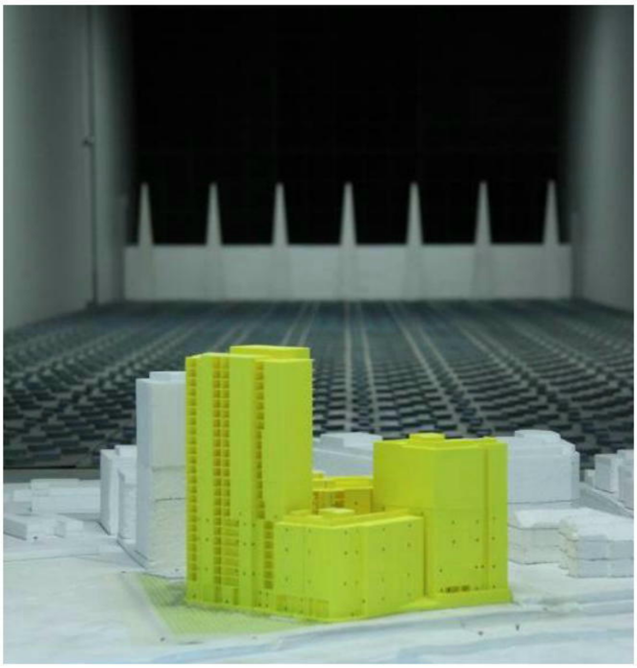

LOT 5, 158-164 HAWKESBURY ROAD & 2A DARCY ROAD, WESTMEAD

NATURAL VENTILATION STUDY

WC963-04F02(REV1) - NV REPORT

MARCH 13, 2017

Prepared for:

Combined Projects (Westmead) P/L

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Redfern, NSW 2016

DOCUMENT CONTROL

Date	Revision History	Issued Revision	Prepared By (initials)	Instructed By (initials)	Reviewed & Authorised by (initials)
March 10, 2017	Initial.	0	MC	TR	KP
March 13, 2017	Ventilated Skylights Included.	1	MC	TR	MC

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EXECUTIVE SUMMARY

This report presents the results from the detailed investigation into the natural ventilation performance of the residential apartments for the proposed development located at Lot 5, 158-164 Hawkesbury Road & 2A Darcy Road, Westmead.

Testing was performed using Windtech's boundary layer wind tunnel facility, which has a 3.0m wide working section and has a fetch length of 14m. Measurements were carried out using a 1:300 scale model of the development. The study model has been constructed based on architectural drawings prepared by the project architect Turner, received January 2017. With window openings and internal layouts based on the architectural drawings and schedules received March, 2017. The proximity model extends to a radius of approximately 375m from the centre of the subject site and includes all of the significant surrounding buildings and topographical effects.

The study model was fitted with a total of 302 individual pressure sensors spread over the external façade of the development which represent the opening locations to all the residential units in the first 9 Levels. A total of 306 different internal natural ventilation flow paths have been considered for the residential apartments in this study. Pressure coefficient measurements are made in the wind tunnel for 36 wind directions, at 10 degree increments for this study. The reference wind climate data used for the air quality criterion is based on an analysis of 22 years of recorded mean wind speed data obtained at the meteorological recording station located within Kingsford Smith Airport in Sydney, from 1995 to 2016. The reference wind climate data used for the thermal comfort criterion is based on an analysis of 74 years of recorded mean wind speed data obtained at the meteorological recording station located within Kingsford Smith Airport in Sydney, from 1940 to 2013.

For this development, the Australian Standard, Ventilation Design for Indoor Air Contaminant Control, AS1668.2-2002 requires a minimum of 2.5 air changes per hours (ACH) for air quality based on occupant and material related contaminants. Also to address occupant thermal comfort, a benchmark was set for airflow velocity through the main living space to achieve a directionally weighted average velocity of 0.4m/s. This is sufficient to provide a thermal cooling sensation and one of the objectives of natural ventilation. Consideration has also been made for the internal apartment layout, including internal openings, on the natural ventilation performance of each unit to ensure suitable circulation is provided throughout the apartment.

The results of the natural cross ventilation characteristics of the various residential apartments of the overall proposed development site indicated the following:

- **Building A** – a total of 62.7% (74 out of 118 residential apartments) in the first 9 storeys of the development will meet the deemed to comply requirements of SEPP65 for natural cross ventilation (i.e. with openings on orthogonal or opposite aspects).

- **Building B** - a total of 50.0% (121 out of 242 residential apartments) in the first 9 storeys of the development will meet the deemed to comply requirements of SEPP65 for natural cross ventilation (i.e. with openings on orthogonal or opposite aspects).

A wind tunnel study was carried out for the remaining residential apartments to determine the adequacy of natural ventilation performance against the abovementioned criteria. The results of the modelled natural ventilation performance are as follows:

- **Building A** –27 of the 44 remaining apartments in the first 9 storeys of the development will achieve the target criteria.
- **Building B** - 67 of the 121 remaining apartments in the first 9 storeys of the development will achieve the target criteria.

With the inclusion of the abovementioned units, the results of the natural ventilation study indicated the following:

- **Building A** – a total of 85.6% (101 of 118 apartments) in the first 9 storeys of the development are naturally cross ventilated (openings on opposite or orthogonal aspects) or achieve the target criteria.
- **Building B** - a total of 77.7% (188 of 242 apartments) in the first 9 storeys of the development are naturally cross ventilated (openings on opposite or orthogonal aspects) or achieve the target criteria.

From the abovementioned results from the detailed study more than 60% of the apartments of the entire development will satisfy the requirements for natural cross ventilation as outlined in SEPP65 or the more stringent criteria as outlined in ventilation standards. Therefore, based on the design of the subject development as proposed, the development will more than satisfy the requirements for natural cross ventilation from Parramatta Council DCP 2011 and SEPP65.

CONTENTS

1 WIND CLIMATE FOR THE SYDNEY REGION

The wind climate for the Sydney region has been refined into two sets of data that will be used in this study in conjunction with the two natural ventilation criterions; air quality and thermal comfort as set out in Section 6.0 of this report.

1.1 Wind Climate for the Air Quality Criterion

The wind climate data used for the air quality criterion is based on an analysis of 22 years of recorded 10-minute mean wind speeds obtained at the meteorological recording station located at Kingsford Smith Airport in Sydney, from 1995 to 2016. The recurrence intervals examined in this study are for the daily average winds.

The air-quality criterion relates to the number of air changes per hour (ACH) required due to expected occupant and material related contaminant production within the dwelling.

The wind climate data used for the air-quality criterion is presented in Table 1a, which also presents the corresponding daily average hourly mean wind speeds. A plot of the wind speed observation data is presented in Figure 1a below, referenced to a height of 10m above ground in open terrain and converted to hourly means. The frequency of occurrence of the regional winds is also shown in Figure 1a for each wind direction.

Table 1a: Regional Directional Wind Speeds for the Sydney Region (daily average hourly mean wind speeds and percentage of observations of wind direction, referenced to 10m height in open terrain)

Wind Direction	Percentage of Observation of Wind Direction (%)	Daily Average Hourly Mean Wind Speed V_{ref} (m/s)
N	6.0	4.0
NNE	8.0	5.8
NE	7.0	6.1
ENE	3.6	5.5
E	3.3	4.9
ESE	3.6	4.8
SE	5.4	5.0
SSE	6.9	6.0
S	9.5	6.7
SSW	6.9	6.7
SW	4.0	5.4
WSW	6.0	6.0
W	6.4	6.2
WNW	7.2	4.9
NW	9.3	4.0
NNW	6.9	3.8

The data indicates that the maximum wind speeds for the region are governed by southerly, north-easterly and westerly winds. These wind directions also correspond to the directions of the most frequent winds for the region.

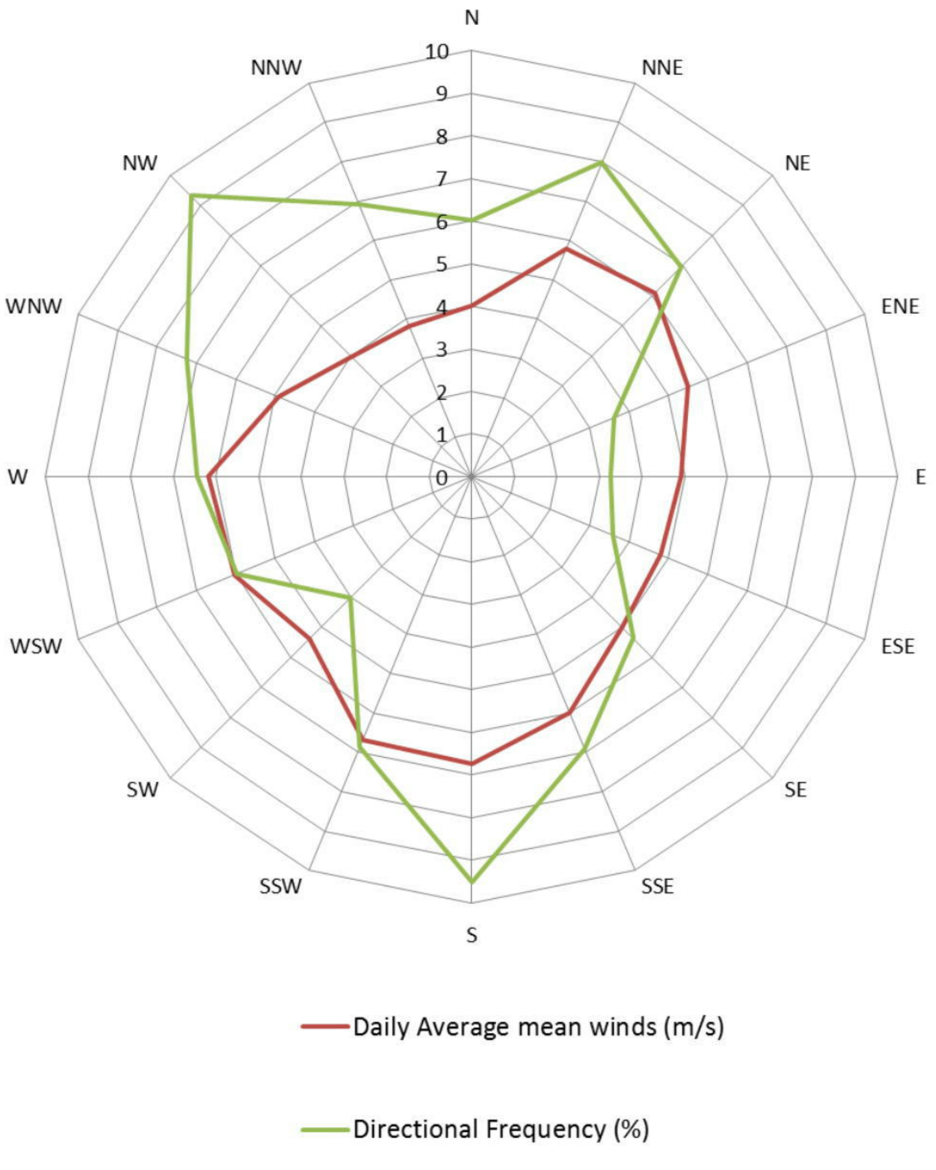

Figure 1a: Daily Maximum Hourly Mean Wind Speeds, and Frequencies of Occurrence, for the Sydney Region (referenced to open terrain at 10m)

1.2 Wind Climate for the Thermal Comfort Criterion

The wind climate data used for the thermal comfort criterion is based on an analysis of 74 years of recorded 10-minute mean wind speeds obtained at the meteorological recording station located at Kingsford Smith Airport in Sydney, from 1940 to 2013. The recurrence intervals examined in this study are for the daily average winds.

The thermal comfort criterion relates to the relation between the impact of air flow within the dwelling and occupant comfort. Hence a separate set of wind climate data has been analysed that excludes events outside the temperature range between 20 °C and 29.5 °C where the cooling sensation provided by the natural movement of air over the human body is more desirable to the occupants of the dwelling.

The wind climate data used for the thermal comfort criterion is presented in Table 1b, which also presents the corresponding daily average hourly mean wind speeds. A plot of the wind speed observation data is presented in Figure 1b below, referenced to a height of 10m above ground in open terrain and converted to hourly means. The frequency of occurrence of the regional winds is also shown in Figure 1b for each wind direction.

Table 1b: Regional Directional Wind Speeds for the Sydney Region (daily average hourly mean wind speeds and percentage of observations of wind direction, referenced to 10m height in open terrain)

Wind Direction	Percentage of Observation of Wind Direction (%)	Daily Average Hourly Mean Wind Speed V_{ref} (m/s)
N	5.8	4.6
NNE	13.0	6.4
NE	15.2	6.5
ENE	6.9	5.8
E	5.7	5.0
ESE	4.6	4.9
SE	7.6	5.1
SSE	8.4	5.8
S	10.4	6.8
SSW	3.4	6.5
SW	1.5	5.1
WSW	2.2	6.6
W	3.0	6.5
WNW	3.7	5.8
NW	4.8	4.7
NNW	3.9	4.8

The data indicates that the maximum wind speeds for the region are governed by southerly, north-easterly, while the westerly winds are significantly reduced due to their predominant occurrence during the cooler winter months of the year.

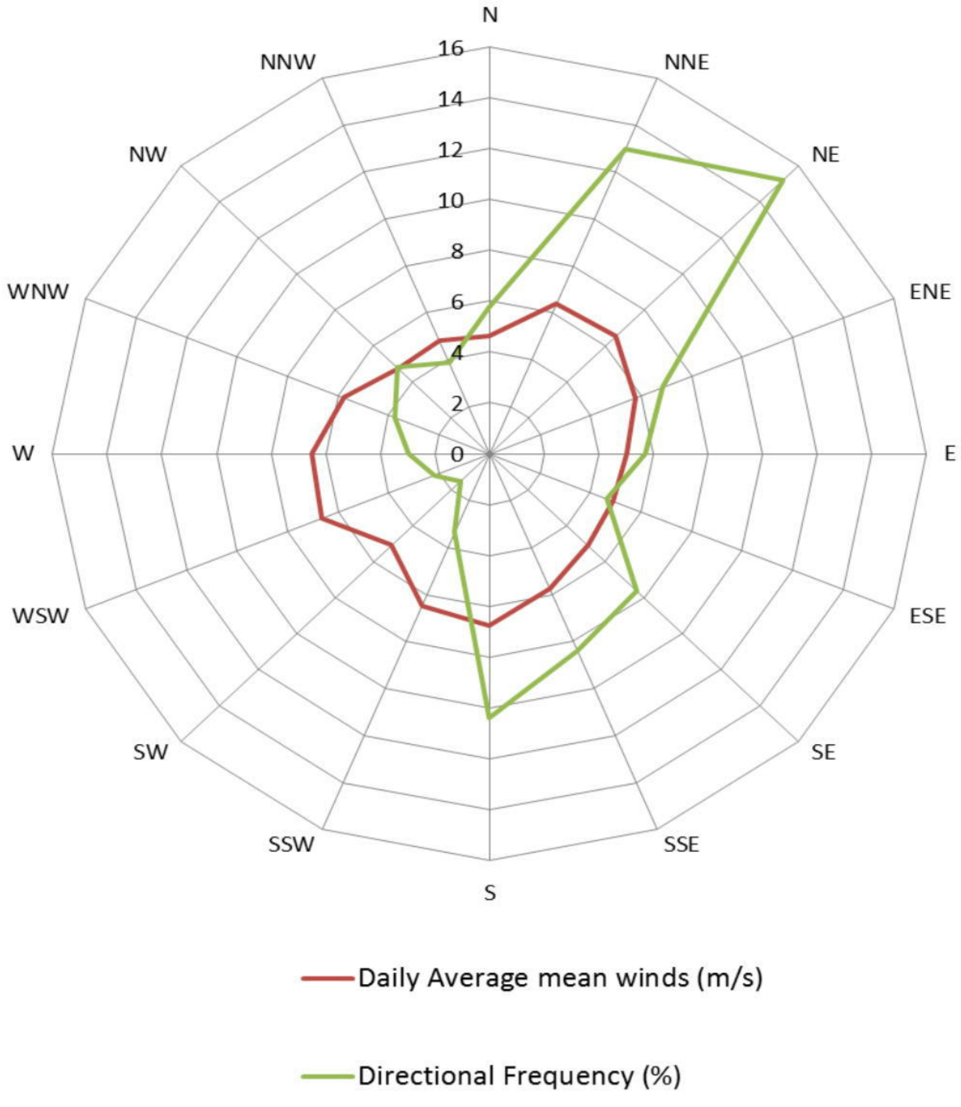

Figure 1b: Daily Maximum Hourly Mean Wind Speeds, and Frequencies of Occurrence for a Temperature Range Between 20 °C and 29.5 °C, for the Sydney Region (referenced to open terrain at 10m)

2 MODEL SETUP

2.1 Wind Model

Testing was performed using Windtech's boundary layer wind tunnel, which has a 3.0m wide working section and has a fetch length of 14m. The model was placed in the appropriate boundary layer wind flow for each of the prevailing wind directions for the wind tunnel testing. The type of wind flow used in a wind tunnel study is determined by a detailed analysis of the surrounding terrain types around the subject site.

The roughness of the earth's surface has the effect of slowing down the prevailing wind near the ground. This effect is observed up to what is known as the boundary layer height, which can range between 500m to 3km above the earth surface depending on the roughness of the surface (i.e.: oceans, open farmland, dense urban cities, etc). Within this range, the prevailing wind forms what is known as a *boundary layer wind profile*.

Various wind codes and standards classify various types of boundary layer wind flows depending on the surface roughness. However, it should be noted that the wind profile does not change instantly due to changes in the terrain roughness. It can take many kilometres (at least 100km) of a constant surface roughness for the boundary layer profile to achieve a state of equilibrium. However, for regions governed by thunderstorm winds, the strong winds are far more localised, and in these situations it is only relevant to analyse the nearby surrounding terrain types.

Description of the standard boundary layer wind profiles for various terrain types are summarised as follows:

- **Terrain Category 1.0**: Extremely flat terrain. Examples include inland water bodies such as lakes, dams, rivers, etc.
- **Terrain Category 1.5**: Relatively flat terrain. Examples include oceans and desert.
- **Terrain Category 2.0**: Open terrain. Examples include grassy fields and plains and open farmland (without buildings or trees)
- **Terrain Category 2.5**: Relatively open terrain. Examples include farmland with scattered trees and buildings and very low-density suburban areas.
- **Terrain Category 3.0**: Suburban and forest terrain. Examples include suburban areas of towns and areas with dense vegetation such as forests, bushland, etc.
- **Terrain Category 3.5**: Relatively dense suburban terrain. Examples include centres of small cities, industrial parks, etc.

- **Terrain Category 4.0**: Dense urban terrain. Examples include centres of large cities with many high-rise towers, and also areas with many closely-spaced mid-rise buildings.

For this study, the shape of the boundary layer wind flows over standard terrain types is defined as per ISO4354:2009. These are summarised in Table 1, referenced to the study reference height of 82.1m above ground. An analysis of the effect of changes in the upwind terrain roughness was carried out for each of the wind directions studied. This has been undertaken based on the method given in ESDU-82026:2002 and ESDU-83045:2002 over a fetch length of 50km, which is appropriate for synoptic wind events. An aerial image showing the surrounding terrain is presented in Figures 2a and 2b for a radius of 5km and 50km respectively (measured from the edge of the wind tunnel proximity model, which is centred on the development site and represents an area with a radius of 375m).

For each of the 36 wind directions tested in this study, the approaching boundary layer wind profiles modelled in the wind tunnel matched the model scale and the overall surrounding terrain characteristics beyond the 375m radius of the proximity model.

Table 2: Terrain and Height Multipliers and Turbulence Intensities, and the Corresponding Roughness Lengths, for the Standard ISO4354:2009 Boundary Layer Profiles

Terrain Category	Terrain and Height Multipliers (at 82.1m above ground)			Turbulence Intensity	Roughness Length (m)
	$k_{tr,T=3600s}$ *(hourly)*	$k_{tr,T=600s}$ *(10-minute)*	$k_{tr,T=3s}$ *(3-second)*	$I_{v,82.1m}$	$z_{0,r}$
1.0	1.01	1.04	1.32	0.100	0.003
1.5	0.96	0.99	1.29	0.116	0.01
2.0	0.91	0.94	1.27	0.134	0.03
2.5	0.84	0.87	1.24	0.160	0.1
3.0	0.76	0.80	1.20	0.191	0.3
3.5	0.66	0.71	1.14	0.242	1
4.0	0.55	0.60	1.07	0.316	3

The hourly mean wind speed and turbulence profiles, as well as the normalised power spectral density function, that were modelled in the wind tunnel match the full-scale equivalent values for the terrains being modelled for each wind direction tested, as indicated in Appendix C.

The reference wind speeds were corrected for changes in the upstream land topography and referenced to the tower reference height for each wind direction tested. These are presented in Table 3 below. Note that the reference height of the development used for this study is 82.1m above ground.

Table 3: Mean Reference Wind Speeds at the Site (at 82.1m)

Wind Direction (degrees)	Mean Terrain and Height Factors at 82.1m $k_{tr,T=3600s}$	Percentage of Observations (%)	Mean Wind Speeds at the Site, Referenced to 82.1m (m/s) $\overline{V}_{daily@82.1m}$
N	0.75	5.8	5.4
NNE	0.77	13.0	7.2
NE	0.79	15.2	7.3
ENE	0.80	6.9	6.5
E	0.81	5.7	5.7
ESE	0.78	4.6	5.7
SE	0.79	7.6	5.8
SSE	0.80	8.4	6.7
S	0.78	10.4	8.7
SSW	0.74	3.4	8.3
SW	0.74	1.5	6.7
WSW	0.74	2.2	8.9
W	0.72	3.0	8.6
WNW	0.75	3.7	7.8
NW	0.74	4.8	6.1
NNW	0.73	3.9	5.7

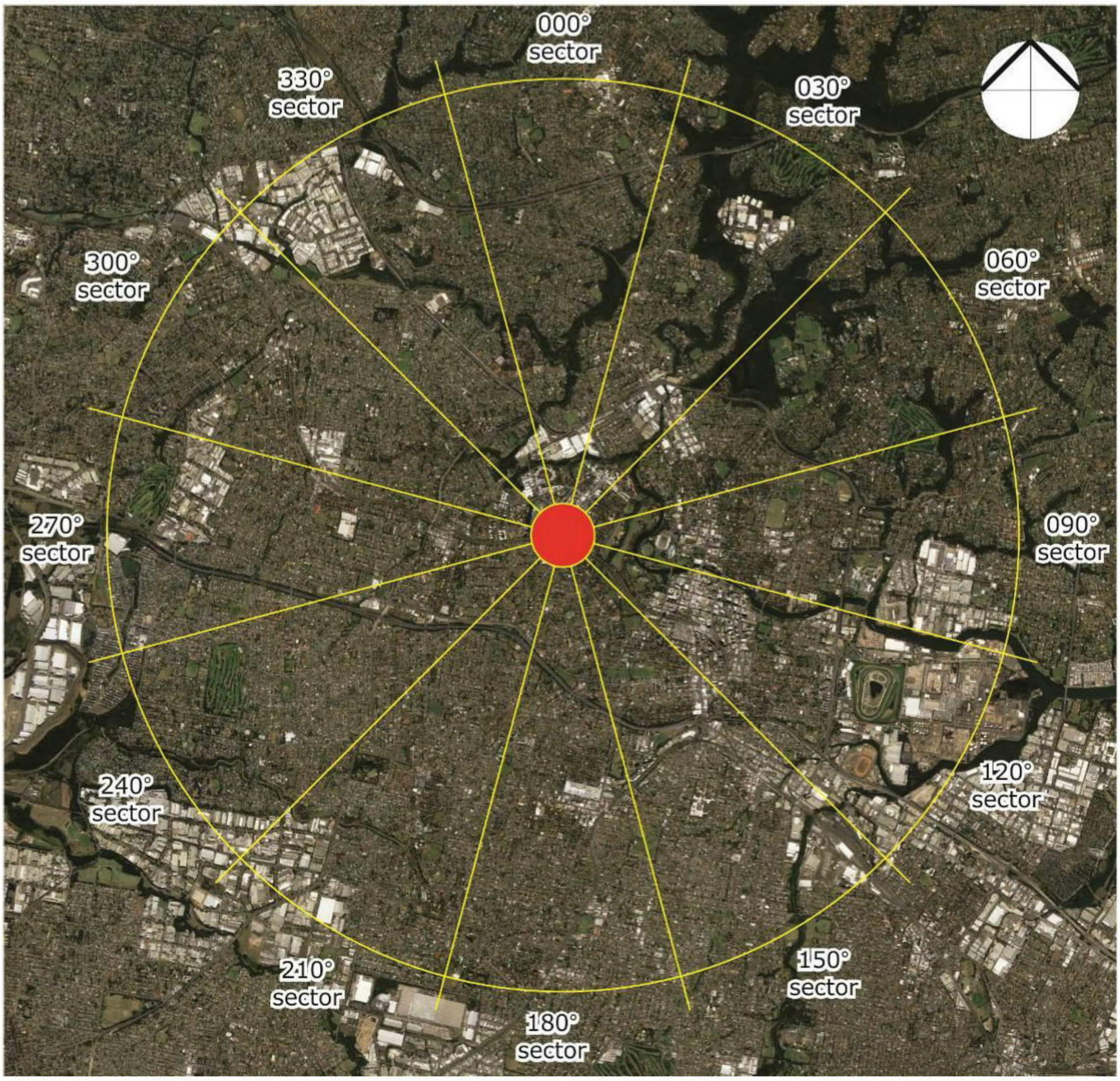

Figure 2a: Aerial Image showing the Surrounding Terrain

(radius of 5km from the edge of the proximity model, which is coloured red)

Figure 2b: Aerial Image showing the Surrounding Terrain
(within a radius of 50km from the edge of the proximity model)

2.2 Study Model

Wind tunnel testing was carried out using a 1:300 scale model of the proposed development. The study model incorporates all of the necessary architectural features on the facades to ensure an accurate wind model is achieved in the wind tunnel. The model was constructed using a Computer Aided Manufacturing (CAM) process to ensure a high level of detail and accuracy were achieved in the study model. The effect of nearby buildings and land topography has been accounted for through the use of a proximity model, which represents a radius of approximately 375m from the development site. Photographs of the model used for the wind tunnel testing of this project are presented in Figures 3a to 3g on the following pages.

The study model was fitted with a total of individual 302 pressure sensors spread across the entire external façade of the development measuring the pressure coefficients at each of the opening locations to the residential units and central atrium of the building. A total of 306 different internal flow path pairings have been considered for the residential units of the building for this study.

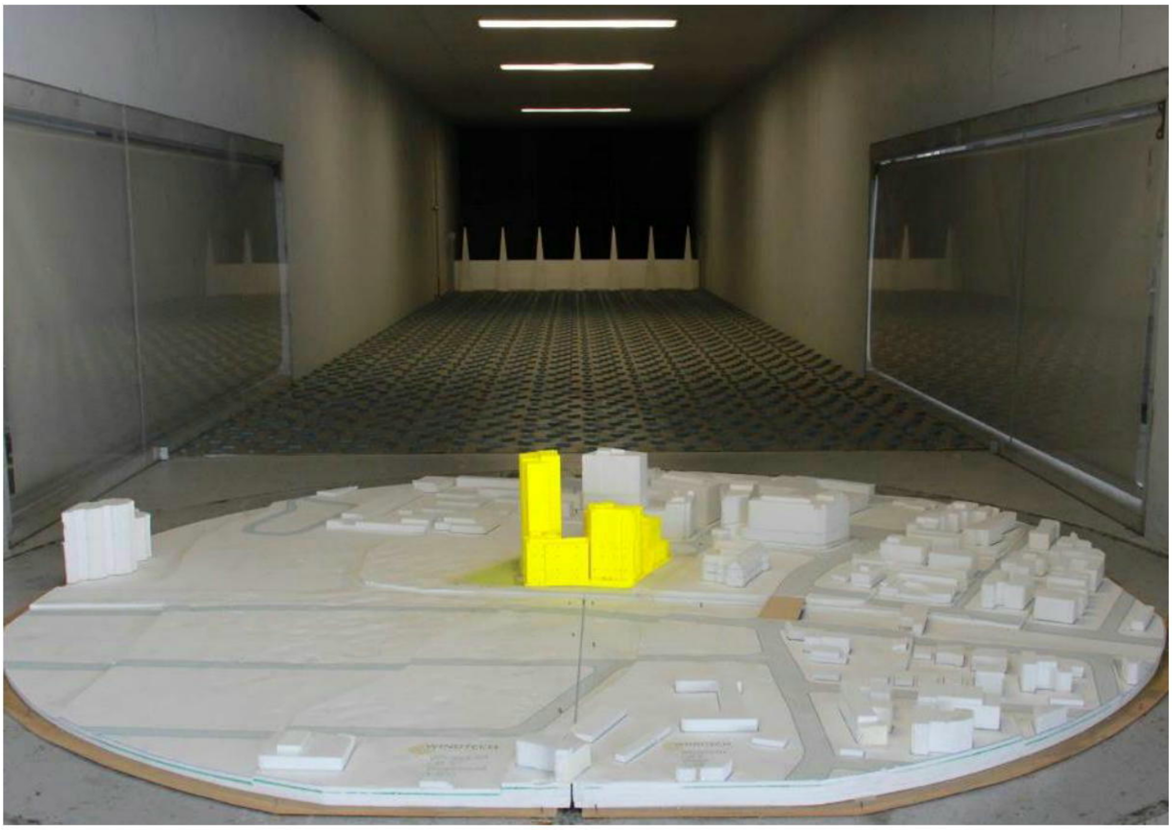

Figure 3a: Photograph of the Wind Tunnel Model (view from the south)

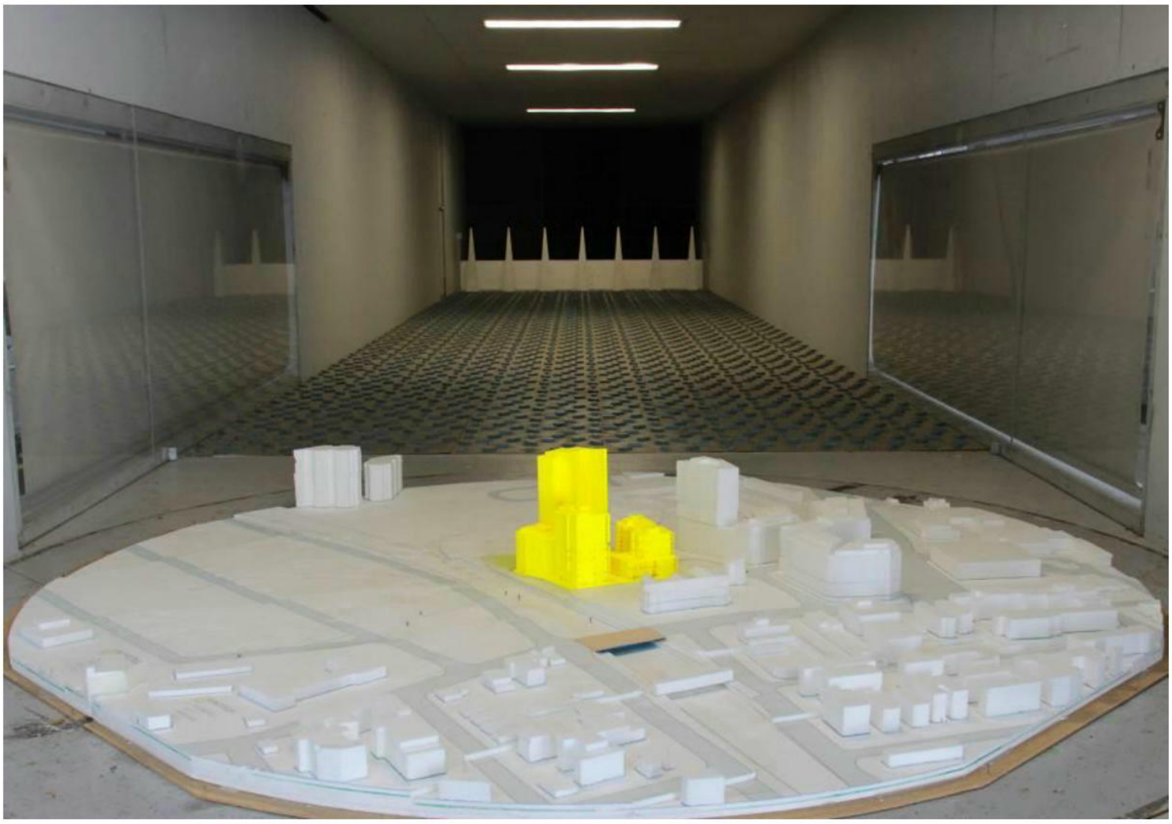

Figure 3b: Photograph of the Wind Tunnel Model (view from the south-east)

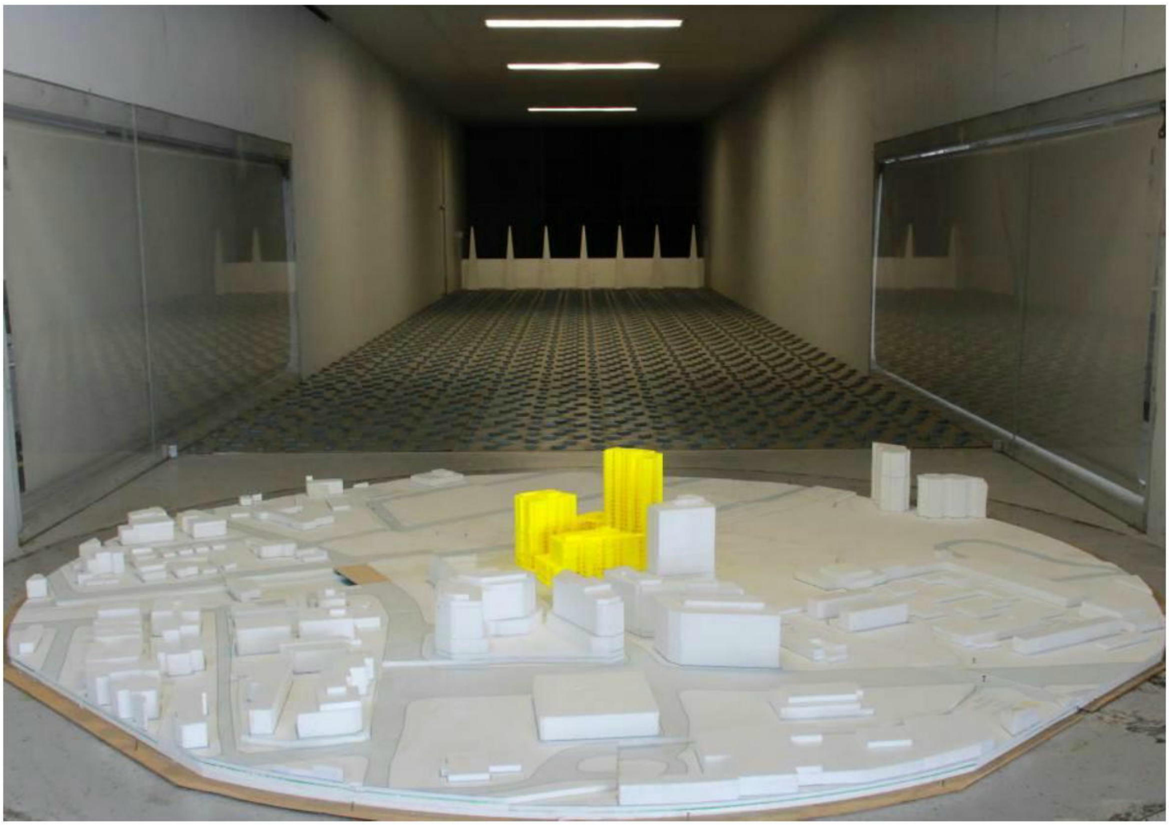

Figure 3c: Photograph of the Wind Tunnel Model (view from the north-east)

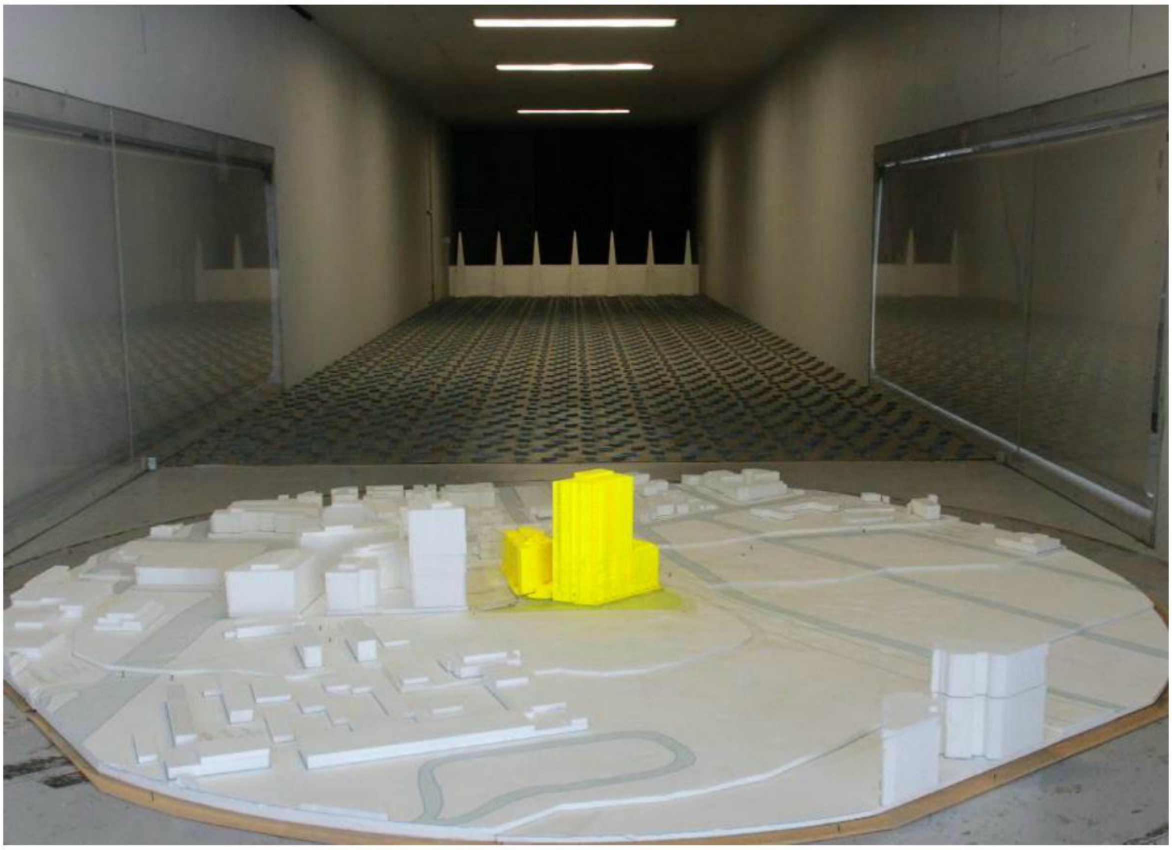

Figure 3d: Photograph of the Wind Tunnel Model (view from the north-west)

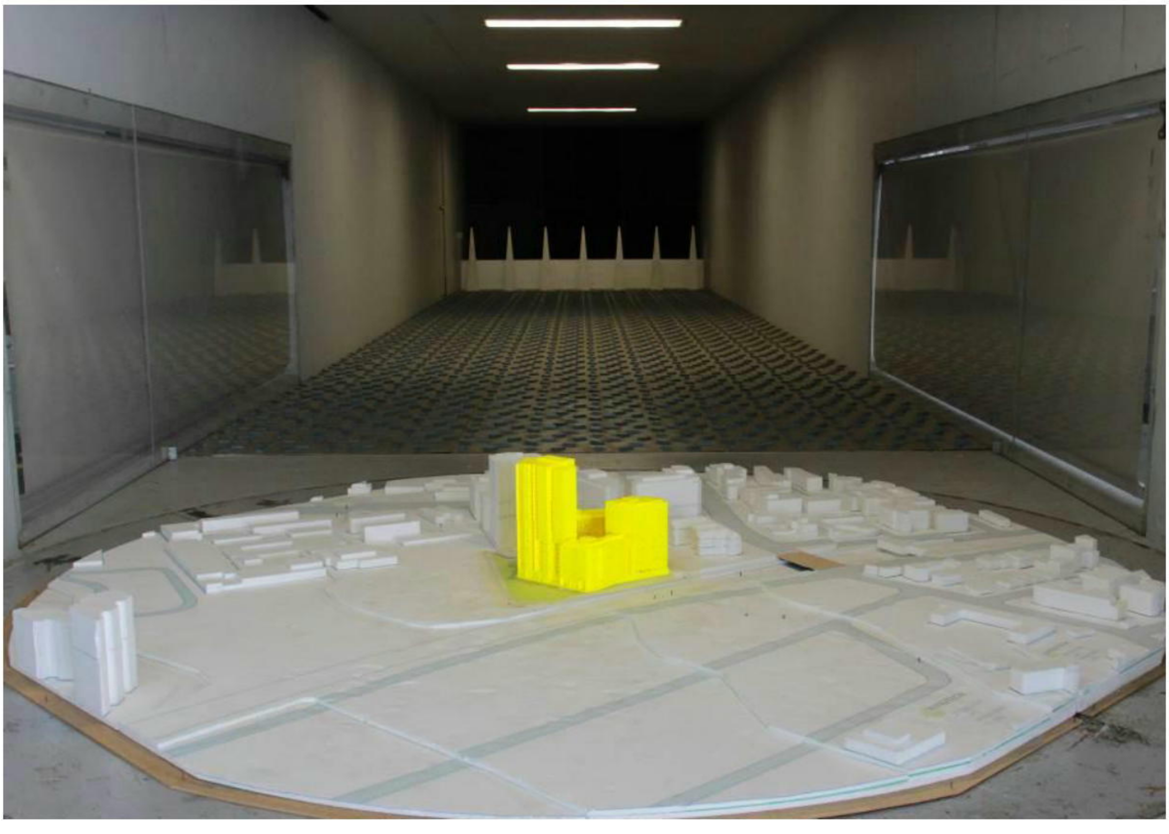

Figure 3e: Photograph of the Wind Tunnel Model (view from the south-west)

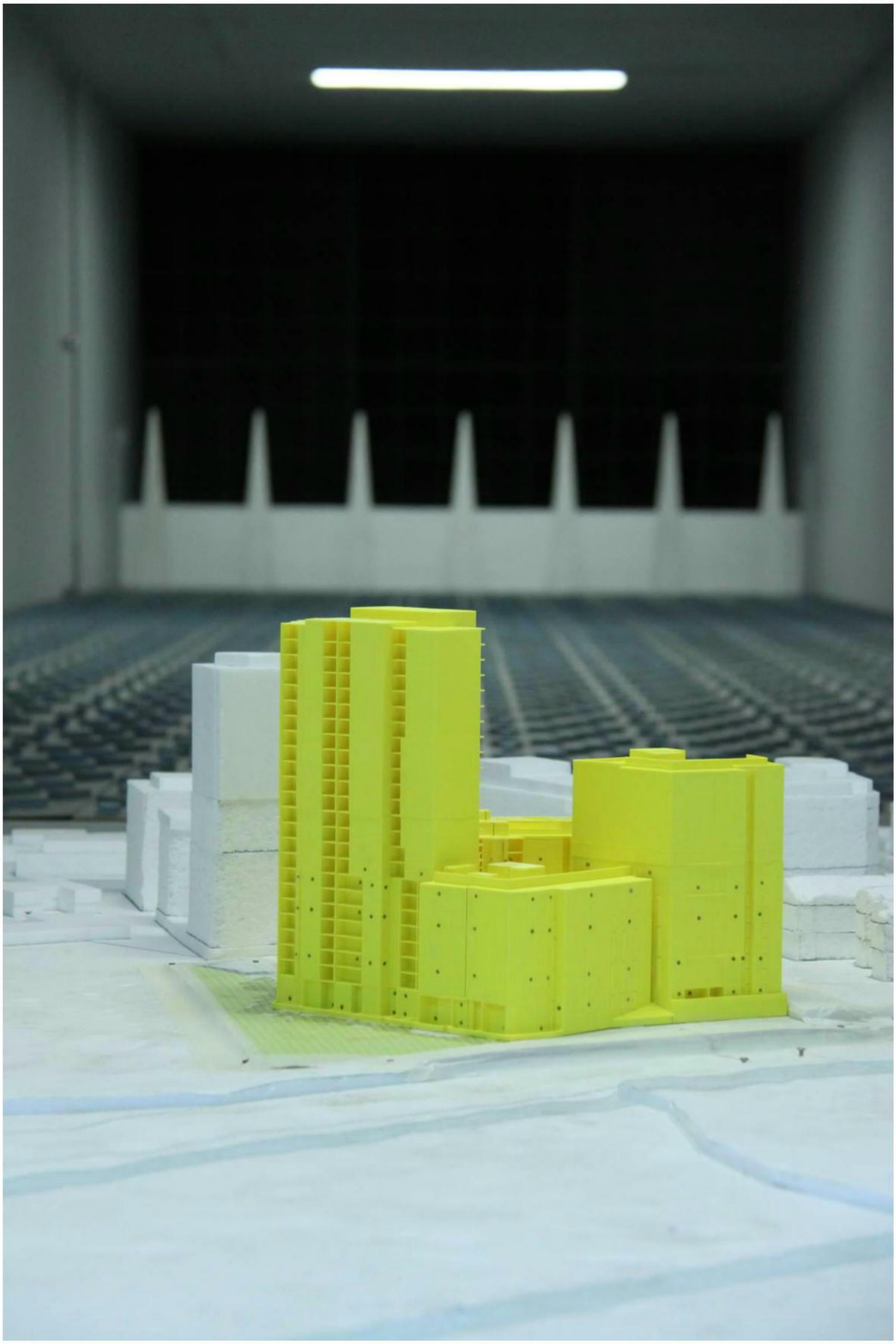

Figure 3f: Photograph of the Wind Tunnel Model (view from the south-west)

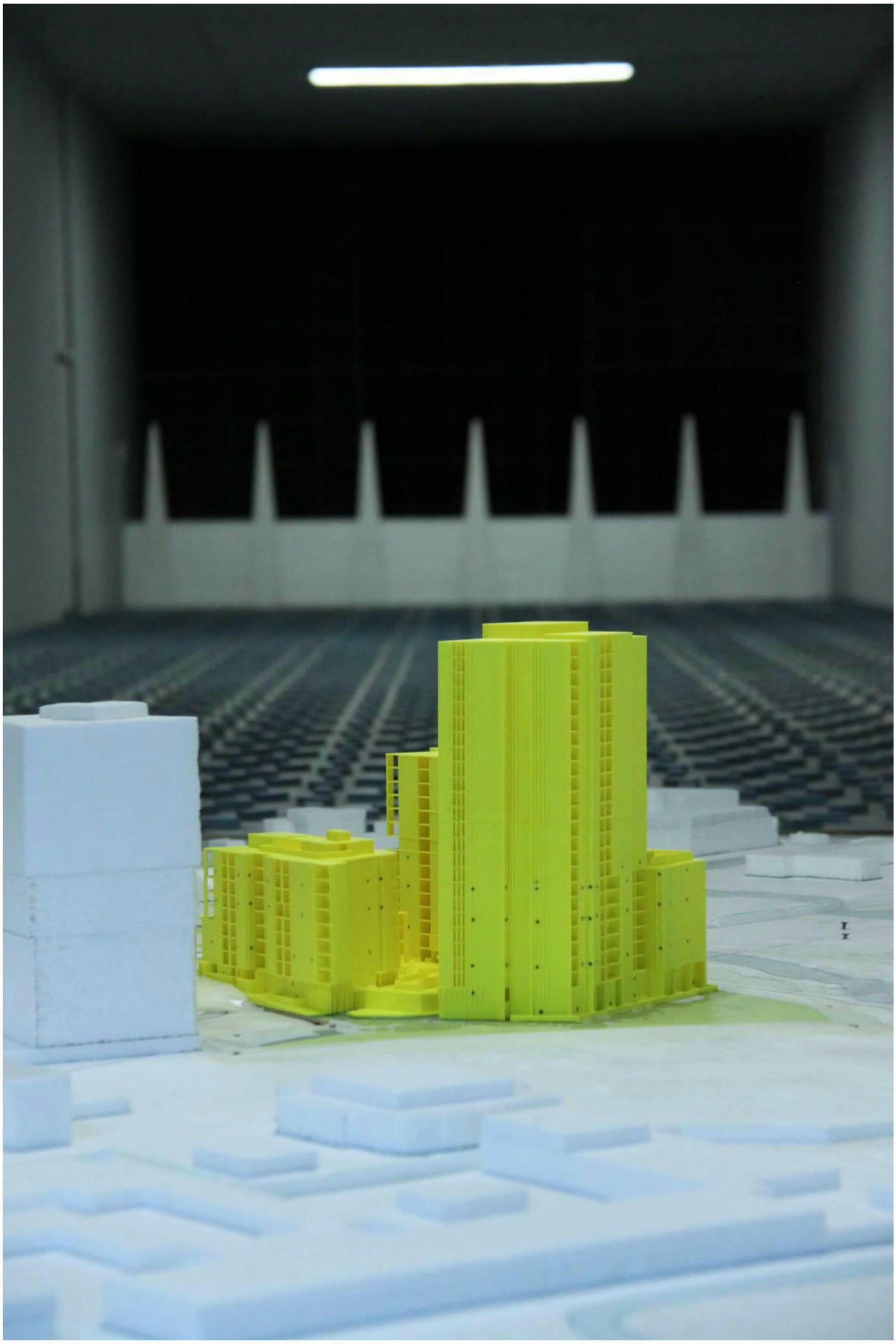

Figure 3g: Photograph of the Wind Tunnel Model (view from the north-west)

3 TEST PROCEDURE

The test procedures followed for the wind tunnel tests performed for this study generally adhere to the guidelines set out in the Australasian Wind Engineering Society Quality Assurance Manual (AWES-QAM-1-2017) and ASCE-7-10 (Chapter C31). The testing was performed in Windtech's blockage tolerant boundary layer wind tunnel facility. The good agreement between Windtech's wind tunnel cladding pressure results and full-scale data from the Texas Tech Experimental Building provides some indication of the accuracy of Windtech's wind tunnel results (Rofail, 1995). Due to the effective design of Windtech's blockage tolerant wind tunnel facility, no corrections for blockage generated by the model were required for this study.

The reference pressure was measured 3m upstream of the study building, at a height of 1.5m in the wind tunnel. This is to ensure that the pitot-static probe, the instrument used to measure the static and total pressure during testing, is located in a low turbulence region of the approaching boundary layer wind profile in the wind tunnel. This height also avoids any interference with the wind flow onto the model. The mean velocity measured at this reference position was measured to be approximately 14.0m/s. A sample time of 32 seconds (model scale time) was used which corresponds to a minimum full-scale sample time of at least 45 minutes, which is suitable for this type of study.

The pressure coefficients measured in the wind tunnel require an adjustment factor to be applied or the difference in the velocity pressure between the reference location and the model reference height. However, note that the pressure coefficients presented in this report have already had this adjustment factor applied, and no further corrections are necessary. The reference pressure is related to the reference mean wind speed by the following equation;

$$\text{Reference Pressure (kPa)} = \frac{1}{2}\rho V^2 = \left(0.6\times10^{-3}\right)V^2 \qquad (3.1)$$

where the air density ρ is taken to be 1.2 kg/m^3, which is typical for sea-level atmospheric conditions.

Mean, standard deviation, maximum and minimum pressures were obtained from the wind tunnel measurements, which were made from 36 wind directions at 10 degree increments. Peak, maximum and minimum pressure coefficients were obtained using the standard upcrossing technique. In this method the pressure range of each signal is divided into very small bands. The data consists of the number of crossings of the various bands by the pressure signal in a positive slope (or negative slope for minimum pressures). This data is used to carry out a statistical analysis of the pressure signal, assuming a Poisson distribution for the number of crossings. The upcrossing analysis of the peak pressures is performed on-line. The peak maximum and minimum pressures are derived from Fisher Tippett Type I parameters (Holmes, 2001). This method produces peak pressures that are more repeatable than simply adopting the measured extreme value and is more efficient than the other statistical techniques as it requires only 30 minutes of sampling time (in full-scale) (Rofail & Kwok, 1991).

The pressure signal was first low-pass filtered at 500Hz and then digital filtering was applied over this range to provide an unbiased response from the pressure measurement system (Rofail et al., 2004). This corresponds to a full-scale frequency range of approximately 0 to 4 Hz in full-scale. The pressure signal was sampled at a rate of 1,024Hz per channel.

The application of wind tunnel testing for the modelling of natural ventilation has been reported previously by Rofail and Aurelius (2004) and Peddie and Rofail (2010 and 2011).

4 DESIGNING FOR NATURAL VENTILATION

Natural ventilation is a primary design concept to reduce or remove the requirement for mechanical ventilation and/or air-conditioning of a building. This provides an environmental benefit by reducing greenhouse gas emissions due to the constant demand for mechanical ventilation and air-conditioning by the occupants. It has also been found that a natural ventilated building will generally reduce the reliance of artificial lighting due to window opening locations to provide ventilation, also providing additional lighting aspects. It is not only environmentally that natural ventilation is beneficial, one other aspects is the financial benefit, both in construction and running costs of the development. Although a naturally ventilated designed building will require more window openings, the benefit of not having to install mechanical ventilation units greatly outweighs this cost. Running costs are also reduced with no ongoing mechanical ventilators and benefits from reduced reliance on artificial lighting. (Peddie and Rofail, 2010)

Furthermore, it has been found that a naturally ventilated building reduces what is commonly known as Sick Building Syndrome (SBS) (Chenvidyakarn, 2010 and Awbi, 2010). Occupants of mechanical or air-conditioned buildings are known to be susceptible to symptoms including itchy eyes, coughs, sneezes and drowsiness. This commonly leads to lower productivity or more people being off sick then when compared to naturally ventilated buildings.

4.1 Natural Ventilation Guidelines

The implementation of natural ventilation into the design of a building is something that should be incorporated from the early stages of the design process to ensure an effective design solution. There are several design guidelines, detailed below, which should be considered in the initial design process when designing for natural ventilation. Some of these may conflict with other climate responsive strategies (such as orientation and shading devices to minimise solar gain) or other design considerations. It is important to understand the general nature of natural ventilation and these guidelines provide some insight to the concept of natural ventilation.

1. In hot, humid climates, maximize air velocities in the occupied zones for bodily cooling. In hot, arid climates, night time ventilation for structural cooling, when the temperature is low is more advantageous.

2. Take advantage of topography, landscaping, and surrounding buildings to redirect airflow and give maximum exposure to breezes. Use vegetation to funnel breezes and avoid wind dams, which reduce the driving pressure differential around the building. Site objects should not obstruct inlet openings.

3. Shape the building to expose maximum surface area to breezes.

4. Use architectural elements such as wing-walls, parapets, and overhangs to promote airflow into the building interior.

5. The long facade of the building and the majority of the door and window openings should be oriented with respect to the prevailing summer breezes. If there is no prevailing direction, openings should be sufficient to provide ventilation regardless of wind direction.

6. Windows should be located in opposing pressure zones. Two openings on opposite sides of a space will increase the area ventilated. Openings on adjacent sides force air to change direction, providing ventilation to a greater area depending on window opening locations. The benefits of the window arrangement depend also on the internal layout of the room.

7. If a room has only one external wall, better airflow is achieved with two widely spaced windows to maximise pressure differentials.

8. If the openings are at the same level and near the ceiling, much of the flow may bypass the occupied level and be ineffective in diluting occupant level contaminants.

9. The stack effect requires sufficient vertical distance between openings be advantageous; the greater the vertical distance, the greater the ventilation potential.

10. Openings in the vicinity of the Neutral Pressure Level (NPL) are least effective for thermally induced ventilation. If the building has only one large opening, the NPL tends to move to that level, reducing the pressure potential across the opening.

11. Greatest flow per unit area of total opening is obtained by inlet and outlet openings of nearly equal areas. An inlet window smaller than the outlet creates higher inlet velocities. An outlet smaller than the inlet creates lower but more uniform air speed through the room.

12. Openings with areas much larger than calculated are sometimes desirable when anticipating increased occupancy or very hot weather.

13. Horizontal windows are generally better than square or vertical windows. This is because they enable airflow over a wider range of wind directions and are most beneficial in locations of shifting prevailing winds.

14. Window openings should be accessible to and operable by occupants to enable control of their environment conditions and comfort levels.

15. Inlet openings should not be obstructed by indoor partitions. Partitions can be placed to split and redirect airflow, but should not restrict flow between the building's inlets and outlets.

16. Vertical airshafts or open staircases can be used to increase and take advantage of stack effects. However, enclosed stair-cases intended for evacuation during a fire should not be used for ventilation.

17. Internal openings should make use of common walls either side of the opening to minimise restriction of the airflow through the opening.

4.2 Types of Natural Ventilation Openings

Natural ventilation openings include: (1) windows, doors; (2) roof ventilators and skylights; (3) stacks; and (4) specially designed inlet or outlet openings.

Windows transmit light and provide ventilation when open and can be operated by sliding vertically or horizontally; by tilting on horizontal pivots at or near the centre; or by swinging on pivots at the top, bottom, or side. The type of pivoting used is important for weather protection and airflow rate. For optimal weather protection a top pivoting window would most suitable, however a horizontal or vertically sliding window will provide the most beneficial airflow rate due to minimal resistance flow path through the opening.

4.3 External Openings

The natural ventilation of a unit is dependent on several factors, some of which are the location, size and type of external opening to the unit. As describe above, there are numerous types of external openings including windows, doors, louvres and vents. The efficiency of these openings to allow airflow into and out of the apartment is dependent on the type of opening and the effective opening area, and also the opening area in relation to the associated wall area.

This efficiency of the opening to allow airflow is known as the discharge coefficient C_d and for a standard window opening is approximately 0.65. Aynsley (1977) has also detailed the variance of the discharge coefficient of an opening which is dependent on the outlet area to wall area ratios.

4.4 Internal Openings

The internal layout of a unit is critical on the natural ventilation performance of the internal flow path. When considering the internal layout of a unit, two key factors need to be taken into account, including:

- Flow path through a unit;
- Internal openings between external openings of the unit.

The flow path through an apartment between two external openings will affect any potential energy loses of the airflow as it travels between two pressure potential areas (external openings). The amount of energy loss which will occur is dependent on the amount of contractions or funnelling of the airflow through the unit. This includes passing through doors and corridors, as well as bends in the internal flow path. Aynsley(1977) provides details for a typical range of discharge coefficients for different internal opening configurations depending on the location and size of the opening.

4.5 Roof Ventilators and Skylights

Roof ventilators provide a weatherproof opening to an internal space and generally operate as an air outlet. Capacity is determined by the ventilator's location on the roof; resistance the ventilator and its ductwork offer to airflow; its ability to use kinetic wind energy to induce flow by centrifugal or ejector action; and the height of the draft.

Natural draft or gravity roof ventilators can be stationary, pivoting, oscillating, or rotating. Selection criteria include ruggedness, corrosion resistance, storm proofing features, dampers and operating mechanisms, noise, cost, and maintenance. Natural ventilators can be supplemented with power-driven supply fans; the motors need only be energized when the natural exhaust capacity is too low. Gravity ventilators can have manual dampers or dampers controlled by thermostat or wind velocity.

A roof ventilator should be positioned so that it unrestricted to the prevailing winds. Turbulence created by surrounding obstructions, including higher adjacent buildings, impairs a ventilator's ejector action. The ventilator inlet should be conical or bell mouthed to give a high flow coefficient. The opening area at the inlet should be increased if screens, grilles, or other structural members cause flow resistance. Building air inlets at lower levels should be larger than the combined throat areas of all roof ventilators.

4.6 Stacks

Stacks or vertical flues should be located where wind can act on them from any direction. Without wind, the roof stacks are still able to remove internal airstack effect alone remove air from the room with the inlets. The resistance to airflow should be minimised to improve the effective ventilation due to stack effect.

A combination of above types of openings can be used to optimise the natural ventilation potential.

