ACTEW Water

Murrumbidgee Ecological Monitoring Program

Burra Creek Geomorphology Update

June 2015

Executive Summary

This report has been prepared as a component of the Murrumbidgee Ecological Monitoring Program to satisfy the requirements of the Murrumbidgee to Googong Water Transfer – Aquatic Ecology Monitoring Plan (2014), which is a sub-plan of the M2G Operation Environmental Management Plan (OEMP, 2014).

The objective of the report is to monitor for potential impact of the Murrumbidgee to Googong transfer pipeline (M2G) operation on the geomorphology of Burra Creek downstream of the discharge point, as well as the abstraction point on the Murrumbidgee River.

The M2G operation is currently in standby mode which involves operating each of the pumps in a maintenance mode to ensure the system can be put into full operation at short notice. The pumping rate is limited to 49 ML/d which is approximately half the 109 ML/d capacity during full operational mode. While in standby mode, geomorphic monitoring requires annual visual inspections at key sites. Before entering operating mode, surveyed transects and site observations should be undertaken to re-establish and confirm baseline condition.

This report serves as an update to the previous report in April 2014. Updates to some site surveyed transects have been included along with visual inspections at key sites. Updated transects have been overlaid with previous transects for ease of comparison.

Results have not identified any geomorphological changes as a direct result of pumping activities to date. As M2G is currently in standby mode, the pumps are only run for a short period over a total of approximately two days. Therefore any impacts from the continuous operation of M2G cannot be determined at this point in time. The only maintenance run undertaken in 2014 was in November using the small pump only (~20 ML/d).

The site at BUR2C, approximately 10 km downstream of the discharge point, and 400m upstream of London Bridge, has previously been identified as having a high erosion potential. This site has been photographed for comparison with previous assessments and for future reference.

Recommendations:

1) An annual walk of Burra Creek from the discharge point to London Bridge should be continued, including photo monitoring points, to characterise any changes occurring as a result of natural flow events and vegetation growth, especially those that could be exacerbated by a continuous discharge from M2G.

2) Visual and photographic monitoring of vegetation encroachment and sediment deposition at the outlet pool (upstream of Williamsdale Rd) should be included in annual monitoring for future reference.

3) In addition to existing monitoring, put in place a risk register and management plan for erosion of any stream banks within Burra Creek, whether naturally occurring or a result of pump maintenance runs, and potential impacts to downstream river ecology and receiving water.

4) A re-survey of all transects should be undertaken before the commencement of continuous pumping operations.

5) The dynamics of the sandbar and macrophyte growth occurring at the pool adjacent to the intake structure at Angle Crossing should continue to be monitored.

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1. Introduction

Icon Water has undertaken the Murrumbidgee to Googong Water Transfer (M2G) project as a means of increasing future water security for the Australian Capital Territory (ACT) and surrounding region. The transfer involves the pumping of up to 109 ML/day from the Murrumbidgee River at Angle Crossing (southern border of the ACT) via a 12 km long buried pipeline discharging into Burra Creek (immediately upstream of Williamsdale Road) that flows to Googong Reservoir via run of river.

This report provides an update to the Geomorphologic Monitoring components of the Murrumbidgee Ecological Monitoring Program (MEMP).

The M2G pipeline construction was completed in August 2012 at which time the commissioning phase was undertaken over an approximate one month period. During that time the various pumps were tested which provided various flow rates up to full capacity.

An initial geomorphic assessment of Burra Creek was undertaken in June 2009 during the approval phase of the M2G project which focused on describing the conditions of Burra Creek and Angle Crossing on the Murrumbidgee River at that time.

The geomorphic assessment was updated in the report issued in April 2014 'Burra Creek geomorphology and vegetation assessment', which contains cross sections and 3D mapping conducted in 2012 and 2013.

This report serves as an update to what has previously been reported to assess whether any changes have occurred in Burra Creek since April 2014. A full geomorphology assessment was not required as the M2G pipeline is currently in standby mode.

While only a visual inspection is required under the revised Geomorphology Monitoring Program (Aquatic Ecology Management Plan, 2014), there have been updates to transects at some of the key sites. Updated transects have been overlayed with previous transects for ease of comparison and can be found in Appendices F to L for those sites.

2. Flow events

Historically there have been several significant storm events which have had an influencing factor upon the geomorphology of the creek and the catchment as a whole.

A plot of Burra Creek flow from 2010 to 2015 is shown in Figure 1 (log scale in ML/d shown). The most significant storm event occurred on 9 December 2010, which was approximately a 1 in 70 year Average Recurrence Interval event (Figure 2). This event occurred at the end of the drought following two smaller events (1 in 2 year to 1 in 5 year ARI events) and dramatically altered the geomorphology of the creek through the large scale removal of macrophyte beds and sediment movement which had built up over many years (see Figure 3 for the October 2010 event). Note that these large events still only lasted for a few hours with the flow remaining above 100ML/d for only a day.

Since the December 2010 event there have been 7 events that have exceeded the 1 in 1 year ARI discharge level (~1000 ML/d); once each in 2011, 2013, 2014 and 2015, and three times in 2012. Three of the events were ~3000 ML/d (two in 2012 and one in 2013), and the remaining 4 events were between approximately 1000 ML/d and 1500 ML/d.

Since the previous report in April 2014, there has only been one event at the 1 in 1 year ARI level in early April 2015.

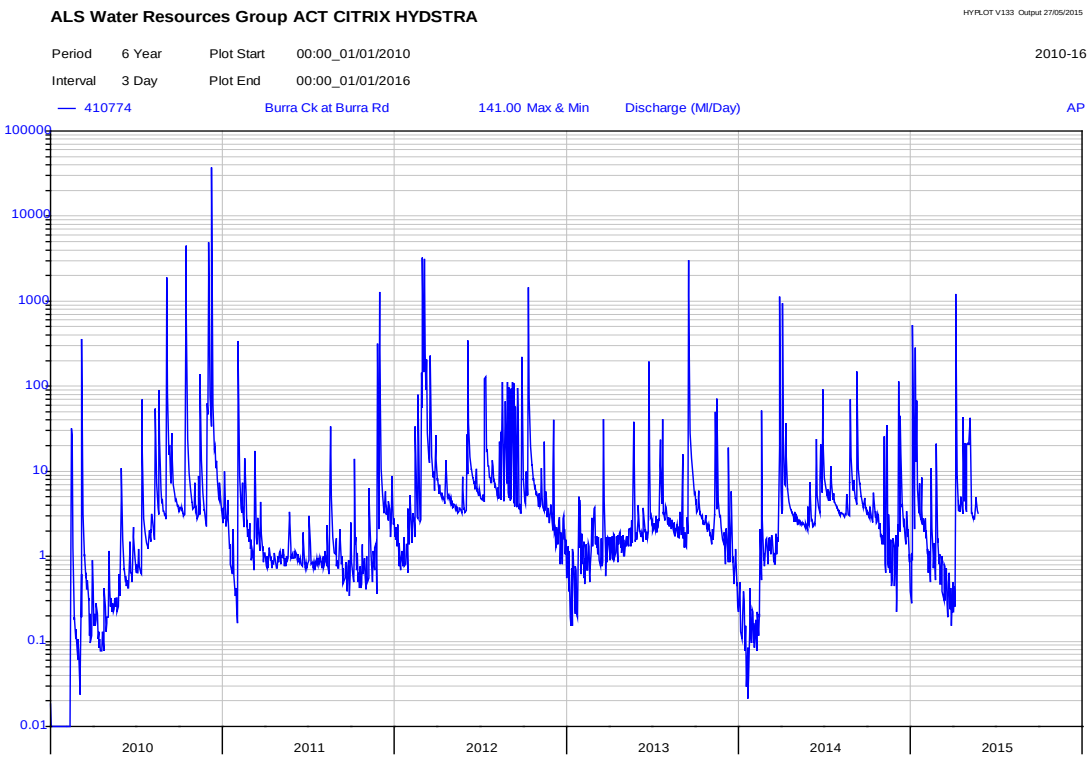


Figure 1 - Burra Creek at Weir (410774) Jan 2010 to Jan-2015

Geomorphological impact from a 1 in 1 year ARI event significantly dominates any impact by a flow of 100 ML/d which represents a natural recurrence interval of less than once in 3 months on average.

The significance of any impact on stream morphology or vegetation created by pumping is most likely to be dictated by the duration of the pumping if it exceeds 2 to 3 weeks.

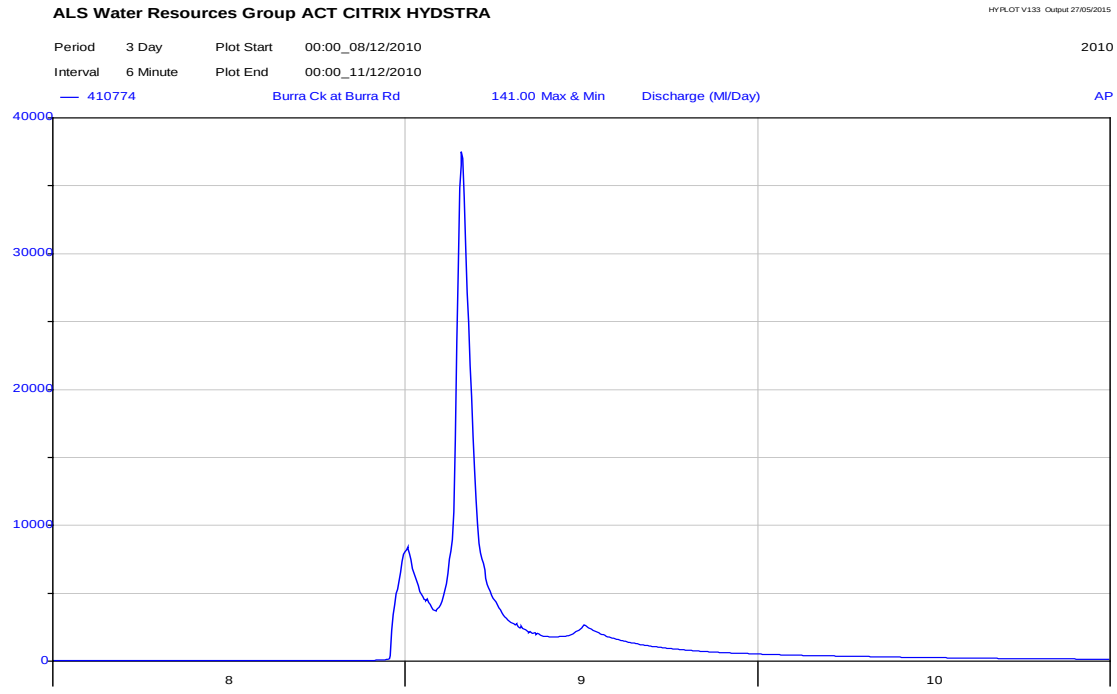


Figure 2 - 410774 Burra Ck 9/12/2010 Event (1 in 70 yr ARI)

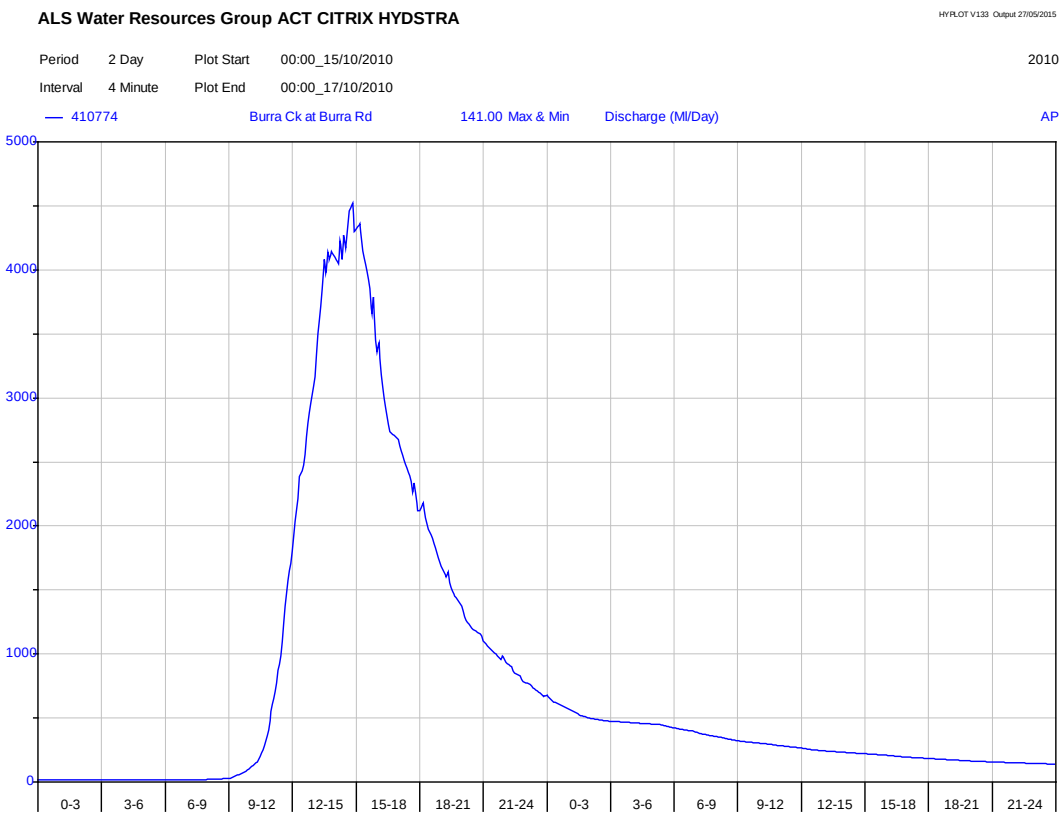


Figure 3 - 410774 Burra Ck 15/10/2010 Event (1 in 5yr ARI)

3. Methodology

The methodology used in this report is based on the Aquatic Ecology Management Plan (2014) of the M2G Operation Environment Management Plan (OEMP, 2014). Monitoring has been modified due to the change in operational expectation of the M2G pipeline to reflect that only maintenance pumping is occurring.

It was expected that once the pipeline was commissioned that water transfer would commence almost immediately. However, due to the large increase in ACT Water Supply storage from 2010 to 2012, and maintained level through to 2014, the need for water transfer in the near future from the Murrumbidgee River is now very unlikely. During the period following the commissioning until now there have been regular events of sufficient volume to keep Googong Reservoir volume well above the pumping threshold of 80%, being at or near the 100% full supply level.

A reduced sampling frequency during the current standby period of maintenance is understood to be as follows:

- Annual visual inspections (by a geomorphologist or suitably qualified hydraulic engineer) at key sites, being upstream and downstream of the abstraction and discharge points.
- Prior to the pipeline commencing in Operating mode for continuous water transfer to improve Googong water storage capacity, surveyed transects and site observations should be undertaken to re-establish and confirm baseline condition.
- Annual reporting to ACTEW (Icon Water)

Due to Googong Reservoir currently being at full supply level there is no requirement to operate the M2G pipeline in continuous mode.

3.1 Creek observations and photogrammetry

Prior to the initial commissioning phase, the length of Burra Creek was walked from the M2G discharge structure downstream to London Bridge. This was done to evaluate the areas of potential bank erosion and riffle zone adjustment during the operation of the M2G pipeline. This initial walk was completed in July 2012. Photos were taken along the length of the creek of pools and riffle zones for future reference for a comparison of change over time, which can be found in Appendix B. Pools were identified by the numbers given to them in the original geomorphic assessment (ACTEW, 2009).

All riffle zones were given an adjustment potential rating of high, moderate or low, while banks were assessed for erosion potential on each side of the creek individually and given an erosion potential of high, moderate or low. These assessments are consistent with the method employed in the previous geomorphic assessment completed during the EIS phase of the M2G project (ACTEW, 2009).

Follow up walks of Burra Creek were undertaken on 19th-21st March 2013 and 5th-6th June 2014 to provide follow up assessment of the condition of key sites which were identified on the pre-commissioning walk, which can be found in Appendices C and D.

3.2 Burra Creek & Murrumbidgee River Geomorphological Surveys

Pre-commissioning surveys were undertaken upstream and downstream of the intake structure on the Murrumbidgee as well as along the length of Burra Creek, upstream and downstream of the outlet structure at Williamsdale Rd. The number of sections surveyed is recorded in Table 3.1 with survey dates. The two sites (D/S Pool 51 & D/S Pool 29) were surveyed after being identified as having a riffle zone adjustment potential of moderate during the walk of Burra Creek given in section 2.1.

Table 3.1. Pre-Commissioning site cross-sections

Site	Number of Survey Sections	Date Surveyed
BUR1	3	10/7/2012
BUR1C	5	6/7/2012
BUR2	3	1/8/2012
BUR2A	4	9/7/2012
D/S Pool 51	3	2/8/2012
D/S Pool 29	2	2/8/2012
BUR2C	4	5/7/2012
MUR18	2	10/1/2010
MUR19	2	10/1/2010

Survey sections pre-commissioning of M2G were measured using a dumpy level and graduated staff, where height measurements were recorded at distance intervals across each transect. GPS co-ordinates were collected for the beginning and end points for each transect, and pegged to readily return to transect locations for later surveys. Transect locations were chosen with specific reference to potential erosion and/or scour points at each site.

Survey sections post-commissioning of M2G were undertaken using a differential GPS unit (DGPS) or using the Dumpy level where necessary (some sites have limited DGPS signal acquisition). At some sites both DGPS and Dumpy were used post-commissioning to ascertain the accuracy and validity of the DGPS method.

The stated accuracy of the DGPS is generally indicated as ± 15mm horizontally, and ± 20mm vertically. This accuracy is dependent on the real time kinetic correction factor as received from the closest CORSNET repeater via an internet link.

The number of post-commissioning survey sections undertaken are recorded in Table 3.2 with indicative dates of surveys.

Cross-sections for each site can be found in Appendices F- L overlayed with previous sections where possible to show relative change in the geomorphology at each transect.

Table 3.2 - Post-Commissioning site cross-sections

Location	Number of Survey Sections	Date Surveyed
BUR1	6	2013, 17/6/2014
BUR1c	5	17/6/2014
BUR2	4	Jul-2013
BUR2A	4	6/1/2015
D/S Pool 51	3	Jul-2013
D/S Pool 29	0	n/a
BUR2C	5	30/8/13, 6/1/2015
MUR18	5	April 2013 Jan 2014, 9/1/2015
MUR19	4	Jan 2013, 18/5/2015

4. Observations & Discussion

4.1 Creek Observations and photogrammetry

The creek observations were undertaken by walking the creek from the M2G discharge point to the London Bridge karst formation. This provided assessments of the riffle zone adjustment potential and the bank erosion potential. The assessments from the observations are presented on the maps found in Appendix A.

4.1.1 Sediment erosion observations

There were nine areas which showed moderate potential for adjustment. The remaining riffle zones were all assessed as having a low adjustment potential. Photos of pools were taken for future comparisons of pool movement and size changes under altered flow conditions and are presented in Appendix B. Subsequent photos of key sites on Burra Creek are shown in Appendix C and Appendix D.

There was potential for a small step (assessed as moderate) located immediately downstream of Williamsdale Road to be adjusted as a result of continuous increased flows from pumping. Plate 1 shows this section of creek at a flow of < 5 ML/d and at 109 ML/d. This step has recently heavily re-vegetated as flows have not been high enough to scour the channel.

Plate 1. Step with moderate adjustment potential immediately downstream of Williamsdale Road, left at <5 ML/d, right at 100 ML/d

In its current condition, flow from the M2G discharge is unlikely to create erosion of the central channel section. Sediment bars are unlikely to be eroded by normal pumping flows. This may change with further adjustments to the system from natural large events.

4.1.2 Bank erosion assessments

The bank area at Pool 5, immediately upstream of the BUR2C macroinvertebrate sampling site, continues to show the highest potential for substantial erosion. This bank area has been made vulnerable by the high flow events which have scoured the bank and undercut sections over time. Photos of the bank in 2012 are shown in Photo 1 to Photo 2, indicating erosion potential along the bottom of the bank which will increase the undercutting of the bank, resulting in bank collapse into the creek. Photo 3 and Photo 4 show the state of the bank in September 2014.

Photo 1 - High erosion potential area downstream of Pool 5 during July (left) and August (right) 2012

Photo 2 - High erosion potential area downstream of Pool 5 during September (left) and October (right) 2012

Photo 3 - Erosion potential area downstream of Pool 5 during October 2013 (Left) and January 2014 (Right)

Photo 4 - Erosion potential area downstream of Pool 5 control in June 2014 (left) and September 2014 (right)

–new erosion above gravel layer in embankment

Photo 5 – Pool 5 left hand side bank starting to erode out above the gravel/boulder layer (September 2014)

The bank immediately upstream of the location shown in Photos 4 and 5 has also started to collapse in sections and eroded significantly since 2009 (refer to photos in Appendix K- BUR 2C: Site Survey).

The other bank areas along Burra Creek assessed as having a high erosion potential would also be vulnerable to a continued elevated flow from the M2G transfer, however not to the same extent. Natural events have a much larger impact potential on the geomorphology than the pump maintenance releases from M2G. However, with the pumps potentially running for a prolonged period (greater than 1 week), this may have additional impact due to increased saturation of the creek embankment and a sustained flow velocity..

4.1.3 Sediment Transport & Deposition

With the pipeline in standby mode updated sediment samples have not been taken.

Previous sediment samples in 2013 of the sand bars from BUR2 and BUR2C show that the majority of sediment being deposited within stream is between 0.5 and 2mm in size as seen in Figure 5. This size corresponds to coarse sand. The sample taken from Angle Crossing has a majority of sediment in the 0.25-1mm range, which corresponds to medium and coarse sand.

Individual sieve analysis results can be found in Appendix E. The sediment analysis indicates that the very fine sediments are being transported through to Googong Reservoir in major and minor events and not captured within Burra Creek. The base of the pool at BUR2C contained minimal sediment as it has been eroded to bedrock. Most of the fine sediment along this flatter section of Burra Creek has also been transported downstream into Googong Reservoir, with only a fine covering over the streambed remaining. This sediment is silt/clay as it is predominately below sand size (<63µm).

Sediment transport during maintenance events shows a first flush effect, with a peak followed by a rapid decrease in turbidity as fine particulate matter is moved. Figure 4 below shows level, discharge and turbidity during a maintenance run in November 2014. The hydrograph shows that pumps were in operation during the 6th, 7th, 11th, 12th and 13th of the month. The initial pumping produced a sharp peak in turbidity which rapidly reduced as the cleaner Murrumbidgee water flowed through the system. When the pumps were switched on again on the 11th and 12th the turbidity peaks were far lower as fine material had already been transported during the initial pump event on the 6th.

In contrast we can see that a minor natural event on the 16th produced a large turbidity spike in comparison with the discharge, as a result of sediment entering the waterway from rainfall runoff.

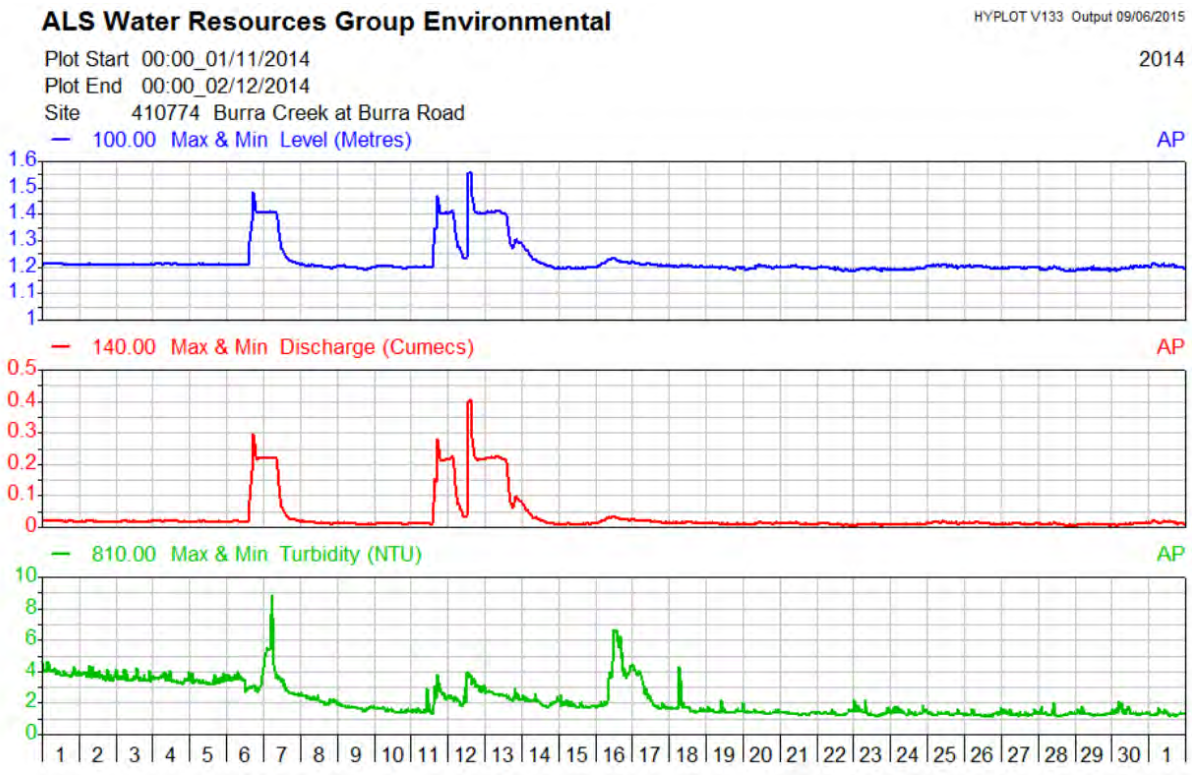


Figure 4 - Burra Weir (410774) flow and turbidity data Nov 2014 maintenance

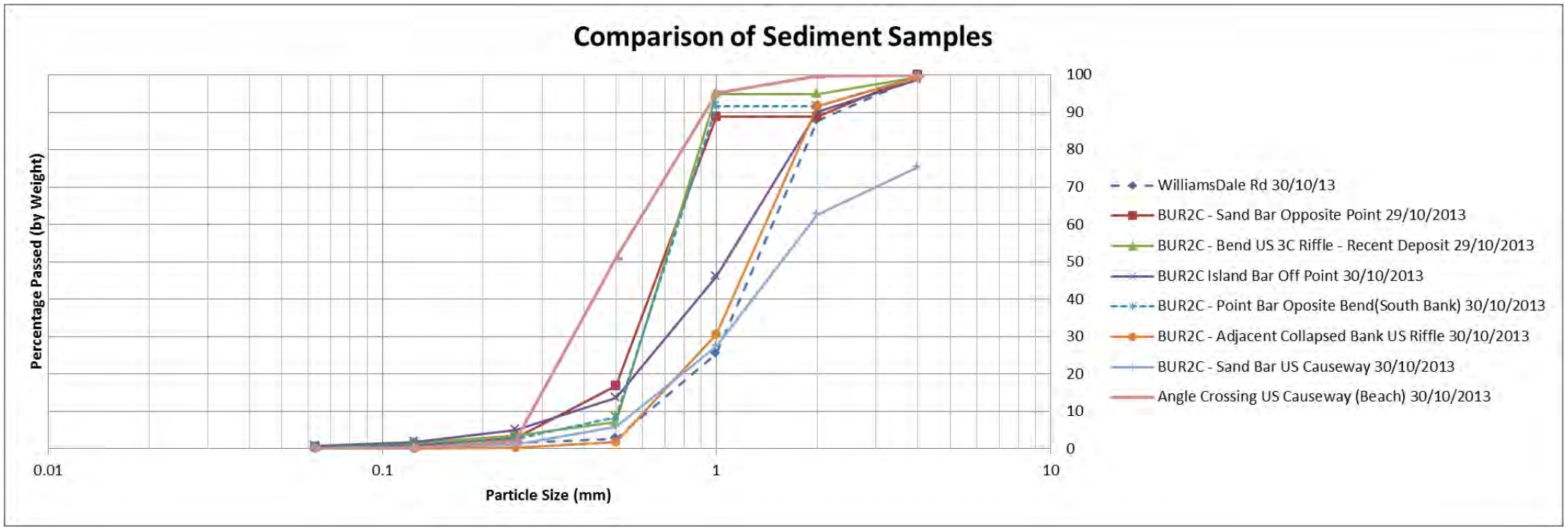


Figure 5 - Comparison of Sediment Sieve samples

4.2 Creek Surveys

Creek surveys were undertaken on Burra Creek (2 upstream, 2 downstream) and Angle Crossing (upstream, at the, intake structure and downstream at bend). Surveys included transects, and 3D DGPS for the pool area near the intake..

4.2.1 Channel Units

The channel units present at each location are shown below. Channel units have not changed since the previous report but are indicated below for reference.

