Design for Human Comfort Outdoors in Cold Climates, with specific Reference to Winnipeg Transit Stops

By Wing Sze Vince Kok

A practicum submitted to the Faculty of Graduate Studies
in partial fulfillment of the requirements for the Degree of
Master of Landscape Architecture
Department of Landscape Architecture
The University of Manitoba
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THE UNIVERSITY OF MANITOBA

FACULTY OF GRADUATE STUDIES
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Acknowledgment

To my parents and brother

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The practicum committee :
Professor Alan Tate (Department of Landscape Architecture),
Professor Leon Feduniw (Department of Interior Design) and
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Abstract

The purpose of this practicum was to research the optimum conditions for human thermal comfort for outdoor activities in cold climates, with specific reference to transit stops in the City of Winnipeg, Manitoba, Canada. The objectives were to identify the natural, physical and psychological factors that affect human thermal comfort, and how the arrangement of buildings, landscape structures, vegetation and landforms can modify microclimate and achieve conditions which fall within the human comfort zone for outdoor activities. The consideration of human thermal comfort generated the design of a transit stop on Dafoe Road, east of the Music Building and south of the Architecture II Building, at the University of Manitoba, Fort Garry Campus, Winnipeg. The design is intended to improve human comfort and visual quality of the site. The future development of the proposed site and an alternative design of a transit passenger shelter was conducted from extensive studies of transit stops and passenger shelters in Winnipeg. The passenger shelter prototype, which was designed for Winnipeg Transit System, replaced the existing bus shelter on the site in March 2001. The existing bus shelter was retro-fitted with a radiant floor heating system, a radiant-heated bench, and solar powered lighting and ventilating system. The University of Manitoba will provide maintenance support for the prototype and Professor Leon Feduniw and his students will monitor the efficiency of the thermal performance of the shelter.

Introduction

A comfortable outdoor space is a landscape design that can use renewable energy efficiently. The landscape elements, planting materials and overall design utilize passive energy systems and response to site conditions in ways to improve human comfort and visual quality of an outdoor space.

The profession of landscape architecture uses design strategies to integrate technology, natural environment, climate, and context of site and their effect on human comfort in creating outdoor spaces that people can enjoy and in which they feel comfortable and secure. Creating landscape design that can respond to climatic conditions to improve human thermal comfort, visual quality and enhance interactions between humans and outdoor environment is the goal of landscape architect.

As landscape architects, how can we create a comfortable outdoor space that can be used by people as part of their daily life? This question raises several possibilities for the landscape design (see Figures I to III, Pages 5 -6).

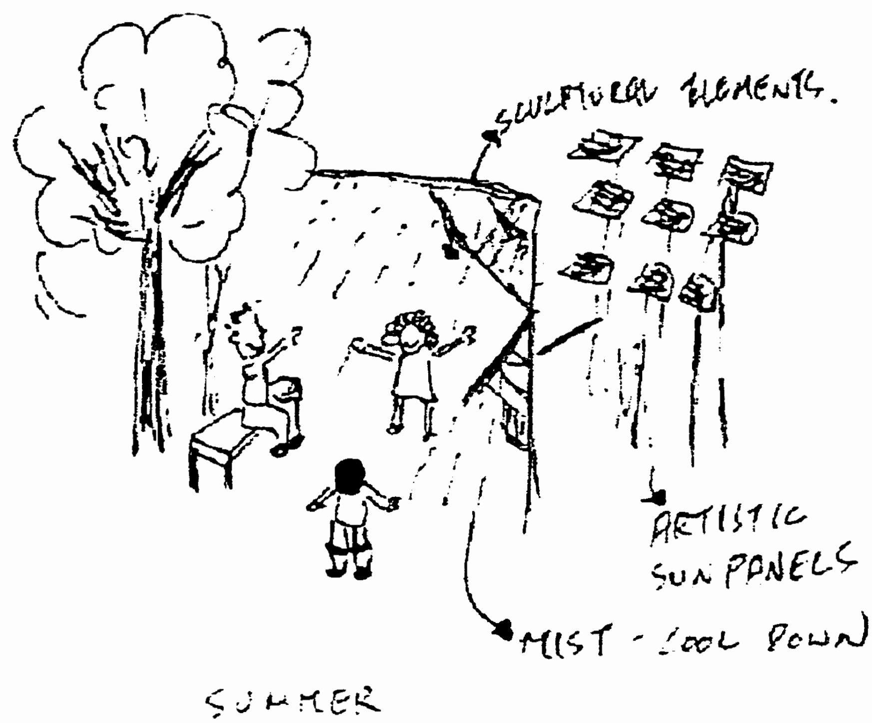


Figure I: Idea about the use of solar energy for cooling system in outdoor space.

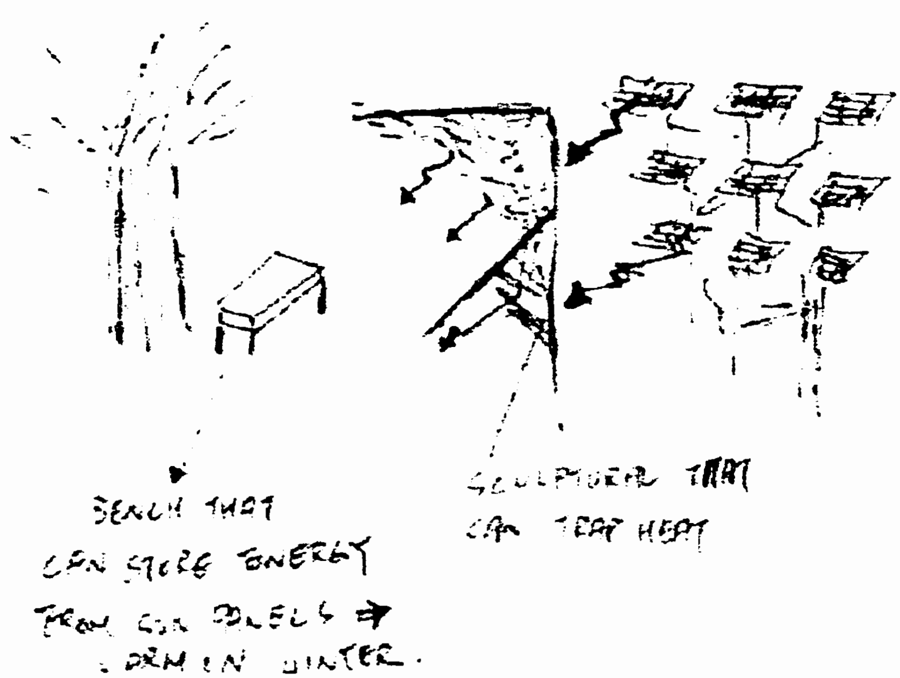


Figure II: Idea about the use of solar energy for heating systems in outdoor space and landscape elements, such as a self-heating bench.

