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September 8, 2015

The Board of Commissioners of Public Utilities
Prince Charles Building
120 Torbay Road, P.O. Box 21040
St. John's, Newfoundland & Labrador
A1A 5B2

Attention: Ms. Cheryl Blundon
Director Corporate Services & Board Secretary

Dear Ms. Blundon:

Re: Newfoundland and Labrador Hydro - the Board's Investigation and Hearing into Supply Issues and Power Outages on the Island Interconnected System – Nostradamus Upgrades Monthly Report

In accordance with item 2.1 of the Liberty Report Recommendations dated December 17, 2014, wherein Hydro is required to "provide the Board with monthly updates on the status of Nostradamus upgrades until the production model is fully in-service and shaken down", please find enclosed the original plus 12 copies of Hydro's report entitled *Accuracy of Nostradamus Load Forecasting at Newfoundland and Labrador Hydro Monthly Report: August 2015.*

We trust the foregoing is satisfactory. If you have any questions or comments, please contact the undersigned.

Yours truly,

NEWFOUNDLAND AND LABRADOR HYDRO

Tracey Pennell

Tracey L. Pennell
Legal Counsel

TLP/bs

cc: Gerard Hayes – Newfoundland Power
Paul Coxworthy – Stewart McKelvey Stirling Scales
Sheryl Nisenbaum – Praxair Canada Inc.
ecc: Roberta Frampton Benefiel – Grand Riverkeeper Labrador
Thomas Johnson – Consumer Advocate
Thomas O' Reilly – Cox & Palmer
Danny Dumaresque

Accuracy of Nostradamus Load Forecasting at Newfoundland and Labrador Hydro

Monthly Report: August 2015

Newfoundland and Labrador Hydro

September 8, 2015

Table of Contents

1 NOSTRADAMUS LOAD FORECASTING 1
1.1 Nostradamus 1
1.2 Short-Term Load Forecasting 1
1.2.1 Utility Load 1
1.2.2 Industrial Load 2
1.2.3 Supply and Demand Status Reporting 2
1.3 Load Forecasting Improvements 3
1.4 Potential Sources of Variance 3
2 AUGUST 2015 FORECAST ACCURACY 4

1 NOSTRADAMUS LOAD FORECASTING

1.1 Nostradamus

Newfoundland and Labrador Hydro (Hydro) uses software called Nostradamus, by Ventyx, for short-term load forecasting with a time frame of seven days. "The Nostradamus Neural Network Forecasting system is a flexible neural network based forecasting tool developed specifically for utility demand forecasting. Unlike conventional computing processes, which are programmed, neural networks use sophisticated mathematical techniques to train a network of inputs and outputs. Neural networks recognize and learn the joint relationships (linear or non-linear) between the ranges of variables considered. Once the network learns these intricate relationships, this knowledge can then easily be extended to produce accurate forecasts." (Nostradamus User Guide, Release 8.2, Ventyx, an ABB Company, May 2014).

The Nostradamus model is trained using a sequence of continuous historic periods of hourly weather and demand data, then forecasts system demand using predictions of those same weather parameters for the next seven days.

1.2 Short-Term Load Forecasting

Hydro uses its short-term load forecast to manage the power system and ensure adequate generating resources are available to meet customer demand.

1.2.1 Utility Load

Hydro contracts Amec Foster Wheeler (Amec) to provide the weather parameters in the form of hourly weather forecasts for a seven-day period. At the same time as the weather forecast data is provided, Amec also provides observed data at the same locations for the previous 24 hours (calendar day). The forecast and actual data are automatically retrieved from Amec and input to the Nostradamus database.

Nostradamus can use a variety of weather parameters for forecasting as long as a historical record is available for training. Hydro currently uses: air temperature, wind speed, and cloud cover. Nostradamus can use each variable more than once, for example both the current and forecast air temperatures are used in forecasting load. Wind chill is not used explicitly as the neural network function of Nostradamus will form its own relationships between load, wind and temperature, which should be superior to the one formula used by Environment Canada to derive wind chill.

