Building Performance Evaluation (BPE) Project

Evaluation Report for Building "B"

EcoSmart Foundation
#501 – 402 West Pender St.
Vancouver, BC
V6B 1T6
Tel: 604-689-4023
Fax: 604-689-4043
info@ecosmart.ca
www.ecosmart.ca

Building Performance Evaluation of Building B

Building performance evaluation (BPE) involves the inspection of buildings one to five years after their construction, and assessment of the extent to which a given building has met its design goals. The primary purpose of BPE is to improve design practice and ensure the continuous improvement of design methods, through the provision of feedback to designers on the effectiveness of their design choices. BPE is also useful to property managers, building operators, and building occupants, as its collation of detailed measurements and occupant feedback highlight which building features are operating optimally, and which features have the potential to be enhanced.

The building assessed in this performance evaluation has been named Building B for the purpose of maintaining anonymity. The product of a design-build competition, Building B is a large office building with a number of sustainable features. The Building Performance Evaluation of Building B was carried out in the summer of 2006.

Executive Summary

Building B is a large office building located in Greater Vancouver, British Columbia. It was designed in 1997 in the context of a design-build competition focused on energy efficiency and cost, and was constructed in 1999. The building has numerous innovative design features that aim both to reduce the building's impact on the environment, and to improve the comfort level of occupants.

The goal of reduced energy consumption in the building was pursued using a high performance envelope, underfloor air distribution systems, and reduced electric lighting energy due to daylighting. Additional energy conservation measures included exposed concrete mass for thermal storage, and use of 'hotelling stations' or shared workstations to reduce the total building area and thus the energy consumed. Actual energy consumption exceeded predicted values, due primarily to operational differences involving extended hours of occupancy, and also seemingly due to conditioning of excess outdoor air. However, average energy consumption during the years assessed was 8% less than the average energy consumption of existing office buildings in BC. Important lessons regarding communication between designers and operators were learned during the evaluation of this building.

The goal of maximizing daylighting in Building B was pursued using large areas of glazing, solar shading, light shelves, and high ceilings. In operation, glare concerns led to the addition of blinds both above and below light shelves, hindering the daylighting strategy. Acoustic ceiling panels added after occupancy reduced the effectiveness of the electrical uplighting strategy, requiring the addition of task lighting.

Optimal thermal comfort was sought in the building using underfloor air distribution systems. Occupant control over thermal comfort was pursued in the design by specifying adjustable diffusers for airflow control. "Snapshot" thermal measurements in the building suggested temperature conditions were within benchmarks, and thermal comfort was rated highly by respondents to the PROBE occupant satisfaction survey, however occupants did not appear to be using the adjustable airflow diffusers appropriately. The owner's concerns about the adequacy of the designed chiller capacity to meet the cooling demands of the building were dispelled after three years of successful summer operation. After this, the owner's specifications for plant equipment became exclusively performance based, without any specified chiller sizes.

The exposed concrete ceilings in the building led to a harder acoustic environment than anticipated, and acoustic ceiling panels were added after occupancy. Measurements taken during the BPE suggest that acoustic concerns were successfully addressed by this measure.

The goal of optimized indoor air quality was pursued in the building using the designed underfloor air systems. Evidence from the BPE suggests that excess outdoor air is likely being conditioned, leading to excellent indoor air quality but also to increased energy consumption.

Table of Contents:

1.0 Building Performance Evaluation Pilot Study

1.1 DEVELOPMENT OF THE PILOT STUDY

Building B was one of six buildings that participated in the Building Performance Evaluation (BPE) Pilot Study. In this Study, the EcoSmart Foundation applied a new protocol for post-occupancy evaluation of buildings to diverse types of commercial and institutional green buildings. The protocol addresses the energy and water consumption, thermal comfort, acoustics, indoor air quality, and lighting in a building, with the Centre for the Built Environment (CBE) Indoor Environment Quality survey employed to gauge occupant satisfaction with each of these elements.

A list of funding partners of the Building Performance Evaluation Pilot Study is included in Appendix 3.4.

1.2 THE BUILDING PERFORMANCE EVALUATION PROTOCOL

The Building Performance Evaluation Protocol is a set of procedures for evaluating the actual performance of occupied buildings as compared to their design goals. The need for evaluation of occupied buildings is apparent to many designers, but this has not yet been built in to standard practice in the field of building design. The BPE Protocol was developed in order to provide a clear set of procedures to enable design firms or other proponents to evaluate occupied buildings using a focused method, asking the right questions and obtaining pertinent results.

It is important to make the distinction between a Building Performance Evaluation and a full building audit. While audits typically focus on one or two elements of a building's performance, for instance its mechanical and electrical systems, performing an exhaustive evaluation of each piece of equipment relating to those elements, a Building Performance Evaluation assesses a building's performance in a broad range of categories, from energy and water consumption to acoustic performance, thermal comfort, lighting, and air quality. A BPE also integrates these assessments with responses from building occupants about their satisfaction with each of these aspects.

While a Building Performance Evaluation may be combined with a full building audit to assess some elements of the building's performance in greater detail, a BPE is designed simply to provide an overview of how the building is performing in relation to its design goals.

A BPE does not involve use of a rating system to certify a building based on its performance. Certification using LEED for Existing Buildings is recommended for project teams interested in using such a rating system.

The following sections describe the elements that make up the BPE Protocol.

1.2.1 Interviews and Administration

A series of interviews were carried out during the Building Performance Evaluation, as shown in Table 1. These interviews were used to gather information essential to the BPE process.

Table 1: Interviews involved in the Building Performance Evaluation

Interviewee	Information Gathered
Building Owner	General building information, successes and opportunities for improvement in building operation
Design Team – Evaluation Kickoff Meeting	Design goals and strategies, building features, description of design process
Building Operator	Operational procedures, successes and difficulties in building operation
Occupants (random sample interviewed)	Satisfaction with various features in the building
Design Team – Evaluation Wrap-Up Meeting	Discuss results of evaluation, lessons learned by designers

1.2.2 The Occupant Satisfaction Survey

A Building Performance Evaluation involves a survey of building occupants to gauge their level of satisfaction with various aspects of the building. The Indoor Environment Quality web-based survey, developed and administered by the Center for the Built Environment (CBE) at the University of California at Berkeley is normally used during the BPE, investigating occupant satisfaction with various elements of the building.

However, in Building B, a PROBE (Post-Occupancy Review of Building Engineering) study of the building had been performed a few years prior to the BPE, and it included an occupant satisfaction survey component. The PROBE study is a system for post-occupancy assessment of buildings, developed in Britain, which has been applied to several Canadian green buildings. The PROBE occupant satisfaction survey is made up of questions relating to occupant satisfaction with lighting, temperature, ventilation, and acoustics, as well as addressing occupants' perceived level of control over these features. The results of this survey were made available to the BPE team and were used instead of the CBE Indoor Environment Quality survey for Building B. However, the PROBE results did not allow for filtering of results to locate areas of concern.

The PROBE survey achieved a very high response rate in the building; 83% of building occupants responded to the survey.

As the PROBE study is a British evaluation system, benchmark responses are based on occupants of UK buildings. It is commonly felt that occupant perception towards indoor environment quality in Europe is very different than in North America, with European occupants having tolerance for a wider range of building comfort conditions. Because of this, the comparison of occupant satisfaction in Building B to a UK benchmark is not appropriate for this evaluation. Instead, averaged responses from occupants in Building B are compared to the midpoint on the survey's satisfaction scale.

1.2.3 Empirical Measurements

Empirical measurements of acoustics, thermal comfort, indoor air quality and lighting are taken on one day during the performance evaluation period. These measurements are intended to complement the qualitative occupant feedback derived from the web-based survey. Ten spaces in areas expected to be of interest in the building are selected for measurement.

It is recognized that measurements taken over one or several days do not necessarily reflect the typical indoor environmental quality. It is thus important to examine this information collectively with the information from occupants, the building operator, and any recorded information available from the building's DDC system. The measurements are considered "snapshots" of the building in operation, and should not be viewed as definitive indicators of the overall indoor environment quality.

1.2.4 Analysis of Energy and Water Consumption

Energy and water consumption estimates, often calculated during the design of green buildings, are compared to actual annual energy and water consumption, metered for the building. More often than not, there are significant differences in occupancy, hours of operation, and building operation from what was anticipated during design, making a direct comparison of predicted and actual consumptions impossible. In such cases, an order of magnitude estimate of the degree to which these factors could impact original energy and water consumption estimates is given.

2.0 The Selected Building

2.1 OVERVIEW OF THE BUILDING

Building B is a large office building located in greater Vancouver, British Columbia, that was designed in 1997 and constructed in 1999. The five storey, 10,700 square metre building was the subject of a design-build competition that focused on the key priorities of energy efficiency and cost. The competition consisted of two separate design phases – the provision of a base building, followed by a fit-out for the interior of the building.

The building is occupied by approximately 600 people, all working for the same organization. The building is located in an urban area close to public transit, and is bordered on its eastern side by a road with heavy traffic.

The building has a long perimeter design to allow workspaces to be predominantly daylit with views, and for occupants to have access to operable windows that allow connection with outdoors. Windows in the building begin about one metre above the floor and extend to the ceiling, which are three metres in height in most areas. Washrooms, elevators, and stairwells, and meeting rooms are located in the core of the building. Private offices surround part of the building's core on some floors, and face outwards into the open office space around the perimeter of the building. The open office is broken into 'neighbourhoods', where a number of occupants have workspaces that back onto a shared area.

The building uses an underfloor air distribution (UFAD) system to provide conditioned air for heating, cooling, and ventilation on its upper floors, while the ground floor receives air from ceiling diffusers. Each of six air handling units provides air to one area on all five floors. The building has the ability to run on 100% outdoor air for free cooling, though this is not intended to be the typical mode of operation.

Building B was designed to be a high performance building, intended to use 30% less energy than specified by ASHRAE 90.1-1989 requirements. The building was not LEED® certified since its design occurred before the launch of the LEED system.

2.2 BUILDING DESIGN PROCESS

The design of building B used an integrated design process (IDP) that was very inclusive. Bi-weekly meetings brought architects, engineers, the contractor and trades together to develop the design of the building. From the designer's perspective, the IDP process allowed substantial cost savings, as everyone involved was encouraged to bring ideas to the table for cost analysis, with effective affordable options being incorporated into the building's design. This approach helped to produce a cost-effective design, which was extremely important for the design build competition. As the contractor was the design team's client on this project, this design process was overseen by the contractor, who came up with many cost-saving innovations in the context of the IDP meetings.