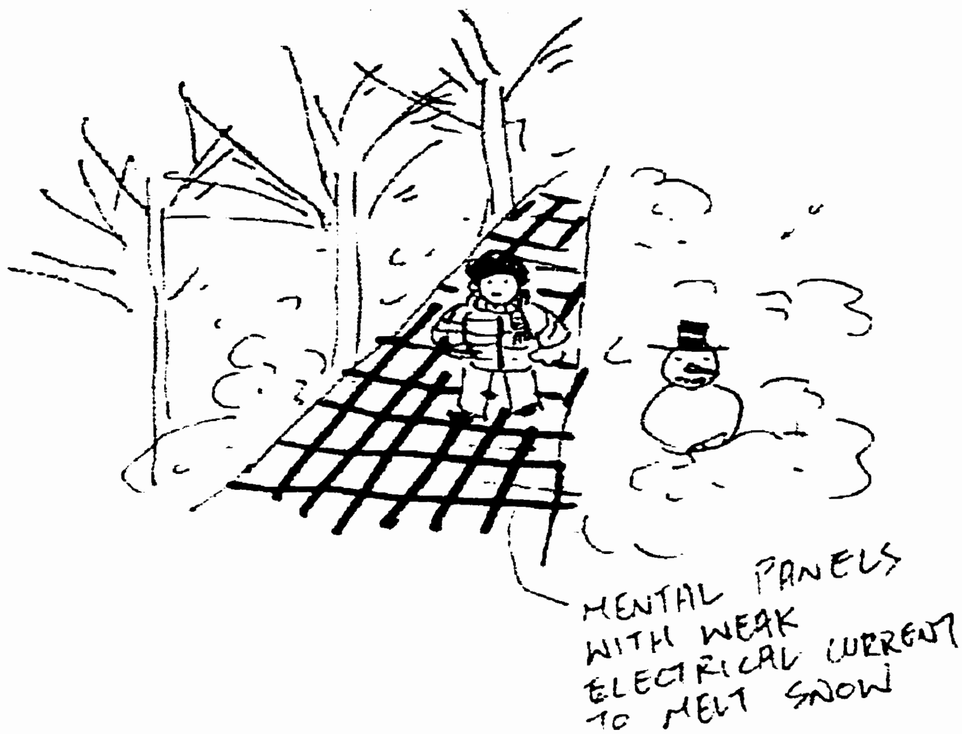


Figure III: Idea about the use of solar energy to provide weak electrical current to melt snow on sidewalks.

It is uncomfortably cold during the winter in Winnipeg, especially when taking the bus and waiting inside a cold passenger shelter. It is possible to have shelters with benches inside that have warm ambient air temperatures to address human thermal comfort. Also, the landscape design of a transit stop can reduce unfavorable climatic conditions by careful planning of landscape elements and vegetation. There is the potential to add new dimensions to landscape design by integrating state of the art technology with passive environmental strategies to fulfil social needs, in both ecological and aesthetic terms.

The purpose of this practicum was to design a passenger shelter that is integrated with its landscape setting. As a landscape architecture student with a background in creating sculpture and environmental art, my knowledge allows me to consider how the methods to capture natural energy, the use of materials, structures and the orientations of objects in space could not only respond to human habitation, but also to the inner feelings of people – how can people perceive, interpret and generate a sense of place.

The basic function of a transit stop is to protect passengers against unfavorable climatic conditions such as wind, sun, rain and snow, and to provide a safe and pleasant environment. In a winter city like Winnipeg, a good transit stop design can improve human comfort and encourage people to use the public transit system all year around. Existing passenger shelter designs are not effective in providing protection for passengers against wind and cold climate. Also, a shelter that can utilize renewable energy can save energy costs and reduce set-up costs for connecting electricity from other sources. Furthermore, a good design can enhance the city's image by being a unique solution to Winnipeg's extreme climatic conditions.

The objectives for this project, are: to identify ambient conditions required for human thermal comfort, especially in cold climatic conditions; to examine existing transit stops and passenger shelters in Winnipeg; to analyses proposed site at the University of Manitoba; to design a transit stop in a sensitive response to the microclimate and contexts of the site; to review the existing design of the passenger shelter and to design a solar-powered passenger shelter prototype. With the help and support of the Winnipeg Transit System, this practicum developed a prototype passenger shelter design and setting for the City of Winnipeg.

This practicum will introduce new ideas to the Winnipeg Transit System to improve the quality of passenger shelters in terms of improving human thermal comfort, and in providing a secure and comfortable environment for passengers; as well as saving electrical energy and reducing operating costs. The transit stop design will be an innovation for the City of Winnipeg with its cold climate conditions.

Chapter 1: Landscape, renewable energy and technology

Currently there are many building that use high-end technologies and renewable sources to generate energy. These buildings use self-regulating systems that work with nature. If these systems can work for buildings, why not also for landscapes or external spaces?

In landscape design, we are not only creating an interaction between outdoor and indoor spaces, but also between physical and spiritual aspects of users, and our relationship with nature. Interactions between humans and outdoor space can help users to discover and enjoy outdoor space and not be overwhelmed by technology. As landscape architects, we can use technologies that work with natural forces and create comfortable outdoor spaces that make users feel secure and comfortable and, most important, to create designs that can reduce energy consumption by responding to the changes within environments.

In order to study the design of landscape elements and how those elements can interact in outdoor space, the starting point for this research was to collect inspirations from some existing art works around the world.

Today, our living, learning and working environments are significantly influenced by computers, cyber-technology and advanced technology. How can we relocate technologies into the deeper structure of cultural and social conditions, and our relationship with the landscape in order to create an comfortable living environment? Krzysztof Wodiczko, an artist based in New York, said: " Modern design is often supposed to resolve a problem but in reality it becomes a facade behind which the actual problem is hidden so that there is only a superficial answer to it. Technology as a technical opportunity and design as the relation between this opportunity and the world of needs." [1] His statement and art works like those shown in Figures 1.1–1.4 (Pages 10 - 11) open up a number of questions for landscape architects -- how can we observe and reveal the unconscious needs of society? How can we re-discover the joy of walking on the streets and enjoy outdoor space again? How can we use both old and new technologies to improve the quality of the outdoor space?