5 METHOD OF ANALYSIS

5.1 Measurement of Pressure Coefficients in the Wind Tunnel

The results are first reduced into the form of pressure coefficients with respect to a reference mean velocity pressure at the building reference height. These external pressure coefficients can be defined by the following equations:

$$C_{p_{mean}} = \frac{\bar{p} - p_0}{\frac{1}{2}\rho \overline{V}_{BH}^{\,2}} \quad (5.1) \qquad C_{p_\sigma} = \frac{p'}{\frac{1}{2}\rho \overline{V}_{BH}^{\,2}} \quad (5.2)$$

$$C_{p_{max}} = \frac{p_{max} - p_0}{\frac{1}{2}\rho \overline{V}_{BH}^{\,2}} \quad (5.3) \qquad C_{p_{min}} = \frac{p_{min} - p_0}{\frac{1}{2}\rho \overline{V}_{BH}^{\,2}} \quad (5.4)$$

Definitions of the terms above are described as follows:

$C_{p_{mean}}$	mean pressure coefficient	$\bar{p}$	mean pressure (Pa)
C_{p_σ}	standard deviation pressure coefficient	p'	standard deviation pressure (Pa)
$C_{p_{max}}$	maximum pressure coefficient	p_{max}	maximum pressure (Pa)
$C_{p_{min}}$	minimum pressure coefficient	p_{min}	minimum pressure (Pa)
ρ	air density (kg/m3)	p_0	reference static pressure (Pa)
$\overline{V}_{BH}$	mean velocity at the building reference height (m/s)		

The directional results of these coefficients are plotted in Appendix A within this report. All coefficient data presented in this report is referenced to the mean velocity pressure at the building reference height.

5.2 Natural Ventilation Driving Mechanisms

Natural ventilation is driven by pressure differences across the openings caused by ambient pressure and temperature differences between different openings within a unit. Alternatively, the differences can be between the internal pressure in a unit and the roof pressure in the case of a room having an auxiliary ventilation system using roof vents (stack effect). For a mid-wall unit the internal pressure is dominated by the pressure at the dominant opening to the unit from the balcony etc.

Natural ventilation is the intentional flow of outdoor air due to wind and thermal pressures through controllable openings and can be used to effectively control both temperature and contaminants, particularly in mild climates. Temperature control by natural ventilation is often the only means of providing cooling when mechanical air-conditioning is not available. The arrangement, location, and control of ventilation openings should combine the driving forces of wind and temperature to achieve desired ventilation rate and good distribution of fresh air through the building.

Our experience is that thermally driven components in natural ventilation are negligible when compared with the pressure driven components. Thermal driven ventilation is becomes more dominant with large, multi-storey internal voids with purpose designed solar/thermal walls.

5.2.1 Wind Driven Ventilation

The characteristics and locations of the external and internal openings determine the above wind driven pressure differences and the resultant flow of air. The wind pressures acting on different openings will determine the internal static pressure of the tunnel in order to maintain the continuity equation (mass flow rate of air into the tunnel is equal to the mass flow rate of air out of the tunnel).

The equivalent air-speed within the unit has then been determined from Equation 6.6 below. The air-speed which would be experienced by the occupant of the apartment has been determined based on a nominal internal area of 1.8m². A nominal size internal area of approximately an internal corridor open has been taken as this provides a more suitable internal air-speed. It is assumed that the external doors and windows will be opened completely to achieve natural ventilation, however the occupants would not necessarily want to stand adjacent to a window opening to experience this affect.

$$v_{\text{internal}} = \frac{Q}{A_{\text{internal}}} \quad (5.5)$$

The average airflow through the internal space is taken as the weighted average of the airflow for all wind directions weighted based on the daily average percentage of occurrence of observations for Sydney. Note that the percentage of occurrence for each wind direction also takes into account the percentage of calm events for the Sydney region.

Full-scale testing and comparison with wind tunnel measurements has also been undertaken by Peddie and Rofail (2011). They provide a direct comparison between the measured natural ventilation performance of a residential building, including between windows and also ventilation shafts. Their paper provided a very close comparison between the two and enabled a far better understanding of the effect of the internal flow path on natural ventilation performance.

5.2.1.1 Openings in Series

The wind driven ventilation between three or more openings in series can be determined by the following:

$$Q = \left[\frac{\left(C_{p_1} - C_{p_{n+1}}\right) v_h^2}{\frac{1}{C_{d_1}^2 A_1^2} + \frac{1}{C_{d_2}^2 A_2^2} + \frac{1}{C_{d_3}^2 A_3^2} + \ldots + \frac{1}{C_{d_n}^2 A_n^2}} \right]^{\frac{1}{2}} \quad (5.6)$$

C_{p_1}	mean pressure coefficient at Opening 1	v_h	Reference mean wind speed at building height, h (m/s)
C_d	discharge coefficient of the opening	A	openable area of the opening (m^2)
Q	mass flow rate along the flow path through the unit (m^3/s)	v_1	average air speed at opening 1 (m/s)

5.2.1.2 Openings in Parallel

The wind driven ventilation between three or more openings in parallel can be determined by determining the internal pressure for the volume linking the various openings. This is obtained by simultaneously equating the flow rate for the various openings using Equation 5.7 while ensuring that the continuity of mass flow is maintained:

$$Q_1 = A_1 C_{d_1} \sqrt{\frac{2(p_1 - p_i)}{\rho}} \quad (5.7)$$

$$\sum Q_n = 0 \quad (5.8)$$

p_1	mean pressure at Opening 1	p_i	mean internal pressure of volume
C_d	discharge coefficient of the opening	A	openable area of the opening (m^2)
Q	mass flow rate along the flow path through opening 1 (m^3/s)	ρ	air density (kg/m3)

5.2.2 Thermal Effects

Temperature differences between indoors and outdoors cause density differences, and therefore pressure differentials that drive natural ventilation. During the heating season, the warmer inside air rises and flows out of the building near its top. It is replaced by colder outdoor air that enters the building near its base. During the cooling season, the flow directions are reversed and generally lower, because the indoor outdoor temperature difference is smaller.

The height at which the interior and exterior pressures are equal is called the Neutral Pressure Level (NPL) (Tamura and Wilson 1966, 1967). Above this point (during heating season), the interior pressure is greater than the exterior; below this point, greater exterior pressure causes airflow into the building.

The pressure difference due to the stack effect at height h is;

$$\Delta P_s = (\rho_o - \rho_i)g(h - h_{NPL}) \tag{5.9}$$

$$= \rho_i g(h - h_{NPL})\frac{(T_i - T_o)}{T_o} \tag{5.10}$$

$$= \frac{1}{2}\rho_i V^2.C_d \tag{5.11}$$

ΔP_s	Pressure difference due to stack effect	T	Average absolute temperature ($^\circ C$)
ρ	Air density (kg/m^3)	C_d	Discharge Coefficient
g	Gravity constant (m^2/s)	V	Average airflow velocity through the opening (m/s)
h	Height of observation (m)	h_{NPL}	Height of neutral pressure level (m)
i	inside	o	outside

Available data on the NPL in various kinds of buildings is limited. The NPL in tall buildings varies from 0.3 to 0.7 of total building height (Tamura and Wilson 1966,67). A value of 0.5 of the height provides adequate accuracy in most applications.

6 CRITERIA FOR ACCEPTANCE

The requirements for natural ventilation is focused on two main facets of flow through a room, these are the air quality within an associated room and the flow rate or velocity through a room. The requirement for air quality is associated with improving the 'health' of a building and reducing what is commonly known as Sick Building Syndrome (SBS). This is encouraged by the circulation and replacement of air within a building with fresh outdoor air. The second facet is associated with a cooling sensation of airflow over a persons' body. The ability to generate a comfortable rate of airflow over the occupants of a room reduces the reliance of mechanical ventilation or air-conditioning to cool the occupants of a room.

The below criteria provide guidance on the mean wind speed and air-changes per hour within a residential apartment without discussing how frequently these should occur. It is not possible for an apartment to be naturally ventilated at all times, as the external wind speed and wind direction varies throughout the day and year. In this study, residential apartments are deemed to be naturally ventilated should it meet the required criteria for more than 50% of the time. To calculate this frequency of occurrence, wind data speed and wind direction data recorded at metrological measuring stations have been combined with the measured wind tunnel results.

6.1 Air Changes per Hour (ACH)

The requirement for air quality within a given room is detailed in the Australian Standard AS1668.2-2002 and the American Standard ANSI/ASHRAE 62.1-2010. Both of these standards consider the need for air quality due to the following two reasons:

- *Occupant Related Contaminants* – This relates to contaminants produced by the occupants of the specified space and is dependent on the type of room, metabolic rate of activity conducted in the room and the number of occupants expected at any time in the room.
- *Material Related Contaminants* – This relates to the expected contaminants generated by the materials associated with specific rooms and the expected uses.

Both of these standards provide general expected contaminant production and number of occupants for the specified room. It should be noted that the required number of air changes per hour is significantly higher for mechanically ventilated rooms as mechanical systems recycle the existing internal air, while natural ventilation incorporates 'fresh' outside air. The required air changes per hour based on the two abovementioned standards is presented in Table 4. These criteria have been based on the worse-case apartment of the development (smallest apartment).

Further to this the American Standard ANSI/ASHRAE 62.1-2010 stipulates the maximum distance which an internal space can be from an operable opening that can be considered to be naturally ventilated. This is determined as a function of the ceiling height along an associated internal flow path between openings and also as a function of the type of opening arrangement:

Single Sided, Double Sided or Corner apartment. These distances have been taken into account when determining the flow paths to be analysed for this report.

Table 4: Comparison of the Requirements for Air Changes Per Hour for the Various Ventilation Codes

Outdoor Air Requirements	AS1668.2-2002	ANSI/ASHRAE 62.1-2010
Required ACH for Occupant Related Contaminants	2.16	-
Required ACH for Material Related Contaminants	0.45	-
Required ACH for both Occupants and Material Related Contaminants	-	1.62

6.2 Air-Speed

ANSI/ASHRAE 55-2010 provides guidance on the thermal environment conditions for human occupancy. Consideration in made within the standard as to the effect of temperature variance, ideal operative temperature for a person, and expected clothing insulation (clo) for a given temperature range. The Graphical Elevated Air Speed Method notes that to provide a 1°C cooling sensation a minimum airspeed of 0.4m/s is required over the skin (this effect assumes that the mean radiant and operative temperature are equal and the effect will vary depending on these conditions). This is shown in Figure 4a below. The method also notes that internal airspeed should also have an upper limit of 0.8m/s for light, primarily sedentary activities such as that undertaken within an apartment, however this can be controlled by the occupant via percentage of window opening.

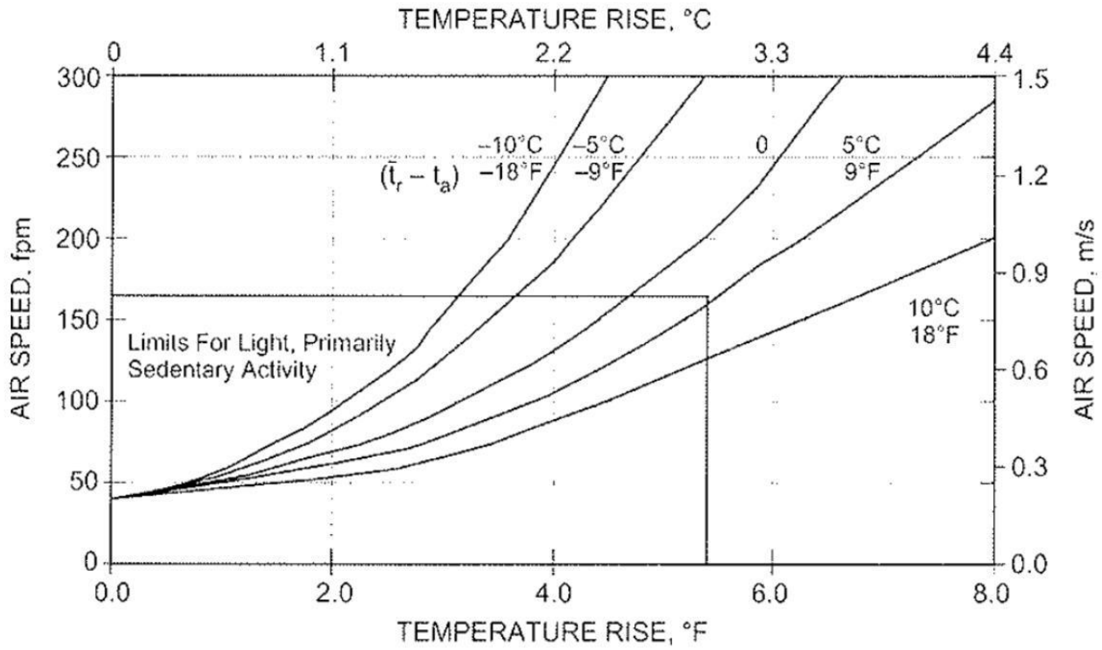

Figure 4a: Airspeed to offset air/radiant temperatures (ANSI/ASHRAE 55-2010)

Current research (Selkowitz, 2004) suggests that the assessment of the adequacy of natural ventilation should be based on the air-speed within the unit rather than solely the amount of air-changes per hour, as the human body reacts to the flow of air rather than just the quality of the air. It is considered that an optimum range for the average daily air speed in a room is of the order of 0.8-1m/s. Airflow in excess of 1m/s starts to impact on occupant comfort due to high air speeds causing papers etc. to move due to the airflow. The relationship between air-speed and cooling sensation is well documented (for example Aynseley and Su, 2005). Figure 4b shows how the movement of air over one's body can induce a cooling sensation. Note that this relies on the person feeling hot such that there is humidity present on the surface of the body.

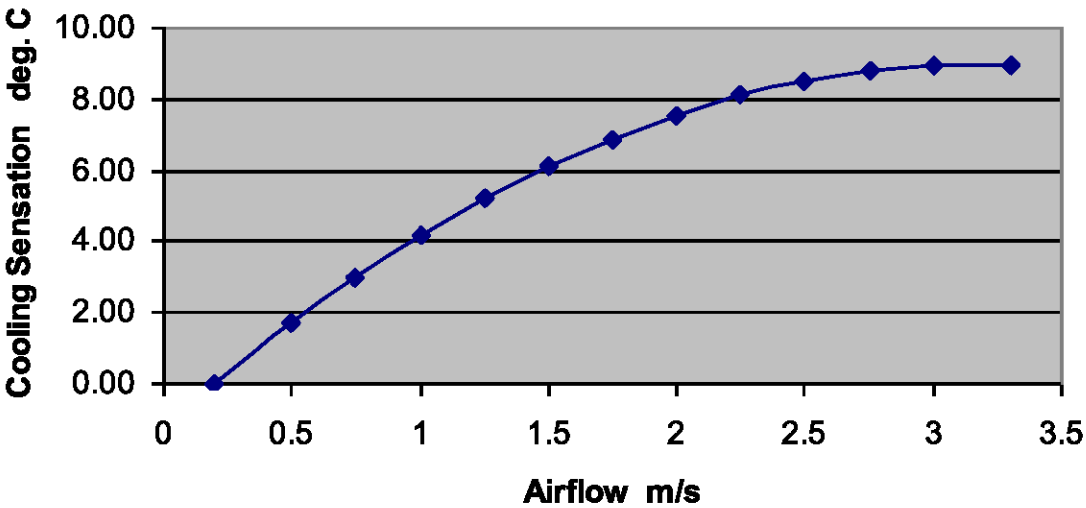

Figure 4b: Cooling Sensation of Air Flow (Aynsley and Su, 2005)

6.3 National Construction Code (NCC)

Reference is made for Deemed-to-Satisfy provision for natural ventilation in Volume 1, Sections F4.5 and F4.6. The code makes mention of providing aggregate opening or openable size of not less than 5% of the floor area of the room required to be ventilated. Furthermore, guidance is provided as to the space which an opening should be connected to for it to be considered as part of this assessment. No mention is made as to the number of apartments or rooms required to comply with these ventilation requirements. The code does not require openings to be fixed ventilation or permanent openings.

6.4 State Environmental Planning Policy (SEPP65)

SEPP 65 defines that a development to be considered naturally cross ventilated, it is required that 60% of the units of the development be naturally cross ventilated. For a unit to be considered naturally cross ventilated, it is required that they perform to the minimum performance of the double-end units or corner units of the development. A double-ended unit is considered a unit with operable access to the living areas of the units on two opposite aspects of the development. It should be noted that due to external and/or internal obstructions potentially reducing the effectiveness of a double-end or corner unit.

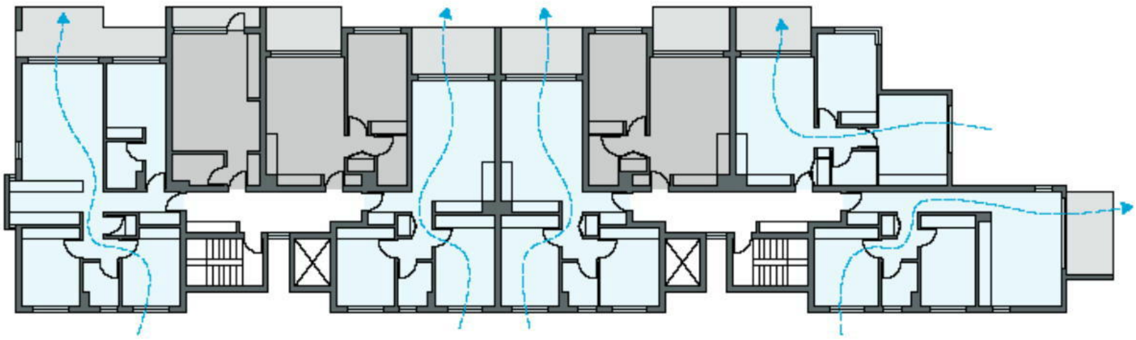

Figure 4b: Living Spaces of a Typical Unit (SEPP 65 ADG, 2015)

6.5 Parramatta Council DCP 2011

The Parramatta Council DCP includes a set of design controls, the object of which is to provide thermal comfort for occupants and to ensure sufficient volumes of fresh air circulate through buildings to create a comfortable indoor environment and optimize cross ventilation. These design controls for natural ventilation are listed below:

- The minimum floor to ceiling height is 2.7m.
- 80% of dwellings are to be naturally cross ventilated.
- Single aspect dwellings are limited in depth to 8m from a window.
- The maximum building depth is 18m.

7 RESULTS AND DISCUSSION

A detailed study of the natural ventilation performance of the residential units of the proposed development located Lot 5, 158-164 Hawkesbury Road & 2A Darcy Road, Westmead has been undertaken. A total 360 units have been investigated as part of this study.

The residential units of the development consist of corner, double ended and single aspect units. Due to the various possible configurations that could be achieved for each unit depending on window openings configuration, up to 2 critical flow paths through the living space of the units have been investigated.

In this study it has been assumed that the occupants of the residential units would not necessarily know the optimal window opening configuration to maximum natural ventilation. As such, it has been assumed that a window is either completely open or completely closed.

The criteria outlined in Section 6 states that the natural ventilation flow through single aspect apartments should meet a minimum daily average of 2.5 ACH for air quality in the room (more than 50% of the time), and an airflow velocity through the main living space equivalent to or better than 0.4m/s as outlined in ANSI/ASHRAE 55-2010. This airflow is determined from a nominal area along the flow path where the occupant of the apartment would be able to experience the air flow. If an occupant would like to experience a large air flow, their instinct would be to move towards an opening where the air flow would be more apparent. The nominal area taken is 1.8m^2, which is approximately the cross-sectional area of a typical corridor.

The performance of the units of the development is reliant of the pressure potential between the various openings connected to each residential apartment. Section 6 of this report describes the general requirements of ACH and recommended flow velocity through a room for natural ventilation.

7.1 Natural Ventilation Performance

As discussed in Section 6 of this report, the required criteria to satisfy the requirements for natural ventilation 2.5 ACH and an internal airflow velocity through the living space of 0.4m/s, which is sufficient to provide thermal cooling effects.

The results of the natural cross ventilation characteristics of the various residential apartments of the overall proposed development site indicated the following:

- **Building A** – a total of 62.7% (74 out of 118 residential apartments) in the first 9 storeys of the development will meet the deemed to comply requirements of SEPP65 for natural cross ventilation (i.e. with openings on orthogonal or opposite aspects).
- **Building B** - a total of 50.0% (121 out of 242 residential apartments) in the first 9 storeys of the development will meet the deemed to comply requirements of SEPP65 for natural cross ventilation (i.e. with openings on orthogonal or opposite aspects).

A wind tunnel study was carried out for the remaining residential apartments to determine the adequacy of natural ventilation performance against the abovementioned criteria. The results of the modelled natural ventilation performance are as follows:

- **Building A** – 27 of the 44 remaining apartments in the first 9 storeys of the development will achieve the target criteria.
- **Building B** - 67 of the 121 remaining apartments in the first 9 storeys of the development will achieve the target criteria.

With the inclusion of the abovementioned units, the results of the natural ventilation study indicated the following:

- **Building A** – a total of 85.6% (101 of 118 apartments) in the first 9 storeys of the development are naturally cross ventilated (openings on opposite or orthogonal aspects) or achieve the target criteria.
- **Building B** - a total of 77.7% (188 of 242 apartments) in the first 9 storeys of the development are naturally cross ventilated (openings on opposite or orthogonal aspects) or achieve the target criteria.

From the abovementioned results from the detailed study more than 60% of the apartments of the entire development will satisfy the requirements for natural cross ventilation as outlined in SEPP65 or the more stringent criteria as outlined in ventilation standards. Therefore, based on the design of the subject development as proposed, the development will more than satisfy the requirements for natural cross ventilation from Parramatta Council DCP 2011 and SEPP65.

Tables 5a and 5b below presents the natural ventilation performance of each individual apartment as proposed and identifies apartments which have a natural ventilation performance equivalent to or better than the SEPP65.

Table 5: Building A Natural Ventilation Performance

Apartment Number	Naturally Cross Ventilated (openings on opposite or orthogonal aspects)	Weighted Air Flow Through the Apartment (m/s)	Percentage of Time Above ACH Criteria	Naturally Cross Ventilated or Achieves Target Criteria
A1.1.01	YES	N/A	N/A	YES
A1.1.02	YES	N/A	N/A	YES
A1.1.03	NO	0.51	79%	YES
A1.1.04	NO	1.47	85%	YES
A1.1.05	YES	N/A	N/A	YES
A1.1.06	YES	N/A	N/A	YES
A1.2.01	YES	N/A	N/A	YES
A1.2.02	YES	N/A	N/A	YES
A1.2.03	NO	0.51	79%	YES
A1.2.04	NO	1.47	85%	YES

Apartment Number	Naturally Cross Ventilated (openings on opposite or orthogonal aspects)	Weighted Air Flow Through the Apartment (m/s)	Percentage of Time Above ACH Criteria	Naturally Cross Ventilated or Achieves Target Criteria
A1.2.05	YES	N/A	N/A	YES
A1.2.06	YES	N/A	N/A	YES
A1.3.01	YES	N/A	N/A	YES
A1.3.02	YES	N/A	N/A	YES
A1.3.03	NO	0.51	79%	YES
A1.3.04	NO	1.47	85%	YES
A1.3.05	YES	N/A	N/A	YES
A1.3.06	YES	N/A	N/A	YES
A1.4.01	YES	N/A	N/A	YES
A1.4.02	YES	N/A	N/A	YES
A1.4.03	NO	0.28	81%	NO
A1.4.04	NO	1.14	85%	YES
A1.4.05	YES	N/A	N/A	YES
A1.4.06	YES	N/A	N/A	YES
A1.5.01	YES	N/A	N/A	YES
A1.5.02	YES	N/A	N/A	YES
A1.5.03	NO	0.28	81%	NO
A1.5.04	NO	1.14	85%	YES
A1.5.05	YES	N/A	N/A	YES
A1.5.06	YES	N/A	N/A	YES
A1.6.01	YES	N/A	N/A	YES
A1.6.02	YES	N/A	N/A	YES
A1.6.03	NO	0.28	81%	NO
A1.6.04	NO	1.14	85%	YES
A1.6.05	YES	N/A	N/A	YES
A1.6.06	YES	N/A	N/A	YES
A1.7.01	YES	N/A	N/A	YES
A1.7.02	YES	N/A	N/A	YES
A1.7.03	NO	0.34	74%	NO
A1.7.04	NO	1.09	85%	YES
A1.7.05	YES	N/A	N/A	YES
A1.7.06	YES	N/A	N/A	YES
A1.8.01	YES	N/A	N/A	YES
A1.8.02	YES	N/A	N/A	YES
A1.8.03	YES	N/A	N/A	YES
A1.8.04	NO	1.09	85%	YES
A1.8.05	YES	N/A	N/A	YES
A1.8.06	YES	N/A	N/A	YES
A1.G.01	NO	0.00	0%	NO

Apartment Number	Naturally Cross Ventilated (openings on opposite or orthogonal aspects)	Weighted Air Flow Through the Apartment (m/s)	Percentage of Time Above ACH Criteria	Naturally Cross Ventilated or Achieves Target Criteria
A1.G.02	NO	0.00	0%	NO
A1.G.03	NO	0.97	85%	YES
A1.LG.01	NO	0.00	0%	NO
A1.LG.02	NO	0.00	0%	NO
A2.1.01	YES	N/A	N/A	YES
A2.1.02	NO	1.05	85%	YES
A2.1.03	NO	0.19	70%	NO
A2.1.04	YES	N/A	N/A	YES
A2.1.05	YES	N/A	N/A	YES
A2.1.06	YES	N/A	N/A	YES
A2.1.07	YES	N/A	N/A	YES
A2.1.08	NO	0.13	61%	NO
A2.1.09	NO	0.00	0%	NO
A2.2.01	YES	N/A	N/A	YES
A2.2.02	NO	1.05	85%	YES
A2.2.03	NO	0.19	70%	NO
A2.2.04	YES	N/A	N/A	YES
A2.2.05	YES	N/A	N/A	YES
A2.2.06	NO	0.21	60%	NO
A2.2.07	YES	N/A	N/A	YES
A2.2.08	YES	N/A	N/A	YES
A2.2.09	NO	0.13	61%	NO
A2.2.10	NO	0.00	0%	NO
A2.3.01	YES	N/A	N/A	YES
A2.3.02	NO	1.05	85%	YES
A2.3.03	NO	0.19	70%	NO
A2.3.04	YES	N/A	N/A	YES
A2.3.05	YES	N/A	N/A	YES
A2.3.06	YES	N/A	N/A	YES
A2.3.07	YES	N/A	N/A	YES
A2.3.08	YES	N/A	N/A	YES
A2.3.09	YES	N/A	N/A	YES
A2.3.10	YES	N/A	N/A	YES
A2.4.01	YES	N/A	N/A	YES
A2.4.02	NO	0.83	85%	YES
A2.4.03	NO	0.75	84%	YES
A2.4.04	YES	N/A	N/A	YES
A2.4.05	YES	N/A	N/A	YES
A2.4.06	YES	N/A	N/A	YES

Apartment Number	Naturally Cross Ventilated (openings on opposite or orthogonal aspects)	Weighted Air Flow Through the Apartment (m/s)	Percentage of Time Above ACH Criteria	Naturally Cross Ventilated or Achieves Target Criteria
A2.5.01	YES	N/A	N/A	YES
A2.5.02	NO	0.83	85%	YES
A2.5.03	NO	0.75	84%	YES
A2.5.04	YES	N/A	N/A	YES
A2.5.05	YES	N/A	N/A	YES
A2.5.06	YES	N/A	N/A	YES
A2.6.01	YES	N/A	N/A	YES
A2.6.02	NO	0.83	85%	YES
A2.6.03	NO	0.75	84%	YES
A2.6.04	YES	N/A	N/A	YES
A2.6.05	YES	N/A	N/A	YES
A2.6.06	YES	N/A	N/A	YES
A2.7.01	YES	N/A	N/A	YES
A2.7.02	NO	0.85	77%	YES
A2.7.03	NO	0.60	84%	YES
A2.7.04	YES	N/A	N/A	YES
A2.7.05	YES	N/A	N/A	YES
A2.7.06	YES	N/A	N/A	YES
A2.8.01	YES	N/A	N/A	YES
A2.8.02	NO	0.85	77%	YES
A2.8.03	NO	0.60	84%	YES
A2.8.04	YES	N/A	N/A	YES
A2.8.05	YES	N/A	N/A	YES
A2.8.06	YES	N/A	N/A	YES
A2.G.01	NO	0.53	84%	YES
A2.G.02	YES	N/A	N/A	YES
A2.G.03	YES	N/A	N/A	YES
A2.G.04	YES	N/A	N/A	YES
A2.G.05	NO	0.11	53%	NO
A2.G.06	NO	0.69	82%	YES

Table 5: Building B Natural Ventilation Performance

Apartment Number	Naturally Cross Ventilated (openings on opposite or orthogonal aspects)	Weighted Air Flow Through the Apartment (m/s)	Percentage of Time Above ACH Criteria	Naturally Cross Ventilated or Achieves Target Criteria
B1.1.01	YES	N/A	N/A	YES
B1.1.02	YES	N/A	N/A	YES

Apartment Number	Naturally Cross Ventilated (openings on opposite or orthogonal aspects)	Weighted Air Flow Through the Apartment (m/s)	Percentage of Time Above ACH Criteria	Naturally Cross Ventilated or Achieves Target Criteria
B1.1.03	NO	0.88	85%	YES
B1.1.04	NO	0.99	85%	YES
B1.1.05	YES	N/A	N/A	YES
B1.1.06	NO	0.50	83%	YES
B1.1.07	NO	0.50	83%	YES
B1.1.08	YES	N/A	N/A	YES
B1.1.09	YES	N/A	N/A	YES
B1.1.10	NO	0.00	0%	NO
B1.2.01	YES	N/A	N/A	YES
B1.2.02	YES	N/A	N/A	YES
B1.2.03	NO	0.88	85%	YES
B1.2.04	NO	0.99	85%	YES
B1.2.05	YES	N/A	N/A	YES
B1.2.06	NO	0.50	83%	YES
B1.2.07	NO	0.50	83%	YES
B1.2.08	YES	N/A	N/A	YES
B1.2.09	YES	N/A	N/A	YES
B1.2.10	NO	0.00	0%	NO
B1.3.01	YES	N/A	N/A	YES
B1.3.02	YES	N/A	N/A	YES
B1.3.03	NO	0.88	85%	YES
B1.3.04	NO	0.99	85%	YES
B1.3.05	YES	N/A	N/A	YES
B1.3.06	NO	0.50	83%	YES
B1.3.07	NO	0.50	83%	YES
B1.3.08	YES	N/A	N/A	YES
B1.3.09	YES	N/A	N/A	YES
B1.3.10	YES	N/A	N/A	YES
B1.4.01	YES	N/A	N/A	YES
B1.4.02	YES	N/A	N/A	YES
B1.4.03	NO	0.85	85%	YES
B1.4.04	NO	0.90	85%	YES
B1.4.05	YES	N/A	N/A	YES
B1.4.06	NO	0.53	85%	YES
B1.4.07	NO	0.53	85%	YES
B1.4.08	YES	N/A	N/A	YES
B1.4.09	YES	N/A	N/A	YES
B1.4.10	NO	0.12	46%	NO
B1.5.01	YES	N/A	N/A	YES

Apartment Number	Naturally Cross Ventilated (openings on opposite or orthogonal aspects)	Weighted Air Flow Through the Apartment (m/s)	Percentage of Time Above ACH Criteria	Naturally Cross Ventilated or Achieves Target Criteria
B1.5.02	YES	N/A	N/A	YES
B1.5.03	NO	0.85	85%	YES
B1.5.04	NO	0.90	85%	YES
B1.5.05	YES	N/A	N/A	YES
B1.5.06	NO	0.53	85%	YES
B1.5.07	NO	0.53	85%	YES
B1.5.08	YES	N/A	N/A	YES
B1.5.09	YES	N/A	N/A	YES
B1.5.10	NO	0.12	46%	NO
B1.6.01	YES	N/A	N/A	YES
B1.6.02	YES	N/A	N/A	YES
B1.6.03	NO	0.85	85%	YES
B1.6.04	NO	0.90	85%	YES
B1.6.05	YES	N/A	N/A	YES
B1.6.06	NO	0.53	85%	YES
B1.6.07	NO	0.53	85%	YES
B1.6.08	YES	N/A	N/A	YES
B1.6.09	YES	N/A	N/A	YES
B1.6.10	NO	0.12	46%	NO
B1.7.01	YES	N/A	N/A	YES
B1.7.02	YES	N/A	N/A	YES
B1.7.03	NO	1.12	85%	YES
B1.7.04	NO	1.17	85%	YES
B1.7.05	YES	N/A	N/A	YES
B1.7.06	NO	0.67	85%	YES
B1.7.07	NO	0.67	84%	YES
B1.7.08	YES	N/A	N/A	YES
B1.7.09	YES	N/A	N/A	YES
B1.7.10	NO	0.16	68%	NO
B1.8.01	YES	N/A	N/A	YES
B1.8.02	YES	N/A	N/A	YES
B1.8.03	YES	N/A	N/A	YES
B1.8.04	NO	0.67	85%	YES
B1.8.05	NO	0.67	84%	YES
B1.8.06	YES	N/A	N/A	YES
B1.8.07	YES	N/A	N/A	YES
B1.8.08	NO	0.16	68%	NO
B1.G.01	YES	N/A	N/A	YES
B1.G.02	YES	N/A	N/A	YES

Apartment Number	Naturally Cross Ventilated (openings on opposite or orthogonal aspects)	Weighted Air Flow Through the Apartment (m/s)	Percentage of Time Above ACH Criteria	Naturally Cross Ventilated or Achieves Target Criteria
B1.G.03	NO	0.71	85%	YES
B1.G.04	NO	0.83	83%	YES
B1.G.05	NO	0.76	85%	YES
B1.G.06	NO	1.23	82%	YES
B1.G.07	YES	N/A	N/A	YES
B1.G.08	YES	N/A	N/A	YES
B1.G.09	NO	0.00	0%	NO
B2.1.01	YES	N/A	N/A	YES
B2.1.02	YES	N/A	N/A	YES
B2.1.03	NO	0.00	0%	NO
B2.1.04	NO	0.39	82%	YES
B2.1.05	YES	N/A	N/A	YES
B2.1.06	NO	0.00	0%	NO
B2.1.07	NO	0.00	0%	NO
B2.1.08	YES	N/A	N/A	YES
B2.1.09	NO	0.00	0%	NO
B2.2.01	YES	N/A	N/A	YES
B2.2.02	YES	N/A	N/A	YES
B2.2.03	NO	0.00	0%	NO
B2.2.04	NO	0.39	82%	YES
B2.2.05	YES	N/A	N/A	YES
B2.2.06	NO	0.00	0%	NO
B2.2.07	NO	0.00	0%	NO
B2.2.08	YES	N/A	N/A	YES
B2.2.09	NO	0.00	0%	NO
B2.3.01	YES	N/A	N/A	YES
B2.3.02	YES	N/A	N/A	YES
B2.3.03	NO	0.00	0%	NO
B2.3.04	NO	0.39	82%	YES
B2.3.05	YES	N/A	N/A	YES
B2.3.06	NO	0.00	0%	NO
B2.3.07	NO	0.00	0%	NO
B2.3.08	YES	N/A	N/A	YES
B2.3.09	NO	0.00	0%	NO
B2.4.01	YES	N/A	N/A	YES
B2.4.02	YES	N/A	N/A	YES
B2.4.03	NO	0.00	0%	NO
B2.4.04	NO	0.17	66%	NO
B2.4.05	YES	N/A	N/A	YES

Apartment Number	Naturally Cross Ventilated (openings on opposite or orthogonal aspects)	Weighted Air Flow Through the Apartment (m/s)	Percentage of Time Above ACH Criteria	Naturally Cross Ventilated or Achieves Target Criteria
B2.4.06	NO	0.00	0%	NO
B2.4.07	NO	0.00	0%	NO
B2.4.08	YES	N/A	N/A	YES
B2.4.09	NO	0.00	0%	NO
B2.5.01	YES	N/A	N/A	YES
B2.5.02	YES	N/A	N/A	YES
B2.5.03	NO	0.00	0%	NO
B2.5.04	NO	0.17	66%	NO
B2.5.05	YES	N/A	N/A	YES
B2.5.06	NO	0.00	0%	NO
B2.5.07	NO	0.00	0%	NO
B2.5.08	YES	N/A	N/A	YES
B2.5.09	NO	0.00	0%	NO
B2.6.01	YES	N/A	N/A	YES
B2.6.02	YES	N/A	N/A	YES
B2.6.03	NO	0.00	0%	NO
B2.6.04	NO	0.17	66%	NO
B2.6.05	YES	N/A	N/A	YES
B2.6.06	NO	0.00	0%	NO
B2.6.07	NO	0.00	0%	NO
B2.6.08	YES	N/A	N/A	YES
B2.6.09	NO	0.00	0%	NO
B2.7.01	YES	N/A	N/A	YES
B2.7.02	YES	N/A	N/A	YES
B2.7.03	YES	N/A	N/A	YES
B2.7.04	NO	0.98	87%	YES
B2.7.05	YES	N/A	N/A	YES
B2.7.06	YES	N/A	N/A	YES
B2.7.07	YES	N/A	N/A	YES
B2.7.08	YES	N/A	N/A	YES
B2.7.09	YES	N/A	N/A	YES
B2.G.01	NO	0.00	0%	NO
B2.G.02	NO	0.00	0%	NO
B2.G.03	YES	N/A	N/A	YES
B2.G.04	NO	0.00	0%	NO
B2.G.05	NO	0.00	0%	NO
B2.LG.03	YES	N/A	N/A	YES
B2.LG.04	NO	0.63	80%	YES
B2.LG.05	NO	0.63	77%	YES

Apartment Number	Naturally Cross Ventilated (openings on opposite or orthogonal aspects)	Weighted Air Flow Through the Apartment (m/s)	Percentage of Time Above ACH Criteria	Naturally Cross Ventilated or Achieves Target Criteria
B2.LG.06	NO	0.00	0%	NO
B2.LG.07	NO	0.00	0%	NO
B3.1.01	YES	N/A	N/A	YES
B3.1.02	YES	N/A	N/A	YES
B3.1.03	YES	N/A	N/A	YES
B3.1.04	NO	0.71	87%	YES
B3.1.05	YES	N/A	N/A	YES
B3.1.06	NO	0.92	85%	YES
B3.1.07	NO	0.97	87%	YES
B3.1.08	YES	N/A	N/A	YES
B3.1.09	NO	0.14	49%	NO
B3.2.01	YES	N/A	N/A	YES
B3.2.02	YES	N/A	N/A	YES
B3.2.03	YES	N/A	N/A	YES
B3.2.04	NO	0.71	87%	YES
B3.2.05	YES	N/A	N/A	YES
B3.2.06	NO	0.92	85%	YES
B3.2.07	NO	0.97	87%	YES
B3.2.08	YES	N/A	N/A	YES
B3.2.09	NO	0.14	49%	NO
B3.3.01	YES	N/A	N/A	YES
B3.3.02	YES	N/A	N/A	YES
B3.3.03	YES	N/A	N/A	YES
B3.3.04	NO	0.71	87%	YES
B3.3.05	YES	N/A	N/A	YES
B3.3.06	NO	0.92	85%	YES
B3.3.07	NO	0.97	87%	YES
B3.3.08	YES	N/A	N/A	YES
B3.3.09	NO	0.14	49%	NO
B3.4.01	YES	N/A	N/A	YES
B3.4.02	YES	N/A	N/A	YES
B3.4.03	YES	N/A	N/A	YES
B3.4.04	NO	1.05	89%	YES
B3.4.05	YES	N/A	N/A	YES
B3.4.06	NO	0.77	86%	YES
B3.4.07	NO	0.79	85%	YES
B3.4.08	YES	N/A	N/A	YES
B3.4.09	NO	0.14	55%	NO
B3.5.01	YES	N/A	N/A	YES

Apartment Number	Naturally Cross Ventilated (openings on opposite or orthogonal aspects)	Weighted Air Flow Through the Apartment (m/s)	Percentage of Time Above ACH Criteria	Naturally Cross Ventilated or Achieves Target Criteria
B3.5.02	YES	N/A	N/A	YES
B3.5.03	YES	N/A	N/A	YES
B3.5.04	NO	1.05	89%	YES
B3.5.05	YES	N/A	N/A	YES
B3.5.06	NO	0.77	86%	YES
B3.5.07	NO	0.79	85%	YES
B3.5.08	YES	N/A	N/A	YES
B3.5.09	NO	0.14	55%	NO
B3.6.01	YES	N/A	N/A	YES
B3.6.02	YES	N/A	N/A	YES
B3.6.03	YES	N/A	N/A	YES
B3.6.04	NO	1.05	89%	YES
B3.6.05	YES	N/A	N/A	YES
B3.6.06	NO	0.77	86%	YES
B3.6.07	NO	0.79	85%	YES
B3.6.08	YES	N/A	N/A	YES
B3.6.09	NO	0.14	55%	NO
B3.7.01	YES	N/A	N/A	YES
B3.7.02	YES	N/A	N/A	YES
B3.7.03	YES	N/A	N/A	YES
B3.7.04	NO	1.16	85%	YES
B3.7.05	YES	N/A	N/A	YES
B3.7.06	NO	1.34	85%	YES
B3.7.07	NO	1.33	85%	YES
B3.7.08	YES	N/A	N/A	YES
B3.7.09	NO	0.12	43%	NO
B3.8.01	YES	N/A	N/A	YES
B3.8.02	YES	N/A	N/A	YES
B3.8.03	YES	N/A	N/A	YES
B3.8.04	NO	0.00	0%	NO
B3.8.05	YES	N/A	N/A	YES
B3.8.06	NO	1.34	85%	YES
B3.8.07	NO	1.33	85%	YES
B3.8.08	YES	N/A	N/A	YES
B3.8.09	NO	0.15	58%	NO
B3.8.10	NO	0.19	73%	NO
B3.G.01	YES	N/A	N/A	YES
B3.G.02	NO	0.00	0%	NO
B3.G.03	NO	0.28	79%	NO

Apartment Number	Naturally Cross Ventilated (openings on opposite or orthogonal aspects)	Weighted Air Flow Through the Apartment (m/s)	Percentage of Time Above ACH Criteria	Naturally Cross Ventilated or Achieves Target Criteria
B3.G.04	NO	0.00	0%	NO
B3.G.05	NO	0.71	88%	YES
B3.LG.01	YES	N/A	N/A	YES
B3.LG.02	NO	1.03	84%	YES
B3.LG.03	NO	0.60	71%	YES
B3.LG.04	NO	0.67	88%	YES

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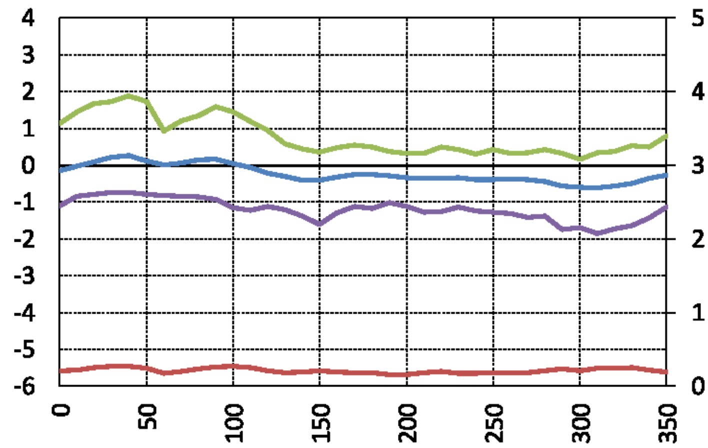
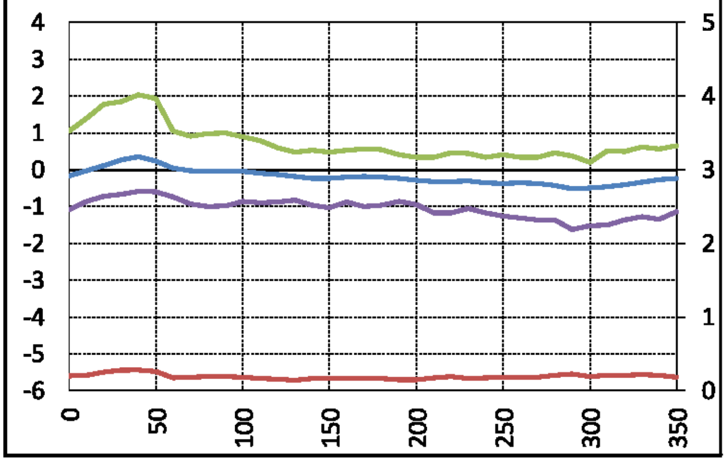
APPENDIX A - PLOTS OF WIND TUNNEL TEST RESULTS

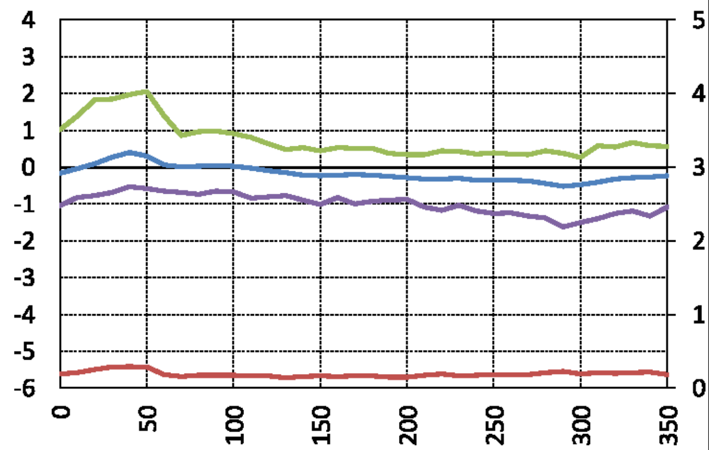
Individual Tap ID: ANE01 **Port ID: 0**



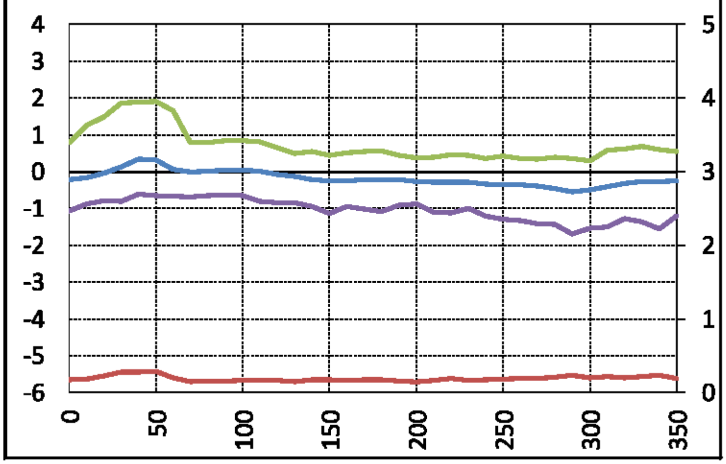
Individual Tap ID: ANE02 **Port ID: 1**



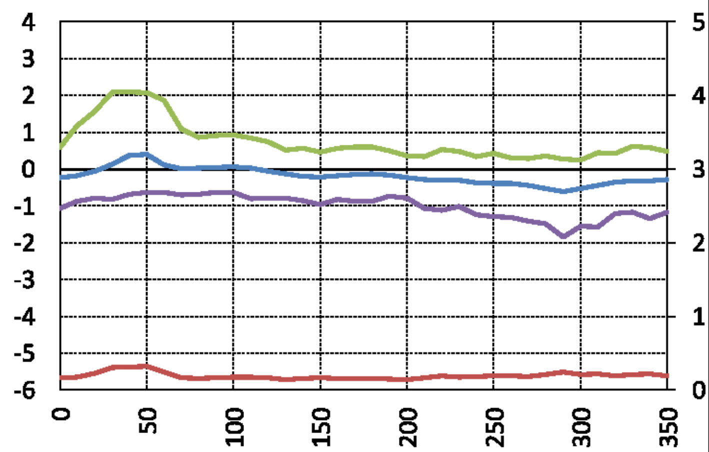
Individual Tap ID: ANE03 **Port ID: 2**



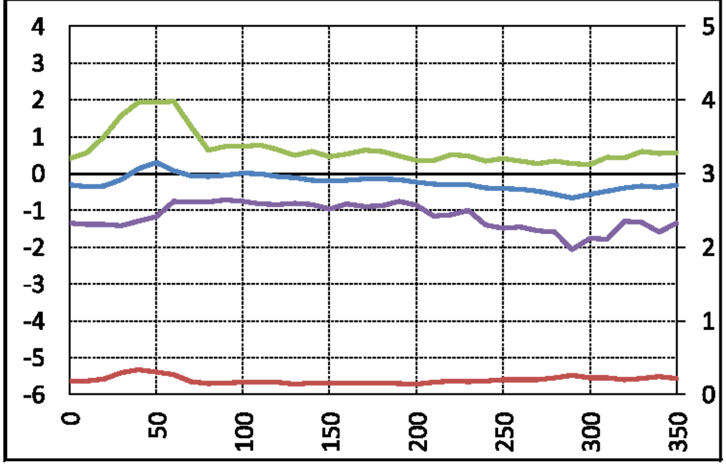
Individual Tap ID: ANE04 **Port ID: 3**



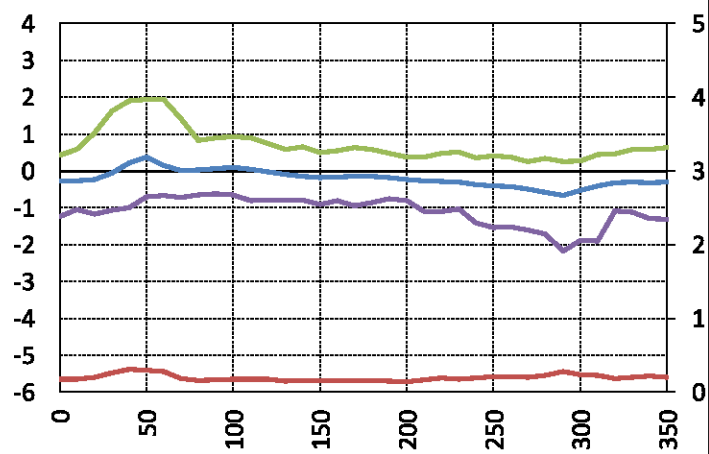
Individual Tap ID: ANE05 **Port ID: 4**



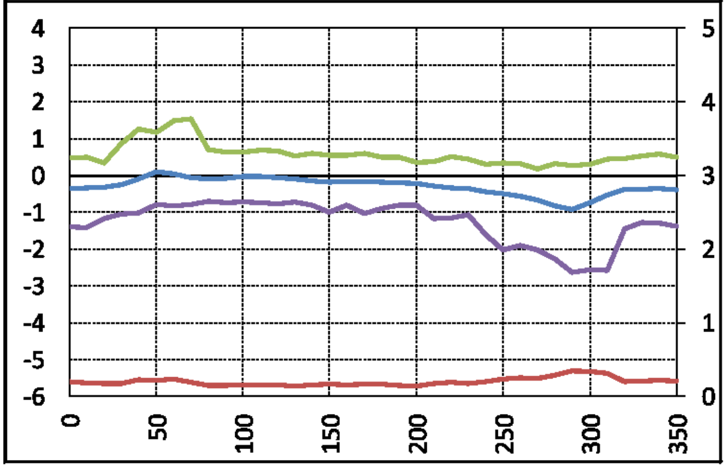
Individual Tap ID: ANE06 **Port ID: 5**



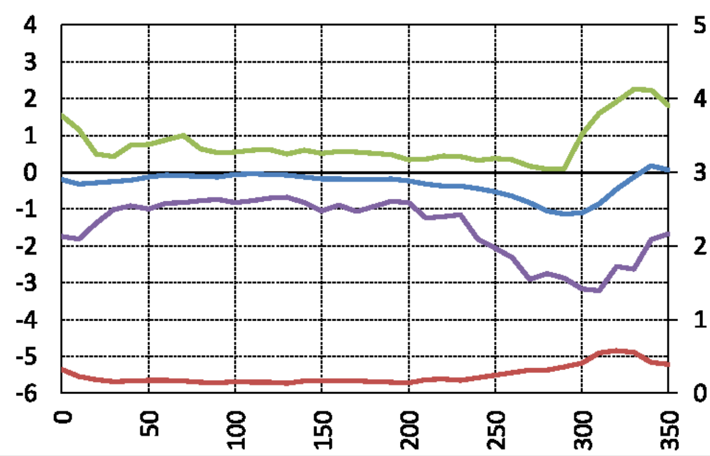
Individual Tap ID: ANE07 **Port ID: 6**



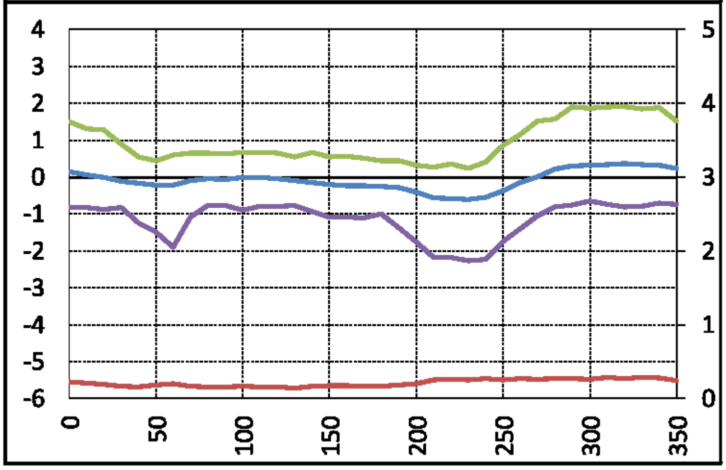
Individual Tap ID: ANE08 **Port ID: 7**



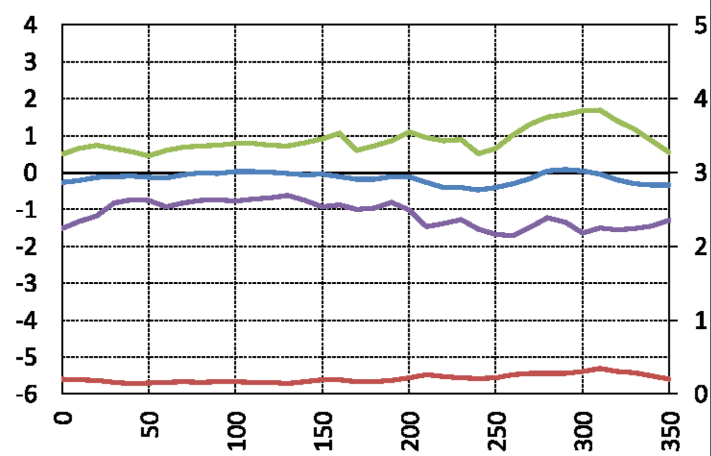
Individual Tap ID: ANE09 **Port ID: 8**



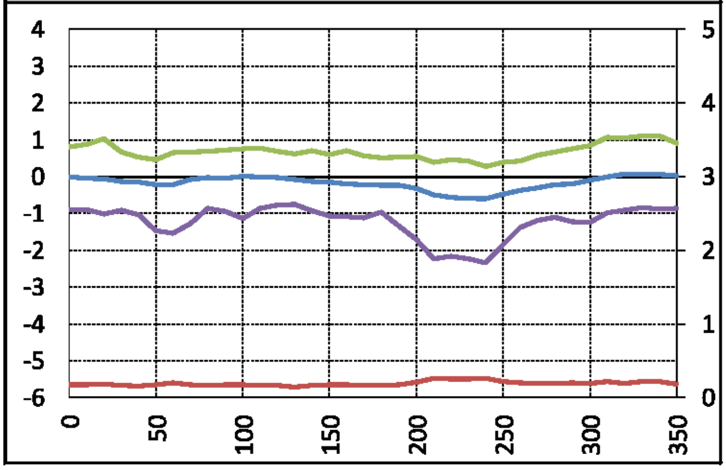
Individual Tap ID: ANE10 **Port ID: 9**



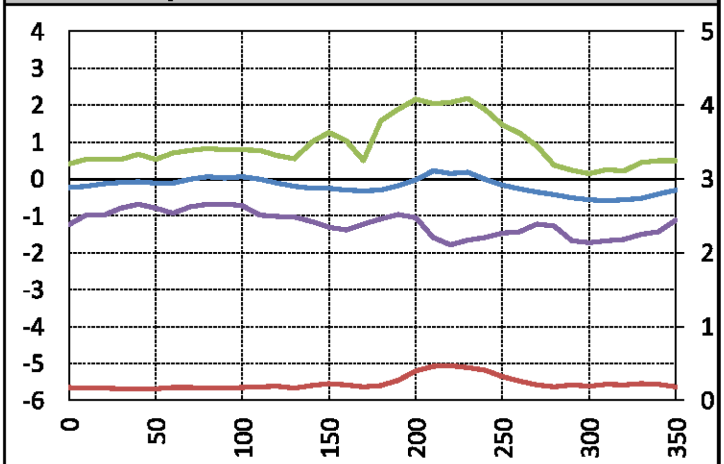
Individual Tap ID: AWE01 **Port ID: 10**



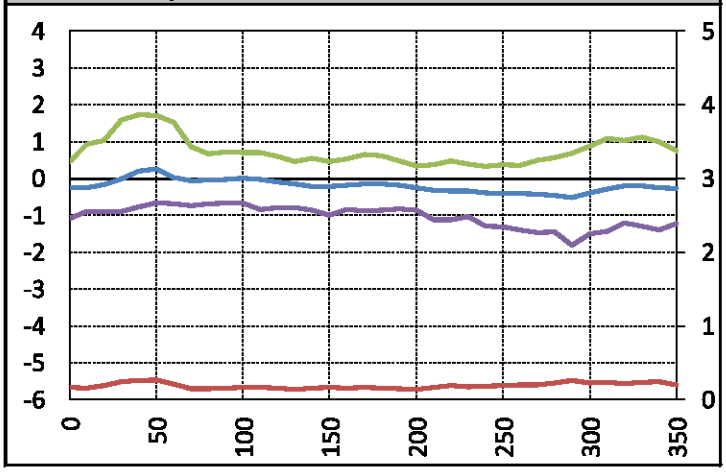
Individual Tap ID: AWE02 **Port ID: 11**



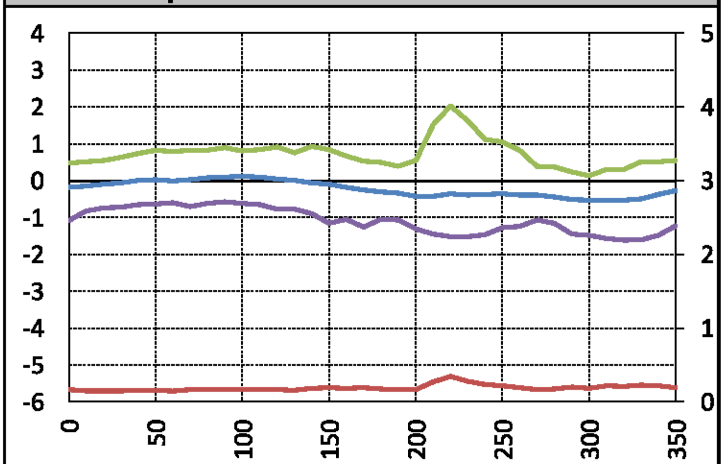
Individual Tap ID: AWE03 **Port ID: 12**



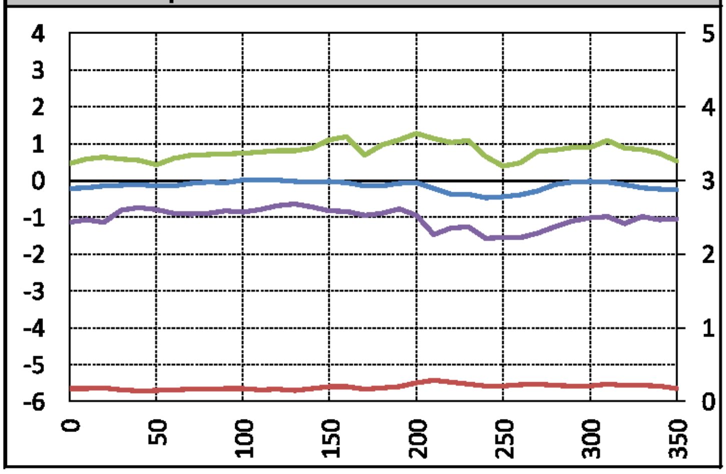
Individual Tap ID: AWE04 **Port ID: 14**



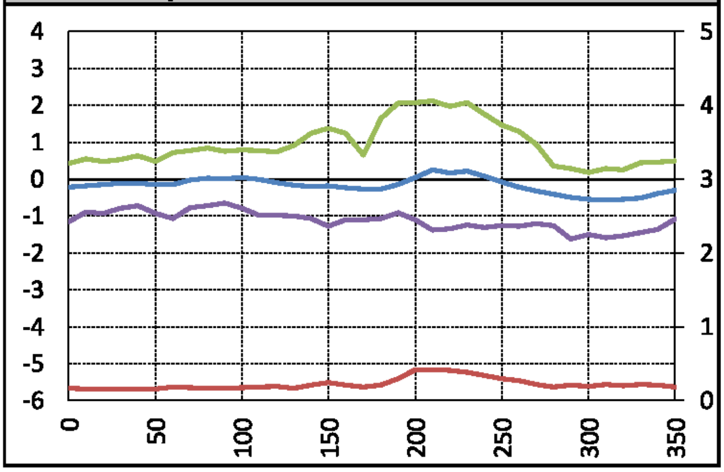
Individual Tap ID: AWE05 **Port ID: 15**



