Memorandum

TO: James Flockton
FROM: Ella Harrison
DATE: 11 May 2018
SUBJECT: North Byron FRMS&P – Mullumbimby Bend Loss Sensitivity Test
PROJECT NUMBER: 117098

1. INTRODUCTION

As part of the peer review undertaken by WMA Water (March 2018) of the hydraulic model developed by BMT WBM for the North Byron Shire Flood Study (2016), it was identified that the bend loss values upstream of Mullumbimby were high considering the river morphology does not change significantly in this area. As such, a sensitivity test on these values was recommended to determine the influence it may have on the flood level.

This area is subject to high development pressures and there is a known discrepancy between Council flood levels (based on the 2016 Flood Study) and those generated by the developer's consultant, of up to 500m difference in the 1% AEP event (with the Council flood study predicting higher levels).

This memo presents the findings of the sensitivity analysis on the bend loss values of the 1D modelled Brunswick River in Mullumbimby in the TUFLOW hydraulic model.

Three different scenarios have been modelled (see Table 1, Figure 1, Figure 2 and Figure 3):

- Scenario 1 - 'No Bend Loss': The 1D section of the Brunswick River around Mullumbimby is modelled without bend losses. This represents a lower limit scenario.
- Scenario 2 – 'March 2017' event: Bend losses have been calibrated for the March 2017 event. Values upstream of Federation Bridge are between 0 and 1, and are set to 0 downstream.
- Scenario 3 – 'Flood Study': Bend losses are the same as those used for the 2016 North Byron Flood Model developed by BMT WBM (between 1.0 and 1.75 upstream of Federation Bridge and between 2.0 and 3.0 downstream). This represents an upper limit scenario.

Table 1: Assessed manning's values range

Scenario	Adopted Bend Loss
1 - No Bend Loss	0 for the whole Brunswick River in Mullumbimby
2 – March 2017 event	Between 0 and 0.5 upstream of Federation Bridge, 0 downstream
3 - Flood Study	between 1.0 and 1.75 upstream of Federation Bridge and between 2.0 and 3.0 downstream

2. BEND LOSSES PARAMETERS

Any significant bend or change in a river shape leads to changes in velocity, magnitude and flow direction. It provokes energy dissipation and thus increases the water level upstream of the bend. In a 1D Flood Model this energy dissipation is modelled via a Form Loss, or Bend Loss. This unit-less number is adjusted via calibration, within the identified 'best practice' range. No value (or 0) means that the rivers profile is regular and that the river has no significant bends. When a significant change in the rivers profile occurs or when the river meanders, a bend loss value may be applied. A value of 1 or 2 is usually used for significant bends like an abrupt 180^{o} turn.

Bend Loss is mainly used as a calibration parameter. Initial values are estimated based on the best practice values and previous experience of the modeller. The calibration process is then used to validate or refine the estimations.

In Mullumbimby, the rivers profile is regular upstream of Federation Bridge. There are slight bends in the river but they are not sudden nor sharp. Thus, a reasonable bend loss value of 0.5/1 is recommended here.

3. SENSITIVITY ANALYSIS

As bend losses are considered calibration parameters, the sensitivity analysis has been initially undertaken based on the historical event from March 2017. A significative portion of Mullumbimby was flooded for this event with 0.5m to 1m flood depths in some residential areas.

Council has identified and surveyed 34 flood marks / calibration points in Mullumbimby. Four of these are inconsistent with surrounding flood marks and have not been included in the analysis. The results of the three bend loss scenarios have been compared with the remaining 30 flood marks.

3.1. Scenario 1 – 'No Bend Loss'

Of the 30 flood marks, 17 are located outside the modelled peak flood extent in this scenario. Two of the remaining flood marks are within ±100mm of the modelled peak levels, and 10 are within ±300mm. Flood levels are shown in Figure 1 and Figure 4 (see appendices).

Globally, the modelled flood extent is not coherent with flood marks and photos taken during the event. This is particularly apparent upstream of Federation Bridge where 16 out of 21 flood marks (76%) are outside modelled flood extent. The model under-predicts flood levels by 400/500mm in Mullumbimby upstream of Federation Bridge.