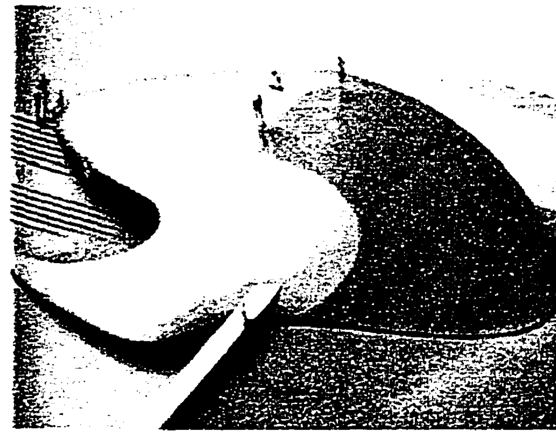


Figure 1.1: *Parascape* is both a sculpture and landscape in Rotterdam, Netherlands. The sculpture absorbs sound from the environment. When speaking visitors stroll by, it starts mumbling.

Source: Oosterhuis, K. (1998). Digital life form. A + U, 334, 109.

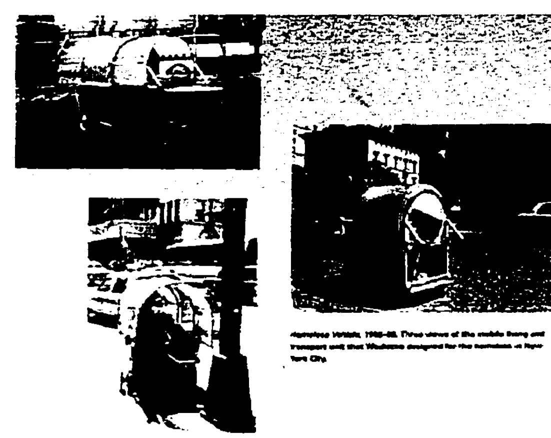


Figure 1.2: Krzysztof Wodiczko. *Homeless Vehicle.* (1988-89). Three views of the mobile living and transport unit that Wodiczko designed for the homeless in New York City.

Source: Paul, C. (1999) The prophet's prosthesis. Sculpture, vol. 18, No. 4, 36.

Figure 1.3 Mariko Mori. *Initiation* (1997), Toronto. This billboard was integrated into the visual life of the city.

Source: Bronson, AA. Accidental encounters with art. <u>International Contemporary Art, Vol. 53,</u> 38.

Figure 1.4: Chrysanne Stathacos. *Wish Machine* (1997), Brooklyn. This vending machine was wrapped in colour photograph of a wishing tree, dispensing natural oils, images, etc. This piece participated in the active life of a city rather than forming part of its structure.

Source: Bronson, AA. Accidental encounters with art. <u>International Contemporary Art, Vol. 53,</u> 38.

These works reflect un-noticeable details of societies that we ignore when we are walking on the streets everyday, and prompt us to think about the relationships between technology, culture, urban contexts and the landscape. Old technology, such as the use of solar and wind energy, can be used to create comfortable outdoor environments with the help of modern technology. The interaction between old and new technologies can add a new dimension to landscape design without ignoring nature and social needs.

The design of *City Hall Plaza Park* (1990, Hargreaves Associates) in San Jose, USA, refers to the cultural and urban contexts of the city (see Figures 1.5 - 1.6). The trees are planted on a grid that refers to the agricultural heritage of the city. The fountain and fountain jets are metaphors for the growth of high-tech firms in the nearby Silicon Valley and to the artesian wells of the city.[2] The fountain responds to changes in phenomena such as wind, time of day and the movement of people. This park displays how technology can harmonize landscape designs with their urban context.

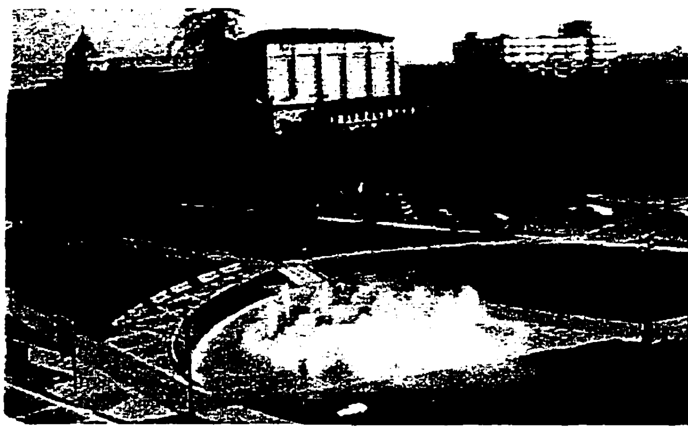


Figure 1.5: Figures 1.5 &1.6 show the fountain in *City Hall Plaza Park* in San Jose, USA

Source: CLIP: Contemporary Landscape Inquiry Project. (No date). City Hall Plaza Park. [On line]. Available: Http://www.clr.utoronto.ca/cgi-bin/clrdb./VIRTU.../clipadd?DB.REPORT=full&DB.RECORD=5 [2000, May 8].

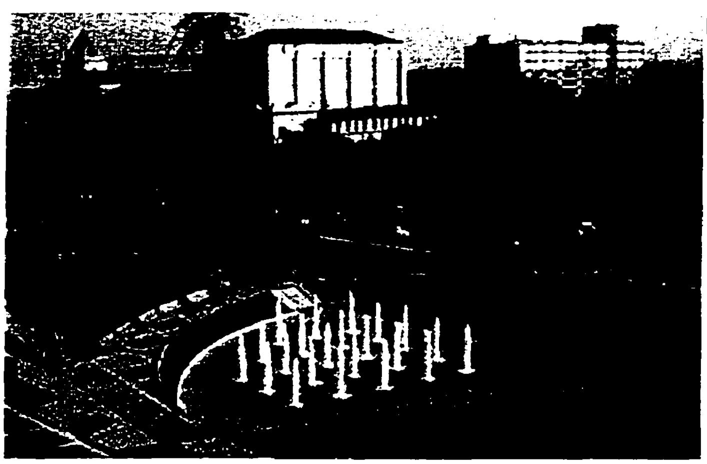


Figure 1.6

In Nagoya City, Japan, a waterscape design by Taisei Kensetsu co. Ltd, (Nagoya Branch) demonstrates modern design and technology combined with natural systems and history in a riverside location. The project consists of a water monument, the Yamazaki Riverside, the green walk of Suido Michi, which is designed to explain how the drinking water of Nagoya is made, and the water square on Wakamiya Avenue, where the space under the highway is utilized as a water sculpture park.[3] (see Figures 1.7 - 1.8)