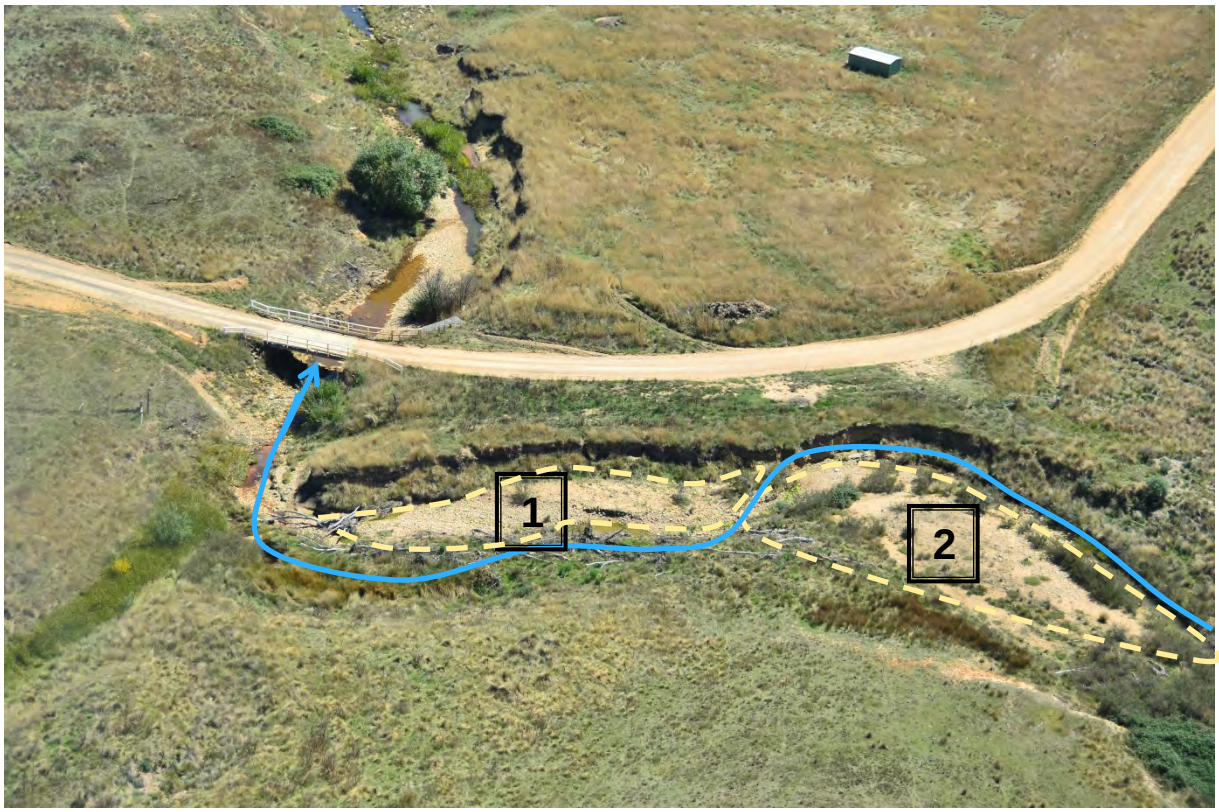


Figure 6 - BUR1 Channel Units 10/3/2013

Table 4.1 - BUR1 Channel Units

Identifier	Fluvial Environment	Comments
1	Sand Bar	Sand/gravel
2	Sand Bar	Sand/cobble
	Ephemeral Channel	Minor Run/Riffle/Pools

Figure 7 - BUR1 Aerial 9/4/2014

Figure 8 - BUR1C Channel Units 10/3/2013

Table 4.2 - BUR1C Channel Units

Identifier	Fluvial Environment	Comments
1	Sand Bar	Sand/gravel
	Ephemeral Channel	Minor Run/Riffle

Figure 9 - BUR1C Aerial 9/4/2014

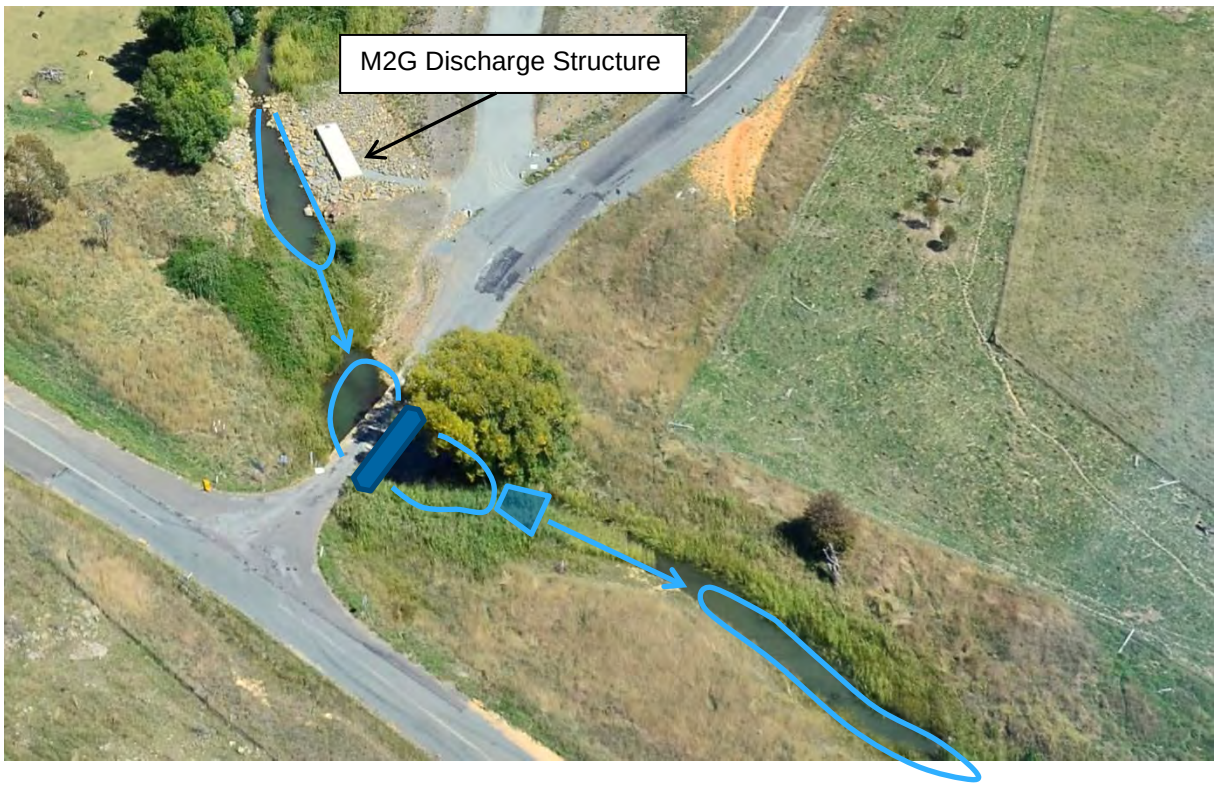


Figure 10 - BUR2 Channel Units 10/3/2013

Table 4.3 - BUR2 Channel Units

Identifier	Fluvial Environment	Comments
	Channel	Minor Run
	Pool	
	Step	Approximately 30cm
	Creek Crossing	Pipe Culvert Crossing Multiple 600mm diameter culverts

Figure 11 - BUR2 Aerial 9/4/2014

Figure 12 – BUR2A Channel Units 10/3/2013

Table 4.4 – BUR2A Channel Units

Identifier	Fluvial Environment	Comments
	Channel	Run/Riffle
	Pool	

Figure 13 - BUR2A Aerial 9/4/2014

Figure 14 – Pool 29 Channel Units 10/3/2013

Table 4.5 - Pool 29 Channel Units

Identifier	Fluvial Environment	Comments
	Channel	Run/Riffle
	Pool	

Figure 15 - Pool 29 Aerial 9/4/2014

Figure 16 – BUR 2C Channel Units 10/3/2013

Table 4.6 – BUR 2C Channel Units

Identifier	Fluvial Environment	Comments
	Channel	Run/Riffle
	Pool	
	Crossing	Cobble
	Sand Bar/Deposit	Sand/Gravel

Figure 17 - BUR2C Aerial 9/4/2014

Figure 18 - Angle Crossing Channel Units 10/3/2013

Table 4.7 - Angle Crossing Channel Units

Identifier	Fluvial Environment	Comments
	Channel	Run
	Pool	
	Causeway	Cement
	Major Riffle	Cobble

4.2.2 Survey Transects

Surveys of the Murrumbidgee and Burra site locations are in Appendices as follows:

- Appendix F – BUR1
- Appendix G – BUR1C
- Appendix H – BUR2
- Appendix I – BUR2A
- Appendix J – Pool 50
- Appendix K – BUR2C
- Appendix L – Angle Crossing

There have been a few noticeable changes in some of the cross-sections since the April 2014 report.

Key observations are:

- There has been removal of bank and channel material at BUR1 which has shifted the position of the central channel, due to the September 2013 event (from site visits undertaken afterwards, see Photo 14 to Photo 16).
- There has been continued undercutting and removal of bank material at BUR2C, cross-section 2 on the outside of the bend.
- Deep channel on the left hand side of the Murrumbidgee (looking downstream) opposite the intake structure has had material deposited in it.
- Sand bar in the middle of the pool near the intake structure has had material removed, flattening the sand bar.
- Depth of water adjacent to the intake structure has remained largely unchanged at approximately 0.5m - 0.7m deep during baseflow conditions.
- Cross-sections at the bend downstream of Angle Crossing (XS-3 & 4) show that the central channel profile has become significantly deeper and wider as the sand bar has been washed out.

For more detailed notes on site cross-sections refer to respective appendices.

The natural shifting of the sand bar occurring at the pool adjacent to the intake structure at Angle Crossing has the potential to interfere with pumping activities. It is possible that shifting of the sandbar could create undesirable increased sediment at the intake structure, causing high levels of sediment material to enter the structure placing a heavy load on screen cleaning and sediment removal equipment.

It is also possible that should the water depth adjacent to the intake structure remain at depths less than 700mm as a result of low flows, significant submerged macrophyte growth could occur, which may also obstruct the intake grates and interfere with pumping operations.

5. Conclusions and Recommendations

From the pump maintenance run, there was no observed erosion from the banks as a direct result of M2G discharge flows. There was also no evidence that flows initiated any channel or riffle zone adjustment, and no movement of sediment deposits except for remobilisation of very fine sediment that temporarily increased turbidity.

Pool 5 above BUR 2C has previously been identified as having a high erosion potential, and continues to erode from natural flows. When M2G is in operation, it is very likely that prolonged flows around 100ML/d will exacerbate the natural erosion occurring along the base of the western embankment.

To date it has not been possible to monitor Burra Creek during long term pumping rates at approximately100ML/d.

The sandbar at the intake structure is dynamic and subject to natural shifting which may impact upon the intake structure and water extraction activities. Ongoing shallow water depths at this location could also result in increased submergent macrophyte growth which could interfere with future pumping operations.

Recommendations:

1) An annual walk of Burra Creek from the discharge point to London Bridge should be continued, including photo monitoring points, to characterise any changes occurring as a result of natural flow events and vegetation growth, especially those that could be exacerbated by a continuous discharge from M2G.
2) Visual and photographic monitoring of vegetation encroachment and sediment deposition at the outlet pool (upstream of Williamsdale Rd) should be included in annual monitoring for future reference.
3) In addition to existing monitoring, put in place a risk register and management plan for erosion of any stream banks within Burra Creek, whether naturally occurring or a result of pump maintenance runs, and potential impacts to downstream river ecology and receiving water.
4) A re-survey of all transects should be undertaken before the commencement of continuous pumping operations.
5) The dynamics of the sandbar and macrophyte growth occurring at the pool adjacent to the intake structure at Angle Crossing should continue to be monitored.

6. References

ACTEW Corporation (2009) *Murrumbidgee to Googong Water Transfer: Environmental Impact Statement*

ACTEW Corporation (2010a). *Murrumbidgee to Googong Water Transfer. Aquatic Ecology Management Plan.*

ACTEW Corporation (2010b). *Murrumbidgee to Googong Water Transfer: Geomorphologic Monitoring Sub Plan.*

ACTEW Corporation (2011). *Murrumbidgee to Googong Water Transfer: Burra Creek Environmental Management Plan.*

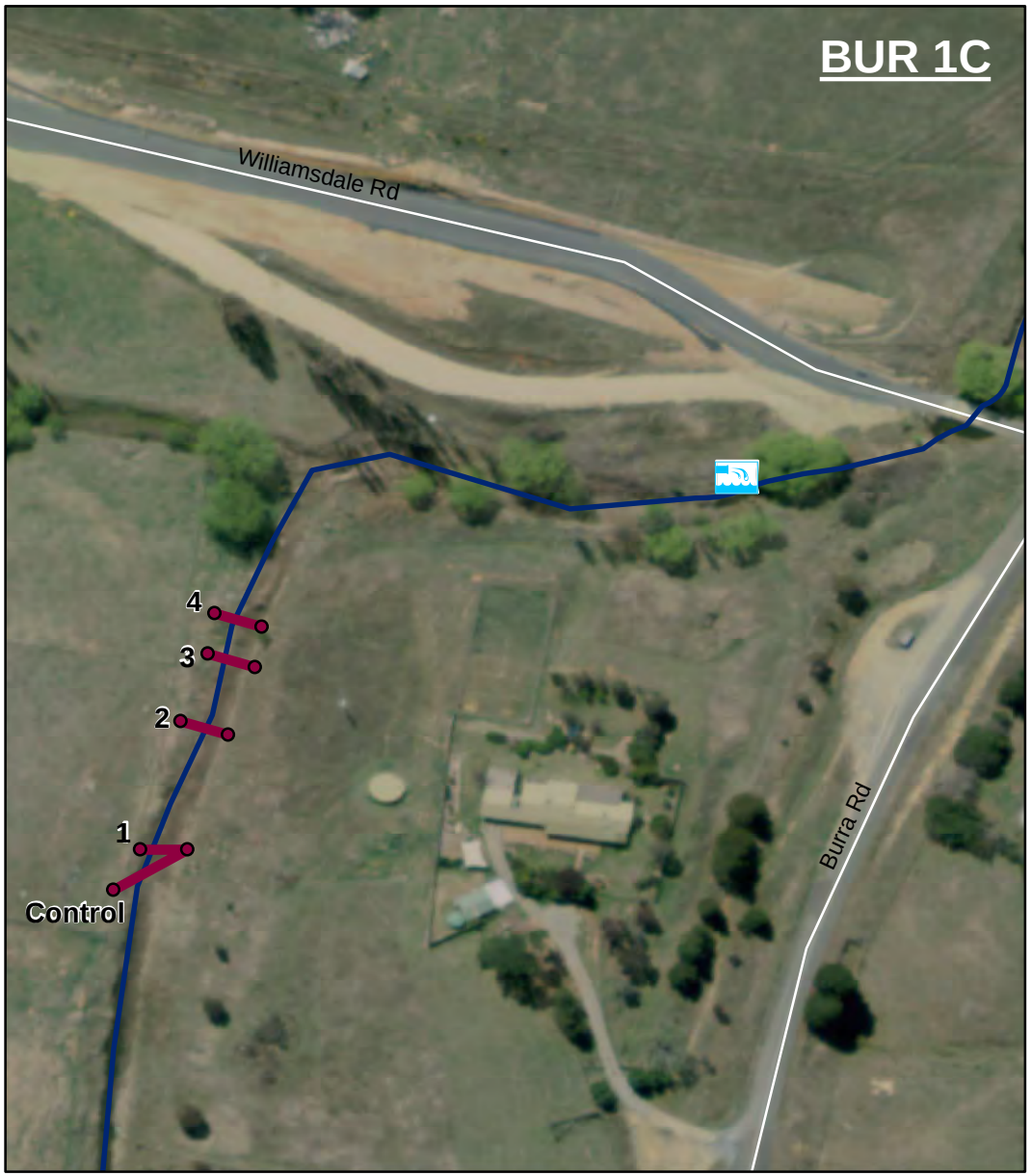
ACTEW Corporation (2012). *Murrumbidgee to Googong Water Transfer: Operation Environmental Management Plan.*

ACTEW Corporation (2014) *Murrumbidgee to Googong Water Transfer: Operation Environmental Management Plan, Version 2.*

ACTEW Corporation (2014) *Murrumbidgee to Googong Water Transfer: Aquatic Ecology Monitoring Plan*

Appendices

Appendix A Creek Maps



1:2,000 (at A4)

0 10 20 40 60 80

Meters

Horizontal Datum: WGS 1984
Grid: GCS WGS 1984

N

Numbered Cross Section

Burra Creek

M2G Discharge Structure

Burra Creek Cross Sections: BUR 1 & BUR 1C

Murrumbidgee Ecological Monitoring Program
ACTEW Water

Job Number	23-14302
Revision	A
Date	01 May 2013

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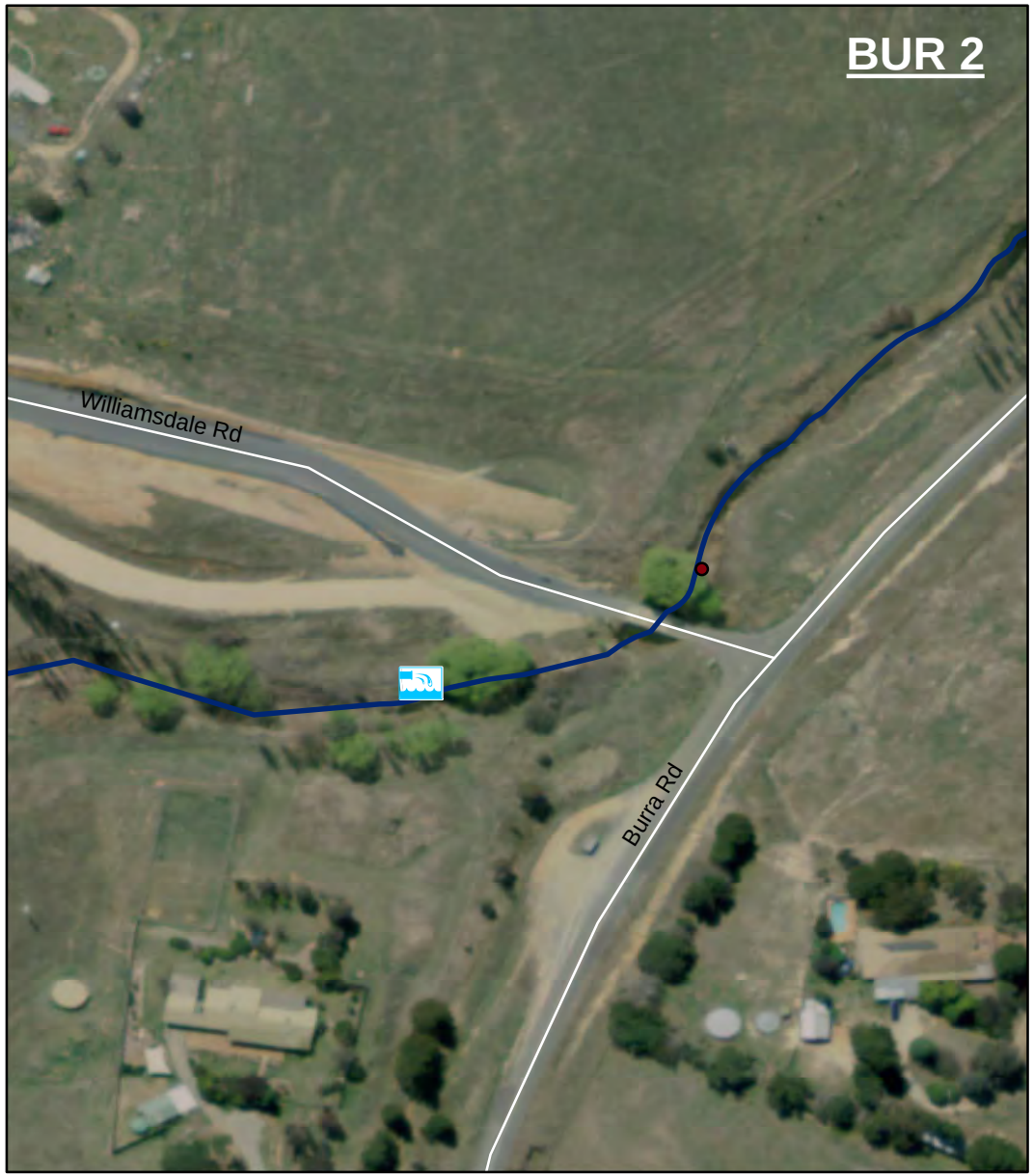
180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: GHD, Burra Creek Surveys, Revision A, 1/5/2013. Created by:jpcox



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Meters

Horizontal Datum: WGS 1984
Grid: GCS WGS 1984

N

Numbered Cross Section

Burra Creek

M2G Discharge Structure

Burra Creek Cross Sections: BUR 2 & BUR 2A

Murrumbidgee Ecological Monitoring Program

ACTEW Water

Job Number	23-14302
Revision	A
Date	01 May 2013

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180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: GHD, Burra Creek Surveys, Revision A, 1/5/2013. Created by:jpcox

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Metres

Horizontal Datum: WGS 1984
Grid: GCS WGS 1984

N

Numbered Cross Section

Burra Creek

Burra Creek Cross Sections: BUR 2C

Murrumbidgee Ecological Monitoring Program
ACTEW Water

Job Number	23-14302
Revision	A
Date	01 May 2013

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180 Lonsdale Street Melbourne VIC 3000 Australia **T** 61 3 8687 8000 **F** 61 3 8687 8111 **E** melmail@ghd.com **W** www.ghd.com

Data source: GHD, Burra Creek Surveys, Revision A 1/5/2013. Created by:jpcox

Appendix B - Pre Commissioning Pool & Riffle Photos

Pool photos were taken on the 24th and 25th July 2012 when the average daily flow at Burra weir (gauging station 410774) was 7.9 and 7.8 ML/day respectively. Pool numbering is consistent with that of the previous geomorphic assessment completed during the EIS phase of the M2G project for ease when comparing changes over time.

Pool 1

Pool 2

Pool 3

Pool 4

Pool 5

Pool 6

Pool 7

Pool 8

Pool 9

Pool 10

Pool 11

Pool 12

Pool 13

Pool 14

Pool 15

Pool 16

Pool 17

Pool 18

Pool 19

Pool 20

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Pool 22

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Pool 69

Pool 70

Pool 71

Appendix C – Post Commissioning Photos (19-21 March 2013): Key Sites

Step D/S Williamsdale Rd Looking U/S

BUR2A Riffle Looking D/S

BUR2A Riffle Looking U/S

Middle of Riffle U/S Pool 50 Looking U/S

Bottom of Riffle U/S Pool 50

Pool 28 Looking U/S

Pool 28 Looking D/S

Bend U/S BUR2C Riffle

There was no visually detectable change at sites except for the embankment at bend U/S BUR2C riffle where erosion had occurred.

Appendix D – Burra Creek Photos (5-6 June 2014): Key Sites

U/S of Step, D/S Williamsdale Rd looking D/S

BUR2A Riffle looking D/S

Riffle U/S Pool 50 looking U/S

Riffle U/S Pool 28

Pool 28 Looking D/S

Bank U/S Bend at BUR2C

Bend U/S BUR2C Riffle

Appendix E - Sieve Analysis Results

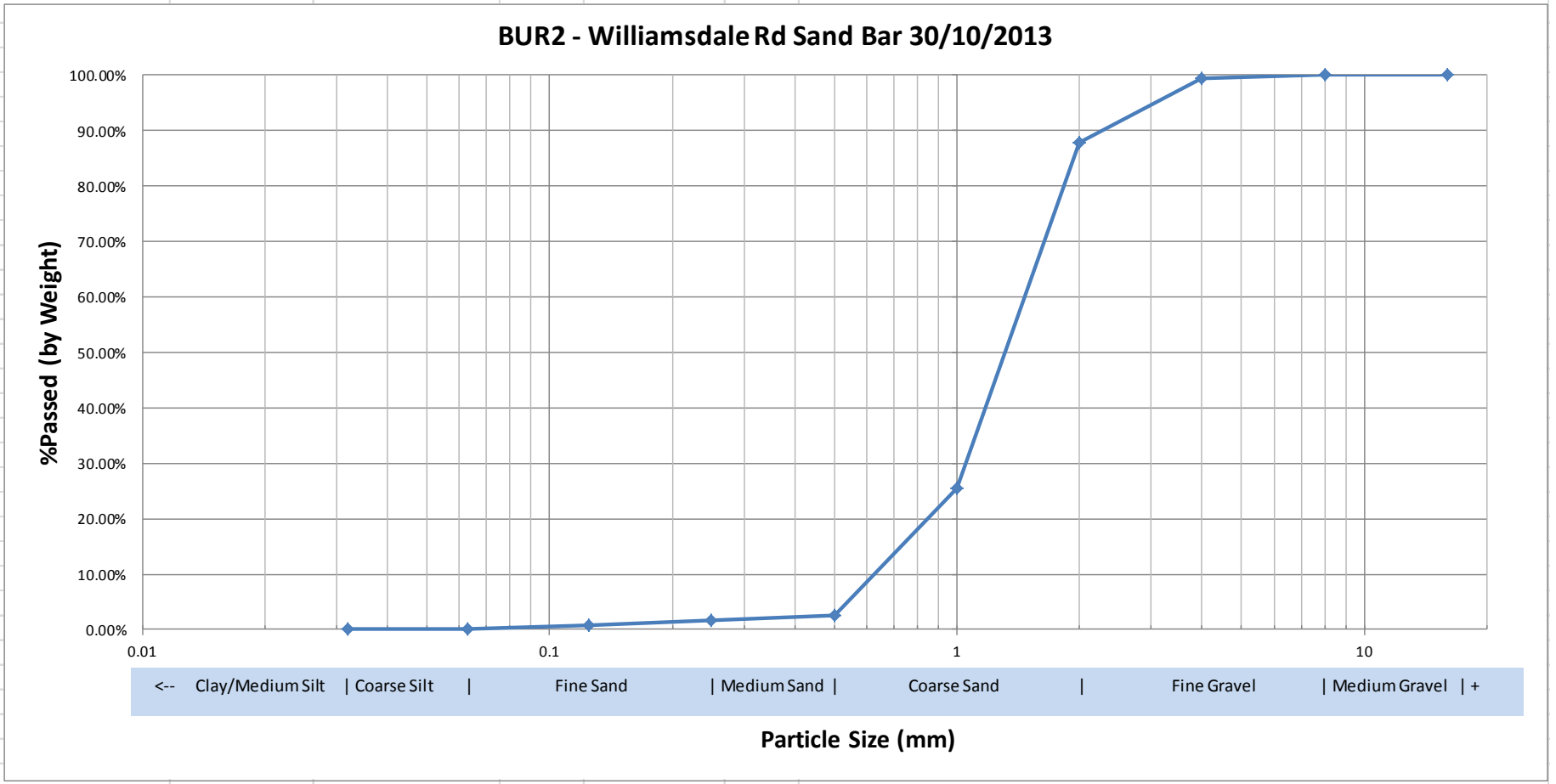
Sediment Sieve Analysis

Sample ID: BUR2 - Williamsdale Rd Sand Bar

Sample Date: 30/10/2013

Container Weight 83.2

	Sieve Size (mm)	Weight w/Container (g)	Weight (g)	% Sample (by Wt)	%Passed	Additional Comments
Medium Gravel/Cobble	16	0	0	0.00%	100.00%	
Medium Gravel	8	0	0	0.00%	100.00%	
Fine Gravel	4	88.12	4.92	0.67%	99.33%	
Fine Gravel	2	168.11	84.91	11.56%	87.77%	
Coarse Sand	1	541.41	458.21	62.38%	25.39%	
Coarse Sand	0.5	250.51	167.31	22.78%	2.61%	
Medium Sand	0.25	90.9	7.7	1.05%	1.57%	
Fine Sand	0.125	88.28	5.08	0.69%	0.87%	
Fine Sand	0.063	88.23	5.03	0.68%	0.19%	
Coarse Silt	0.032	84.59	1.39	0.19%	0.00%	
	Total Weight (g)		734.55	100.00%		