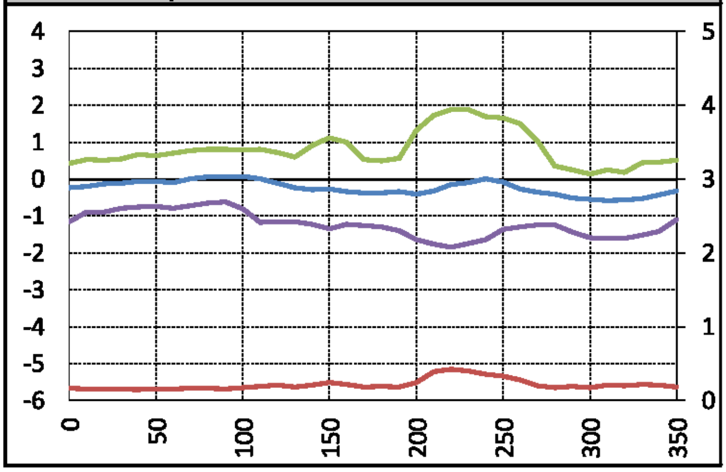
Individual Tap ID: ASE01 **Port ID: 16**



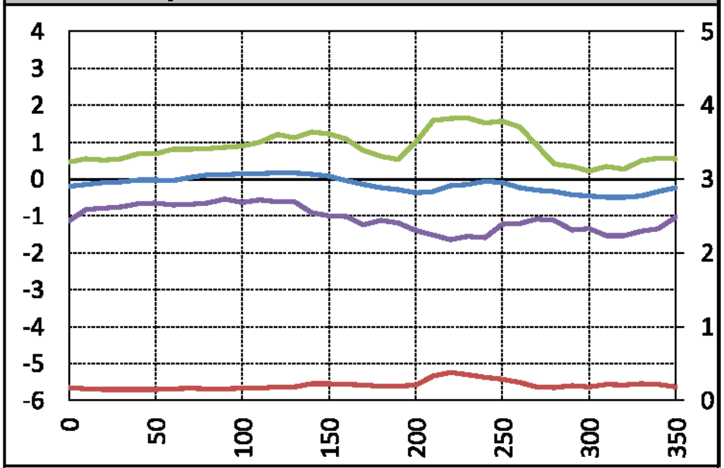
Individual Tap ID: ASE02 Port ID: 17



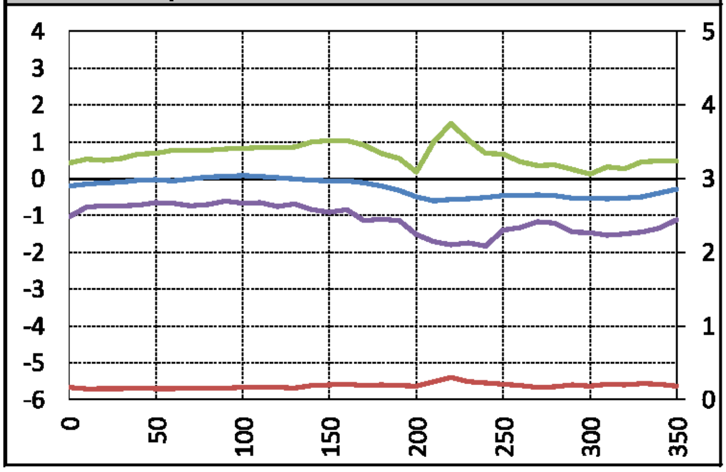
Individual Tap ID: ASE03 Port ID: 18



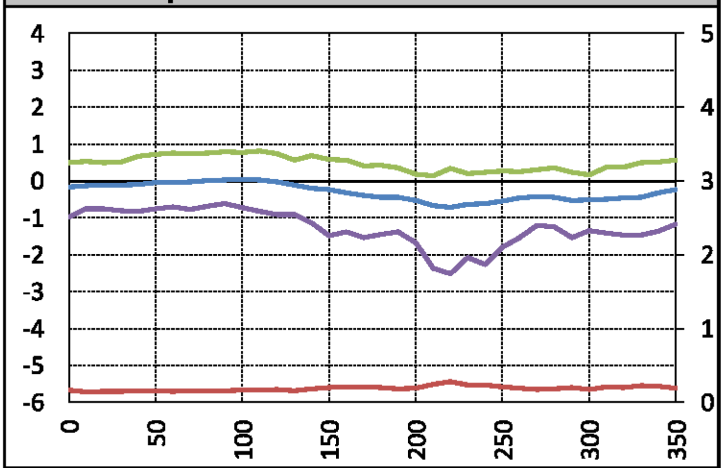
Individual Tap ID: ASE04 Port ID: 19



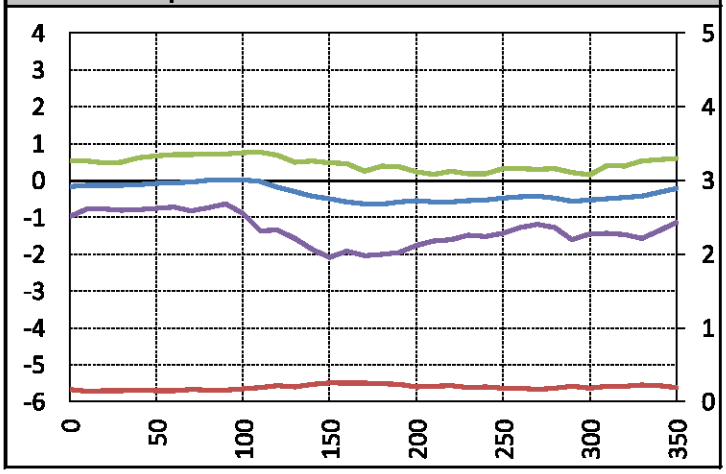
Individual Tap ID: ASE05 Port ID: 20



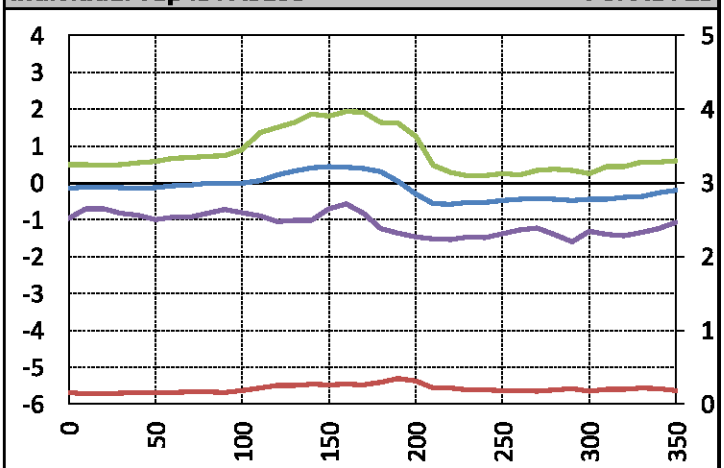
Individual Tap ID: ASE06 Port ID: 21



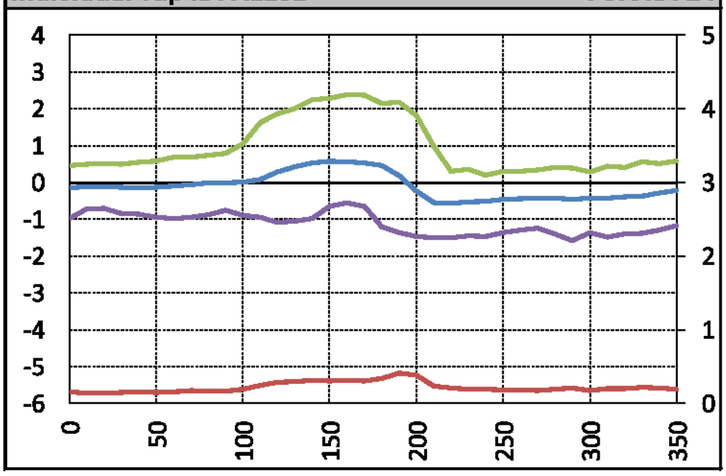
Individual Tap ID: ASE07 Port ID: 22



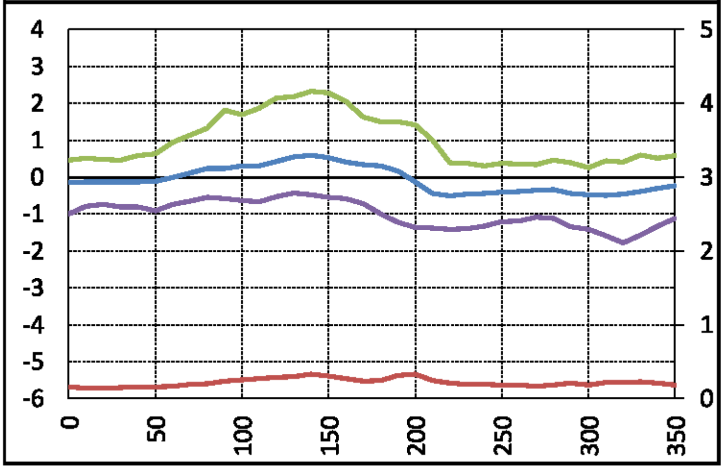
Individual Tap ID: ASE08 Port ID: 23



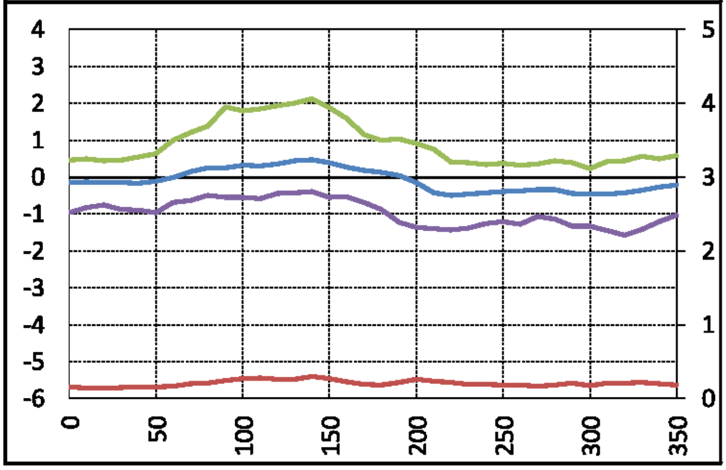
Individual Tap ID: AEE01 Port ID: 24



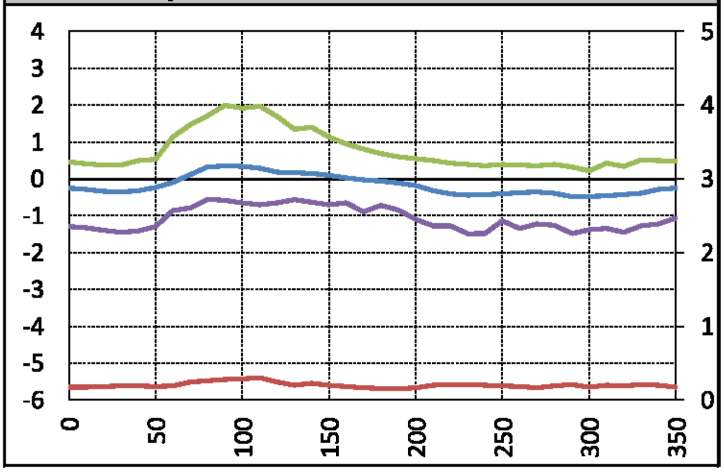
Individual Tap ID: AEE02 **Port ID: 25**



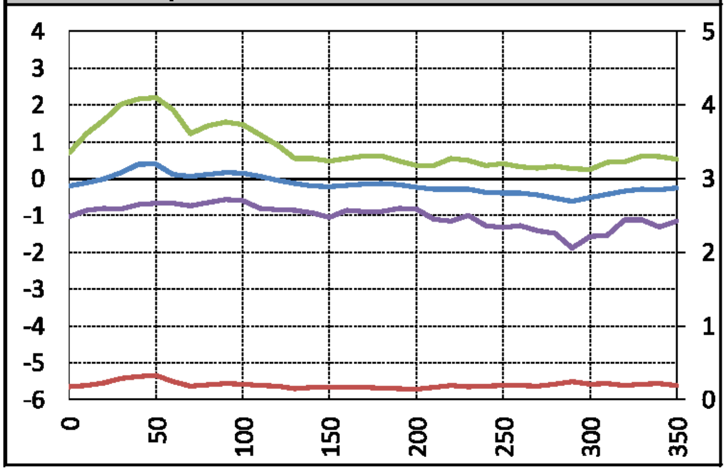
Individual Tap ID: AEE03 **Port ID: 26**



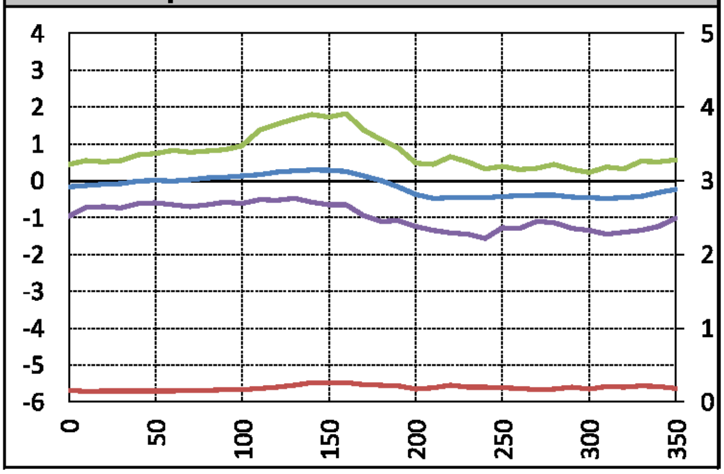
Individual Tap ID: AEE04 **Port ID: 27**



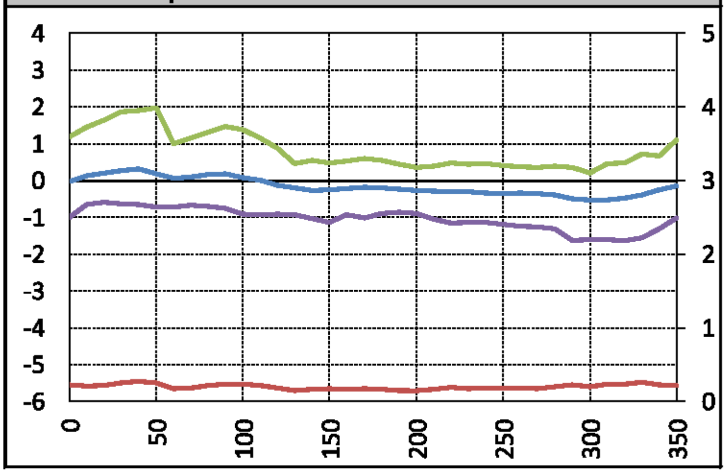
Individual Tap ID: AEE05 **Port ID: 28**



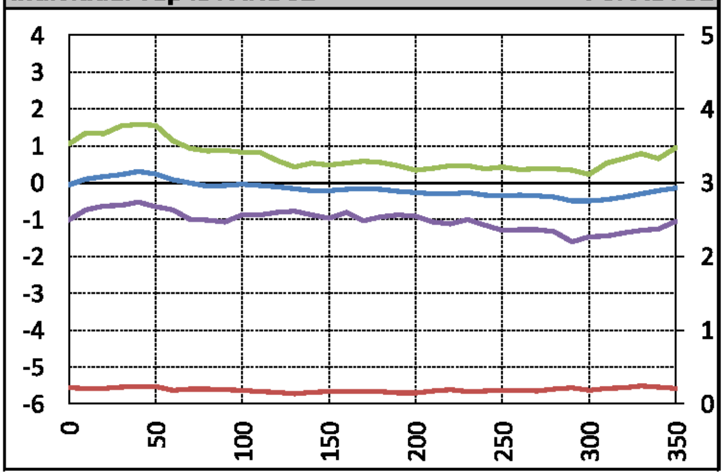
Individual Tap ID: AEE06 **Port ID: 29**



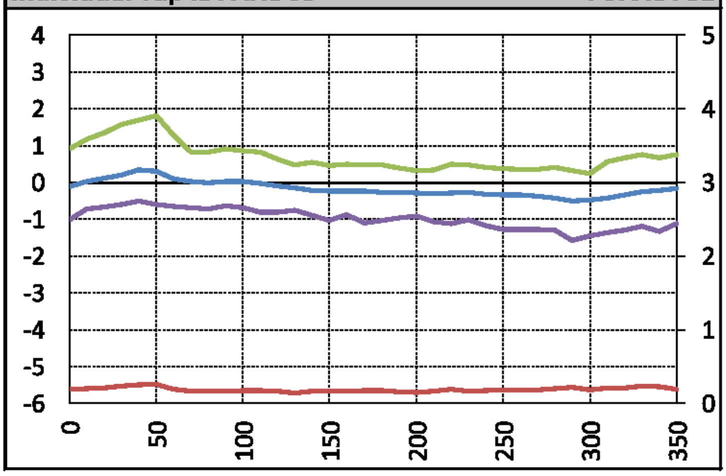
Individual Tap ID: AND01 **Port ID: 30**



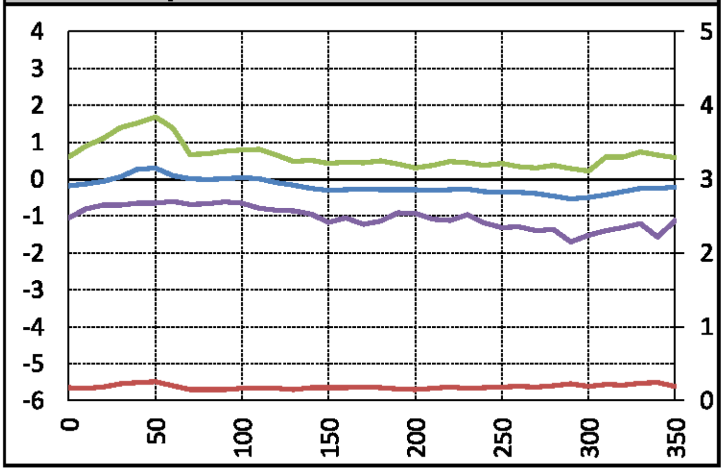
Individual Tap ID: AND02 **Port ID: 31**



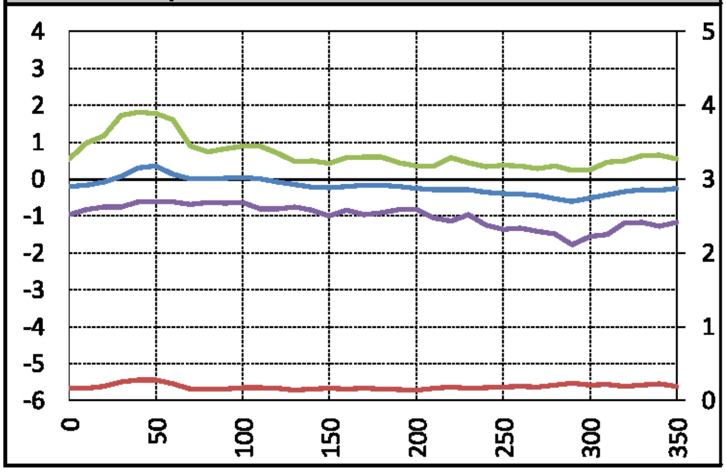
Individual Tap ID: AND03 **Port ID: 32**



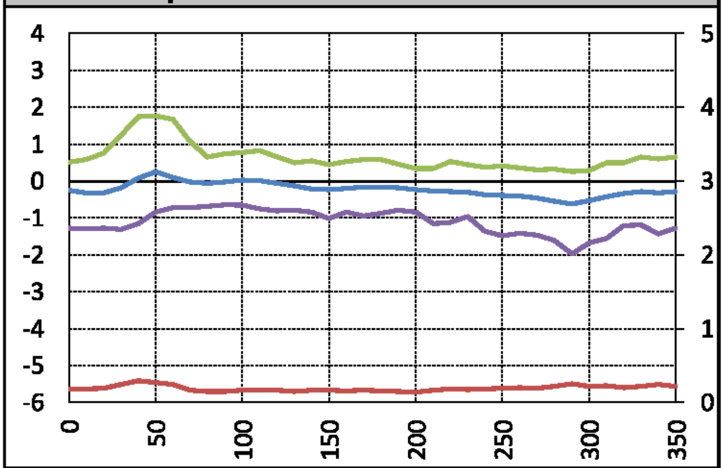
Individual Tap ID: AND04 Port ID: 33



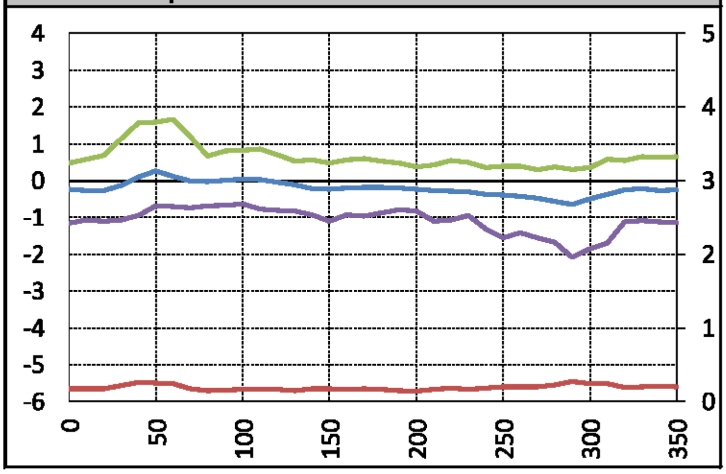
Individual Tap ID: AND05 Port ID: 34



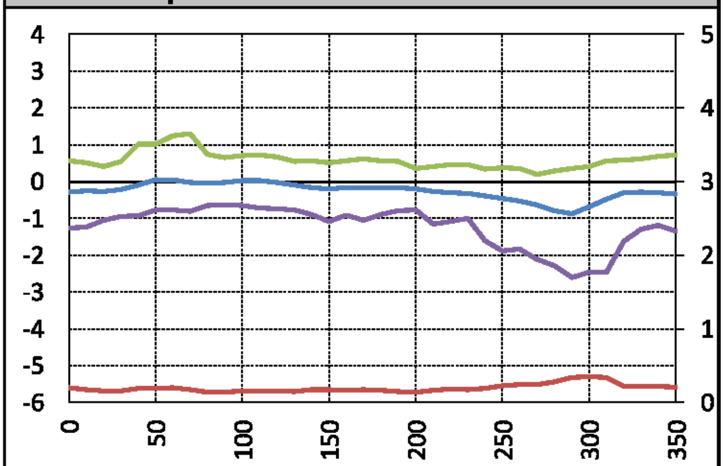
Individual Tap ID: AND06 Port ID: 35



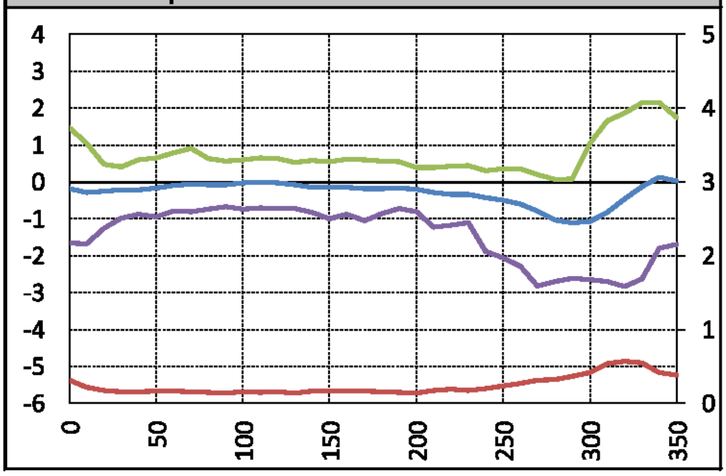
Individual Tap ID: AND07 Port ID: 36



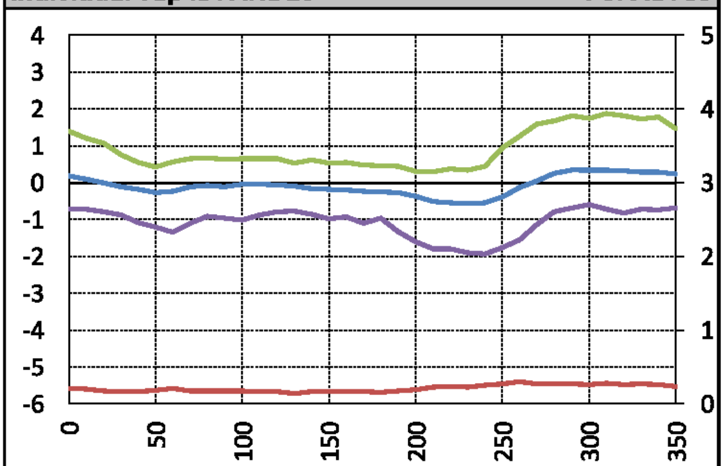
Individual Tap ID: AND08 Port ID: 37



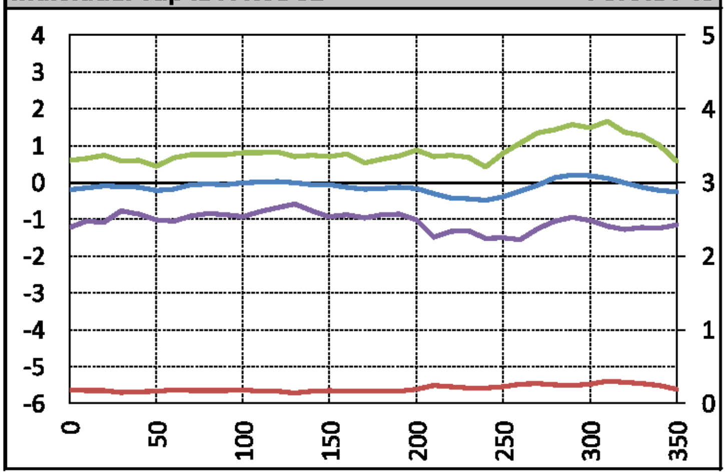
Individual Tap ID: AND09 Port ID: 38



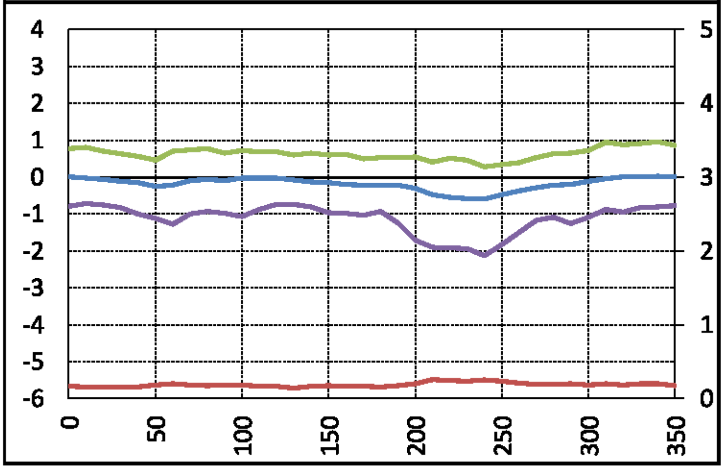
Individual Tap ID: AND10 Port ID: 39



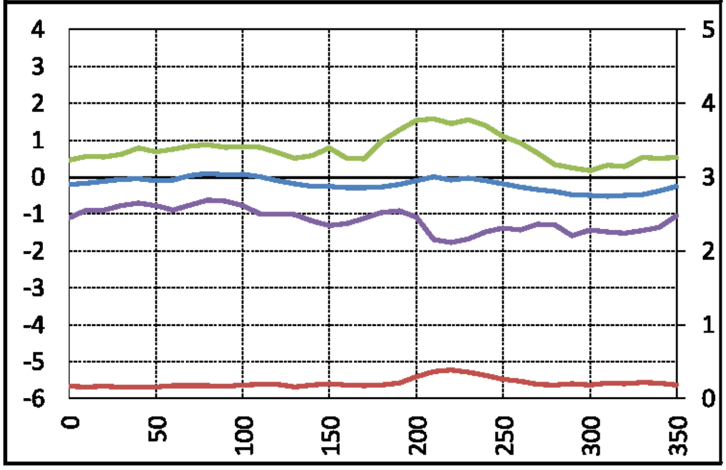
Individual Tap ID: AWD01 Port ID: 40



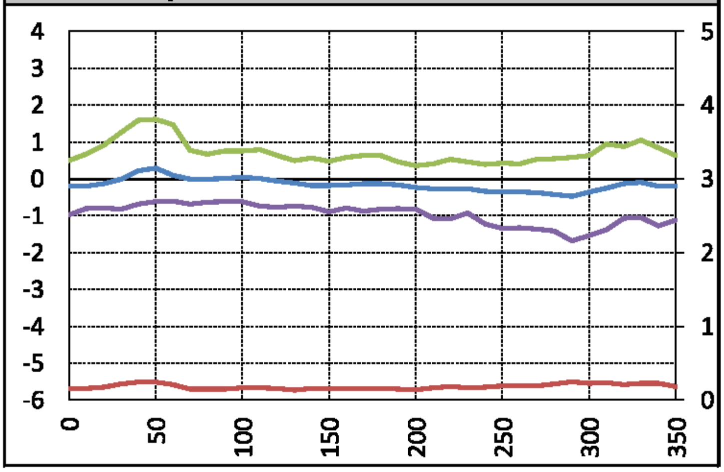
Individual Tap ID: AWD02 **Port ID: 41**



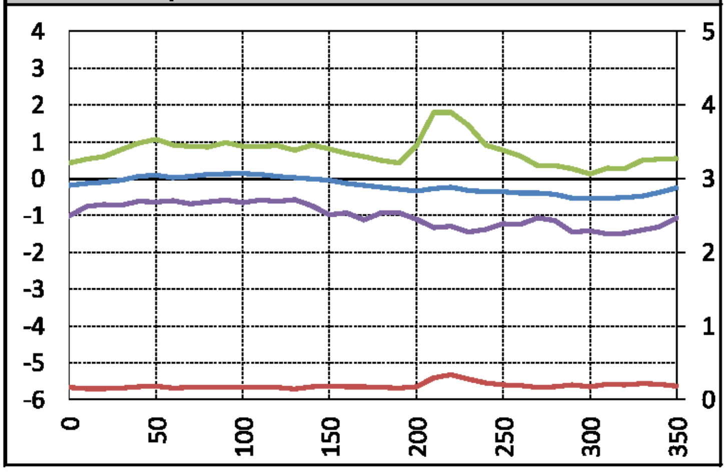
Individual Tap ID: AWD03 **Port ID: 42**



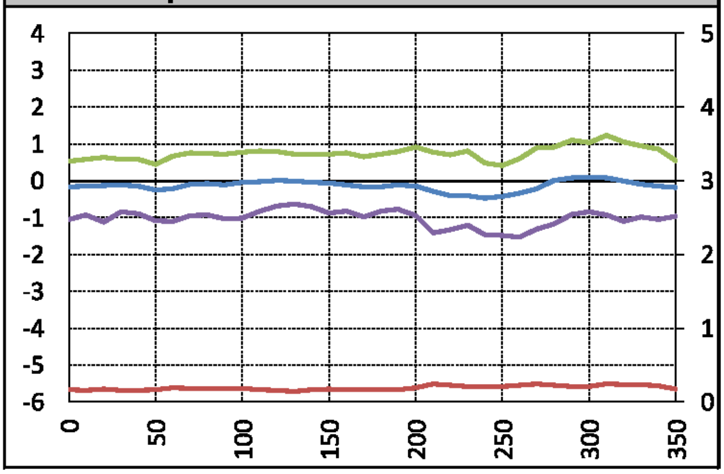
Individual Tap ID: AWD04 **Port ID: 43**



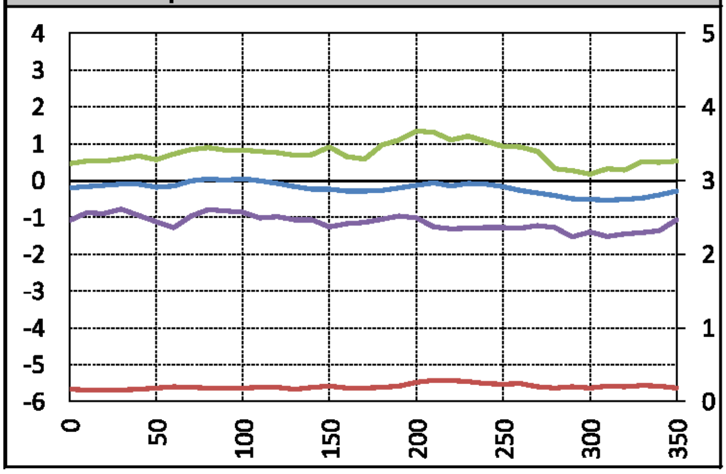
Individual Tap ID: AWD05 **Port ID: 44**



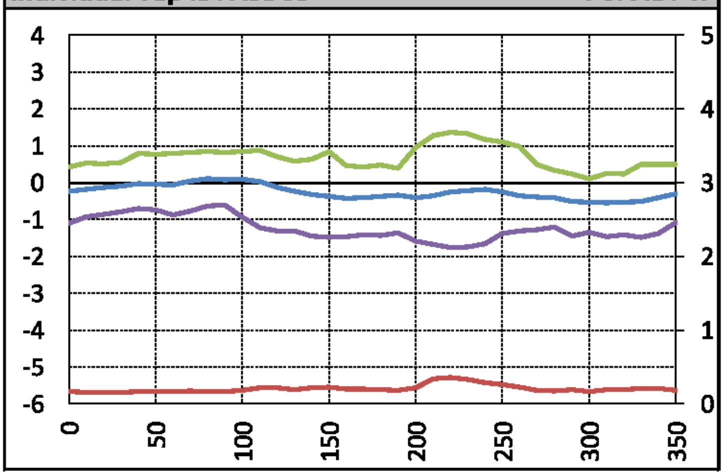
Individual Tap ID: ASD01 **Port ID: 45**



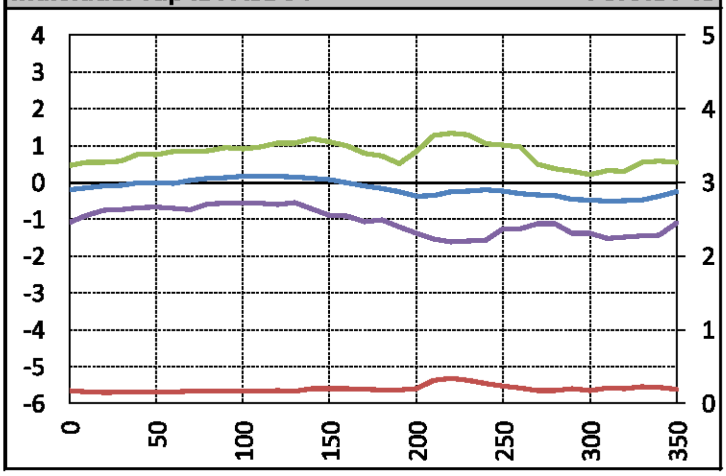
Individual Tap ID: ASD02 **Port ID: 46**



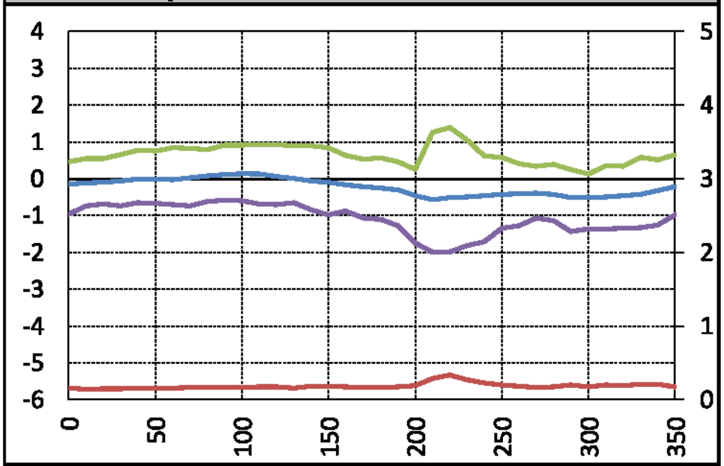
Individual Tap ID: ASD03 **Port ID: 47**



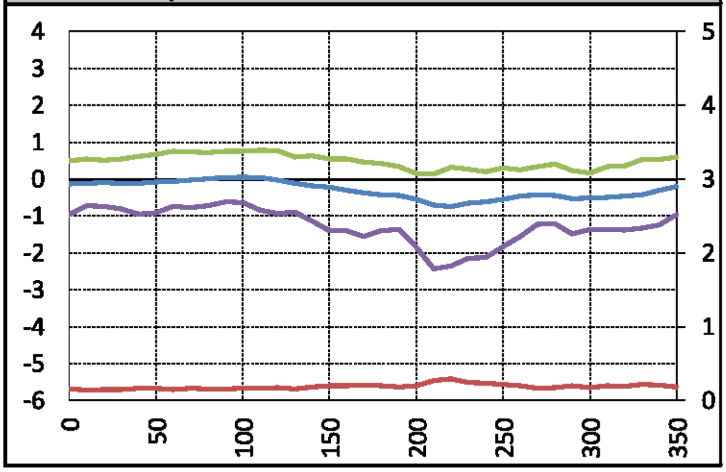
Individual Tap ID: ASD04 **Port ID: 48**



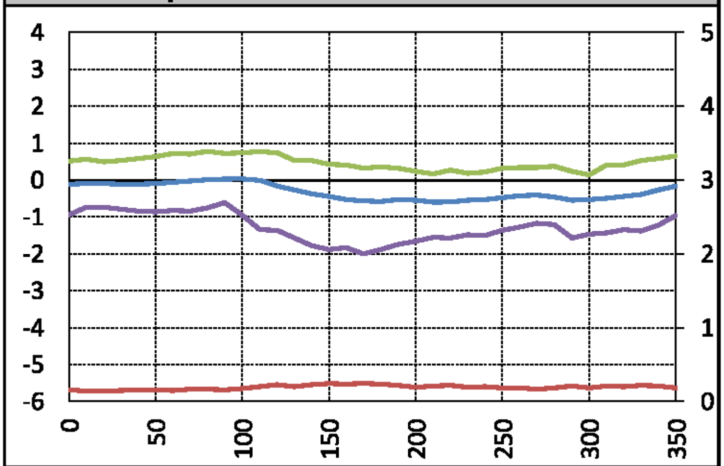
Individual Tap ID: ASD05 **Port ID: 49**



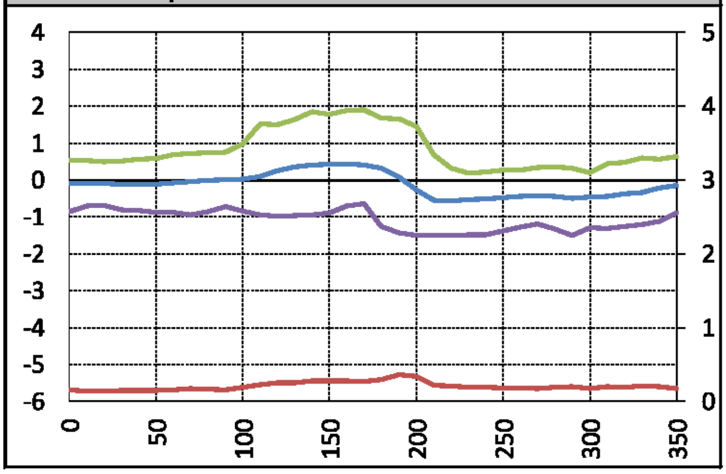
Individual Tap ID: ASD06 **Port ID: 50**



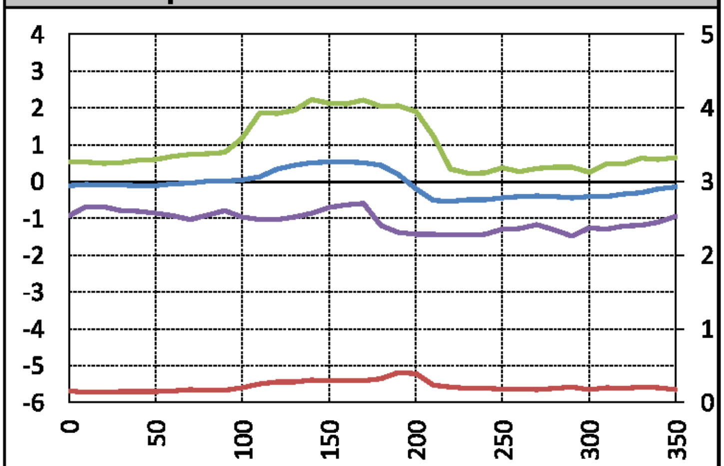
Individual Tap ID: ASD07 **Port ID: 51**



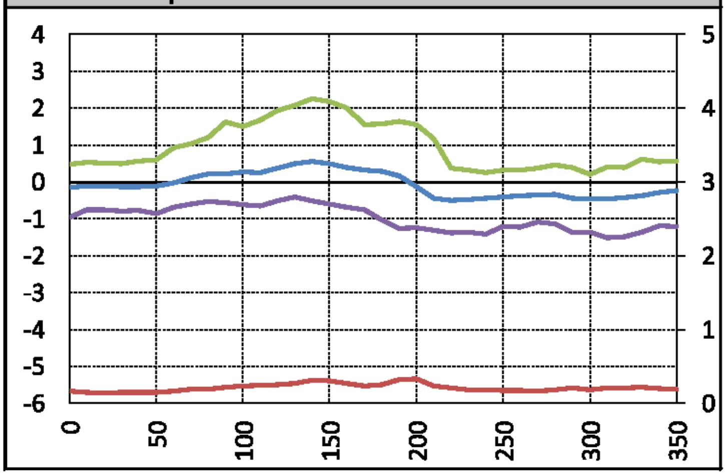
Individual Tap ID: ASD08 **Port ID: 52**



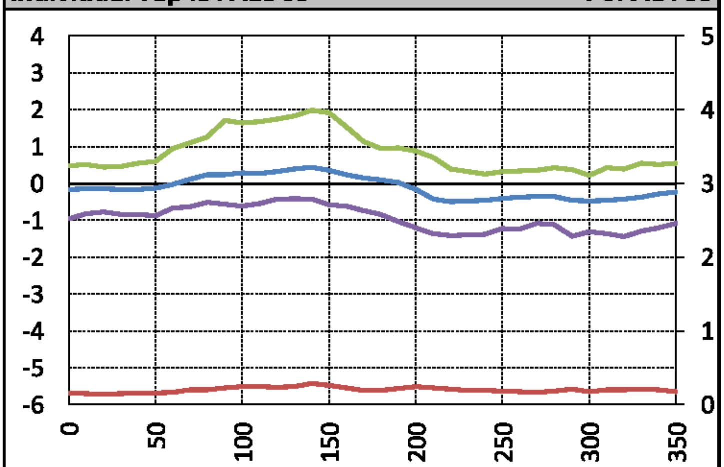
Individual Tap ID: AED01 **Port ID: 53**



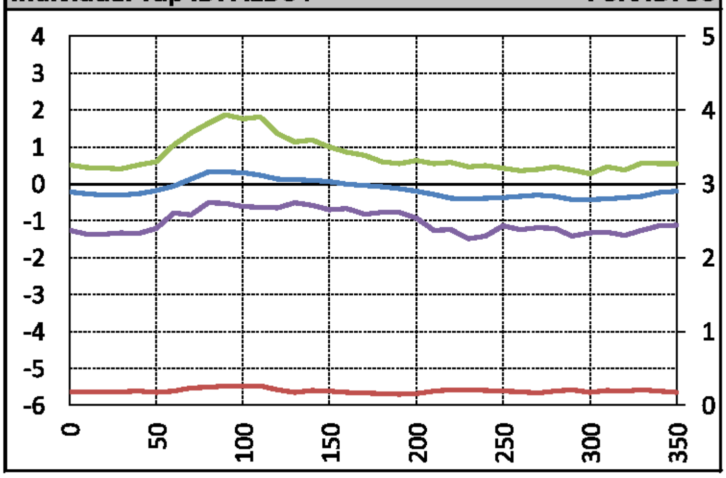
Individual Tap ID: AED02 **Port ID: 54**



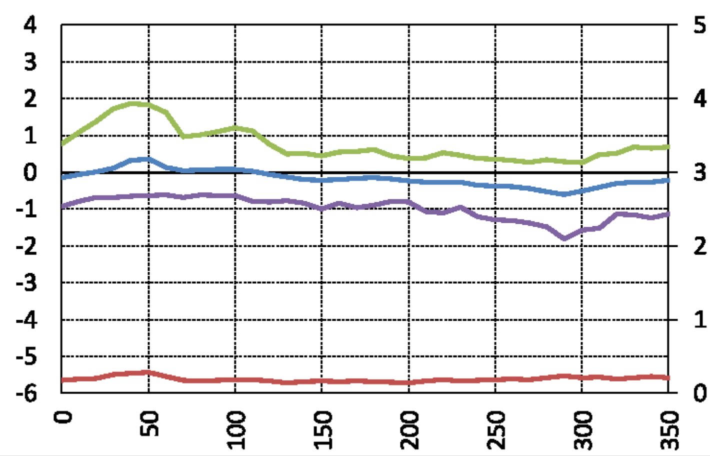
Individual Tap ID: AED03 **Port ID: 55**



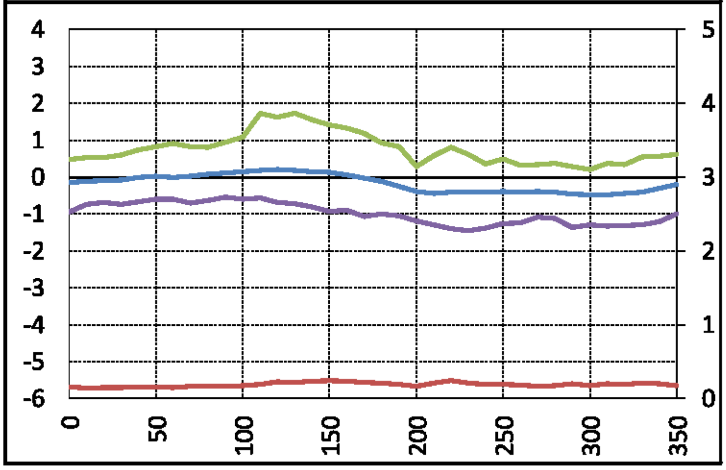
Individual Tap ID: AED04 **Port ID: 56**



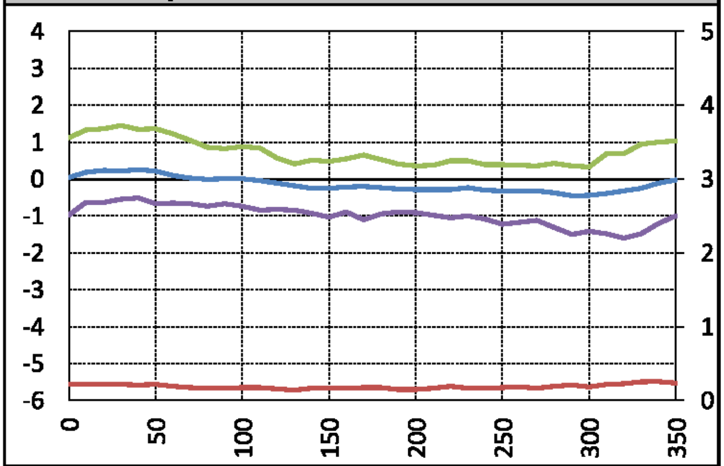
Individual Tap ID: AED05 Port ID: 57



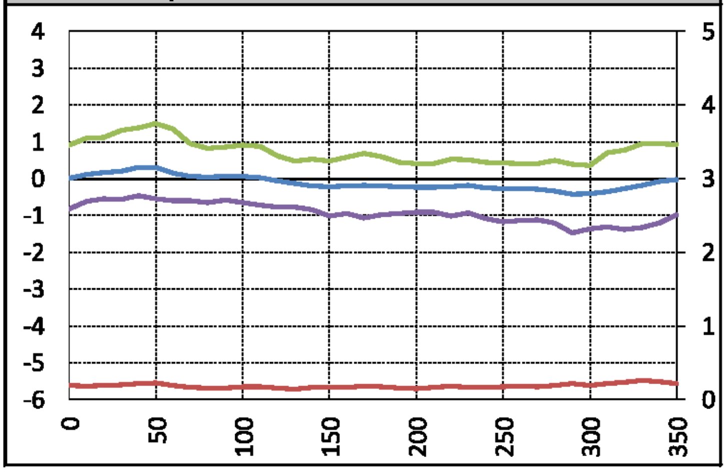
Individual Tap ID: AED06 Port ID: 58



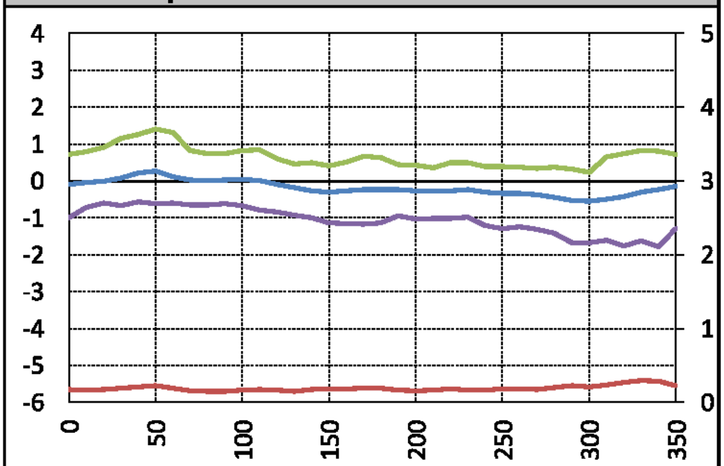
Individual Tap ID: ANC01 Port ID: 59



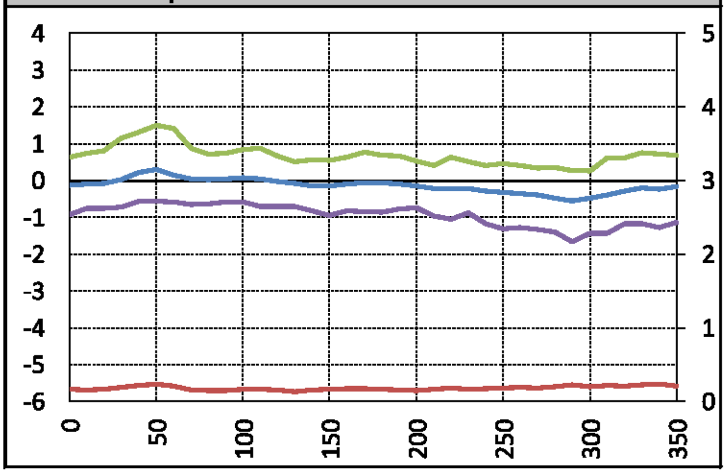
Individual Tap ID: ANC02 Port ID: 60



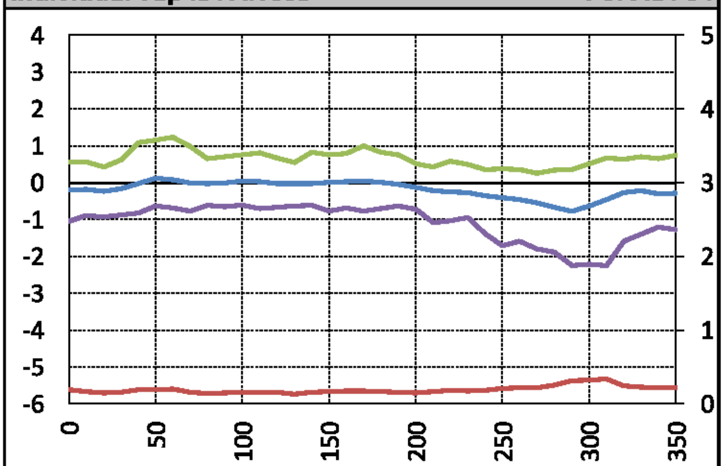
Individual Tap ID: ANC03 Port ID: 61



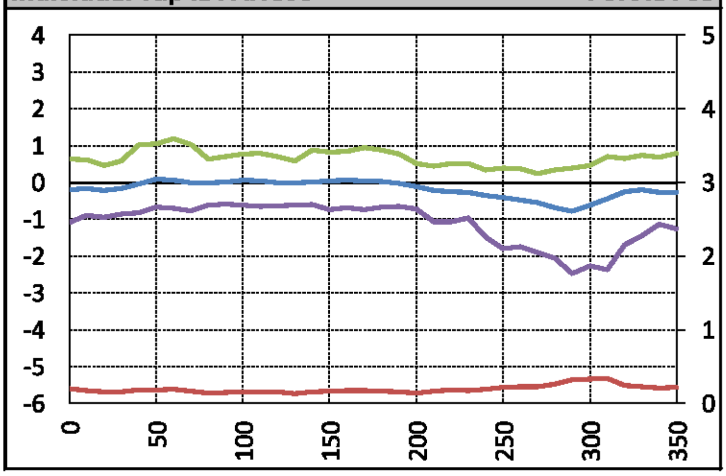
Individual Tap ID: ANC04 Port ID: 62



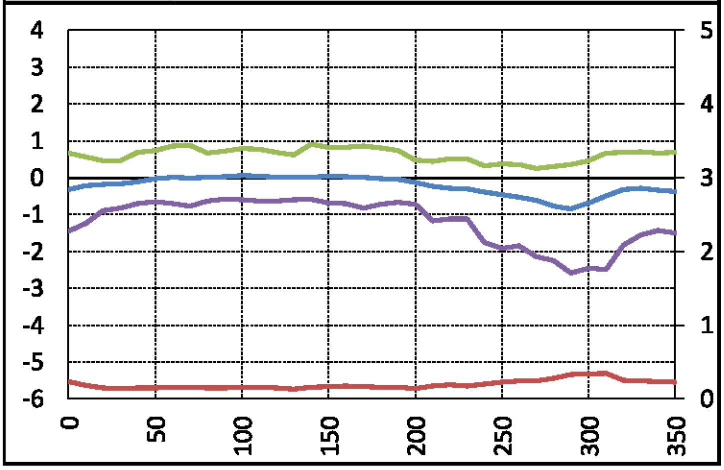
Individual Tap ID: ANC05 Port ID: 64



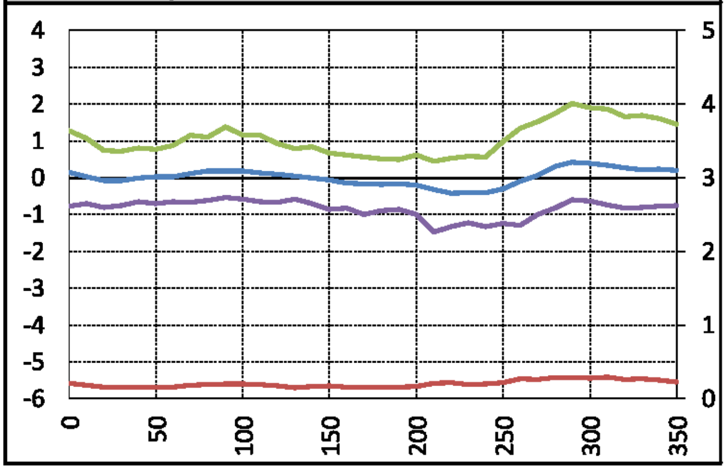
Individual Tap ID: ANC06 Port ID: 65



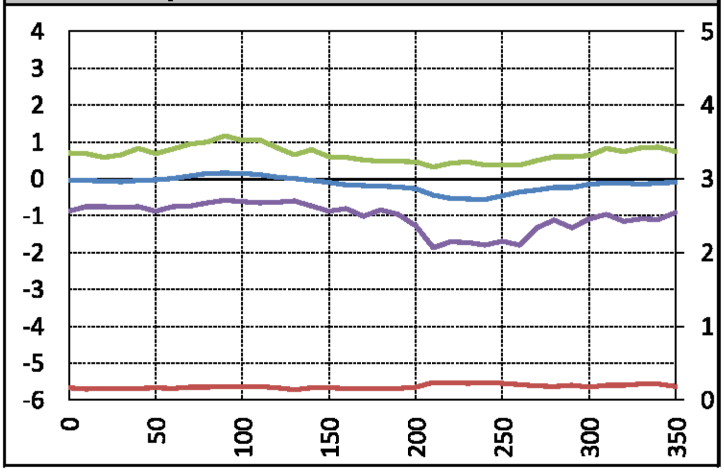
Individual Tap ID: ANC07 **Port ID: 66**



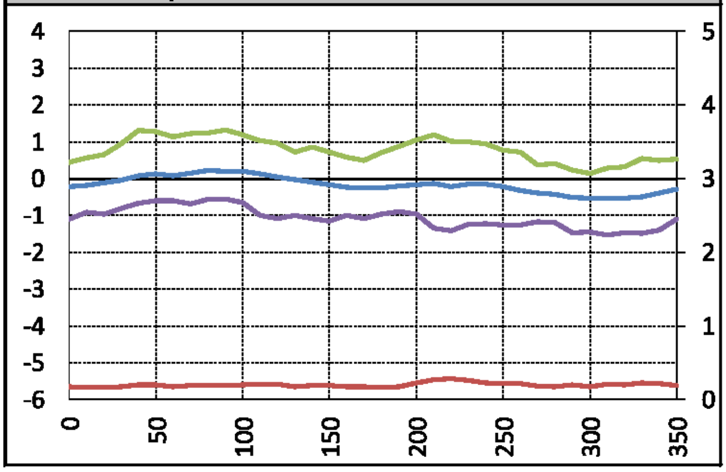
Individual Tap ID: AWC01 **Port ID: 67**



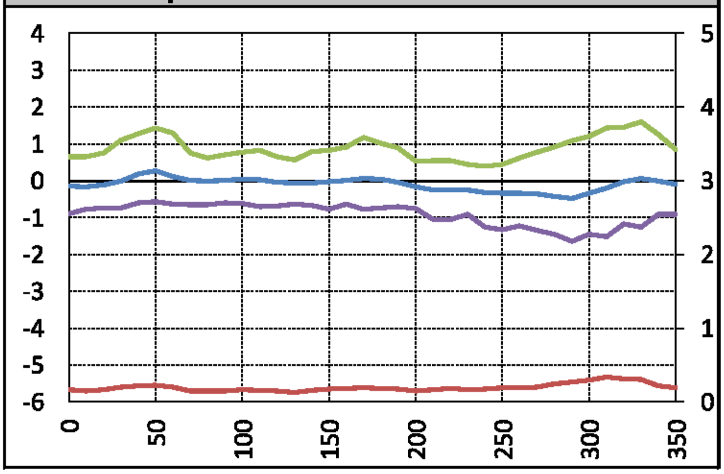
Individual Tap ID: AWC02 **Port ID: 68**



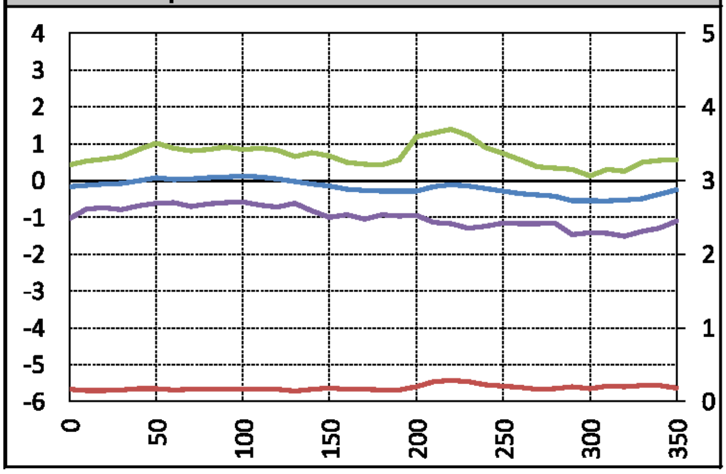
Individual Tap ID: AWC03 **Port ID: 69**