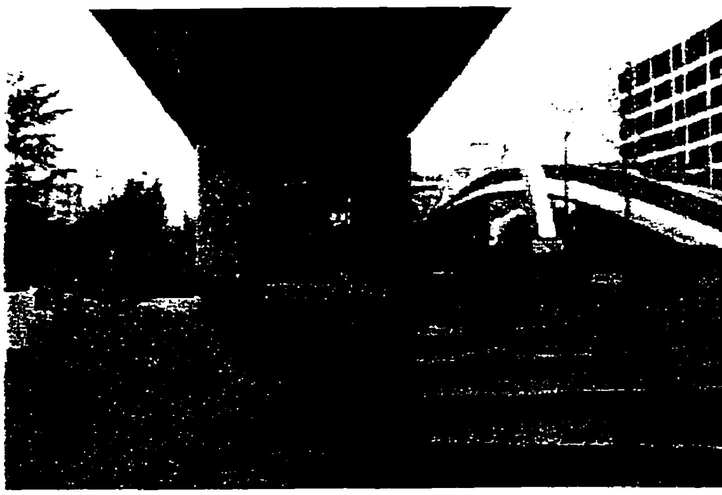


Figure 1.7 Water sculpture *Wave Weaving* on Wakamiya Avenue, Nagoya City, Japan

Source: New Images Publishing Ltd. (Editor). (1982). Elements and total concept of urban waterscape design. Taiwan: New Images Publishing Ltd. 55.

Figure 1.8: Water sculpture *Wave Weaving* at night. The designer stated that :" water splashes through space which becomes flows and waves. The sculpture starts to move by the flow of water. Water fosters all life and gives peace to human hearts in the park."

Source: New Images Publishing Ltd. (Editor). (1982). Elements and total concept of urban waterscape design. Taiwan: New Images Publishing Ltd. 55.

The above examples imply that technologies are a 'new set of clothes' to landscape architecture. They should be integrated functionally, ecologically and aesthetically with the natural characteristics of a site and with the cultural and historical characteristics of the societies for whom they are designed. Also, there are increasing possibilities for the use of renewable energy in urban development in order to create human thermal comfort in outdoor spaces. For example, there is a pedestrian based, temperature controlled urban environment in the *Millennium Village* in Greenwich.[4] Between the years 2000 and 2025, *Eco-Media Cities* will be developed in Kuala Lumpur in Malaysia, Shenzhen in mainland China and at Chubu in Japan, that will use bio-electronics, bio-sensors and bio-reactors to monitor environmental changes and set up optimal living conditions.[5] Also, in Sydney, Australia, there was a solar-powered *Athletes' Village* for the 2000 Olympic games.[6] We need to understand that the use of technology in landscape design should be integrated with the landscape, not just seen as technological innovation.

Kim Sorvig, a research professor in architecture and planning at the University of New Mexico, stated that, "plants, water bodies, clouds, wind and landforms, all play major roles in transforming solar energy so people can use it..........how landscape processes help generate energy and how energy-generating facilities shape or misshape the landscape." [7] As landscape architects, we need to relate renewable energy and technology to landscape in order to use landscape as an energy transformers to utilize energy.

The *Living Energy Center* proposal for Bien Hoa, Vietnam by Mark Sorensen and Mark von Wodtke; the *Institute for Regenerative Studies* in Pomana, USA (1993) by John Lyle and the California State Polytechnic University, and the *Real Goods Trading Corporation's Solar Living Center* by Land and Place, Booneville, California and Sin van der Ryn Architect, Sausalito, California are projects that demonstrate how landscape designs can address global issues such as dependence upon fossil fuels and other non-renewable energy, pollution and lack of recreational spaces. Also these designs can educate the public in how to use renewable energy wisely through the employment of old and new technologies.

The theory of the proposal for *Living Energy Center* in Bien Hoa, Vietnam is to introduce "landscape as energy transformers."[8] The proposal is based on the principle that one component in the landscape can produce energy for other components of the landscape. The proposal would cover roofs of buildings with photovoltaic (PV) cells, from which energy would be used for other components. Also the proposal would dedicate 6.5 hectares (16 acres) for arrays of PV panels, which would integrate with crop-land and irrigation channels (see Figures 1.9 & 1.10, Page 16).[9] Daytime excess energy from PV cells would run an electrolyzer to change water to hydrogen; stored hydrogen would run fuel cells for night electricity. Also, the methane which is collected from decomposing crop wastes and sewage would be used to drive microturbine generators (see Figure1.10, Page 16). These are effective 'hybrid' systems and well integrated in landscape.

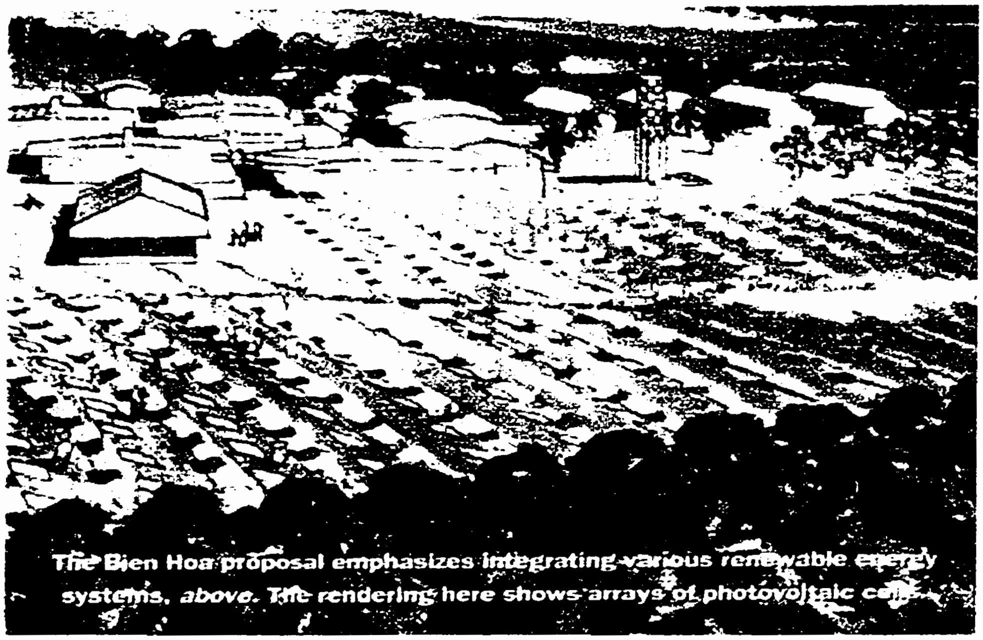


Figure 1.9: *Living Energy Center* in Bien Hoa, Vietnam, emphasizes integrating various renewable energy system. This picture shows arrays of photovoltaic cells.