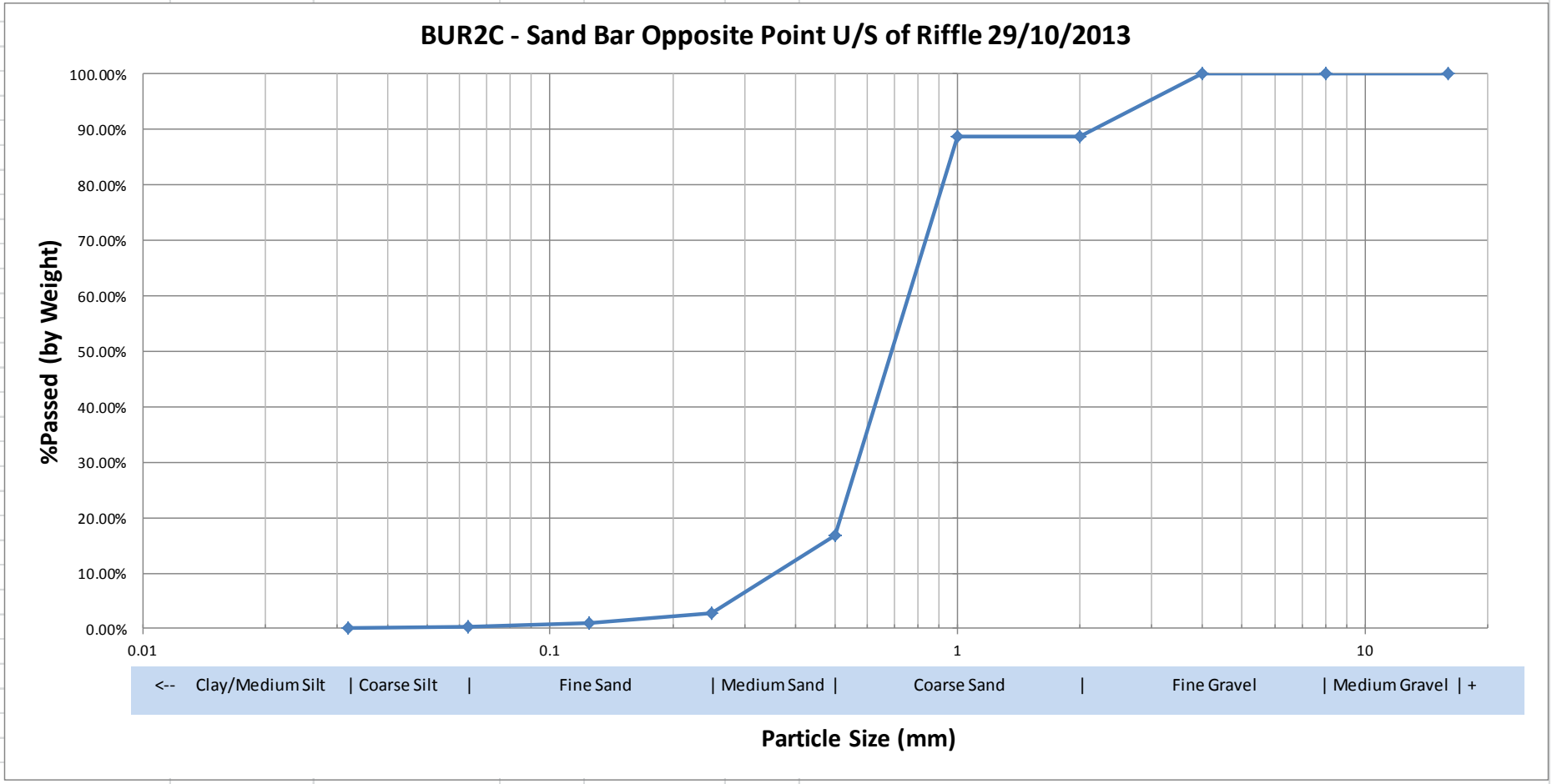
Sediment Sieve Analysis

Sample ID: BUR2C - Sand Bar Opposite Point U/S of Riffle

Sample Date: 29/10/2013

Container Weight 83.2

	Sieve Size (mm)	Weight w/Container (g)	Weight (g)	% Sample (by Wt)	%Passed	Additional Comments
Medium Gravel/Cobble	16		0	0.00%	100.00%	
Medium Gravel	8		0	0.00%	100.00%	
Fine Gravel	4		0	0.00%	100.00%	
Fine Gravel	2	139.2	56	11.24%	88.76%	
Coarse Sand	1		0	0.00%	88.76%	
Coarse Sand	0.5	441.2	358	71.89%	16.87%	
Medium Sand	0.25	153.2	70	14.06%	2.81%	
Fine Sand	0.125	92.2	9	1.81%	1.00%	
Fine Sand	0.063	86.2	3	0.60%	0.40%	
Coarse Silt	0.032	85.2	2	0.40%	0.00%	
	Total Weight (g)		498	100.00%		



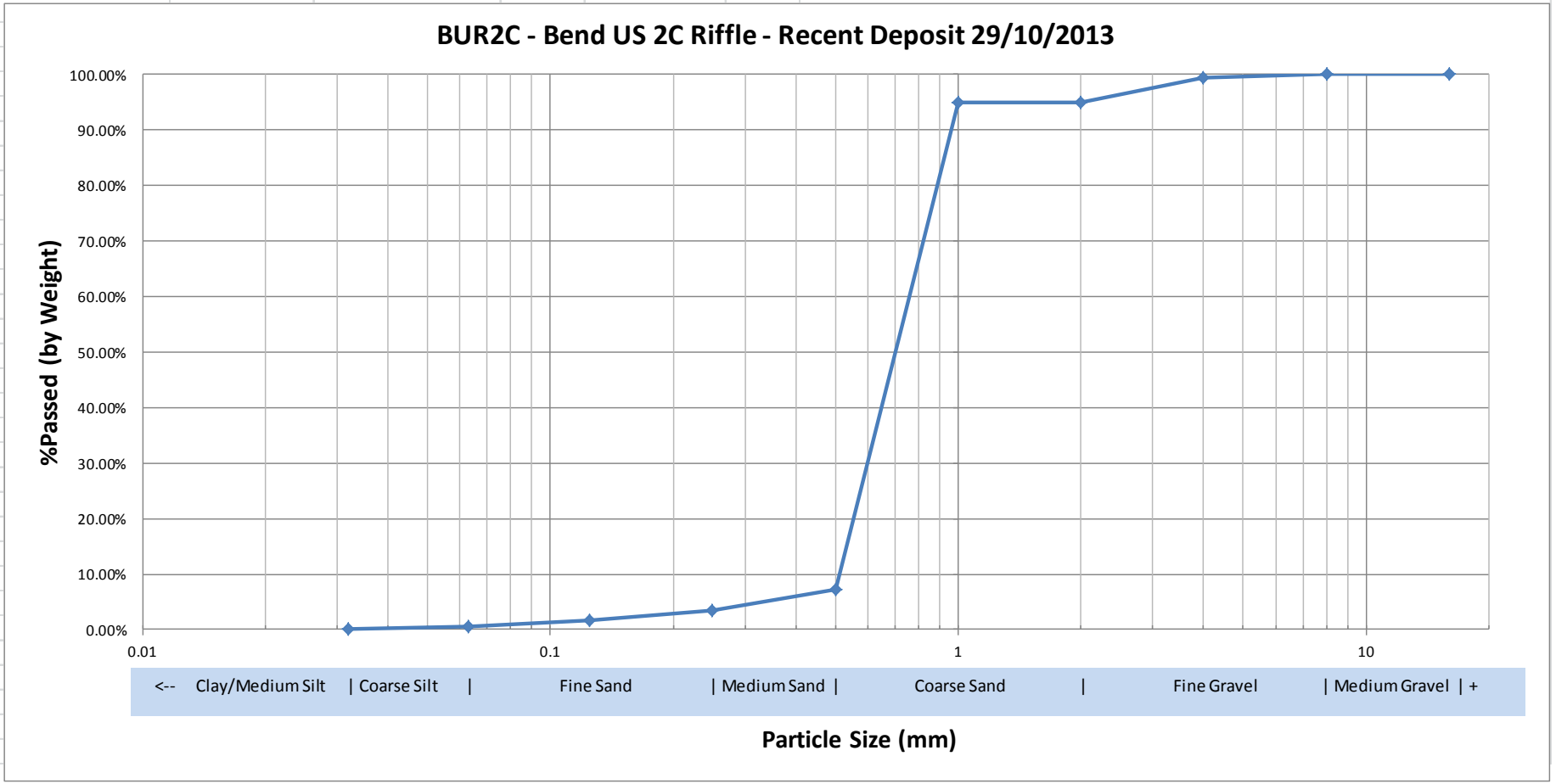
Sediment Sieve Analysis

Sample ID: BUR2C - Bend US 2C Riffle - Recent Deposit

Sample Date: 29/10/2013

Container Weight 83.2

	Sieve Size (mm)	Weight w/Container (g)	Weight (g)	% Sample (by Wt)	%Passed	Additional Comments
Medium Gravel/Cobble	16		0	0.00%	100.00%	
Medium Gravel	8		0	0.00%	100.00%	
Fine Gravel	4	86.2	3	0.61%	99.39%	
Fine Gravel	2	105.2	22	4.48%	94.91%	
Coarse Sand	1		0	0.00%	94.91%	
Coarse Sand	0.5	514.2	431	87.78%	7.13%	
Medium Sand	0.25	101.2	18	3.67%	3.46%	
Fine Sand	0.125	92.2	9	1.83%	1.63%	
Fine Sand	0.063	88.2	5	1.02%	0.61%	
Coarse Silt	0.032	86.2	3	0.61%	0.00%	
	Total Weight (g)		491	100.00%		



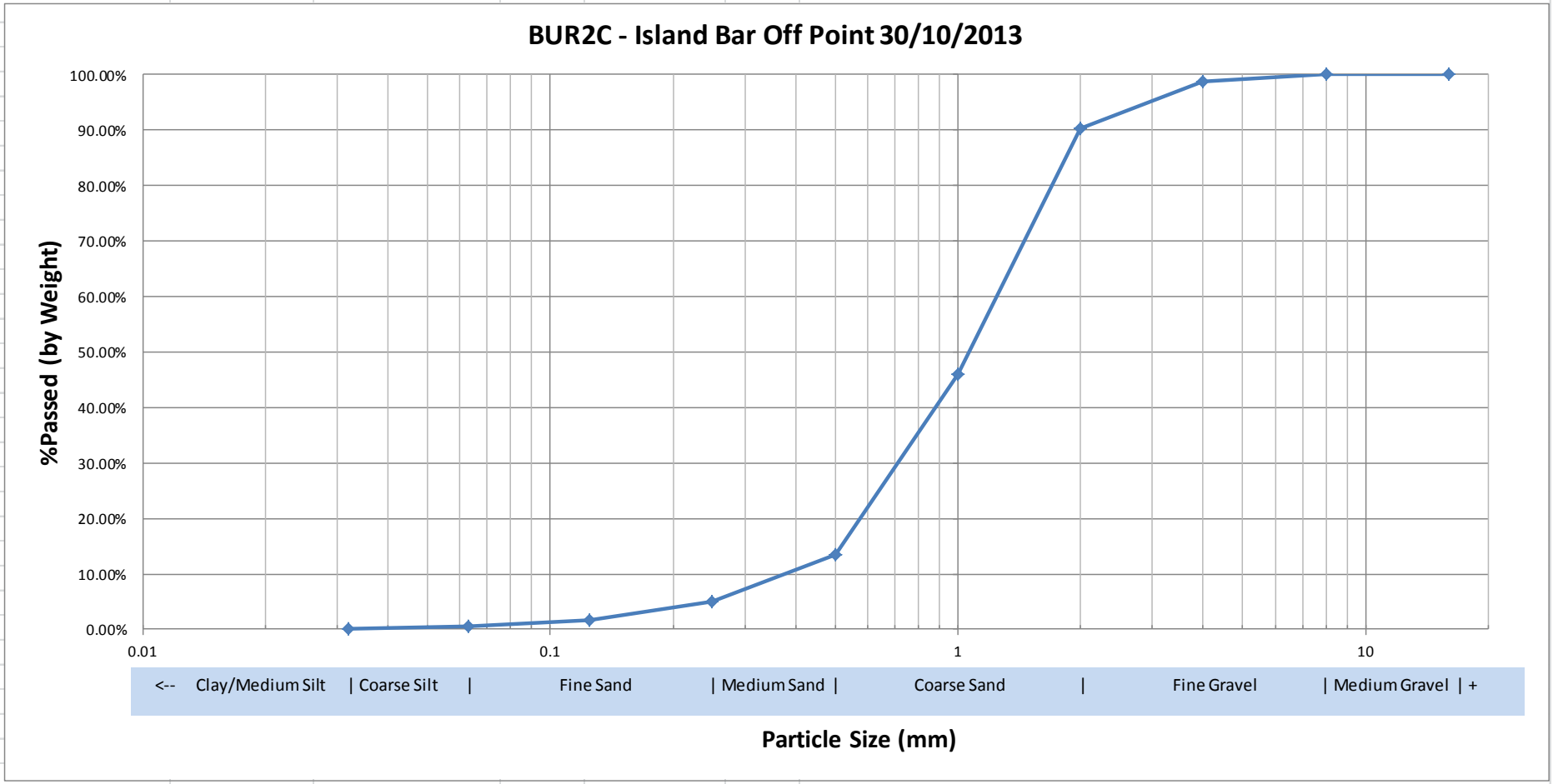
Sediment Sieve Analysis

Sample ID: BUR2C - Island Bar Off Point

Sample Date: 30/10/2013

Container Weight 83.2

	Sieve Size (mm)	Weight w/Container (g)	Weight (g)	% Sample (by Wt)	%Passed	Additional Comments
Medium Gravel/Cobble	16		0	0.00%	100.00%	
Medium Gravel	8		0	0.00%	100.00%	
Fine Gravel	4	89	5.8	1.31%	98.69%	
Fine Gravel	2	120.7	37.5	8.49%	90.20%	
Coarse Sand	1	278.1	194.9	44.12%	46.08%	
Coarse Sand	0.5	226.87	143.67	32.52%	13.56%	
Medium Sand	0.25	120.5	37.3	8.44%	5.11%	
Fine Sand	0.125	98.09	14.89	3.37%	1.74%	
Fine Sand	0.063	88.09	4.89	1.11%	0.63%	
Coarse Silt	0.032	86	2.8	0.63%	0.00%	
	Total Weight (g)		441.75	100.00%		



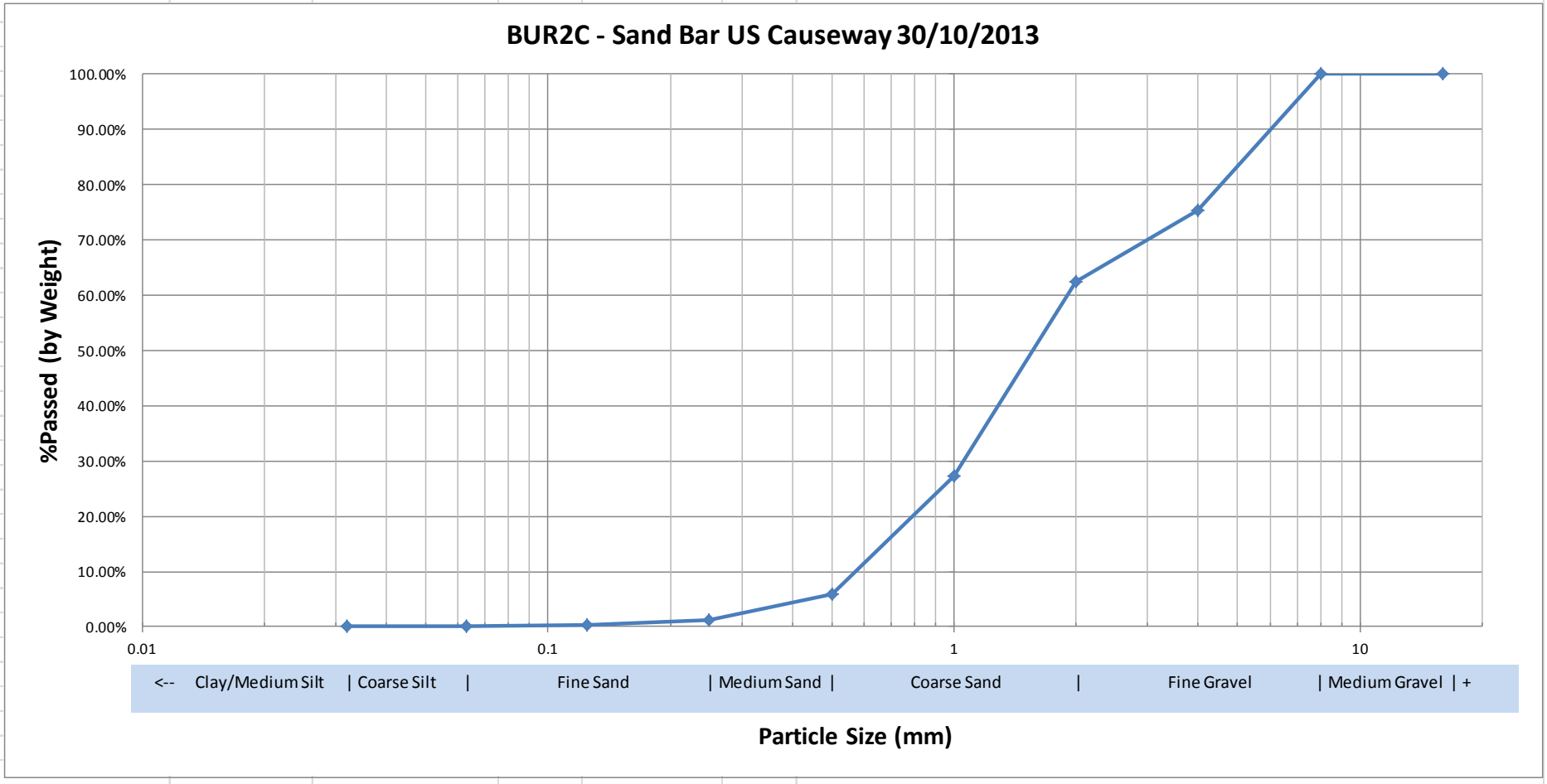
Sediment Sieve Analysis

Sample ID: BUR2C - Sand Bar US Causeway

Sample Date: 30/10/2013

Container Weight 83.2

	Sieve Size (mm)	Weight w/Container (g)	Weight (g)	% Sample (by Wt)	%Passed	Additional Comments
Medium Gravel/Cobble	16		0	0.00%	100.00%	
Medium Gravel	8		0	0.00%	100.00%	
Fine Gravel	4	332.05	248.85	24.65%	75.35%	
Fine Gravel	2	212.51	129.31	12.81%	62.54%	
Coarse Sand	1	438.71	355.51	35.21%	27.33%	
Coarse Sand	0.5	299.26	216.06	21.40%	5.93%	
Medium Sand	0.25	131.73	48.53	4.81%	1.12%	
Fine Sand	0.125	91.58	8.38	0.83%	0.29%	
Fine Sand	0.063	85.13	1.93	0.19%	0.10%	
Coarse Silt	0.032	84.23	1.03	0.10%	0.00%	
	Total Weight (g)		1009.6	100.00%		



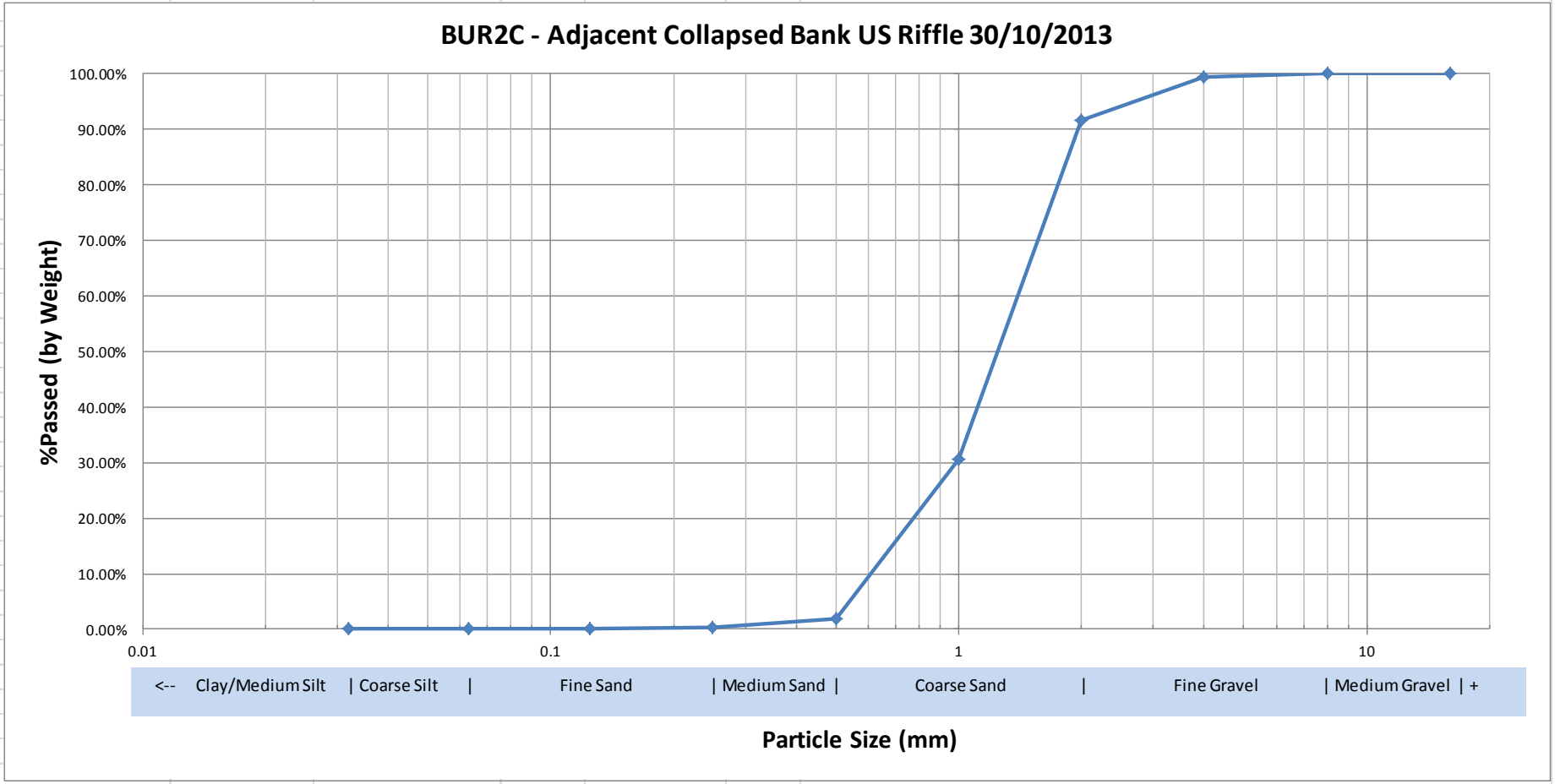
Sediment Sieve Analysis

Sample ID: BUR2C - Adjacent Collapsed Bank US Riffle

Sample Date: 30/10/2013

Container Weight 83.2

	Sieve Size (mm)	Weight w/Container (g)	Weight (g)	% Sample (by Wt)	%Passed	Additional Comments
Medium Gravel/Cobble	16		0	0.00%	100.00%	
Medium Gravel	8		0	0.00%	100.00%	
Fine Gravel	4	87.3	4.1	0.65%	99.35%	
Fine Gravel	2	131	47.8	7.62%	91.73%	
Coarse Sand	1	466.5	383.3	61.06%	30.67%	
Coarse Sand	0.5	264.1	180.9	28.82%	1.85%	
Medium Sand	0.25	93.05	9.85	1.57%	0.28%	
Fine Sand	0.125	84.4	1.2	0.19%	0.09%	
Fine Sand	0.063	83.75	0.55	0.09%	0.00%	
Coarse Silt	0.032		0	0.00%	0.00%	
	Total Weight (g)		627.7	100.00%		



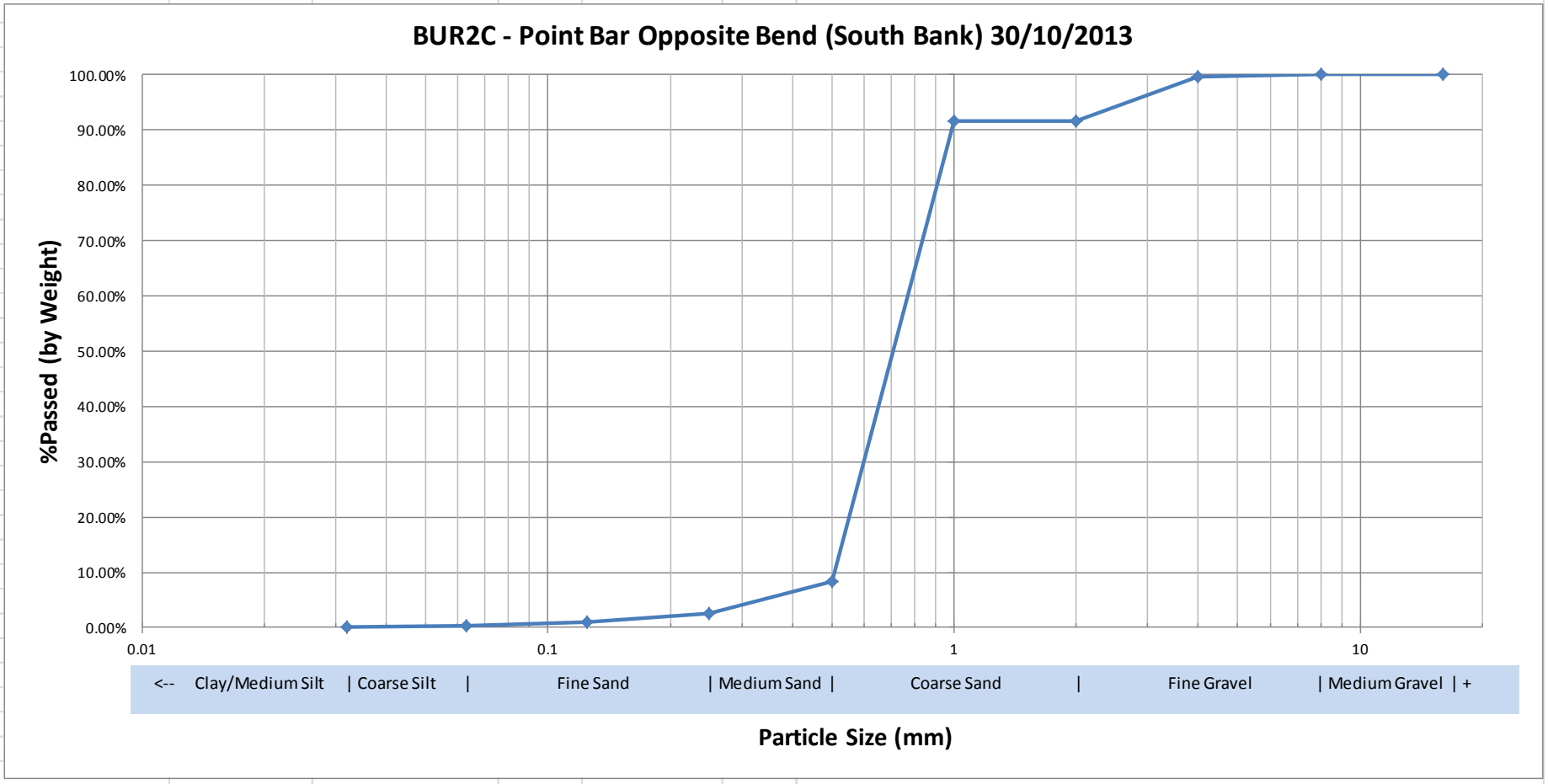
Sediment Sieve Analysis

Sample ID: BUR2C - Point Bar Opposite Bend (South Bank)

Sample Date: 30/10/2013

Container Weight 83.2

	Sieve Size (mm)	Weight w/Container (g)	Weight (g)	% Sample (by Wt)	%Passed	Additional Comments
Medium Gravel/Cobble	16		0	0.00%	100.00%	
Medium Gravel	8		0	0.00%	100.00%	
Fine Gravel	4	85.2	2	0.44%	99.56%	
Fine Gravel	2	119.8	36.6	7.97%	91.60%	
Coarse Sand	1		0	0.00%	91.60%	
Coarse Sand	0.5	465.2	382	83.17%	8.43%	
Medium Sand	0.25	110.2	27	5.88%	2.55%	
Fine Sand	0.125	90	6.8	1.48%	1.07%	
Fine Sand	0.063	86.6	3.4	0.74%	0.33%	
Coarse Silt	0.032	84.7	1.5	0.33%	0.00%	
	Total Weight (g)		459.3	100.00%		