3.2. Scenario 2 – 'March 2017 event'

For this scenario, bend loss has been optimized to minimize the difference between modelled flood levels and surveyed flood marks. Bend loss has been set to 0 for the whole Brunswick River except for 5 sectors upstream of Federation Bridge in Mullumbimby where the river bends. On these sectors, bend loss values are set between 0.5 and 1.

In upstream Mullumbimby, two flood marks are outside modelled flood extent. The other flood marks located upstream of Federation Bridge (21) are well aligned, with the majority of flood marks within ±100mm (67%) and 81% of them within ±200mm (see Figure 5 and Table 5).

In downstream Mullumbimby, 2 out of 9 flood marks are within ±100mm (22%) and 8 are within ±300mm (89%).

3.3. Scenario 3 – 'Flood Study'

The Flood Study bend loss scenario uses the same bend losses for the Brunswick River in Mullumbimby as the 2016 North Byron Flood Study Model. Bend loss are higher than in the previous scenario, they are set to 1.0 and 1.75 upstream of Federation Bridge and between 2.0 and 3.0 downstream.

As shown on Figure 6, the model over-predicts flood levels in Mullumbimby by 200mm or 300mm. 10% of the flood marks are within ±100mm. 19 modelled flood level are at least 200mm higher than the recorded level (63%).

4. VERIFICATION WITH OTHER HISTORICAL EVENTS

Five other historical flood events have been modelled to calibrate the hydraulic model. The model has been changed to match historical ground conditions and hydraulic configurations for every event. For Tallowood Estate, the ground level is set as it was in 2010 for all historical events including the June 2012 flood event.

Table 2 compares the observed level and modelled level derived from Scenario 3 (Flood Study) and Scenario 2 (March 2017 update.)

Table 2: Observed and Modelled flood level in Tallowood Estate

Tallowood Estate	March 2017	June 2012	June 2005	March 1987	May 1978	March 1974
Observed	7.30	5.94	No data	No data	6.41	No data
Scenario 2 – March 2017 event	7.37 (+1%)	6.15 (+4%)	6.13	6.68	6.54 (+2%)	6.90
Scenario 3 - Flood Study	7.60 (+4%)	6.24 (+5%)	6.32	6.78	6.60 (+3%)	6.92

Historical flood levels have been recorded at Tallowood for the June 2012 and May 1978 flood events. For both events, the Scenario 2 (March 2017) compares better than Scenario 3 (Flood Study). The model still over predicts flood levels in this area but by a lower margin (+150/200mm instead of +200/300mm).

Table 3 compares level at the Federation Bridge.

Table 3: Observed and Modelled flood level at Federation Bridge

Federation Bridge	March 2017	June 2012	June 2005	March 1987	May 1978	March 1974
Observed	4.36*	4.02	4.14	4.62	≈4.80**	No data
Scenario 2 – March 2017 event	4.94	4.44 (+10%)	4.02 (-3%)	4.75 (+3%)	4.62 (-4%)	4.79
Scenario 3 - Flood Study	4.90	4.39 (+9%)	4.28 (+3%)	4.64 (+<1%)	4.53 (-6%)	4.73

**Discrepancy between gauges*
***based on adjacent flood mark*

There is no consistent recorded level at Federation Bridge for the March 2017 flood event. For June 2012 and March 1987, Scenario 2 (March 2017) compares worse than Scenario 3 (Flood Study) but it compares better with the May 1978 and June 2005 flood events.

5. IMPACT ON DESIGN EVENTS

Adopting the Scenario 2: “March 2017” bend losses will lower the flood level and reduce the flood extent in Mullumbimby upstream of Federation Bridge. Whilst the design events have not yet been modelled, evidence from the historical events suggest that for a 1%AEP design event:

- In the area of the Tallowood estate development, flood levels would decrease by 200/250mm. The flood extent would likely reduce north of the development area, and remain similar on the rest of the Tallowood estate.
- The modelled flood level between Main Arm Road and Garden Avenue should decrease and the flood extent in this area will likely reduce.
- There is unlikely to have any significant impact downstream of Federation Bridge.

6. CONCLUSION

The sensitivity tests on bend losses undertaken show that this parameter can significantly affect flood levels in Mullumbimby, with a global difference of 600/700mm between the different scenarios tested. It also has significant impact on flood extent due to the flat topography in Mullumbimby. The total flood extent for Scenario 1 (No bend loss) is 1.4 km^2, compared to 2.2km^2 under Scenario 3 (Flood Study).