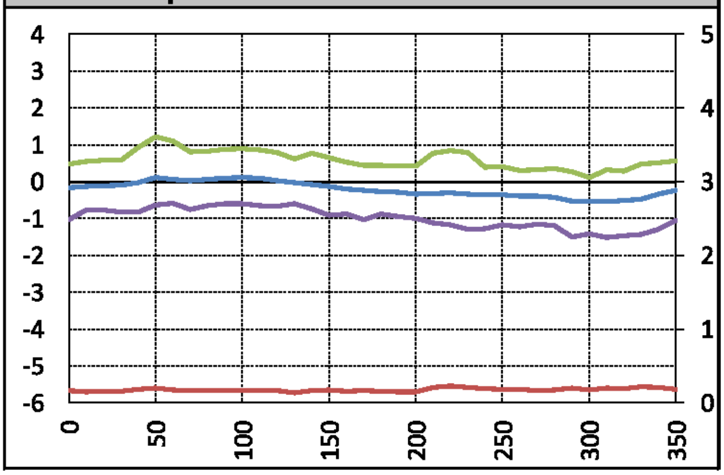
Individual Tap ID: AWC04 **Port ID: 70**



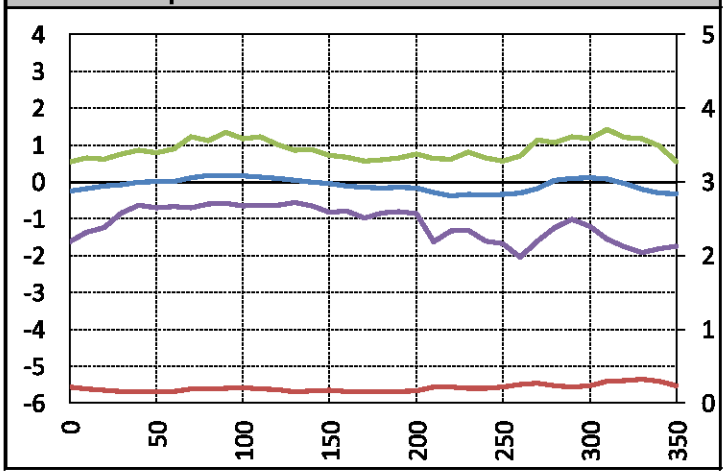
Individual Tap ID: AWC05 **Port ID: 71**



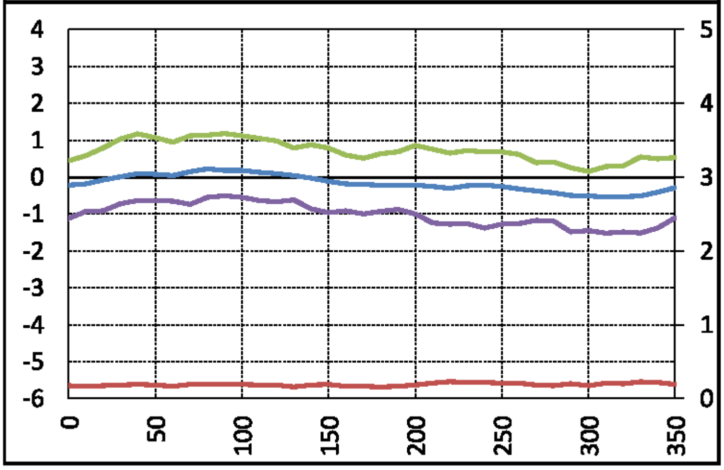
Individual Tap ID: AWC06 **Port ID: 72**



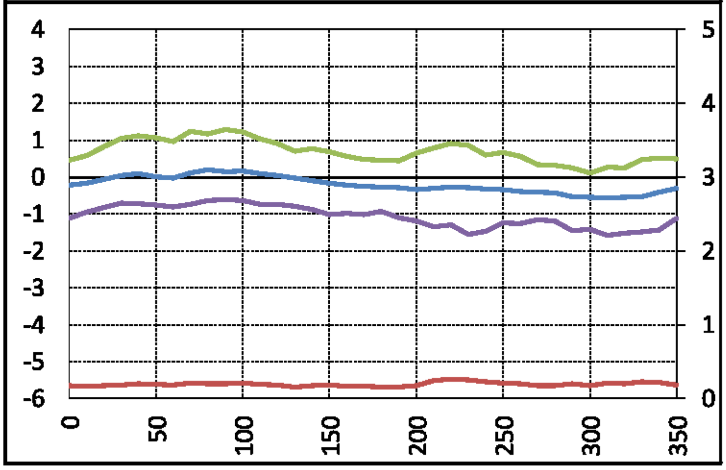
Individual Tap ID: ASC01 **Port ID: 73**



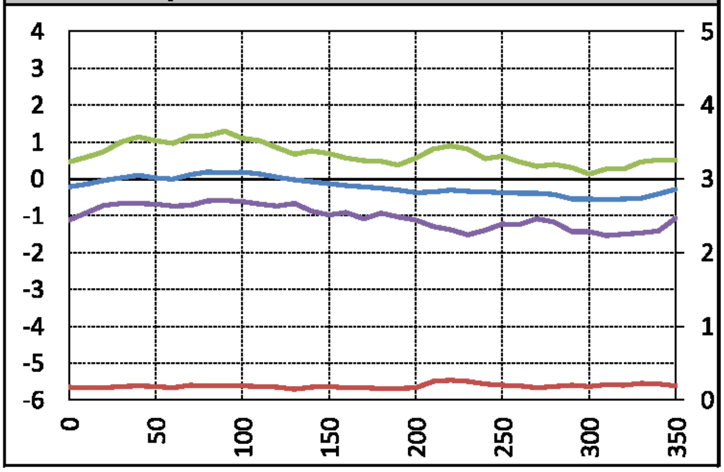
Individual Tap ID: ASC02 Port ID: 74



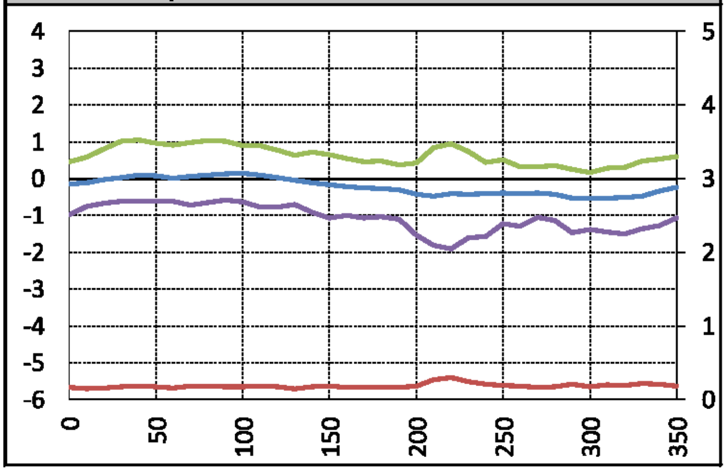
Individual Tap ID: ASC03 Port ID: 75



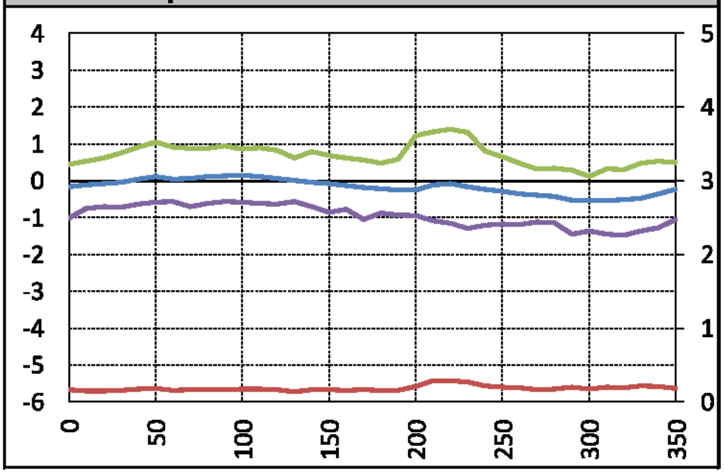
Individual Tap ID: ASC04 Port ID: 76



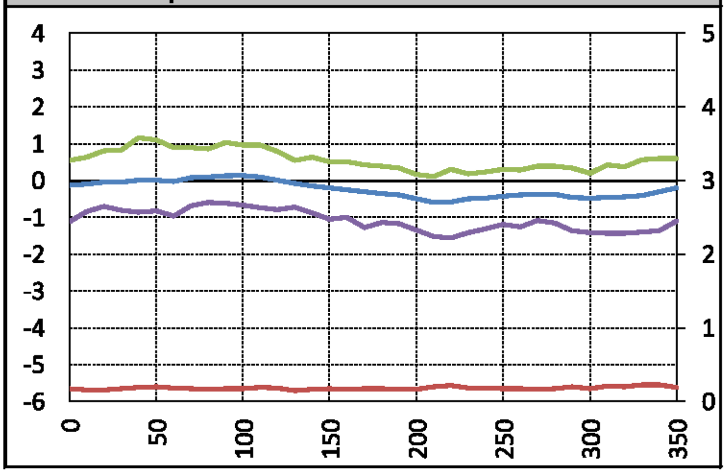
Individual Tap ID: ASC05 Port ID: 77



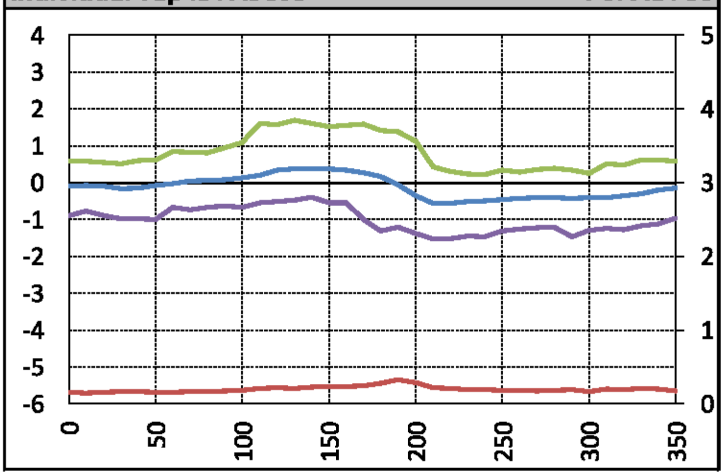
Individual Tap ID: ASC06 Port ID: 78



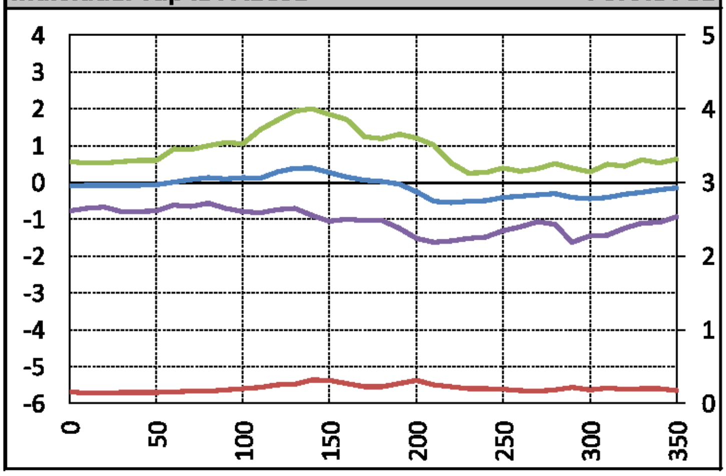
Individual Tap ID: ASC07 Port ID: 79



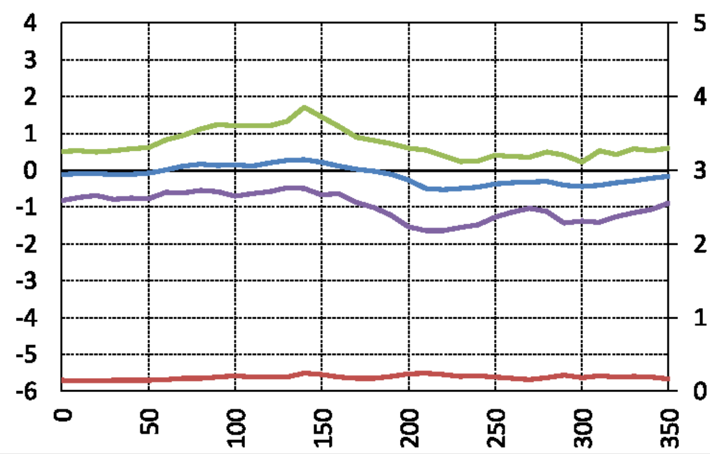
Individual Tap ID: ASC08 Port ID: 80



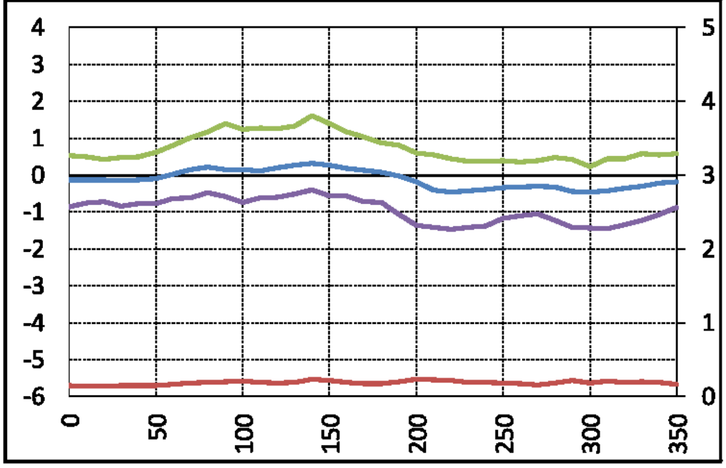
Individual Tap ID: AEC01 Port ID: 81



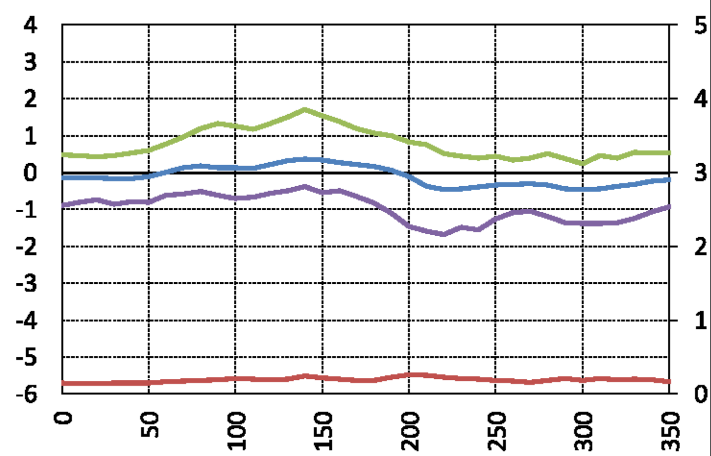
Individual Tap ID: AEC02 Port ID: 82



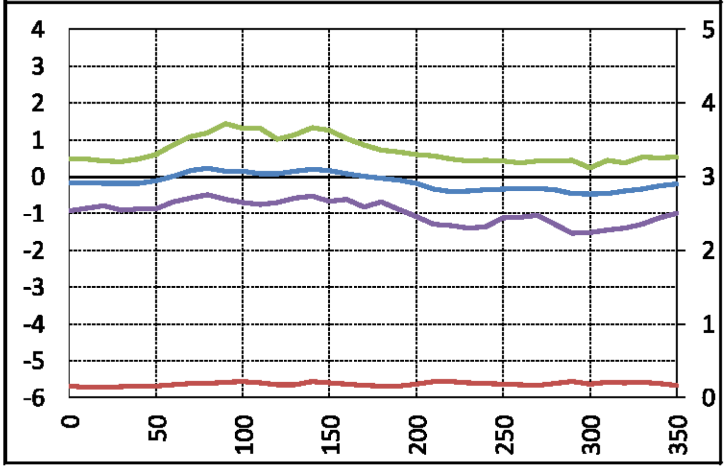
Individual Tap ID: AEC03 Port ID: 83



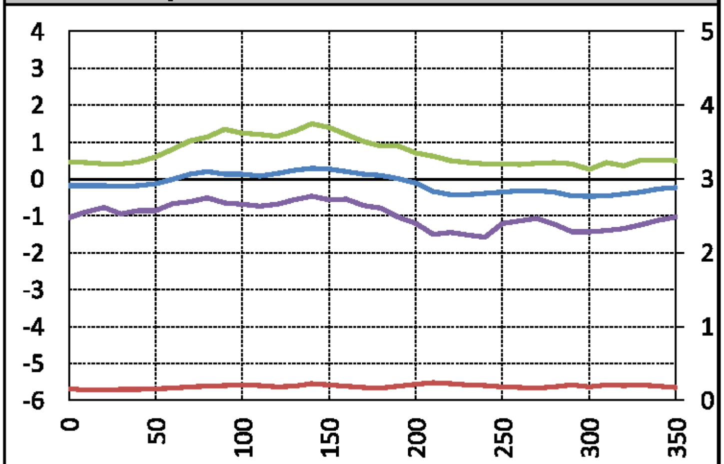
Individual Tap ID: AEC04 Port ID: 84



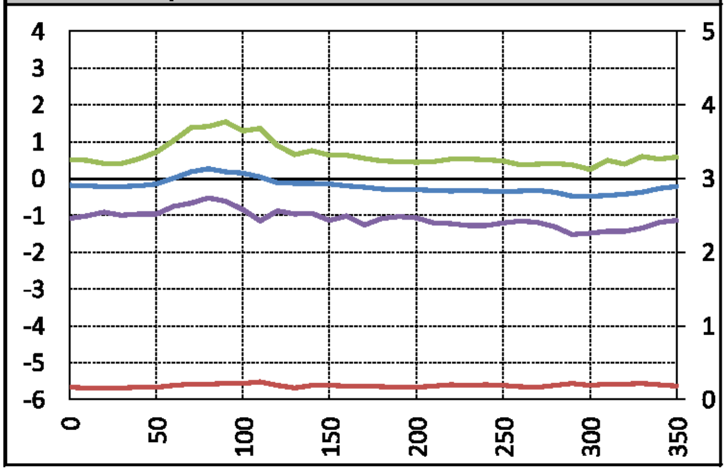
Individual Tap ID: AEC05 Port ID: 85



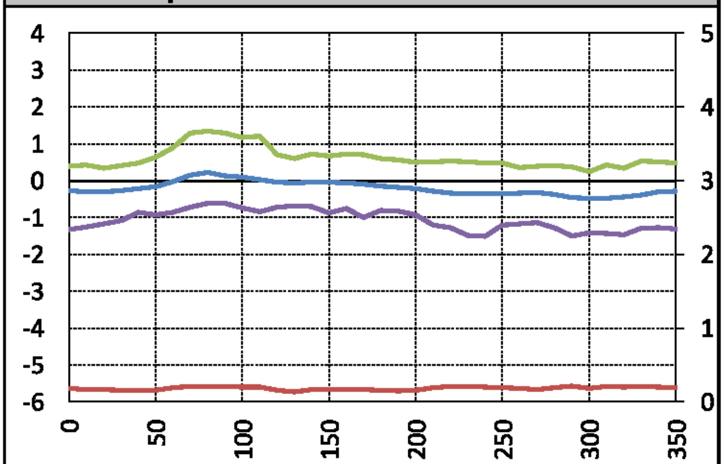
Individual Tap ID: AEC06 Port ID: 86



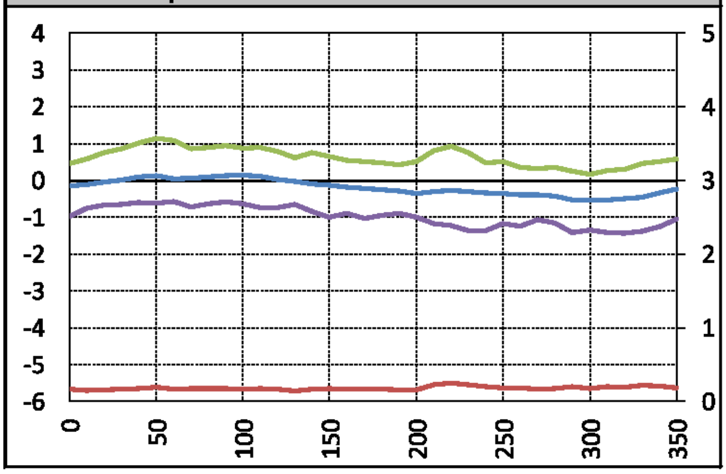
Individual Tap ID: AEC07 Port ID: 87



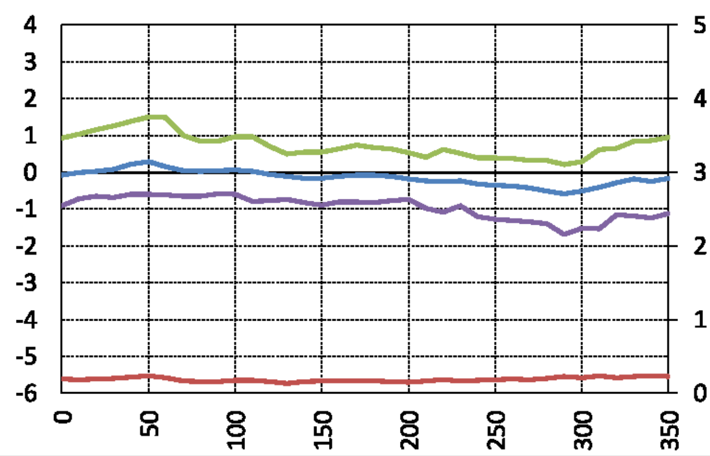
Individual Tap ID: AEC08 Port ID: 88



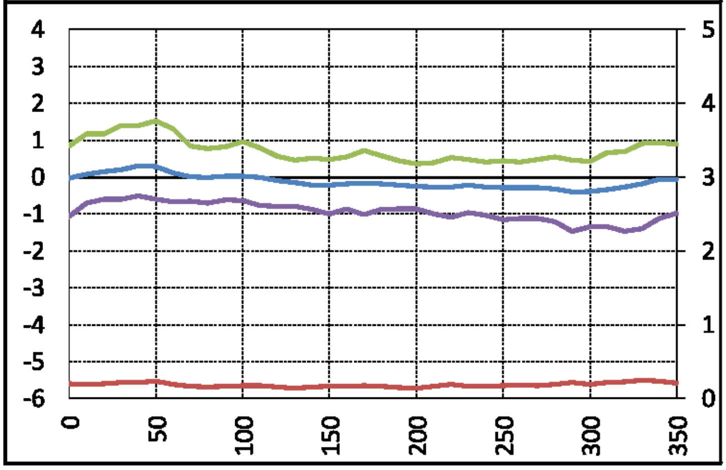
Individual Tap ID: AEC09 Port ID: 89



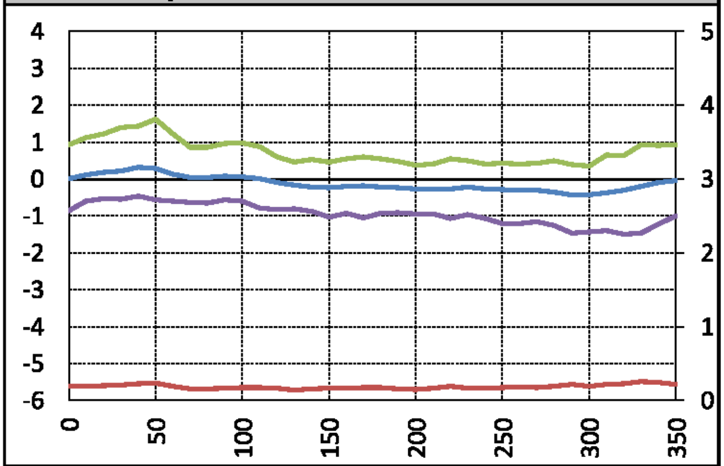
Individual Tap ID: AEC10 — **Port ID: 90**



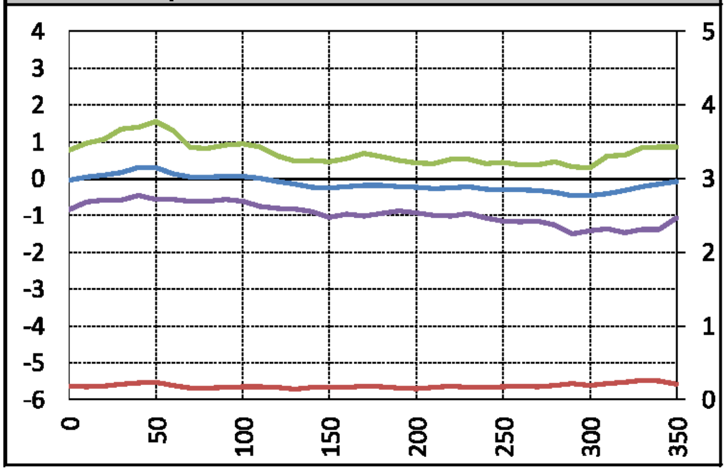
Individual Tap ID: ANB01 — **Port ID: 91**



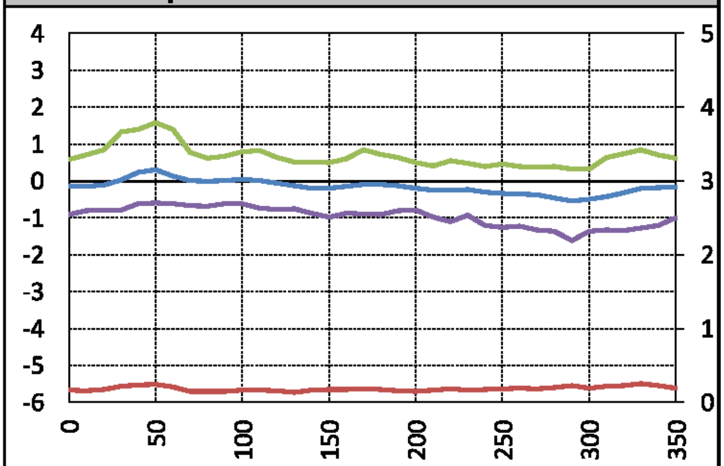
Individual Tap ID: ANB02 — **Port ID: 92**



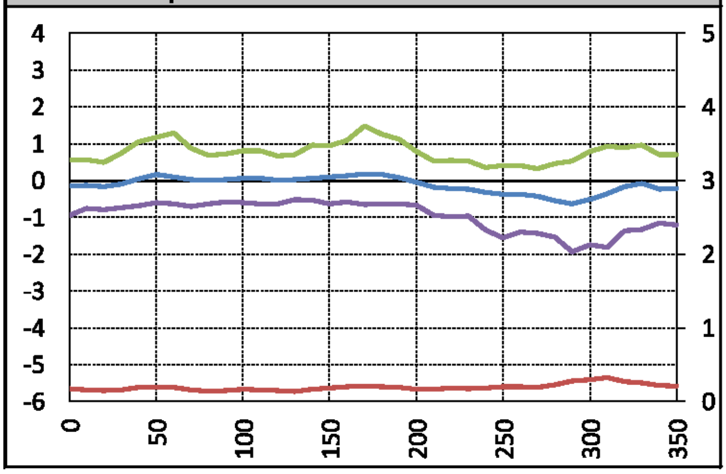
Individual Tap ID: ANB03 — **Port ID: 93**



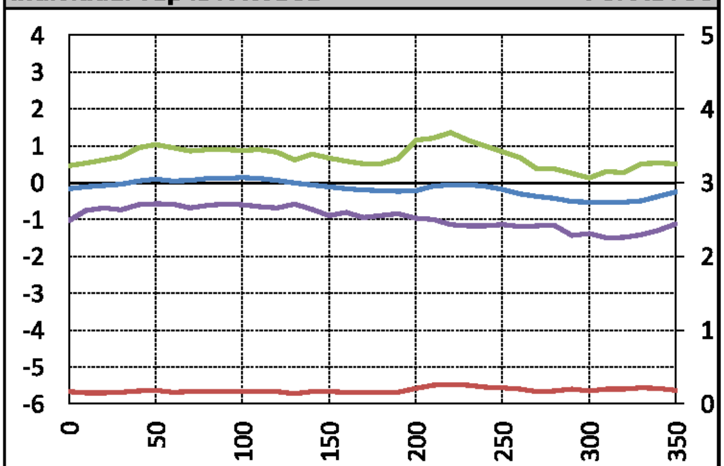
Individual Tap ID: ANB04 — **Port ID: 94**



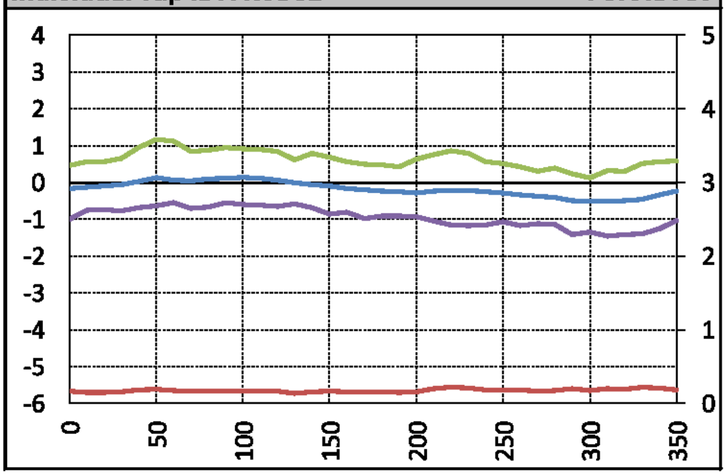
Individual Tap ID: ANB05 — **Port ID: 95**



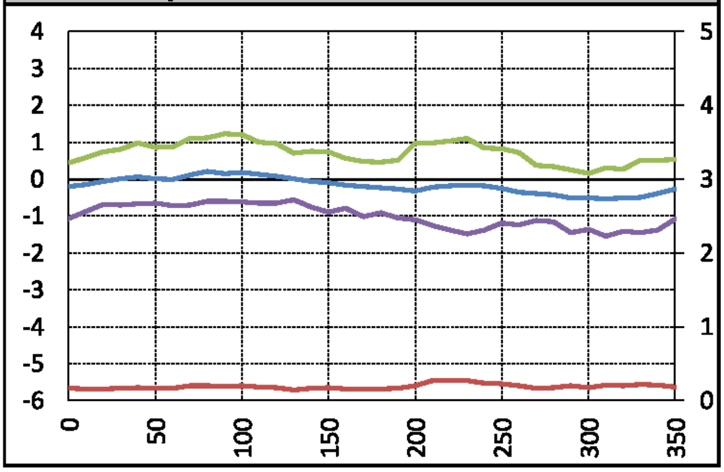
Individual Tap ID: AWB01 — **Port ID: 96**



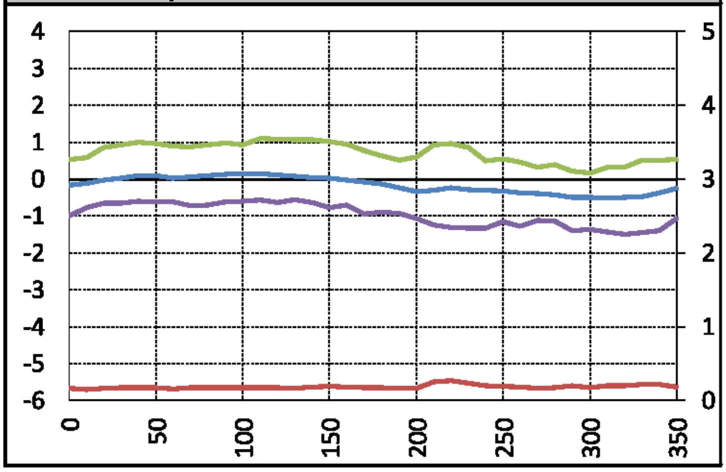
Individual Tap ID: AWB02 — **Port ID: 97**



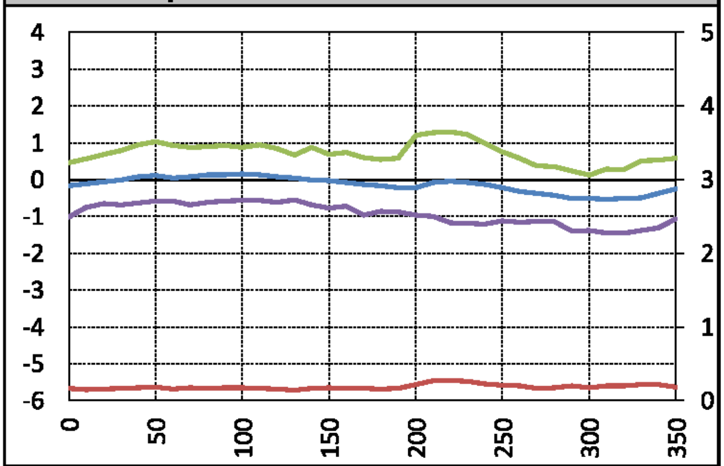
Individual Tap ID: ASB01 **Port ID: 98**



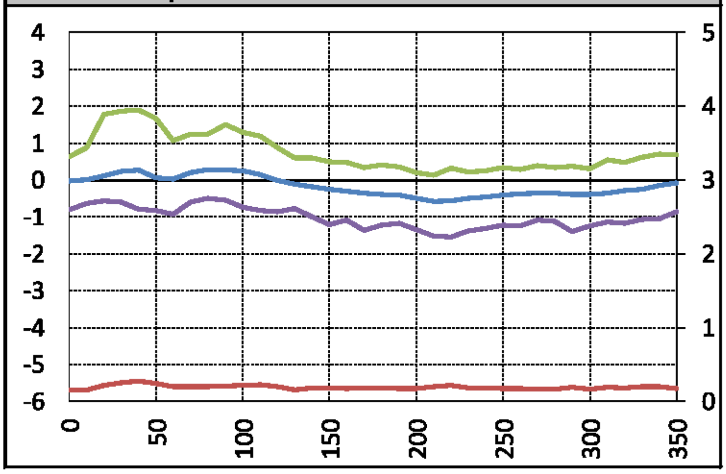
Individual Tap ID: ASB02 **Port ID: 99**



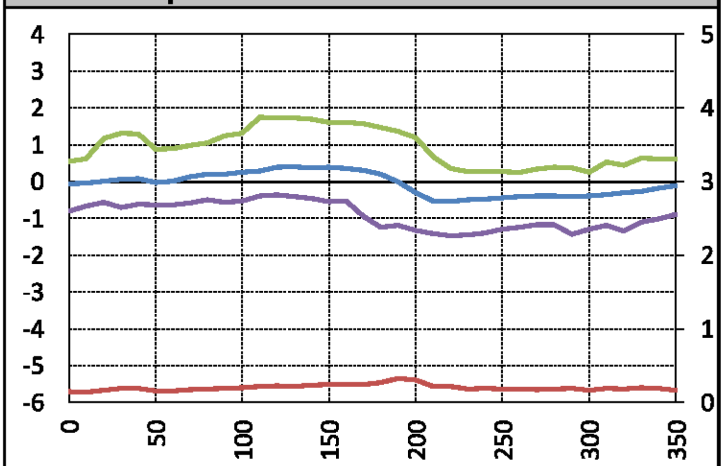
Individual Tap ID: ASB03 **Port ID: 100**



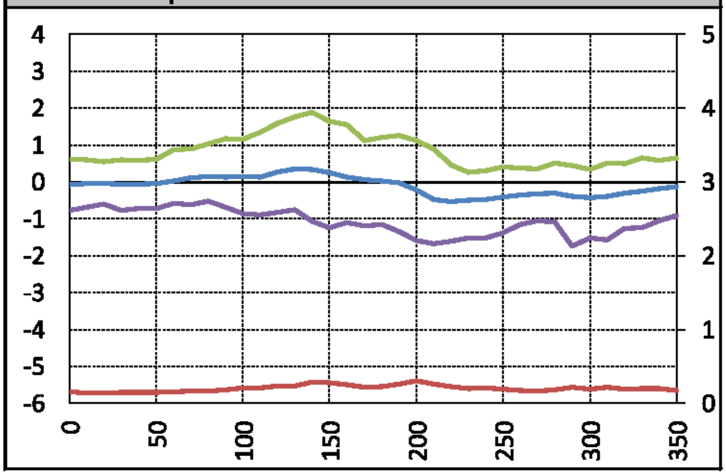
Individual Tap ID: ASB04 **Port ID: 101**



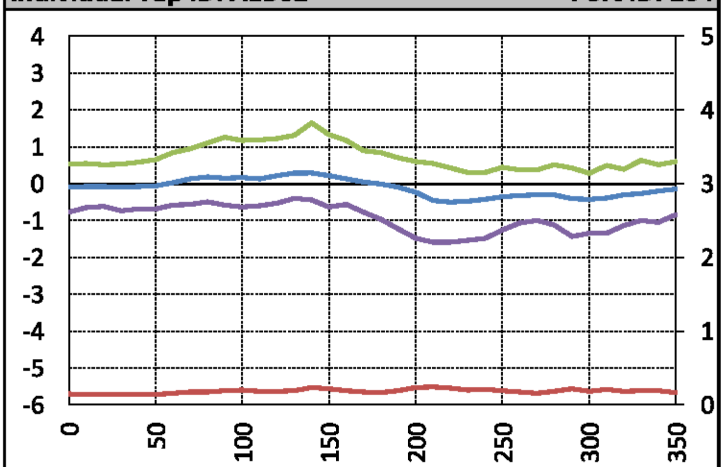
Individual Tap ID: ASB05 **Port ID: 102**



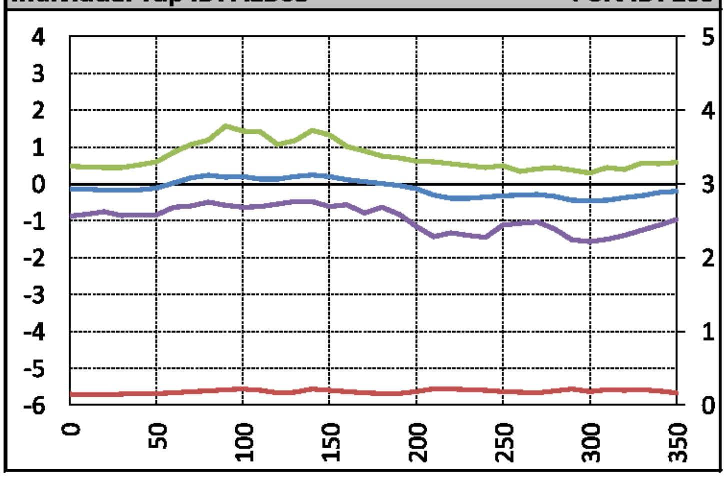
Individual Tap ID: AEB01 **Port ID: 103**



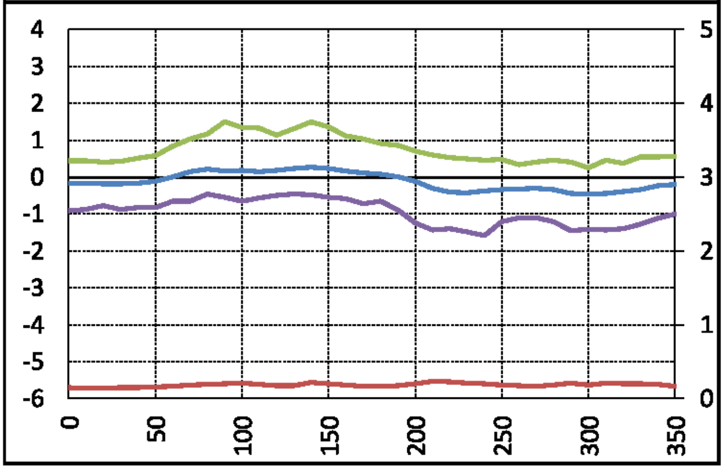
Individual Tap ID: AEB02 **Port ID: 104**



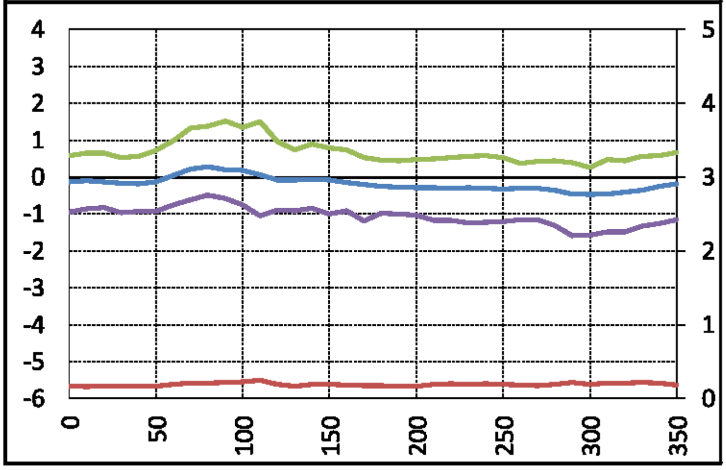
Individual Tap ID: AEB03 **Port ID: 105**



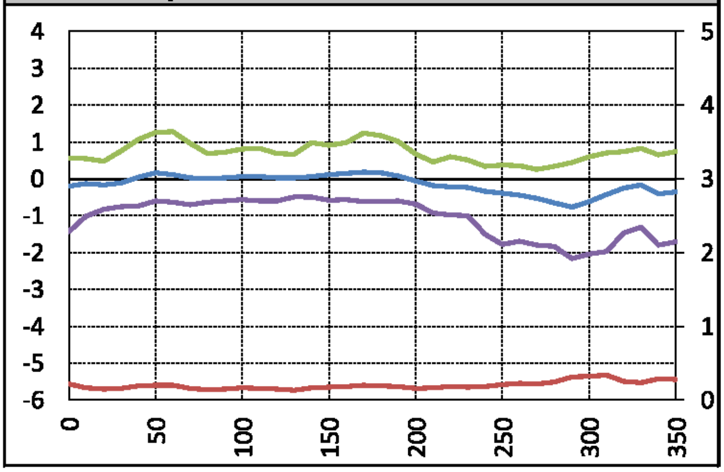
Individual Tap ID: AEB04 **Port ID: 106**



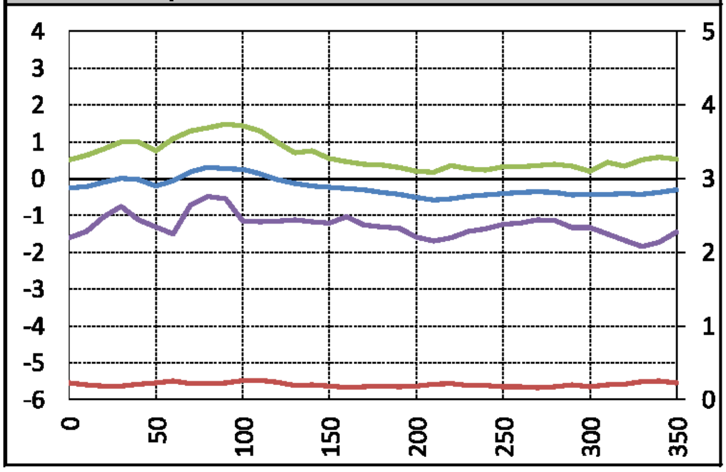
Individual Tap ID: AEB05 **Port ID: 107**



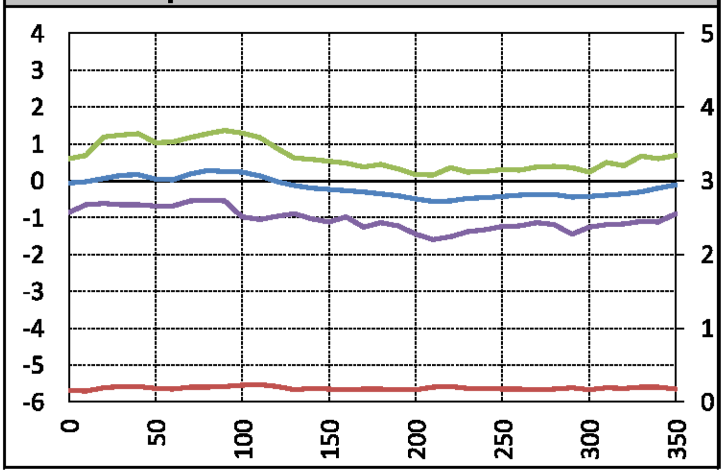
Individual Tap ID: ANA01 **Port ID: 108**



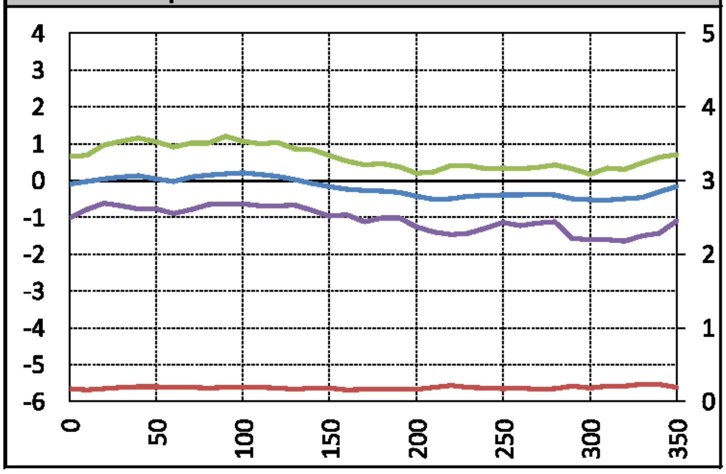
Individual Tap ID: BNB01 **Port ID: 111**



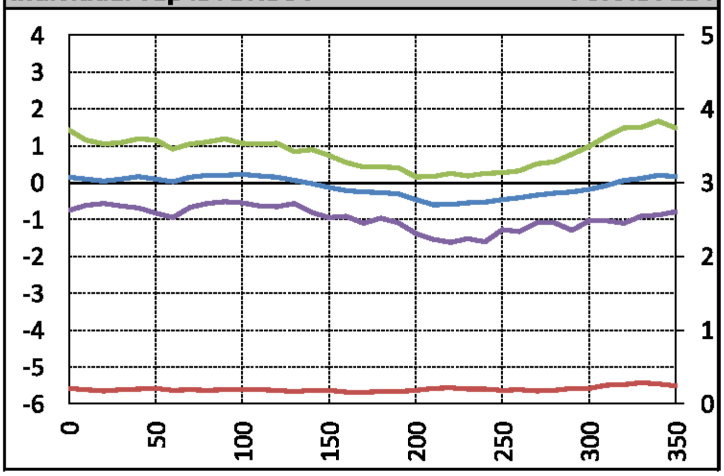
Individual Tap ID: BNB02 **Port ID: 112**



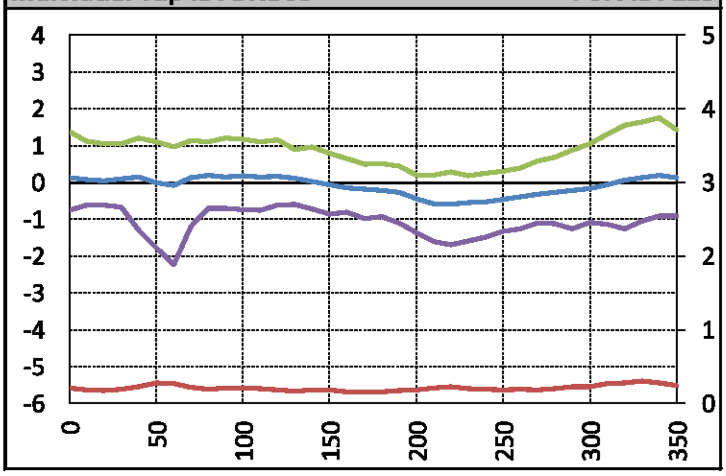
Individual Tap ID: BNB03 **Port ID: 113**



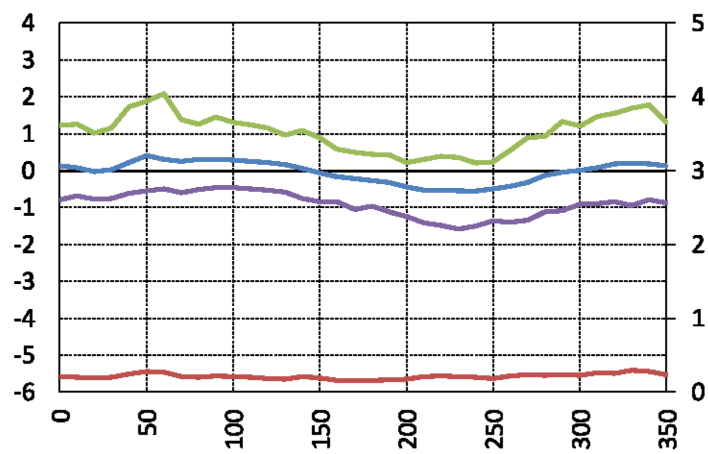
Individual Tap ID: BNB04 **Port ID: 114**



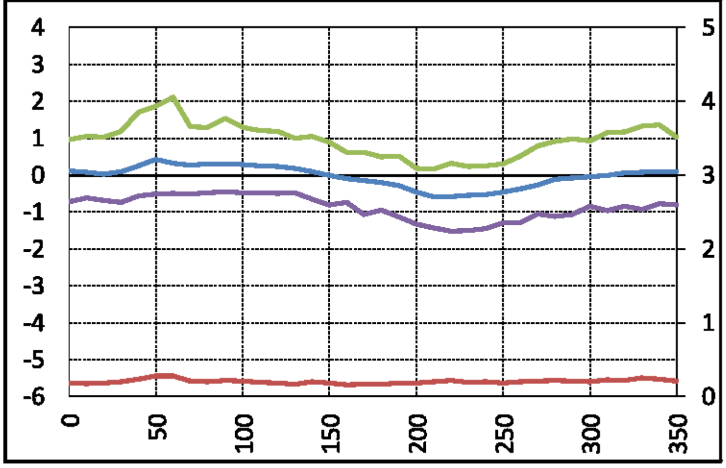
Individual Tap ID: BNB05 **Port ID: 115**



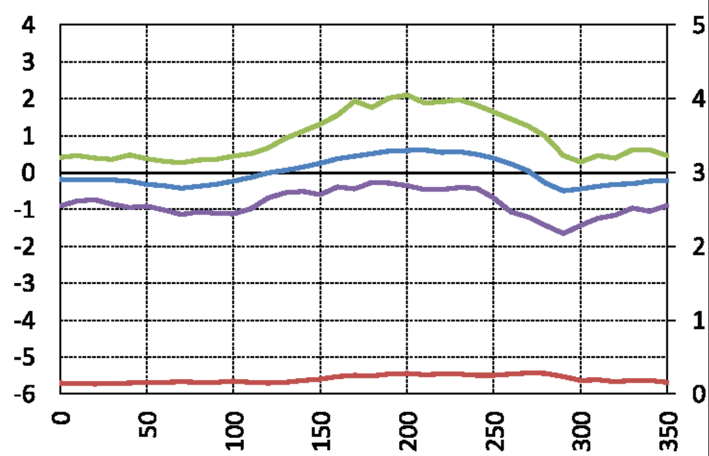
Individual Tap ID: BNB06 Port ID: 116



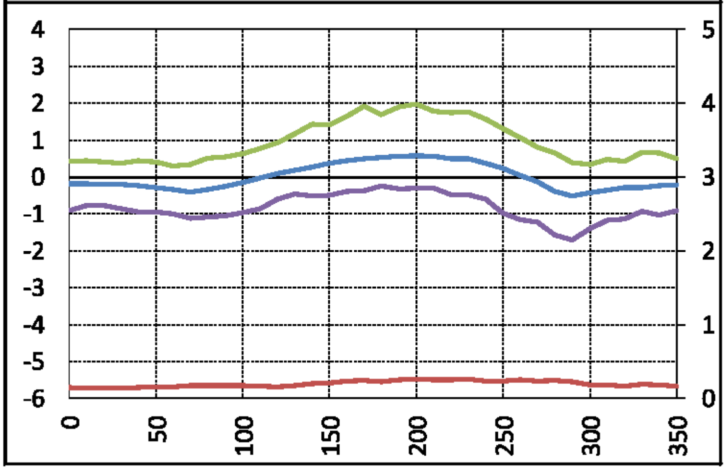
Individual Tap ID: BNB07 Port ID: 117



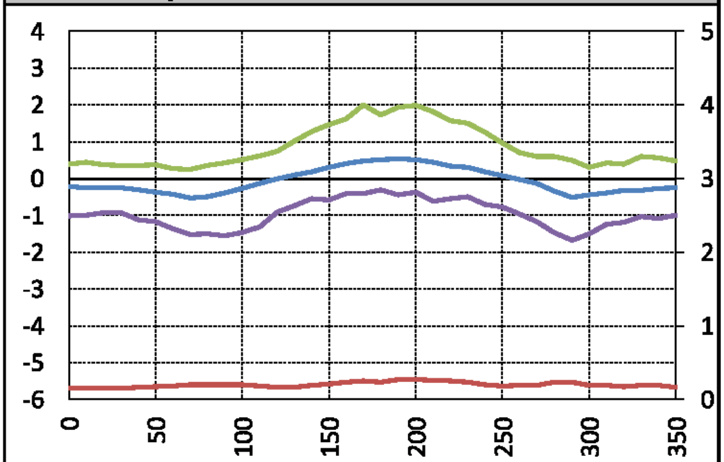
Individual Tap ID: BWB06 Port ID: 118



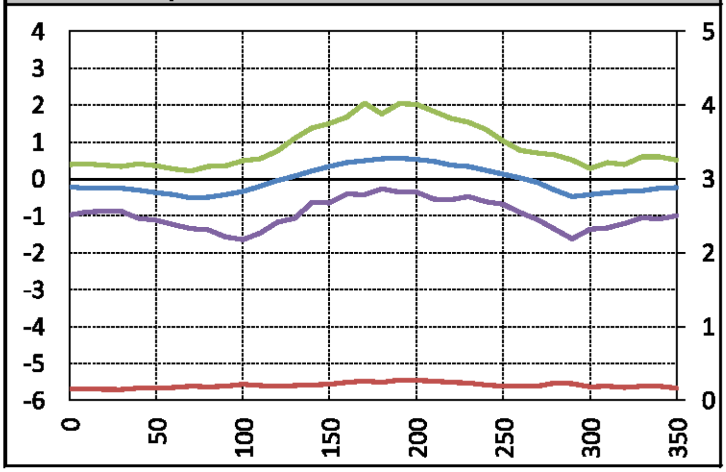
Individual Tap ID: BSB02 Port ID: 119



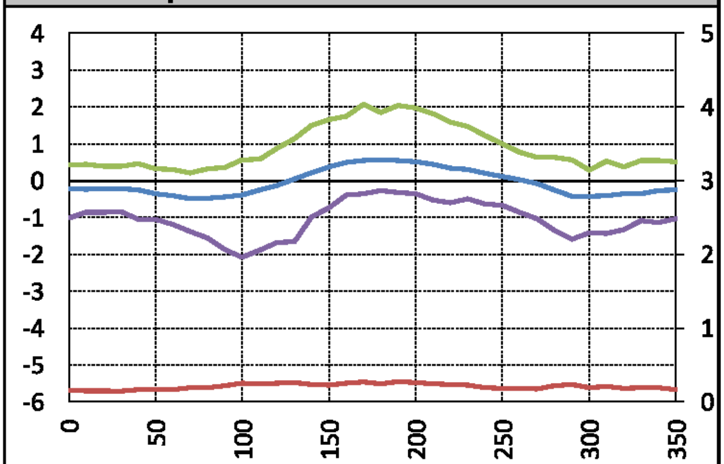
Individual Tap ID: BSB03 Port ID: 120



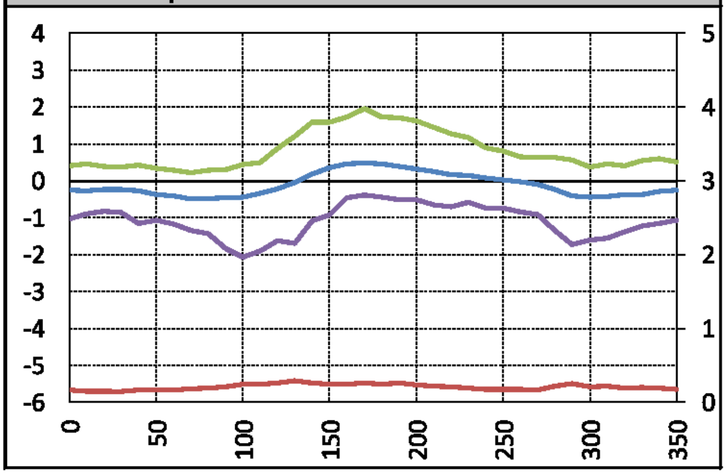
Individual Tap ID: BSB04 Port ID: 121



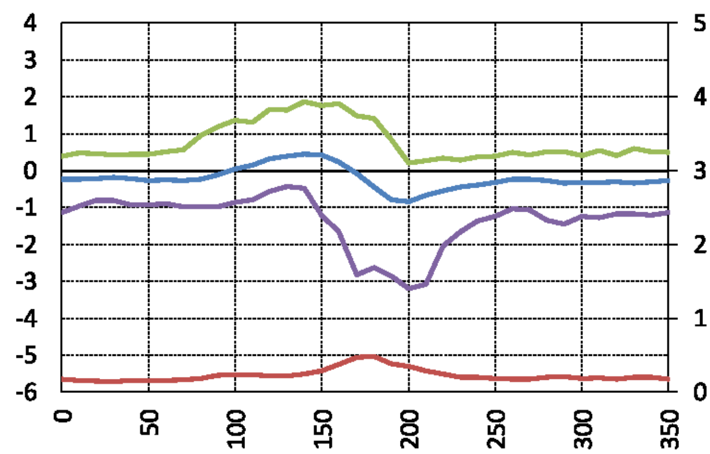
Individual Tap ID: BSB05 Port ID: 122



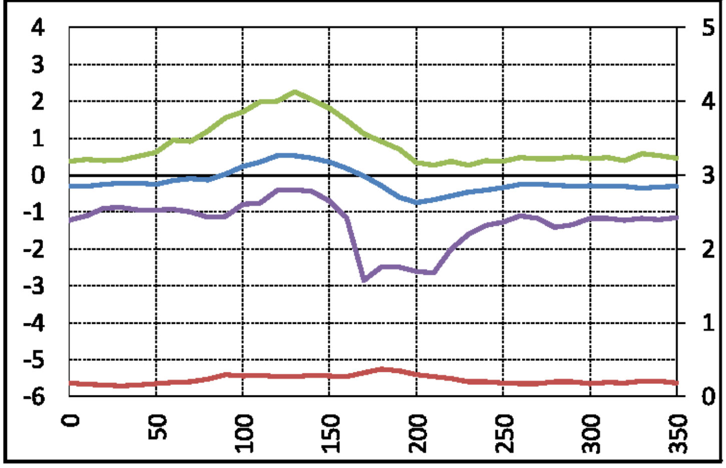
Individual Tap ID: BSB06 Port ID: 123



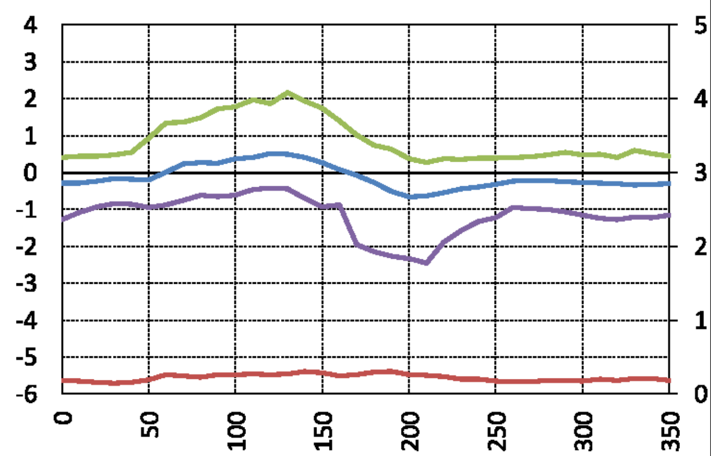
Individual Tap ID: BEB01 Port ID: 124



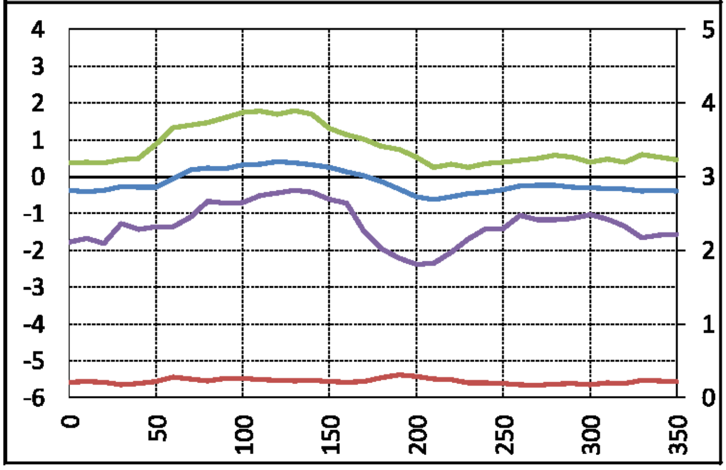
Individual Tap ID: BEB02 Port ID: 125



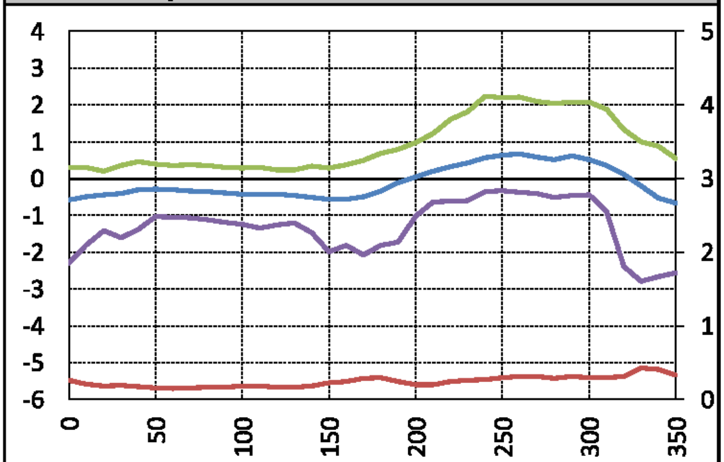
Individual Tap ID: BEB03 Port ID: 126



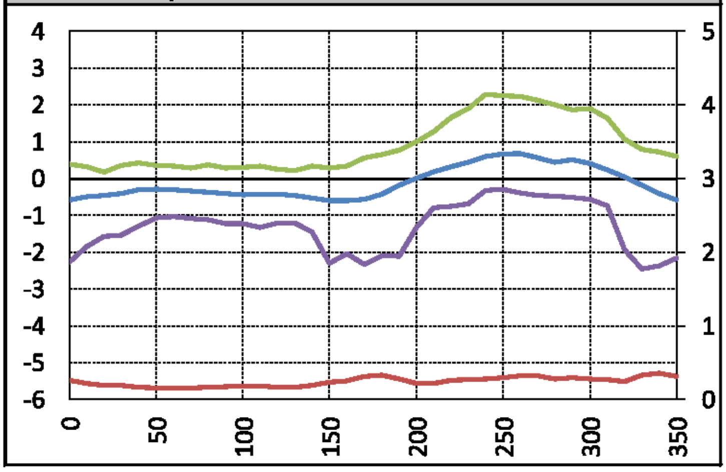
Individual Tap ID: BEB04 Port ID: 127



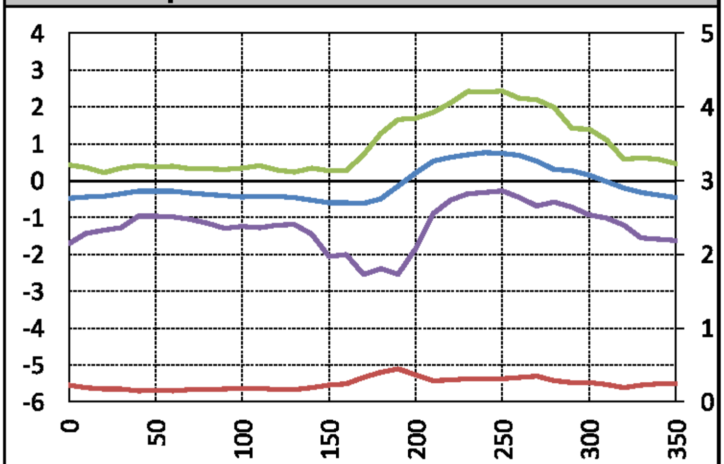
Individual Tap ID: BWF01 Port ID: 128



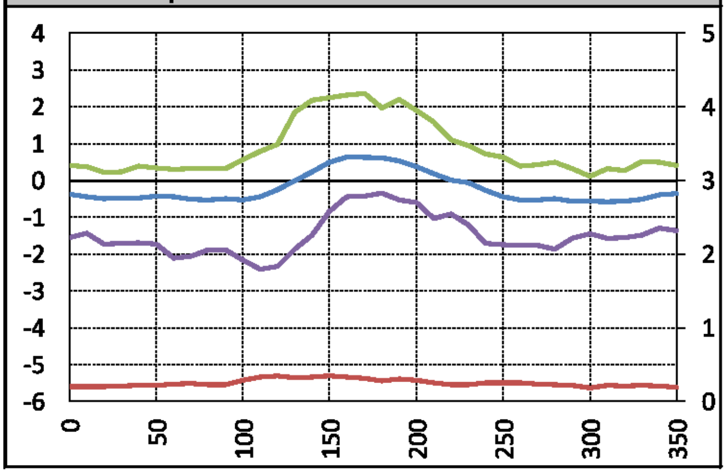
Individual Tap ID: BWF02 Port ID: 129



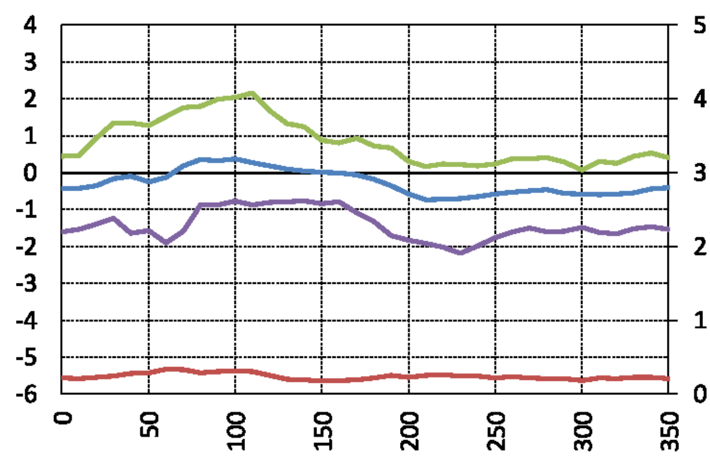
Individual Tap ID: BWF03 Port ID: 130



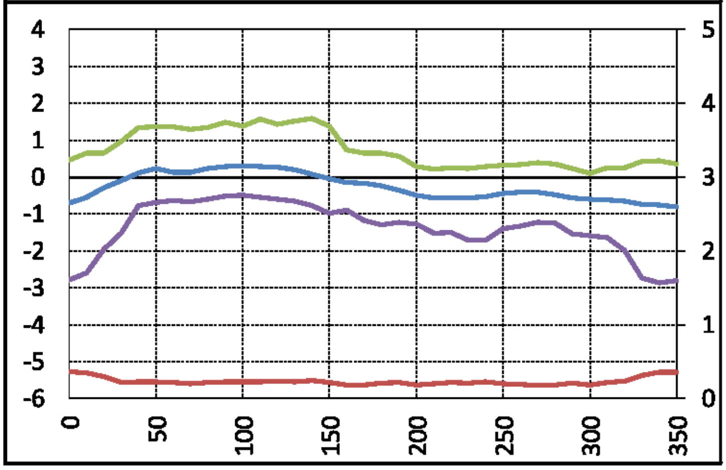
Individual Tap ID: BSF01 Port ID: 131



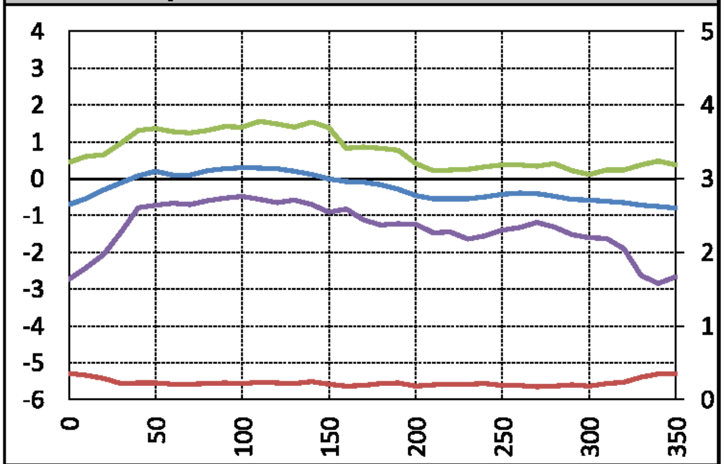
Individual Tap ID: BEF01 **Port ID: 132**