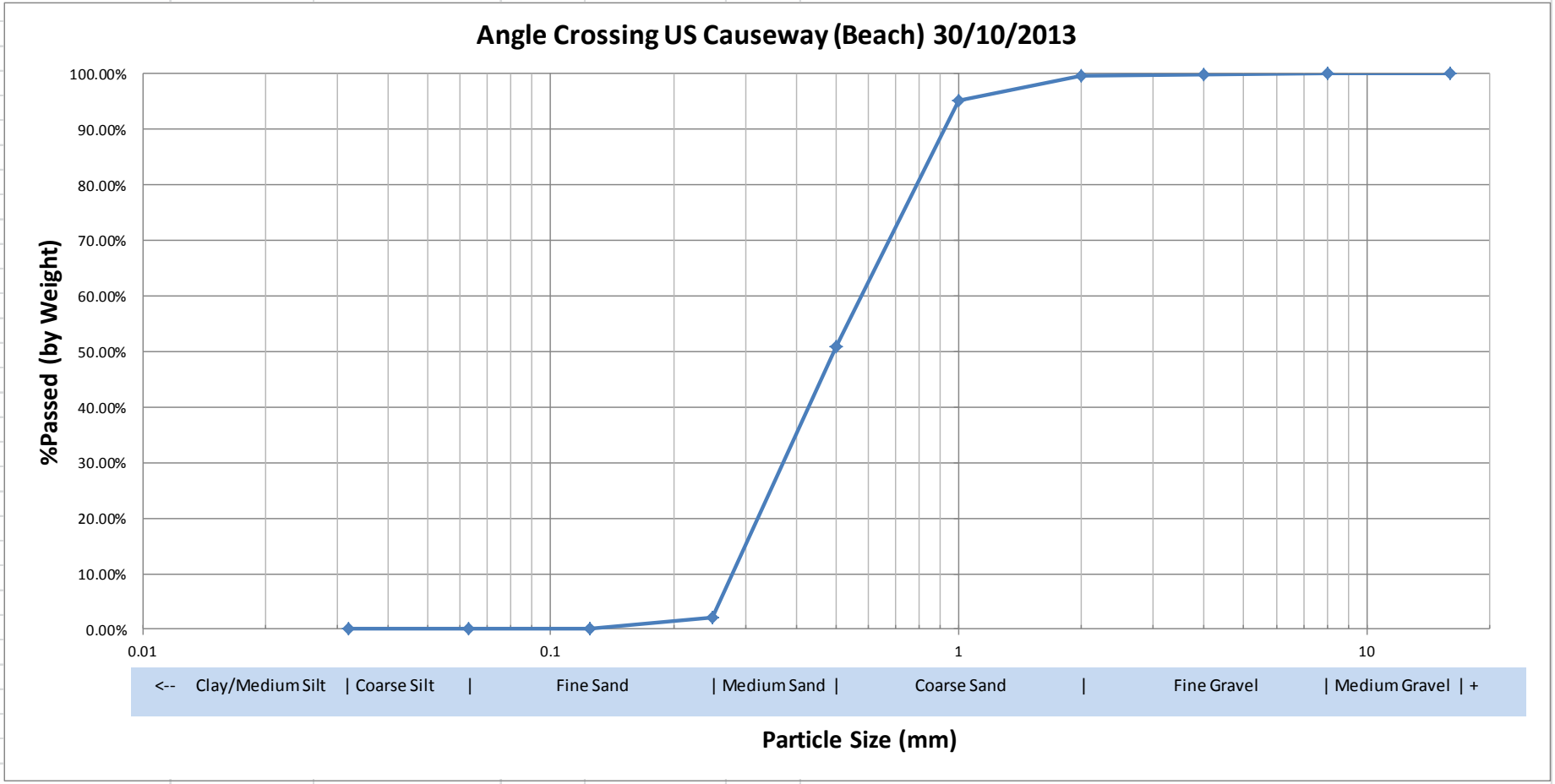
Sediment Sieve Analysis

Sample ID: Angle Crossing US Causeway (Beach)

Sample Date: 30/10/2013

Container Weight 83.2

	Sieve Size (mm)	Weight w/Container (g)	Weight (g)	% Sample (by Wt)	%Passed	Additional Comments
Medium Gravel/Cobble	16	0	0	0.00%	100.00%	
Medium Gravel	8	0	0	0.00%	100.00%	
Fine Gravel	4	83.88	0.68	0.08%	99.92%	
Fine Gravel	2	85.81	2.61	0.31%	99.61%	
Coarse Sand	1	120.1	36.9	4.38%	95.23%	
Coarse Sand	0.5	457.25	374.05	44.41%	50.82%	
Medium Sand	0.25	492.57	409.37	48.60%	2.22%	
Fine Sand	0.125	100.81	17.61	2.09%	0.12%	
Fine Sand	0.063	84.18	0.98	0.12%	0.01%	
Coarse Silt	0.032	83.27	0.07	0.01%	0.00%	
	Total Weight (g)		842.27	100.00%		



Appendix F - BUR 1: Site Survey

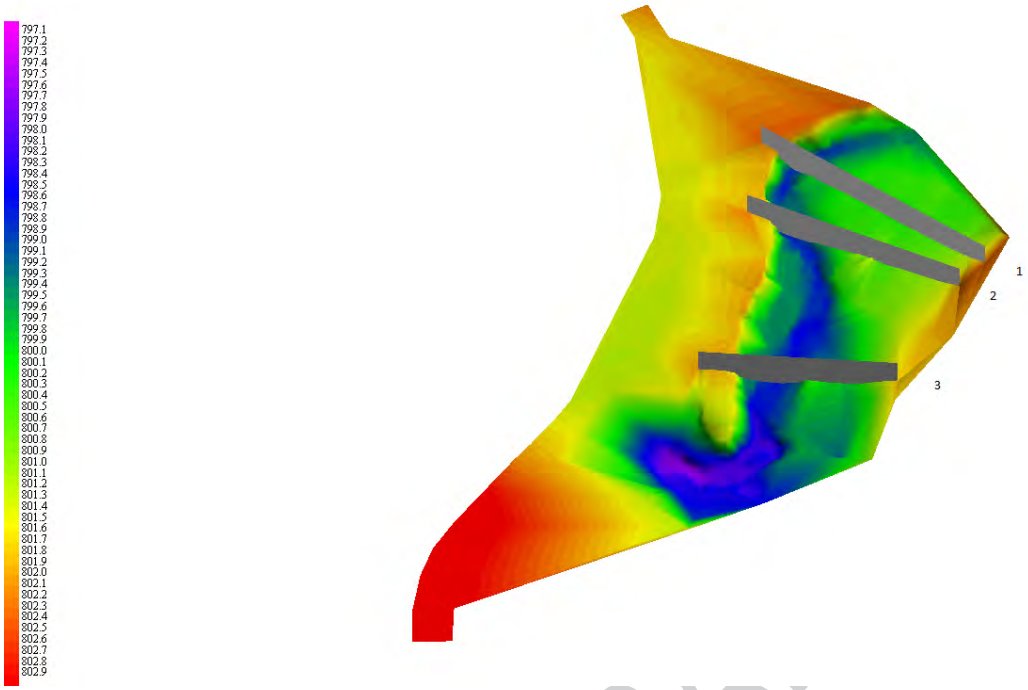


Figure 19 - BUR 1 3D DGPS Model (July 2013)

		2012		3D Model	
Section	Bank Side*	Latitude	Longitude	Latitude	Longitude
1	LHS	35.59797 S	149.22783 E	35.59799 S	149.22784 E
	RHS	35.59758 S	149.2277 E	35.59759 S	149.22771 E
2	LHS	35.59797 S	149.22777 E	35.59773 S	149.22777 E
	RHS	35.59768 S	149.22758 E	35.59767 S	149.22759 E
3	LHS	35.59803 S	149.22755 E	35.59806 S	149.22754 E
	RHS	35.59785 S	149.22728 E	35.59783 S	149.22728 E

* As seen looking Downstream (flow direction is top right to bottom left in 3D model, LHS closest to section numbers)

Cross-Section

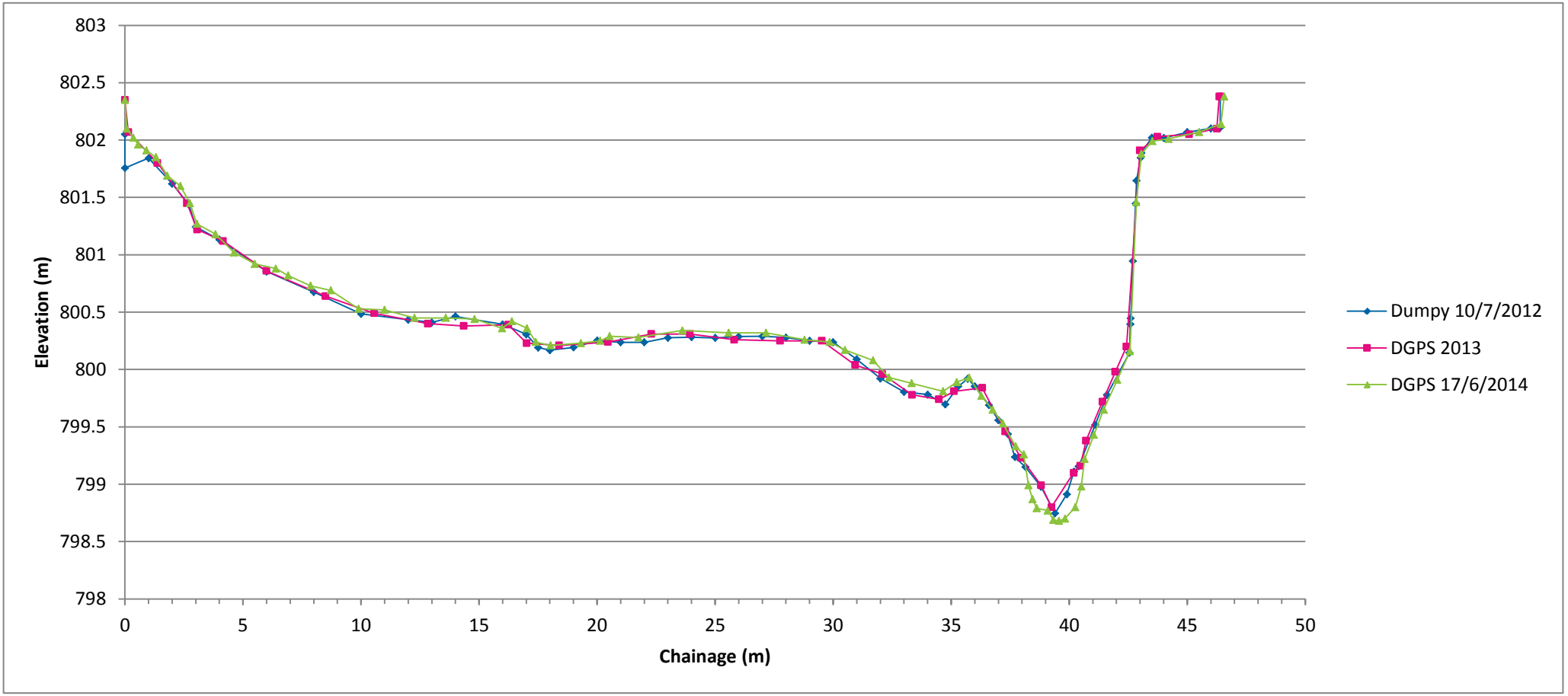


Figure 20 – BUR1 XS-1

- The 2013 cross section taken using a DGPS unit (Red) closely matches the cross section recorded by dumpy in 2012(Blue)
- The 2014 cross section closely matches previous sections except for in the bottom of the channel, which shows widening of the channel.

Cross-Section

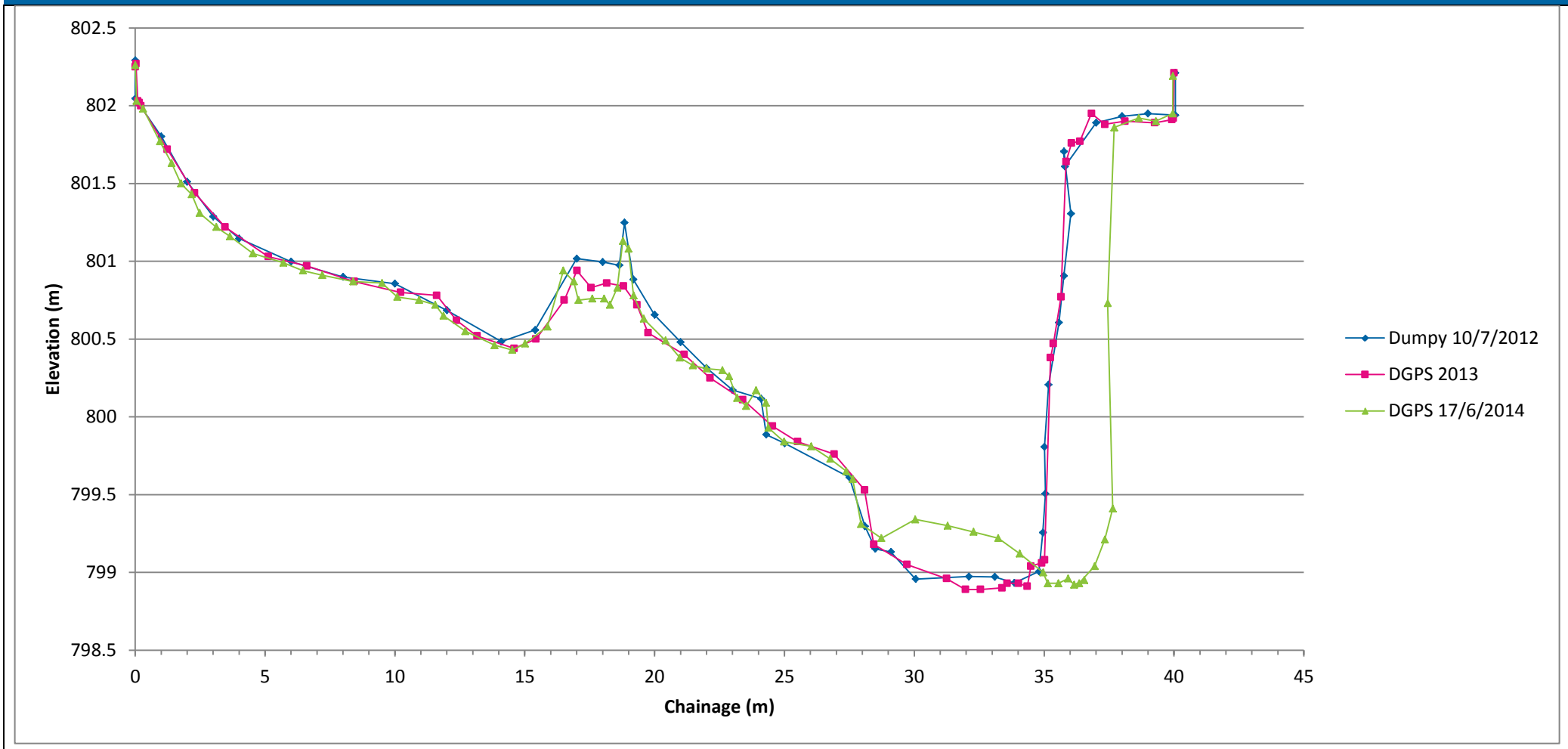


Figure 21 – BUR1 XS-2

- The 2013 cross section taken using the DGPS unit (Red) closely matches the cross section recorded by dumpy in 2012 (Blue)
- Difference at CH16-20m due to flood debris that has moved or eroded away. Peak point ~CH19m on top of log.
- The 2014 cross section closely matches on the left hand side, however the right hand side shows some erosion to the bank. Some of the difference is due to the shear vertical bank making it difficult to take sections exactly up the same part of the bank as previously, actual material removal from the bank is ~1m.
- Left hand side of the channel at chainage 30m, which is on the inside of the bend, shows deposition of material from high flows.

Cross-Section

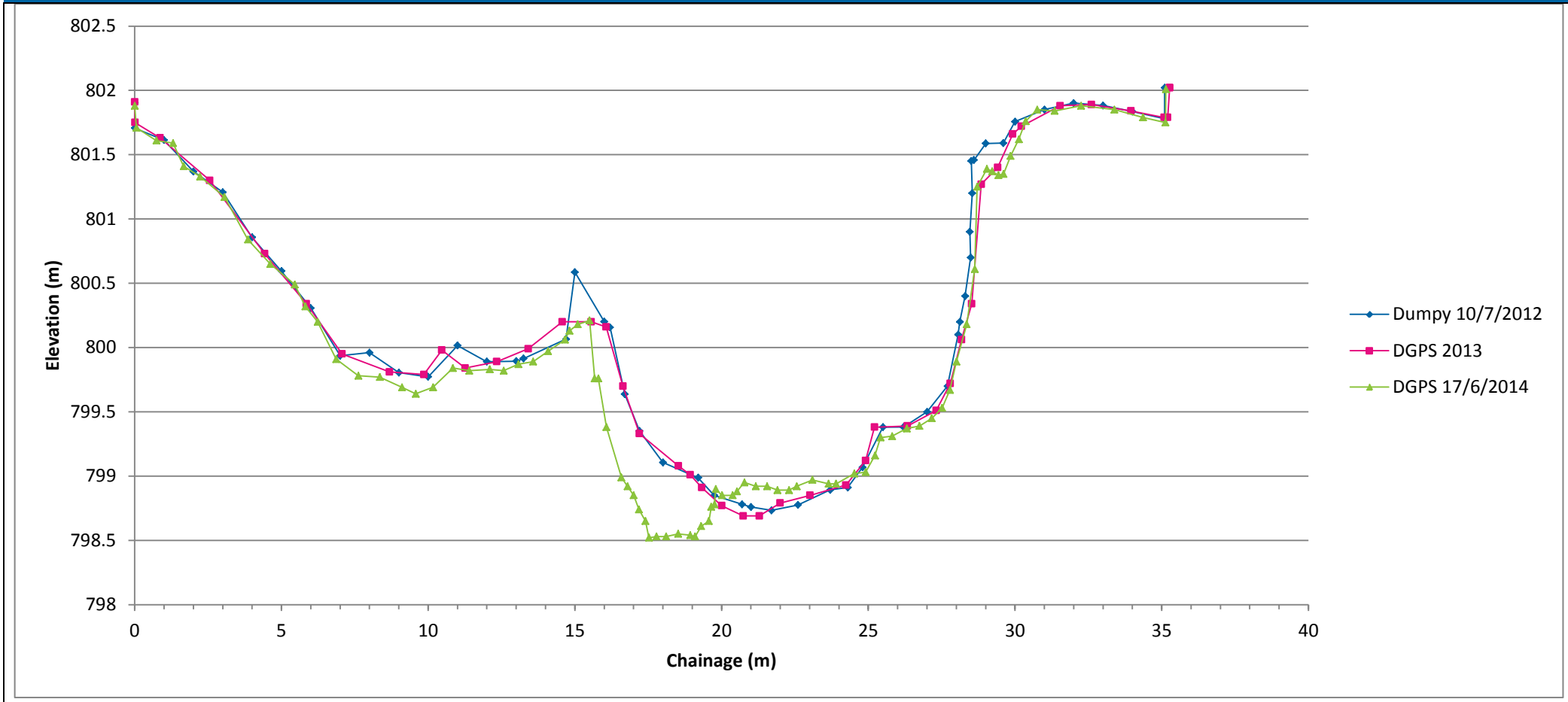


Figure 22 – BUR1 XS-3

- The 2013 cross section taken using the DGPS unit (Red) closely matches the 2012 cross section recorded by dumpy (Blue)
- Some erosion from top of bank at ~CH29m
- Spike at ~CH15m difference due to flood debris, top of branch.
- The 2014 cross section closely matches the 2013 section, however the central channel has shifted from chainage 22m to 18m, and become deeper and more defined.

Photo	Comment
 Photo 6 - BUR1 24/10/2009	- First photo on record for BUR1 - Evidence of erosion outside of bend. - Stable vegetation on 60%-80% of visible stream banks. - Sediment deposits within channel. - Creek channel dry.
 Photo 7 - BUR1 9/12/2010	- DS of BUR1 sample area at Cassidy's Crk confluence. - Turbid Burra Creek flowing left to right bottom of photo. - Less suspended material entering through Cassidy's Ck, due to less bank erosion and highly vegetated channel.

Photo	Comment
 Photo 8 - BUR1 9/12/2010	- Tail end of severe flood event. Peak of event went over the RHS bank. - Scouring of banks and channel - Vegetation removal - Highly turbid water indicates significant sediment transport. - Heavy debris load deposited by flood waters including tree on RHS bank.
 Photo 9 - BUR1 17/12/2010	- About a week after event. Evidence of bank undercutting as result of flood waters. - Large riparian vegetation removed with significant new debris and sediment deposited. - Banks unstable after vegetation revmoval.

Photo	Comment
 Photo 10 - BUR1 26/11/2011	- Grass re-established on banks - Native Shrubs re-re-establishing in riparian zone.
 Photo 11 - BUR1 1/3/2012	- High flow event - High turbidity from native reserve upstream

Photo	Comment
 Photo 12 - BUR1 8/3/2012	- Evidence of additional bank erosion on outside of bend - Bankside grass vegetationon LHS flattened by previous flow.
 Photo 13 - BUR1 20/11/2012	- Bank shows signs of minor erosion from October '12 event - Bankside vegetation recovered And growing strongly after decent rainfall

Photo	Comment
 Photo 14 - BUR1 24/1/2013	• Summer die off of grasses • Increased vegetation recovery from previous year • Surface flow has ceased but sub surface remains moist
 Photo 15 - BUR1 17/9/2013	- 3000 Ml/d event (1 in 3yr ARI) -

Photo	Comment
 Photo 16 - BUR1 19/9/2013	- Significant removal of material from right hand bank from large event.
 Photo 17 - BUR1 15/10/2013	- Right hand side bank collapse and deposition of material on outside of bend. - Majority of bankside vegetation retained through event.

Photo	Comment
 Photo 18 - BUR1 12/12/2013	- Strong vegetation growth after rain and warm weather.
 Photo 19 - BUR1 17/3/2014	- Dry conditions causing grass die off.

Photo	Comment
 Photo 20 - BUR1 17/4/2014	- Following two events > 1 in 3 month ARI vegetation is showing signs of growth.
 Photo 21 - BUR1 26/5/2014	

Photo	Comment
 Photo 22 - BUR1 25/7/2014	
 Photo 23 - BUR1 15/9/2014	

Photo	Comment
 Photo 24 - BUR1 19/12/2014	- Evidence of channel shift and bank erosion following event in previous week. - Vegetation growth on left hand side bank has spread, stabalising more of the bank.
 Photo 25 - BUR1 4/2/2015	- Evience of further bank collapse

Photo	Comment
 Photo 26 - BUR1 15/5/2015	- Little change, evidence of some weathering on right hand side bank

Appendix G - BUR 1C: Site Survey

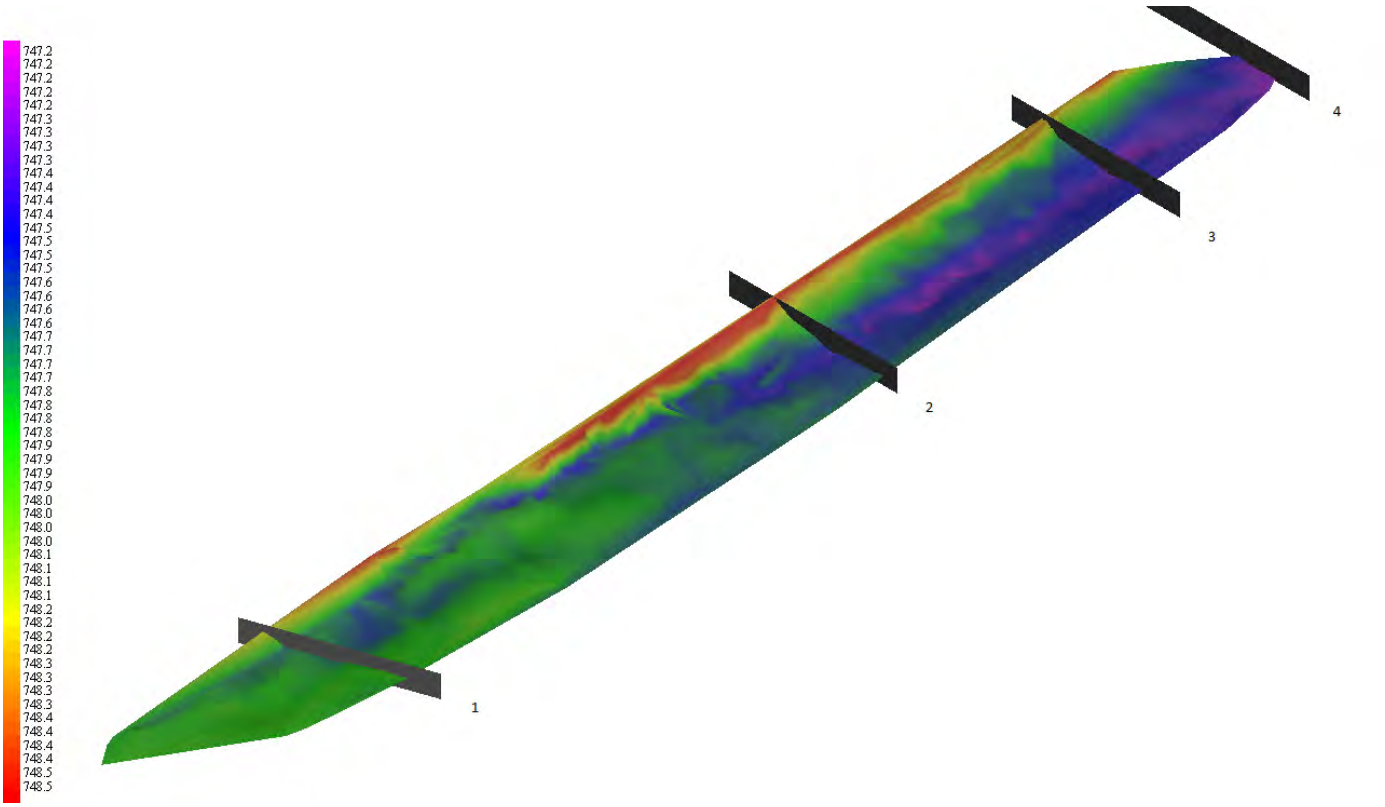
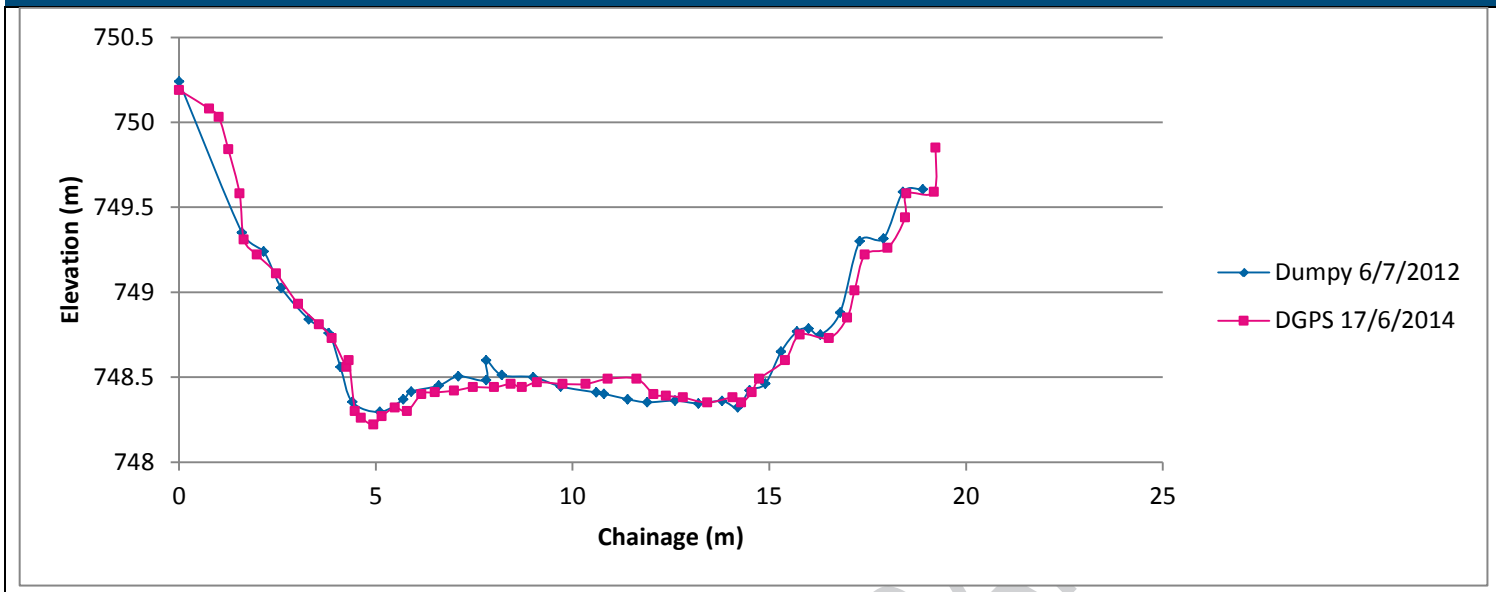
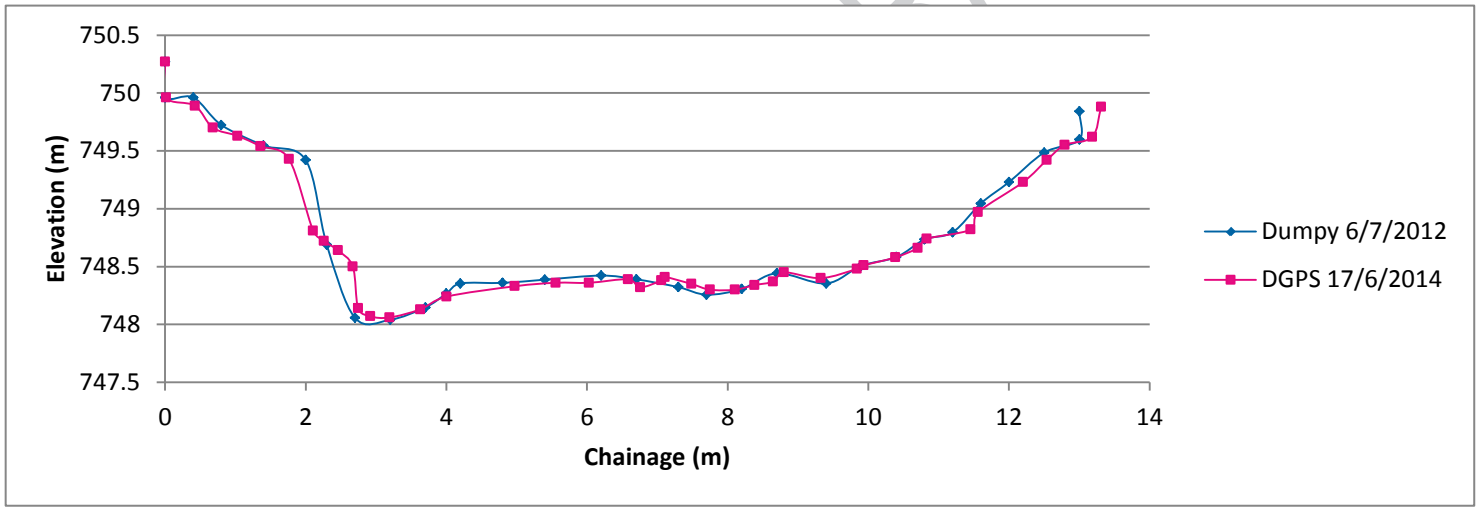