The building designers held over thirty meetings and focus groups with the building owner and future occupants to ensure their goals and requirements for the building were met.

The requirements for the building design were clearly set out in the RFP document, specifying a high performance building within the cost structure of a traditional building. In the end, construction of the building came in on budget and on time.

2.2.1 Design Goals

The project's goal of producing an environmentally conscious green building was set as a basis for the design-build competition. The following five main goals pursued in the design of the building were identified by the design team, and led to the implementation of the specific design strategies discussed in the next section.

<u>Goal #1: Reduce Energy Consumption</u>

A major goal expressed in the RFP was to design for approximately 30% energy savings over the American Society for Heating, Refrigeration and Air Conditioning Engineers (ASHRAE) 90.1-1989 baseline requirements. This was the owner's goal for the building, and the designers were eager to design for reduced energy consumption as much as possible while providing a thoroughly comfortable building. The target energy consumption for the building was set out to be between 140-195 kWh/m^2/year.

<u>Goal #2: Maximize Daylighting</u>

The goal of creating a building with maximum access to daylight was set during design, and was pursued using the strategies discussed in Section 2.2.2.

<u>Goal #3: Optimize Thermal Comfort</u>

The goal of creating a thermally comfortable building was sought using the designed systems. Since occupant control over one's thermal environment is a factor contributing to thermal comfort, this controllability was part of the design intent.

<u>Goal #4: Create High-Quality Acoustic Environment</u>

The goal of a high-quality acoustic environment for this building was targeted using strategies discussed in Section 2.2.2.

<u>Goal #5: Optimize Indoor Air Quality</u>

Optimal air quality inside the building was sought using the designed systems, as outlined in the next section.

2.2.2 Key Design Strategies Implemented

The following strategies were developed during the design of Building B in order to achieve the goals expressed above. The results of all of these strategies in operation will be examined in Section 2.3.5.

Goal #1: Reduce Energy Consumption

The goal of reduced energy consumption led to the design of a high performance envelope for the building, using low-E glazing and solar shading to reduce heating and cooling demands.

Internal load sources were also reduced using lower electric lighting demands due to efficient lighting and daylighting strategies. Whereas typical office buildings at the time the building was designed used about 15 Watts of electricity per square metre, the lighting in Building B was designed for only 9.6 W/m^2.

A system of underfloor air delivery for heating, ventilation and air conditioning was designed for Building B. This type of system was not commonplace during the time the building was designed, but the principle of supplying air closer to occupant level and taking advantage of natural air stratification was known to be associated with energy savings. In addition, economizer capability was designed into these systems, allowing use of 100% outdoor air for “free cooling” when outdoor climate conditions permit, reducing cooling energy.

In order to offset the cost of the access floor required for the underfloor air distribution system, the design team decided to leave the concrete ceilings in the building exposed. This measure was also seen as an opportunity to use the thermal storage capability of the exposed mass, softening the cooling demand peaks in the building and allowing for reduced chiller size.

Another strategy which was employed to achieve significant energy savings in Building B was the principle of “hotelling”; using shared workstations for employees who were frequently out of the office rather than having many offices empty much of the time. This efficient use of space allowed for the organization to be housed within a smaller building, intrinsically leading to energy savings.

Goal #2: Maximize Daylighting

Daylighting strategies included in the design of Building B involved large areas of glazing, high ceilings and a long perimeter, with exterior shading to control direct sunlight. Light shelves were used within the space to reflect daylight deeper into the core of the building. Daylight sensors were used to control electric lighting in response to available daylight. Mockups of the building were created for lighting analysis, allowing the design team to verify that sufficient light levels would exist in the building.

The electric lighting strategy for the building involved direct/indirect lighting (30%/70%), with reflection off exposed concrete ceilings that were painted white to reflect more light.

Goal #3: Optimize Thermal Comfort

Optimal thermal comfort was pursued in the design using the underfloor air distribution systems in the building. Heating capacity was designed into the perimeter areas of the building, but not the core areas.

Occupant control of thermal comfort was sought by installing adjustable underfloor air diffusers to control air volumes and temperatures. Occupants were trained in how to operate the adjustable diffusers for thermal control.

Goal #4: Create High-Quality Acoustic Environment

An acoustician joined the design team working on the fit-out of Building B, and research was performed into the acoustic problems experienced in other buildings owned by the same client, in order to develop appropriate acoustic strategies. Carpet was included in most areas of the building, and workspace partitions were selected for their noise absorption properties in the open-plan office areas, which made up most of the building. As the exposed concrete ceiling in Building B was expected to lead to a harder acoustic environment, these strategies were intended to counter this effect.

Goal #5: Optimize Indoor Air Quality

The underfloor air distribution strategy was intended to provide optimal indoor air quality by delivering ventilation air closer to the occupant level. The systems' economizer capability, which allows for use of 100% outdoor air for free cooling when climate conditions permit, was also expected to enhance indoor air quality when in operation.

The results of all of the above strategies in operation will be examined in Section 2.3.5.

2.3 RESULTS IN THE OCCUPIED BUILDING

2.3.1 Building Commissioning

A commissioning manager hired by the owner and a contracted mechanical commissioning agent were employed for the commissioning of Building B. It appears to the BPE team upon review of commissioning documents that the mechanical consultant's site inspector and the controls installation firm carried out a majority of the commissioning tasks.

The final commissioning documentation for this building was not made available for the BPE team to assess, however it appears that commissioning of mechanical systems was successfully undertaken by the mechanical site inspector. While more recent green building projects often make use of a commissioning authority to perform design intent reviews as per LEED, this practice had not yet been developed at the time of Building B's commissioning.

2.3.2 Building Operation

The operation of Building B relies heavily on the DDC system installed in the building, which the operator checks every morning and considers excellent. The facilities management contractor's policies were given to the building operator for direction in operation of the building. According to the operator, a balance is found between operating the building efficiently and responding to occupant requests.

The building operator noted that while the underfloor air distribution systems were operating well, they were often a challenge to balance. The operator also felt that opening of operable windows on very hot days caused the mechanical cooling system to work harder.

When asked for suggestions relating to the building's design or operation that could be passed on for future building designs, the operator indicated that having more air handling units so that each floor can be controlled separately would be useful. Another issue that was raised was the desire for direction from building designers recommending changes to lighting and acoustic strategies when office layouts are altered.

2.3.3 Disparity between Design and Occupied Building

During tenant fit-out several private offices were added to the predominantly open layout.

Indoor air quality measurements taken after the building was occupied, in 2001, indicated that indoor CO_2 levels were in the range of 450 ppm, similar to outdoor levels. The fact that these measurements were taken in winter, when economizer operation for free cooling was not needed, indicated to the designers that the building was conditioning significantly more outdoor air than intended by the design.

Issues with glare in the occupied building led to the addition of window films and then internal shading blinds as a retrofit. Designers recommended the selection of mesh blinds to allow for some visibility and daylighting. They also recommended installation of these blinds only below the light shelves, allowing natural light to enter the building above the light shelves where glare would not be a concern. However, less costly blinds were purchased and installed both above and below the light shelves.

A decision was also made to add acoustic panels to the ceilings in open plan office areas to suit occupant concerns about noise. These panels were darker than recommended by the design team and thus hindered the electrical uplighting strategy, which relied on reflection of light from ceiling surfaces. Many areas in the building were subsequently perceived as too dark, and task lights were added to these areas.

Operations staff were concerned about dust accumulating in the underfloor plenum of the air distribution system, therefore filters were added to each individual air diffuser.

An underheating problem on the building's second floor caused the need for addition of insulation where floor slabs projected as overhangs from the building; this was an area where insulation had been value-engineered out of the original design.

2.3.4 Occupant Satisfaction Survey

Results of a PROBE (Post-Occupancy Review of Building Engineering) study that was recently carried out for Building B were made available to the BPE team. This study included a survey component in which occupants were asked rate their satisfaction with various aspects of their building's performance, including lighting, noise, temperature, ventilation, and controllability. However, as described in Section 1.2.2, the PROBE benchmarks for comparison of occupant responses are based on UK buildings, where occupant tolerance for a wider range of comfort conditions exists. Also, these survey results cannot be filtered to locate areas of concern within the building.

The majority of the roughly 300 occupants present on the day the survey was distributed responded to the PROBE survey; 250 responses were obtained so the response rate was 83%.

On average, respondents to the PROBE survey from Building B were satisfied with the building overall, as indicated by a higher score than the midpoint on the satisfaction scale. Average scores were also above the midpoint for temperature and ventilation (both in winter and in summer). On average, satisfaction with acoustics was rated near the midpoint of the satisfaction scale. Lighting was the only category rating below the midpoint on the satisfaction scale; occupants expressed the desire for more natural and electric light and less glare.

Compared to the British benchmark group, comfort levels for Building B were found to be about average, and higher than benchmarks for summer conditions. As mentioned, extensive comparison to a British benchmark group is not relevant to this evaluation and therefore is not included in this report.

Survey responses pertaining to the results of key design strategies are included in Section 2.3.5 below.

2.3.5 Results of Key Design Strategies

The Building Performance Evaluation of Building B assessed the post-occupancy performance of each of the design strategies outlined in Section 2.2.2. Results in actual operation of the building, including operator experiences and empirical measurements, relating to each of these strategies are outlined below.

Goal #1: Reduce Energy Consumption

As discussed in Section 2.3.6.1, the actual energy consumption in Building B is considerably higher than original modeling results indicated, primarily due to differences in building use and operation from what was anticipated during design. However, comparison to a benchmark for existing office buildings in BC, Building B achieves an 8% energy savings, which is notable given the extended hours of operation in this building.

The major factor leading to the disparity between modeled and actual results in Building B is the fact that actual hours of operation are much longer than modeled, leading to a significant increase in energy use. As described in the next section, re-simulation of the building's energy consumption was carried out in 2001 using the building's actual hours of operation. The results of the model were within 5% of the actual electricity use in the building and were still in the targeted range of 30% savings over ASHRAE 90.1-1989.

The other major reason for increased energy use over predicted amounts was surmised in the winter of 2001 when indoor air quality readings showed CO_2 levels close to those of outdoor air. This suggested that much higher rates of outdoor air were entering the building than designed, leading to significantly higher gas consumption to heat this excess outdoor air.