Weather data for four locations are used in Nostradamus: St. John's, Gander, Deer Lake, and Port aux Basques. Data from April 1, 2012 to March 31, 2015 are being used for

training and verification purposes. The training and verification periods are selected to provide a sufficiently long period to ensure that a range of weather parameters are included, e.g., high and low temperatures, but short enough that the historic load is still representative of loads that can be expected in the future.

In addition to the weather and demand data, a parameter that indicates daylight hours each day is input to Nostradamus.

Demand data for the Avalon Peninsula alone and for the Island Interconnected System as a whole are input to Nostradamus automatically each hour. Only total utility load (conforming), Newfoundland Power's and Hydro's, is input in the Nostradamus model. Industrial load (non-conforming), which is not a function of weather, is forecast outside the Nostradamus program and added to the forecasts from Nostradamus to derive the total load forecast.

During the process of training the Nostradamus model, it creates separate submodels for weekdays, weekends and holidays to account for the variation in customer use of electricity. Nostradamus has separate holiday groups for statutory holidays and also for days that are known to have unusual loads, for instance the days between Christmas and New Year's and the school Easter break.

1.2.2 Industrial Load

Industrial load tends to be almost constant, as industrial processes are independent of weather. Under the current procedure, the power-on-order for each Industrial Customer, plus the expected owned generation from Corner Brook Pulp and Paper (CBPP), is used as the industrial load forecasts unless System Operations engineers modify the forecast based on some knowledge of customer loads, for instance a decrease due to reduced production at CBPP or a ramp up in the load expected at Vale. Engineers can change the expected load in one or more cells of a seven by twenty-four hour grid, or can change the default value to be used indefinitely.

1.2.3 Supply and Demand Status Reporting

The forecast peak reported to the Board of Commissioners of Public Utilities (the Board) on the daily Supply and Demand Status Report is the forecast peak as of 7:20 am. The weather forecast for the next seven days and the observed weather data for the previous day are input at approximately 5:00 am. Nostradamus is then run every hour of the day and the most recent forecast is available for reference by System Operations engineers and the Energy Control Centre operators for monitoring and managing available spinning reserves. The within day forecast updates are used by operators to decide if additional spinning reserve is required in advance of forecast system peaks.

1.3 Load Forecasting Improvements

Hydro has implemented the following changes to the load forecasting process since January 2014:

- Additional training for staff;
- Revised training and verification periods and additional quality control of the weather data, including the data from January 2014 which will improve the capability of the model to forecast loads at low temperatures;
- Adding weather parameters for cloud cover and daylight hours;
- Modifying actual demand data used in Nostradamus training to remove unusual system conditions such as significant outages;
- Changing forecasting processes so that Nostradamus forecasts only utility load, with industrial forecasts done separately;
- Changing forecasting process to allow adjustments to the generated forecast to account for unusual system conditions (e.g., to account for an abnormal system configuration that may result in more or less system losses); and
- Creation of new plots and tables showing the load forecast, spinning reserve, and available reserve, which are available on demand to System Operations staff for managing the system;
- Requirement for regular weather forecast accuracy reviewing and reporting from Amec; and
- Move to two weather forecasts per day and an update of observed weather data midday.
- Version 8.2.4 of the Nostradamus software was installed on Production in mid-August 2015. Implementation of the new version had no noticeable effect on the forecasts.

1.4 Potential Sources of Variance

Improvements made to the Nostradamus forecasting model and Hydro's processes for load forecasting have improved the reliability of the load forecasts. As with any forecasting, however, there will be ongoing discrepancies between the forecast and the actual values. Typical sources of variance in the load forecasting are as follows:

- Differences in the industrial load forecast due to unexpected changes in customer loads;
- Inaccuracies in the weather forecast, particularly temperature, wind speed or cloud cover; and
- Non-uniform customer behaviour which results in unpredictability.