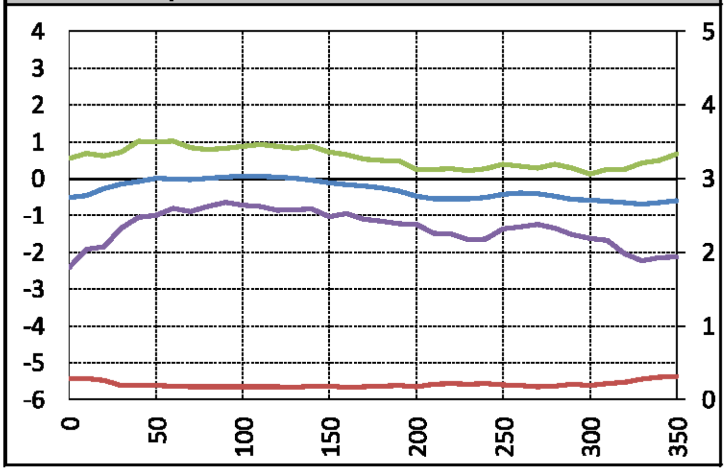
Individual Tap ID: BEF02 **Port ID: 133**



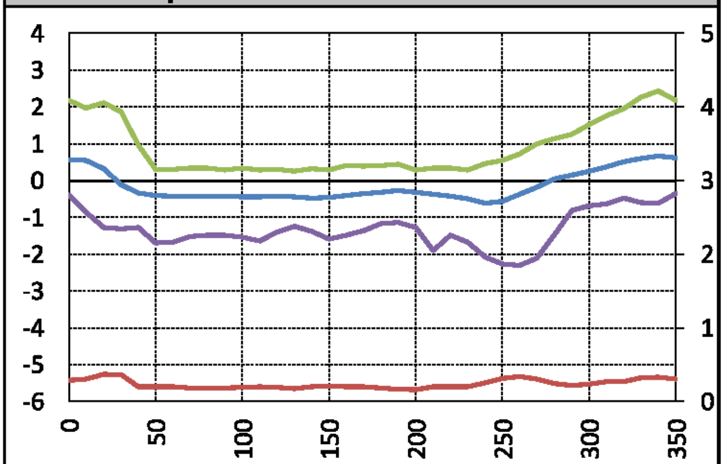
Individual Tap ID: BEF03 **Port ID: 134**



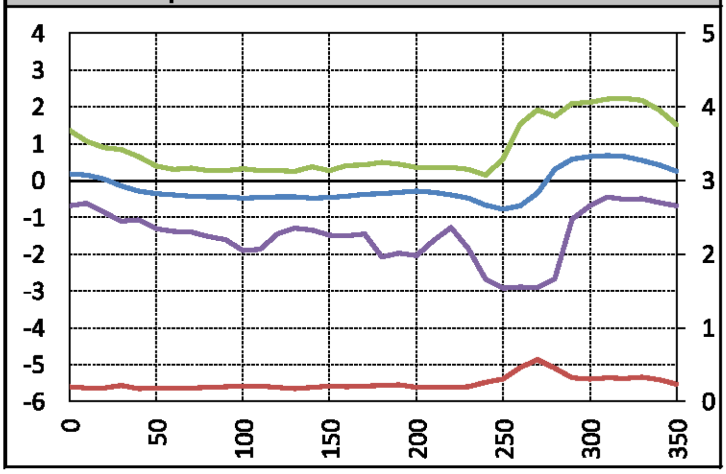
Individual Tap ID: BNE09 **Port ID: 135**



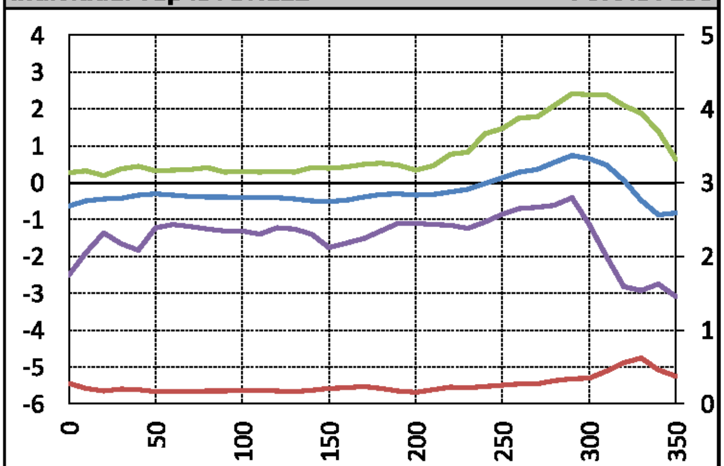
Individual Tap ID: BNE10 **Port ID: 136**



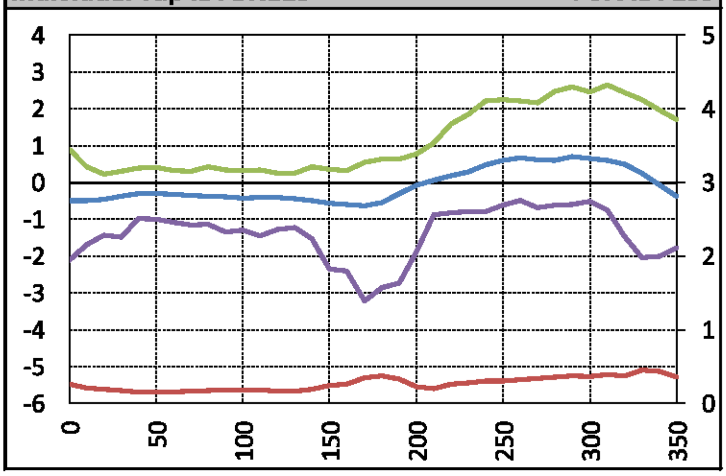
Individual Tap ID: BNE11 **Port ID: 137**



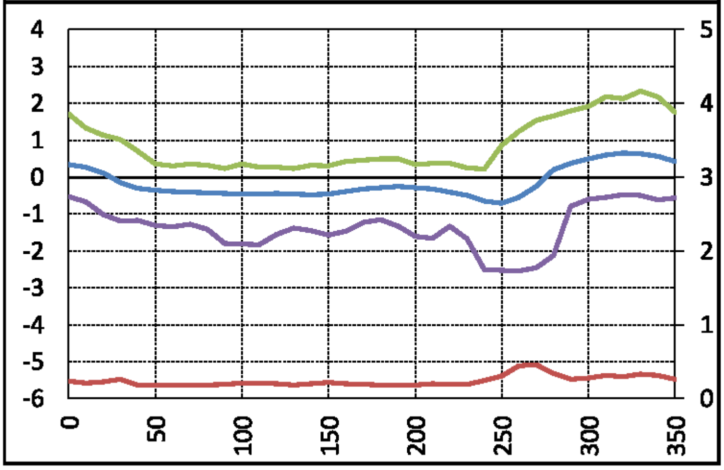
Individual Tap ID: BNE12 **Port ID: 138**



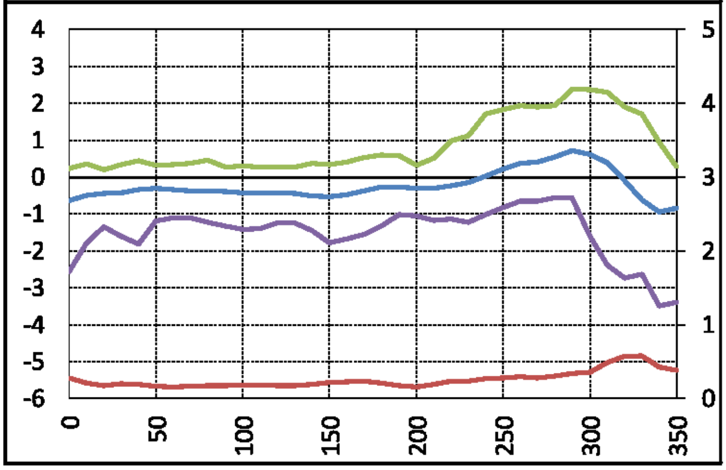
Individual Tap ID: BNE13 **Port ID: 139**



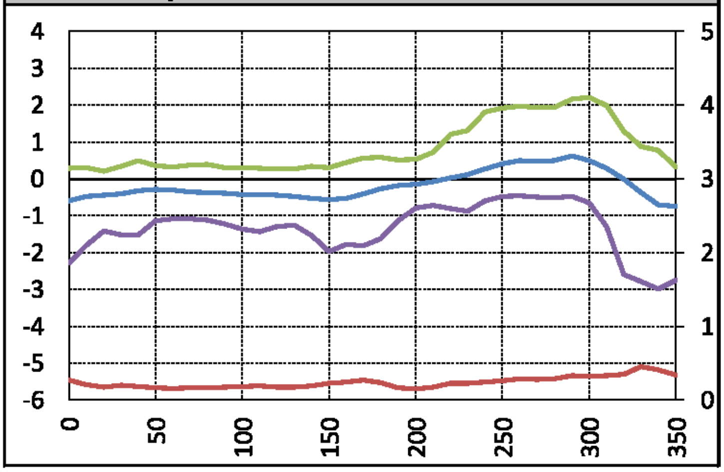
Individual Tap ID: BWE01 Port ID: 140



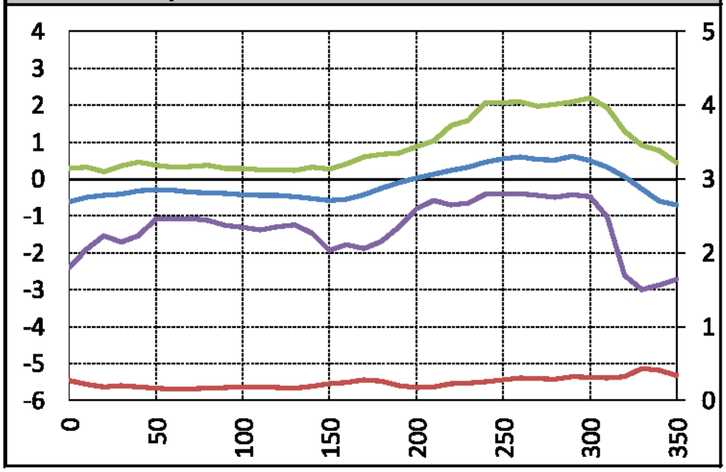
Individual Tap ID: BWE02 Port ID: 141



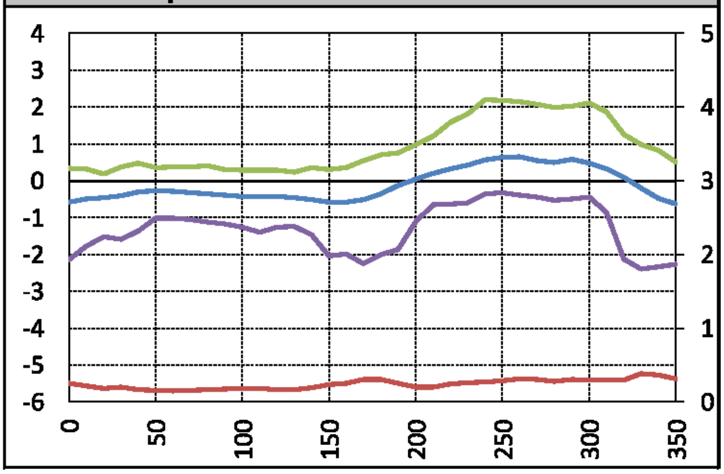
Individual Tap ID: BWE03 Port ID: 142



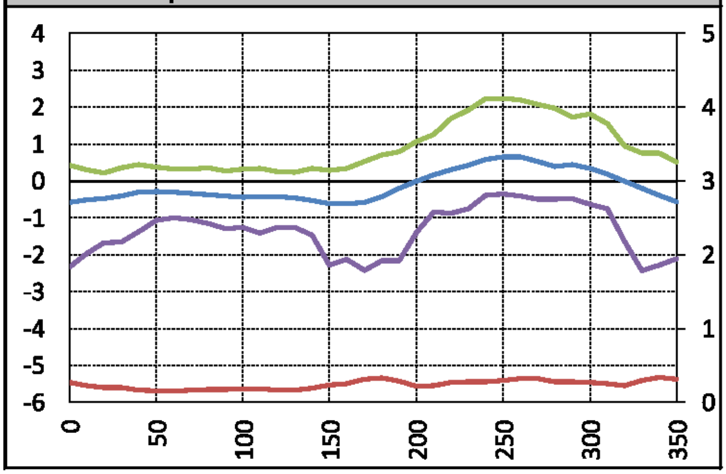
Individual Tap ID: BWE04 Port ID: 143



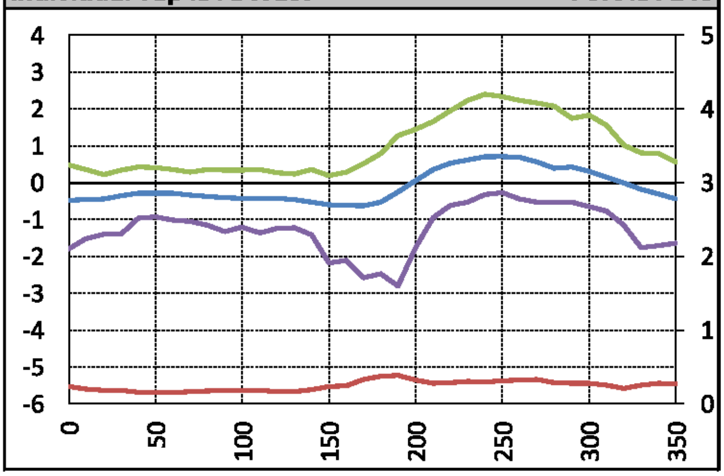
Individual Tap ID: BWE05 Port ID: 144



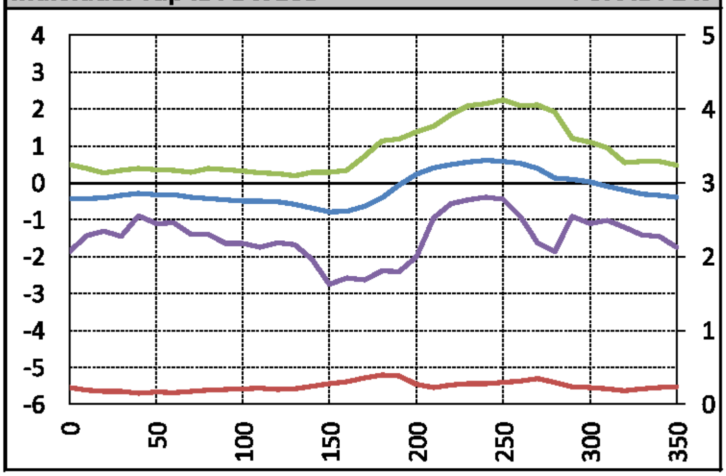
Individual Tap ID: BWE06 Port ID: 145



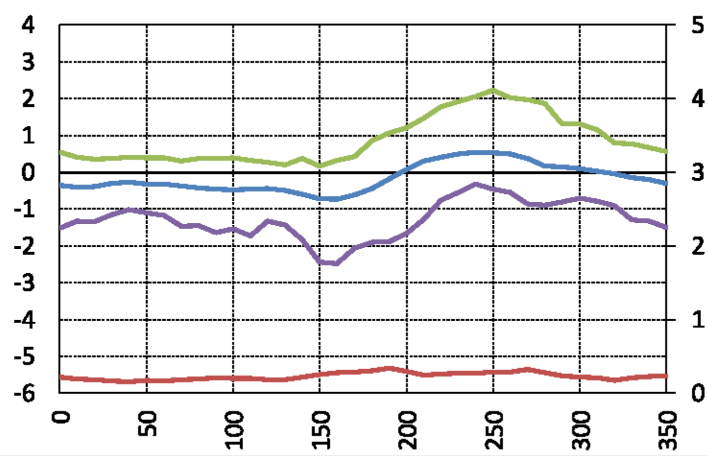
Individual Tap ID: BWE07 Port ID: 146



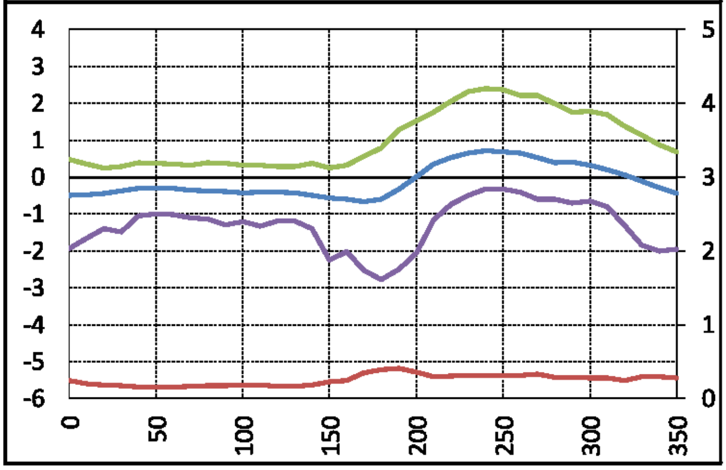
Individual Tap ID: BWE08 Port ID: 147



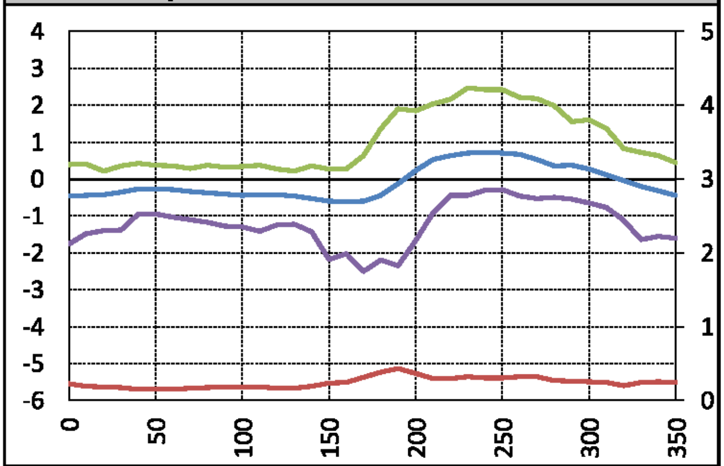
Individual Tap ID: BWE09 Port ID: 148



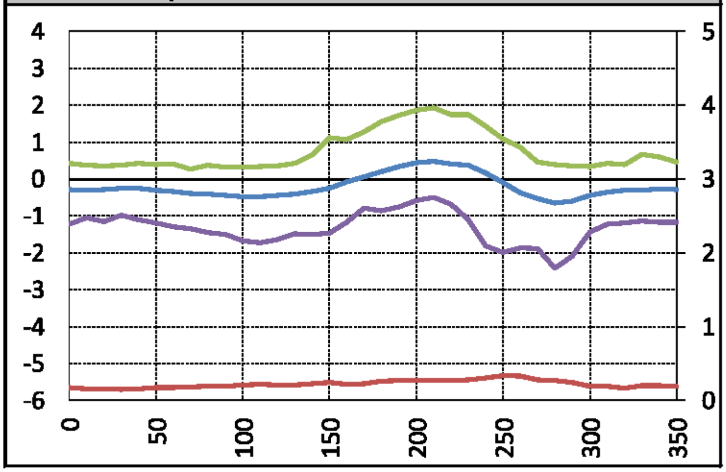
Individual Tap ID: BWF06 Port ID: 149



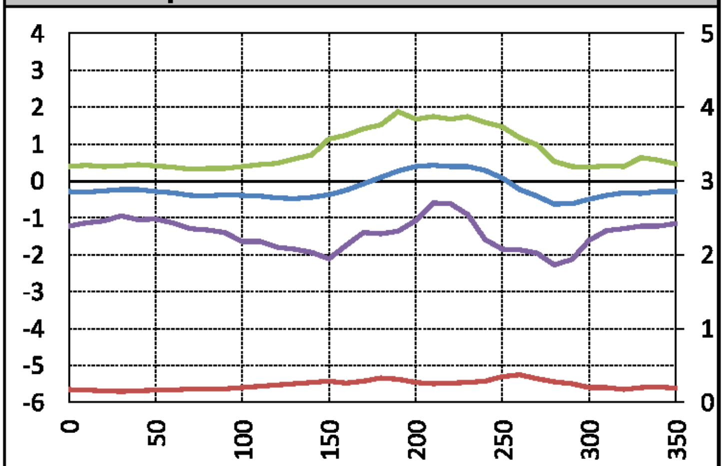
Individual Tap ID: BSE01 Port ID: 150



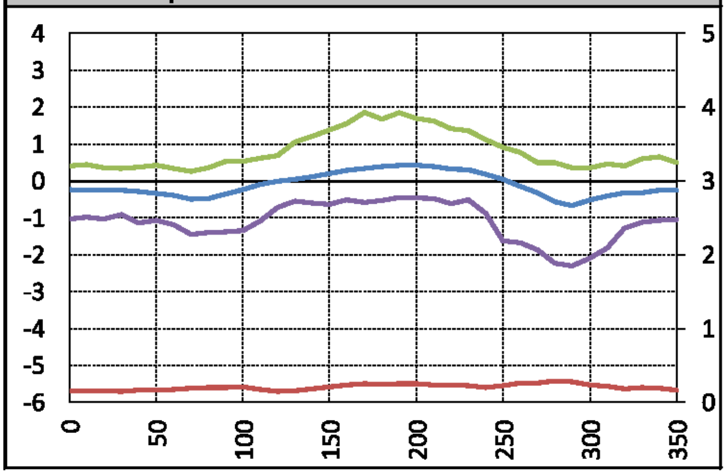
Individual Tap ID: BSE02 Port ID: 151



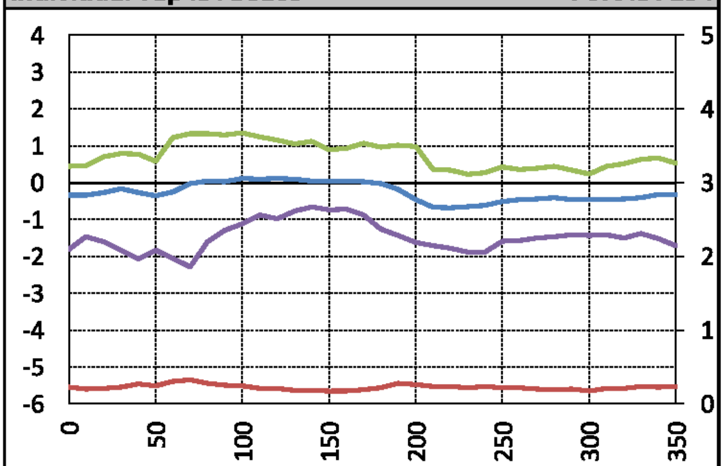
Individual Tap ID: BSE03 Port ID: 152



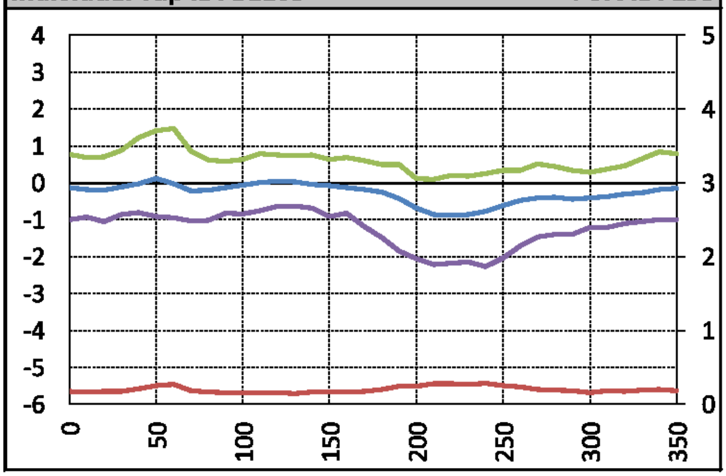
Individual Tap ID: BSE04 Port ID: 153



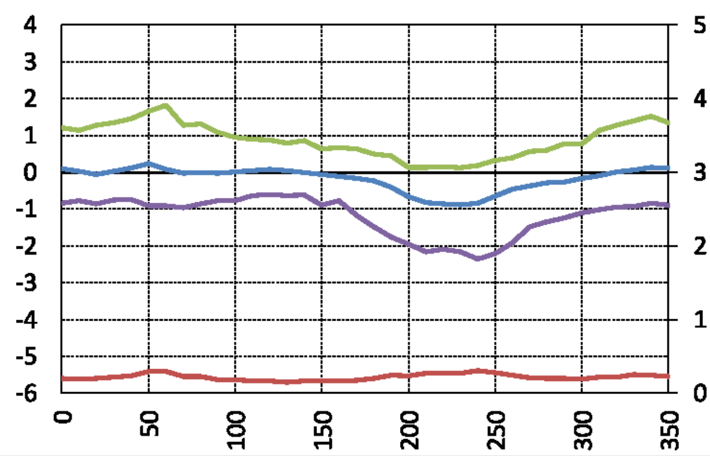
Individual Tap ID: BSE09 Port ID: 154



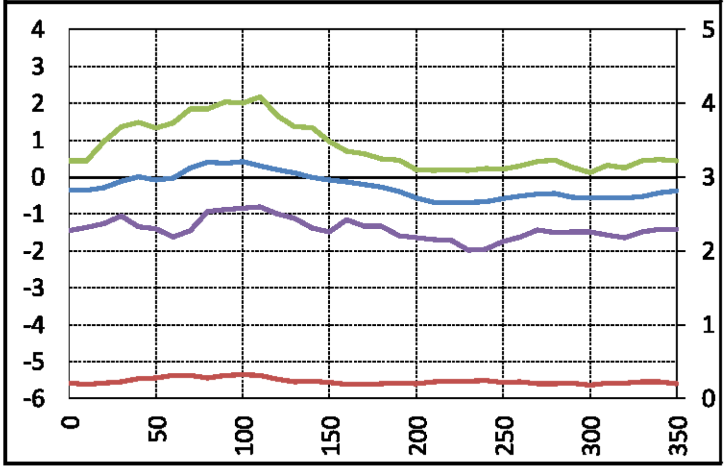
Individual Tap ID: BEE05 Port ID: 155



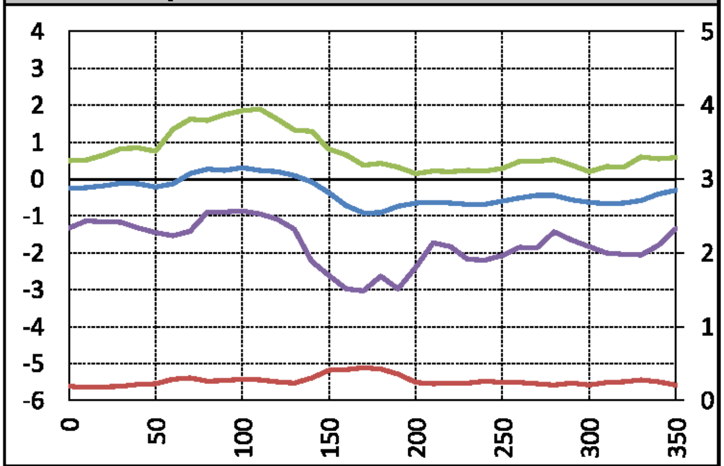
Individual Tap ID: BEE06 Port ID: 156



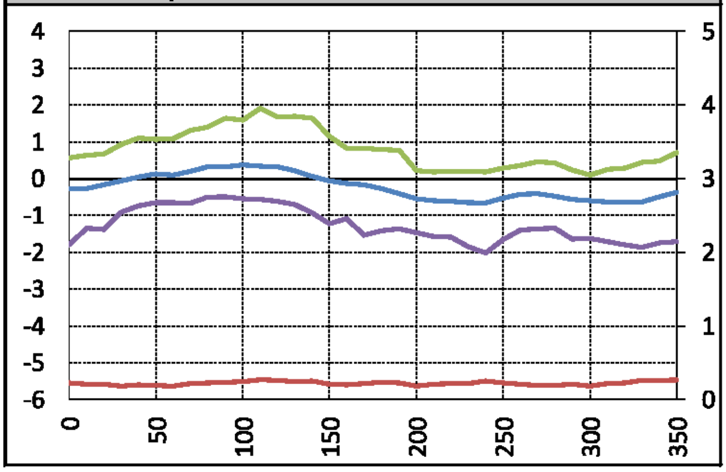
Individual Tap ID: BEE07 Port ID: 157



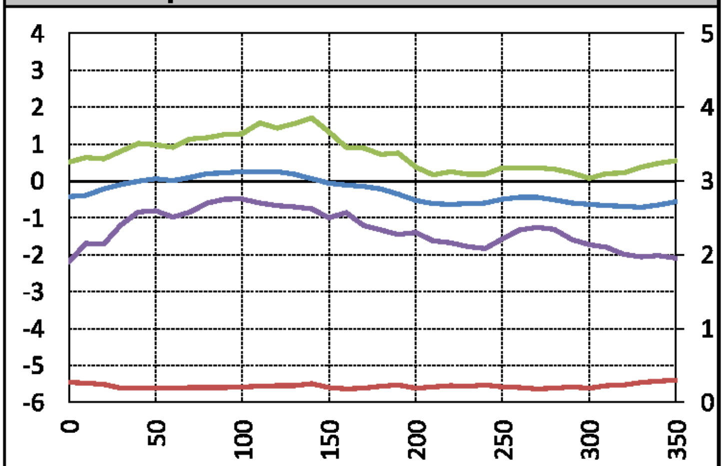
Individual Tap ID: BEE08 Port ID: 158



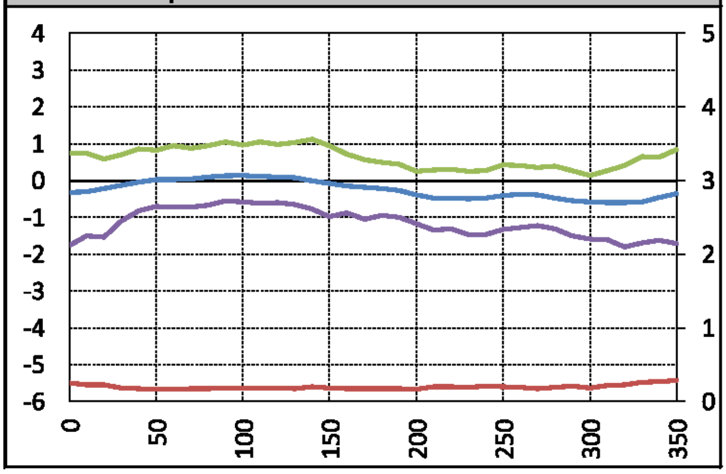
Individual Tap ID: BEE09 Port ID: 159



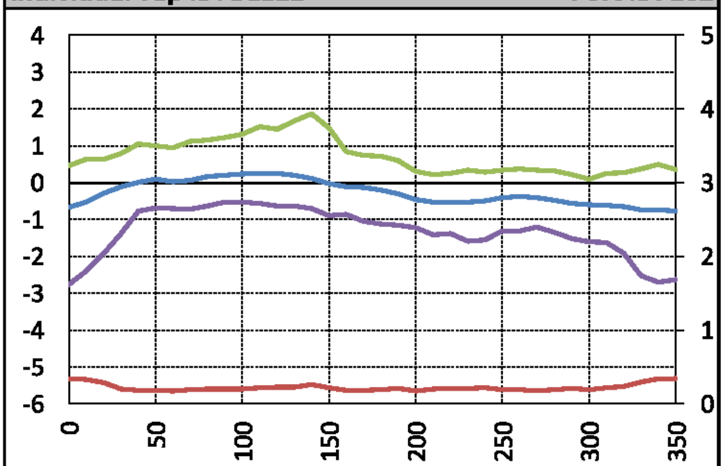
Individual Tap ID: BEE10 Port ID: 160



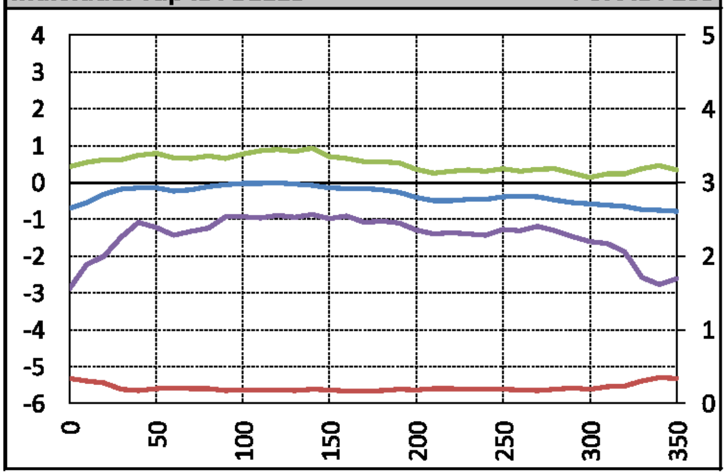
Individual Tap ID: BEE11 Port ID: 161



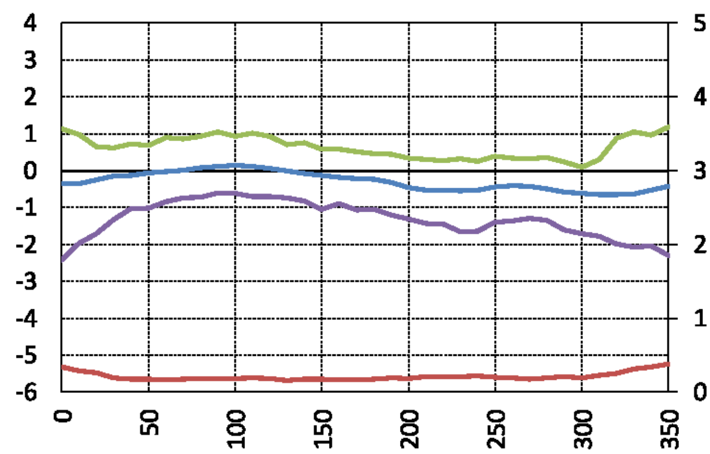
Individual Tap ID: BEE12 Port ID: 162



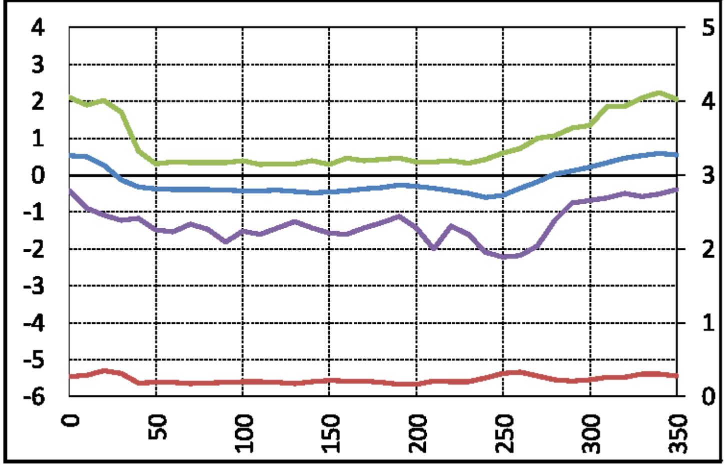
Individual Tap ID: BEE13 Port ID: 163



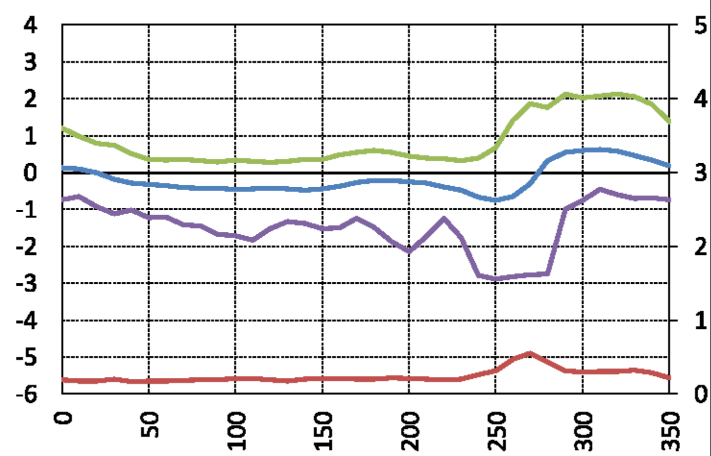
Individual Tap ID: BND09 Port ID: 164



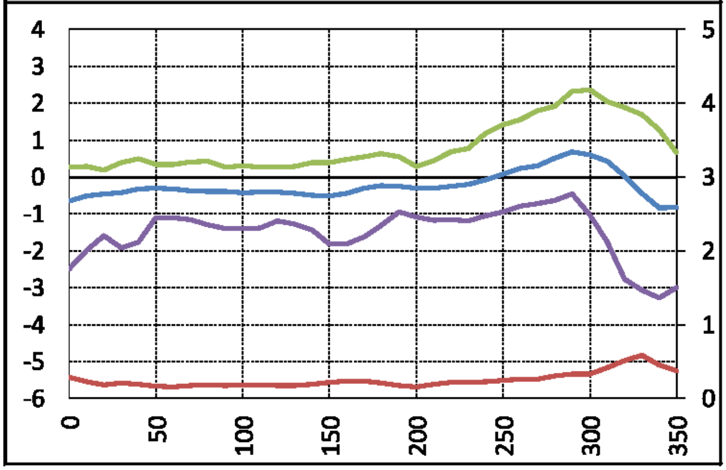
Individual Tap ID: BND10 Port ID: 165



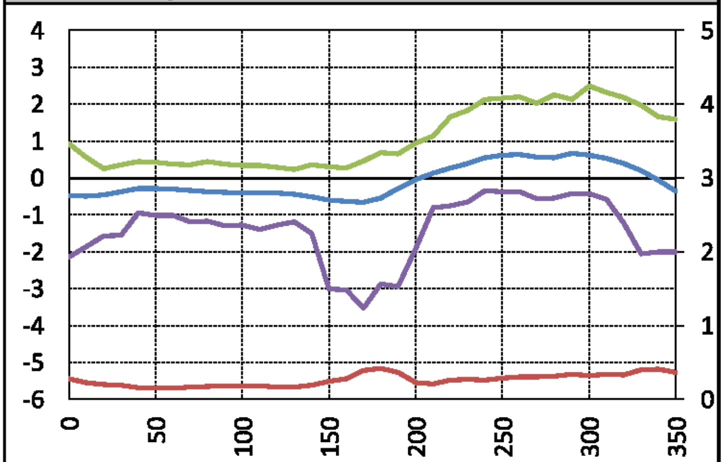
Individual Tap ID: BND11 Port ID: 166



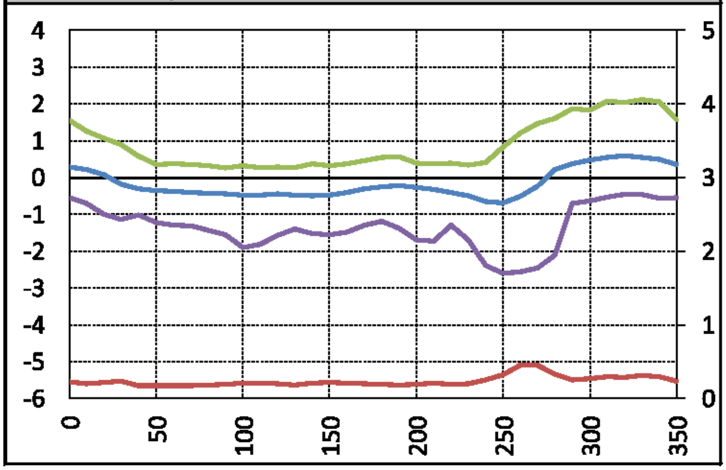
Individual Tap ID: BND12 Port ID: 167



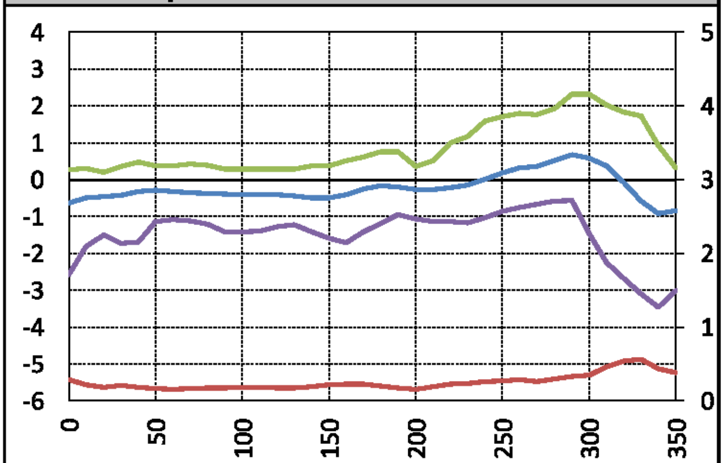
Individual Tap ID: BND13 Port ID: 168



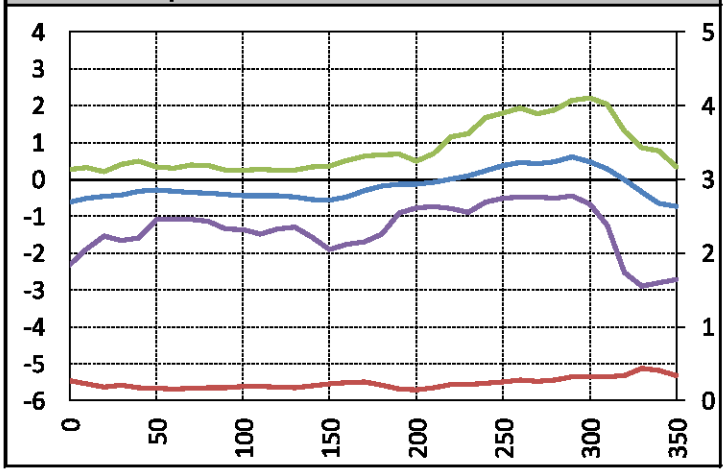
Individual Tap ID: BWD01 Port ID: 169



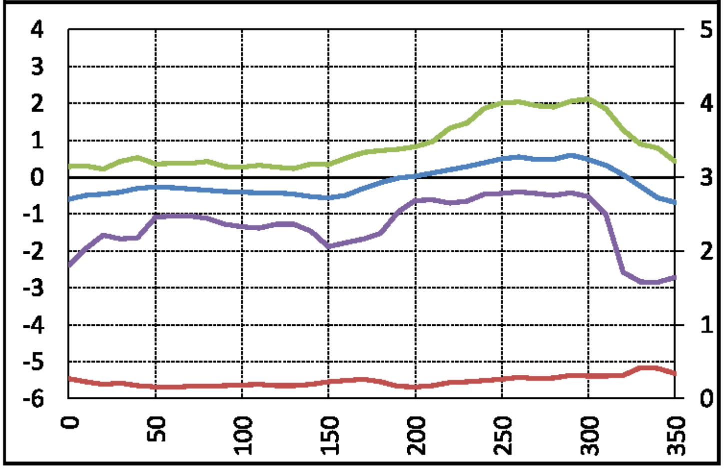
Individual Tap ID: BWD02 Port ID: 171



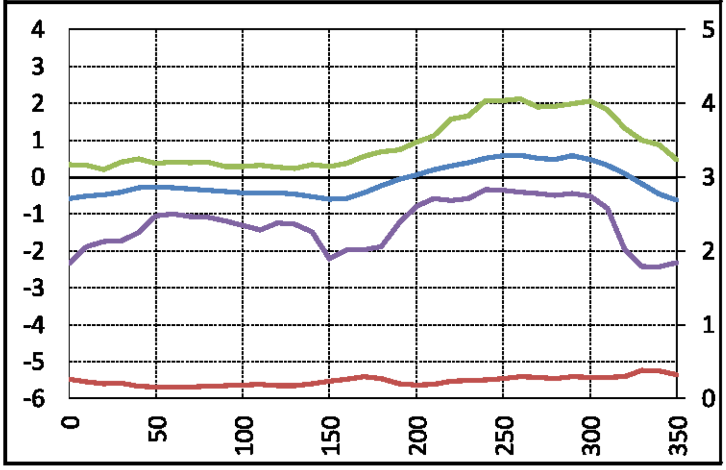
Individual Tap ID: BWD03 Port ID: 172



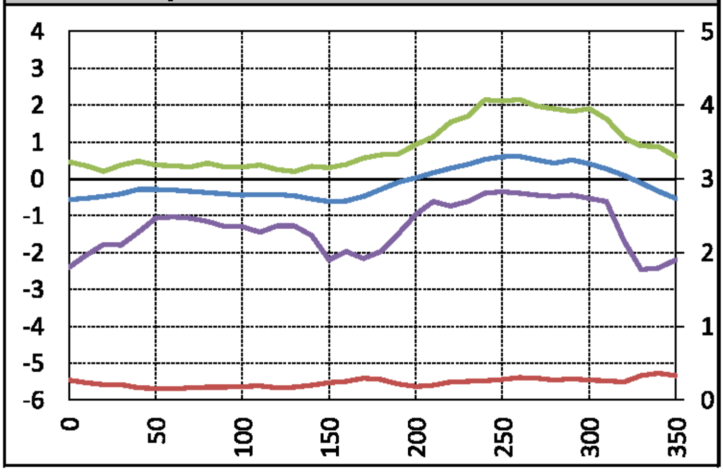
Individual Tap ID: BWD04 **Port ID: 173**



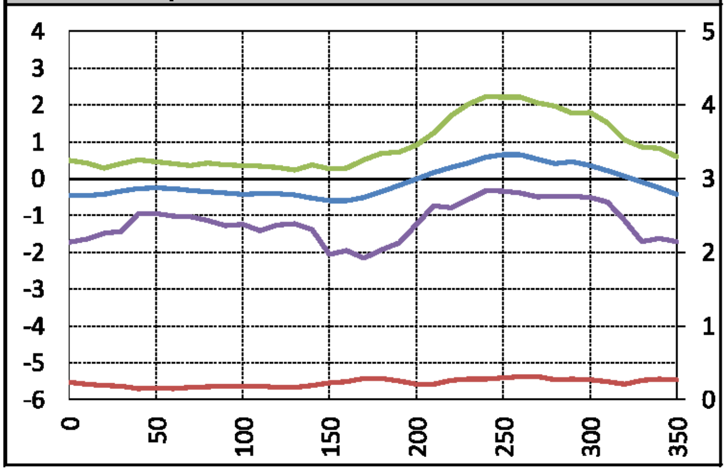
Individual Tap ID: BWD05 **Port ID: 174**



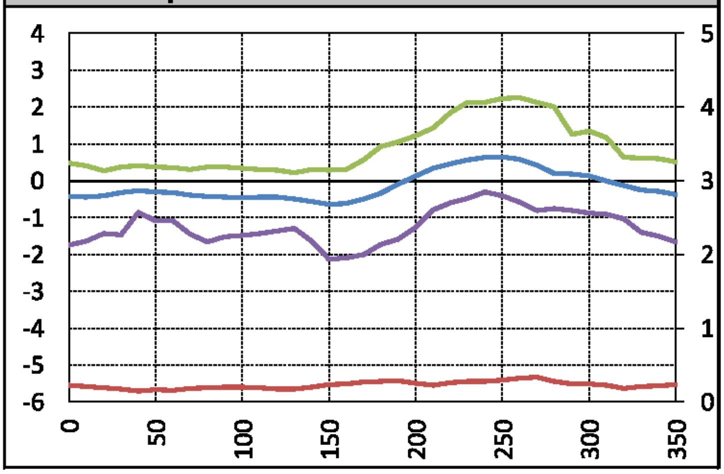
Individual Tap ID: BWD06 **Port ID: 175**



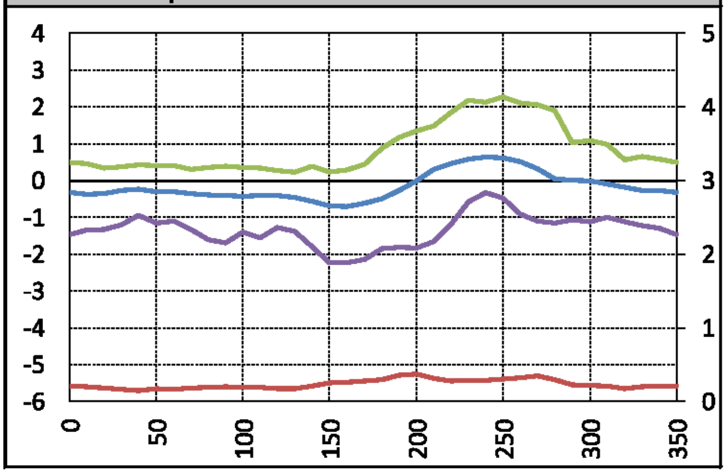
Individual Tap ID: BWD07 **Port ID: 176**



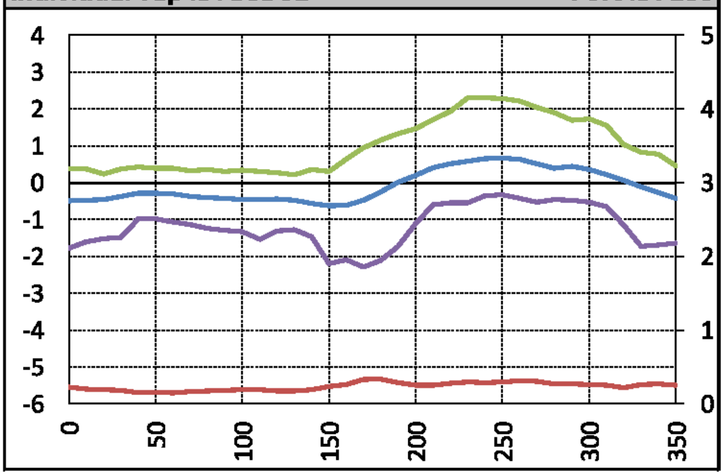
Individual Tap ID: BWD08 **Port ID: 177**



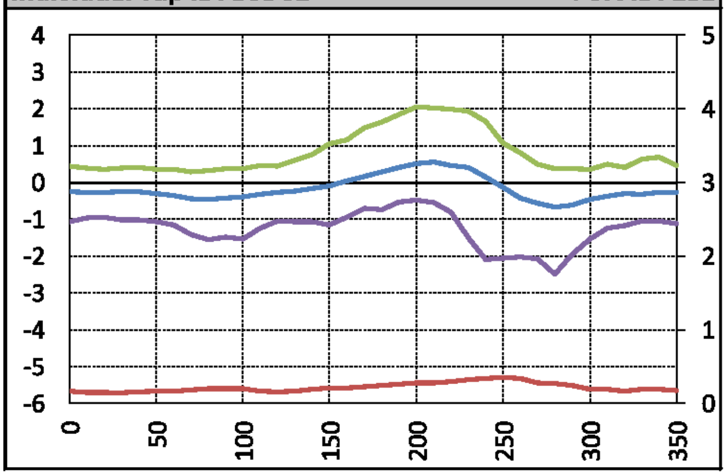
Individual Tap ID: BWD09 **Port ID: 178**



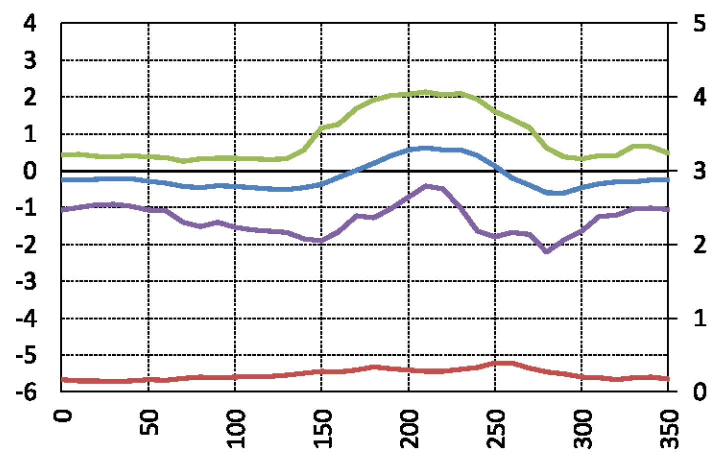
Individual Tap ID: BSD01 **Port ID: 180**



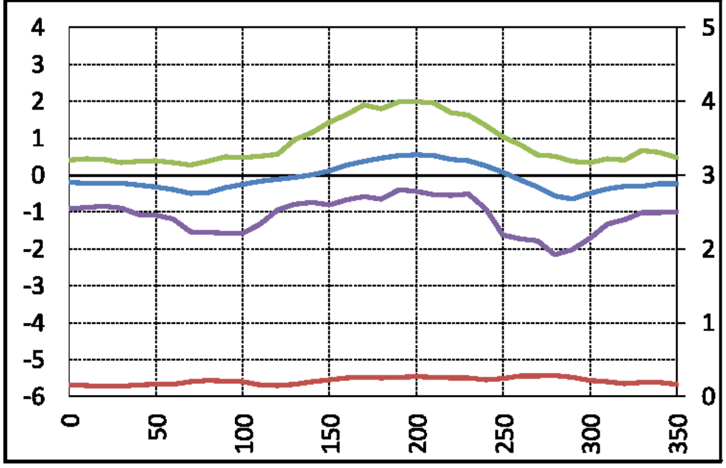
Individual Tap ID: BSD02 **Port ID: 181**