The post-occupancy changes made in the building to address glare and noise concerns hindered the daylighting and electrical uplighting strategies, leading to the addition of task lights and increased lighting energy consumption.

Summer setpoint temperatures, which were designed at 24°C based on the owner's documentation, were observed on the day of measurement to be between 22-23°C. The additional cooling energy associated with these lower summer setpoints leads to an increase in energy consumption for the building over predicted amounts.

The successful operation of the underfloor air distribution strategy led to the owner's specification of this type of system in subsequent buildings. Energy savings due to this strategy are assumed, but cannot be confirmed due to the influence of the other factors described above on energy consumption.

Detailed analysis of the energy consumption of Building B is found in Section 2.3.6.1.

Goal #2: Maximize Daylighting

The daylighting strategy employed in Building B initially allowed much natural light into the building, however major concerns with glare in the building led to retrofitting after occupancy. Addition of film to the windows did not succeed in alleviating the glare problem to the owner's satisfaction, therefore blinds were added to the windows, above as well as below the light shelves. The project designers were opposed to the addition of blinds above the light shelves as this impeded the daylighting strategy. In addition, the designers had recommended mesh blinds to allow visibility and some daylighting while controlling glare, however different blinds were selected that did not allow this.

Furnishings initially selected by the occupant organization were dark in colour, allowing for less reflection of light and leading to low light levels. These furnishings have since been replaced with lighter coloured materials.

Also, acoustic concerns in the building after occupancy led to the addition of acoustic ceiling panels. These panels were darker than recommended by the design team. Because the electric uplighting strategy in the building relied on light coloured exposed concrete ceilings for reflection of light, the presence of these acoustic panels hindered this strategy. As the installed electric lighting was subsequently considered insufficient, extensive task lighting was added at high cost to the owner.

On average, occupant satisfaction from the PROBE study indicated a desire for more natural light, less glare from the sun and sky, and more electric light.

Light level sampling data from the day of measurement is found in Appendix 3.2.4. It is important to note that these “snapshot” samples do not definitively describe the overall lighting conditions in the building.

<u>Goal #3: Optimize Thermal Comfort</u>

An underheating problem arose on the building’s second floor where floor slabs projected as overhangs from the building. Insulation in these areas had been value-engineered out of the project during design, but the underheating problem led to the addition of insulation after occupancy, as well as the addition of some electric heaters to these areas. These measures resolved the underheating problem on the second floor.

Because of the high performance envelope and energy efficient systems designed for the building, the chiller size was greatly reduced from the owner’s expectations and from the size denoted in their specification. Concerns that the chiller would not be adequate to cool the building led the owner to hold back $200,000 as a performance bond until the cooling capacity in the building was proven to be adequate. Monitoring of the building’s cooling systems was carried out for three summers, after which the chiller capacity was determined to be sufficient.

Part of the reason for the above situation was the fact that two specifications existed relating to the chiller, one performance specification indicating the performance requirements for the chiller, and one specification stating the size of the chiller plant. According to the design team, the size specified for the chiller was much larger than the chiller size required to meet the performance specification.

In current operation, there is some concern on the part of the owner that more than three days with ambient temperatures above 30°C leads to somewhat higher internal temperatures, however these higher temperatures are still within the performance levels set for the building.

Evidence gathered during the BPE suggests that the underfloor air distribution systems in Building B are performing as intended to optimize thermal comfort. During the hot summer day thermal measurements were taken in the building, the majority of spaces sampled were between 22-23℃ and within 1℃ of their setpoint temperatures.

The design intent for summer setpoint temperatures of 24℃, as stated in the owner's specification, was not observed on the day of measurement, instead setpoints were between 22-23℃. It is possible that occupant temperature change requests led to this operational adjustment, or that this intent was not adequately communicated to the operator.

Sampling data from the day of thermal measurement is found in Appendix 3.2.2. It is important to note that these "snapshot" samples do not definitively describe the overall thermal conditions in the building.

On average, the occupant survey responses for thermal comfort in Building B indicated high satisfaction with thermal conditions in both summer and winter, with average scores for temperature very close to the midpoint (neither "too hot" nor "too cold"). Summer conditions in particular were rated very high.

In terms of occupant control of thermal conditions, it appears occupants were not using the operable diffusers appropriately, despite having been trained in their use for control over thermal comfort. Operations staff ended up disabling the manual control mechanism on these diffusers when they found that occupants were leaving them completely closed, leading to balancing problems. When the design team heard the manual control of the diffusers had been disabled, they advised the operator to remove the sheet metal screws that were being used to keep these diffusers open. In the PROBE survey results, average ratings relating to occupants' perceived control over thermal conditions were quite low, indicating little perceived control.

Goal #4: Create High-Quality Acoustic Environment

The harder than anticipated acoustic environment brought about by the exposed concrete ceilings in Building B led the owner to add acoustic material to the ceilings after occupancy. Glass baffles were added to the ceiling for acoustic control, but later the majority of these were removed due to perceived safety concerns. Acoustic ceiling panels were subsequently added, but unfortunately their colour hinders the daylighting strategy and the effectiveness of electric uplighting, leading to the addition of task lights.

Measurements of acoustic quality taken during the Building Performance Evaluation period indicate that acoustic conditions are substantially improved in the vicinity of acoustic ceiling panels, and even more so near the remaining glass ceiling baffles.

Noise levels and reverberation times were within benchmark ranges in open plan areas, but noise levels increased, as expected, on the side of the building facing the busy road when windows were open. The noise from the road was anticipated during design of the building, yet the owner opted in favour of operable windows on this side of the building regardless, because of the ventilation control and connection with outdoors that these windows afford occupants.

In the private offices that were added during tenant fit-out, an absence of acoustic ceiling material leads to higher reverberation times, giving a perceived "noisiness" to these spaces. However, these private offices were not factored into the base building design.

Detailed sampling data from the day of acoustic measurements is found in Appendix 3.2.3. It is important to note that these "snapshot" samples do not definitively describe the overall acoustic conditions in the building.

According to results of the PROBE study, the average occupant satisfaction rating for acoustics was very close to the midpoint on the satisfaction scale. Noise from colleagues and other people was felt to be the biggest concern relating to acoustics, whereas on average, noise from outside was not felt to be a major problem. This indicates that for the most part, respondents were not very concerned about the noise entering the building through operable windows.

As the majority of workstations in Building B are in open plan office areas, it is likely that concerns about noise from other colleagues relate to this open concept. Indeed, open plan office areas are often associated with acoustic concerns, particularly in occupants who have previously worked in private offices. This is an area where occupant attitudes and expectations play a large role in satisfaction outcomes.

<u>Goal #5: Optimize Indoor Air Quality</u>

In regards to indoor air quality, operations staff were concerned about dust accumulating in the underfloor plenum of the air distribution system, therefore filters were added to each individual air diffuser. Operations staff recommended cleaning of the underfloor plenums every five years to avoid accumulation of dust.

Empirical measurements of air quality, taken on a July day, showed excellent air quality in all areas monitored, with very low VOC levels, and CO_2 levels approaching those of outdoor air. These very low levels may be due to the system operating in economizer mode on this summer day, however these results in combination with the very high heating energy consumption described in Section 2.3.6.1 likely indicate that the building is being operated using significantly more outdoor air than intended during design.

Detailed sampling data from the day air quality measurements were taken is found in Appendix 3.2.1. It is important to note that these "snapshot" samples do not definitively describe the overall indoor air quality in the building.

On average, occupant responses to the PROBE study relating to air quality were slightly above the scale midpoint with respect to stuffiness (indicating a mild concern) but below the midpoint with respect to odour. It is evident from responses in the CBE survey database that air quality is typically one of the categories with lower occupant satisfaction, indicating that the responses received for Building B are not unusual.

2.3.6 Resource Use Analysis

2.3.6.1 Energy Use

An energy model was produced during design of Building B, and results of this model were compared to a benchmark building meeting the American Society for Heating, Ventilation and Air Conditioning Engineers (ASHRAE) 90.1-1989 code requirements. Based on this model, the predicted energy use of the building was 30% lower than the ASHRAE 90.1-1989 baseline, at 188 kWh/m^2/year. It is important to note that in the energy model created during the design of the building, standardized schedules of operation and equipment loads were used, and also the selection of systems is somewhat limited, so CBIP model results should usually not be viewed as accurate predictions of a building's actual energy performance. Instead, they provide a comparison between the designed and baseline building based on a standard set of conditions.

Annual energy consumption values for gas and electricity were provided by the owner for this building for the years 2002 - 2004, and the average annual energy consumption was compared to the energy model values. The actual energy performance for the two year period from January 2003 to December 2004 is shown in Figure 1.

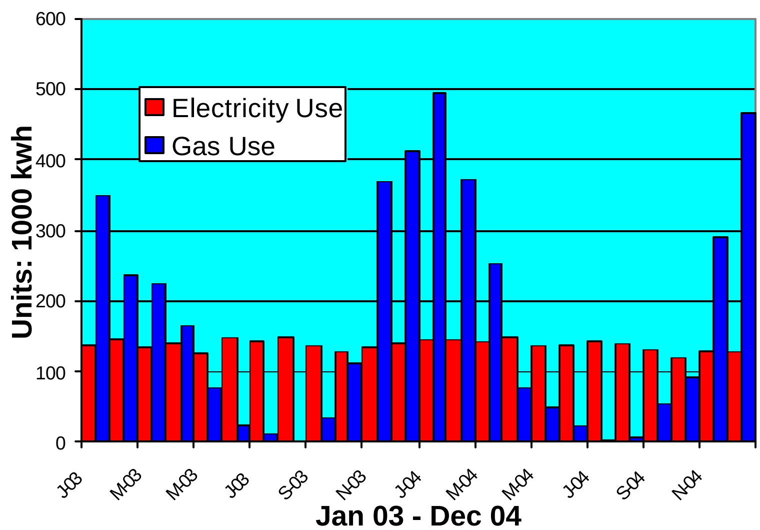

Figure 1: Actual Energy Consumption for Building B

Many factors in the actual operation of the building were different from what was modeled. These factors must be reconciled before a comparison of predicted and actual energy values can be made.