Source: Sorvig, K. (2000). Landscapes for sustainable energy. Landscape Architecture, Vol. 90, No. 6, 48.

Energy production at the *Institute for Regenerative Studies* (see Figure 1.11) is

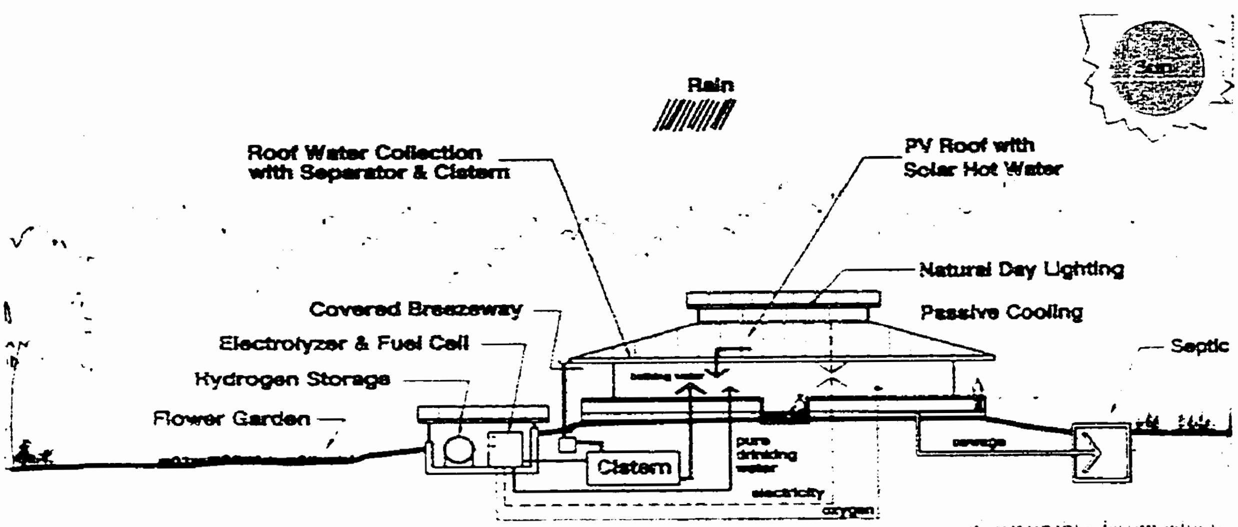


Figure 1.10: The proposal for Bien Hoa would cover the roof with photovoltaic cells , from which the energy would be used for other components in the design.

Source: Sorvig, K. (2000). Landscapes for sustainable energy. Landscape Architecture, Vol. 90, No. 6, provided by solar collectors, ethanol and methanol fuels, and wind generators. Transportation is provided by solar powered golf carts. The goals of the center are: a) to develop and research new technologies, b) to integrate the new technologies in order to provide more energy output while reducing waste, c) to demonstrate the benefits of these types of technologies to the public.[10]

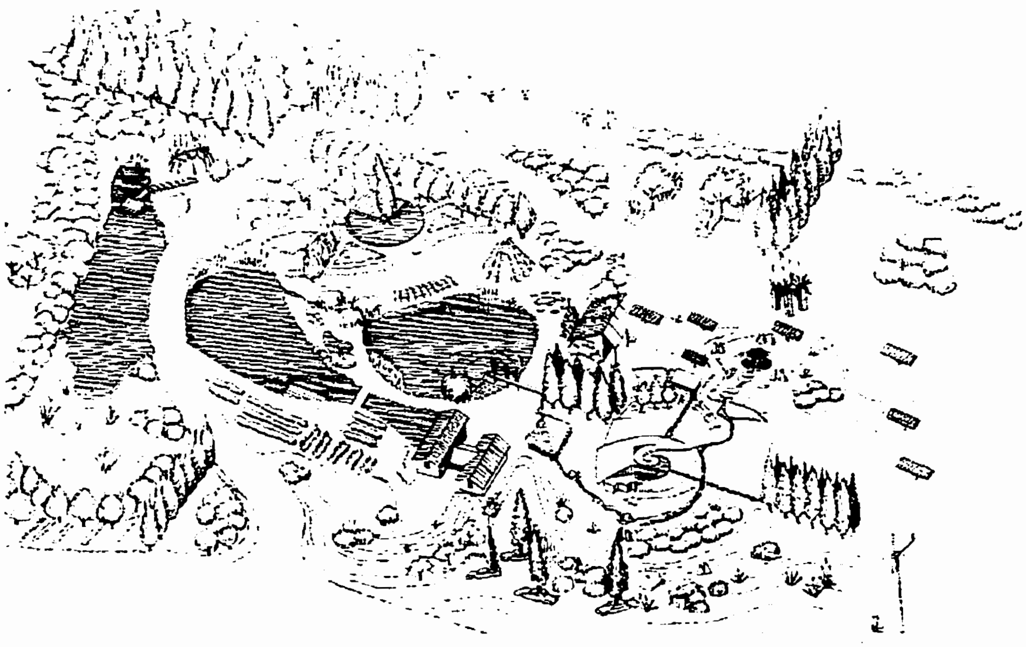
Figure 1.11: Institute for Regenerative Studies.

Source: CLIP: Contemporary Landscape Inquiry Project. (No date). Institute for Regenerative Studies. [On line]. Available: Http://www.clr.utoronto.ca:1080/cgi-bin/cl.../CLIP/clipadd?DB.REPORT=full&DB.RECORD=153 [1999, September 20].

John Schaeffer, founder and CEO of the *Real Goods Trading Corporation* (a corporation which promotes and sells alternative energy systems), tried to expand its mission beyond "trying to change the world by selling gadgets'" to "trying to change the world by actually changing the world." , by building a *Solar Living Center.* The center displays how planting materials, systems aquifer recharger, gray water recycler and native landscape celebration, can be designed according to the landforms and position of the sun (see Figure1.12). Also, the sculptures created from native planting materials and recycled materials, respond to the site's context, landform and the sun (see Figures 1.13 & 1.14, Page 19). Altogether, the center is highly functional as a recreational and educational space. The design serves the purpose that Schaeffer wanted – to re-examine the way we live now and to seek new ways to live.

Figure 1.12: The plan of *Solar Living Center.* The center was organized into two areas, separated by the building in the middle. The courtyard, to the right, and the pastoral landscape, to the left, are structural compositions of trees that correspond to the directions of the sun that demonstrate an understanding of the natural processes that create the design.