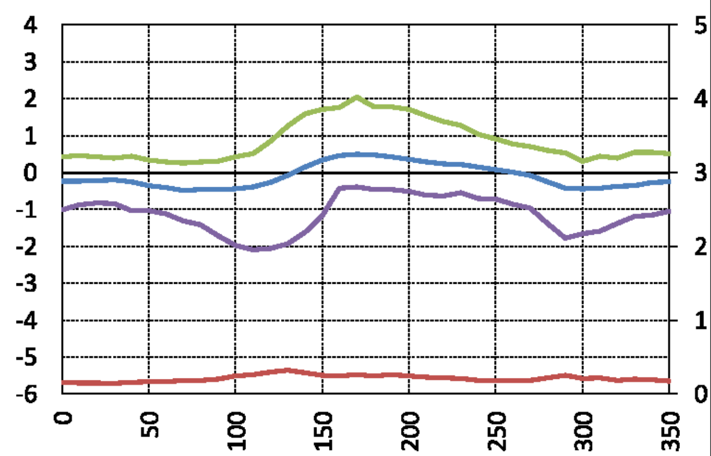
Individual Tap ID: BSD03	Port ID: 182



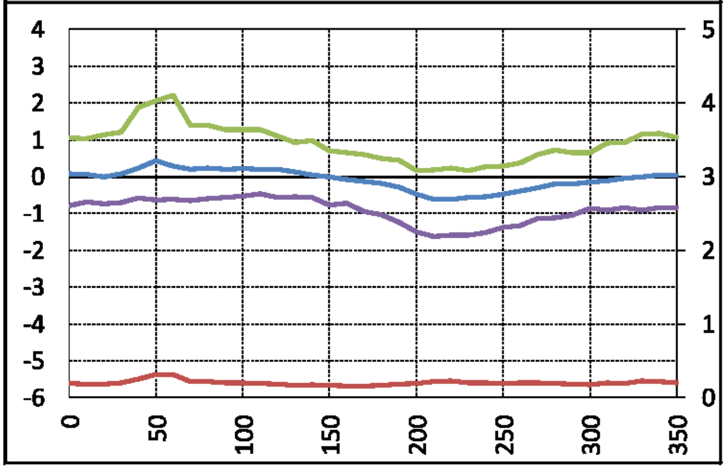
Individual Tap ID: BSD04	Port ID: 183



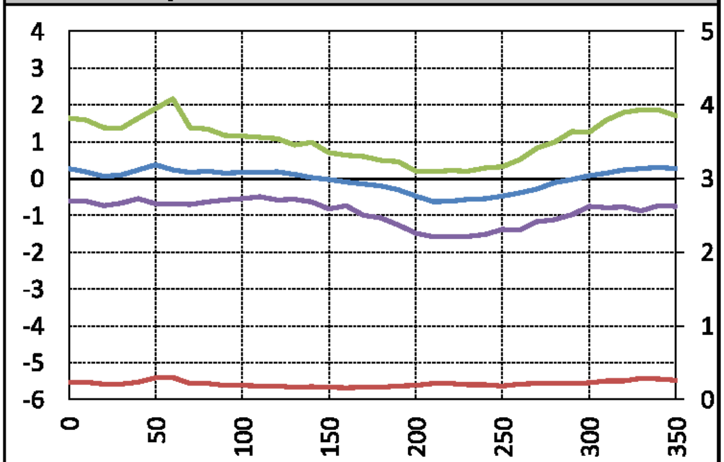
Individual Tap ID: BSD09	Port ID: 184



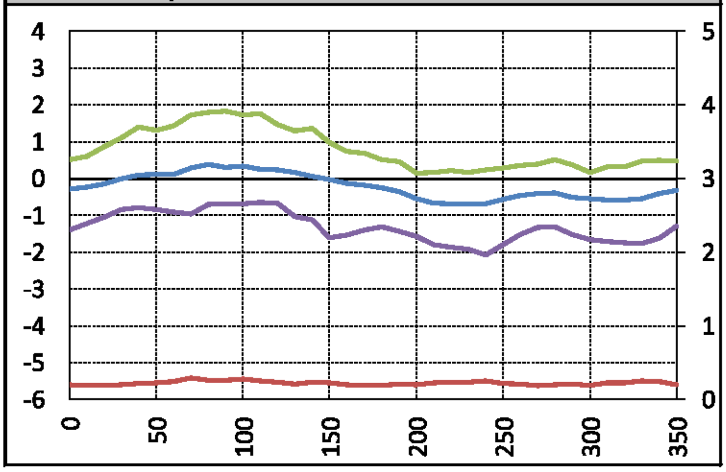
Individual Tap ID: BED05	Port ID: 185



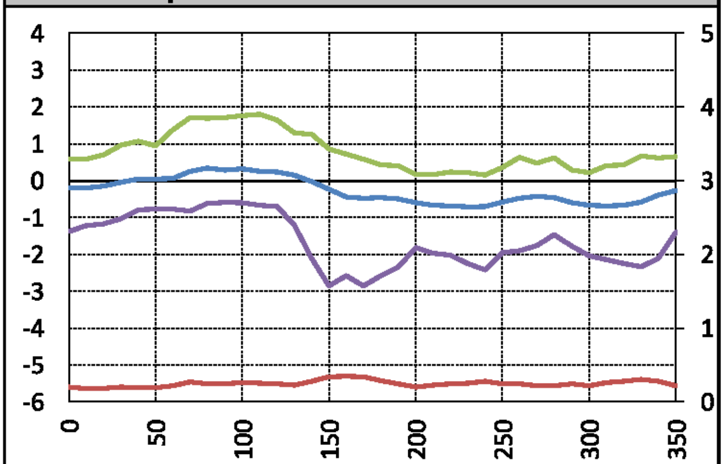
Individual Tap ID: BED06	Port ID: 186



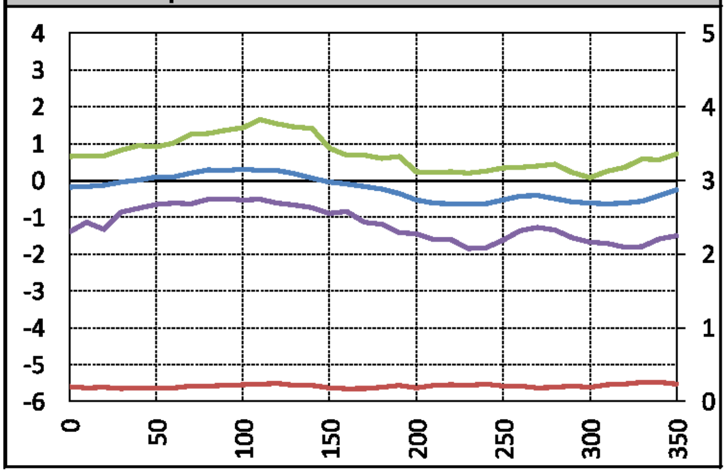
Individual Tap ID: BED07	Port ID: 187



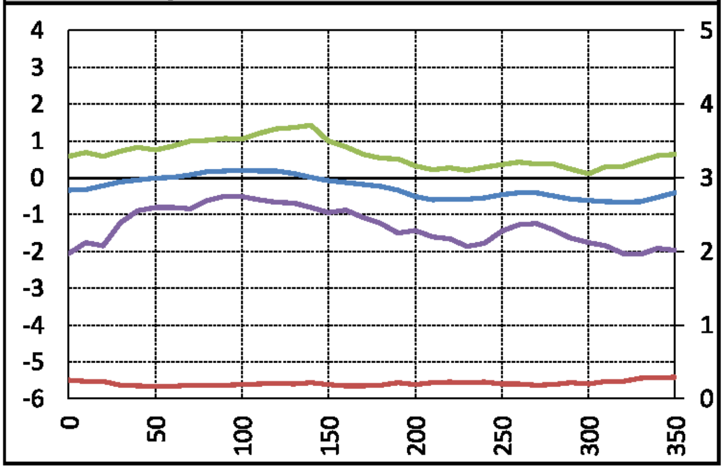
Individual Tap ID: BED08	Port ID: 188



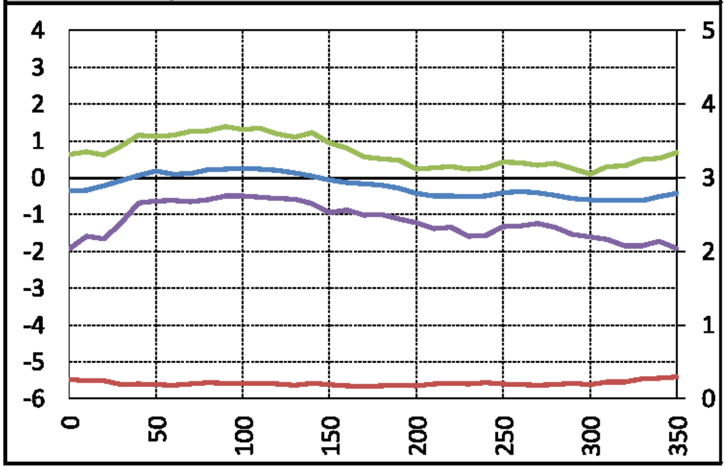
Individual Tap ID: BED09	Port ID: 189



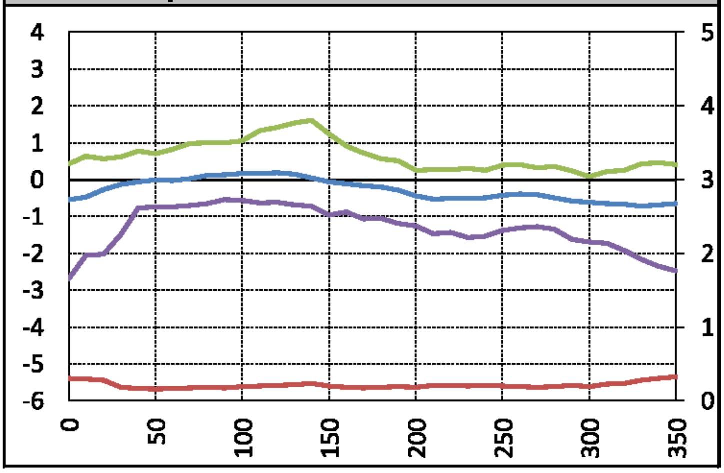
Individual Tap ID: BED10	Port ID: 192



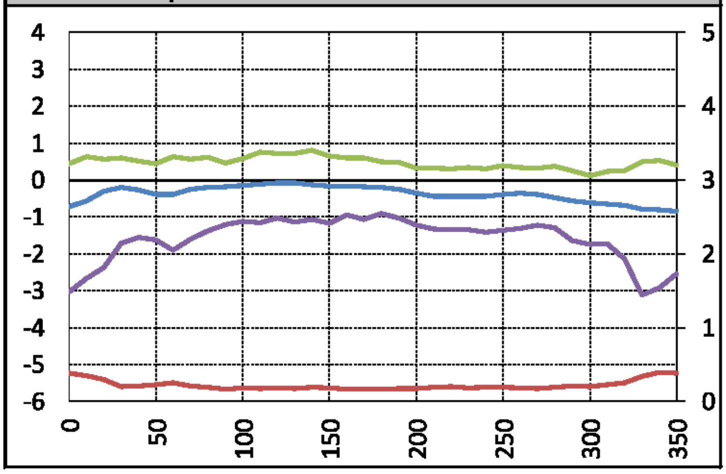
Individual Tap ID: BED11	Port ID: 193



Individual Tap ID: BED12	Port ID: 194



Individual Tap ID: BED13	Port ID: 196



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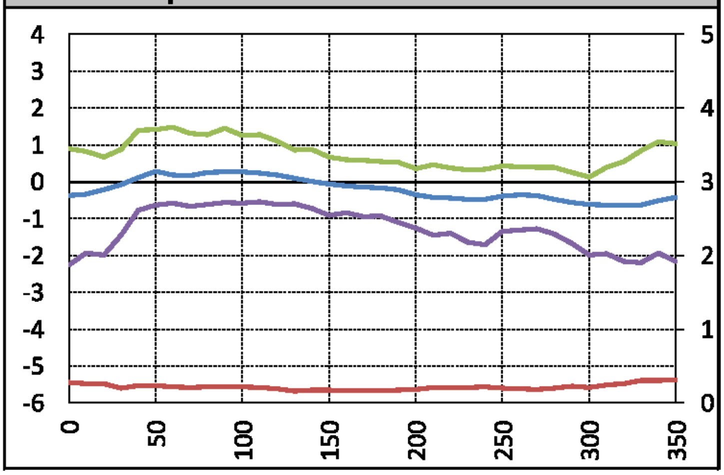
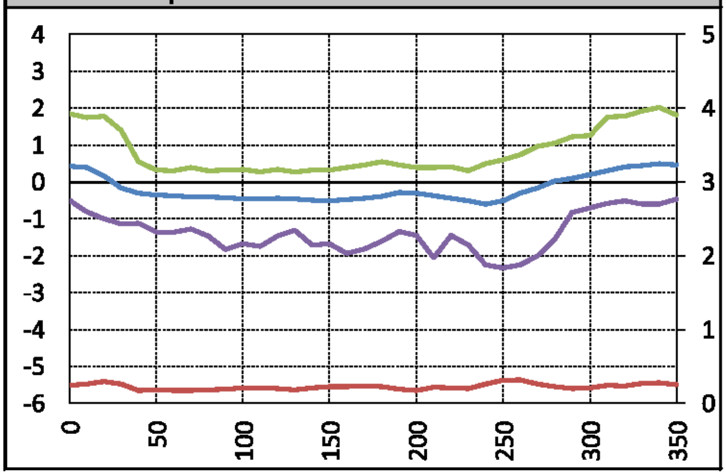
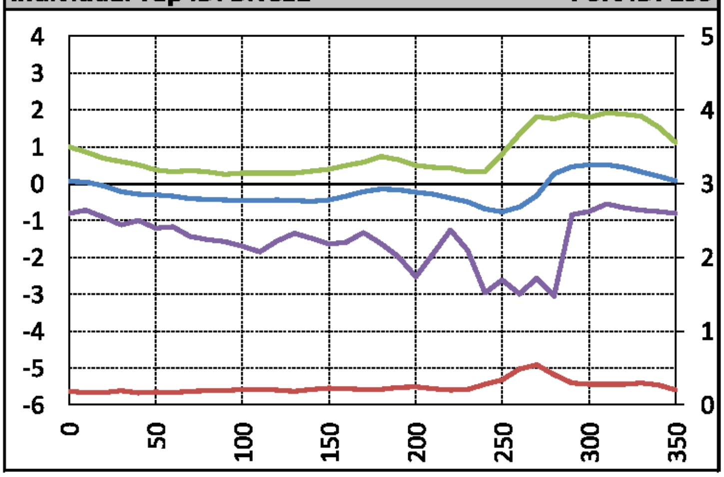


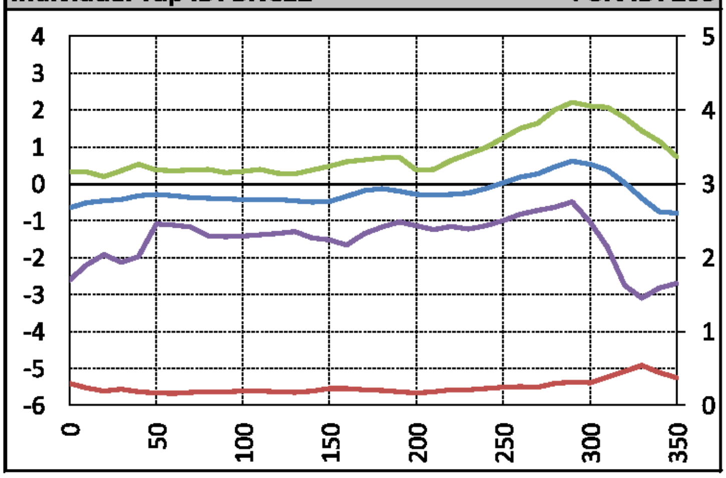
Individual Tap ID: BNC10	Port ID: 198



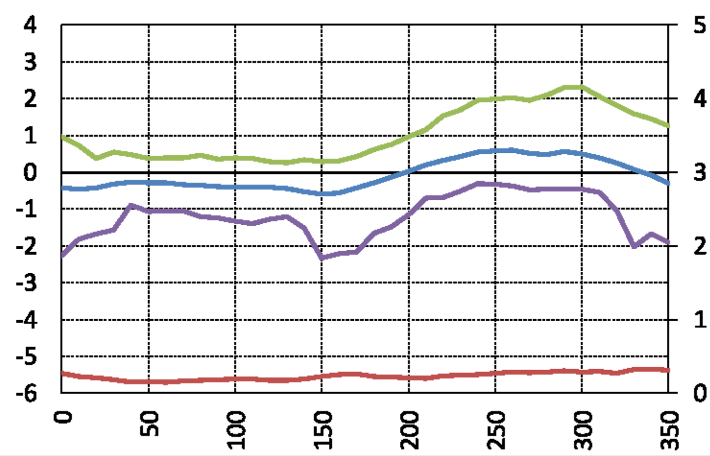
Individual Tap ID: BNC11	Port ID: 199



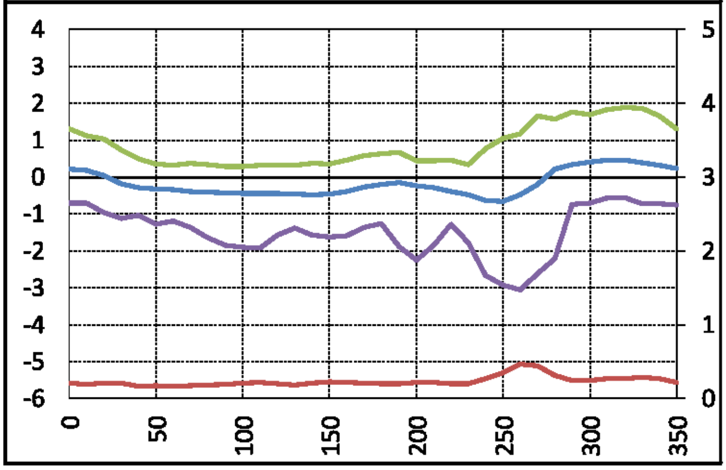
Individual Tap ID: BNC12	Port ID: 200



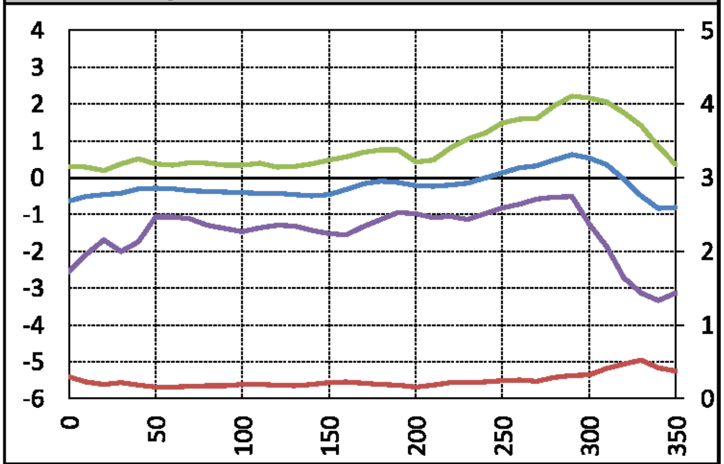
Individual Tap ID: BNC13 Port ID: 201



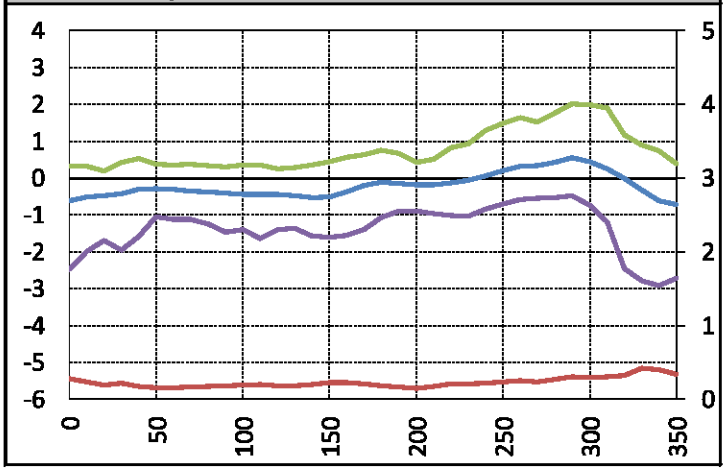
Individual Tap ID: BWC01 Port ID: 202



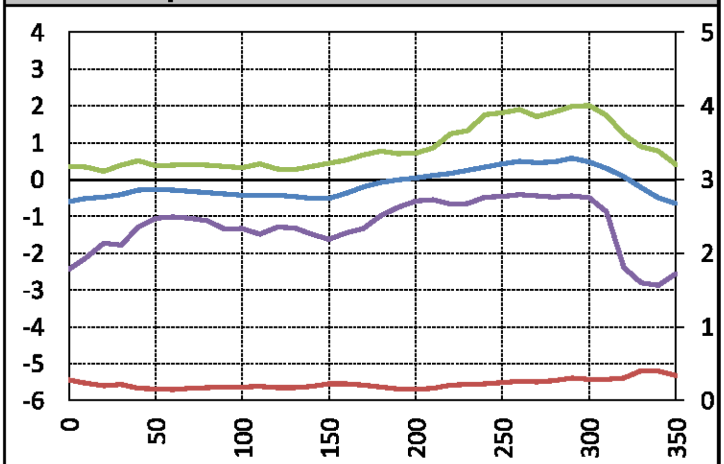
Individual Tap ID: BWC02 Port ID: 203



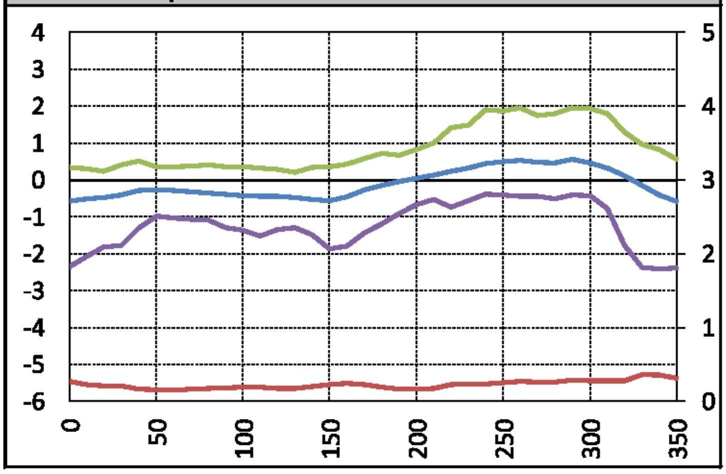
Individual Tap ID: BWC03 Port ID: 204



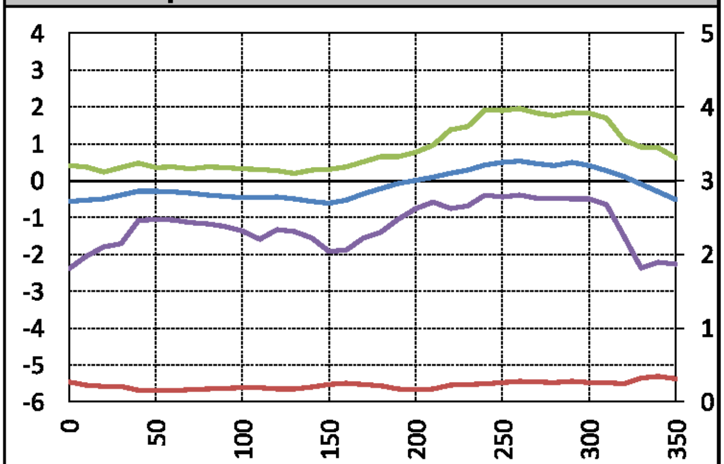
Individual Tap ID: BWC04 Port ID: 205



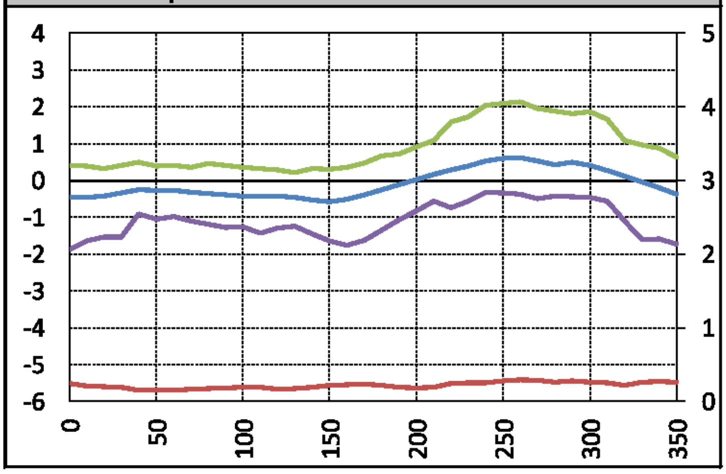
Individual Tap ID: BWC05 Port ID: 206



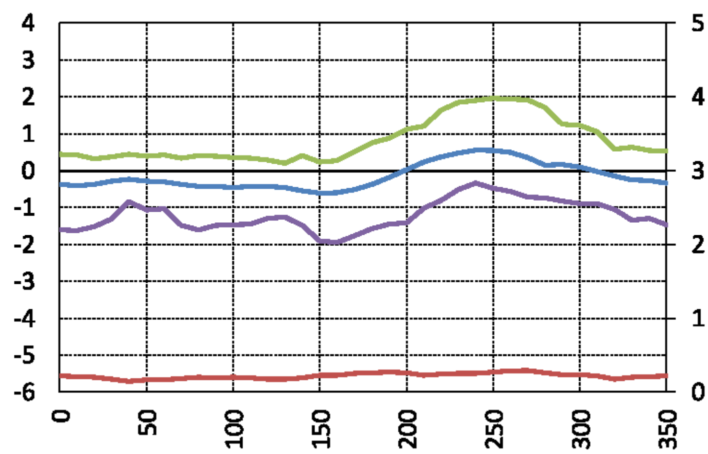
Individual Tap ID: BWC06 Port ID: 207



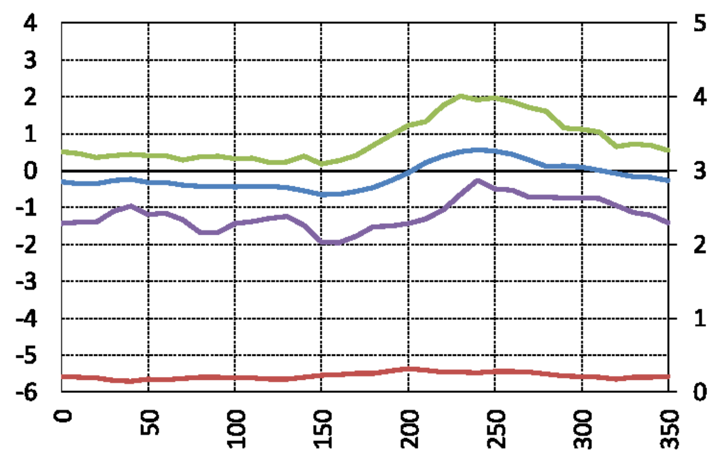
Individual Tap ID: BWC07 Port ID: 208



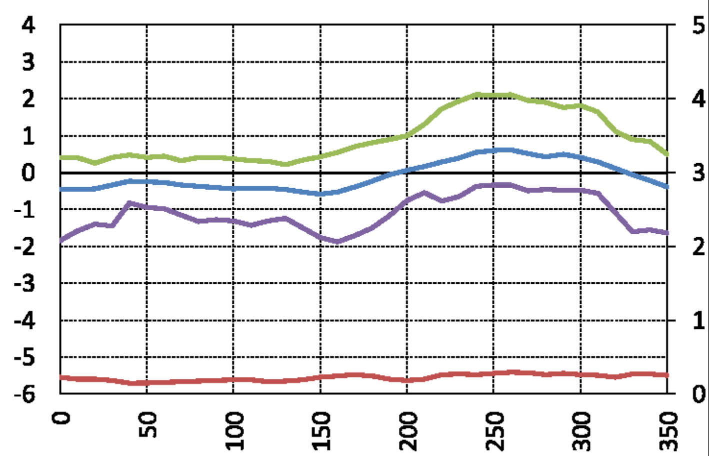
Individual Tap ID: BWC08 **Port ID: 209**



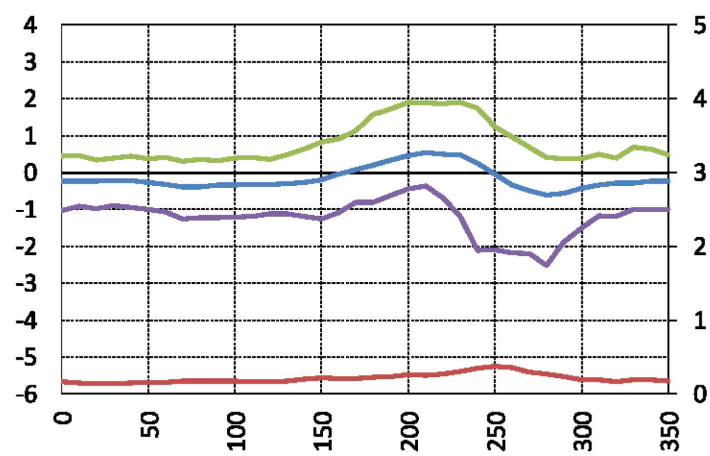
Individual Tap ID: BWC09 **Port ID: 210**



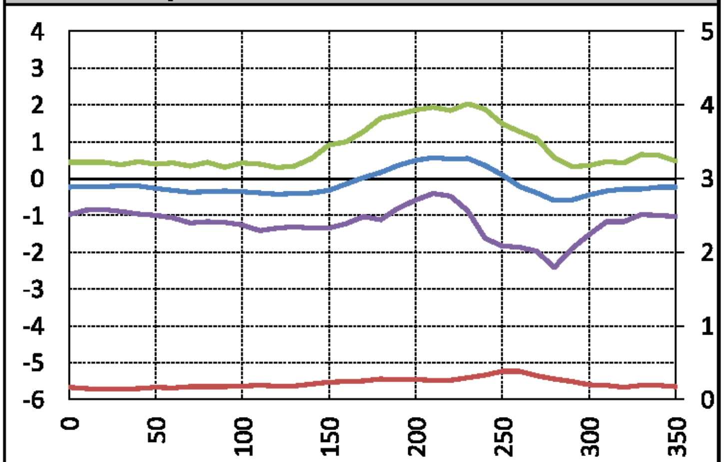
Individual Tap ID: BSC01 **Port ID: 212**



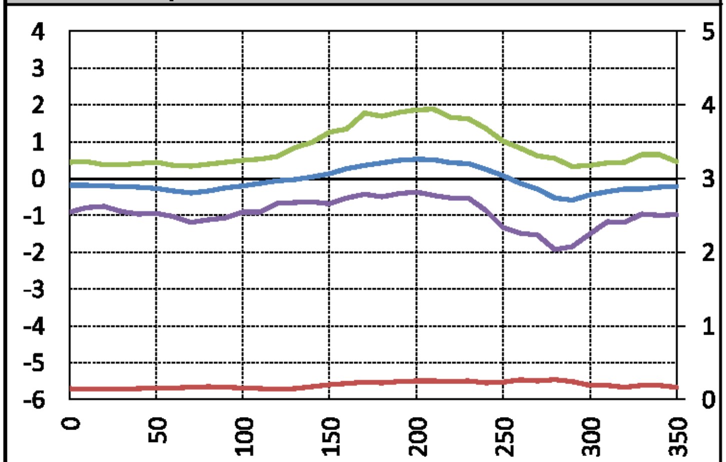
Individual Tap ID: BSC02 **Port ID: 213**



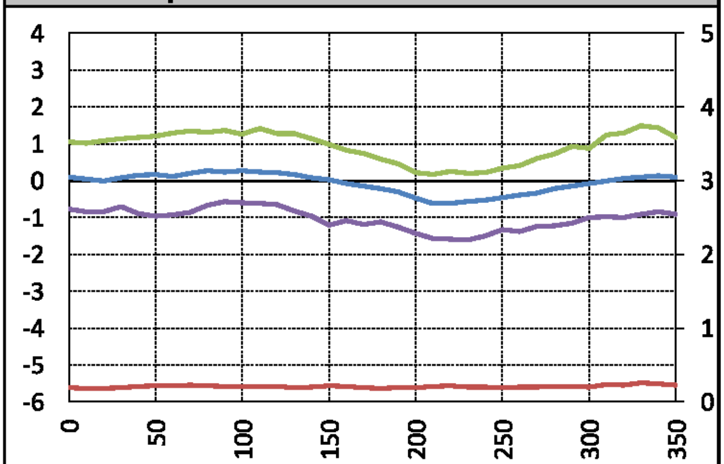
Individual Tap ID: BSC03 **Port ID: 214**



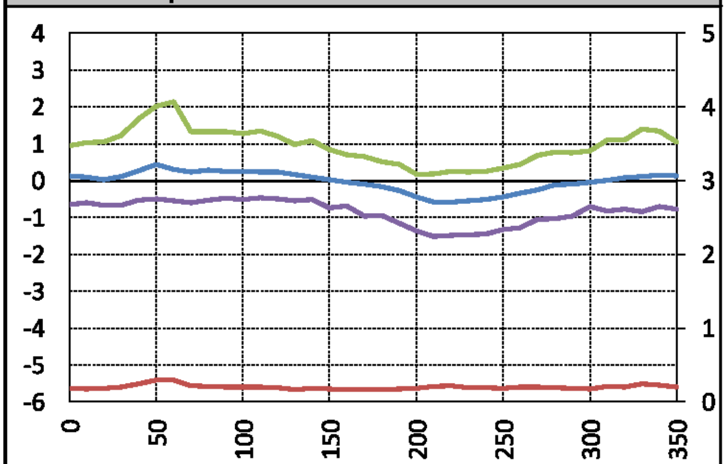
Individual Tap ID: BSC04 **Port ID: 215**



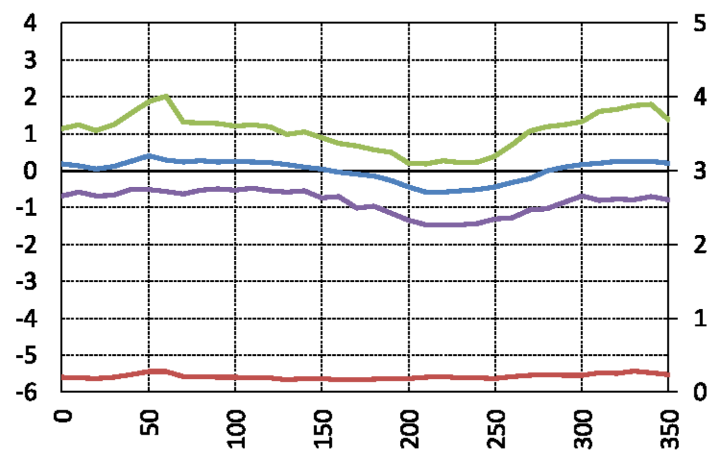
Individual Tap ID: BSC10 **Port ID: 216**



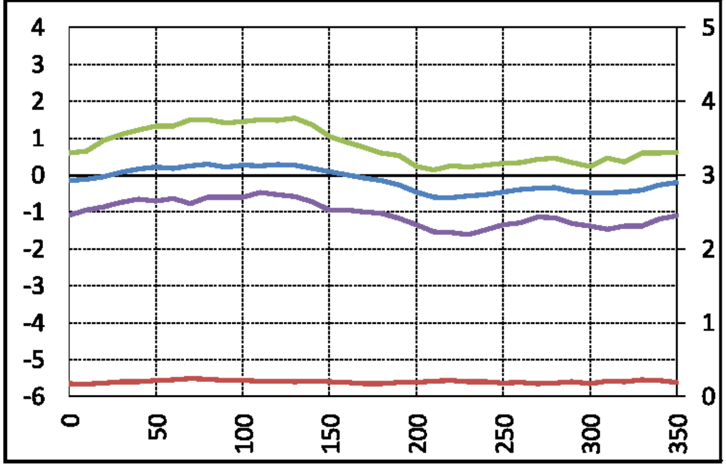
Individual Tap ID: BEC05 **Port ID: 217**



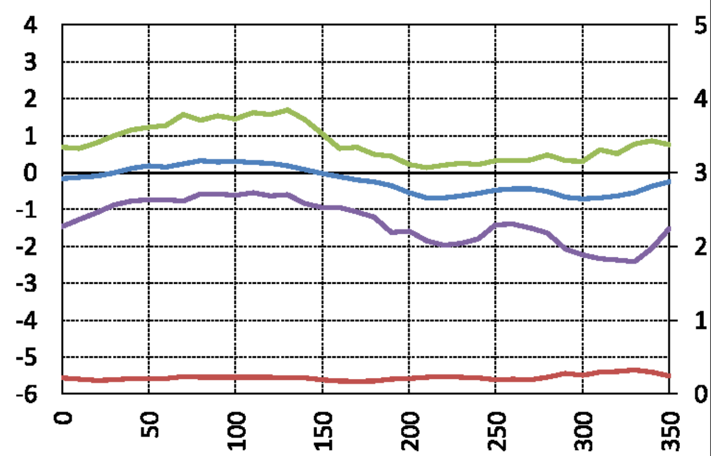
Individual Tap ID: BEC06 **Port ID: 218**



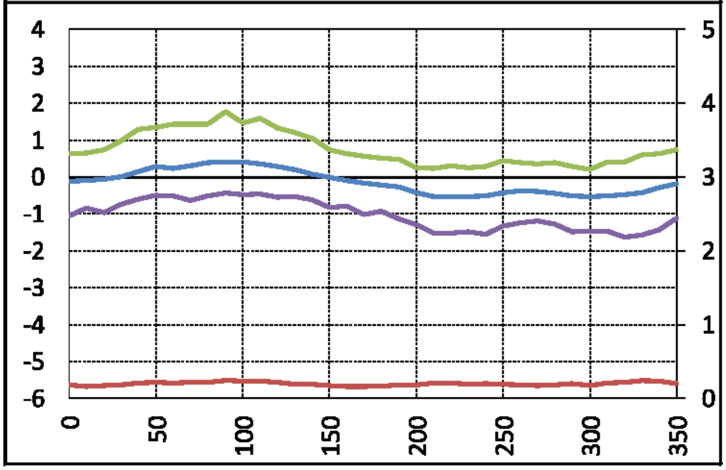
Individual Tap ID: BEC07 **Port ID: 219**



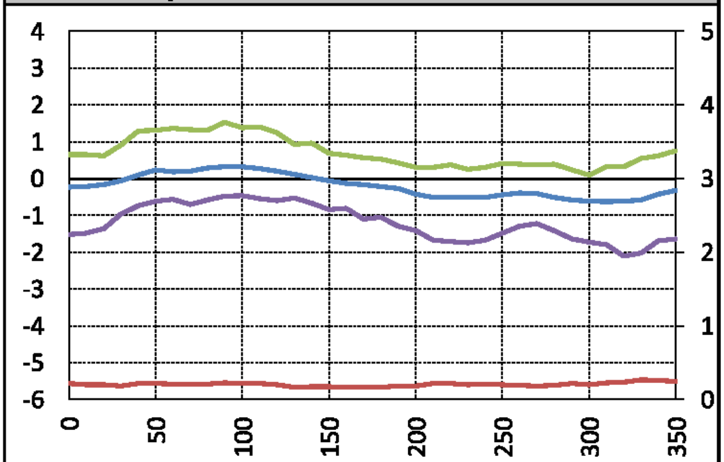
Individual Tap ID: BEC08 **Port ID: 220**



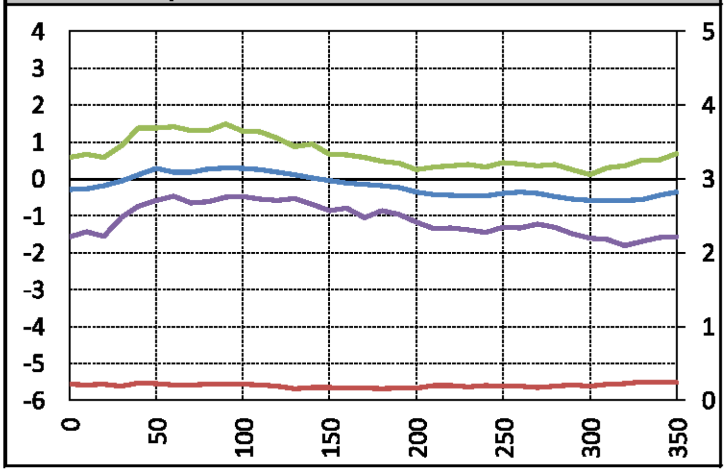
Individual Tap ID: BEC09 **Port ID: 221**



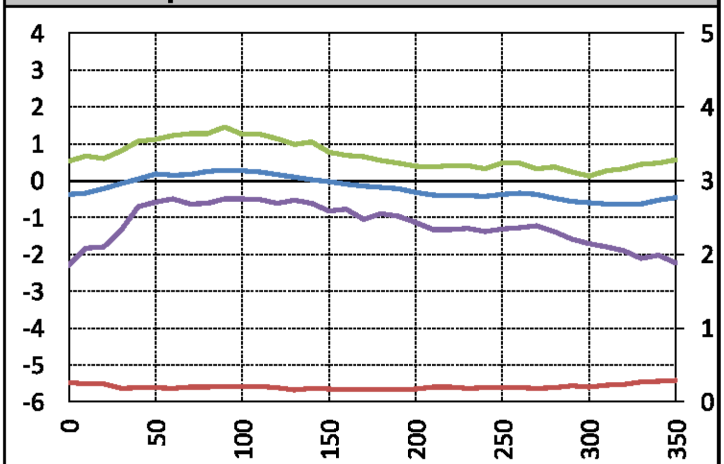
Individual Tap ID: BEC10 **Port ID: 222**



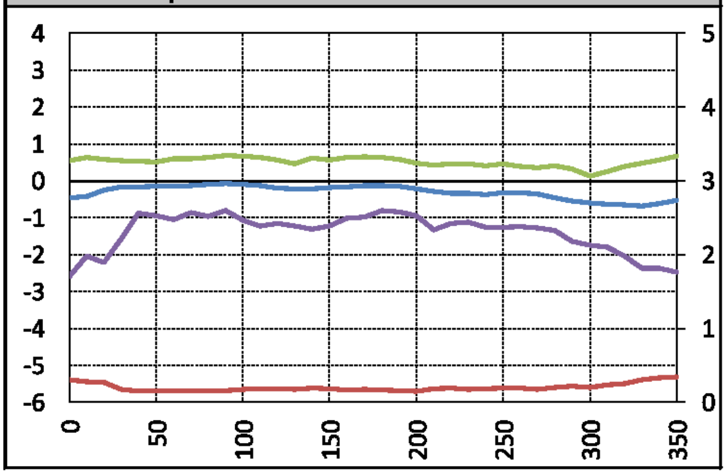
Individual Tap ID: BEC11 **Port ID: 223**



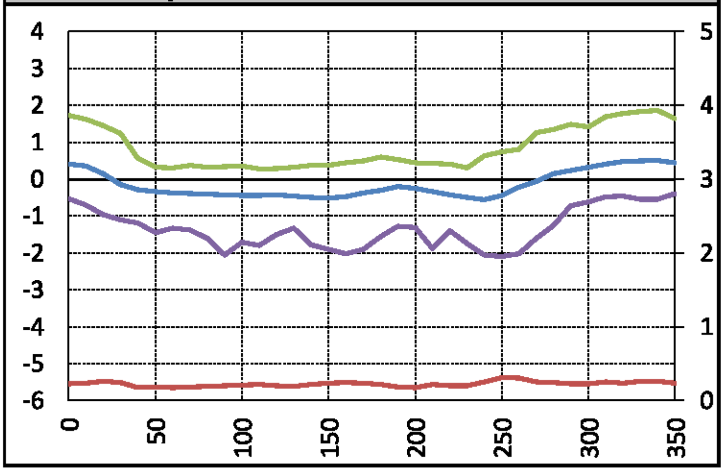
Individual Tap ID: BEC12 **Port ID: 224**



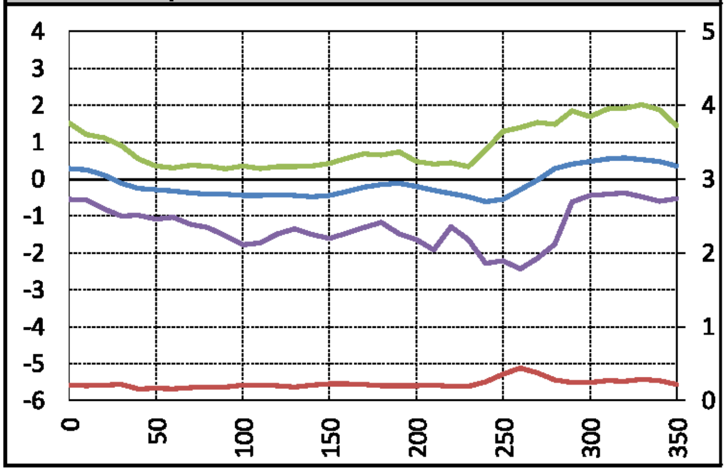
Individual Tap ID: BEC13 **Port ID: 225**



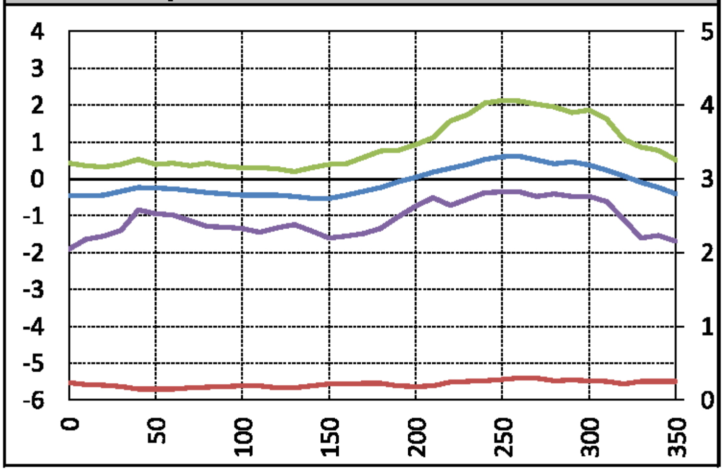
Individual Tap ID: BNB08 Port ID: 226



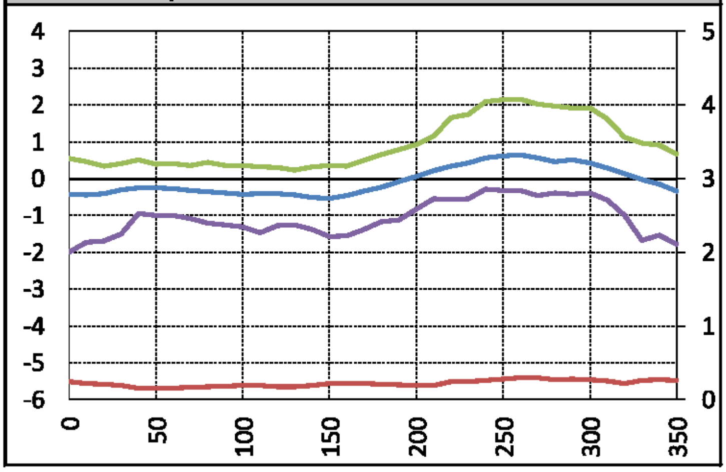
Individual Tap ID: BWB01 Port ID: 227



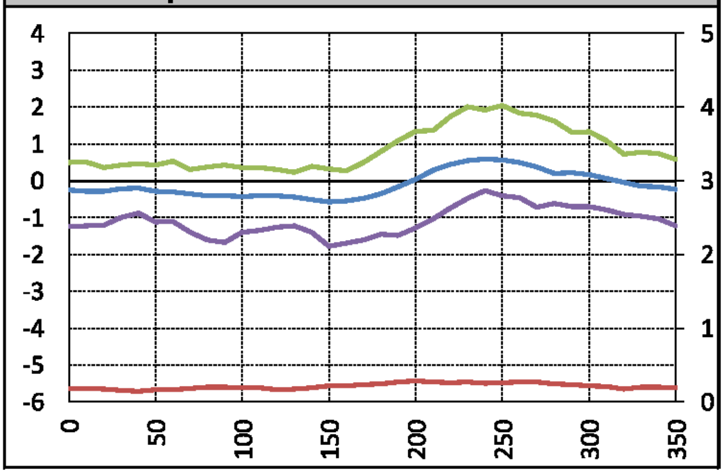
Individual Tap ID: BWB02 Port ID: 228



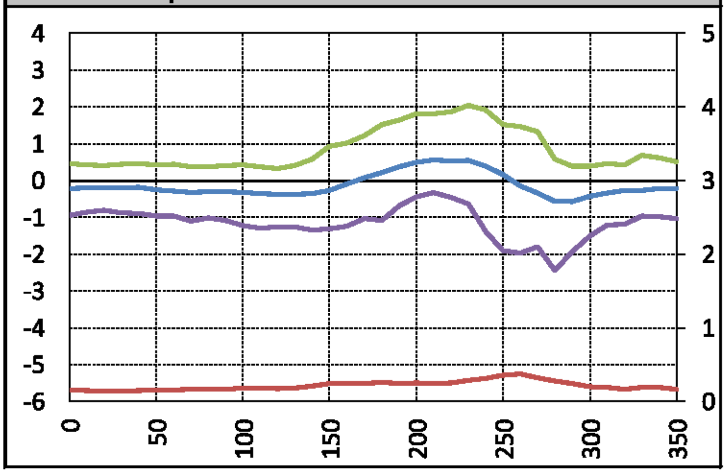
Individual Tap ID: BWB03 Port ID: 229



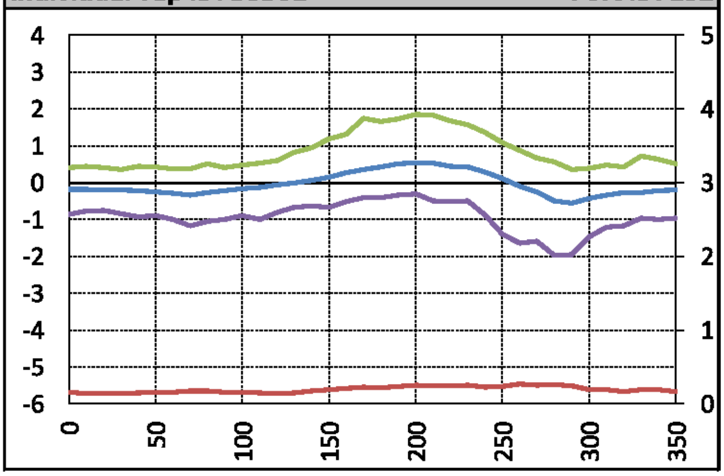
Individual Tap ID: BWB04 Port ID: 230



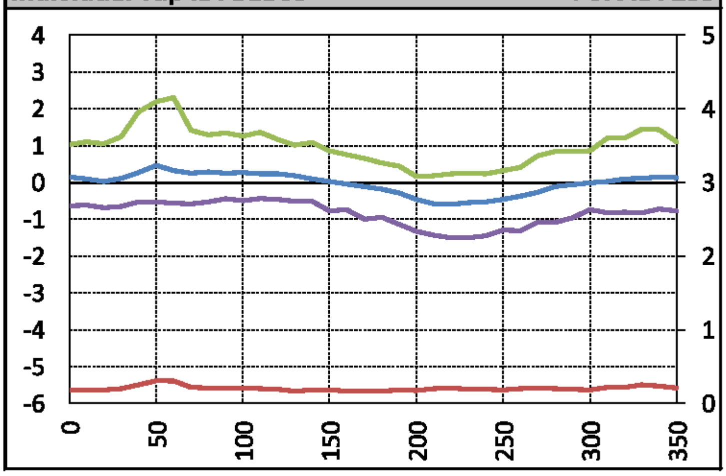
Individual Tap ID: BWB05 Port ID: 231



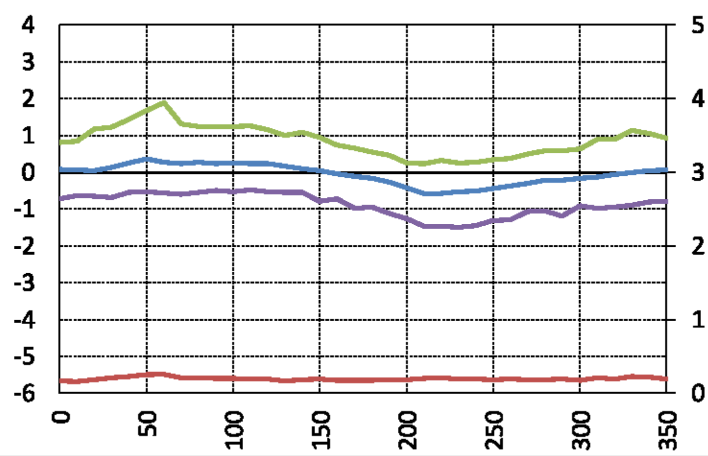
Individual Tap ID: BSB01 Port ID: 232



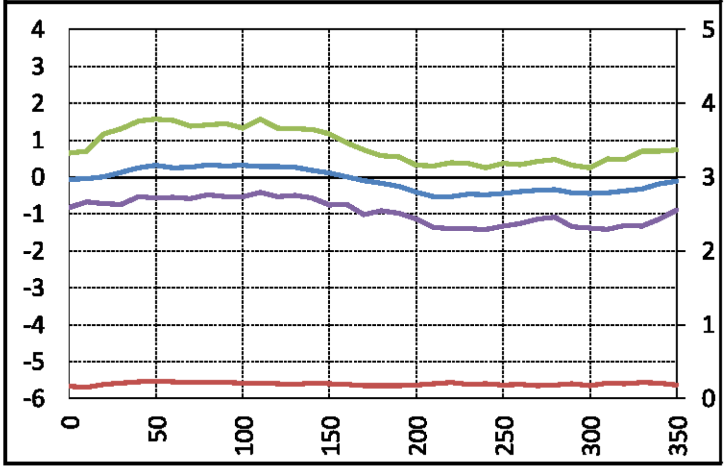
Individual Tap ID: BEB05 Port ID: 233



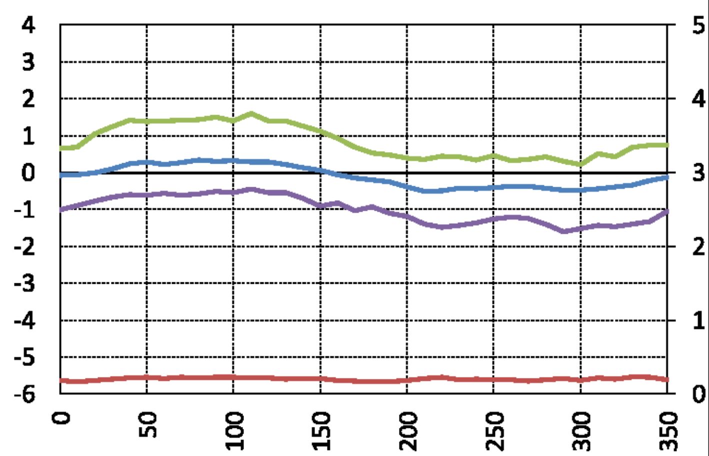
Individual Tap ID: BEB06 **Port ID: 234**



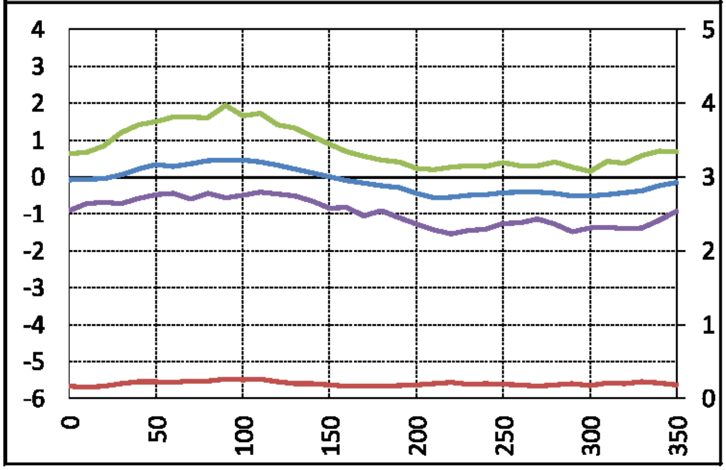
Individual Tap ID: BEB07 **Port ID: 235**



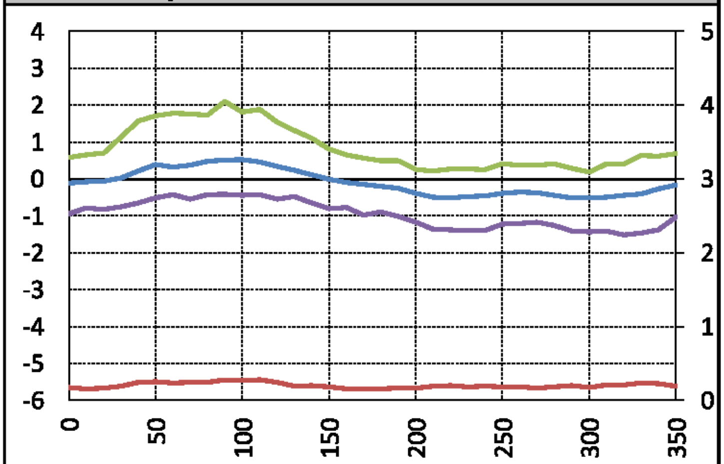
Individual Tap ID: BEB08 **Port ID: 236**



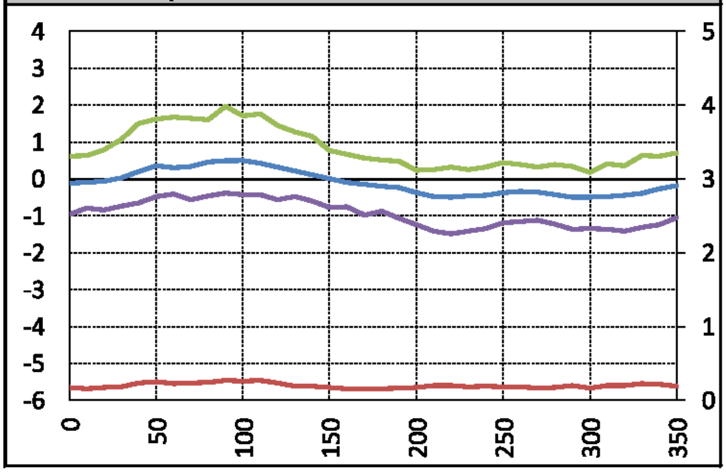
Individual Tap ID: BEB09 **Port ID: 237**



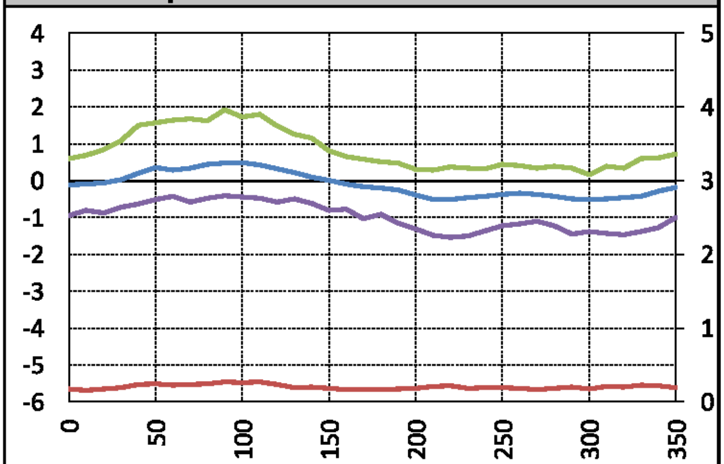
Individual Tap ID: BEB10 **Port ID: 238**