In 2001, disparities between actual electricity and gas consumption and original energy modeling results led designers to re-simulate the energy model with the actual hours of operation. As a result of this remodeling, designers found that modeled electricity consumption results were within 5% of the actual values. The reason the actual gas consumption was higher than modeled was surmised after winter indoor air quality readings showed CO_2 levels in the range of 450 ppm, very close to those of outdoor air. This suggests that the volumes of outdoor air entering the building are much higher than the minimum ventilation requirements for which the building was designed. The energy required to heat this excess outdoor air leads to a significant increase in gas consumption.

Information gathered during the BPE indicates it is likely that the building is still operating with outdoor air volumes much higher than designed. The fact that indoor air quality readings were much better than benchmarks, with CO_2 levels close to those of outdoors, in combination with the fact that gas consumption is much higher than expected, suggests this may be the case. Gas consumption increased significantly each year over the three years analyzed, 2002 to 2004, even though climate conditions during these years did not warrant this increase. Due to this factor as well as to the increased hours of operation, the average annual gas consumption in Building B was almost three times the predicted amount.

Table 2 below indicates the elements in the energy model that were significantly different from actual building operation as observed during the Building Performance Evaluation. This Table is intended to reconcile differences in building use between modeled and actual conditions, without re-simulating the energy consumption of the building, which is outside the scope of the Building Performance Evaluation. In the case of this building, the actual hours of operation are considerably longer than anticipated during design, and are regularly extended during some portions of the year. As well, summer setpoint temperatures observed during the BPE were lower than designed, leading to increased cooling energy. Energy use is also dependent on changes made after occupancy, such as the increase in lighting energy associated with the changes to the daylighting scheme.

In the Table below, some order of magnitude estimates are made of the effect incorporating these actual conditions into the modeled results. It must be stressed that these estimates are based on review of the energy model results but that no modeling was performed to confirm these estimates, and as such they are “order of magnitude” only.

Other factors that may play a minor part in the difference between modeled and actual results include climate variations and the margin of error associated with the limitations of the modeling software.

Table 2: Reconciling of energy model and actual energy consumption results

Building Use	Design Assumptions	Actual Conditions	Effect of actual conditions on energy model results
Hours of Operation	7am – 6pm Mon-Fri (55 hours per week)	Considerably longer hours during portions of the year (exact schedules unknown)	Large energy increase (30-50% or more, order of magnitude)
Building Operation	**Energy Model**	**Actual Conditions**	**Effect of actual conditions on energy model results**
Lighting Energy	Low lighting power (9.6 W/m^2); daylighting	Addition of task lights, leading to higher lighting power; less daylighting	Significant energy increase
Outdoor Air Levels	Minimum outdoor air settings with economizer capability for energy savings	Suspected higher outdoor air volumes than designed	Potentially a very large energy increase (up to 100%, order of magnitude)
Temperature Setpoints	Summer setpoints of 24°C	Summer setpoints of 22-23°C	Minor energy increase
Other Factors			**Effect of actual conditions on energy model results**
Climate variations	Climate variability during years of measurement compared to statistically averaged weather file used in model		Minor energy increase/decrease
Modeling Software	Margin of error associated with software's limited system selection		Minor energy increase/decrease
Results	**Energy Model**	**Actual Conditions (average of 2002-2004)**	**Effect of actual conditions on energy model results**
Annual Energy Consumption	188 $kWh/m^2/year$	347 $kWh/m^2/year$	The above changes could result in actual and modeled results being within a reasonable range.

From Table 2, it is apparent that with energy model results reconciled with actual conditions of building use and building operation, model results and actual energy consumption figures would be within a reasonable range. More precise information regarding the comparison of actual and modeled energy use would be obtained through additional modelling, however this is outside the scope of the BPE. To reduce gas consumption and its associated costs, it is recommended that outdoor air settings on air handling units be confirmed and adjusted if they are indeed higher than the designed amounts.

According to the *Commercial and Institutional Building Energy Use Survey of 2000* (CIBEUS)[1], average energy consumption for existing office buildings in British Columbia is 378 kWh/m^2/year. Using this provincial average as a baseline, Building B's consumption of 347 kWh/m^2/year achieves an 8% energy savings by comparison. Indeed, it is important to stress that although operational differences have led to increased energy consumption over the predicted level, the building is still performing better than the average for buildings of this type, which is of particular note due to the longer hours of operation in this building than in typical offices.

2.3.6.2 Water Use

No specific water consumption targets were set during the design of Building B, and medium-flow water fixtures were installed. Actual water consumption in the building is quite low given the absence of water conservation strategies. The average annual water consumption for 2002 – 2004 was 4,930,000 litres per year, or roughly 32 litres per occupant per day, as calculated in Appendix 3.3. This compares very favorably with the American Society of Plumbing Engineers (ASPE) baseline estimated water requirement of 76 L/occupant/day (20 gallons per capita per day).[2]

2.4 DESIGN LESSONS LEARNED

The final stage of the Building Performance Evaluation was a wrap-up meeting with the design team, during which the post-occupancy results of the key design strategies were discussed. What follows are the design lessons expressed by design team members based on these results. Where no lesson was explicitly stated by designers relating to a significant result, lessons felt to be apparent to the Building Performance Evaluation team were deduced.

Goal #1: Reduce Energy Consumption

According to the design team, the predominant reason for the difference between predicted and actual energy use in Building B was that it is likely being operated during significantly longer hours than assumed in the energy model. As well, evidence gathered during the BPE suggests that the building is conditioning much more outdoor air than designed. The effect of these factors on energy use demonstrates the huge impact that building use and operating conditions have on energy consumption.

---

[1] Commercial and Institutional Building Energy Use Survey 2000, December 2002, conducted by Statistics Canada on behalf of the Office of Energy Efficiency of National Resources Canada.
[2] Steele, Alfred. Advanced Plumbing Technology. Elmhurst: Construction Industry Press, 1984, p 155.

An important design lesson was learned by the design team relating to the involvement of the operator during the design of the building. In the case of Building B, designers felt they had insufficient communication with the operations staff. The design team expressed that in the design of subsequent buildings, they endeavored to involve the operations staff in IDP meetings to ensure adequate communication of design intent between the designers and the operator, and also to allow the operator to have input into the selection of appropriate energy conservation strategies during design.

Designers also felt that longer periods of interaction between designers and operators after occupancy would assist in ensuring that the building would be operated continually as intended during design. Discussion centered on building a budget into projects for post-occupancy interaction with building operators, and ensuring that designers receive energy consumption data for the first several years of building occupancy.

The influence of acoustic and shading retrofits on increased lighting consumption in Building B also suggested an important lesson to the design team about their involvement in these changes to the building, as described below.

Goal #2: Maximize Daylighting

One lesson learned by the design team relating to the issue of glare in Building B, and applied in future buildings, was to use areas closest to windows where glare exists for circulation, while allowing workspaces to benefit from the increased amount of daylight in the building. In addition, some designers referred to the use of additional external shading as a lesson learned.

The implications of glare control strategies implemented after occupancy on the daylighting strategy in the building suggested to the designers that they should be involved in the selection of appropriate blinds, and indeed that the blinds concept should be part of the initial design. The designers felt that in this building blinds above the light shelves should not be used, to allow for daylighting without glare at occupant level.

The effect of acoustic treatment strategies on reducing the amount of daylighting in the building also suggested to designers that they should have input into major changes to the building, to ensure that the original design intent is adhered to as much as possible. To resolve the acoustic concerns in Building B after occupancy, the design team suggested white floating panels just below the ceiling to minimize the impact on daylighting; it was felt that this would have reduced the need for additional task lighting in the building, and would have improved occupant satisfaction with light levels.

In relation to the above issue, another lesson learned from the BPE process for Building B was about the need for a set of design guidelines for tenant fit-out. These guidelines would be prepared by the building design team with the intent of ensuring that the goals and strategies involved in the original building design are followed during fit-out.

Goal #3: Optimize Thermal Comfort

In regards to the issue of chiller size, the owner's concerns that the chiller would prove inadequate were alleviated after three years of successful summer operation. From that point forward, the owner's future specifications included the performance-based requirement for plant operation and did not include specified capacities.

The fact that thermal comfort was rated so highly by building occupants during the PROBE survey attests to the performance of the underfloor air systems in achieving optimal heating and cooling.

The interesting response from respondents to the PROBE survey about their perceived control over thermal conditions in the building may possibly relate to the disabling of the diffuser control feature in the building. This operations decision was made to increase thermal comfort, as the operator noted that the manual control feature was not being used appropriately by occupants despite occupant education initiatives regarding use of this feature. This situation highlights the challenge of occupant education, particularly with the transfer of information to new occupants when turnover occurs. It appears that occupant education processes carried out during design may not prove effective in the long term without a formalized educational procedure carried out by the owner and applied with all new occupants.

Goal #4: Create High-Quality Acoustic Environment

The exposed concrete ceilings in Building B resulted in a harder acoustic environment than anticipated during design. Changes applied after occupancy to address this issue were successful in creating a high-quality acoustic environment in most areas of the building.

Unfortunately the acoustic treatment strategies selected after occupancy interfered with the daylighting electrical uplighting strategy, as described above. This issue points to the fact that many design strategies in green buildings are intertwined and cannot be addressed in isolation without influencing other strategies. For this reason, designers' involvement in the selection of acoustic treatment is important.

Goal #5: Optimize Indoor Air Quality

The indoor air quality measurements in Building B showed that indoor air quality was excellent in all areas assessed, indicating filtration media on the air handling units achieved appropriate removal of particulates. CO_2 and VOC levels were extremely low in the building, which was one factor leading to the concern that the building is operating on substantially more outdoor air than designed. As stated above, this would lead to significantly increased energy consumption over what was anticipated during design.

The Building Performance Evaluation matrix in Appendix 3.1 summarizes the key design goals for the building, the strategies implemented to achieve these goals, and the results of these strategies found during the BPE.