Scenario 2 (March 2017 update) reproduces most of the recorded flood levels in this area within ±100mm difference, and is more consistent with the river morphology in this area. It is thus recommended to use these bend loss values for calibration and design events.

List of Figures

Reference

North Byron Shire Flood Study (BMT WBM, 2016)

Byron Shire Flood Review for Ex-Tropical Cyclone Debbie (BMT WBM, 2017)

Figure 1: Bend losses in Mullumbimby – Scenario 1: No Bend Loss

Figure 2: Bend losses in Mullumbimby – Scenario 2: March 2017 values

Figure 3: Bend losses in Mullumbimby – Scenario 3: Flood study

Figure 4: Calibration Results – March 2017, Scenario 1: No Bend Loss

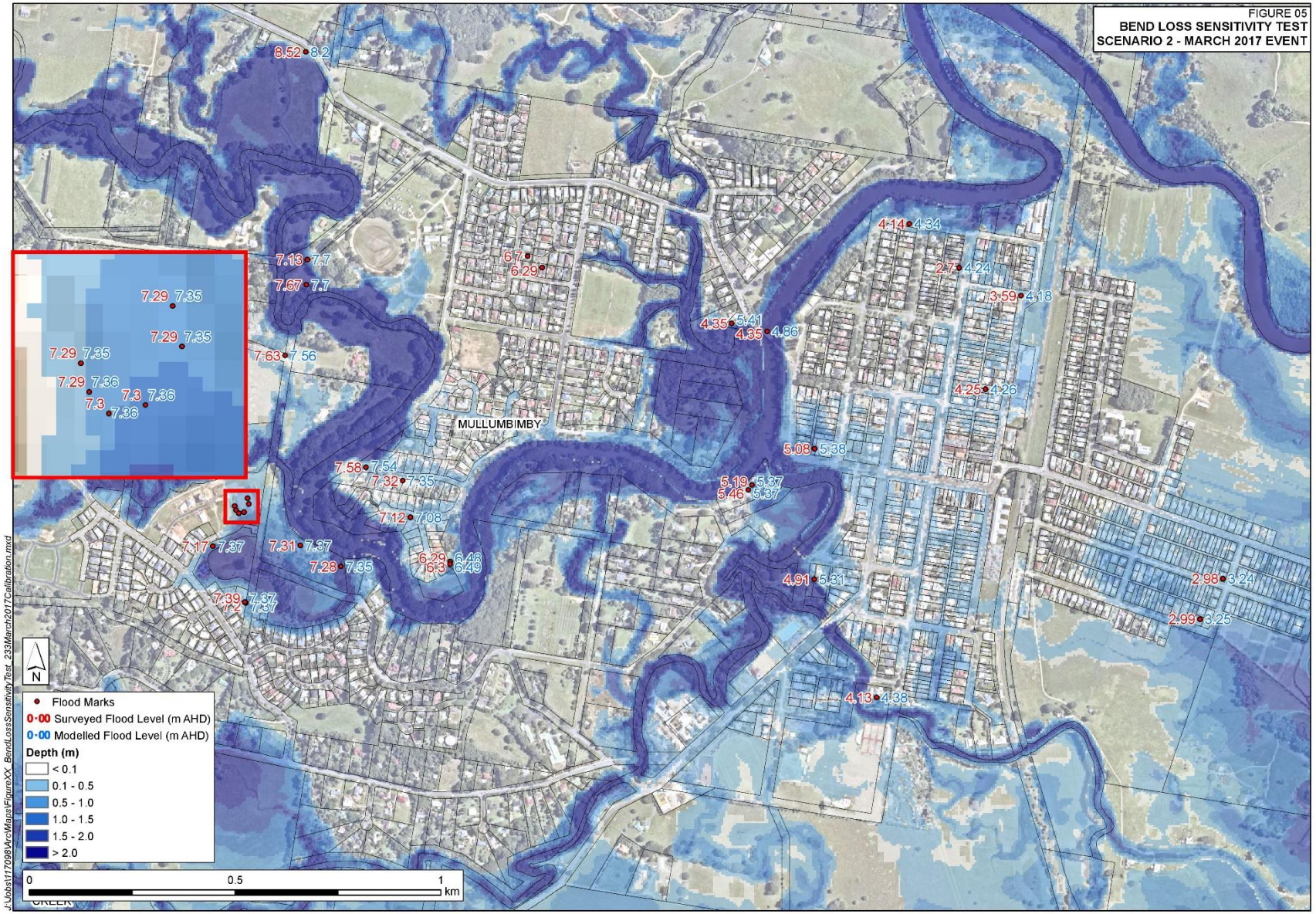

Figure 5: Calibration Results – March 2017, Scenario 2: March 2017 Bend Loss

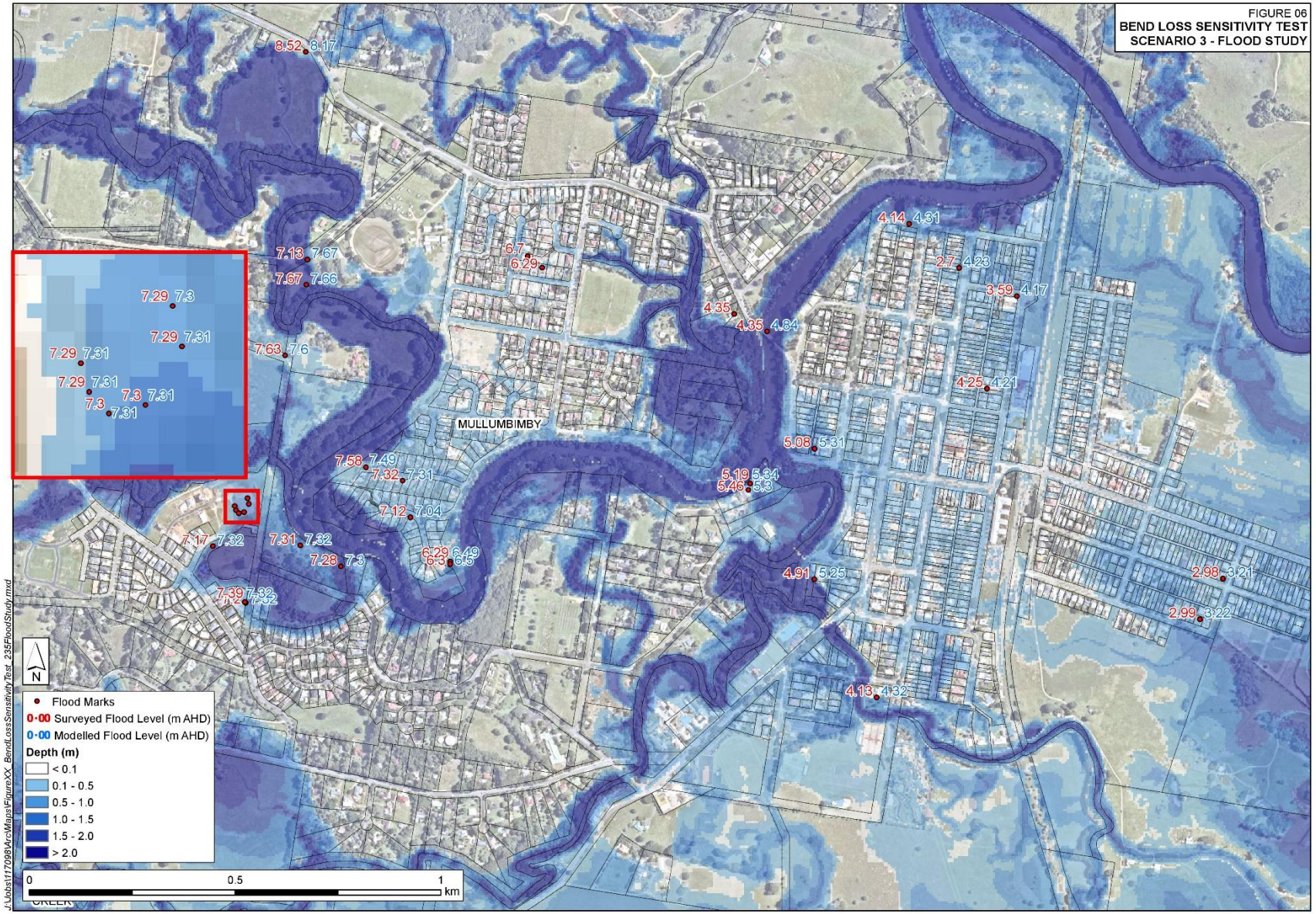

Figure 6: Calibration Results – March 2017, Scenario 3: Flood Study Bend Loss

Table 4: Mullumbimby flood marks for the No Bend loss scenario

ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)
2	2.99	3.16	0.165
3	6.7	Not Flooded	Not flooded