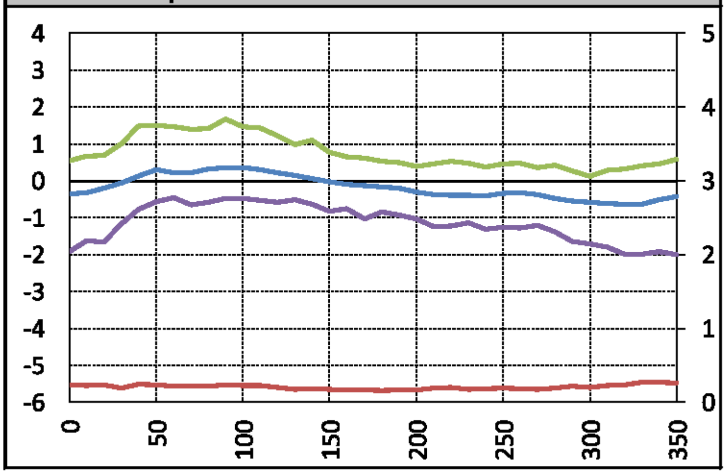
Individual Tap ID: BEB11 **Port ID: 239**



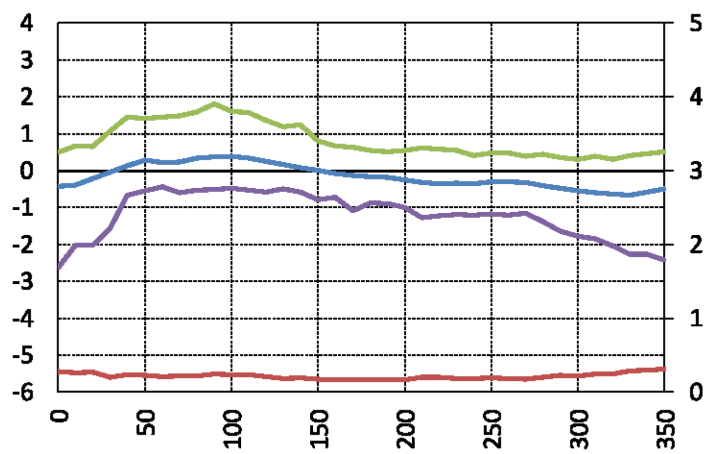
Individual Tap ID: BEB12 **Port ID: 240**



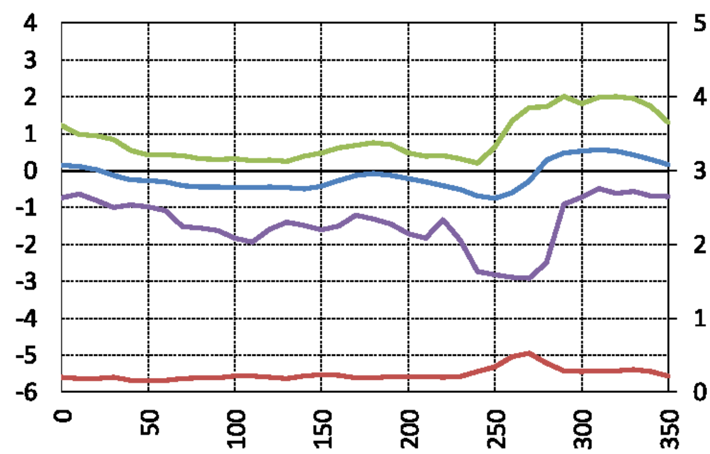
Individual Tap ID: BEB13 **Port ID: 241**



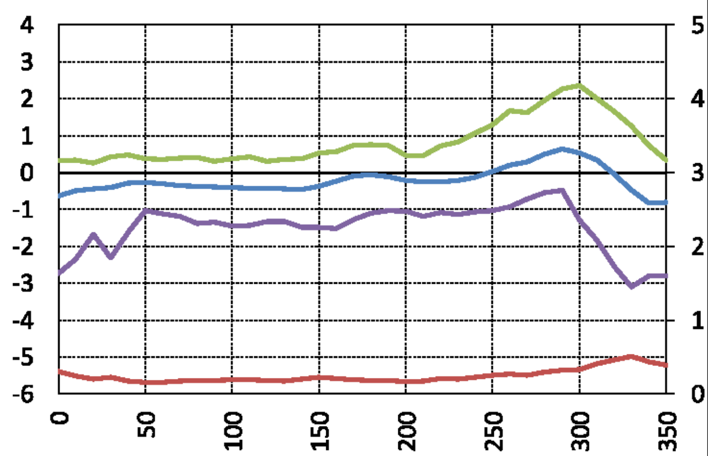
Individual Tap ID: BEB14 **Port ID: 242**



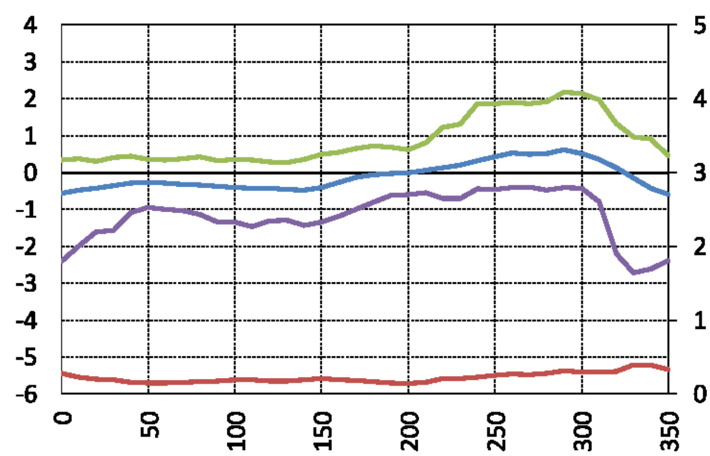
Individual Tap ID: BNA01 **Port ID: 243**



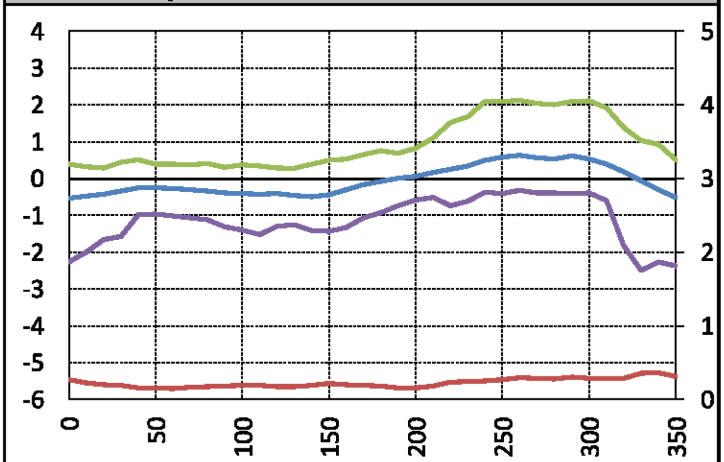
Individual Tap ID: BWA01 **Port ID: 244**



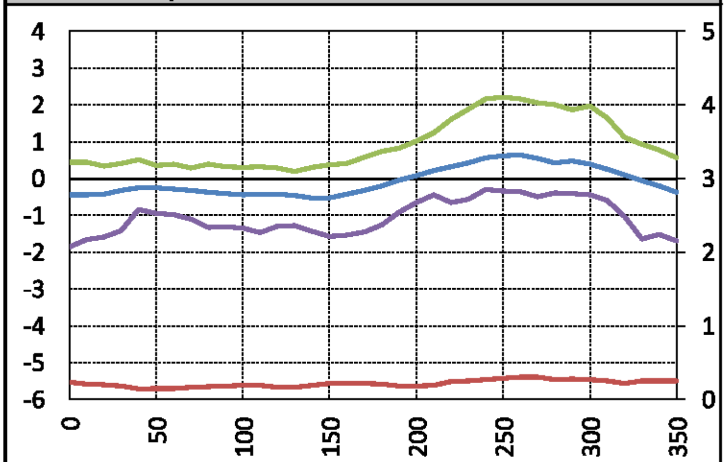
Individual Tap ID: BWA02 **Port ID: 245**



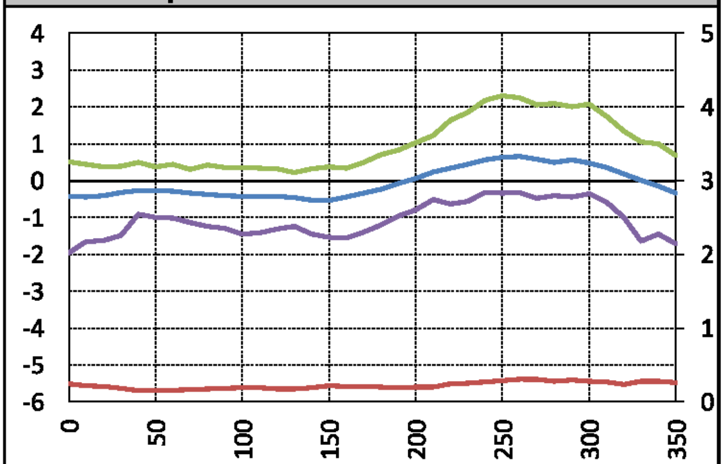
Individual Tap ID: BWA03 **Port ID: 246**



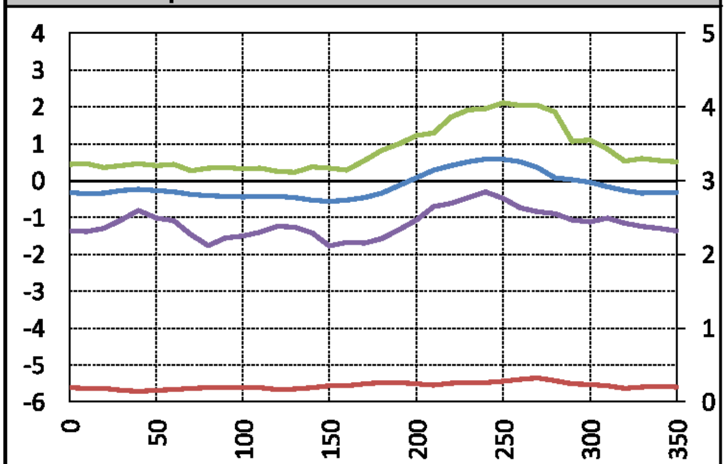
Individual Tap ID: BWA04 **Port ID: 247**



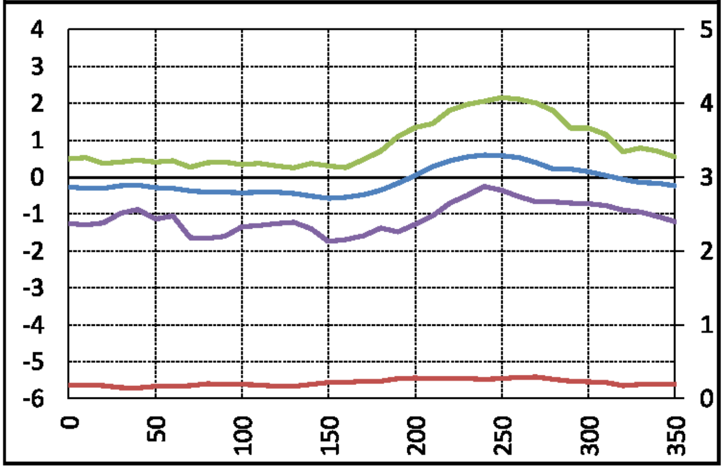
Individual Tap ID: BWA05 **Port ID: 248**



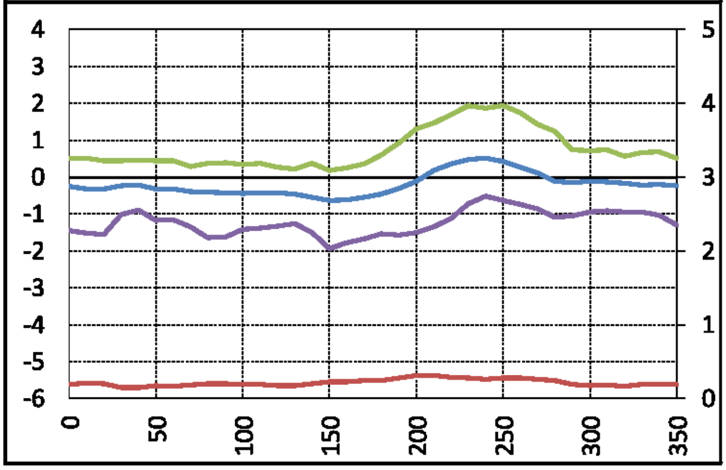
Individual Tap ID: BWA06 **Port ID: 249**



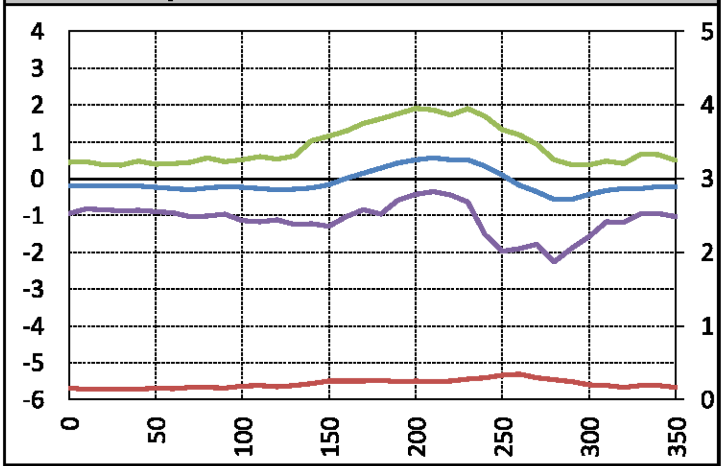
Individual Tap ID: BWA07 Port ID: 250



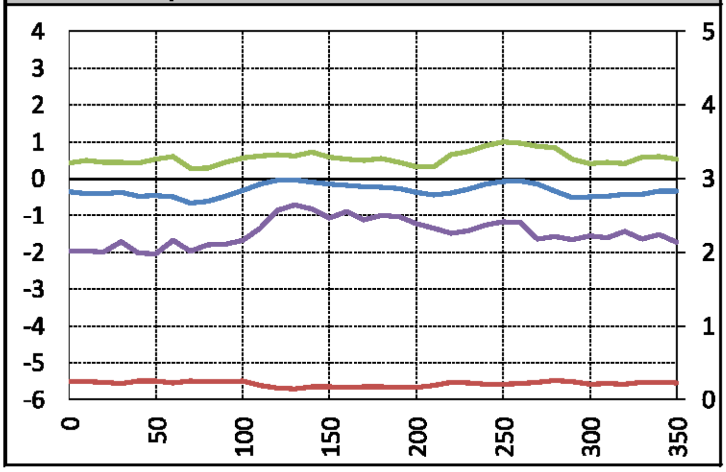
Individual Tap ID: BWA08 Port ID: 251



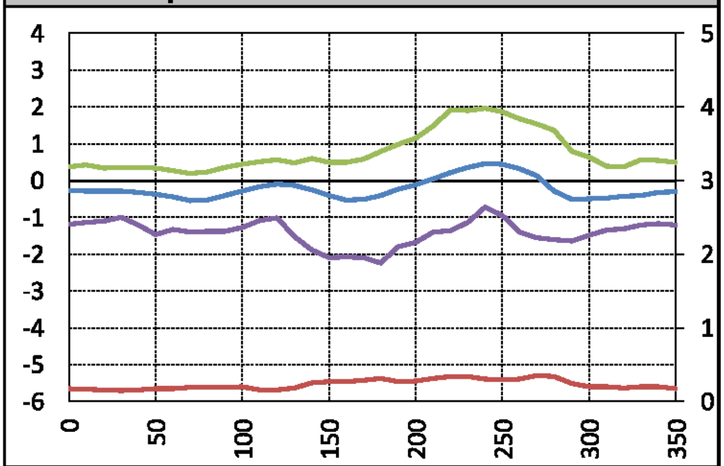
Individual Tap ID: BSA01 Port ID: 252



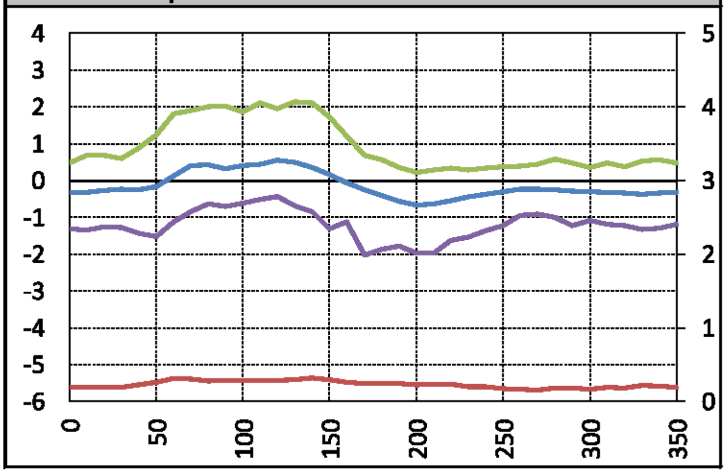
Individual Tap ID: BWF04 Port ID: 256



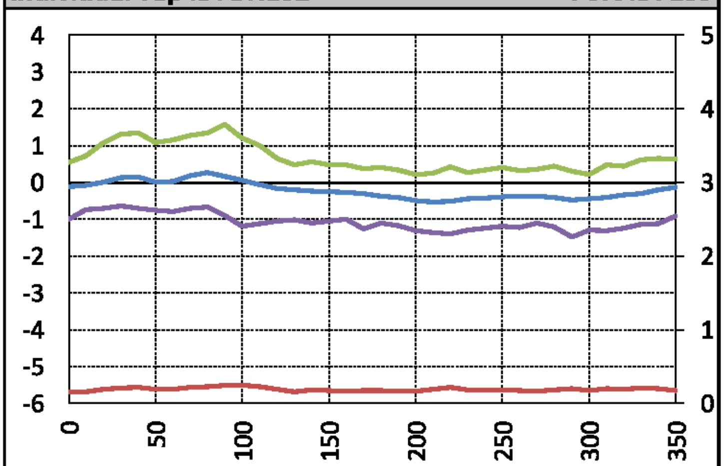
Individual Tap ID: BWF05 Port ID: 257



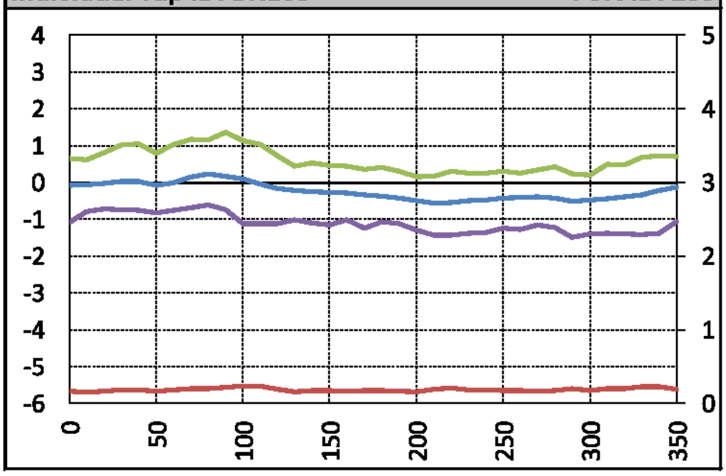
Individual Tap ID: BNE01 Port ID: 258



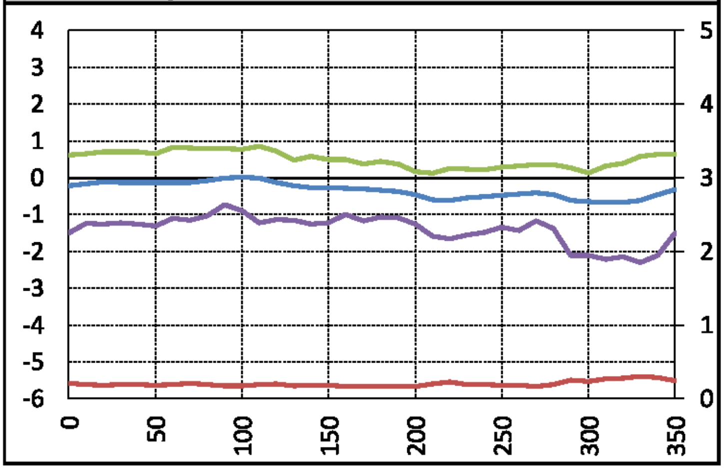
Individual Tap ID: BNE02 Port ID: 259



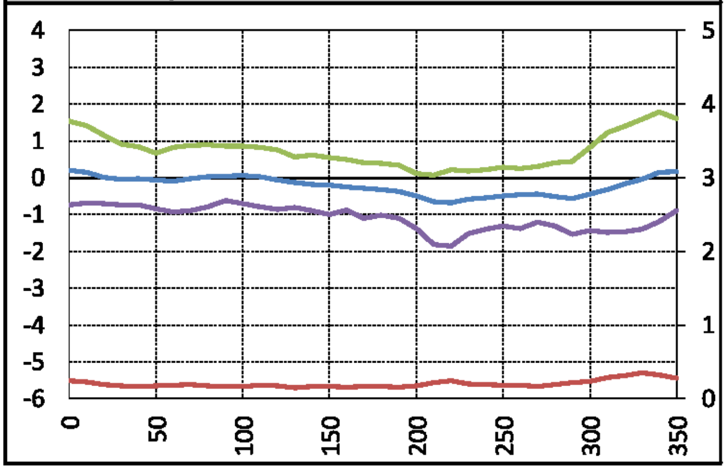
Individual Tap ID: BNE03 Port ID: 260



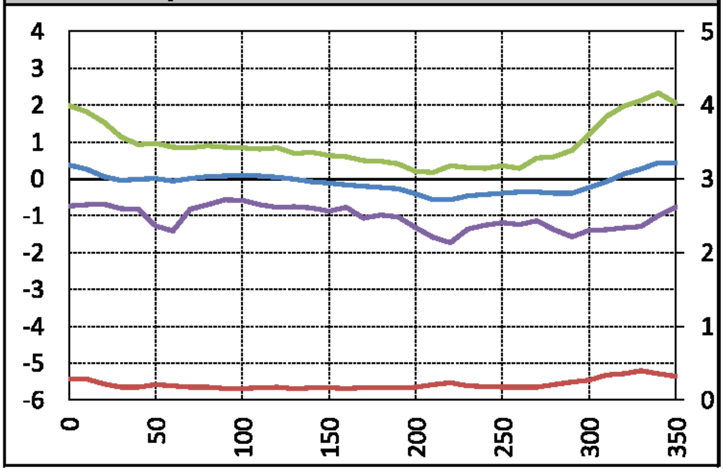
Individual Tap ID: BNE04 Port ID: 261



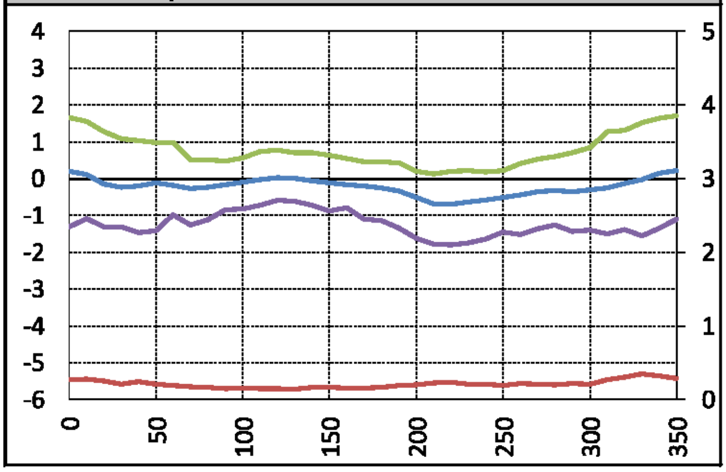
Individual Tap ID: BNE05 Port ID: 262



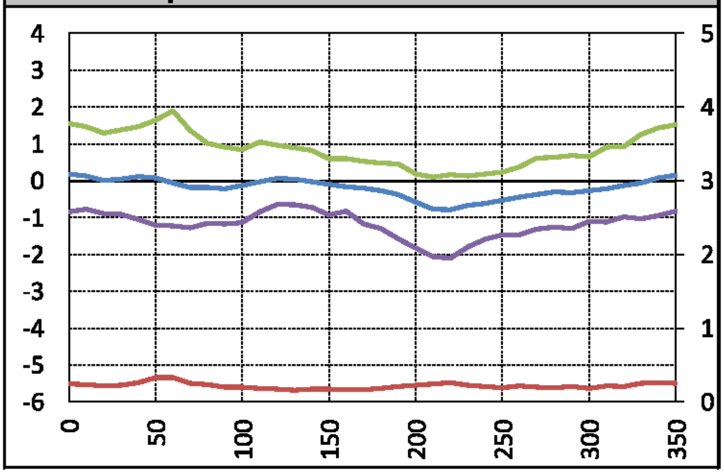
Individual Tap ID: BNE06 Port ID: 263



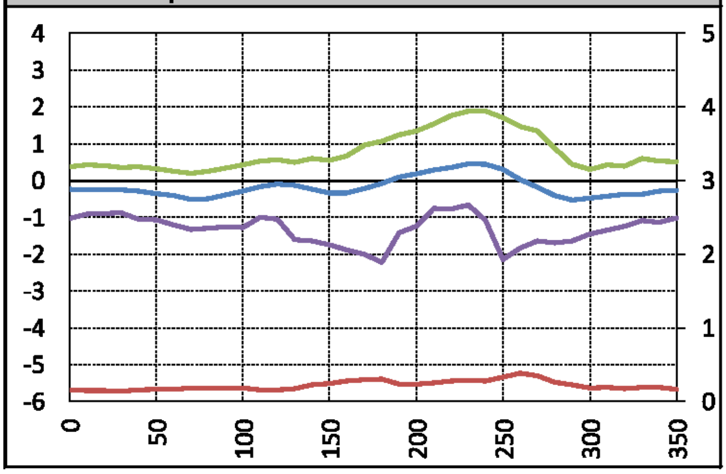
Individual Tap ID: BNE07 Port ID: 264



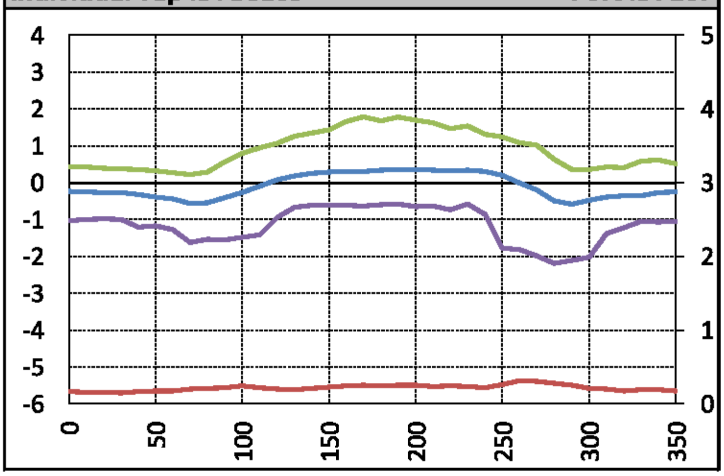
Individual Tap ID: BNE08 Port ID: 265



Individual Tap ID: BWE10 Port ID: 266



Individual Tap ID: BSE05 Port ID: 267



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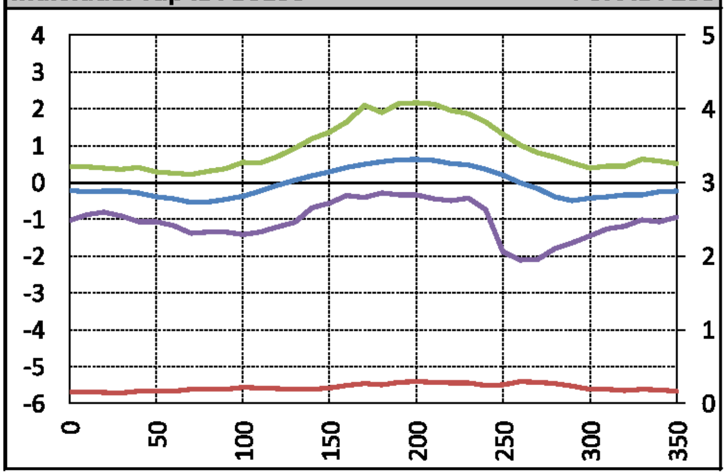

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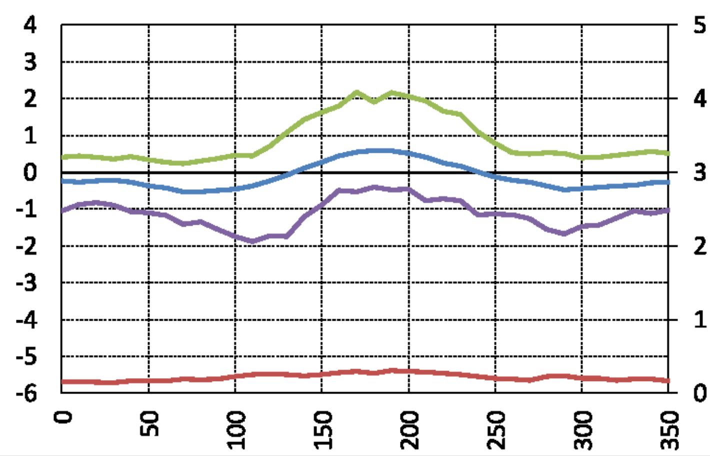

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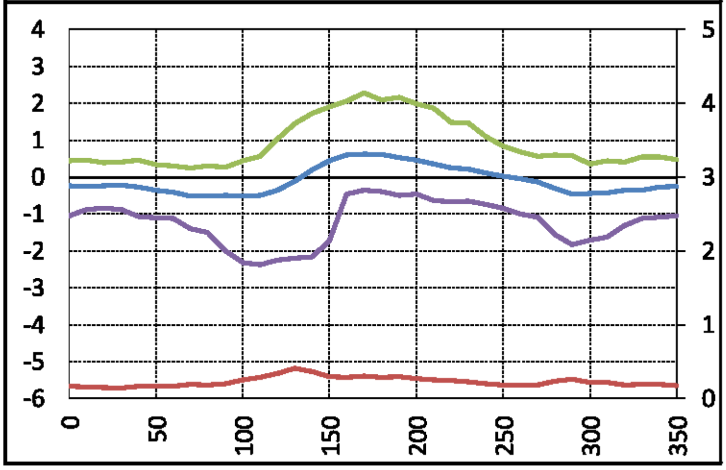
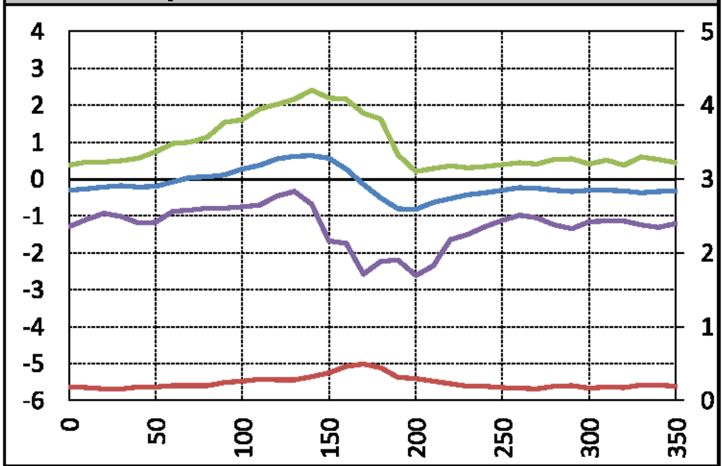
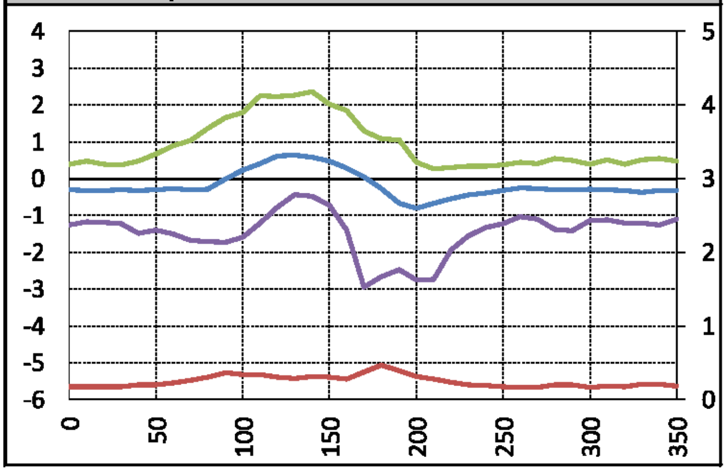


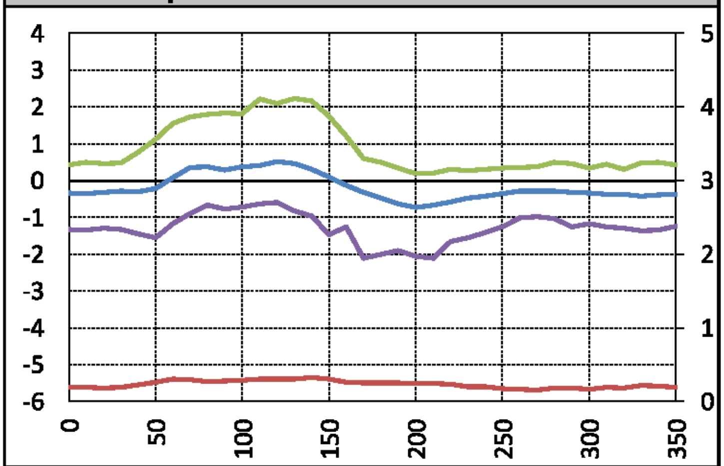
Individual Tap ID: BEE01 Port ID: 271



Individual Tap ID: BEE02 Port ID: 272



Individual Tap ID: BEE03 Port ID: 273



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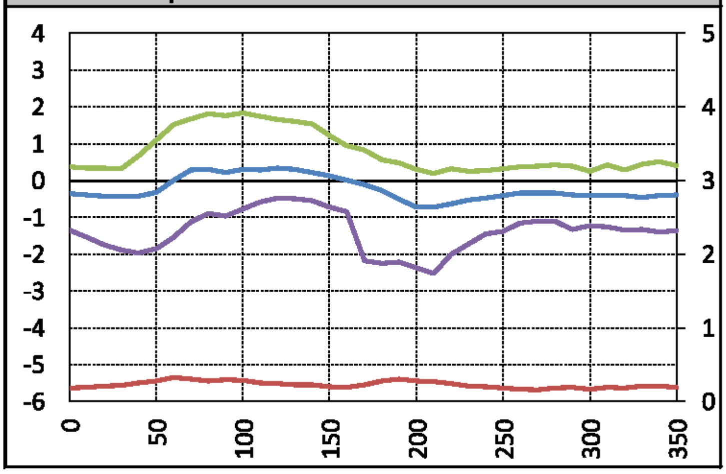

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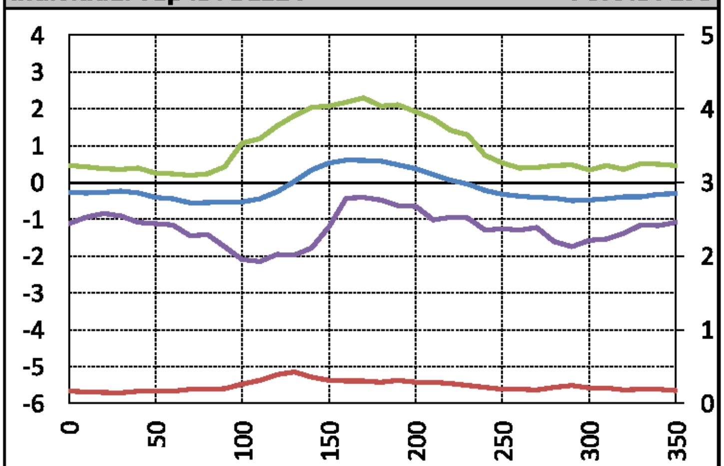

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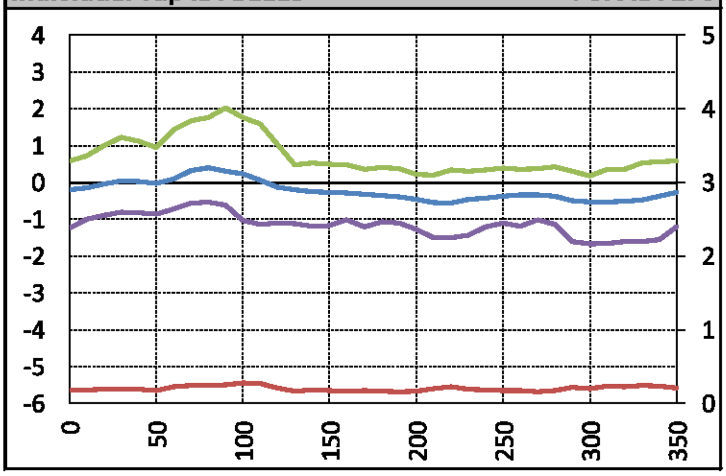
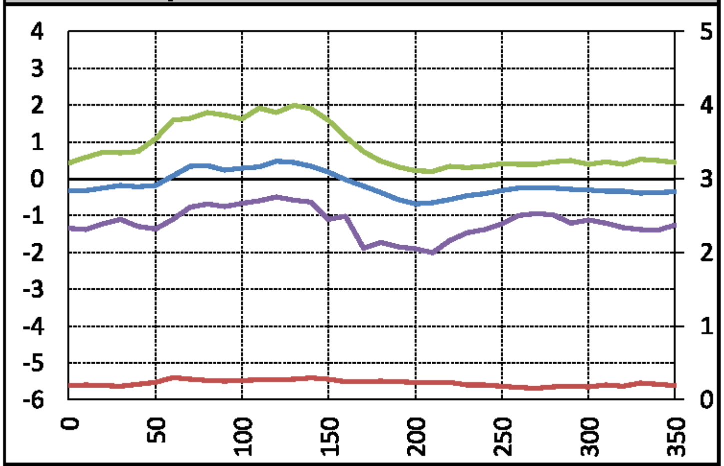


Individual Tap ID: BND01 Port ID: 277



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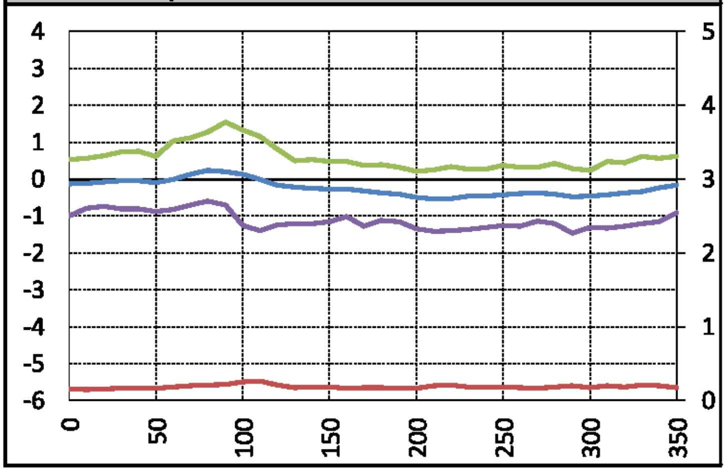

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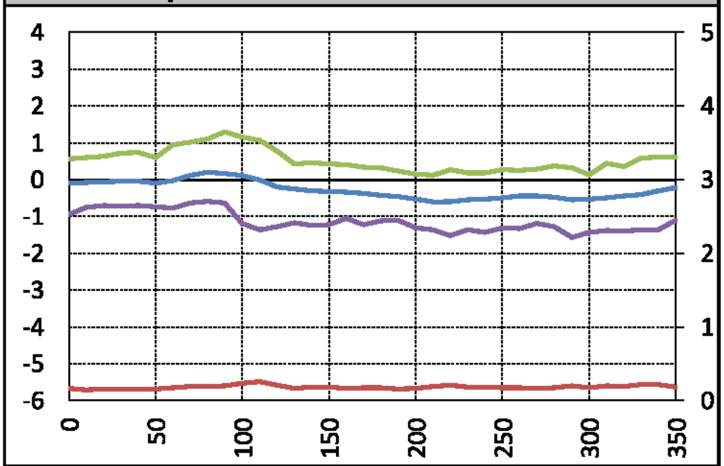
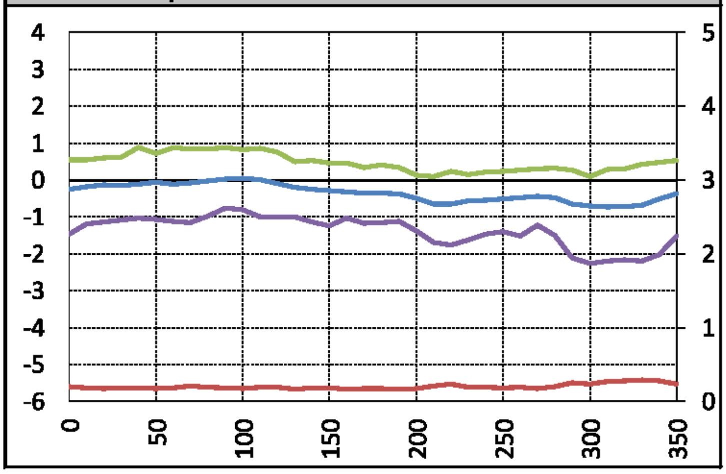
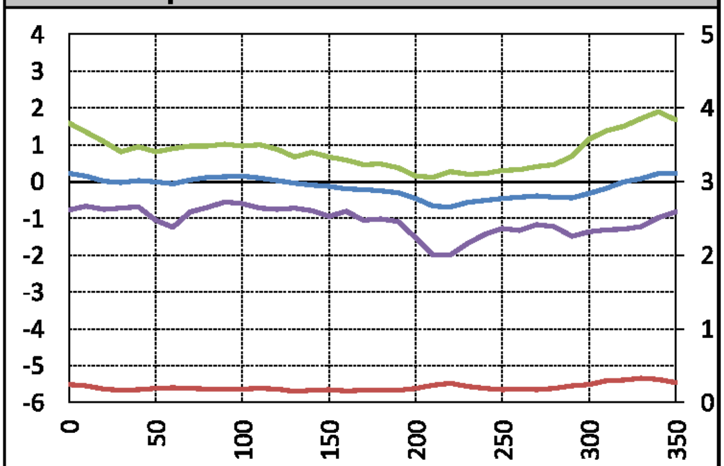


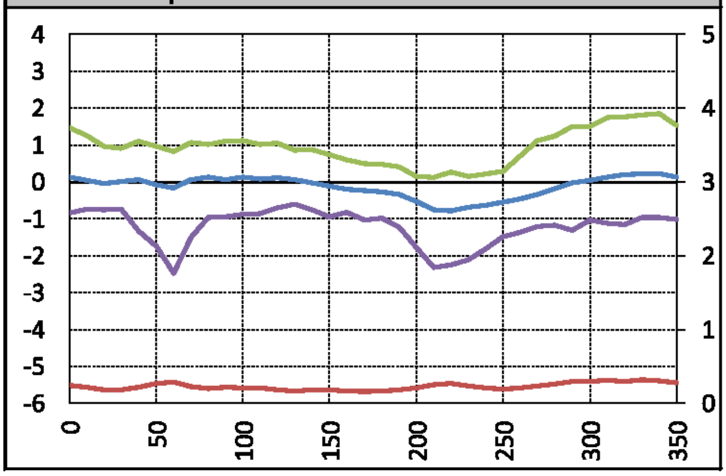
Individual Tap ID: BND04 Port ID: 280



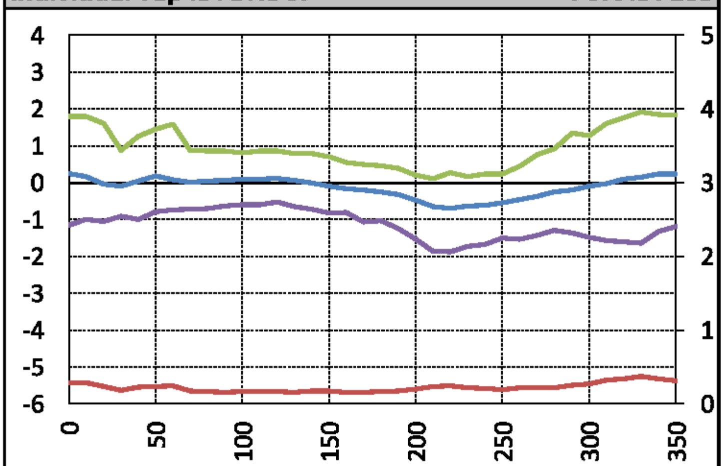
Individual Tap ID: BND05 Port ID: 281



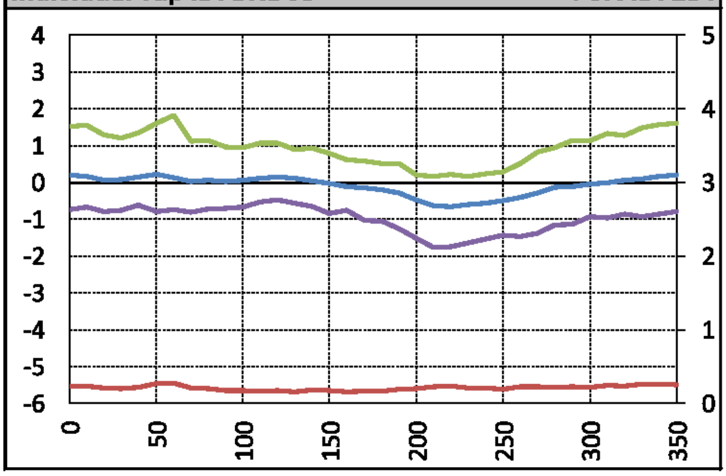
Individual Tap ID: BND06 Port ID: 282



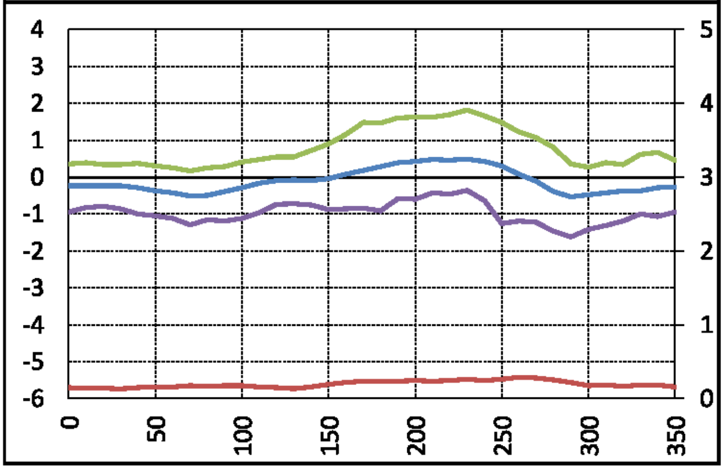
Individual Tap ID: BND07 Port ID: 283



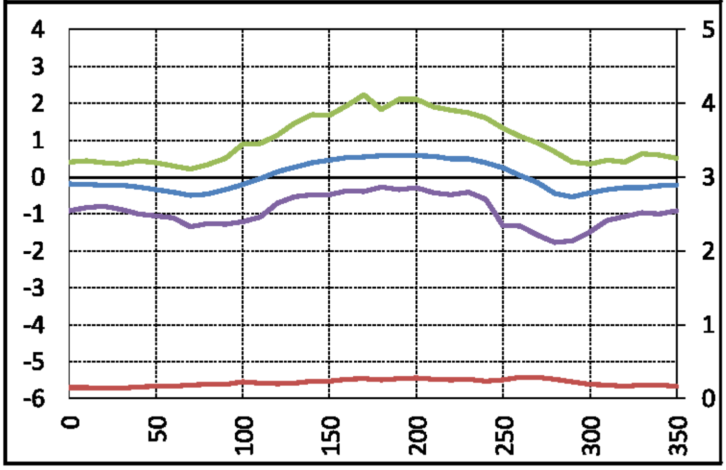
Individual Tap ID: BND08 Port ID: 284



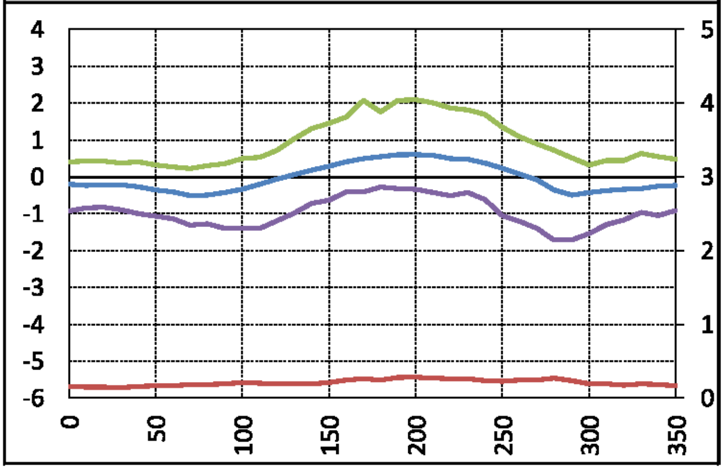
Individual Tap ID: BWD10 Port ID: 285



Individual Tap ID: BSD05 Port ID: 286



Individual Tap ID: BSD06 Port ID: 287



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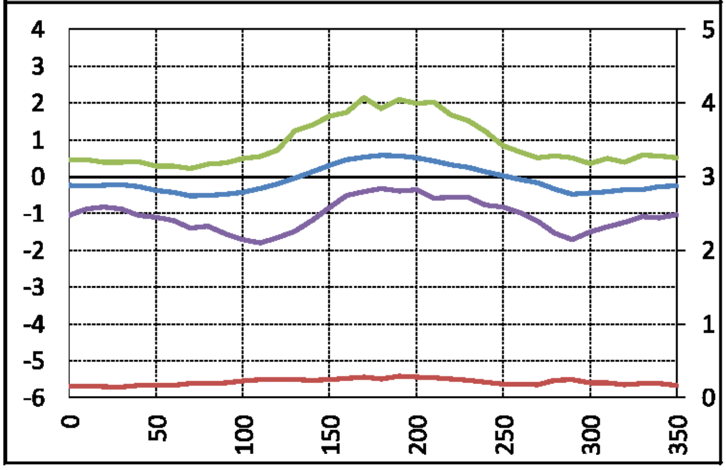
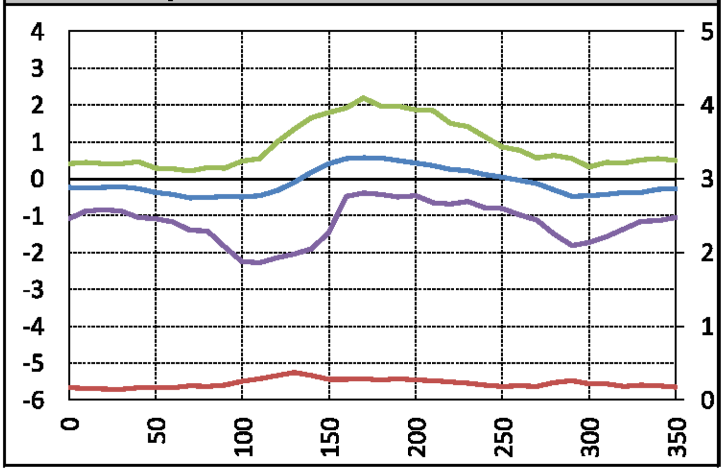
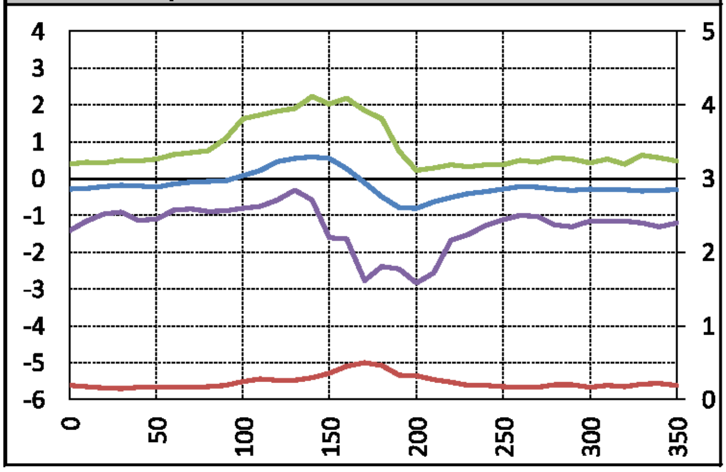