3.0 Appendices

3.1 BUILDING PERFORMANCE EVALUATION MATRIX

Appendix 3.1: Building Performance Evaluation Matrix for Building B

LEED CATEGORY	COMPONENT	GOAL	STANDARD PRACTICE GOAL	STRATEGY	STANDARD PRACTICE STRATEGY	PREDICTED VALUES	MEASURED VALUES	BENCHMARKS	COMMENTS / DIFFERENCES BETWEEN DESIGN AND OCCUPIED BUILDING	OCCUPANT SATISFACTION SURVEY * (see note)	TRADEOFFS OR SYNERGIES	DESIGN LESSONS LEARNED
Site Considerations	**Alternative Transportation**	Enable occupants to use sustainable commuting options	-	Bicycle storage; proximity to public transit	-	-	-	-	-	-	-	Building Performance Evaluation pilot study did not directly evaluate this topic
Water Efficiency	**Domestic water consumption**	None	-	Medium-flow fixtures	-	-	32 L/occupant/day	76 L/occupant/day [ASPE standard water use estimate]	Water efficiency was not specifically targeted in design, however water consumption is low compared to benchmarks.	-	-	-
Energy and Atmosphere	**Energy consumption**	30% below ASHRAE 90.1-1989; 140-195 kwh/m^2/year	-	Reduced lighting power at 9.6 W/m^2, direct/indirect lighting	15 W/m^2 direct electric lighting	30% savings over ASHRAE 90.1-1989	Energy intensity of 347 kWh/m^2/year	378 kWh/m^2/year [CIBEUS, Office Buildings, BC]	Retrofitted acoustic panels were darker than desired, leading to reduced uplighting effectiveness. Task lighting added.	-	-	Input from design team into selection of retrofitted features would help to ensure design intent is not compromised.
				High performance envelope, low-E glass	-				Smaller chiller capacity required by efficient envelope and systems. Doubts about sufficiency of the chiller capacity were dispelled after successful chiller operation over a 3-year trial period.	-	-	Subsequent specifications by the owner were performance based and did not specify chiller size.
				Solar shading	-				Film and blinds added to windows to reduce glare.	-	Retrofitted blinds reduced glare but hindered daylighting strategy.	-
				Economizer capability ("free cooling" by using up to 100% outdoor air)	-				Winter indoor air quality readings in 2001 suggest building was heating excess outdoor air. Evidence gathered during the BPE suggests this may still be the case.	-	-	Involvement of operations staff during design, as well as longer involvement of design team post-occupancy, would help to ensure design intent was understood.
				Underfloor air distribution	Air supply from ceiling				Operations staff concerned about dust in underfloor air plenum, filters added to each diffuser.	-	Operator indicated adjustable diffusers are difficult to balance.	Energy savings are expected with this strategy, however other factors influenced overall energy consumption.
				Thermal storage in exposed concrete ceilings	-				Acoustic ceiling panels added as a retrofit due to noise concerns.	-	Leaving concrete ceilings exposed was a cost saving measure to offset cost of raised access floors.	-
				"Hotelling" system of shared workspaces for employees frequently out of the office, for space and energy efficiency	-				-	-	-	Buidling Performance Evaluation pilot study did not directly evaluate this feature.
Materials and Resources	-	-	-	-	-	-	-	-	-	-	-	Building Performance Evaluation pilot study did not directly evaluate this topic.
Indoor Environmental Quality	**Lighting**	540 lux (50 footcandles) at work surfaces at 9.6 W/m^2	540 lux (50 footcandles) at work surfaces at 15 W/m^2	Direct/indirect lighting with reflection off exposed concrete ceiling	Direct lighting	540 lux (50 footcandles) at work surfaces	"Snapshot" measurements of lighting conditions indicate excursions both above and below benchmarks in certain areas, see report	Illuminance levels of 200 - 540 lux based on tasks	Retrofitted acoustic panels were darker than desired, leading to reduced uplighting effectiveness. Task lighting added.	Desire for more electric light and less glare.	-	Changes made to one strategy may adversely affect another strategy in dynamic green buildings. Input from design team into selection of retrofitted features would help to ensure design intent is not compromised.

Appendix 3.1: Building Performance Evaluation Matrix for Building B

LEED CATEGORY	COMPONENT	GOAL	STANDARD PRACTICE GOAL	STRATEGY	STANDARD PRACTICE STRATEGY	PREDICTED VALUES	MEASURED VALUES	BENCHMARKS	COMMENTS / DIFFERENCES BETWEEN DESIGN AND OCCUPIED BUILDING	OCCUPANT SATISFACTION SURVEY * (see note)	TRADEOFFS OR SYNERGIES	DESIGN LESSONS LEARNED
Indoor Environmental Quality (cont'd)	**Thermal Comfort**	Optimize thermal comfort	-	Underfloor air distribution for heating and cooling	Air supply from ceiling for heating and cooling	Moderate design air temperature setpoints of up to 24℃ in summer indicated in owner's specification	"Snapshot" measurements of thermal conditions on a mild July day indicated majority of spaces between 22-23℃ and within 1℃ of setpoints	Typical air temperature setpoints of 21℃ in winter, 23℃ in summer	Insulation was added to second floor slab projections due to cold concerns; this insulation was value-engineered out of original design. Actual summer setpoints lower than designed.	Ratings for thermal comfort above the midpoint on the satisfaction scale, both in summer and in winter.	-	Underfloor distribution system was effective in achieving thermal comfort.
		Occupant control of thermal comfort	Limited occupant control	Adjustable diffuser airflows; occupant education in use of diffusers to control thermal environment	-				Improper adjustment of diffusers by occupants led operator to disable manual control feature.	Perceived control over heating and cooling was quite low.	Operator indicated adjustable diffusers are difficult to balance.	Occupant education processes carried out during design may not prove effective in the long term without a formalized educational procedure carried out by the owner for new occupants.
	Daylight and Views	Maximize daylighting	-	Large areas of glazing	-	540 lux (50 footcandles) at work surfaces	"Snapshot" measurements of lighting conditions indicate excursions both above and below benchmarks in certain areas, see text	200 - 500 lux based on tasks	Glare concerns led to addition of film and then blinds to windows, hindering daylighting strategy.	Desire for more natural light and less glare.	Large amounts of glass are effective for daylighting but may lead to increased heating and cooling loads, and glare.	Potential to use of perimeter areas for circulation instead of workspaces. Desireability of increased external shading.
				Light shelves and reflective surfaces	-				Blinds added above light shelves, hindering their effectiveness for daylighting. Dark furnishings, high cabinets, and added acoustic ceiling panels reduced reflection of light within the building.		-	Input from design team into selection of retrofitted features would help to ensure design intent is not compromised.
	Indoor air quality	Increased ventilation effectiveness	-	Underfloor air distribution provides fresh air at occupant level	Air supplied at ceiling	-	Snapshot measurements of air quality were all within benchmark ranges; VOC levels low and CO_2 levels close to those of outdoor air	Air quality measurements of CO_2:600-1000ppm VOC < 300ppb	Operations staff concerned about dust in underfloor air plenum, filters added to each diffuser.	Level of concern about stuffiness slightly above scale midpoint; concern about odour below scale midpoint.	Decreased energy consumption is anticipated with underfloor air distribution.	Owner appears satisfied with underfloor air distribution concept.
				Economizer capability ("free cooling" by using up to 100% outdoor air)	-				Winter indoor air quality readings in 2001 suggest building was heating excess outdoor air. Evidence gathered during the BPE suggests this may still be the case.		Economizer capability is usually associated with energy savings, however in this case excess outdoor air is likely conditioned even in winter, leading to increased energy consumption.	Involvement of operations staff during design, as well as longer involvement of design team post-occupancy, would help to ensure design intent was understood.
	Acoustic quality	Noise reduction in open plan areas	-	Carpets and sound absorbing partitions	-	-	Acoustic quality high where acoustic panels present; higher noise levels in private offices	Acoustic measurements of NC30-40 dB RT<0.75 s SII:0.2-0.7 NIC30-40 dB	Noise concerns led to addition of glass acoustic ceiling baffles, majority were removed due to perceived safety concerns; acoustic ceiling panels were subsequently added. Building was not originally designed for private offices, acoustic consideration was for open-plan environment. Noise from road through operable windows was perceived.	Satisfaction with acoustics near scale midpoint; noise from colleagues a concern; external noise from operable windows was not a great concern.	Acoustic ceiling panels assist in noise reduction but in this building their colour hinders daylighting and electric uplighting strategies. Noise from the road through operable windows was perceived but was acceptable to occupants and owner due to the other benefits of operable windows.	Acoustic effect of exposed concrete ceilings was more pronounced than anticipated. Input from design team into selection of retrofitted features would help to ensure other design strategies are not compromised.
Design Process	**Design-Build Competition, team led by Contractor**	Fixed budget, specific performance targets	**-**	Biweekly meetings; contractor involved in all design meetings to provide continuous focus on cost-effective design	Segregation of design tasks and decisions between disciplines	-	-	-	Building was completed on time and on budget.	-	-	Many cost effective ideas came from the contractor, whose involvement was very useful. In future, involvement of building operations staff during design is desired.

*** PROBE (Post-Occupancy Review of Building Engineering) survey used in this building was based on a British benchmark group, where tolerance for a wider range of comfort conditions is felt to be common. No comparison was made to benchmark group.**
All survey results are based on the average of all responses, and could not be filtered. The PROBE survey achieved an 83% response rate among the occupants present on the day of the survey.

3.2 EMPIRICAL DATA

3.2.1 Indoor Air Quality Measurements

Twenty-four sites were selected in Building B for evaluation of indoor air quality. These sites were located on the second, third, and fifth floors. Carbon dioxide, carbon monoxide, ultrafine particulate and composite volatile organic compounds were evaluated in the morning and in the afternoon of July 13th, 2006 to assess variability over the day. Passive monitors for aldehydes were exposed for approximately 24 hours to collect integrated samples.

Results from sampling locations on each floor are shown in the following Tables. Optimal values in the rightmost column represent benchmark ranges for each measured variable.

Detailed results for each sampling location are included on the pages following the Tables.

Table 1: Selected parameters of indoor air quality from 2nd floor.

2nd floor (n = 10)	**unit**	**1st sample (11:15 – 12:40)**	**2nd sample (3:30 – 4:10 pm)**	**Optimal**
Composite Volatile Organic Compounds (range)	ppb	< 1 – 90	< 1 – 75	< 300
Ultrafine particulate: Indoor to outdoor (range)	ratio	0.2	0.2 – 0.3	0.2
Aldehydes				
CO_2 (range)	ppm	437 – 611	428 – 505	410 – 1000

Table 2: Selected parameters of indoor air quality from 3rd floor.