2 AUGUST 2015 FORECAST ACCURACY

Table 1 presents the daily forecast peak, the observed peak, and the available system capacity, as included in Hydro's daily Supply and Demand Status Reports submitted to the Board for each day in August 2015. The data are also presented in Figure 1. The actual peaks, as reported to the Board, varied from 629 MW on August 29 to 822 MW on August 10.

The available capacity during the month was between 1130 MW on August 7 and 1520 MW on August 1. Reserves were sufficient throughout the period.

Table 2 presents error statistics for the peak forecasts during the month of August 2015. Figure 2 is a plot of the forecast and actual peaks, as shown in Figure 1, but with the addition of a bar chart showing the difference between the two data series. In both the tables and the figures, a positive error is an overestimate; a negative error is an underestimate.

For much of August, the CBPP load was significantly below the default forecast of 107 MW. The lower load was not planned, and Hydro was not informed in advance, so the industrial forecast was not adjusted. This led to significant apparent error (overestimate) in the forecast. Figure 3 shows the CBPP load forecast, the actual load, and the discrepancy. On August 13 through 16 and 29 through 31, the CBPP load was 80 to 95 MW below normal. Hydro's Energy Control Centre has a real time feed of the CBPP load and therefore operators were well aware of the lower than normal load and adjusted generation correspondingly. Because the load forecast is a total of the utility and industrial load forecasts, the result of the industrial load being lower than forecast is additional reserves available to the system.

Because the apparent error in the forecast was a result of lower than forecast industrial load, it was not a reflection of the accuracy of the Nostradamus model which forecasts utility load only. Table 3 is a repeat of the statistics table showing utility load only; the industrial load forecast and the industrial load have been removed.

Through the month of August the forecast utility peak was in a range between 5.0% below the actual peak and 5.4% above the actual peak, but most days the forecast was within 3% of actual peak. On the best days the forecast peak was essentially the same as the actual peak; on the worst day it was 34 MW too low. On average, the forecast peak was 13 MW different than the actual peak, or 2.1%.

Table 1 August 2015 Load Forecasting Data

Date	Forecast Peak, MW	Actual Peak, MW	Available Island Supply, MW	Forecast Reserve, MW
1-Aug-15	800	812	1520	720
2-Aug-15	755	736	1345	590
3-Aug-15	775	755	1240	465
4-Aug-15	760	755	1220	460
5-Aug-15	765	730	1215	450
6-Aug-15	785	780	1220	435
7-Aug-15	770	760	1130	360
8-Aug-15	755	717	1260	505
9-Aug-15	765	743	1225	460
10-Aug-15	810	822	1280	470
11-Aug-15	785	756	1240	455
12-Aug-15	775	725	1225	450
13-Aug-15	795	756	1340	545
14-Aug-15	785	680	1265	480
15-Aug-15	730	638	1430	700
16-Aug-15	720	709	1430	710
17-Aug-15	775	730	1300	525
18-Aug-15	790	750	1240	450
19-Aug-15	765	735	1355	590
20-Aug-15	775	754	1325	550
21-Aug-15	755	775	1325	570
22-Aug-15	735	734	1330	595
23-Aug-15	745	736	1325	580
24-Aug-15	780	752	1315	535
25-Aug-15	765	764	1265	500
26-Aug-15	770	752	1330	560
27-Aug-15	765	739	1300	535
28-Aug-15	770	778	1240	470
29-Aug-15	720	629	1225	505
30-Aug-15	730	645	1215	485
31-Aug-15	780	693	1215	435

Notes:

Forecast peak, available capacity and forecast reserve are rounded to the nearest 5 MW.

Forecast peak and available capacity presented is as reported to the Board. The forecast is updated hourly throughout the day for use in maintaining adequate generation reserves. Forecast Reserve = Available Island Supply - (Forecast Peak - CBPP Interruptible Load (when applicable) - the impact of voltage reduction).