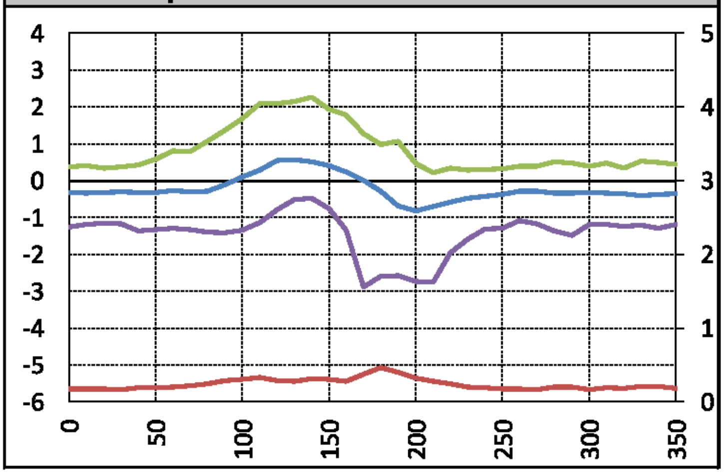
Individual Tap ID: BSD08 Port ID: 289



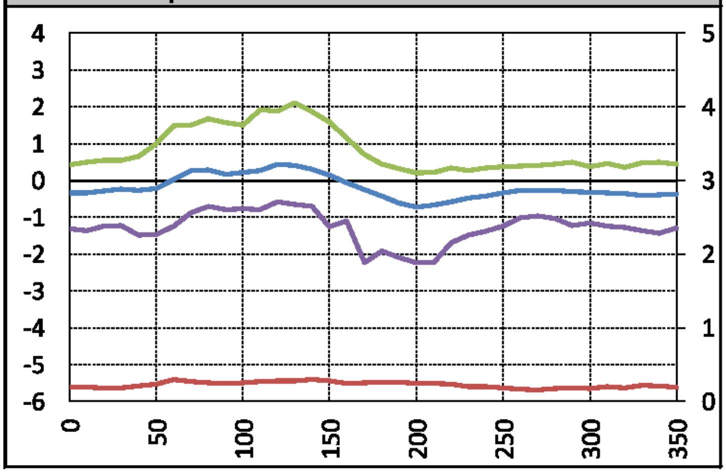
Individual Tap ID: BED01 Port ID: 290



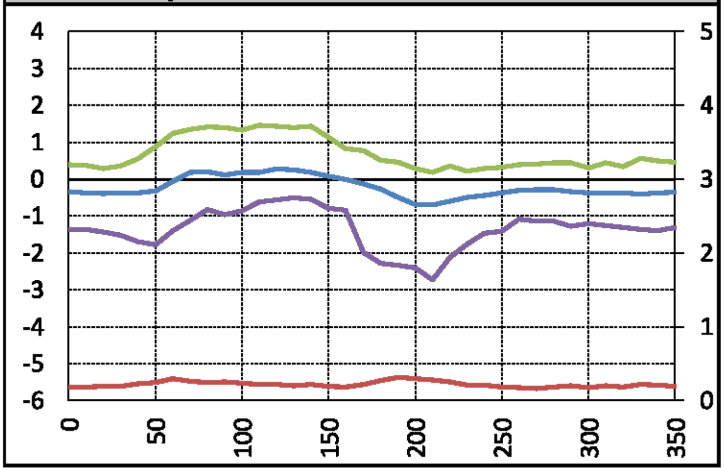
Individual Tap ID: BED02 Port ID: 291



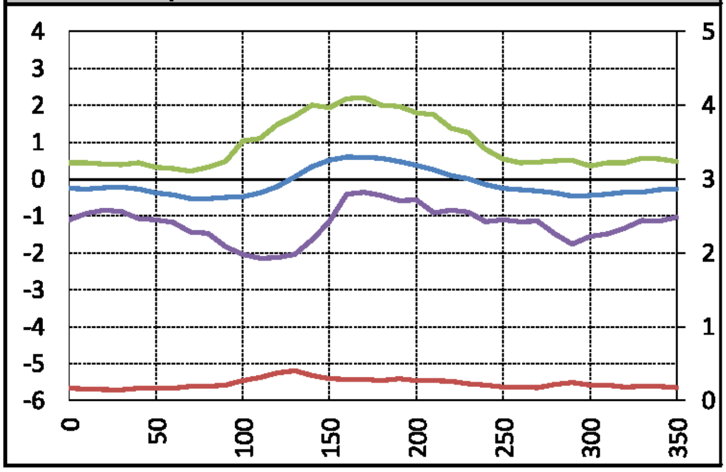
Individual Tap ID: BED03 Port ID: 292



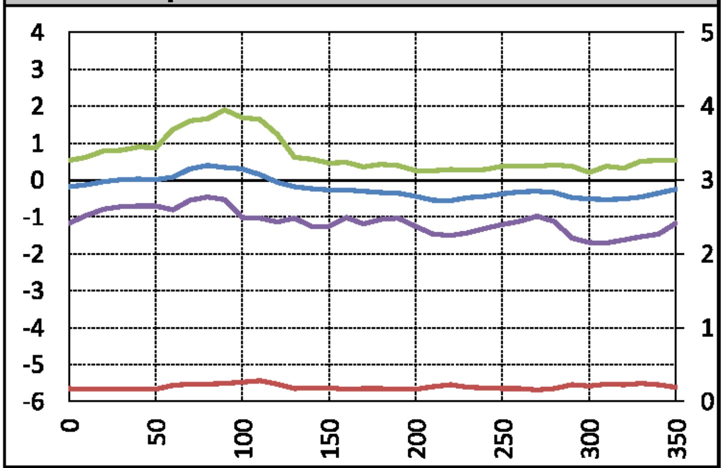
Individual Tap ID: BED04 Port ID: 293



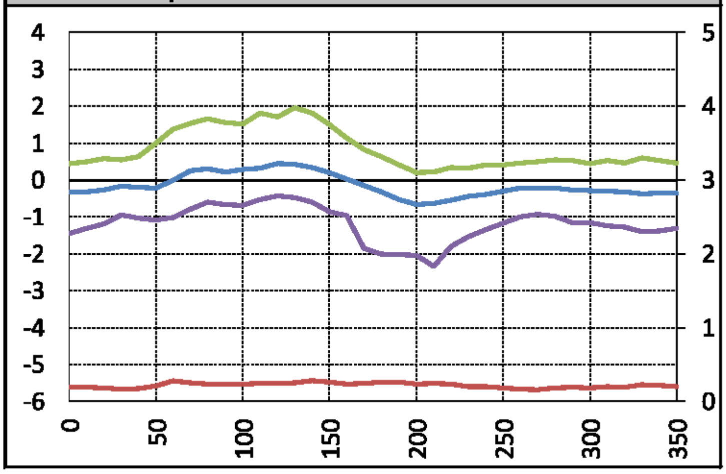
Individual Tap ID: BED14 Port ID: 294



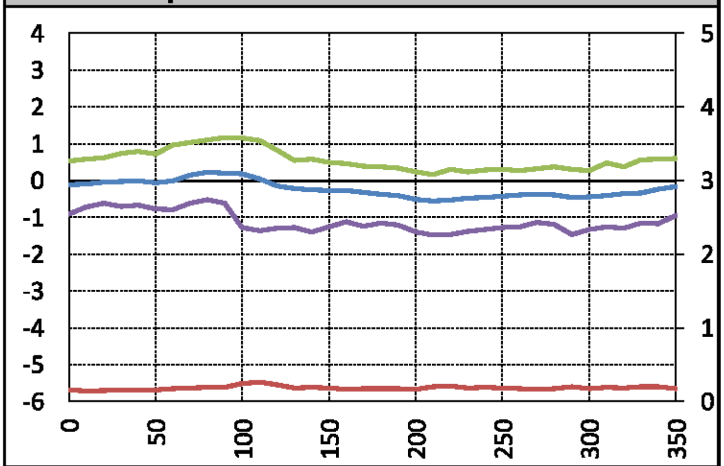
Individual Tap ID: BED15 Port ID: 295



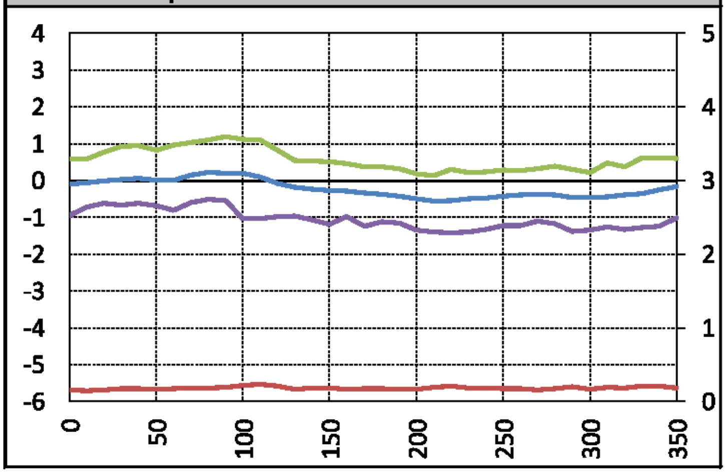
Individual Tap ID: BNC01 Port ID: 296



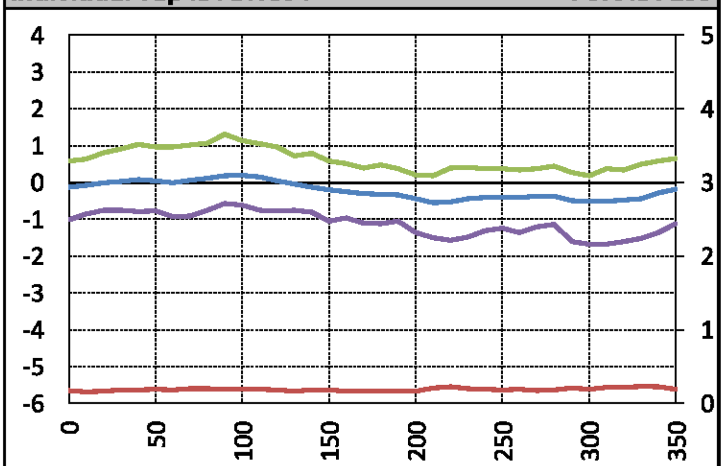
Individual Tap ID: BNC02 Port ID: 297



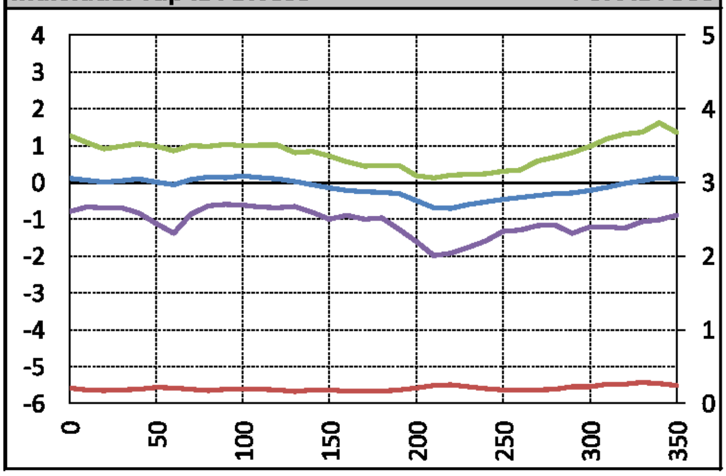
Individual Tap ID: BNC03 Port ID: 298



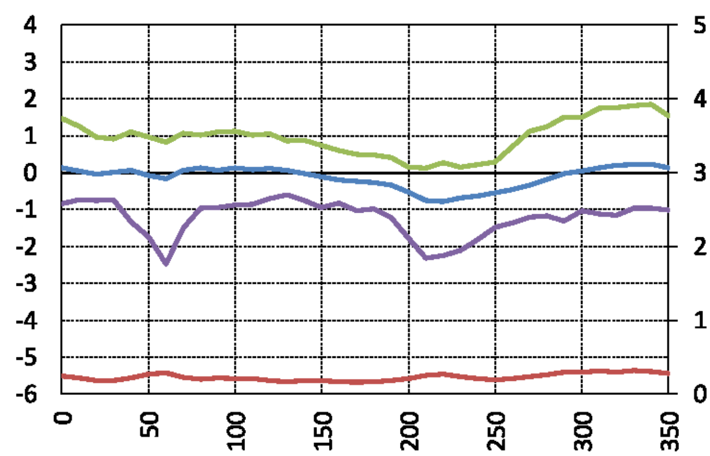
Individual Tap ID: BNC04 Port ID: 299



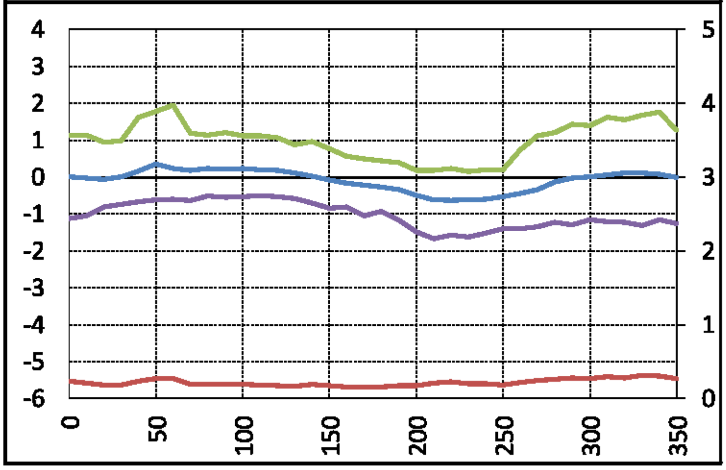
Individual Tap ID: BNC05 Port ID: 300



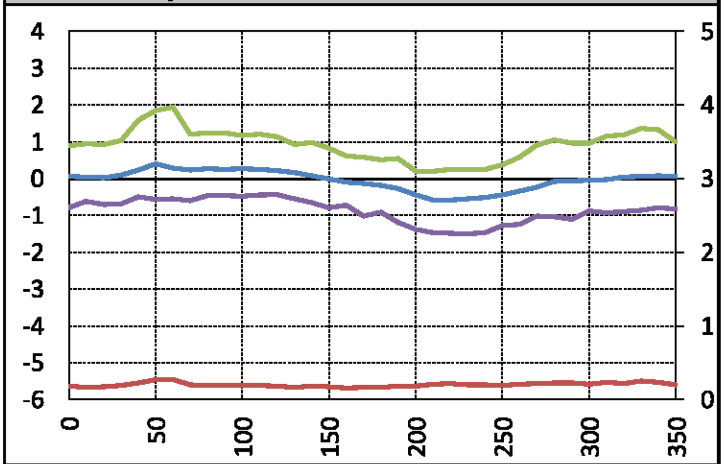
Individual Tap ID: BNC06 Port ID: 301



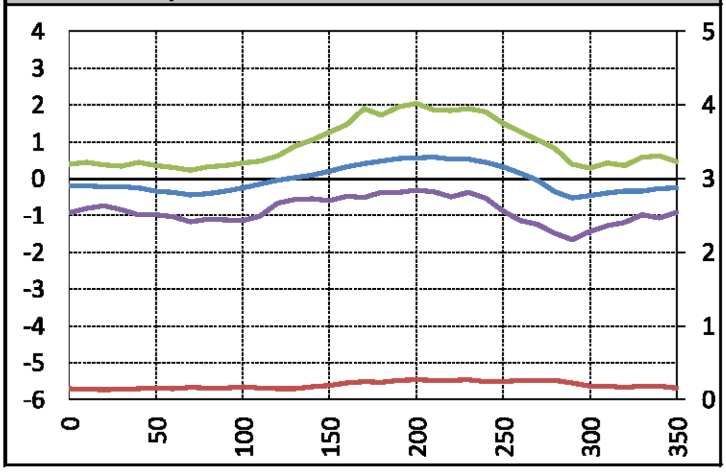
Individual Tap ID: BNC07 Port ID: 302



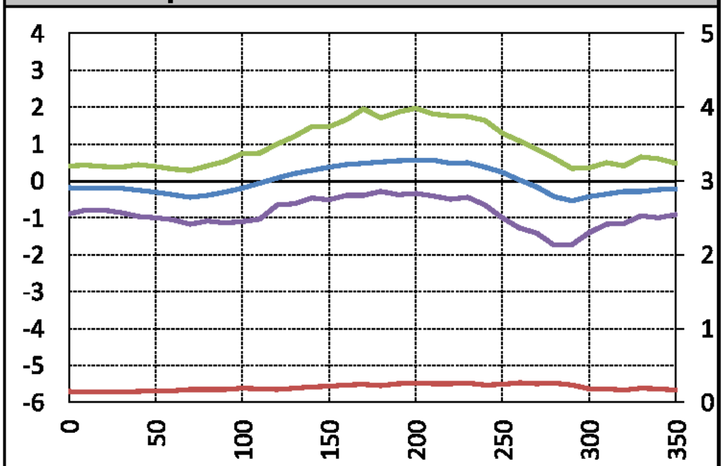
Individual Tap ID: BNC08 Port ID: 303



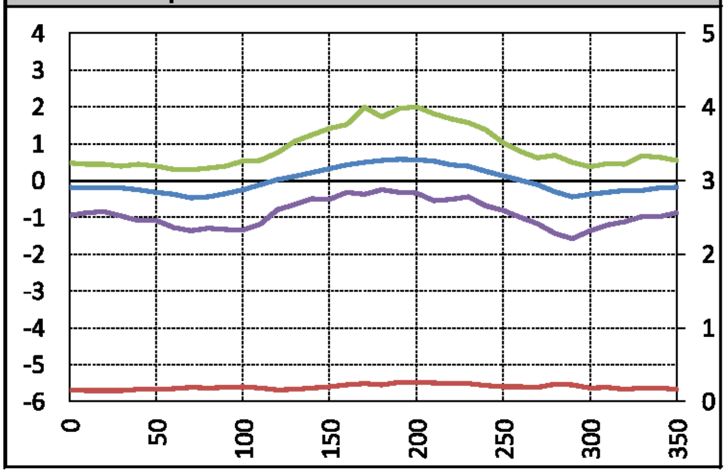
Individual Tap ID: BWC10 Port ID: 304



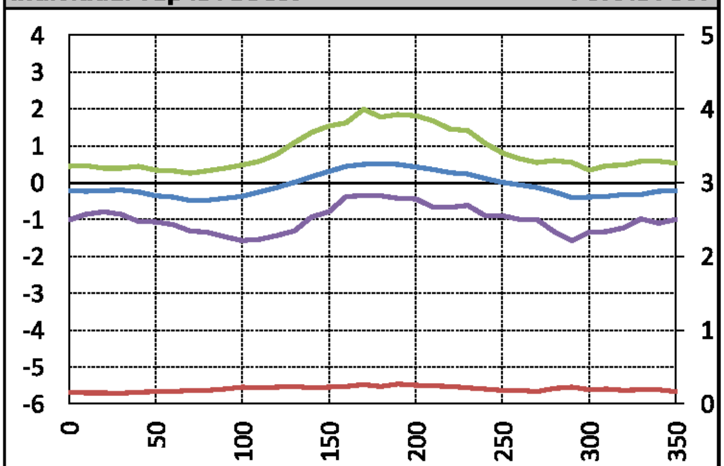
Individual Tap ID: BSC05 Port ID: 305



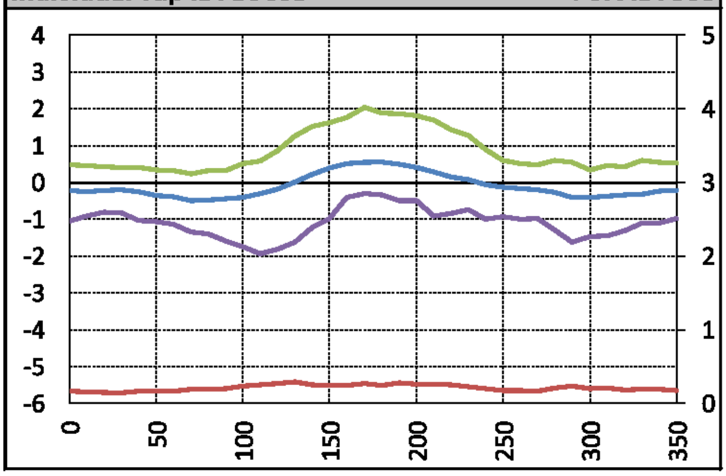
Individual Tap ID: BSC06 Port ID: 306



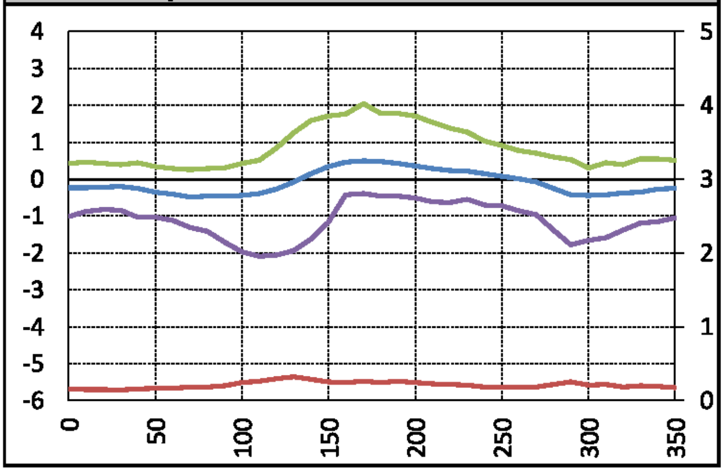
Individual Tap ID: BSC07 Port ID: 307



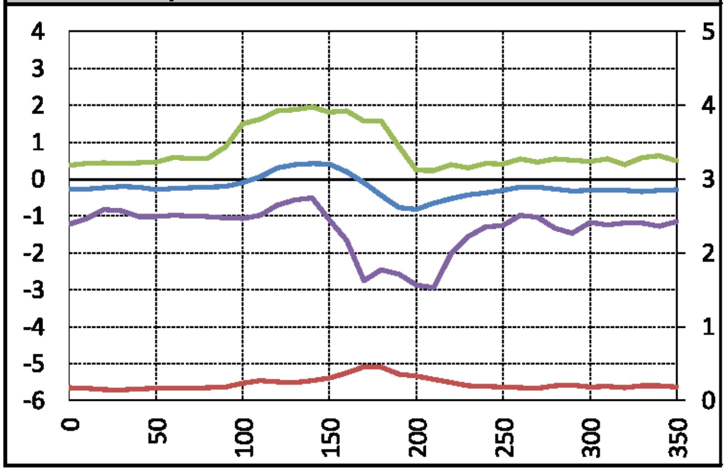
Individual Tap ID: BSC08 Port ID: 308



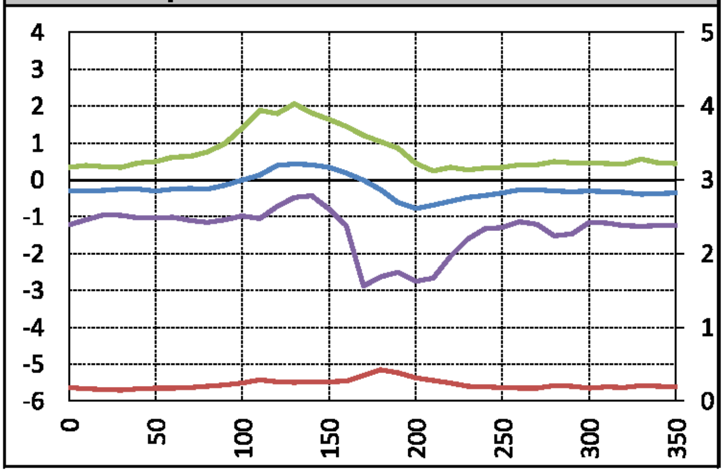
Individual Tap ID: BSC09 **Port ID: 309**



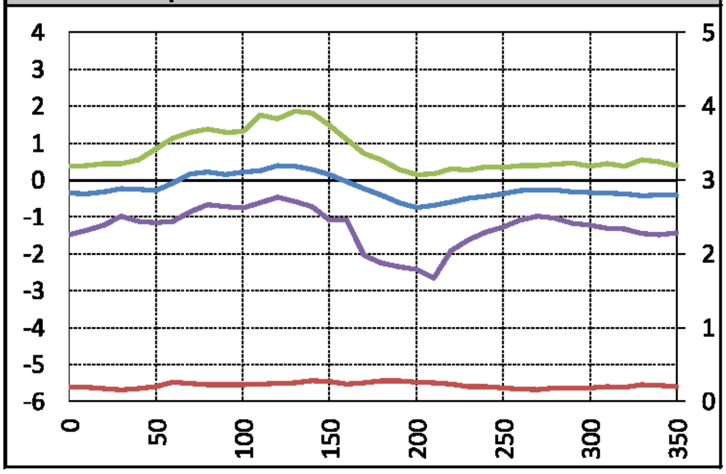
Individual Tap ID: BEC01 **Port ID: 310**



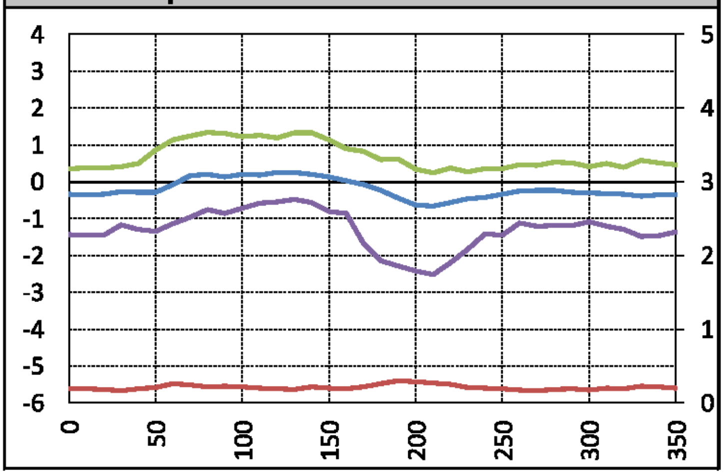
Individual Tap ID: BEC02 **Port ID: 311**



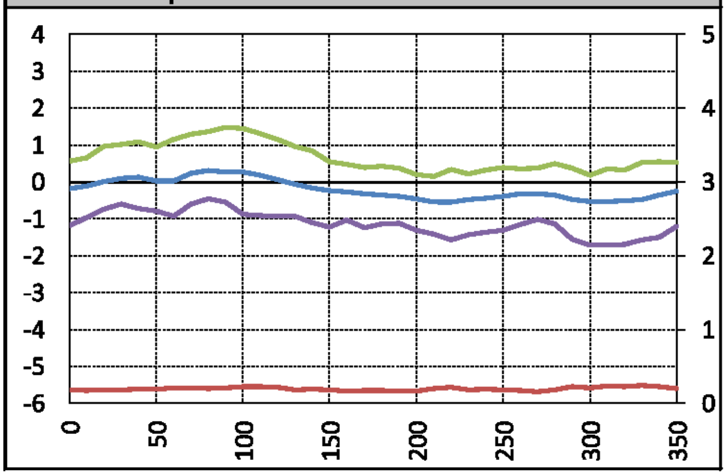
Individual Tap ID: BEC03 **Port ID: 312**

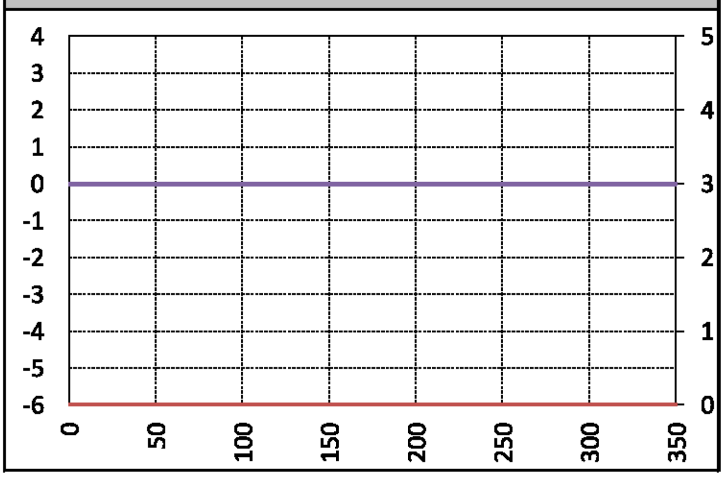


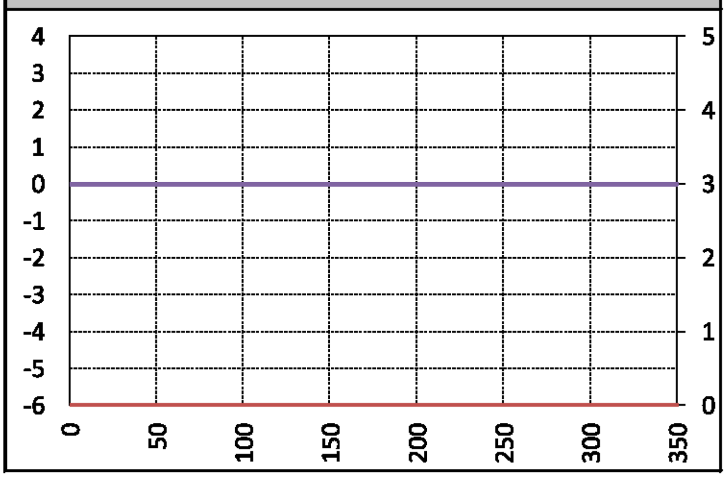
Individual Tap ID: BEC04 **Port ID: 313**



Individual Tap ID: BEC14 **Port ID: 314**







APPENDIX B - APARTMENT OPENING PARAMETERS

Appendix B1 – Window Opening Sizes

Tap id	Configuration 1			Configuration 2		
	Discharge Coefficient	Opening Area (m^2)	Internal Wall Area (m^2)	Discharge Coefficient	Opening Area (m^2)	Internal Wall Area (m^2)
ANE01	0.651	3.35	12.47			
ANE02	0.652	3.02	10.44			
ANE03	0.650	2.30	8.70	0.650	2.58	10.15
ANE04						
ANE05	0.651	3.16	11.31	0.651	3.35	12.18
ANE06						
ANE07	0.650	2.68	10.15	0.650	2.68	10.15
ANE08	0.633	0.48	21.75	0.694	6.05	11.02
ANE09	0.652	3.54	12.47			
ANE10						
AWE01	0.635	0.36	7.25			
AWE02	0.634	0.35	9.86			
AWE03	0.633	0.40	13.63			
NIL						
AWE04	0.639	1.76	19.72			
AWE05	0.634	0.31	9.28			
ASE01						
ASE02	0.651	3.54	13.05	0.657	3.00	8.70
ASE03						
ASE04	0.651	3.16	11.60			
ASE05	0.634	0.38	11.60	0.635	0.38	8.12
ASE06	0.650	2.58	9.86			
ASE07						
ASE08	0.634	0.31	8.70			
AEE01	0.632	0.35	18.27			
AEE02	0.647	2.61	12.18	0.642	2.58	20.01
AEE03	0.633	0.35	11.60			
AEE04	0.636	0.49	9.28			
AEE05	0.641	3.02	24.36			
AEE06	0.632	0.31	20.88			
AND01	0.651	3.45	12.76			
AND02	0.650	3.02	11.60			
AND03	0.650	2.30	8.70	0.650	2.58	10.15
AND04	0.634	0.36	11.31	0.635	0.50	11.31
AND05	0.651	2.49	9.28	0.651	3.35	12.18
AND06						
AND07	0.650	2.68	10.15	0.650	2.68	10.15
AND08	0.633	0.48	21.75	0.694	6.05	11.02
AND09	0.652	3.54	12.47			
AND10	0.640	0.30	2.90			
AWD01	0.635	0.36	7.25			
AWD02	0.634	0.35	9.86			
AWD03	0.633	0.40	13.63			
AWD04	0.638	1.76	20.59			
AWD05	0.634	0.31	9.28			
ASD01						
ASD02	0.651	3.54	13.05	0.657	3.00	8.70
ASD03						

Appendix B1 - Window Opening Sizes

Tap id	Configuration 1			Configuration 2		
	Discharge Coefficient	Opening Area (m^2)	Internal Wall Area (m^2)	Discharge Coefficient	Opening Area (m^2)	Internal Wall Area (m^2)
ASD04	0.651	3.16	11.60			
ASD05	0.634	0.38	11.60	0.634	0.38	9.28
ASD06	0.659	3.52	9.86	0.644	3.52	21.75
ASD07						
ASD08	0.634	0.31	8.70			
AED01	0.632	0.35	18.56			
AED02	0.647	2.61	12.18	0.644	2.58	15.08
AED03	0.634	0.35	10.73			
AED04	0.634	0.35	9.57			
AED05	0.641	3.02	24.36			
AED06	0.632	0.31	20.88			
ANC01	0.635	0.38	8.70			
ANC02	0.650	2.39	8.99	0.656	3.64	11.02
ANC03						
ANC04	0.651	3.06	11.31	0.651	3.35	12.18
NIL						
ANC05	0.650	2.68	10.15	0.650	2.68	10.15
ANC06	0.694	6.05	11.02			
ANC07	0.632	0.48	22.04	0.633	0.54	22.04
AWC01	0.636	0.38	7.25			
AWC02	0.634	0.35	9.57	0.634	0.35	9.86
AWC03	0.633	0.40	13.63			
AWC04	0.638	1.76	20.59			
AWC05	0.651	3.16	11.60			
AWC06	0.635	0.43	8.70	0.634	0.31	8.70
ASC01						
ASC02	0.651	3.54	13.05	0.660	3.19	8.70
ASC03						
ASC04	0.651	3.16	11.31			
ASC05	0.634	0.38	11.60	0.634	0.38	9.28
ASC06						
ASC07	0.633	0.56	18.27			
ASC08	0.634	0.34	8.70			
AEC01						
AEC02	0.651	3.16	11.60			
AEC03	0.651	3.16	11.60			
AEC04	0.637	0.58	8.70			
AEC05	0.650	2.68	10.15			
AEC06						
AEC07	0.632	0.31	23.20			
AEC08	0.633	0.35	11.60			
AEC09	0.632	0.30	21.17			
AEC10	0.641	3.02	24.36			
ANB01	0.660	2.48	6.67			
ANB02	0.654	3.00	9.57	0.653	2.48	8.41
ANB03	0.655	2.35	7.25			
ANB04						
ANB05						

Appendix B1 - Window Opening Sizes

Tap id	Configuration 1			Configuration 2		
	Discharge Coefficient	Opening Area (m^2)	Internal Wall Area (m^2)	Discharge Coefficient	Opening Area (m^2)	Internal Wall Area (m^2)
AWB01	0.652	3.35	11.89	0.651	2.68	9.57
AWB02	0.635	0.43	8.70	0.634	0.30	8.70
ASB01	0.656	3.06	9.28			
ASB02	0.656	3.83	11.60			
ASB03	0.649	3.13	12.47			
ASB04	0.634	0.58	17.69			
ASB05	0.634	0.35	8.70			
AEB01						
AEB02	0.652	3.25	11.60			
AEB03	0.657	3.00	8.70			
AEB04						
AEB05	0.632	0.30	23.49			
ANA01						
NIL						
NIL						
BNB01	0.636	0.40	6.67	0.680	4.59	9.28
BNB02	0.646	2.01	10.15	0.651	3.06	11.02
BNB03	0.648	2.01	8.99			
BNB04	0.650	1.91	7.25	0.651	3.06	11.02
BNB05	0.685	5.37	10.44			
BNB06	0.652	2.52	8.70			
BNB07	0.651	2.49	8.99	0.652	2.87	10.15
BWB06	0.634	0.53	16.82	0.635	0.33	7.25
BSB02	0.634	0.30	8.41	0.634	0.33	8.41
BSB03						
BSB04	0.661	2.61	6.96			
BSB05						
BSB06	0.638	0.60	7.25			
BEB01						
BEB02	0.635	0.45	9.28			
BEB03	0.637	0.45	6.96			
BEB04						
BWF01	0.650	1.91	7.25	0.651	2.49	9.28
BWF02	0.638	0.73	9.57	0.636	0.70	11.60
BWF03						
BSF01						
BEF01	0.656	3.06	9.28			
BEF02						
BEF03						
BNE09	0.634	0.56	16.82			
BNE10	0.634	0.49	13.63			
BNE11	0.635	0.51	10.73			
BNE12	0.632	0.31	15.37	0.632	0.31	15.37
BNE13	0.633	0.35	15.08			
BWE01						
BWE02	0.635	0.31	6.96			
BWE03						
BWE04	0.650	1.91	7.25			

Appendix B1 - Window Opening Sizes

Tap id	Configuration 1			Configuration 2		
	Discharge Coefficient	Opening Area (m^2)	Internal Wall Area (m^2)	Discharge Coefficient	Opening Area (m^2)	Internal Wall Area (m^2)
BWE05						
BWE06	0.650	2.39	8.99			
BWE07	0.651	2.68	9.57	0.651	2.49	8.99
BWE08	0.647	1.72	7.83	0.656	3.06	9.28
BWE09	0.636	0.55	9.28	0.634	0.38	11.02
BWF06	0.637	0.59	9.28	0.638	0.58	6.96
BSE01	0.632	0.31	18.85			
BSE02						
BSE03	0.636	0.43	6.96			
BSE04	0.651	2.87	10.44			
BSE09	0.632	0.35	19.72			
BEE05	0.649	3.02	12.18			
BEE06	0.643	1.26	8.70			
BEE07	0.635	0.45	9.28	0.635	0.41	8.41
BEE08	0.648	2.73	12.18	0.686	4.81	9.28
BEE09	0.656	2.68	8.12	0.650	1.91	7.25
BEE10						
BEE11	0.669	3.02	6.96			
BEE12	0.656	3.16	9.57			
BEE13	0.635	0.45	9.28			
BND09	0.632	0.35	16.82			
BND10	0.634	0.49	13.34			
BND11	0.635	0.51	10.73			
BND12	0.632	0.31	15.08			
BND13	0.633	0.35	15.08			
BWD01						
NIL						
BWD02	0.635	0.30	6.96			
BWD03						
BWD04	0.650	1.91	7.25			
BWD05	0.652	2.97	10.44			
BWD06						
BWD07	0.651	2.68	9.57	0.644	2.58	15.08
BWD08	0.647	1.72	7.83			
BWD09	0.634	0.36	8.99			
NIL						
BSD01	0.632	0.31	18.85			
BSD02						
BSD03	0.636	0.43	6.96			
BSD04						
BSD09	0.632	0.35	19.43			
BED05	0.633	0.35	12.18			
BED06	0.656	2.87	8.70			
BED07	0.635	0.45	9.28	0.635	0.43	8.41
BED08	0.648	2.73	12.18	0.686	4.81	9.28
BED09	0.651	2.20	8.12	0.650	1.91	7.25
NIL						
NIL						

Appendix B1 - Window Opening Sizes

Tap id	Configuration 1			Configuration 2		
	Discharge Coefficient	Opening Area (m^2)	Internal Wall Area (m^2)	Discharge Coefficient	Opening Area (m^2)	Internal Wall Area (m^2)
BED10						
BED11	0.669	3.02	6.96			
BED12	0.651	2.58	9.28			
NIL						
BED13	0.635	0.45	9.28			
BNC09	0.632	0.35	17.11			
BNC10	0.634	0.49	13.05			
BNC11	0.635	0.51	10.44			
BNC12	0.632	0.31	15.08			
BNC13	0.632	0.35	16.53			
BWC01						
BWC02	0.635	0.31	6.67			
BWC03						
BWC04	0.650	1.91	7.25			
BWC05	0.651	2.39	8.70			
BWC06						
BWC07	0.651	2.49	8.99	0.651	2.58	9.28
BWC08	0.647	1.66	7.54			
BWC09	0.634	0.36	9.28			
NIL						
BSC01	0.632	0.31	18.56			
BSC02						
BSC03	0.636	0.43	6.96			
BSC04						
BSC10	0.632	0.35	19.43			
BEC05	0.649	3.02	12.18			
BEC06	0.643	1.26	8.70			
BEC07	0.636	0.45	8.41	0.635	0.41	9.28
BEC08	0.675	5.67	12.18	0.686	4.81	9.28
BEC09	0.651	2.20	8.12	0.651	2.20	8.12
BEC10						
BEC11	0.661	2.64	6.96			
BEC12	0.651	2.58	9.28			
BEC13	0.636	0.45	7.83			
BNB08						
BWB01	0.649	2.54	10.15			
BWB02						
BWB03						
BWB04						
BWB05						
BSB01						
BEB05						
BEB06						
BEB07						
BEB08	0.656	2.58	7.83			
BEB09	0.652	2.35	8.12			
BEB10						
BEB11	0.651	2.58	9.28			

Appendix B1 - Window Opening Sizes

Tap id	Configuration 1			Configuration 2		
	Discharge Coefficient	Opening Area (m^2)	Internal Wall Area (m^2)	Discharge Coefficient	Opening Area (m^2)	Internal Wall Area (m^2)
BEB12	0.662	2.80	7.25			
BEB13						
BEB14	0.656	1.96	5.80			
BNA01	0.632	0.30	14.50			
BWA01	0.656	3.06	9.28	0.651	2.30	8.41
BWA02	0.656	2.68	8.12	0.656	2.30	6.96
BWA03	0.651	2.68	9.86	0.656	2.68	8.12
BWA04	0.656	1.82	5.51			
BWA05						
BWA06	0.656	2.30	6.96	0.656	2.30	6.96
BWA07	0.651	2.68	9.57	0.651	2.68	9.57
BWA08	0.656	5.26	15.95			
BSA01	0.635	0.30	7.25			
NIL						
NIL						
NIL						
BWF04	0.637	0.60	9.28			
BWF05	0.634	0.54	16.53			
BNE01	0.632	0.35	22.04			
BNE02	0.636	0.39	6.67	0.666	4.59	11.02
BNE03	0.643	1.53	10.44			
BNE04						
BNE05	0.651	2.39	8.70	0.650	2.01	7.54
BNE06	0.685	5.37	10.44			
BNE07	0.650	2.52	9.57			
BNE08	0.644	2.58	15.08	0.652	2.87	10.15
BWE10	0.634	0.54	16.53			
BSE05	0.636	0.46	8.41	0.635	0.30	6.96
BSE06	0.647	3.06	13.92	0.647	3.06	13.92
BSE07	0.647	1.79	8.12			
BSE08	0.638	0.60	7.54			
BEE01						
BEE02	0.637	0.68	9.57			
BEE03	0.636	0.45	7.25			
BEE04						
BEE14	0.632	0.30	18.27			
BEE15	0.632	0.35	17.98			
BND01	0.632	0.35	22.04			
BND02	0.636	0.39	6.67	0.666	4.59	11.02
BND03	0.643	1.53	10.44			
BND04						
BND05	0.651	2.39	8.70	0.650	2.01	7.54
BND06	0.685	5.37	10.44			
BND07	0.650	2.52	9.57			
BND08	0.644	2.58	15.08	0.652	2.78	9.86
BWD10	0.634	0.54	16.53			
BSD05	0.636	0.45	8.41	0.634	0.31	8.41
BSD06	0.647	3.06	13.92			

Appendix B1 - Window Opening Sizes

Tap id	Configuration 1			Configuration 2		
	Discharge Coefficient	Opening Area (m^2)	Internal Wall Area (m^2)	Discharge Coefficient	Opening Area (m^2)	Internal Wall Area (m^2)
BSD07	0.647	1.79	8.12			
BSD08	0.638	0.60	7.54			
BED01						
BED02	0.637	0.68	9.57			
BED03	0.636	0.45	7.25			
BED04						
BED14	0.632	0.30	18.56	0.632	0.30	18.27
BED15	0.632	0.35	17.98			
BNC01	0.632	0.35	21.75			
BNC02	0.636	0.40	6.96	0.666	4.59	11.02
BNC03	0.643	1.53	10.44			
BNC04						
BNC05	0.651	2.39	8.70	0.650	2.01	7.54
BNC06	0.685	5.37	10.44			
BNC07	0.650	2.52	9.57			
BNC08	0.651	2.49	9.28	0.652	2.78	9.86
BWC10	0.634	0.54	16.82	0.636	0.43	7.25
BSC05	0.634	0.30	8.41	0.635	0.43	8.41
BSC06	0.647	3.06	13.92			
BSC07	0.647	1.79	8.12			
BSC08						
BSC09	0.638	0.60	7.25			
BEC01						
BEC02	0.637	0.63	8.99			
BEC03	0.637	0.44	6.96			
BEC04						
BEC14	0.632	0.34	17.98			

Appendix B2 - Internal Flow Path

Unit Number	Corner or Double	Volume of Unit (m3)	Flow Path	External Opening 1	Opening Config	External Opening 2	Opening Config	Internal Opening 1	Internal Opening 1 Area	Internal Opening Type 2	Internal Opening 2 Area
A1.G.03	NO	248.385	1	ASB01	1	ASB02	1	4	2.5	3	2.5
A1.2.01	YES	219.269	1	AWC02	1	ASC02	2	1	2.5		
A1.2.01	YES	219.269	2	AWC02	2	ASC02	1	4	2.5		
A1.2.02	YES	239.685	1	AWC01	1	ANC07	1	4	2.5		
A1.2.03	NO	145	1	ANC06	1	ANC05	2	2	2.5		
A1.2.04	NO	157.76	1	AEC10	1	ANC05	1	3	2.5		
A1.2.05	YES	232.29	1	ANC04	1	ASC05	1	3	2.5		
A1.2.06	YES	178.466	1	ASC04	1	AWC03	1	3	2.5		
A1.2.06	YES	178.466	2	AEC09	1	AWC03	1	3	2.5		
A1.5.01	YES	219.269	1	ASD02	1	AWD02	1	4	2.5		
A1.5.01	YES	219.269	2	ASD02	2	AWD02	1	3	2.5	3	2.5
A1.5.02	YES	239.685	1	AND08	1	AWD01	1	3	2.5		
A1.5.02	YES	239.685	2	AND09	1	AWD01	1	3	2.5	3	2.5
A1.5.03	NO	145	1	AND08	2	AND07	2	2	2.5		
A1.5.04	NO	157.76	1	AED05	1	AND07	1	3	2.5		
A1.5.05	YES	232.29	1	ASD05	1	AND05	1	4	2.5		
A1.5.06	YES	178.466	1	ASD04	1	AWD03	1	3	2.5		
A1.5.06	YES	178.466	2	AED06	1	AWD03	1	3	2.5		
A1.7.01	YES	219.269	1	ASE02	1	AWE02	1	4	2.5		
A1.7.01	YES	219.269	2	ASE02	2	AWE02	1	2	2.5	3	2.5
A1.7.02	YES	239.685	1	ANE08	1	AWE01	1	3	2.5		
A1.7.02	YES	239.685	2	ANE09	1	AWE01	1	3	2.5	3	2.5
A1.7.03	NO	145	1	ANE08	2	ANE07	2	2	2.5		
A1.7.04	NO	157.76	1	AEE05	1	ANE07	1	3	2.5		
A1.7.05	YES	232.29	1	ANE05	1	ASE05	1	3	2.5		
A1.7.06	YES	178.466	1	ASE04	1	AWE03	1	3	2.5		
A1.7.06	YES	178.466	2	AEE06	1	AWE03	1	3	2.5		
A2.G.01	NO	204.044	1	ANB01	1	ANB03	1	2	2.5		
A2.G.01	NO	204.044	2	ANB02	1	ANB03	1	2	2.5		
A2.G.01	NO	204.044	3	ANB01	1	ANB02	2	2	2.5		

Appendix B2 - Internal Flow Path

Unit Number	Corner or Double	Volume of Unit (m3)	Flow Path	External Opening 1	Opening Config	External Opening 2	Opening Config	Internal Opening 1	Internal Opening 1 Area	Internal Opening Type 2	Internal Opening 2 Area
A2.G.02	YES	182.961	1	AEB05	1	AEB03	1	3	2.5		
A2.G.03	YES	225.272	1	AEB02	1	ASB05	1	3	2.5		
A2.G.04	YES	153.671	1	ASB04	1	AWB02	1	2	2.5		
A2.G.05	NO	166.141	1	AWB01	1	AWB02	2	3	2.5		
A2.G.06	NO	180.902	1	AWB01	2	ASB03	1	3	2.5		
A2.2.01	YES	247.312	1	ANC04	2	ASC05	2	3	2.5		
A2.2.02	NO	169.882	1	AWC04	1	ANC02	1	3	2.5		
A2.2.03	NO	218.689	1	ANC02	2	ANC01	1	3	2.5		
A2.2.04	YES	238.641	1	AEC08	1	ANC02	2	3	2.5	3	2.5
A2.2.05	YES	188.819	1	AEC07	1	AEC05	1	3	2.5		
A2.2.06	NO	261.493	1	AEC03	1	AEC04	1	3	2.5		
A2.2.07	YES	225.272	1	AEC02	1	ASC08	1	3	2.5		
A2.2.08	YES	153.671	1	ASC07	1	AWC06	1	3	2.5		
A2.2.09	NO	166.141	1	AWC05	1	AWC06	2	3	2.5		
A2.5.01	YES	234.9	1	AND05	2	ASD05	2	3	2.5		
A2.5.02	NO	169.882	1	AWD04	1	AND03	1	3	2.5		
A2.5.03	NO	145	1	AND03	2	AND02	1	2	2.5		
A2.5.04	YES	150.945	1	AND01	1	AED04	1	3	2.5		
A2.5.05	YES	223.532	1	AED03	1	ASD08	1	3	2.5		
A2.5.05	YES	223.532	2	AED02	2	AED03	1	3	2.5		
A2.5.06	YES	161.472	1	AED01	1	ASD06	1	3	2.5		
A2.5.06	YES	161.472	2	AED01	1	AWD05	1	3	2.5		
A2.7.01	YES	234.9	1	ANE05	2	ASE05	2	3	2.5		
A2.7.02	NO	169.882	1	AWE04	1	ANE03	1	3	2.5		
A2.7.03	NO	145	1	ANE02	1	ANE03	2	2	2.5		
A2.7.04	YES	150.945	1	ANE01	1	AEE04	1	3	2.5		
A2.7.05	YES	223.532	1	AEE03	1	ASE08	1	3	2.5		
A2.7.05	YES	223.532	2	AEE03	1	AEE02	1	3	2.5		
A2.7.06	YES	161.472	1	AEE01	1	AWE05	1	3	2.5		
A2.7.06	YES	161.472	2	AEE01	1	ASE06	1	3	2.5		

Appendix B2 - Internal Flow Path

Unit Number	Corner or Double	Volume of Unit (m3)	Flow Path	External Opening 1	Opening Config	External Opening 2	Opening Config	Internal Opening 1	Internal Opening 1 Area	Internal Opening Type 2	Internal Opening 2 Area
B1.G.01	YES	244.963	1	BWB06	1	BSB04	1	3	2.5		
B1.G.02	YES	219.82	1	BNB07	1	BSB02	1	3	2.5		
B1.G.02	YES	219.82	2	BNB07	1	BWB06	2	3	2.5		
B1.G.03	NO	145.203	1	BNB07	1	BNB06	1	3	2.5		
B1.G.04	NO	157.528	1	BNB04	2	BNB05	1	3	2.5		
B1.G.05	NO	159.5	1	BNB03	1	BNB04	1	3	2.5		
B1.G.06	NO	168.2	1	BNB01	2	BNB02	2	3	2.5		
B1.G.07	YES	223.097	1	BNB02	1	BEB03	1	3	2.5		
B1.G.07	YES	223.097	2	BEB03	1	BNB01	1	2	2.5	3	2.5
B1.G.08	YES	287.245	1	BEB02	1	BSB06	1	3	2.5		
B1.2.01	YES	244.963	1	BWC10	1	BSC06	1	4	2.5	2	2.6
B1.2.02	YES	219.82	1	BNC08	1	BSC05	1	3	2.5		
B1.2.02	YES	219.82	2	BNC08	1	BWC10	2	3	2.5		
B1.2.03	NO	145.203	1	BNC08	1	BNC07	1	2	2.5		
B1.2.04	NO	157.528	1	BNC05	1	BNC06	1	3	2.5		
B1.2.05	YES	160.486	1	BEC14	1	BNC05	2	3	2.5		
B1.2.06	NO	157.76	1	BNC02	2	BNC03	1	2	2.5		
B1.2.07	NO	168.287	1	BNC02	2	BNC03	1	2	2.5		
B1.2.08	YES	223.097	1	BNC02	1	BEC03	1	3	2.5	3	2.5
B1.2.09	YES	287.245	1	BNC01	1	BSC09	1	3	2.5		
B1.2.09	YES	287.245	2	BEC02	1	BSC09	1	3	2.5		
B1.3.10	YES	153.671	1	BED14	1	BSC07	1	3	2.5	2	2.1
B1.5.01	YES	244.963	1	BWD10	1	BSD06	1	4	2.5	2	2.6
B1.5.02	YES	219.82	1	BND08	1	BSD05	1	3	2.5		
B1.5.03	NO	145.203	1	BND08	1	BND07	1	2	2.5		
B1.5.04	NO	157.528	1	BND05	1	BND06	1	3	2.5		
B1.5.05	YES	160.486	1	BED15	1	BND05	2	3	2.5		
B1.5.06	NO	157.76	1	BND02	2	BND03	1	2	2.5		
B1.5.07	NO	168.287	1	BND02	2	BND03	1	2	2.5		
B1.5.08	YES	223.097	1	BED03	1	BND02	1	2	2.5	3	2.5

Appendix B2 - Internal Flow Path

Unit Number	Corner or Double	Volume of Unit (m3)	Flow Path	External Opening 1	Opening Config	External Opening 2	Opening Config	Internal Opening 1	Internal Opening 1 Area	Internal Opening Type 2	Internal Opening 2 Area
B1.5.09	YES	287.245	1	BND01	1	BSD08	1	3	2.5		
B1.5.09	YES	287.245	2	BED02	1	BSD08	1	3	2.5		
B1.5.10	NO	153.671	1	BED14	2	BSD07	1	3	2.5	3	2.1
B1.7.01	YES	244.963	1	BWE10	1	BSE06	1	4	2.5	2	2.6
B1.7.02	YES	219.82	1	BNE08	1	BSE05	1	3	2.5		
B1.7.03	NO	145.203	1	BNE08	1	BNE07	1	2	2.5		
B1.7.04	NO	157.528	1	BNE05	1	BNE06	1	3	2.5		
B1.7.05	YES	160.486	1	BEE15	1	BNE05	2	3	2.5		
B1.7.06	NO	157.76	1	BNE02	2	BNE03	1	2	2.5		
B1.7.07	NO	168.287	1	BNE02	2	BNE03	1	2	2.5		
B1.7.08	YES	223.097	1	BEE03	1	BNE02	1	2	2.5	3	2.5
B1.7.09	YES	287.245	1	BNE01	1	BSE08	1	3	2.5		
B1.7.09	YES	287.245	2	BEE02	1	BSE08	1	3	2.5		
B1.7.10	NO	153.671	1	BEE14	1	BSE07	1	3	2.5	3	2.1
B1.8.01	YES	244.963	1	BWF05	1	BSE06	2	4	2.5	2	2.6
B1.8.02	YES	157.528	1	BNE05	1	BWF04	1	3	2.5		
B2.LG.03	YES	378.627	1	BWA08	1	BSA01	1	3	2.6		
B2.LG.04	NO	259.0365	1	BWA07	1	BWA06	1				
B2.LG.05	NO	257.298	1	BWA07	2	BWA06	2				
B2.G.03	YES	217.732	1	BNB07	2	BSB02	2	3	2.5		
B2.2.01	YES	157.557	1	BNC13	1	BWC08	1	3	2.5	2	2.6
B2.2.02	YES	146.305	1	BWC07	2	BEC07	2	3	2.5		
B2.2.04	NO	146.479	1	BEC05	1	BEC06	1				
B2.2.05	YES	217.732	1	BNC08	2	BSC05	2	3	2.5		
B2.2.08	YES	217.587	1	BWC09	1	BSC03	1	3	2.5		
B2.5.01	YES	157.557	1	BND13	1	BWD08	1	3	2.5	2	2.6
B2.5.02	YES	146.305	1	BWD07	1	BED07	1	3	2.5		
B2.5.04	NO	146.479	1	BED05	1	BED06	1				
B2.5.05	YES	217.732	1	BND08	2	BSD05	2	3	2.5		
B2.5.08	YES	217.587	1	BWD09	1	BSD03	1	3	2.3		

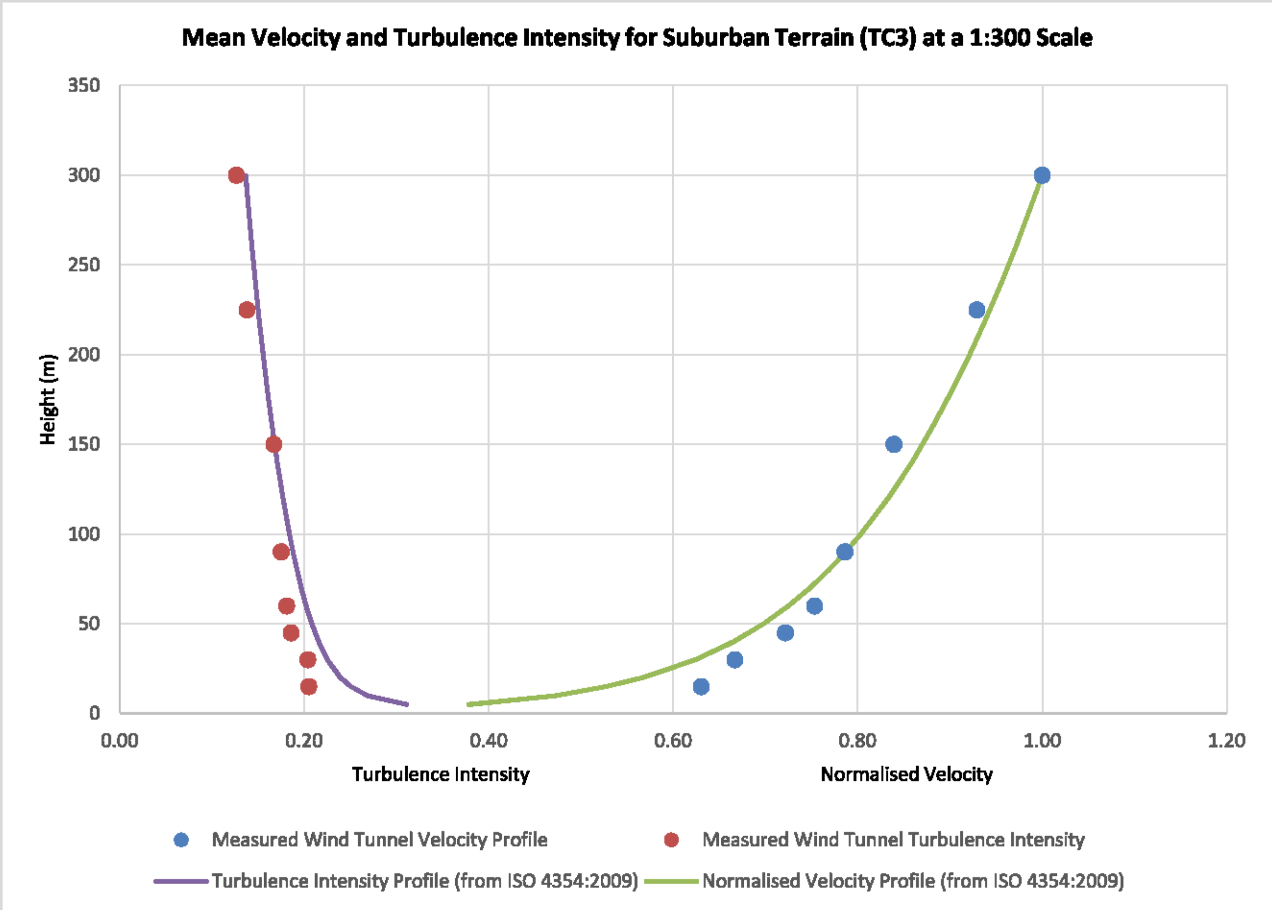
Appendix B2 - Internal Flow Path

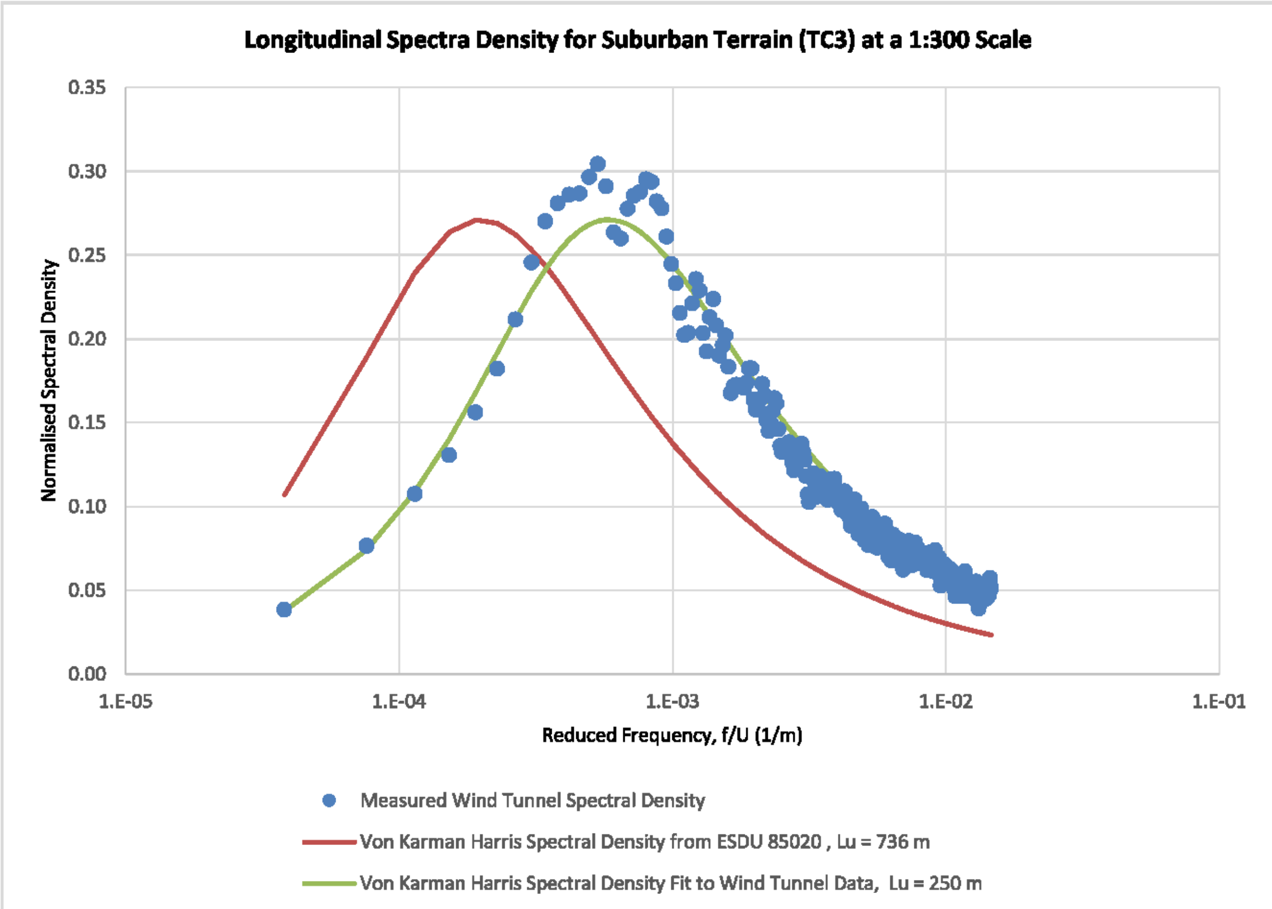
Unit Number	Corner or Double	Volume of Unit (m3)	Flow Path	External Opening 1	Opening Config	External Opening 2	Opening Config	Internal Opening 1	Internal Opening 1 Area	Internal Opening Type 2	Internal Opening 2 Area
B2.7.01	YES	157.557	1	BNE13	1	BWE08	1	3	2.5	2	2.6
B2.7.02	YES	146.305	1	BWE07	1	BEE07	1	3	2.5		
B2.7.04	NO	146.479	1	BEE05	1	BEE06	1				
B2.7.05	YES	217.732	1	BNE08	2	BSE05	2	3	2.5		
B2.7.06	NO	147.088	1	BSE05	2	BSE04	1	3	2.5		
B2.7.08	YES	217.587	1	BWE09	1	BSE03	1	3	2.5		
B2.7.09	NO	148.074	1	BWE08	2	BWE09	2				
B3.LG.01	YES	378.932	1	BWA01	1	BNA01	1	3	2.6		
B3.LG.02	NO	282.6435	1	BWA01	2	BWA02	1				
B3.LG.03	NO	280.6305	1	BWA03	1	BWA02	2				
B3.LG.04	NO	299.6015	1	BWA03	2	BWA04	1				
B3.G.01	YES	175.102	1	BWB01	1	BEB14	1	3	2.5		
B3.G.03	NO	150.046	1	BEB11	1	BEB12	1	3	2.5		
B3.G.05	NO	174.667	1	BEB08	1	BEB09	1	3	2.5		
B3.2.01	YES	156.774	1	BNC12	1	BWC04	1	3	2.5		
B3.2.02	YES	218.921	1	BNC11	1	BWC02	1	3	2.5		
B3.2.03	YES	230.028	1	BNC10	1	BEC13	1	3	2.5		
B3.2.04	NO	167.794	1	BEC12	1	BEC11	1	3	2.5		
B3.2.05	YES	159.906	1	BNC09	1	BEC09	1	3	2.5		
B3.2.06	NO	161.82	1	BEC08	1	BEC09	2	2	2.5		
B3.2.07	NO	191.168	1	BEC08	2	BEC09	2	3	2.5		
B3.2.08	YES	241.976	1	BWC07	1	BEC07	1	3	2.5		
B3.2.09	NO	248.82	1	BSC01	1	BWC05	1	4	2.5		
B3.5.01	YES	156.774	1	BND12	1	BWD04	1	3	2.5		
B3.5.02	YES	218.921	1	BND11	1	BWD02	1	3	2.5		
B3.5.03	YES	230.028	1	BND10	1	BED13	1	3	2.5		
B3.5.04	NO	167.794	1	BED12	1	BED11	1	3	2.5		
B3.5.05	YES	159.906	1	BND09	1	BED09	1	3	2.5		
B3.5.06	NO	161.82	1	BED08	1	BED09	2	2	2.5		
B3.5.07	NO	191.168	1	BED08	2	BED09	2	3	2.5		

Appendix B2 - Internal Flow Path

Unit Number	Corner or Double	Volume of Unit (m3)	Flow Path	External Opening 1	Opening Config	External Opening 2	Opening Config	Internal Opening 1	Internal Opening 1 Area	Internal Opening Type 2	Internal Opening 2 Area
B3.5.08	YES	241.976	1	BWD07	2	BED07	2	3	2.5		
B3.5.09	NO	248.82	1	BSD01	1	BWD05	1	4	2.5		
B3.7.01	YES	156.774	1	BNE12	1	BWE04	1	3	2.5		
B3.7.02	YES	218.921	1	BNE11	1	BWE02	1	3	2.5		
B3.7.03	YES	230.028	1	BNE10	1	BEE13	1	3	2.5		
B3.7.04	NO	167.794	1	BEE12	1	BEE11	1	3	2.5		
B3.7.05	YES	159.906	1	BNE09	1	BEE09	1	3	2.5		
B3.7.06	NO	161.82	1	BEE08	1	BEE09	2	2	2.5		
B3.7.07	NO	191.168	1	BEE09	2	BEE08	2	3	2.5		
B3.7.08	YES	241.976	1	BWE07	2	BEE07	2	3	2.5		
B3.7.09	NO	248.82	1	BSE01	1	BWE06	1	3	2.5		
B3.8.01	YES	156.774	1	BNE12	2	BWF01	1	3	2.5		
B3.8.08	YES	261.058	1	BEF01	1	BWF06	1	3	2.5		
B3.8.09	NO	235.48	1	BWF02	1	BWF06	2	3	2.5		
B3.8.10	NO	151.09	1	BWF01	2	BWF02	2	2	2.5		

APPENDIX C - WIND TUNNEL PROFILES FOR THE VELOCITY AND TURBULENCE INTENSITY


Mean Velocity and Turbulence Intensity for Suburban Terrain (TC3) at a 1:300 Scale
Height (m)
350
300
250
200
150
100
50
0
0.00
0.20
0.40
0.60
0.80
1.00
1.20
Turbulence Intensity
Normalised Velocity
Measured Wind Tunnel Velocity Profile
Measured Wind Tunnel Turbulence Intensity
Turbulence Intensity Profile (from ISO 4354:2009)
Normalised Velocity Profile (from ISO 4354:2009)


Longitudinal Spectra Density for Suburban Terrain (TC3) at a 1:300 Scale
Normalised Spectral Density
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1.E-05
1.E-04
1.E-03
1.E-02
1.E-01
Reduced Frequency, f/U (1/m)
Measured Wind Tunnel Spectral Density
Von Karman Harris Spectral Density from ESDU 85020 , Lu = 736 m
Von Karman Harris Spectral Density Fit to Wind Tunnel Data, Lu = 250 m