3rd floor (n = 10)	**unit**	**1st sample (12:50 – 1:45)**	**2nd sample (4:15 – 4:40 pm)**	**Optimal**
Composite Volatile Organic Compounds (range)	ppb	< 1 – 140	< 1 – 30	< 300
Ultrafine particulate: Indoor to outdoor (range)	ratio	0.2 – 0.4	0.1– 0.3	0.2
Aldehydes				
CO_2 (range)	ppm	443 – 589	440 – 630	410 – 1000

Table 3: Selected parameters of indoor air quality from 5th floor.

5th floor (n = 4)	**unit**	**1st sample (2:00 – 2:30)**	**2nd sample (4:45 – 5:00 pm)**	**Optimal**
Composite Volatile Organic Compounds (range)	ppb	< 1 – 45	< 1	< 300
Ultrafine particulate: Indoor to outdoor (range)	ratio	0.1 – 0.3	0.2	0.2
Aldehydes				
CO_2 (range)	ppm	435 – 505	450 – 458	410 – 1000

Building Performance Evaluation: IAQ

Date: 13-Jul-06

Building: Bldg B 2nd Floor

Position:

Sample 1	2nd Floor SW corner
Sample 2	2nd Floor centre desk S end
Sample 3	2nd Floor W side private office
Sample 4	2nd Floor NW near corner
Sample 5	2nd Floor NE near corner
Sample 6	2nd Floor busy road side NE near corner
Sample 7	2nd Floor busy road side NW at corner
Sample 8	2nd Floor busy road side N near centre core at window
Sample 9	2nd Floor centre open office near kitchen
Sample 10	2nd Floor busy road side S at window 1/2 way to end

Notes:

2nd Floor, Building B

1st sample	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Sample 10**
Time:	11:14	11:30	11:43	11:52	11:58	12:07	12:17	12:22	12:28	12:39
weather:	cloudy	cloudy	NA	cloudy	cloudy	sunny breaks	sunny breaks	sunny breaks	sunny breaks	cloudy
ppbRAE	56	30	28	5	50	<1	<1	<1	90	25
P-Track	2020	1770	1970	1650	1520	1500	1600	2090	1930	1640
CO2	540	509	611	495	508	466	540	448	480	437
CO	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Temperature	22.5	22.4	22.3	22.8	22.9	23.5	23.5	23.1	22.9	23.2
%RH	47.1	49.5	50.2	49	47.3	45.5	44.2	44.3	46.3	46.5

Outdoor measurments: (Take measurements near air intake)

VOC (ppb) outdoor 2

P-track (pt/cc) 9950

CO2 (ppm) outdoor 458

	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Sample 10**
I:O VOC	28	15	14	2.5	25	0	0	0	45	12.5
I:O P-track	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

2nd Floor, Building B

2nd sample	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Sample 10**
Time:	3:34	3:40	3:46	3:48	3:51	4:02	3:59	3:56	4:05	4:08
weather:	sunny	sunny	sunny	partly cloudy	p/c	p/c	p/c	sunny	sunny	p/c
ppbRAE	18	<1	20	<1	53	75	60	<1	<1	<1
P-Track	2260	2150	2570	2030	2020	1590	1380	1700	1870	1510
CO2	445	505	477	435	460	456	428	453	455	448
CO	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Temperature	24.9	24.1	23.7	23.8	23.6	23.7	23.8	23.4	23.6	23.6
%RH	38.1	40.2	42.1	42.2	42.8	42.5	43	42.9	43.1	43.1

Outdoor measurments: (Take measurements near air intake)

VOC (ppb) outdoor	<1
P-track (pt/cc)	7020
CO2 (ppm) outdoor	430

	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Sample 10**
I:O VOC	18	0	20	0	53	75	60	0	0	0
I:O P-track	0.3	0.3	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Building Performance Evaluation: IAQ

Date: 13-Jul-06

Building: Bldg B 3rd Floor

Position:

Sample 1	3rd Floor SW corner at window (both sides)
Sample 2	3rd Floor SE corner near window
Sample 3	3rd Floor S centre desk
Sample 4	3rd Floor S centre private office
Sample 5	3rd Floor Centre training room
Sample 6	3rd Floor N end of west arm
Sample 7	3rd Floor busy road side NW
Sample 8	3rd Floor busy road side centre
Sample 9	3rd Floor busy road side SE
Sample 10	3rd Floor busy road side end of arm

Notes:

3rd Floor, Building B

1st sample	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Sample 10**
Time:	12:52	1:00	1:04	1:10	1:16	1:21	1:29	1:32	1:36	1:44
weather:	cloudy	cloudy	cloudy	cloudy	NA	cloudy	sunny breaks	sunny breaks	sunny breaks	sunny breaks
ppbRAE	<1	140	10	60	20	<1	<1	<1	<1	<1
P-Track	3300	3110	2500	1580	2220	1800	1940	1840	1740	1320
CO2	550	540	490	589	475	500	458	445	443	488
CO	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Temperature	23.4	23.2	23.3	23.4	22.9	23.5	23.6	23.6	23.7	23.6
%RH	46.3	46.9	46.4	47.2	47.1	47.4	46.6	45.8	45.2	45.5

Outdoor measurments: (Take measurements near air intake)

VOC (ppb) outdoor	2
P-track (pt/cc)	9950
CO2 (ppm) outdoor	458

	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Sample 10**
I:O VOC	0	140	10	60	20	0	0	0	0	0
I:O P-track	0.4	0.4	0.3	0.2	0.3	0.2	0.2	0.2	0.2	0.2

3rd Floor, Building B

2nd sample	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Sample 10**
Time:	4:18	4:20	4:22	4:25	4:27	4:29	4:32	4:34	4:41	4:37
weather:	sunny	sunny	sunny	sunny	NA	sunny	sunny	sunny	sunny	sunny
ppbRAE	30	10	<1	10	<1	<1	<1	<1	<1	<1
P-Track	2160	1770	1790	1340	1780	1650	1530	1620	1430	1220
CO2	580	480	490	630	470	510	447	490	455	440
CO	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1
Temperature	23.9	24	24	24	23.7	23.8	24.7	24.2	23.9	24
%RH	42.4	41.9	42.2	42.4	42	42.2	42	41.3	42.1	41.7

Outdoor measurments: (Take measurements near air intake)

VOC (ppb) outdoor <1

P-track (pt/cc) 7020

CO2 (ppm) outdoor 430

	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Sample 10**
I:O VOC	30	10	0	10	0	0	0	0	0	0
I:O P-track	0.3	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1

Building Performance Evaluation: IAQ

Date: 13-Jul-06

Building: Bldg B 5th Floor

Position:

Sample 1	5th Floor W side overlooking second building, across from photocopier
Sample 2	5th Floor W side centre open office, next to blue wall
Sample 3	5th Floor W side open office, red wall, next to red wall
Sample 4	5th Floor W side next to windows facing N

Notes:

5th Floor, Building B

1st sample	Sample 1	Sample 2	Sample 3	Sample 4
Time:	2:02	2:06	2:19	2:22
weather:	sunny breaks	sunny breaks	sunny breaks	sunny breaks
ppbRAE	45	<1	<1	<1
P-Track	1200	1850	2140	1600
CO2	435	484	505	467
CO	<1	<1	<1	<1
Temperature	23.9	24.1	24	24.1
%RH	42.7	43.3	42.4	42.5

Outdoor measurments: (Take measurements near air intake)

VOC (ppb) outdoor 2

P-track (pt/cc) 9950

CO2 (ppm) outdoor 458

	Sample 1	Sample 2	Sample 3	Sample 4
I:O VOC	45	0	0	0
I:O P-track	0.1	0.2	0.3	0.2

5th Floor, Building B

2nd sample	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**
Time:	4:46	4:48	4:52	4:54
weather:	sunny	sunny	sunny	sunny
ppbRAE	<1	<1	<1	<1
P-Track	1490	1740	2010	1360
CO2	450	458	454	453
CO	<1	<1	<1	<1
Temperature	24.3	24.4	24.3	24.1
%RH	42.3	41.8	41.4	41.6

Outdoor measurments: (Take measurements near air intake)

VOC (ppb) outdoor	<1
P-track (pt/cc)	7020
CO2 (ppm) outdoor	430

	Sample 1	**Sample 2**	**Sample 3**	**Sample 4**
I:O VOC	0	0	0	0
I:O P-track	0.2	0.2	0.2	0.2

3.2.2 Thermal Comfort Measurements

Fifteen sites were selected for thermal measurements in Building B. Both internal workspaces and spaces near windows were selected for thermal measurement.

The following Table shows thermal measurement results for the fifteen sample locations, taken twice during the day to assess variability. The dry bulb temperature in the fourth column indicates the air temperature in each space, and the setpoint temperature value in the fifth column is the temperature to which the space is conditioned by the building’s systems.

Date: 13-Jul-06 Building: Building B

Note: the building's BMS does have short term trendlogging capability, however, trendlogging was only done for the 3rd floor, and was not initiated by the building operator until 3pm

wo=window open
bo=blinds open

Second Floor

time (morn)	weather	location	dry bulb	setpoint	BMS temp	BMS pt#	air velocity	[setpoint-actual]	windows and environmental factors
11:25	cloudy	1	22.1	22.8		9.1C9	0.013	0.700	0/3 wo, 4/7 ebo, 3/9 sbo, 3/6 wbo
11:36	cloudy	2	23	22.8		9.1C14	0.000	0.200	2/3 wbo
11:56	cloudy	3	23	23		11.1C14	0.010	0.000	all bo, no wo
12:08	cloudy	4	23.5	23		11.1C11	0.000	0.500	0/2 nbo, 0/2 ebo, 0/2 wo
12:19	cloudy	5	23.4	23.1		11.1C12	0.030	0.300	0/2 wbo, 2/3 nbo, 0/2 wo
12:30	cloudy	6	23.4	23		11.1C10	0.010	0.400	3/9 ebo, 1/3 wo
12:42	cloudy	7	23.6	23.3		9.1C12	0.010	0.300	0/3 wo, 2/5 ebo, 1/4 sbo