7	7.58	Not Flooded	Not flooded
13	4.91	5.16	0.249
18	7.17	6.76	-0.407
39	4.13	4.22	0.095
40	4.14	3.93	-0.215
47	2.98	3.14	0.164
48	7.28	6.74	-0.545
50	4.25	Not Flooded	Not flooded
51	7.12	Not Flooded	Not flooded
B1	8.52	Not Flooded	Not flooded
B10	7.63	Not Flooded	Not flooded
B11	7.2	6.76	-0.437
B12	7.39	Not Flooded	Not flooded
B14	7.29	6.76	-0.53
B15	7.29	6.76	-0.531
B16	7.29	Not Flooded	Not flooded
B17	7.29	Not Flooded	Not flooded
B18	7.3	6.76	-0.539
B19	7.3	6.76	-0.54
B20	5.46	5.20	-0.261
B21	5.19	5.20	0.008
B30	7.67	7.29	-0.377
B32	7.315	Not Flooded	Not flooded
B33	7.31	6.77	-0.535
B34	6.29	Not Flooded	Not flooded
B35	5.08	5.21	0.125
B8	6.29	6.27	-0.023
B9	6.3	6.27	-0.025

Table 5: Mullumbimby flood marks for the March2017 Calibrated scenario

ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)
2	2.99	3.14	0.152
3	6.7	Not Flooded	Not flooded
7	7.58	7.53	-0.053
13	4.91	5.11	0.201
18	7.17	7.36	0.188
39	4.13	4.17	0.036
40	4.14	3.90	-0.242
47	2.98	3.13	0.153
48	7.28	7.34	0.059
50	4.25	4.13	-0.117
51	7.12	7.06	-0.056
B1	8.52	8.19	-0.329
B10	7.63	7.60	-0.026