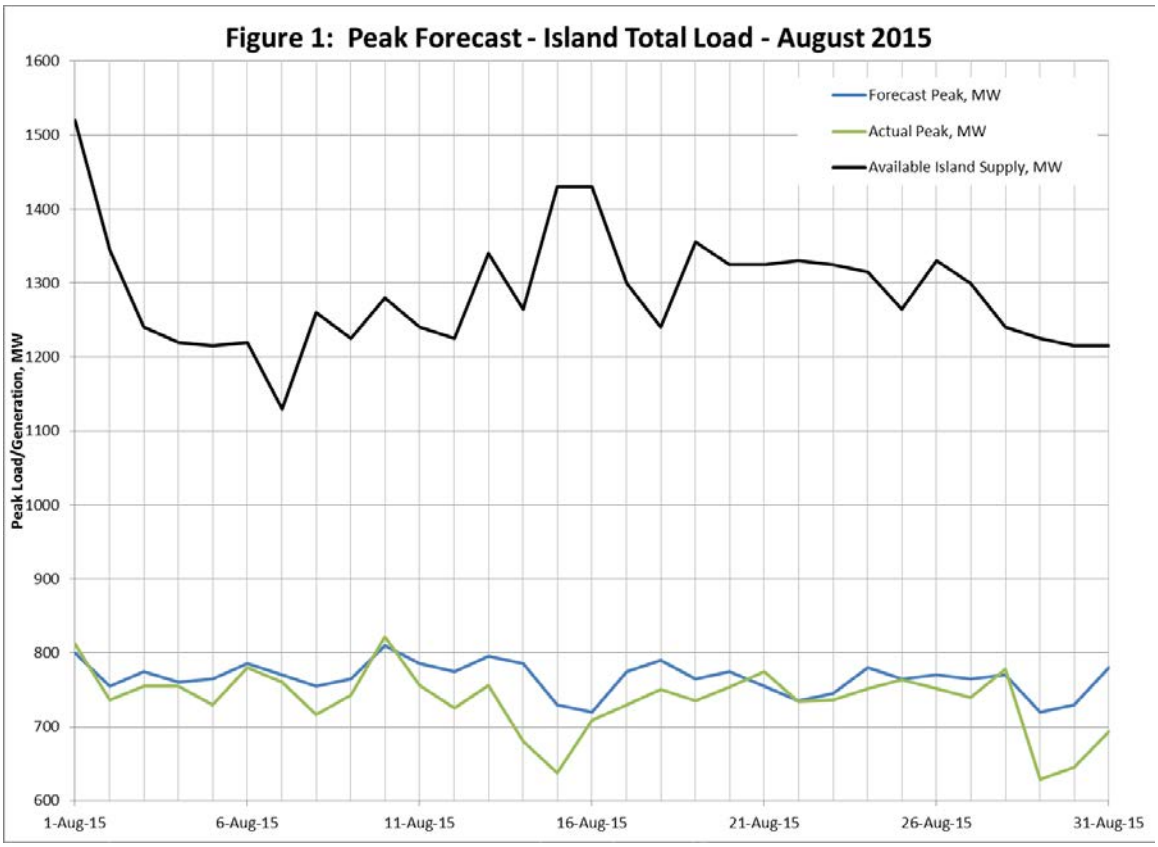
Figure 1: Peak Forecast - Island Total Load - August 2015
Peak Load/Generation, MW
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
1-Aug-15
6-Aug-15
11-Aug-15
16-Aug-15
21-Aug-15
26-Aug-15
31-Aug-15
Forecast Peak, MW
Actual Peak, MW
Available Island Supply, MW