Second Floor

time (morn)	weather	location	dry bulb	setpoint	BMS temp	BMS pt#	air velocity	[setpoint-actual]	windows and environmental factors
2:59	cloudy	1	23.1	22.8		9.1C9	0.003	0.300	0/3 wo, 4/7 ebo, 3/9 sbo, 3/6 wbo
3:07	cloudy	2	23.6	22.8		9.1C14	0.000	0.800	0/3 wbo
3:14	cloudy	3	23	23		11.1C14	0.000	0.000	all bo, no wo
3:20	cloudy	4	23.6	23		11.1C11	0.000	0.600	0/2 nbo, 0/2 ebo, 0/2 wo
3:54	cloudy	5	23.4	23.1		11.1C12	0.000	0.300	0/2 wbo, 2/3 nbo, 0/2 wo
3:26	cloudy	6	23.3	23		11.1C10	0.000	0.300	3/9 ebo, 1/3 wo
3:45	cloudy	7	23.7	23.3		9.1C12	0.000	0.400	0/3 wo, 2/5 ebo, 4/4 sbo

Third Floor

time (mid)	weather	location	air temp	setpoint	BMS temp	BMS pt#	air velocity	[setpoint-actual]	windows and environmental factors
12:55	cloudy	1	23.5	22.5		9.1C16	0.025	1.000	no bo, no wo
1:02	cloudy	2	23.1	21.5		11.1C25	0.000	1.600	3/6 bo, 0/3 wo
1:12	cloudy	3	23.4			none	0.015		private office, no blinds or operable wind.
1:19	cloudy	4	22.8	none		11.1C23.1	0.091		door open, no windows
1:29	cloudy	5	23.8	22.8		11.1C23	0.000	1.000	2/6 ebo, 4/5 nbo, 0/3 wo
1:36	cloudy	6	23.8	22.6		11.1C21	0.000	1.200	1/3 bo, 0/1 wo
1:45	cloudy	7	23.6	22.6		11.1C20	0.000	1.000	1/5 ebo, 2/4 nbo, 0/2 wo
1:52	cloudy	8	23.4	22.7		11.1C18	0.051	0.700	3/4 bo, 0/1 wo

Third Floor

time (mid)	weather	location	air temp	setpoint	BMS temp	BMS pt#	air velocity	[setpoint-actual]	windows and environmental factors
4:20	sun	1	24.2	22.5	23.2	9.1C16	0.000	1.700	no bo, no wo
4:26	cloud+sun	2	23.6	21.5	23.3	11.1C25	0.000	2.100	3/6 bo, 0/3 wo
4:32	cloud+sun	3	23.7			none	0.038		private office, no blinds or operable wind.
4:38	cloud+sun	5	23.8	22.8		11.1C23	0.000	1.000	0/6 ebo, 4/5 nbo, 0/3 wo
4:45	cloud+sun	6	23.8	22.6	23.1	11.1C21	0.097	1.200	0/3 bo, 1/1 wo - note, sun entering anyway

3.2.3 Acoustic Measurements

Based on a walk-through acoustical survey of Building B, acoustic measurements were made in the following locations, expected to be of particular interest acoustically, and under various conditions:

- R1 – 3rd floor west, open-office cubicle with 1.6m partitions, glass ceiling baffles and acoustic ceiling panels
- R2 – Ground floor, interview cubicle
- R3 – 2nd floor east, open-office cubicle with 1.2m partitions and acoustic ceiling panels
- R4 – Ground floor, Reception
- R5 – Ground floor, Lobby
- R6 – 3rd floor internal, private office
- R7 – 2nd floor west, open-office cubicle with 1.6m partitions, sliding door and acoustic ceiling panels
- R8 – Training room

The following variables were measured at each sample location, as appropriate. Benchmark ranges for each variable are shown in the following Table.

Table 3: Acoustic measured variables and benchmark ranges

Measured Variable	Benchmark Ranges
Background-noise level, BN in dB	NC30-35 in meeting and conference rooms, NC35-40 in workspaces
Mid-frequency Reverberation time, RT in s	RT < 0.75 s for a comfortable environment and easy verbal communication
Speech Intelligibility Index, SII	Speech intelligibility requires SII > 0.7, Speech privacy requires SII < 0.2
Noise Isolation Class, NIC in dB	NIC35-40 dB for private offices and conference rooms, NIC30-35 dB for open offices and meeting rooms

Measurements were made under relevant operational and environmental conditions – for example, windows open and closed, office doors open and closed.

Results for each sampling location are found in the following Table.

Table 2. Acoustic measurement results for each sample location

Location	*Background Noise (dB)*	*Reverberation Time (sec)*	*Speech Intelligibility (SII)*	*Noise Isolation (NIC dB)*
R1	NC28 unoccupied, window closed NC30 unoccupied, window open	0.4	0.64/0.38/0.30 unoccupied, over open office partition, casual voice, without acoustic panel/with acoustic panel/with glass baffle	-
R2	NC50 occupied	1.1	0.37/0.48/0.57 across desk, casual/normal/loud voice 0.03/0.18/0.50 from adjacent cubicle, casual/normal/loud voice	-
R3	NC37 unoccupied, window closed NC53 unoccupied, window open	0.4	0.66/0.27-0.36/0.41 from nearby open office cubicles, casual voice, without acoustic panel/with acoustic panel/with sliding door closed	-
R4	NC48 unoccupied NC50 occupied	1.1	-	-
R5	NC50 unoccupied NC55 occupied	1.4	-	-
R6	NC26 unoccupied, door closed	0.9	0.31/0.45 from nearby open office cubicles, door open, casual/normal voice	26 outside to inside, door closed
R7	NC35 unoccupied window closed	0.4	-	-
R8	NC31 unoccupied, door closed	0.5	0.45/0.58/0.69/0.73 across conference table, door closed, casual/normal/raised/loud voice	24 from hallway door closed 40 meeting room to private office, door closed

3.2.4 Lighting Measurements

Twenty-four sites were selected for evaluation of lighting levels in Building B. These sites were located on the second, third, and fifth floors. Sites were evaluated in the morning and in the afternoon of July 13th, 2006, to assess light level variability over the day.

Detailed results for each sampling location are shown in the following Tables. Optimal values in the rightmost column represent benchmark ranges for each measured variable.

Detailed results for each sampling location are included on the pages following the Tables.

Table 2: Light measurements taken from 2nd floor perimeter workstations.

2nd floor perimeter (n=7)	**unit**	**1st sample (11:15 – 12:40)**	**2nd sample (3:30 – 4:10 pm)**	**Optimal**
Use of blinds:				
Blinds open	n	4	4	NA
Blinds closed or greater than 50% closed	n	3	3	
Glare:				
Yes, veiling glare on work surface	n	4	4	NA
No glare	n	3	3	
Incident light				
Measured range	lux	235 – 1280	245 – 830	200 – 500
Task lighting				
Use of task lighting	n	1	1	NA
Comfort ratios				
Incident light to background	ratio	0.9 – 2.0	1.0 – 1.8	0.3 – 3
Computer to background		0.1 – 1.7	0.2 – 1.1	0.1 – 10
Morning to afternoon incident light ratio (range)	ratio	0.6 – 2.8		NA

Table 3: Light measurements taken from 2nd floor core workstations

2nd floor core (n=4)	**unit**	**1st sample (11:15 – 12:40)**	**2nd sample (3:30 – 4:10 pm)**	**Optimal**
Use of blinds:				
Blinds open	n	1	1	NA
Blinds closed or greater than 50% closed	n	0	0	
Not applicable	n	3	3	
Glare:				
Yes, veiling glare on work surface	n	3	1	NA
No glare	n	1	3	
Incident light				
Measured range	lux	205 – 520	160 – 550	200 – 500
Task lighting				
Use of task lighting	n	0	0	NA
Comfort ratios				
Incident light to background	ratio	0.9 – 6.0	0.8 – 16.0	0.3 – 3
Computer to background		0.4 – 5.7	0.2 – 15.0	0.1 – 10
Morning to afternoon incident light ratio (range)	ratio	0.9 – 1.3		NA

Table 4: Light measurements taken from 3rd floor perimeter workstations.

3rd Floor perimeter (n=5)	**unit**	**1st sample (12:50 – 1:45 pm)**	**2nd sample (4:15 – 4:40 pm)**	**Optimal**
Use of blinds:				
Blinds open	n	1	1	NA
Blinds closed or greater than 50% closed	n	4	4	
Glare:				
Yes, veiling glare on work surface	n	0	0	NA
No glare	n	5	5	
Incident light				
Measured range	lux	270 – 720	240 – 1300	200 – 500
Task lighting				
Use of task lighting	n	2	2	NA
Comfort ratios				
Incident light to background	ratio	0.3 – 3.7	0.2 – 9.8	0.3 – 3
Computer to background		0.1 – 1.2	0.1 – 1.1	0.1 – 10
Morning to afternoon incident light ratio (range)	ratio	0.5 – 1.2		NA

Table 5: Light measurements taken from 3rd floor core workstations.

3rd Floor core (n=5)	**unit**	**1st sample (12:50 – 1:45 pm)**	**2nd sample (4:15 – 4:40 pm)**	**Optimal**
Use of blinds:				
Blinds open	n	0	0	NA
Blinds closed or greater than 50% closed	n	0	0	
Not applicable	n	5	5	
Glare:				
Yes, veiling glare on work surface	n	3	2	NA
No glare	n	2	3	
Incident light				
Measured range	lux	260 – 620	215 – 560	200 – 500
Task lighting				
Use of task lighting	n	2	2	NA
Comfort ratios				
Incident light to background	ratio	2.4 – 6.5	2.6 – 6.3	0.3 – 3
Computer to background		0.8 – 1.8	1.2 – 2.5	0.1 – 10
Morning to afternoon incident light ratio (range)	ratio	1.0 – 1.2		NA

Table 6: Light measurements taken from 5th floor perimeter workstations.

5th Floor perimeter (n=2)	unit	1st sample (2:00 – 2:25 pm)	2nd sample (4:45 – 5:00 pm)	Optimal
Use of blinds:				
Blinds open	n	2	2	NA
Blinds closed or greater than 50% closed	n	0	0	
Glare:				
Yes, veiling glare on work surface	n	1	1	NA
No glare	n	1	1	
Incident light				
Measured range	lux	600 – 2100	765 – 2250	200 – 500
Task lighting				
Use of task lighting	n	0	0	NA
Comfort ratios				
Incident light to background	ratio	0.2 – 5.5	0.5 – 4.8	0.3 – 3
Computer to background		0.1 – 0.8	0.1 – 0.3	0.1 – 10
Morning to afternoon incident light ratio (range)	ratio	0.2 – 0.9		NA

Table 7: Light measurements taken from 5th floor core workstations.