B11	7.2	7.36	0.156
B12	7.39	7.36	-0.034
B14	7.29	7.34	0.047
B15	7.29	7.34	0.049
B16	7.29	7.34	0.051
B17	7.29	7.35	0.057
B18	7.3	7.35	0.049
B19	7.3	7.34	0.045
B20	5.46	5.14	-0.315
B21	5.19	5.16	-0.028
B30	7.67	7.69	0.017
B32	7.315	7.33	0.014
B33	7.31	7.36	0.046
B34	6.29	Not Flooded	Not flooded
B35	5.08	5.15	0.07
B8	6.29	6.44	0.147
B9	6.3	6.45	0.149

Table 6: Mullumbimby flood marks for the BMT WBM Bend Loss Scenario

ID	Surveyed Flood Level (m AHD)	Modelled flood Level (m AHD)	Difference (m)
2	2.99	3.24	0.25
3	6.7	6.28	-0.419
7	7.58	7.73	0.15
13	4.91	5.23	0.318
18	7.17	7.60	0.426
39	4.13	4.30	0.165
40	4.14	4.34	0.197
47	2.98	3.23	0.252
48	7.28	7.58	0.304
50	4.25	4.21	-0.036
51	7.12	7.37	0.251
B1	8.52	8.33	-0.185
B10	7.63	7.69	0.057
B11	7.2	7.59	0.394
B12	7.39	7.59	0.204
B14	7.29	7.55	0.257
B15	7.29	7.55	0.264
B16	7.29	7.56	0.267
B17	7.29	7.57	0.277
B18	7.3	7.57	0.272
B19	7.3	7.57	0.266
B20	5.46	5.27	-0.186
B21	5.19	5.29	0.099
B30	7.67	7.86	0.189
B32	7.315	7.52	0.203
B33	7.31	7.60	0.286
B34	6.29	6.14	-0.146
B35	5.08	5.28	0.202
B8	6.29	6.73	0.443
B9	6.3	6.74	0.443