm)
0 10 20 30
< 2 2 2.8 4 5.6 8 11.3 16 22.6 32 45.3 64 90 128 180 300


CR 2
2015
2013
Percent finer than
Diameter (mm)
0 50 100
1 10 100 1000


CR 2
2015
2013
Percent of pebbles
Diameter (mm)
0 20 40 60
< 2 2 2.8 4 5.6 8 11.3 16 22.6 32 45.3 64 90 128 180 300


CR 3
2015
2013
Percent finer than
Diameter (mm)
Percent of pebbles
CR 4
CR 5
CR 6
< 2
2
2.8
4
5.6
8
11.3
16
22.6
32
45.3
64
90
128
180
300