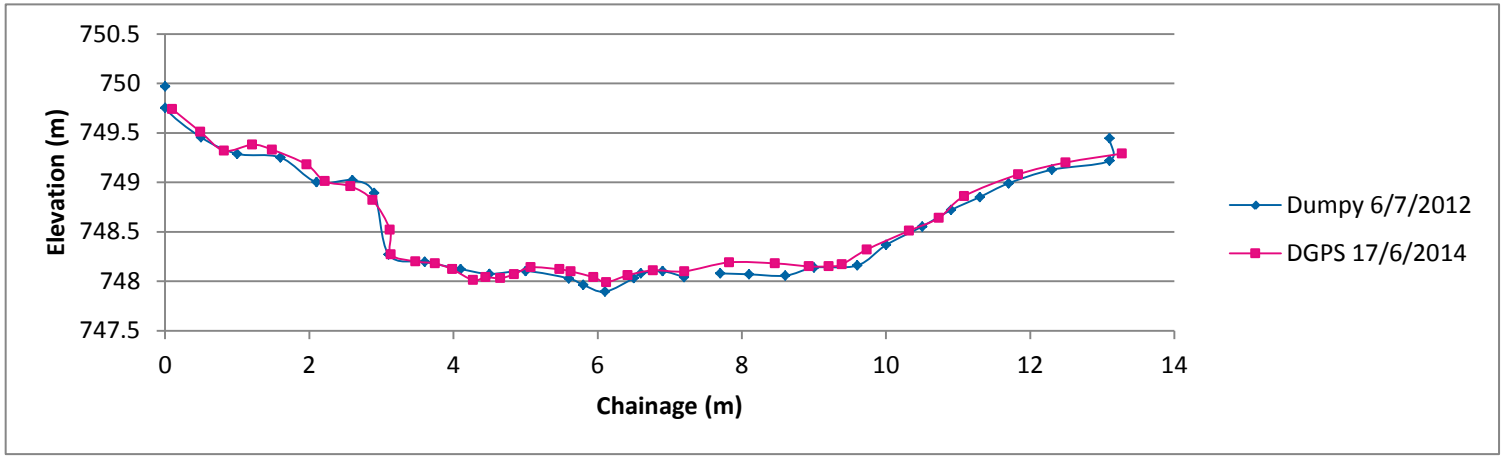
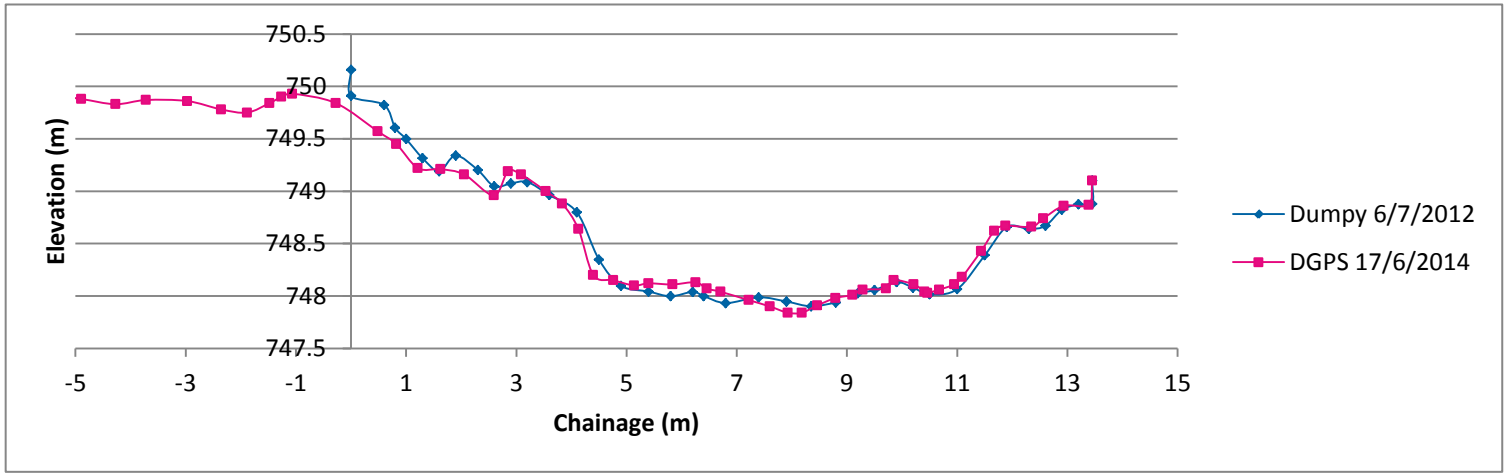
Figure 23 - Burra 1C 3D DGPS Model (July 2013)

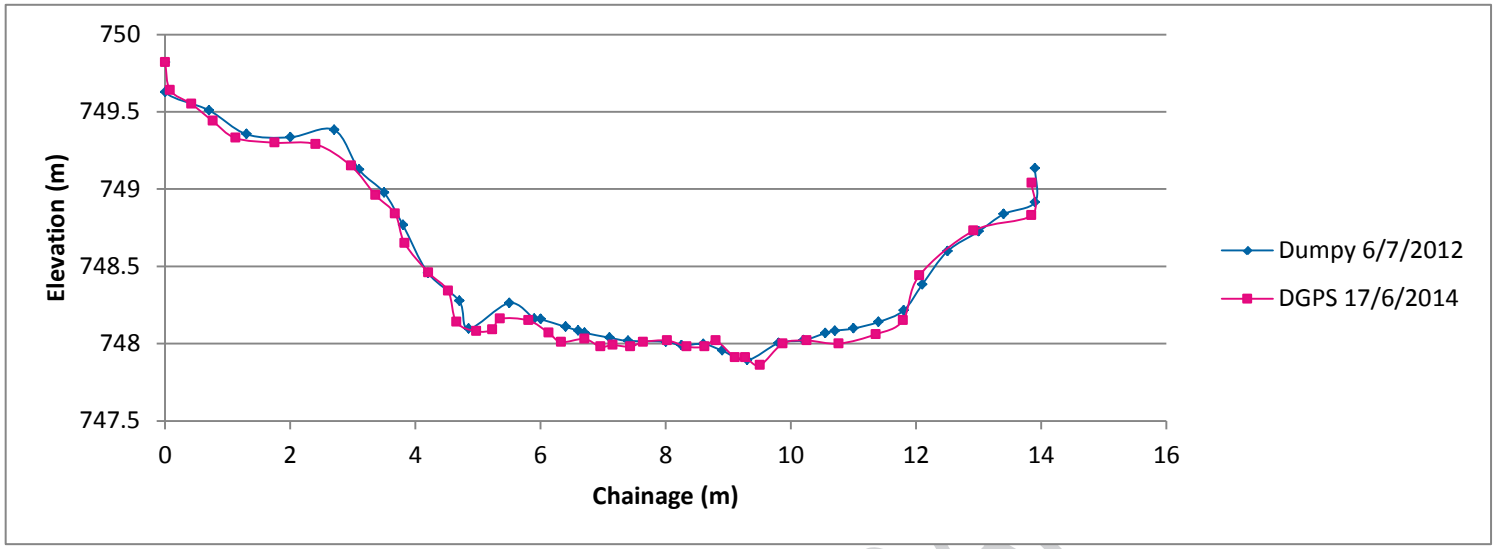
		2012		3D Model	
Section	Bank Side*	Latitude	Longitude	Latitude	Longitude
1	LHS	35.55682 S	149.221 E	35.55682 S	149.22099 E
	RHS	35.55682 S	149.22112 E	35.55679 S	149.22111 E
2	LHS	35.5565 S	149.2211 E	35.55650 S	149.22110 E
	RHS	35.55653 S	149.22122 E	35.55653 S	149.22122 E
3	LHS	35.55633 S	149.22117 E	35.55633 S	149.22117 E
	RHS	35.55637 S	149.22128 E	35.55637 S	149.22128 E
4	LHS	35.55623 S	149.22118 E	35.55623 S	149.22118 E
	RHS	35.55627 S	149.22093 E	35.55627 S	149.22130 E

* As seen looking downstream (flow direction bottom left to top right in 3D image)

DGPS Survey equipment experiencing signal difficulties at this site, resulting in DGPS cross-sections not matching dumpy sections.

Cross-Section	Comment
 Figure 24 - BUR1C XS-1A  Figure 25 - BUR1C XS-1B	- XS-1B lies perpendicular to the channel while XS-1A starts at the same point but runs at an angle to the channel to a different end point DS.. - Cross Sections from 2012 and 2014 closely match, differences due to slightly different line taken over/through vegetation.

Cross-Section	Comment
 Figure 26 - BUR1C XS-2	- 2012 and 2014 cross sections closely match, differences due to variations in vegetation growth. - There has been some deepening of the central channel at chainage 6m.
 Figure 27 - BUR1C XS-3	- 2012 and 2014 cross sections closely match, marker pegs could not be found in 2012 for exact points, survey in 2014 was made using GPS coordinates. Minor differences due to vegetation.

Cross-Section	Comment
 Figure 28 - BUR1C XS-4	- Resurvey of cross section with DGPS required to complete/append to DGPS model - 2012 and 2014 cross sections closely match, minor differences due to vegetation.

Appendix H - BUR 2 (Discharge Location): Site Survey

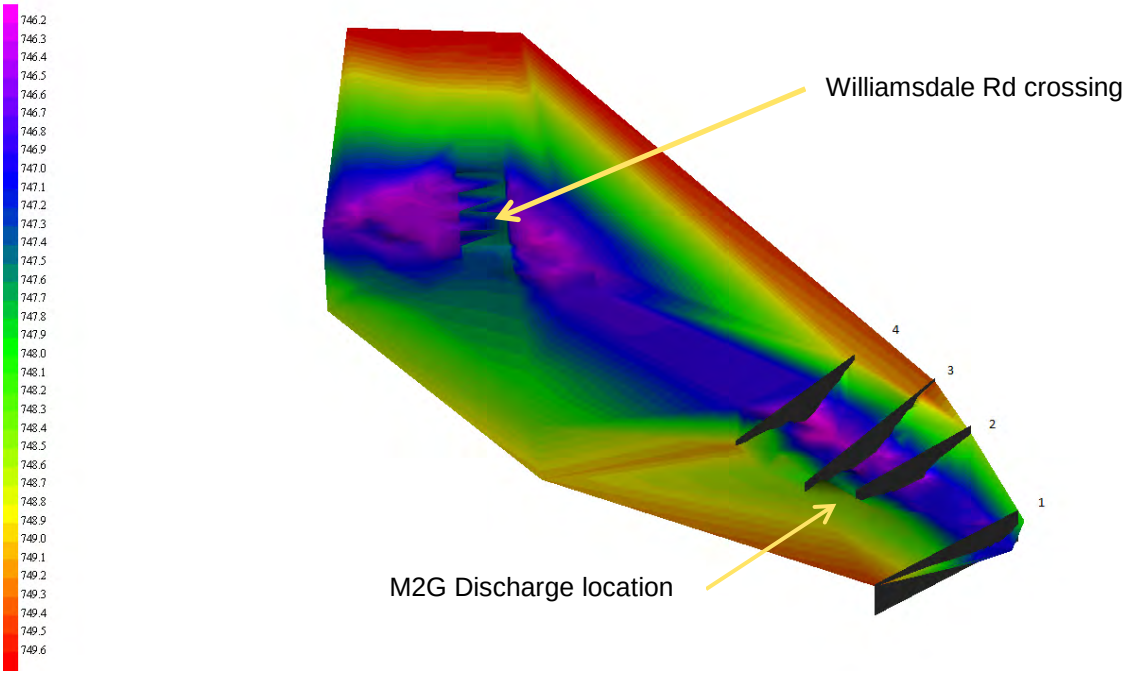


Figure 29 - BUR Discharge 3D DGPS Model (July 2013)

		3D Model	
Section	Bank Side*	Latitude	Longitude
1	LHS	35.55585 S	149.22228 E
	RHS	35.55601 S	149.22233 E
2	LHS	35.55589 S	149.22243 E
	RHS	35.55602 S	149.22248 E
3	LHS	35.55585 S	149.22247 E
	RHS	35.55602 S	149.22257 E
4	LHS	35.55582 S	149.22256 E
	RHS	35.55597 S	149.22264 E

* As seen looking downstream (flow direction from bottom right to top left in 3D image)

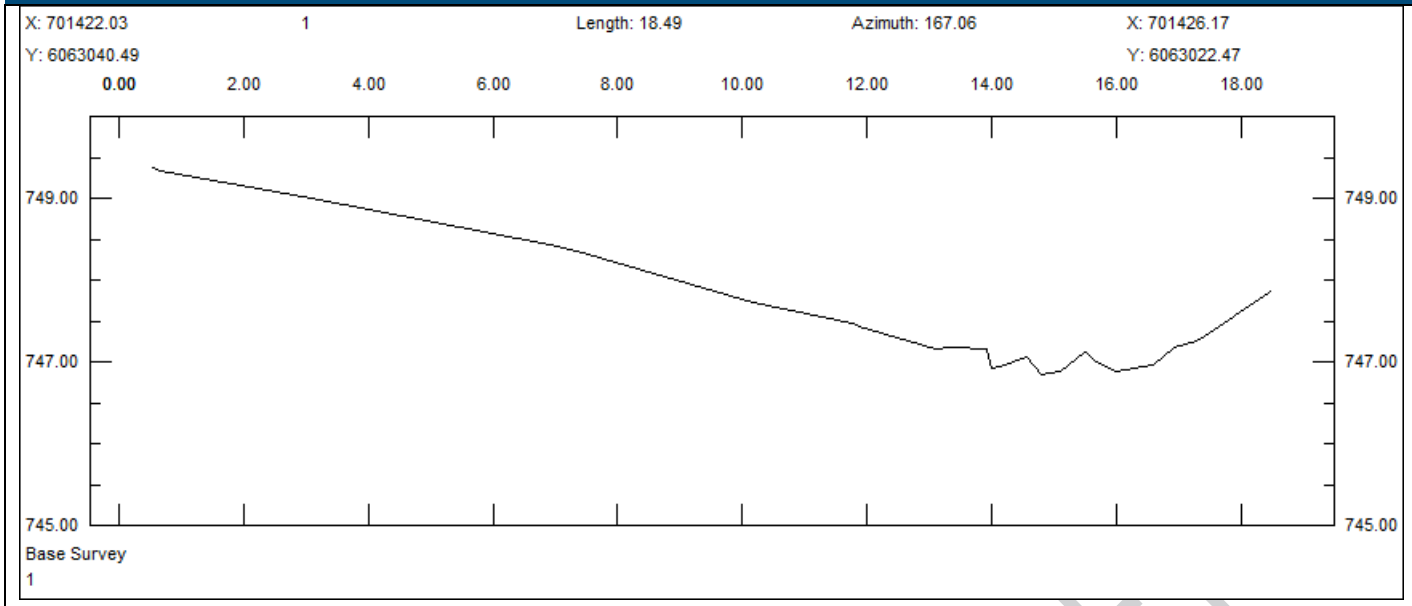
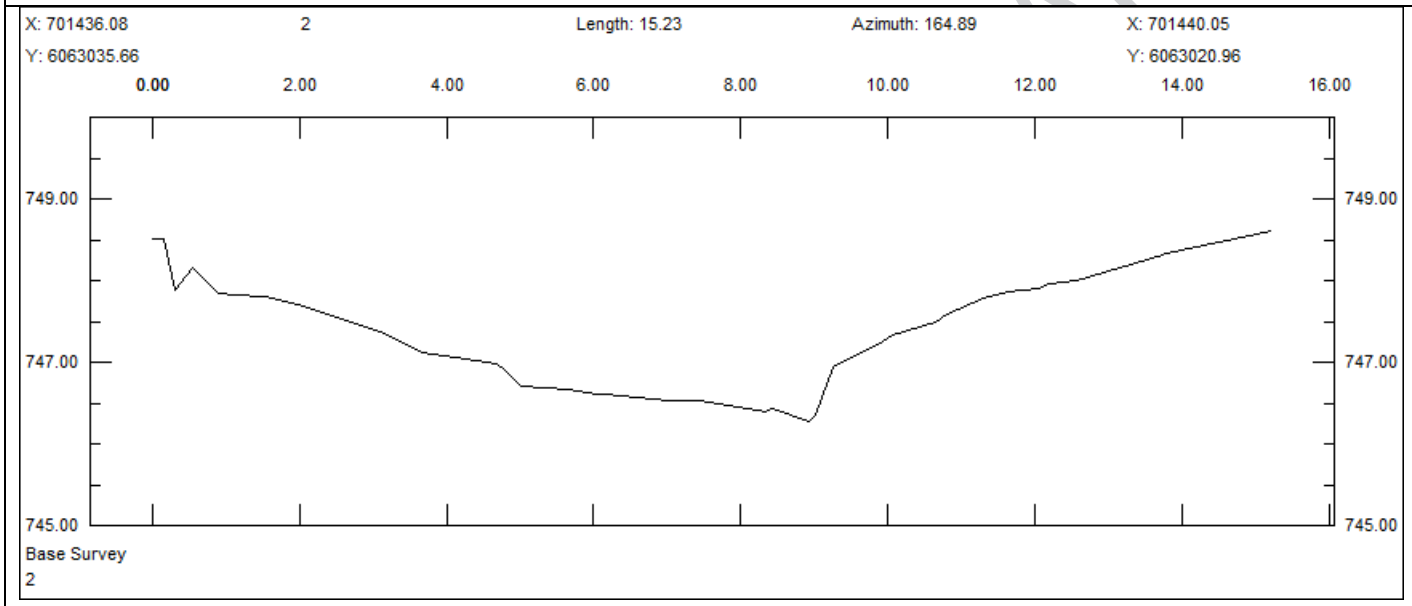
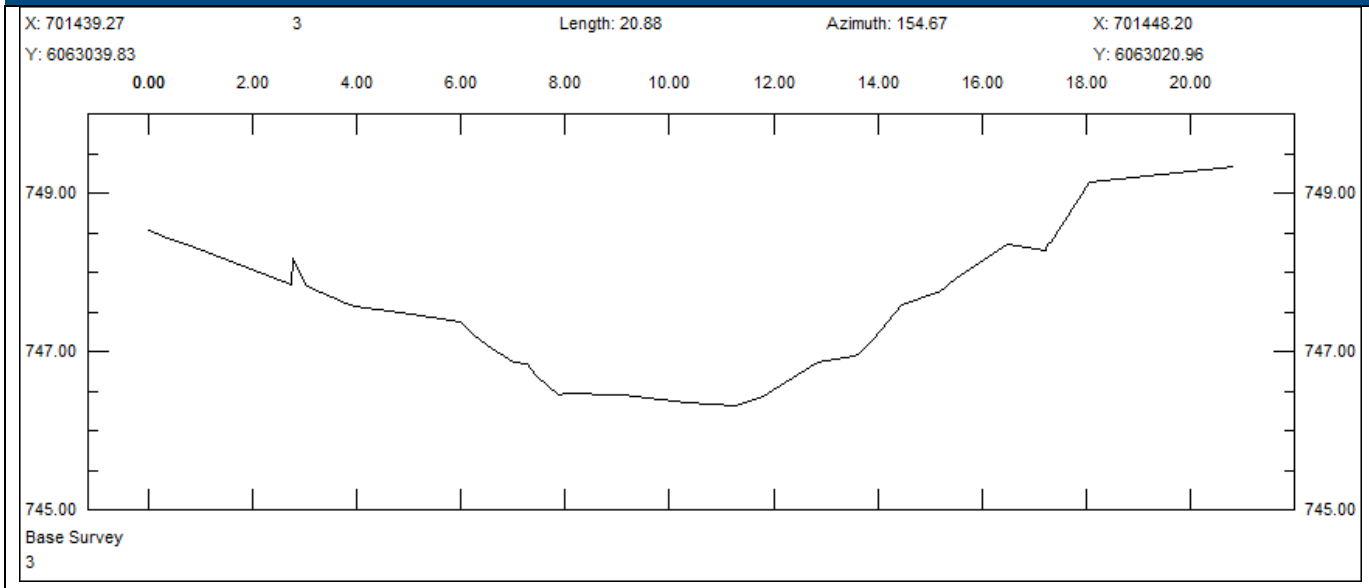
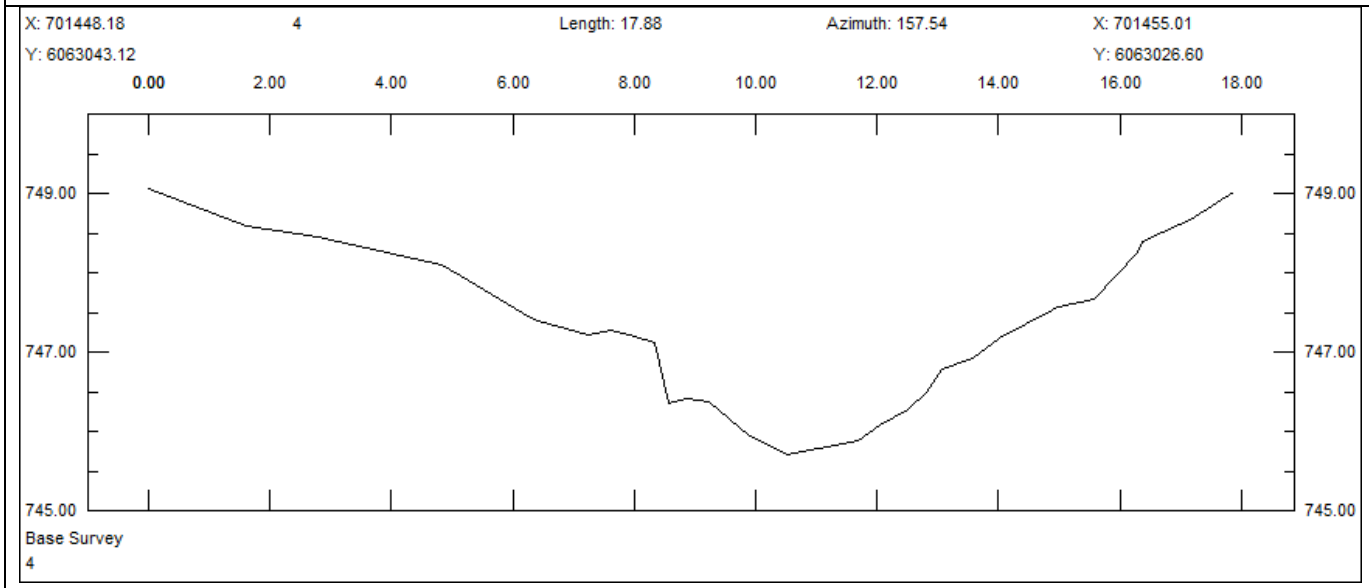
Cross-Section	Comments
	
	

Figure 30 - BUR Discharge 3D GPS XS-1

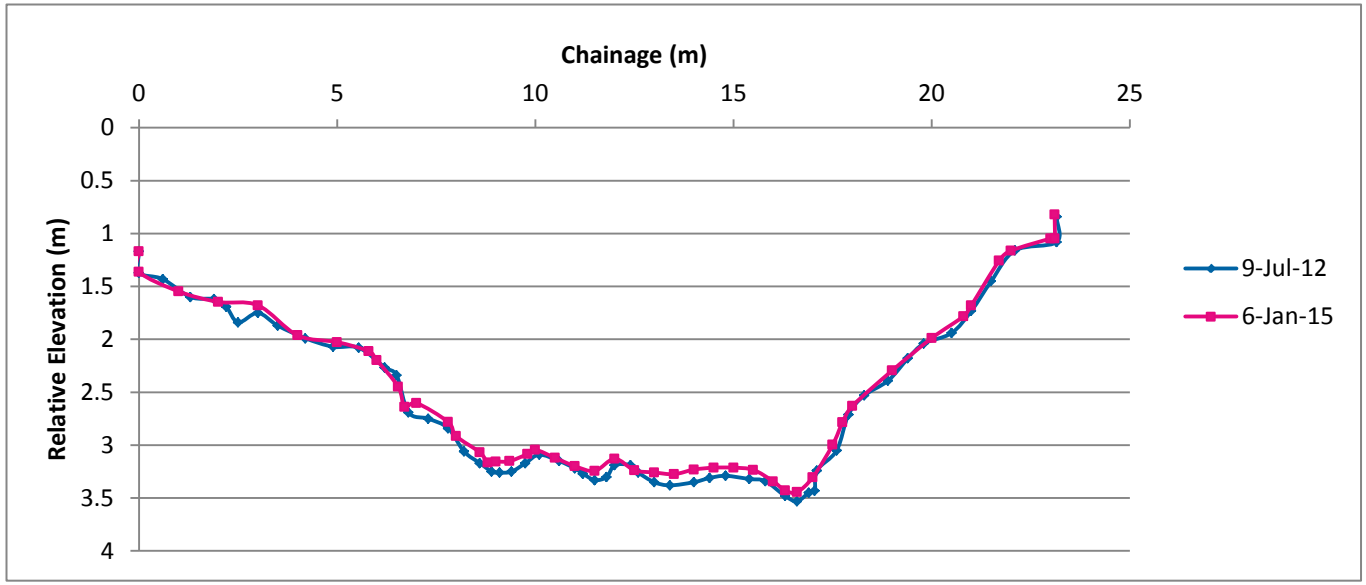
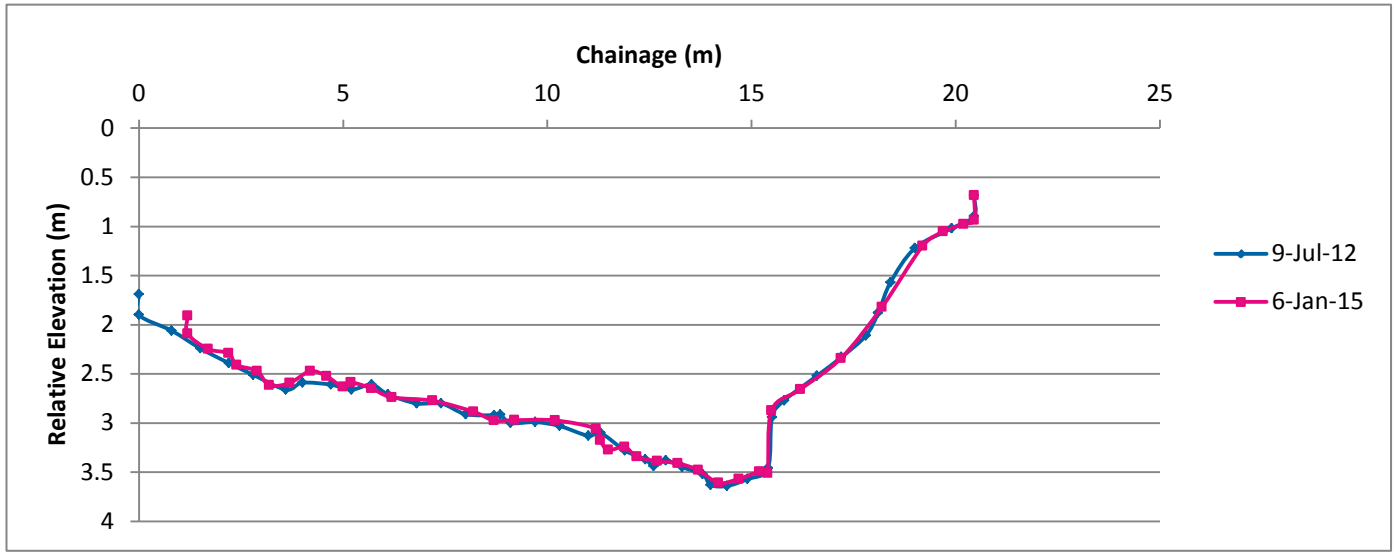
Figure 31 - BUR Discharge 3D GPS XS-2

Cross-Section	Comments
 Figure 32 - BUR Discharge 3D GPS XS-3	
 Figure 33 - BUR Discharge 3D GPS XS-4	

Appendix I - BUR 2A: Site Survey

Figure 34 - BUR2A Aerial Photograph (2012 NSW SIX MAPS)

		2012	
Section	Bank Side*	Latitude	Longitude
1	LHS	35.55372 S	149.22492 E
	RHS	35.55382 S	149.22525 E
2	LHS	35.55362 S	149.22512 E
	RHS	35.55373 S	149.22528 E
3	LHS	35.55357 S	149.22513 E
	RHS	35.55353 S	149.22528 E
4	LHS	35.55348 S	149.22517 E
	RHS	35.55343 S	149.22527 E

Cross-Section	Comments
 Figure 35 - BUR2A XS-1 _ 2012	- There is little difference between the pre and post commissioning cross sections. - Variation in sections from ~8m to ~17m due to summer macrophyte growth in channel
 Figure 36 - BUR2A XS-2 _ 2012	- No observable difference between pre and post commissioning sections - Left hand side peg had been knocked out and was repositioned due to wombat activity.