Table 2 August 2015 Analysis of Total Forecast Error

Date	Actual Peak, MW	Forecast Peak, MW	Error, MW	Absolute Error, MW	Percent Error	Absolute Percent Error	Actual/ Forecast
1-Aug-15	812	800	-12	12	-1.5%	1.5%	-1.5%
2-Aug-15	736	755	19	19	2.6%	2.6%	2.5%
3-Aug-15	755	775	20	20	2.6%	2.6%	2.6%
4-Aug-15	755	760	5	5	0.7%	0.7%	0.7%
5-Aug-15	730	765	35	35	4.8%	4.8%	4.6%
6-Aug-15	780	785	5	5	0.6%	0.6%	0.6%
7-Aug-15	760	770	10	10	1.3%	1.3%	1.3%
8-Aug-15	717	755	38	38	5.3%	5.3%	5.0%
9-Aug-15	743	765	22	22	3.0%	3.0%	2.9%
10-Aug-15	822	810	-12	12	-1.5%	1.5%	-1.5%
11-Aug-15	756	785	29	29	3.8%	3.8%	3.7%
12-Aug-15	725	775	50	50	6.9%	6.9%	6.5%
13-Aug-15	756	795	39	39	5.2%	5.2%	4.9%
14-Aug-15	680	785	105	105	15.4%	15.4%	13.4%
15-Aug-15	638	730	92	92	14.4%	14.4%	12.6%
16-Aug-15	709	720	11	11	1.6%	1.6%	1.5%
17-Aug-15	730	775	45	45	6.2%	6.2%	5.8%
18-Aug-15	750	790	40	40	5.3%	5.3%	5.1%
19-Aug-15	735	765	30	30	4.1%	4.1%	3.9%
20-Aug-15	754	775	21	21	2.8%	2.8%	2.7%
21-Aug-15	775	755	-20	20	-2.6%	2.6%	-2.6%
22-Aug-15	734	735	1	1	0.1%	0.1%	0.1%
23-Aug-15	736	745	9	9	1.2%	1.2%	1.2%
24-Aug-15	752	780	28	28	3.7%	3.7%	3.6%
25-Aug-15	764	765	1	1	0.1%	0.1%	0.1%
26-Aug-15	752	770	18	18	2.4%	2.4%	2.3%
27-Aug-15	739	765	26	26	3.5%	3.5%	3.4%
28-Aug-15	778	770	-8	8	-1.0%	1.0%	-1.0%
29-Aug-15	629	720	91	91	14.5%	14.5%	12.6%
30-Aug-15	645	730	85	85	13.2%	13.2%	11.6%
31-Aug-15	693	780	87	87	12.6%	12.6%	11.2%
Minimum	629	720	-20	1	-2.6%	0.1%	-2.6%
Average	737	766	29	33	4.2%	4.7%	3.9%
Maximum	822	810	105	105	15.4%	15.4%	13.4%

Notes:
Forecast peak is rounded to the nearest 5 MW
Forecast peak presented is as reported to the Board. The forecast is updated hourly throughout the day for use in maintaining adequate generation reserves.