Source: Bennett, P. (2000). A place in the sun. Landscape Architecture, Vol. 90, No. 1, 61.



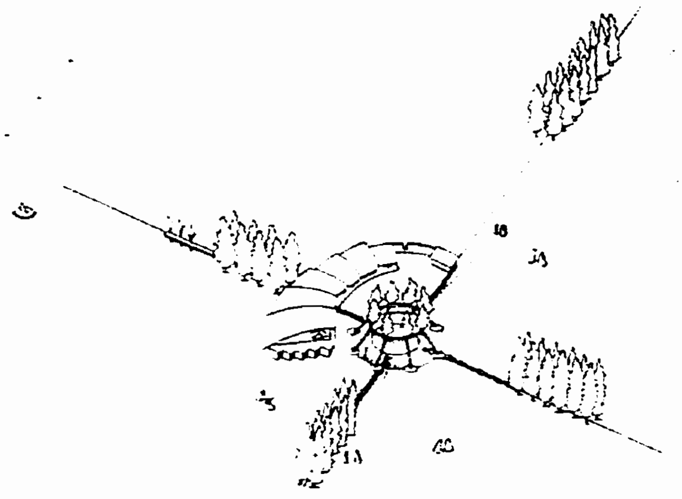


Figure 1.13: The symbol of the *Solar Living Center* is a large steel ring that serves as the heart of an ecological sundial. Pairs of rough-hewn, upright stones and a cleft in the wall, mark the sunrises and sunsets at various times of year.

Source: O'Connell, K. A. (2000). Mapping the sun. Landscape Architecture, Vol. 90, No. 1, 20.

Figure 1.14: *Memorial Car Grove* is one of the living sculptures at the *Solar Living Center.*

Source: Bennett, P. (2000). A place in the sun. Landscape Architecture, Vol. 90, No. 1, 60.

The above examples demonstrate that we have a choice as to the way we live with the respect to the consumption of non-renewable resources and other related issues.

One landscape element common to every North American city is the passenger shelter. There are passenger shelter designs in Phoenix (see Figure 1.15) and another in Minneapolis, USA, that use photovoltaic (PV) energy to provide electricity for lighting and cooling systems. In Europe there are passenger shelter designs which demonstrate that a functional passenger shelter does not have to be boring. In Basel, Switzerland, architects from around the world designed nine passenger shelters that fit into the urban context (see Figures 1.16 & 1.17, Page 21), enhancing the visual quality of the streets in which they are located. In Germany and in Britain, there are passenger shelters with computer and radar systems linked to buses in order to provide arrival information for passengers (see Figures 1.18 - 1.21, Pages 21 - 22).

The purpose of this practicum is to demonstrate that passenger shelters in Winnipeg, like these examples, can be attractive and functional, and can utilize solar energy and be integrated with their surroundings to enhance human thermal comfort at transit stops.

Figure 1.15: A passenger shelter in Phoenix, USA. The photovoltaic panel on the roof of the shelter provide electricity for lighting and cooling systems. Mist is emitted to cool off the waiting passengers when the temperature is too high.

Source unknown.

Figure 1.16: A passenger shelter design by Frank O. Gehry at Braunschweiger Platz, Hannover. The roof is composed by sheet iron which allows daylight to be part of the construction. B.J. Arche commented on this design, "the bus stop looks like some friendly armadillo stooped in its tracks to wait for humans to gather under its woven skin.....Frank break the code of the urban waiting room and makes it seem like a canopy one might find in a rain forest."

Source: BUSSTOPS: Frank O. Gehry. [On line]. Available: Http://www.uestra.de/busstops/gehry.html [1999, September 11]

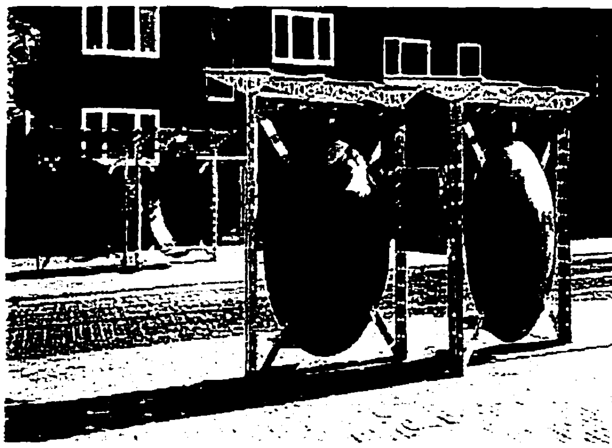


Figure 1.17: This train stop is located at Haltestelle NieschlagstraBe, Hannover. Wolfgang Laubersheimer developed the form of this stop around the communications principle of a whispering gallery, a domed room in which the words whispered at one place can be heard at a place a particular distance away, transported by reflection. He used spherical segments placed opposite to one another and it is possible for people to talk to each other while sitting yards apart waiting for different trains.

Source: BUSSTOPS: Wolfgang Laubersheimer. (On line). Available: Http://www.uestra.de/busstops/lauber.html [1999, September 11].

Figure 1.18: A data supply system with current data information from MABEG Cooperation in Germany. The bus transmits its location to the central headquarters via data transmission. The central headquarters then forwards the departure times calculated from this to the information columns via a permanent telephone line to the information panels.

Source: Catalog from MABEG. address: Ferdinand-Gabriel - Weg 10 D-59494 Soest.

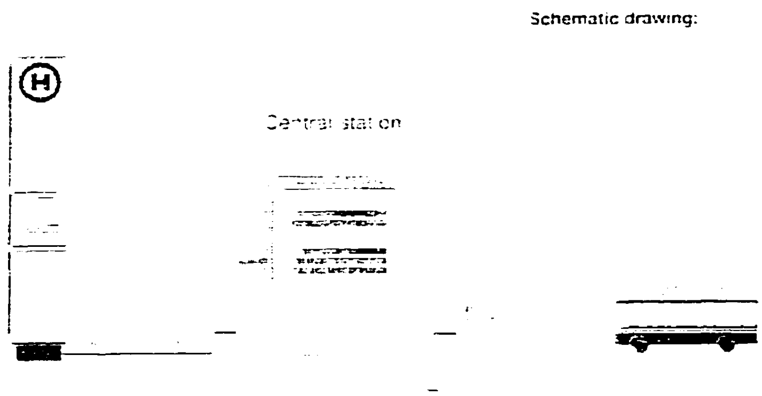


Figure 1.19: Schematic drawing of the data supply system.