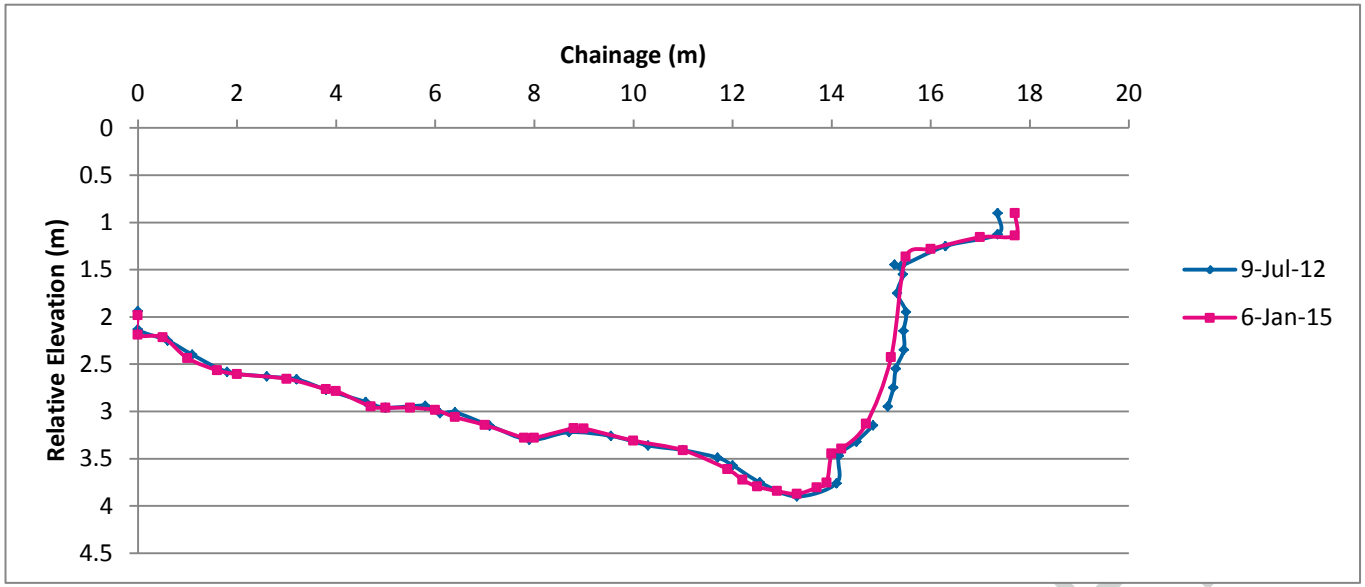
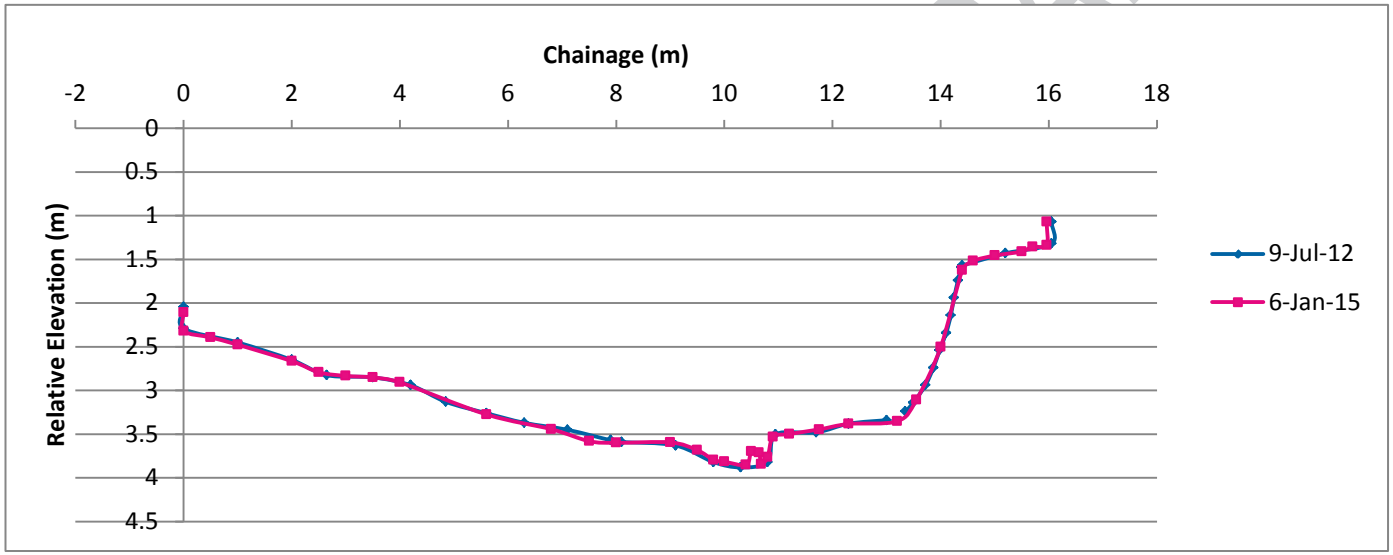
Cross-Section	Comments
 Figure 37 - BUR2A XS-3 _ 2012	- No significant difference between pre and post commissioning sections. - RHS peg was knocked out and slightly repositioned.
 Figure 38 - BUR2A XS-4 _ 2012	- No notable difference between pre and post commissioning surveys. - Variations between sections at ~11m due to a rock that was not picked up in 2012.

Photo	Comments
 Photo 27 - BUR2A 14/2/2012	- Looking upstream - Stable riparian vegetation present
 Photo 28 - BUR2A 8/3/2012	- Flow event ~ 100 ML/d - Evidence of higher waters pushing vegetation over - No evidence of erosion

Photo	Comments
 Photo 29 - BUR2A 5/7/2012	- Normal water levels - Evidence of vegetation die off during winter months for emergent macrophytes
 Photo 30 - BUR2A 13/7/2012	- Med flow event - ~110ML/d

Photo	Comments
 Photo 31 - BUR2A 10/9/2012	- Med flow event (This includes an M2G pump maintenance run ~20ML/d +~5ML/d baseflow) - No evidence of new bank erosion from pumped flow - Turbidity low
 Photo 32 - BUR2A 22/11/2012	

Photo	Comments
 Photo 33 - BUR2A 24/1/2013	• Noticeable increase in reed growth along left side of stream
 Photo 34 - BUR2A 13/1/2014	- Bank has remained stable

Photo	Comments
 Photo 35 - BUR2A 5/6/2014	
 Photo 36 - BUR2A 4/11/2014	- Vegetation growth on banks has prevented any significant erosion.

Photo	Comments
 Photo 37 - BUR2A 18/5/2015	- No evidence of change - Autumn die-back of vegetation

Appendix J - BUR U/S Pool 50: Site Survey

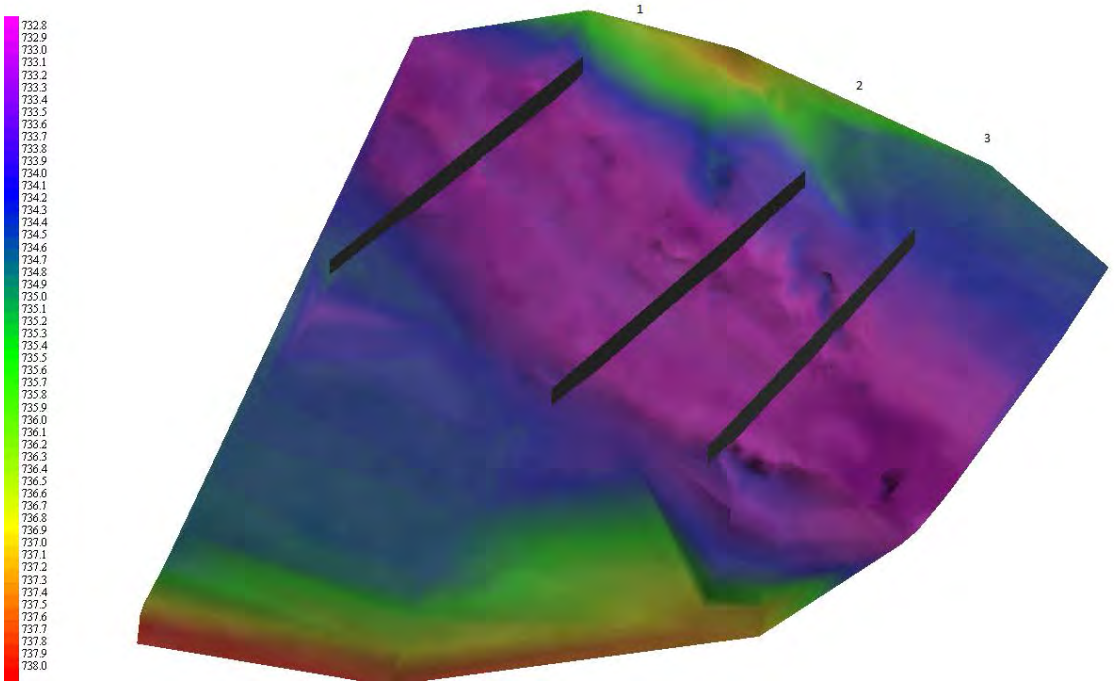


Figure 39 - Burra U/S Pool 50 DGPS 3D Model (July 2013)

		2012		3D Model	
Section	Bank Side*	Latitude	Longitude	Latitude	Longitude
1	LHS	35.54125 S	149.22625 E	35.54124 S	149.22626 E
	RHS	35.54123 S	149.22607 E	35.54124 S	149.22600 E
2	LHS	35.54138 S	149.22627 E	35.54139 S	149.22633 E
	RHS	35.5414 S	149.2261 E	35.54140 S	149.22606 E
3	LHS	35.54147 S	149.22628 E	35.54147 S	149.22637 E
	RHS	35.54148 S	149.22615 E	35.54149 S	149.22613 E

* As seen looking downstream (flow direction from left to right in 3D image)

Cross-Section	Comments

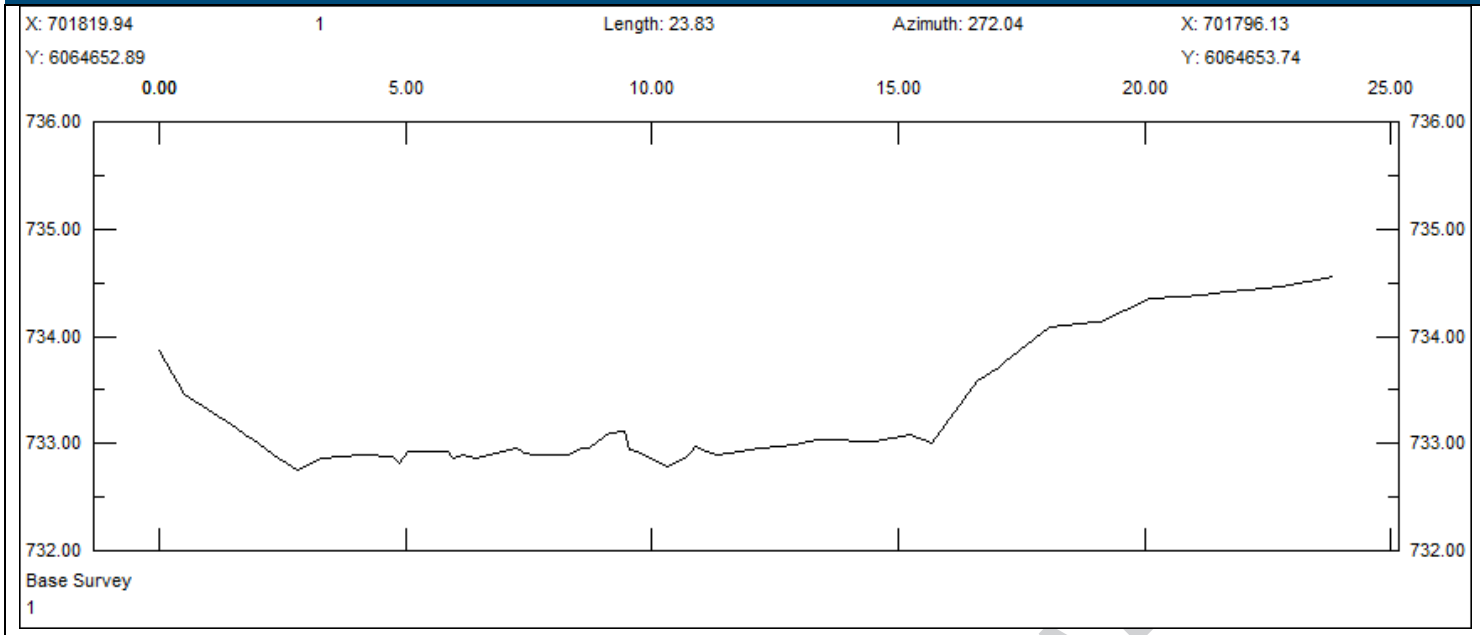


Figure 40 - BUR U/S Pool 50 3D GPS XS-1

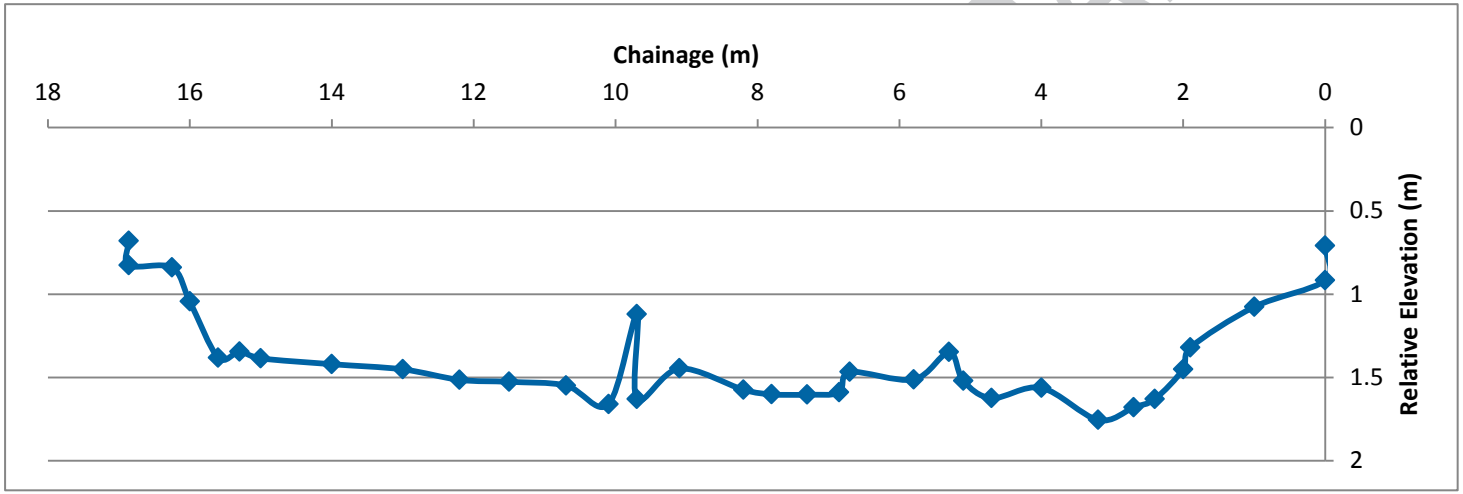


Figure 41 - BUR U/S Pool 50 XS-1 _ 2012

- DGPS survey longer than Dumpy cross section to accommodate 3D profiling
- Original survey pegs could not be found at time of 3D survey.
- Channel sections indicate similar profile, accurate survey needed to re-establish section

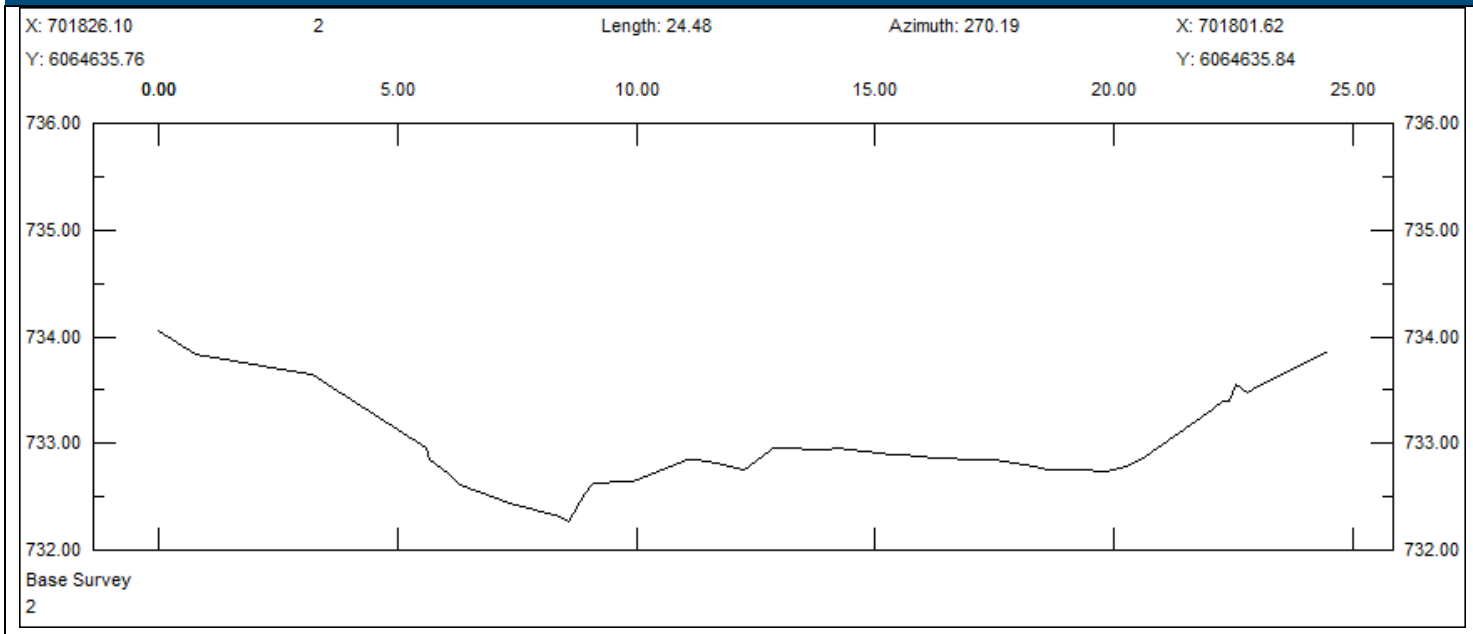
Cross-Section	Comments
	- DGPS survey longer than Dumpy cross section to accommodate 3D profiling - Original survey pegs could not be found at time of 3D survey. - Channel sections indicate similar profile, accurate survey needed to re-establish section

Figure 42 - BUR U/S Pool 50 3D GPS XS-2

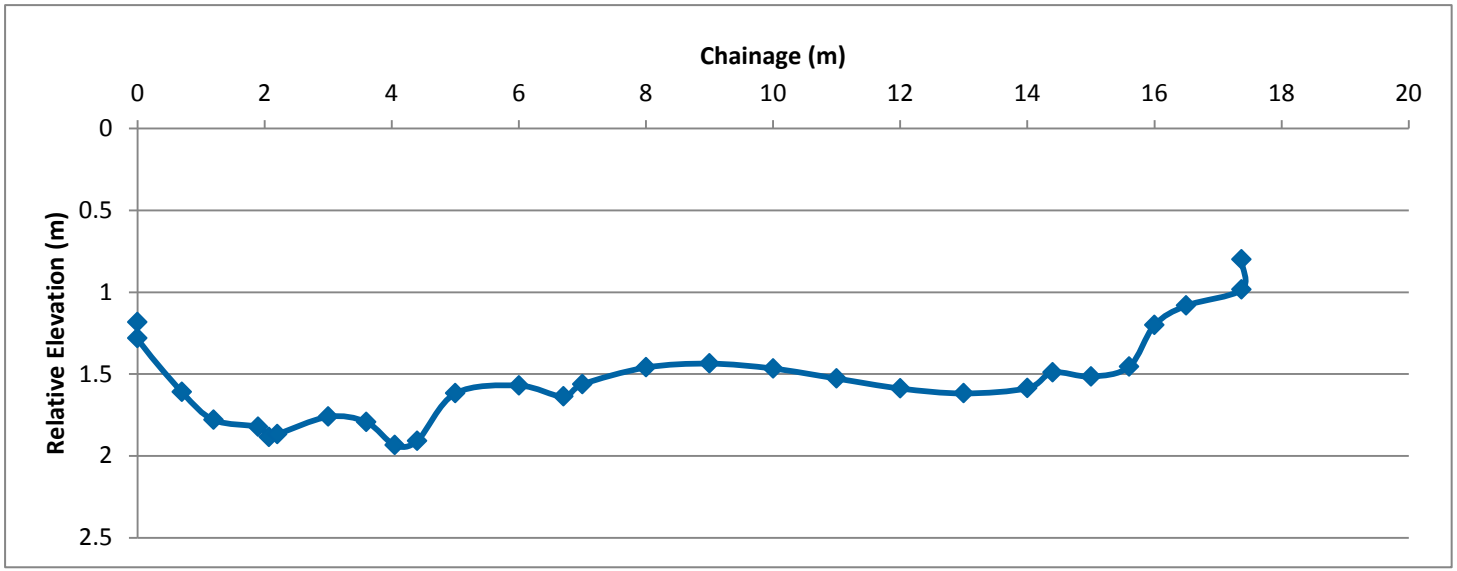
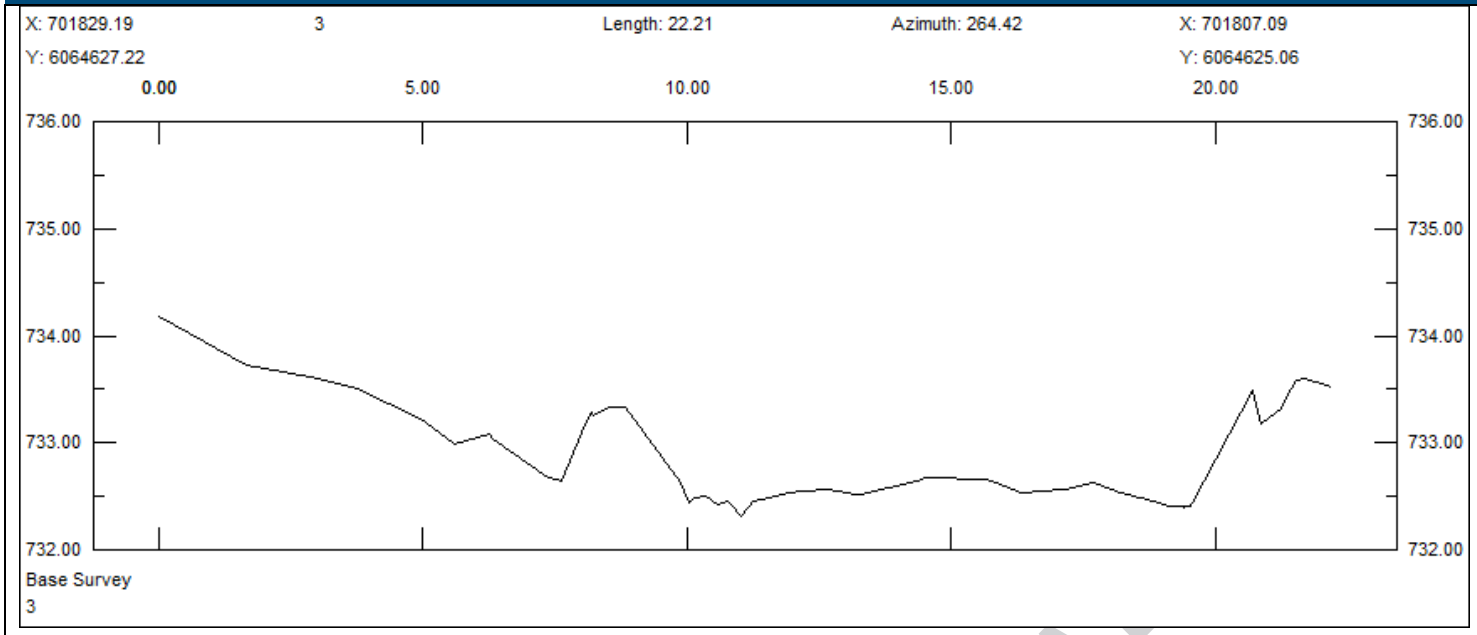
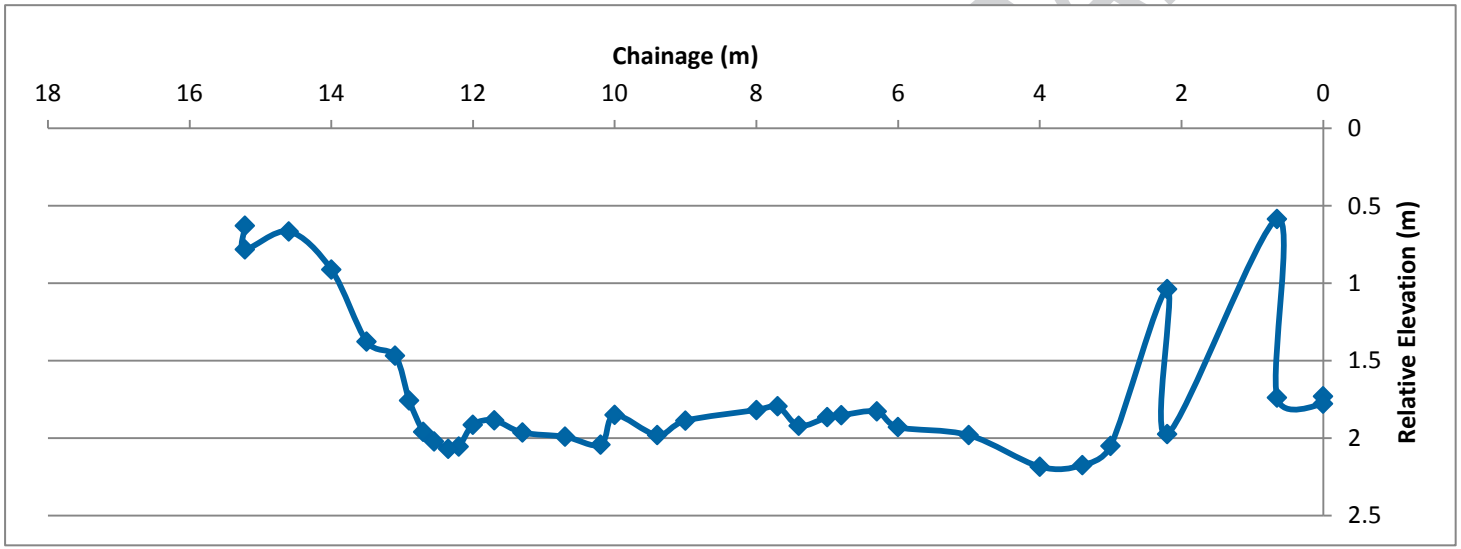


Figure 43 - BUR U/S Pool 50 XS-2 _ 2012

Cross-Section	Comments
 Figure 44 - BUR U/S Pool 50 3D GPS XS-3  Figure 45 - BUR U/S Pool 50 XS-3 _ 2012	- DGPS survey longer than Dumpy cross section to accommodate 3D profiling - Original survey pegs could not be found at time of 3D survey. - Channel sections indicate similar profile, accurate survey needed to re-establish section - Differences due to rock outcrops picked up in ~1m misalignment of cross sections

Appendix K - BUR 2C: Site Survey

Yellow lines indicate location of cross-sections at BUR2C.

Some original cross-section pegs have moved due to erosion effects or earthwork impact from moving of the creek crossing.