Figure 2: Peak Forecast - Island Total Load - August 2015

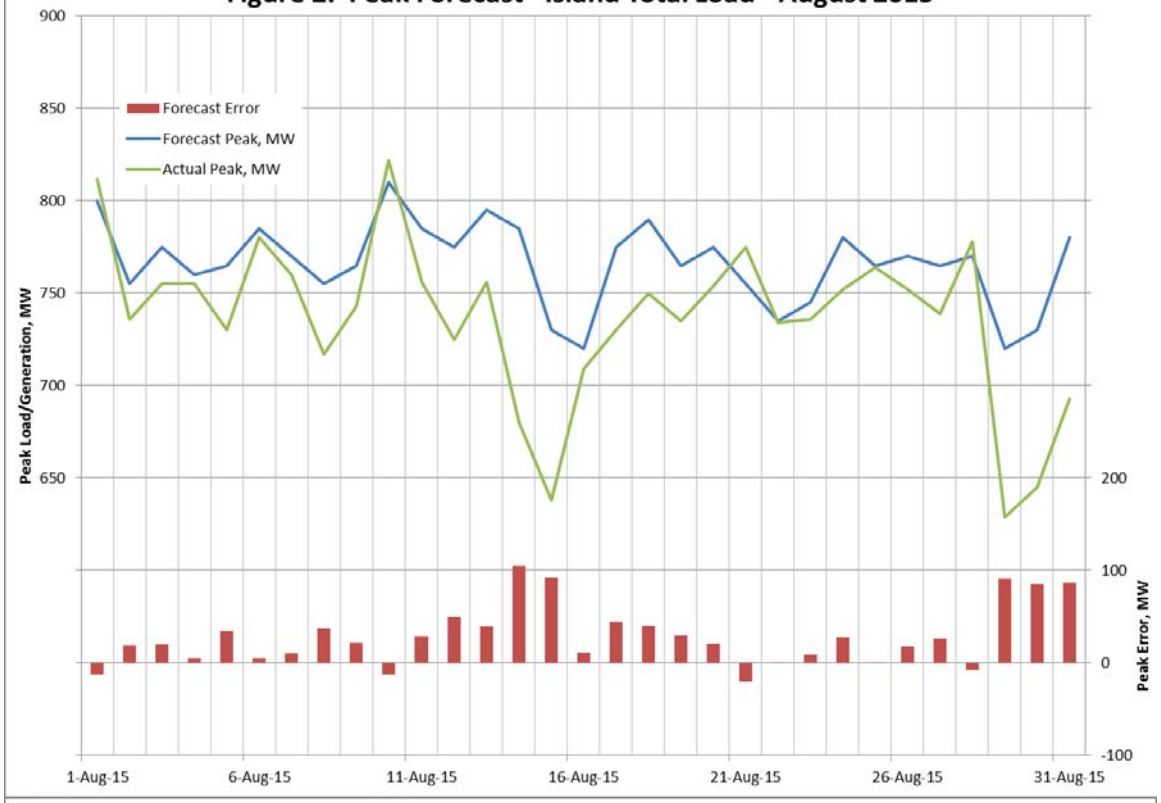

Figure 3: CBPP Load, August 2015, MW

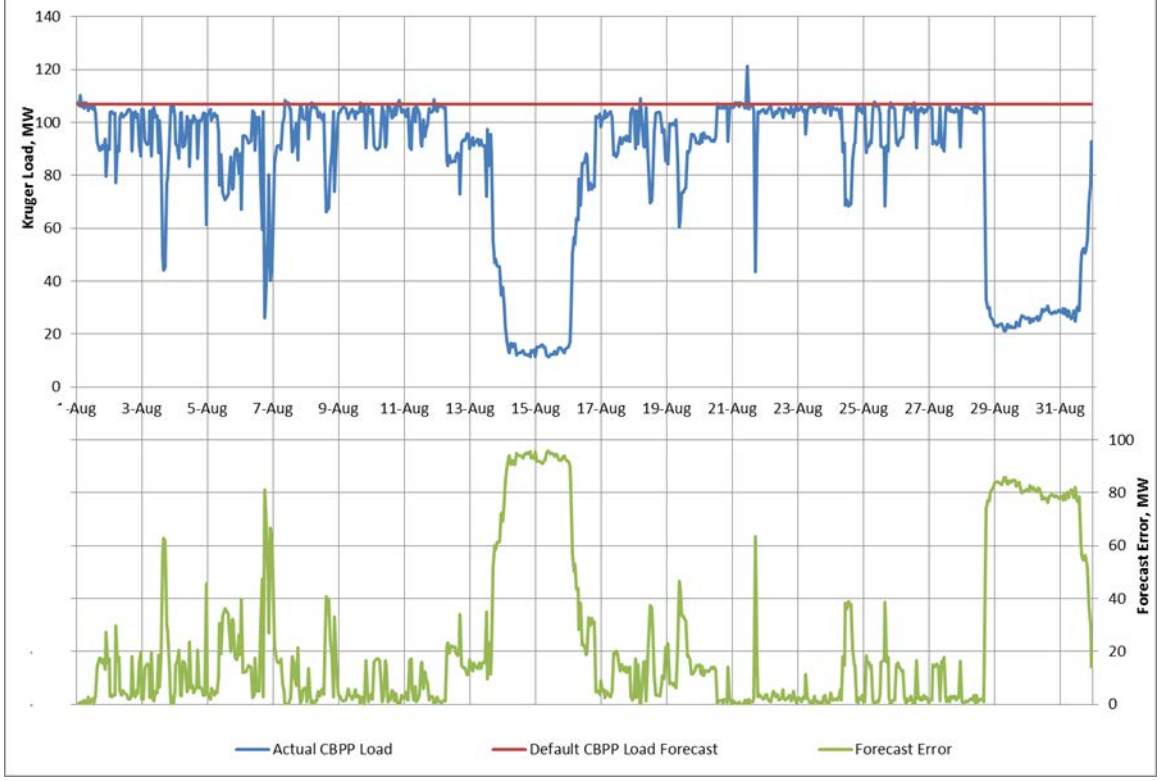

Table 3 August 2015 Analysis of Utility Forecast Error

Date	Actual Peak, MW	Forecast Peak, MW	Error, MW	Absolute Error, MW	Percent Error	Absolute Percent Error	Actual/ Forecast
1-Aug-15	674	640	-34	34	-5.0%	5.0%	-5.3%
2-Aug-15	601	596	-5	5	-0.8%	0.8%	-0.8%
3-Aug-15	617	614	-3	3	-0.5%	0.5%	-0.5%
4-Aug-15	609	601	-8	8	-1.3%	1.3%	-1.3%
5-Aug-15	626	602	-24	24	-3.8%	3.8%	-4.0%
6-Aug-15	630	627	-3	3	-0.5%	0.5%	-0.5%
7-Aug-15	612	608	-4	4	-0.7%	0.7%	-0.7%
8-Aug-15	581	591	10	10	1.7%	1.7%	1.7%
9-Aug-15	604	605	1	1	0.2%	0.2%	0.2%
10-Aug-15	680	652	-28	28	-4.1%	4.1%	-4.3%
11-Aug-15	612	625	13	13	2.1%	2.1%	2.1%
12-Aug-15	601	617	16	16	2.7%	2.7%	2.6%