5th Floor core (n=2)	unit	1st sample (9:40 – 10:30 am)	2nd sample (2:50 – 3:30 pm)	Optimal
Use of blinds:				
Blinds open	n	0	0	NA
Blinds closed or greater than 50 % closed	n	0	0	
Not applicable	n	2	2	
Glare:				
Yes, veiling glare on work surface	n	1	1	NA
No glare	n	1	1	
Incident light				
Measured range	lux	170 – 930	180 – 790	300 – 500
Comfort ratios				
Incident light to background	ratio	3.1 – 6.8	4.9 – 7.9	0.3 – 3
Computer to background		1.0 – 1.2	1.8 – 6.5	0.1 – 10
Morning to afternoon incident light ratio (range)	ratio	1.2 – 3.8		NA

Building Performance Evaluation: Lighting

Date: 13-Jul-06

Building: Bldg B 2nd Floor

Position:

Sample 1	2nd Floor SW corner
Sample 2	2nd Floor centre desk S end
Sample 3	2nd Floor SE corner
Sample 4	2nd Floor W side private office
Sample 5	2nd Floor NW near corner
Sample 6	2nd Floor NE near corner
Sample 7	2nd Floor busy road side NE near corner
Sample 8	2nd Floor busy road side NW at corner
Sample 9	2nd Floor busy road side N near centre core at window
Sample 10	2nd Floor centre open office near kitchen
Sample 11	2nd Floor busy road side S at window 1/2 way to end

Notes:

2nd Floor, Building B

1st sample	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10	Sample 11
Time:	11:14	11:30	11:36	11:43	11:52	11:58	12:07	12:17	12:22	12:28	12:39
weather:	cloudy	cloudy	cloudy	cloudy	cloudy	cloudy	sunny breaks	sunny breaks	sunny breaks	sunny breaks	cloudy
fenestration:	closed	NA	90% open	NA	open	open	open	50% closed	open	NA	closed
Incident (lux)	380	205	385	375	380	1280	470	1206	520	300	235
Task lighting	No	No	No	No	No	Yes	No	No	No	No	No
Glare (Y/N)	Yes	Yes	No	No	No	Yes	Yes	No	Yes	Yes	No

Contast:

Comp:bkg	0.5	5.7	0.9	2.3	0.8	0.1	0.4	0.2	0.4	4.0	1.7
Incident:bkg	0.9	5.9	1.8	4.3	1.6	0.9	0.9	0.9	0.9	6.0	2.0

Notes:

Samples 1 & 3 windows on both sides

2nd Floor, Building B

2nd samples	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Sample 10**	**Sample 11**
Time:	3:34	3:40	3:43	3:46	3:48	3:51	4:02	3:59	3:56	4:05	4:08
weather:	sunny	sunny	sunny	sunny	partly cloudy	p/c	p/c	p/c	sunny	sunny	p/c
fenestration:	closed	NA	50% closed	NA	open	open	open	open	open	NA	closed
Incident (lux)	680	160	245	380	371	450	317	830	550	300	245
Glare (Y/N)	No	No	No	No	Yes	Yes	Yes	Yes	Yes	No	No

Contast:

Comp:bkg	0.3	15.0	1.1	0.7	0.5	0.3	0.6	0.2	0.2	3.3	1.0
Incident:bkg	1.5	16.0	1.8	5.0	1.2	1.0	1.9	1.0	0.8	6.7	1.6
AM:PM	0.6	1.3	1.6	1.0	1.0	2.8	1.5	1.5	0.9	1.0	1.0

Notes:

Building Performance Evaluation: Lighting

Date: 13-Jul-06

Building: Bldg B 3rd Floor

Position:

Sample 1	3rd Floor SW corner at window (both sides)
Sample 2	3rd Floor SE corner near window
Sample 3	3rd Floor S centre desk
Sample 4	3rd Floor S centre private office
Sample 5	3rd Floor Centre training room
Sample 6	3rd Floor N end of west arm
Sample 7	3rd Floor busy road side NW
Sample 8	3rd Floor busy road side centre
Sample 9	3rd Floor busy road side SE
Sample 10	3rd Floor busy road side end of arm

Notes:

3rd Floor, Building B

1st sample	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6	Sample 7	Sample 8	Sample 9	Sample 10
Time:	12:52	1:00	1:04	1:10	1:16	1:21	1:29	1:32	1:36	1:44
weather:	cloudy	cloudy	cloudy	cloudy	NA	cloudy	sunny breaks	sunny breaks	sunny breaks	sunny breaks
fenestration:	closed	50% closed	NA	NA	NA	open	50% closed	NA	closed	NA
Incident (lux)	590	270	260	485	385	720	670	400	400	620
Task lighting	No	Yes	Yes	Yes	No	No	No	No	Yes	No
Glare (Y/N)	No	No	No	Yes	No	No	No	Yes	No	Yes

Contast:

Comp:bkg	0.5	0.3	1.8	1.7	1.1	0.3	0.1	0.8	1.2	0.8
Incident:bkg	3.7	0.3	6.5	4.2	2.9	1.5	0.6	3.3	3.1	2.4

Notes:

3rd Floor, Building B

2nd sample	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**	**Sample 5**	**Sample 6**	**Sample 7**	**Sample 8**	**Sample 9**	**Sample 10**
Time:	4:18	4:20	4:22	4:25	4:27	4:29	4:32	4:34	4:41	4:37
weather:	sunny	sunny	sunny	sunny	NA	sunny	sunny	sunny	sunny	sunny
fenestration:	closed	75% closed	NA	NA	NA	open	closed	NA	closed	NA
Incident (lux)	690	240	212	496	397	672	1300	380	322	560
Glare (Y/N)	No	No	No	Yes	No	No	No	Yes	No	No

Contast:

Comp:bkg	0.8	0.1	1.8	1.8	1.2	0.3	0.4	2.5	1.1	1.2
Incident:bkg	2.6	0.2	2.6	4.1	3.2	1.3	1.2	6.3	9.8	4.3
1st : 2nd	0.9	1.1	1.2	1.0	1.0	1.9	0.5	1.1	1.2	1.1

Notes:

Building Performance Evaluation: Lighting

Date: 13-Jul-06

Building: Bldg B 5th Floor

Position:

Sample 1	5th Floor W side overlooking second building, across from photocopier
Sample 2	5th Floor W side centre open office, next to blue wall
Sample 3	5th Floor W side open office, next to red wall
Sample 4	5th Floor W side next to windows facing N

Notes:

5th Floor, Building B

!st sample	Sample 1	Sample 2	Sample 3	Sample 4
Time:	2:02	2:06	2:19	2:22
weather:	sunny breaks	sunny breaks	sunny breaks	sunny breaks
fenestration:	open	NA	NA	open
Incident (lux)	2100	930	171	600
Task lighting	No	Yes	No	No
Glare (Y/N)	Yes	Yes	No	No

Contast:

Comp:bkg	0.8	1.0	1.2	0.1
Incident:bkg	5.5	3.1	6.8	0.2

Notes:

5th Floor, Building B

2nd sample	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**
Time:	4:46	4:48	4:52	4:54
weather:	sunny	sunny	sunny	sunny
fenestration:	open	NA	NA	open
Incident (lux)	2250	790	182	765
Glare (Y/N)	Yes	Yes	No	No

Contast:

Comp:bkg	0.3	1.8	6.5	0.1
Incident:bkg	4.8	4.9	7.9	0.5
1st:2nd	0.9	1.2	3.8	0.2

Notes:

3.3 RESOURCE CONSUMPTION DATA

3.3.1 Energy and Water Consumption Data

The following Table displays the monthly energy consumption in Building B for the January 2003 to December 2004, for gas and electricity. This information was provided by the owner.

The Table also displays the annual water consumption in the building for the years 2001 - 2004.

Building B – Energy and Water Consumption Data

Natural Gas		
Date	1000 kwh	GJ
Jan-03	349.1946	1257
Feb-03	236.9634	853
Mar-03	224.7402	809
Apr-03	165.0132	594
May-03	76.395	275
Jun-03	23.0574	83
Jul-03	11.6676	42
Aug-03	0	0
Sep-03	33.8916	122
Oct-03	111.6756	402
Nov-03	368.085	1325
Dec-03	412.533	1485
Jan-04	495.0396	1782
Feb-04	371.9742	1339
Mar-04	251.9646	907
Apr-04	75.8394	273
May-04	50.004	180
Jun-04	21.6684	78
Jul-04	2.2224	8
Aug-04	6.945	25
Sep-04	54.171	195
Oct-04	91.3962	329
Nov-04	291.1344	1048
Dec-04	466.1484	1678
total 2004 gas (1000kwh):		2178.508
total 2003 (1000 kwh) gas:		2013.217
annual kwh per square foot:		18.06778
kwh/m^2=		194.4863

Electricity		
Date	kwh	1000 kwh
Jan-03	136920	136.92
Feb-03	145740	145.74
Mar-03	134400	134.4
Apr-03	139860	139.86
May-03	126420	126.42
Jun-03	146580	146.58
Jul-03	142800	142.8
Aug-03	148260	148.26
Sep-03	135660	135.66
Oct-03	127260	127.26
Nov-03	133980	133.98
Dec-03	139440	139.44
Jan-04	143430	143.43
Feb-04	143430	143.43
Mar-04	141120	141.12
Apr-04	148260	148.26
May-04	136080	136.08
Jun-04	136920	136.92
Jul-04	142380	142.38
Aug-04	139020	139.02
Sep-04	130620	130.62
Oct-04	119280	119.28
Nov-04	129360	129.36
Dec-04	127680	127.68
total 2004 elect:		1637580
total 2003 elect:		1657320
annual kwh per square foot:		14.20215517
kwh/m^2=		152.8757284

Water		
Date	m^3	L/day/occ
2001	4732	30.33333
2002	5628	36.07692
2003	5107	32.73718
2004	4251	27.25
AVG	4929.5	
	32	**L/day/occ**
Based on	600	Occupants
	260	Workdays/yr

3.4 LIST OF FUNDING ORGANIZATIONS

The following organizations participated in the funding of this Building Performance Evaluation:

- Western Economic Diversification
- Real Estate Foundation
- Industry Canada
- Terasen Gas
- BC Hydro
- Clivus Multrum
- Public Works and General Services Canada
- Greater Vancouver Regional District
- Building B Owner
- Building B Architect
- Building B Mechanical Engineer