Locations to be confirmed

		2010		2012 & 2013	
Section	Bank Side*	Latitude	Longitude	Latitude	Longitude
D/S – XS4	LHS	35.51774 S	149.26123 E	35.51768 S	149.26128 E
	RHS	35.51758 S	149.26156 E	35.51758 S	149.2615 E
@ Bend – XS3	LHS	35.51808 S	149.26141 E	35.51815 S	149.26148 E
	RHS	35.51835 S	149.26154 E	35.51832 S	149.26157 E
XS2	LHS			35.51816 S	149.26114 E
	RHS			35.51831 S	149.26131 E
@ Old Road Xing – XS1	LHS	35.51880 S	149.26135 E	35.51883 S	149.26125 E
	RHS	35.51867 S	149.26154 E	35.51862 S	149.2616 E

* As seen looking downstream (flow direction is bottom to top in the adjacent figure)

Figure 46 - BUR2C Aerial Photo (2012 NSW SIX Maps)

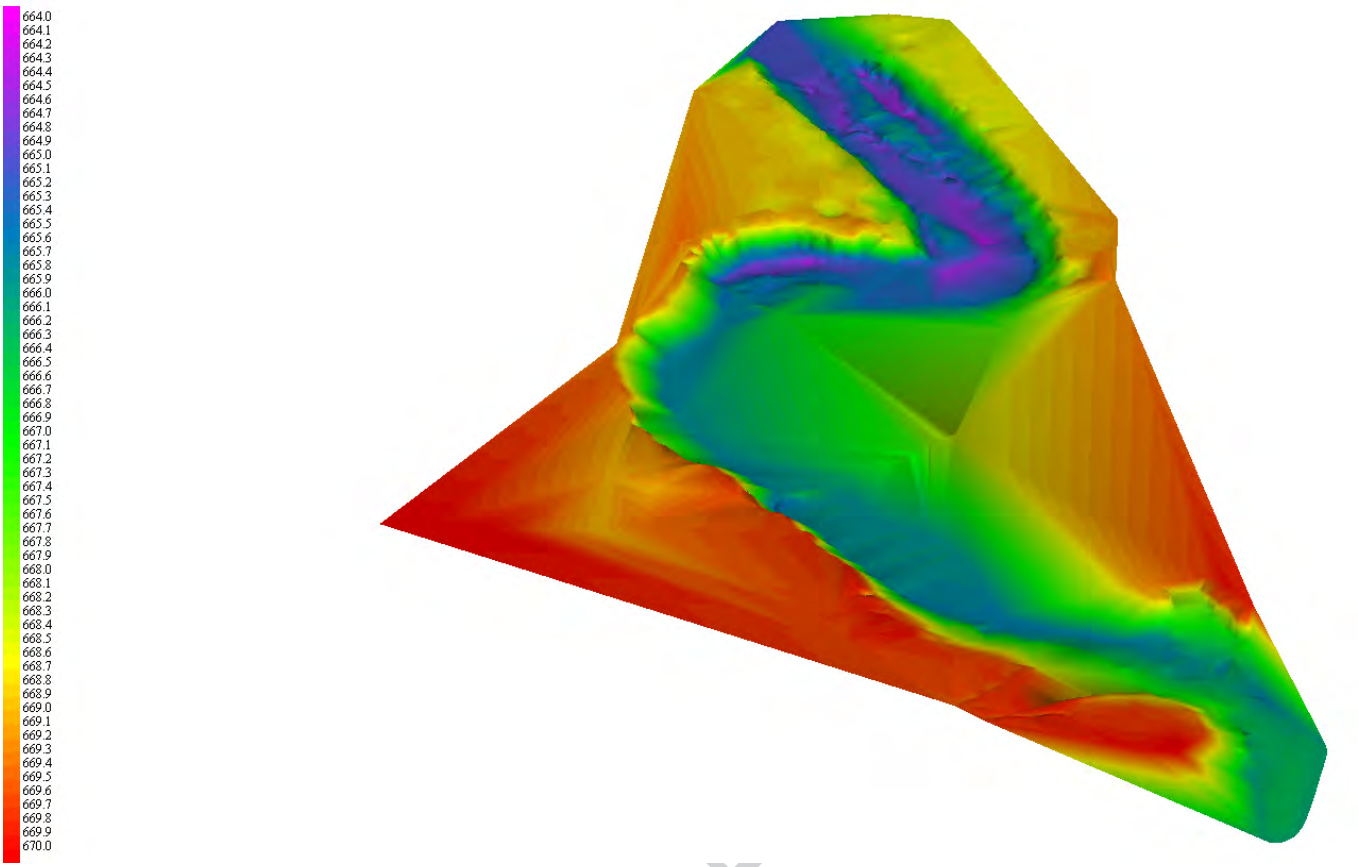
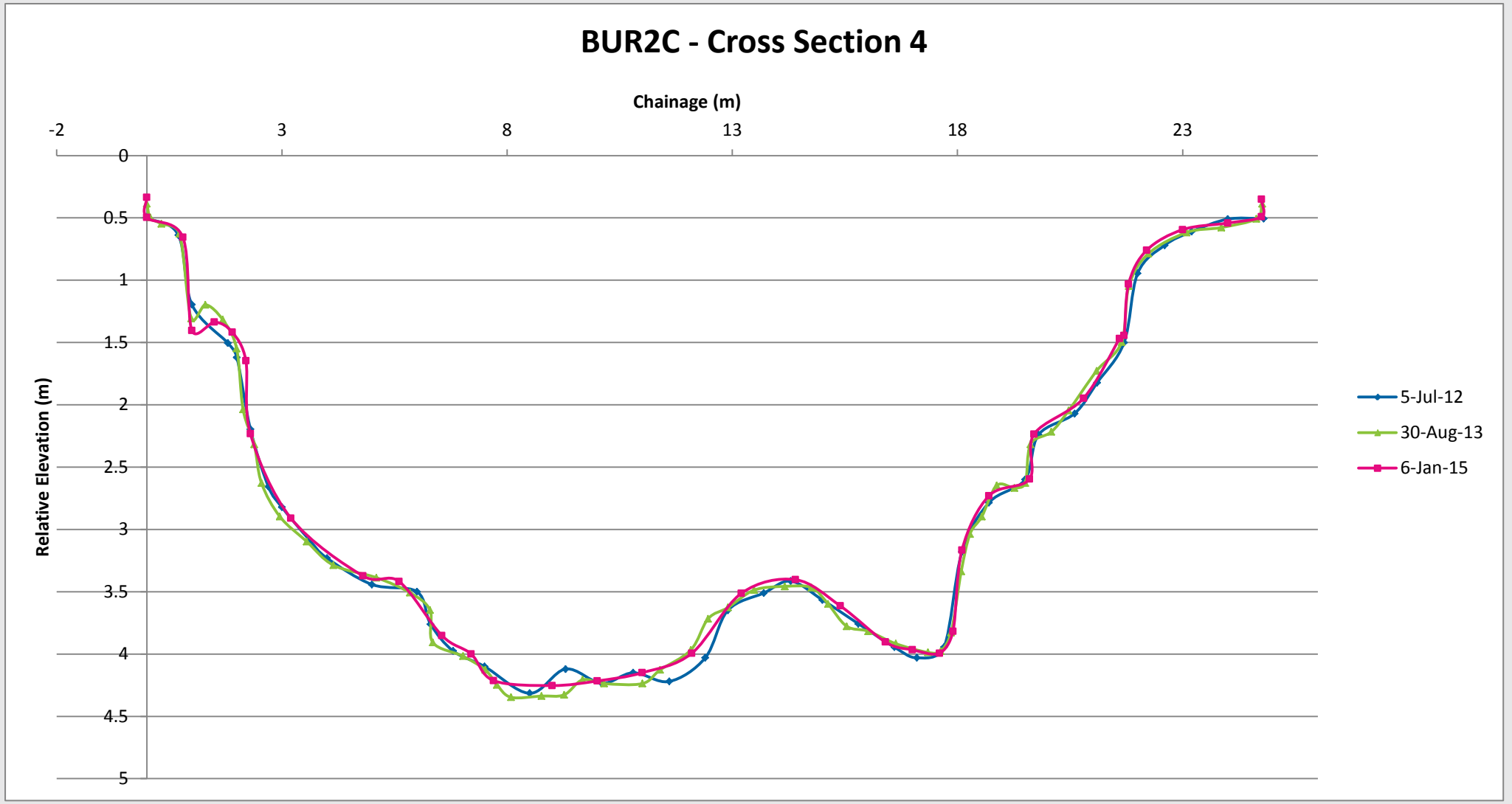
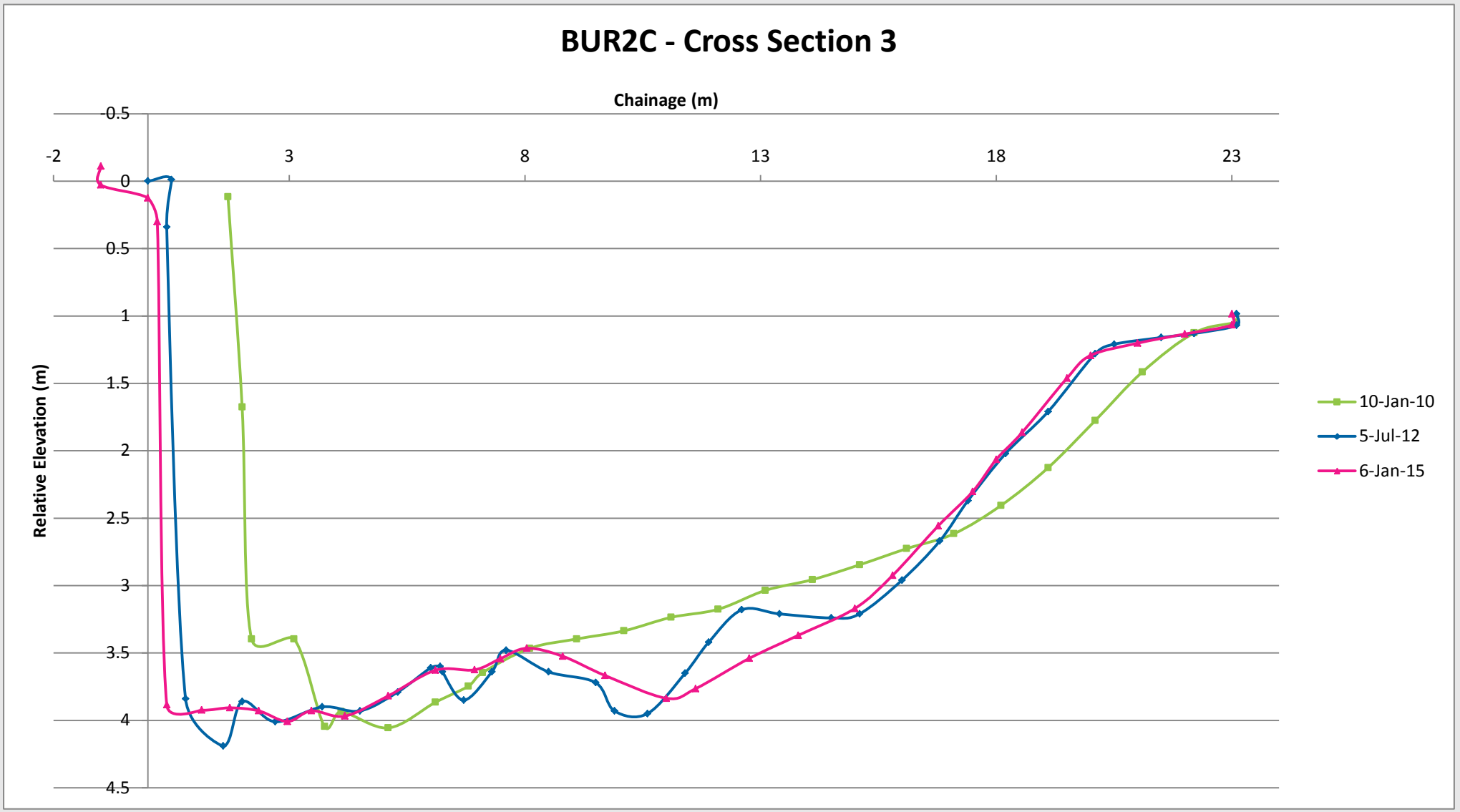


Figure 47 - BUR2C DGPS 3D Model (July 2013)

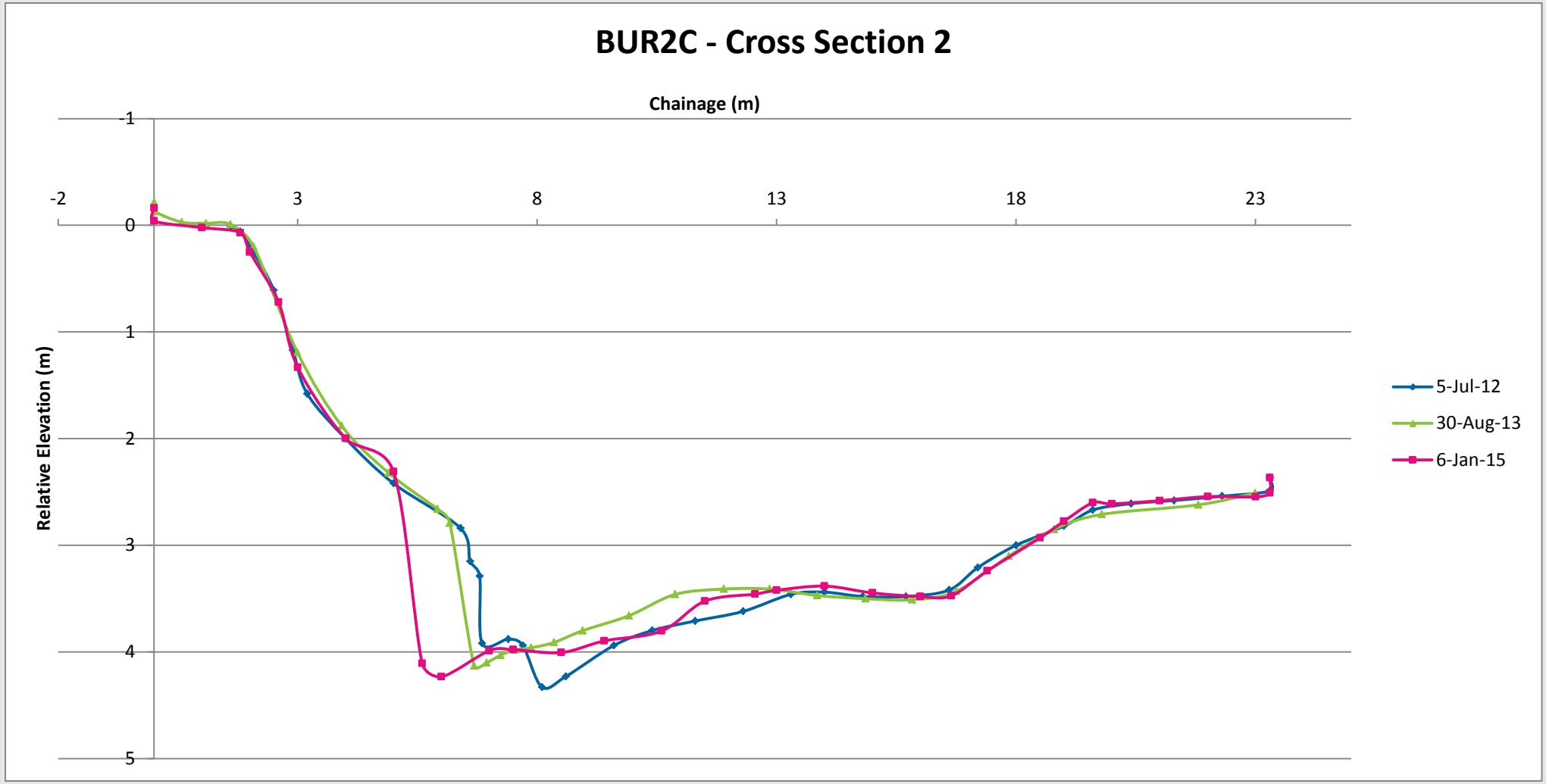
- In-stream points U/S of Riffle absent due to water level or loss of DGPS correction signal at base of embankment during survey.

Sect		
D/S Site 2C XS-4		
comments	2013 section using DGPS	Cross sections all closely match Material in central channel has shifted slightly

U/S 2C @ Bend XS-3



Comments		
	All sections by Dumpy	Continued erosion from left hand side bank. LHS peg repositied again. Some reforming of sand bar on right hand side bank at ~13m

BUR2C @ Undercut Bank XS-2	
Comments	2013 section using DGPS Central channel continues to erode the bank on left hand side Sand has been eroded on RHS bank at ~10m

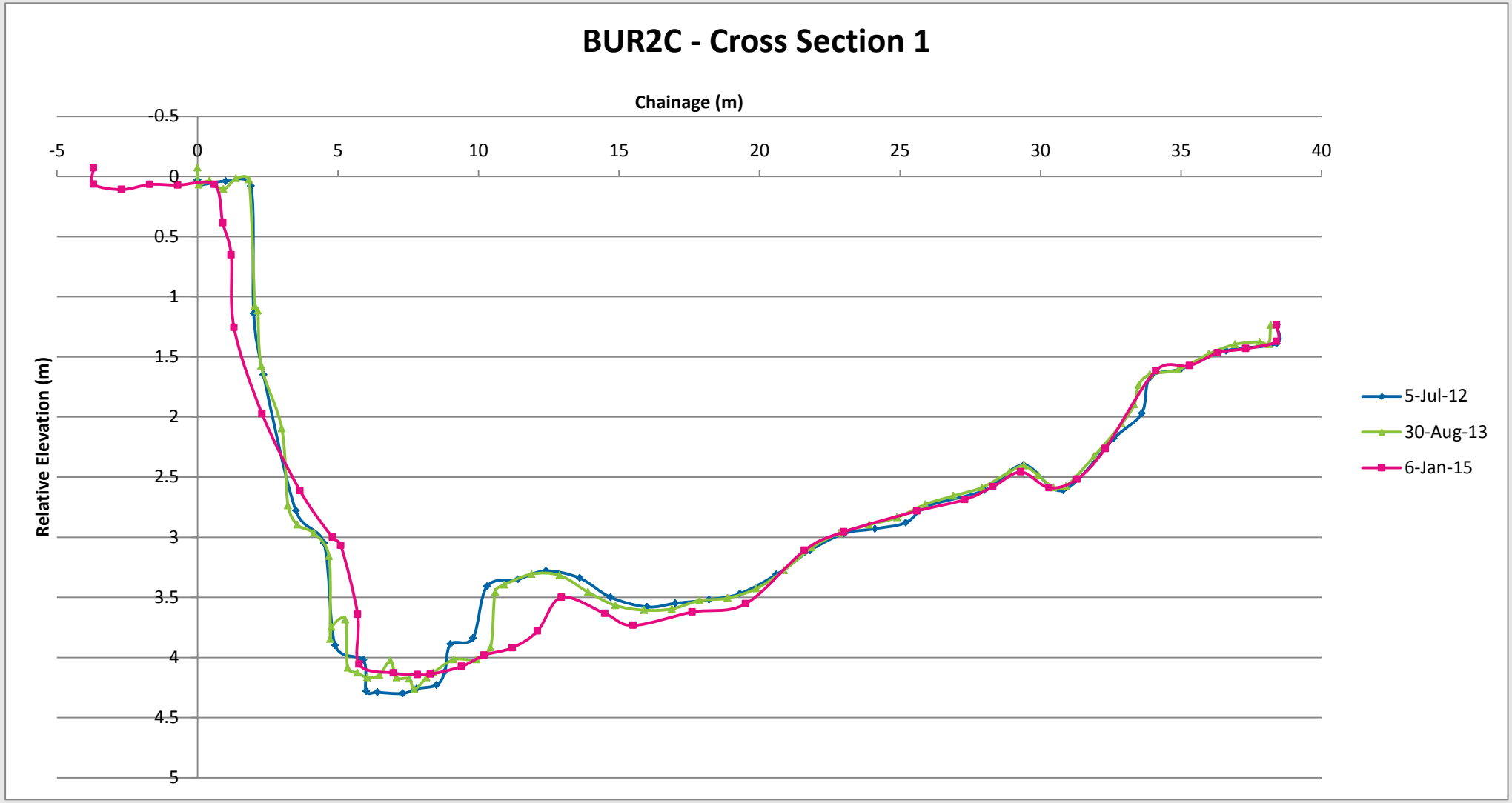
U/S @ Old Road Crossing XS-1	
Comments	2013 section using DGPS (slight discrepancies in 2013 section at ~1m and ~5m probably due to signal problems under trees on top of bank and signal shadow close to the base of the bank)
	Left hand side bank has slumped at the top at ~2m, depositing material closer to the channel at !~5m. Sand bar at ~11m has been eroded away during an event.

Photo	Comments
 Photo 38 – BUR2C 22/10/2009	- Earliest photo on project record for BUR2C - Taken upstream of BUR2C riffle - Some grass coverage on banks
 Photo 39 - BUR2C 22/10/2009	• Region of dense macrophyte growth above BUR2C prior to 2010 events which scoured the whole channel to bedrock

Photo	Comments
 Photo 40 - BUR2C 3/8/2011	- looking upstream at dog-leg upstream of BUR 2C riffle site. - Bedrock visible in pool with algal growth - Significant sediment and cobble deposit on inside of bend as a result of December 2010 flood event
 Photo 41 - BUR2C 3/8/2011	- Ongoing bank erosion - Site of XS-3 - High algal growth due to elevated nutrient levels and warmer water temperature as vegetation previously shading the creek was washed out during flood

Photo	Comments
 Photo 42- BUR2C 20/3/2012	- Evidence of bank erosion caused by flood - Little bank vegetation remaining. - XS-2 located at the downstream end of the eroded embankment - XS-3 in foreground location
 Photo 43 - BUR2C 20/3/2012	- Further bank erosion downstream of bend.

Photo	Comments
 Photo 44 - BUR2C 5/7/2012	- Entire bank on outside of bend eroding - No vegetation recovery during winter evident
 Photo 45 - BUR2C 13/7/2012	- Elevated flows - Turbid flows indicate suspended sediment transport

Photo	Comments
 Photo 46 - BUR2C 13/7/2012	
 Photo 47 - BUR2C 13/7/2012	• Embankment erosion further upstream from BUR2C

Photo	Comments
 Photo 48 - BUR2C 3/9/2012	- Sediment deposition evident on outside of bend.
 Photo 49 - BUR2C 10/9/2012	- Woody debris present in channel - Fine Sediment deposit evident - Eroded banks too steep to allow easy vegetation regrowth for stability

Photo	Comments
 Photo 50 - BUR2C 3/10/2012	- Bank collapse
 Photo 51 - BUR2C 18/10/2012	- Sediment deposits in areas of low velocity

Photo	Comments
 Photo 52 - BUR2C 23/1/2013	- Sloping banks show signs of vegetation recovery - Vegetation growth commencing on sediment deposits
 Photo 53 - BUR2C 23/1/2013	

Photo	Comments
 Photo 54 - BUR2C 29/4/2013	- Section of bank has slumped into channel.
 Photo 55 - BUR2C 30/10/2013	- Significant section of embankment scoured after Sept event

Photo	Comments
 Photo 56 - BUR2C 30/10/2013	- slumping of embankment sections following Sept 2013 storm event
 Photo 57 - BUR2C 30/10/2013	- Bank Scour from Sept event - Reforming of point bar from the event. - Mid and outer bend scoured to bedrock

Photo	Comments
 Photo 58 - BUR2C 30/10/2013	- Movable gravel bed control for Pool 5
 Photo 59 - BUR2C 13/1/2014	- Shallow pool over bedrock with no shading riparian vegetation allows for ready growth of filamentous algae

Photo	Comments
 Photo 60 - BUR2C 13/1/2014	Flow beginning to cause significant undercutting of bank.
 Photo 61 - BUR2C 6/6/2014	Bank has had minor collapsed from undercutting

Photo	Comments
 Photo 62 - BUR2C 4/9/2014	- Erosion at Pool 5 within soft embankment layer has commenced and will cause significant collapse in future
 Photo 63 - BUR2C 18/5/2015	- No evidence of major geomorphic change at bend from 2013. - Increase in macrophyte re-establishment

Appendix L - Angle Crossing – Site Survey

Figure 48 - Angle Crossing Aerial Photo (2012 NSW SIX Maps)

Original cross section locations in yellow (10th jan 2010). US Cross Section 2 not accessible during M2G construction.

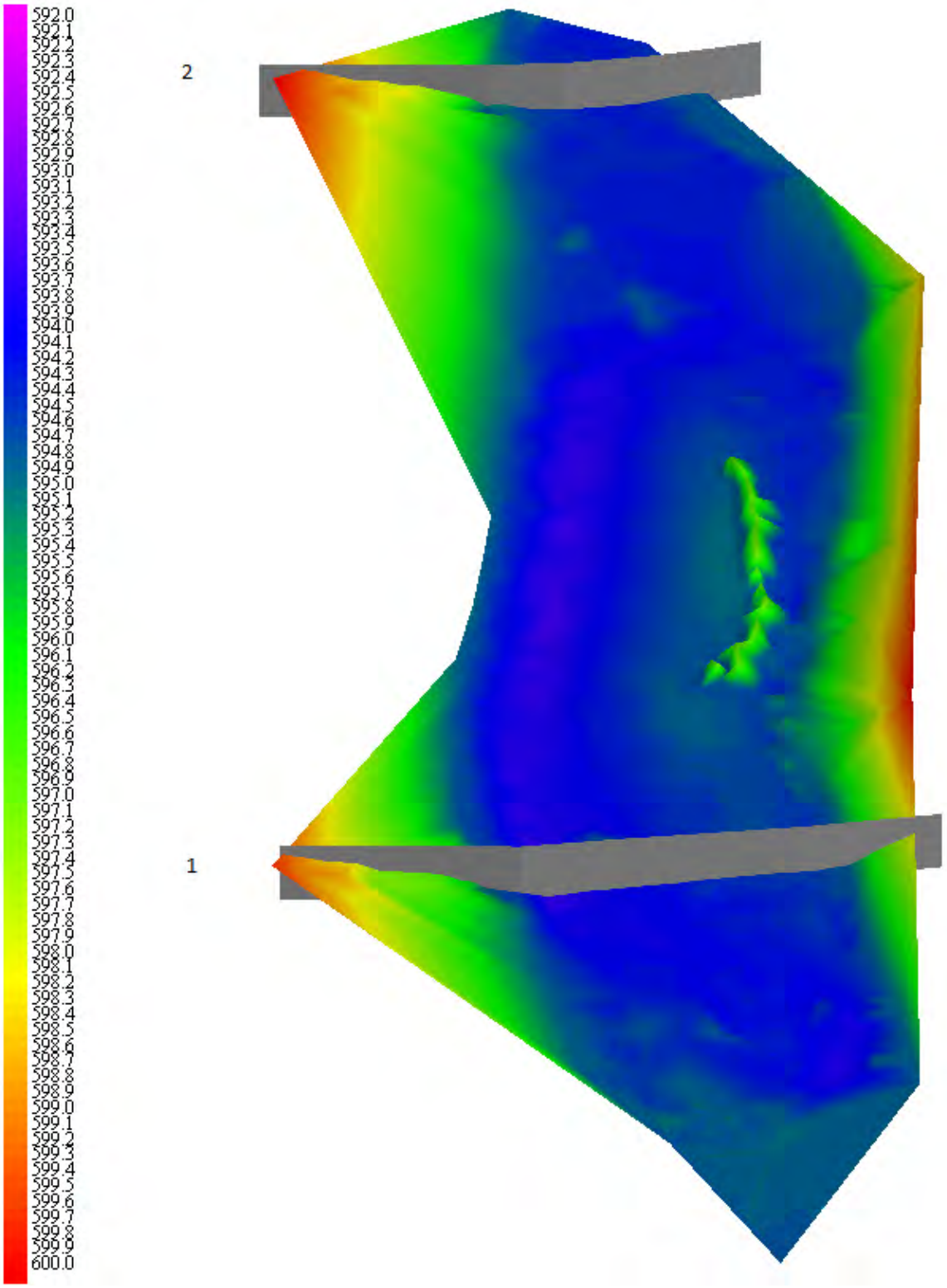


Figure 49 - Angle Crossing D/S DGPS Model (Jan 2013)

*DGPS Model corresponds to area between the pink cross-sections in previous Figure 48. The change in the downstream sandbar due to the 2010 and 2012 flood events

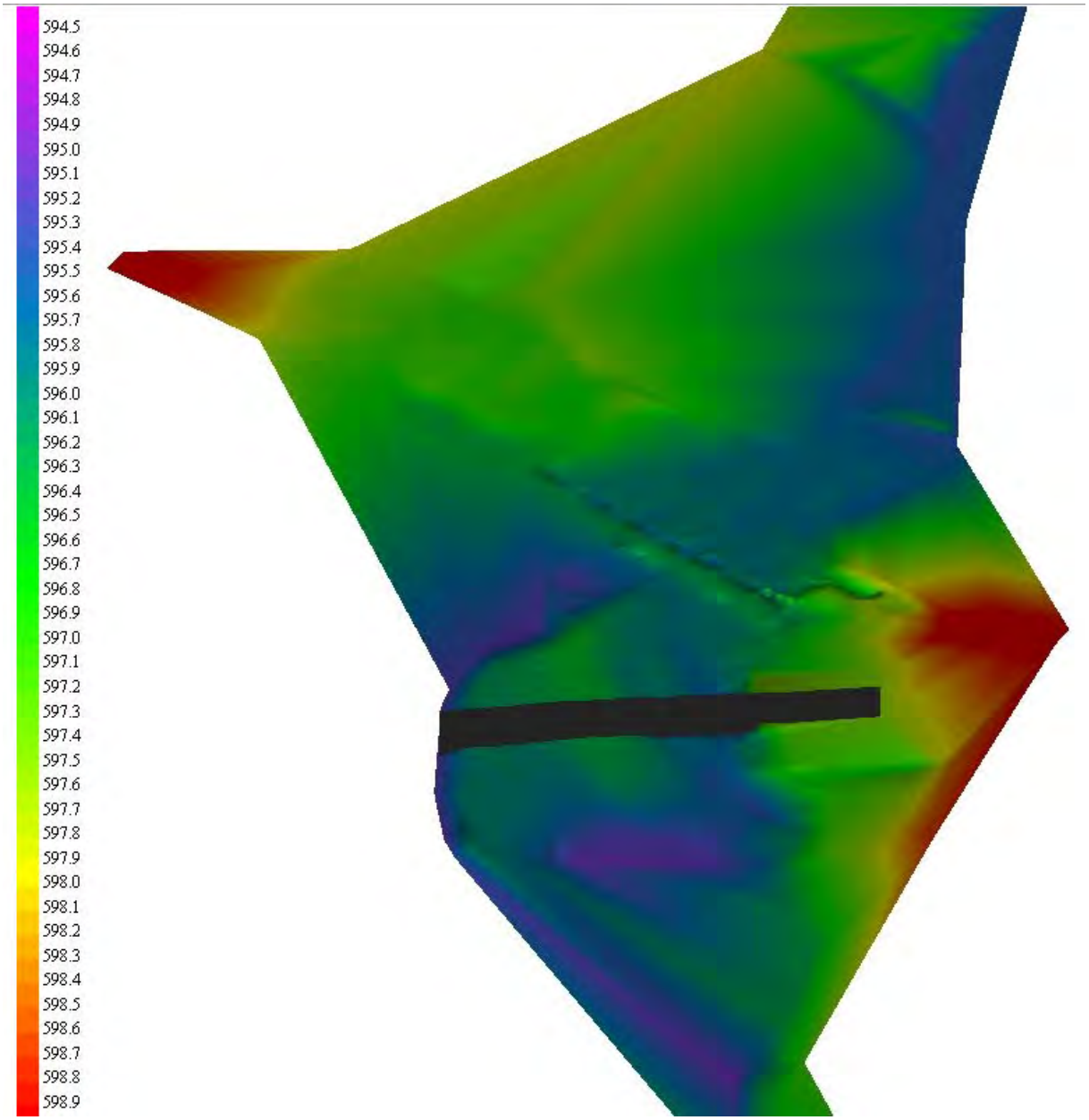


Figure 50 - Angle Crossing DGPS Model Jan 2014

Cross section shown in Figure 50 corresponds to the upstream corner of the inlet structure. The DGPS model does not cover the full extent of river due to the water level being outside of the range of the DGPS at some locations. This was outside of the designated survey area being near the inlet structure. The raised ridge in green through the centre of the river bathymetry is due to points collected along the concrete causeway.