Source : Catalog from MABEG. address: Ferdinand-Gabriel - Weg 10 D-59494 Soest.

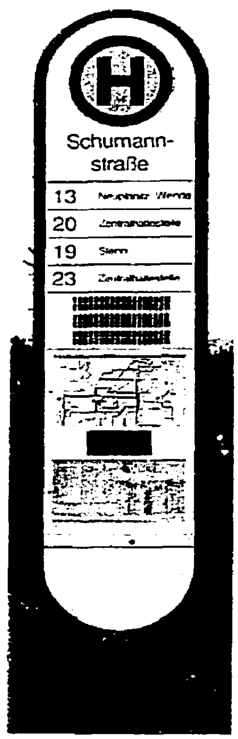


Figure 1.20: Electric timetable with solar supply by MABEG cooperation.

Source: MABEG catalog, address: Ferdinand-Gabriel - Weg 10 D-59494 Soest.

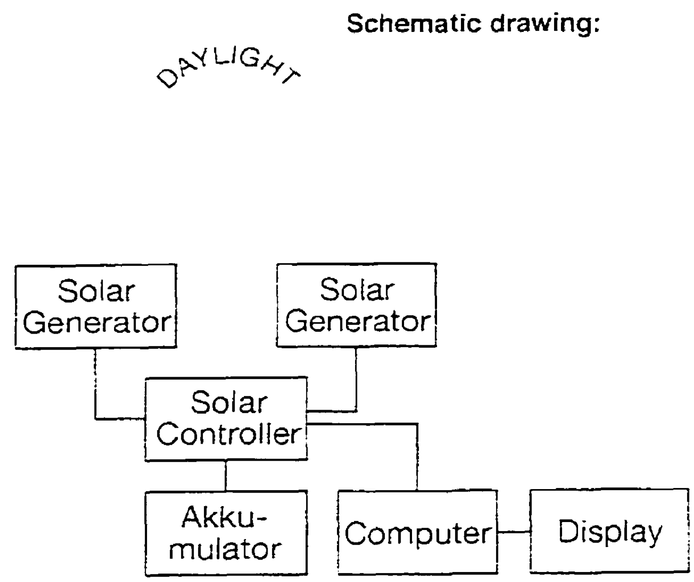


Figure 1.21: Schematic drawing of the electric timetable with solar supply. The timetable is continuously displayed during the daytime; while at night, the display is shown with back-lighting at the press of a button. When no more buses are running during the night, the timetable display is automatically switched off.

Source: MABEG catalog. address: Ferdinand-Gabriel - Weg 10 D-59494 Soest.

Endnotes for Chapter 1

1.Paul, C. (1999). The Prophet's Prosthesis. Sculpture, Vol. 18, No. 4, 37.

2. CLIP: Contemporary Landscape Inquiry Project. (No date). City Hall Plaza Park.
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7.Sorvig, K. (2000). Landscapes for sustainable energy. Landscape Architecture, Vol. 90, No. 6, 50.

8.Ibid, 50.

9.Ibid, 52.

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Http://www.clr.utoronto.ca:1080/cgi-bin/cl.../CLIP/clipadd?DB.REPORT=full&DB.RECORD=153
[1999, September 20].

Chapter 2: Solar Energy and Human Thermal Comfort in Landscape Design

2.1 Brief History of Solar System Development

It is reasonable to associate solar energy with intelligent outdoor space because, as the Science Council of Canada has indicated, while the sun generates power at a rate of 3.8×10^{23} KW, only 1.1×10^{14} KW reaches the earth' s surface . This amount of energy is more than enough to meet the world's current and future energy needs. If only ten percent of this energy were used, it would provide the same amount of electrical power as the present generating capacity of the United States.[1] In Manitoba, Canada, the direct solar radiation received is equal to almost two billion terajoules of energy per year. If only one percent of this energy was converted into electricity it would be equal to almost 200 times the annual output of all the hydroelectric dams in Manitoba.[2] There is good reason to utilize this free and clean renewable energy as the world is looking for an inexhaustible, cheap and clean energy sources to replace non-renewable energy sources such as fossil fuels.

All living creatures are dependent on the energy of the sun. Human-beings have consciously utilized solar energy from as early as 500 B.C. Augustin Mouchot (1860), a French pioneer in solar-powered machinery, stated that: "One must not believe, despite the silence of modern writing, that the idea of using solar heat for mechanical operations is recent. On the contrary, one must recognize that this idea is very ancient and in its slow development across the centuries it has given birth to various curious devices."[3] Ancient Greeks used passive solar systems in housing developments in the 5th century B.C. after Socrates realized that there was a shortage of fuel. The prehistoric structures of Arizona and Southwest America also utilized solar energy in their cliff dwelling designs; they built them in response to climate and cultural standards and their need for adequate shelter.[4]

The history of recent solar power development is associated with an awareness of the global shortage of non-renewable resources. In the 16th and 17th centuries A.D. there were great investments in solar energy to meet the needs of the horticulture and agriculture industries (see Figure 2.1). Research on titling angles and heat-trapping materials for greenhouses became the foundation for the solar technology of today (see Figure 2.2). The Industrial Revolution was another productive period for investment in solar technologies due to shortage of fuels. The 'hot box' invented by French-Swiss scientist Horace de Saussure in 1767 and other solar-powered devices created by Augustin Mouchot in this period became the prototypes for solar collectors after the late 19th and 20th centuries (see Figure 2.3).

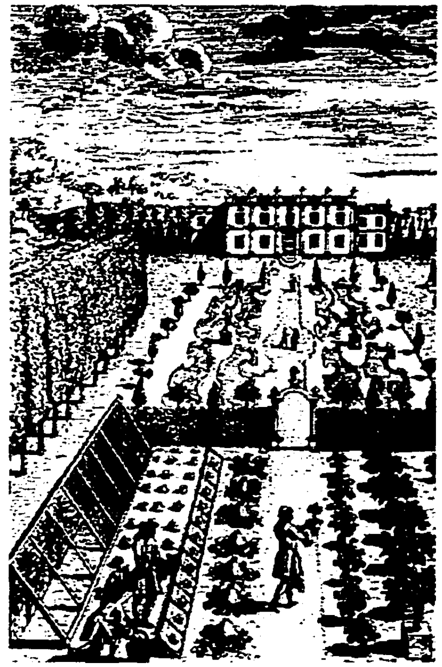

Figure 2.1: English horticulturalists commonly used glass"cold frames" to extend the growing season. Source: Butti. K, & Perkub, J. (1980). <u>A golden thread: 2500 years of solar architecture and technology.</u> Palo Alto, CA. : Cheshire Books. 46.