13-Aug-15	616	636	20	20	3.2%	3.2%	3.1%
14-Aug-15	623	627	4	4	0.6%	0.6%	0.6%
15-Aug-15	575	569	-6	6	-1.0%	1.0%	-1.1%
16-Aug-15	569	561	-8	8	-1.4%	1.4%	-1.4%
17-Aug-15	610	615	5	5	0.8%	0.8%	0.8%
18-Aug-15	611	629	18	18	2.9%	2.9%	2.9%
19-Aug-15	591	589	-2	2	-0.3%	0.3%	-0.3%
20-Aug-15	597	618	21	21	3.5%	3.5%	3.4%
21-Aug-15	606	583	-23	23	-3.8%	3.8%	-3.9%
22-Aug-15	574	558	-16	16	-2.8%	2.8%	-2.9%
23-Aug-15	573	583	10	10	1.7%	1.7%	1.7%
24-Aug-15	612	620	8	8	1.3%	1.3%	1.3%
25-Aug-15	603	603	0	0	0.0%	0.0%	0.0%
26-Aug-15	593	610	17	17	2.9%	2.9%	2.8%
27-Aug-15	572	603	31	31	5.4%	5.4%	5.1%
28-Aug-15	616	610	-6	6	-1.0%	1.0%	-1.0%
29-Aug-15	550	558	8	8	1.5%	1.5%	1.4%
30-Aug-15	556	569	13	13	2.3%	2.3%	2.3%
31-Aug-15	594	618	24	24	4.0%	4.0%	3.9%
Minimum	550	558	-34	0	-5.0%	0.0%	-5.3%
Average	603	604	2	13	0.3%	2.1%	0.3%
Maximum	680	652	31	34	5.4%	5.4%	5.1%