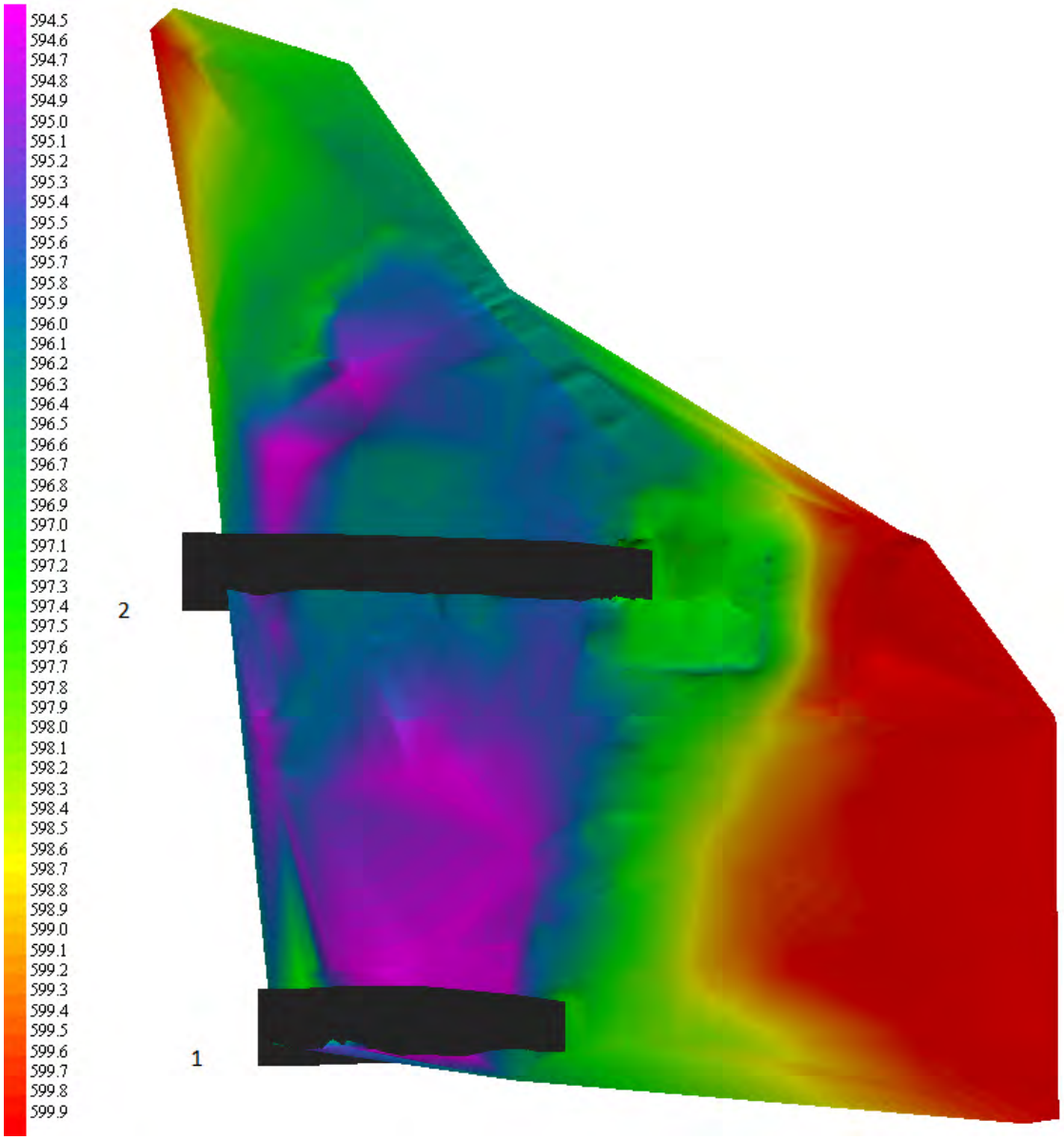
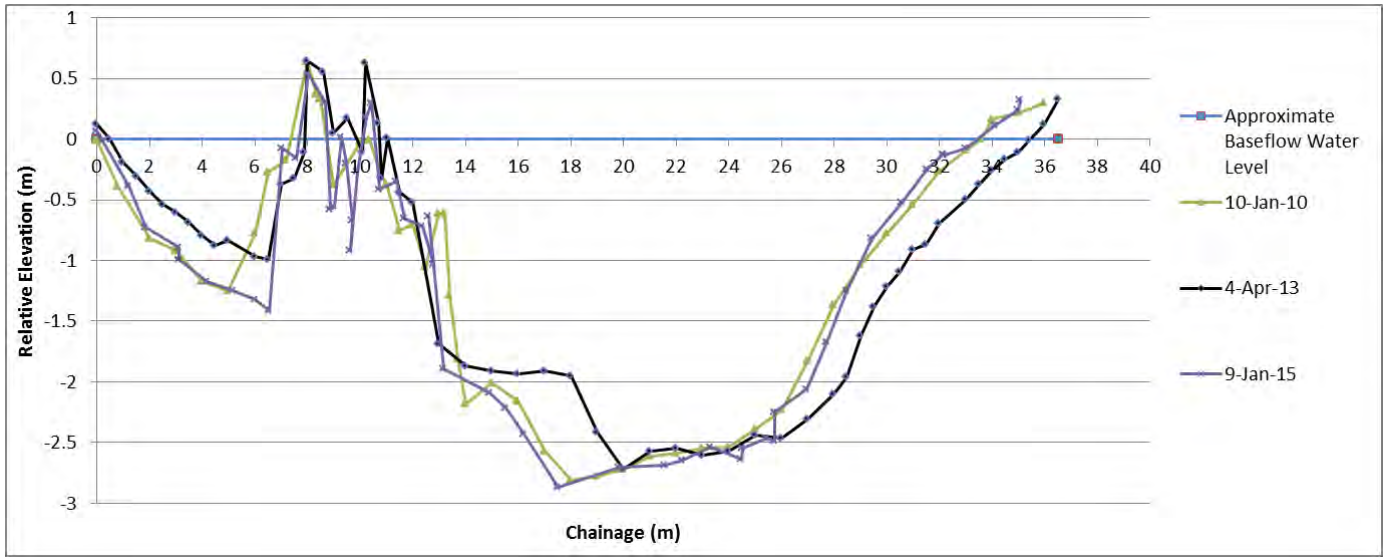
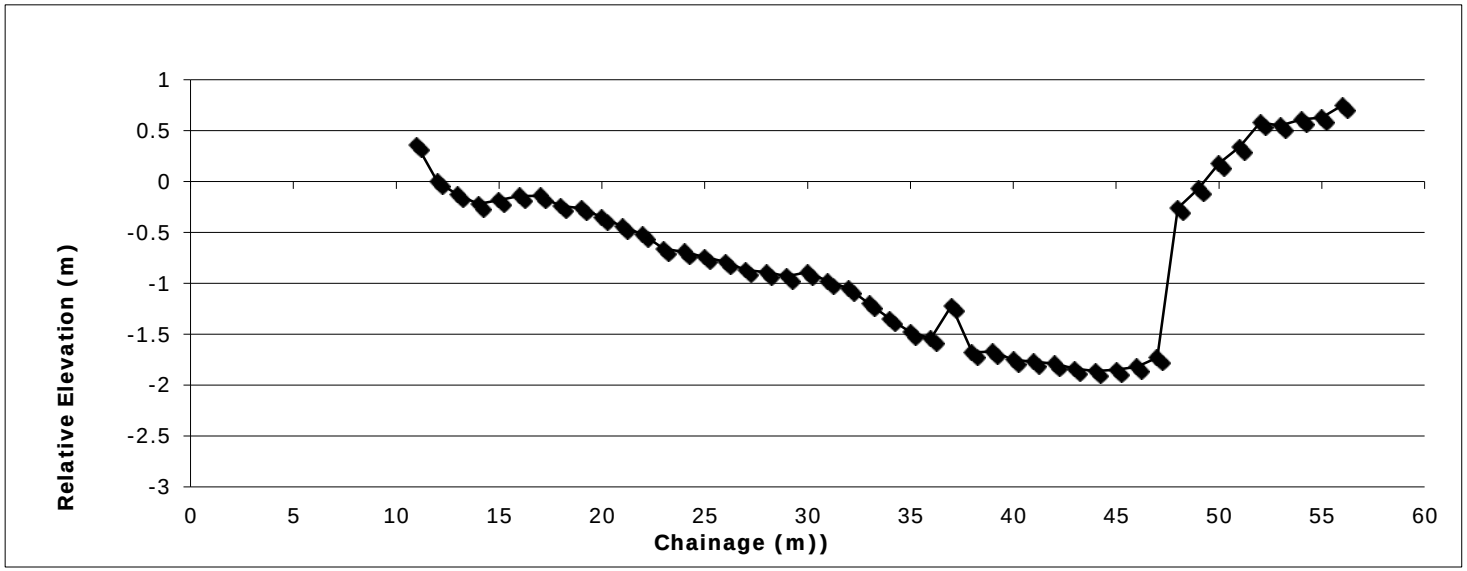


Figure 51 - Angle Crossing Intake Pool 2015

Sections shown in Figure 51 correspond to U/S cross sections 1 and 2. Left hand side of 3D model is incomplete as the bank cannot be accessed due to dense vegetation growth.

		2010		GPS Model		2013	
Section	Bank Side*	Latitude	Longitude	Latitude	Longitude	Latitude	Longitude
1	LHS	35.58403 S	149.10779 E	35.57947 S	149.11024 E	35.58403 S	149.10779 E
	RHS	35.58423 S	149.10810 E	35.57940 S	149.11107 E	35.58423 S	149.10810 E
2	LHS	35.58343 S	149.10806 E	35.57787 S	149.11017 E		
	RHS	35.58363 S	149.10862 E	35.57781 S	149.11080 E		
3	LHS	35.58092 S	149.11102 E				
	RHS	35.58081 S	149.11136 E				
4	LHS	35.58057 S	149.11091 E				
	RHS	35.58044 S	149.11134 E				

Cross Section	Comments
 Figure 52 - Angle Crossing U/S 2010 - XS 1	- Differences due to taking a slightly different line through the rock outcrop - 2015 section follows closely with line of 2010 survey, river bed in central channel is bedrock.
 Figure 53 - Angle Crossing U/S 2010 - XS 2	

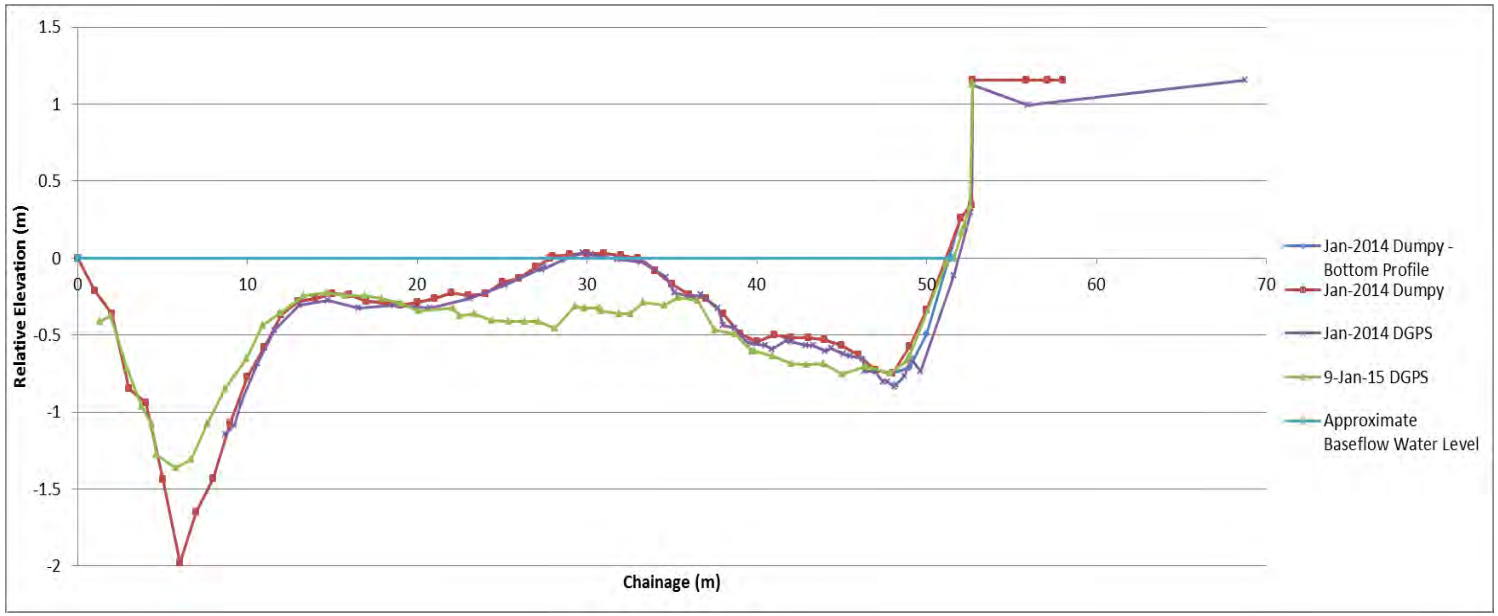


Figure 54 - Angle Crossing Cross Section at U/S Corner of Inlet Structure

- 2014 and 2015 cross sections do not quite match on slope of inlet grate due to differences in RTK adjustment and slight error induced by whether previous GPS survey on or beside concrete edge.
- All sections have been aligned to top corner of intake structure
- 2015 sections shows that the sand bar in the river has shifted, becoming flatter in the centre, and slightly deeper adjacent to the intake ~Ch.43m.
- Deep channel on left hand side has had ~0.6 m of sand deposited since 2014 survey.

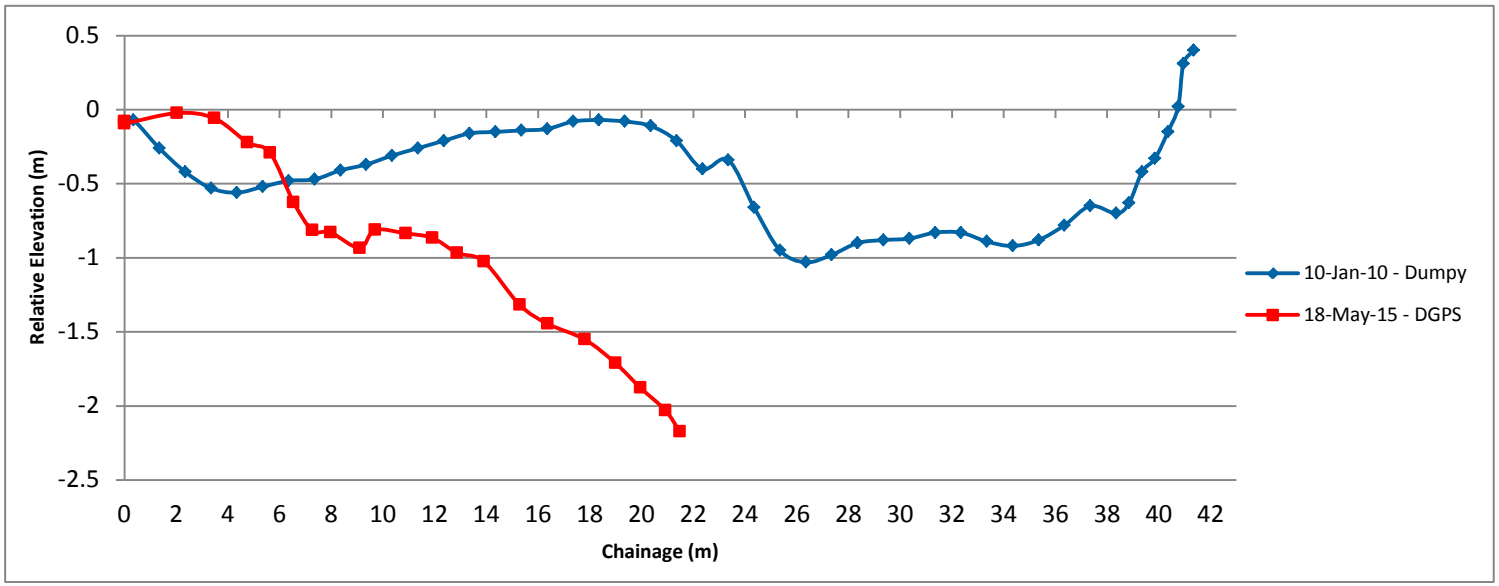


Figure 55 - Angle Crossing D/S - XS 3

- Cross sections were aligned to left hand side (looking downstream) GPS point. Original marker lost.
- Sections adjusted to level at left hand side end point to show relative change in elevation.
- Significant removal of sediment bar in main channel resulting in deep cross-section.
- 2015 cross-section was not completed due to depth and water velocity now present at section. Boat survey required to complete section.

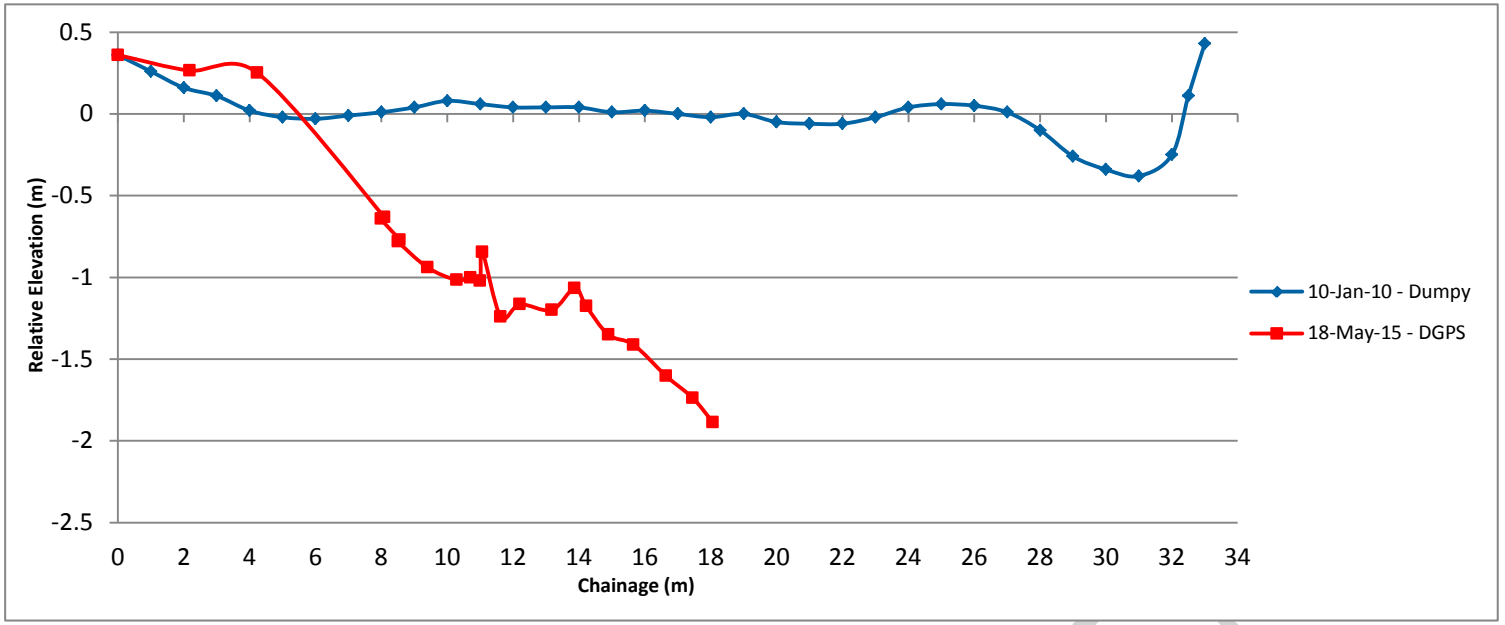


Figure 56 - Angle Crossing D/S - XS 4

- Cross sections were aligned to left hand side (looking downstream) GPS point.
- Sections adjusted to level at left hand side end point to show relative change in elevation.
- Significant removal of sediment bar in channel resulting in deep cross-section.
- 2015 cross-section was not completed due to depth and water velocity now present at section. Boat survey required to complete section.

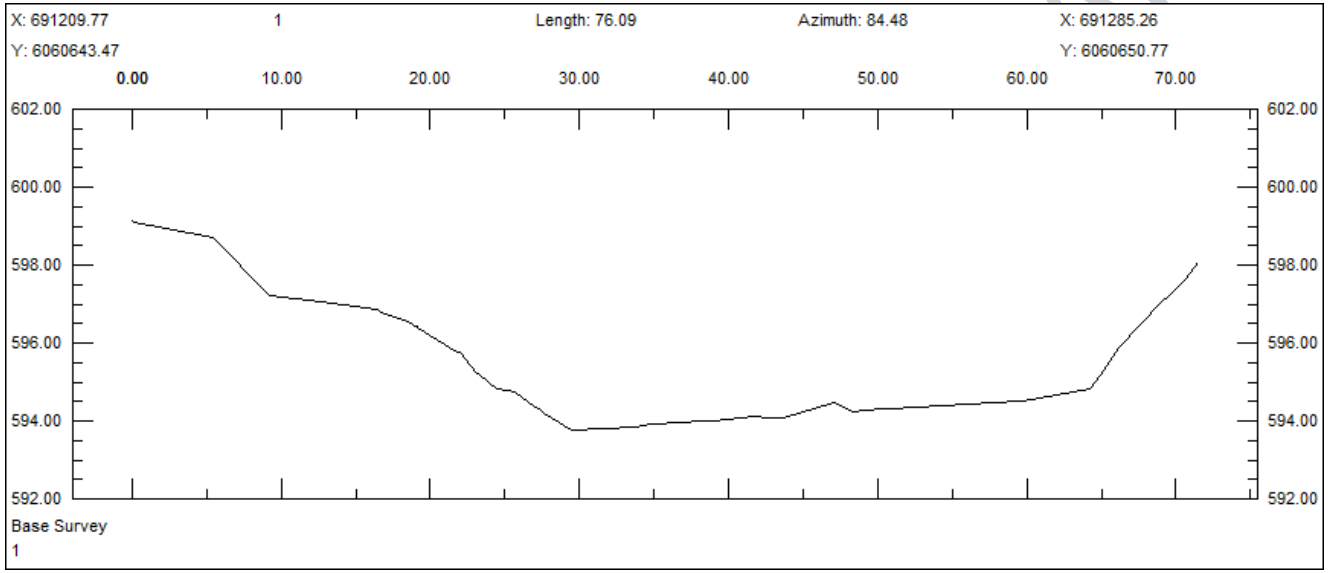


Figure 57 - Angle Crossing D/S 3D GPS XS-1, Jan 2013

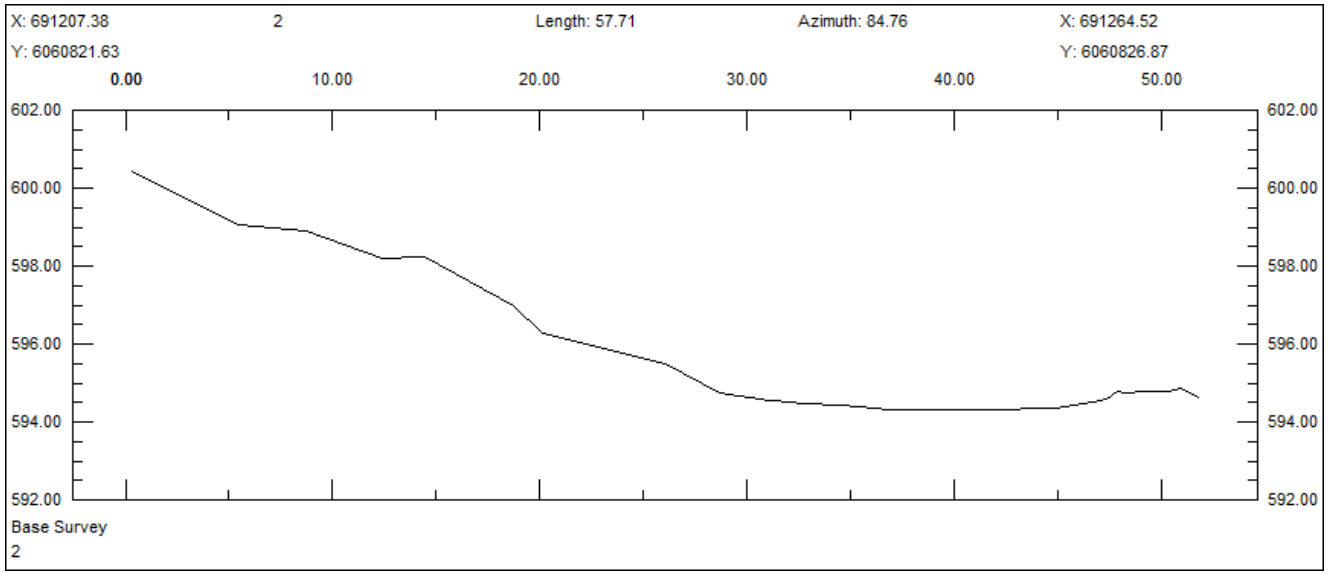


Figure 58 - Angle Crossing D/S 3D GPS XS-2, Jan 2013

- DGPS cross section ends in-stream due to water level and vegetation not allowing access to opposite bank at time of survey

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Rev No.	Author	Reviewer		Approved for Issue		
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1	D Ainsworth N Mueller	N. Mueller		Norm Mueller		18/06/2015
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