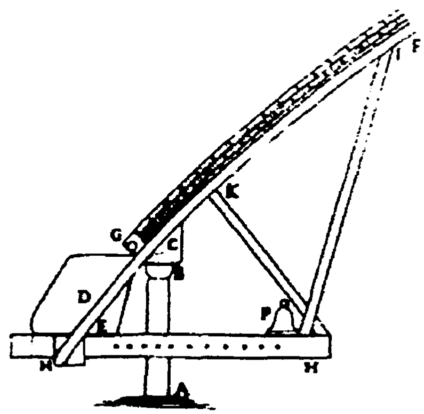

Figure 2. 2: Fatio de Duillier's sun tracking fruit wall in 1699. It pivoted about the A-B axis and followed the sun's daily motion across the sky. Source: Butti. K, & Perkub, J. (1980). <u>A golden thread: 2500 years of solar architecture and technology.</u> Palo Alto, CA. : Cheshire Books. 46.

In 1839, French physicist Edmund Becquerel discovered that when sunlight is absorbed by certain materials it can produce electricity. The terms 'solar cell' and 'photovoltaic' came into use and solar technologies in today's world were influenced by Becquerel's research. In 1889, the first solar cell was invented by Charles Fritts. This was made of selenium and gold film. In 1954, when purification techniques for semiconductors were improved, a breakthrough in solar cell technology was made by Calvin Fuller, Gordon Pearson and Darryl Chapin from Bell Telephone Laboratories to meet the needs of the emerging space program. They invented the first silicon solar cell in 1954 and by 1958 a small silicon array was used to supply electrical power to a U.S. satellite.[5] Their invention is still the backbone of solar technology today. Photovoltaic technology continues to have many applications that reduce the consumption of non-renewable energy.

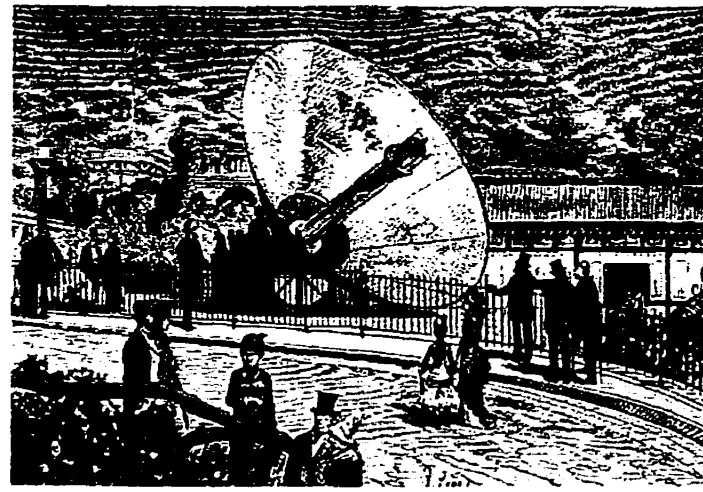

Figure 2. 3: Mouchot's largest sun machine on display at the Universal Exposition in Paris, 1878.
Source:Butti. K, & Perkub, J. (1980). A golden thread: 2500 years of solar architecture and technology. Palo Alto, CA. : Cheshire Books. 62.

Improved technology in photovoltaic (PV) panels allows systems to operate more efficiently with less expense. The possibility of PV- powered houses, automobiles, aircrafts and other similar applications was increased significantly.

In New York, architects Gregory Kiss and Nicholas Goldsmith designed a number of solar-collecting structures for outdoor locations. The *Solar Tensile/ Pavilion* (see Figure 2.4) uses its thin-film photovoltaic technology to generate electricity for ventilation and lighting systems. Kiss and Goldsmith also designed a *Solar Time Piece* (see Figure 2.5) which consisted of 12 chairs arranged in a 25' diameter circle and served both as a sun-dial and sun clock. Their sculptures demonstrate how solar technology can be artistic but, they did not demonstrate how this technology can be integrated into its landscape and how comfortable the environment is in the *Solar Tensile / Pavilion.*

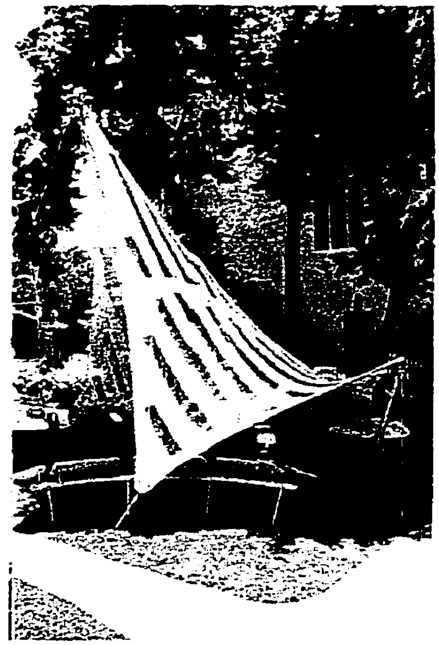

Figure 2.4: *The Solar Tensile [tent] Pavilion* can be rolled up and moved to another location.

Source: Solar U PVG Record. (Fall, 1998). Design museum puts solar on exhibit. [On line]. Available: Http://www.ttcorp.com/upvg/record/rc298ndm.html [1999, October 30].

Landscape architects are not only putting PV systems into landscape design. They are also considering the need to create environments that are within the human thermal comfort zone. Understanding how natural energy relates to human comfort and how human bodies react to different climatic conditions are important considerations in landscape design.

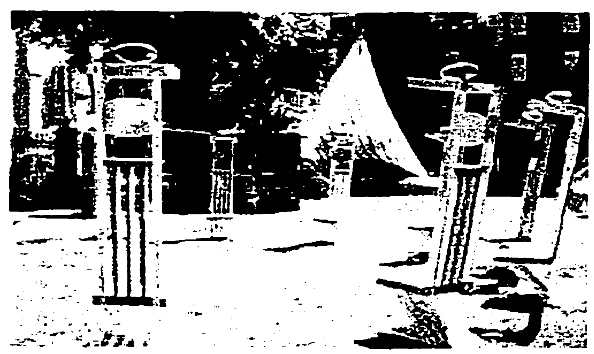

Figure 2.5: *Solar Time Piece*

Source: Solar UPVG Record. (Fall, 1998). Design museum puts solar on exhibit. [On line]. Available: Http://www.ttcorp.com/upvg/record/rc298ndm.html [1999, October 30].

2.2 Landscape design and human comfort

From both Chinese and western points of view, it is essential to understand how humans can utilize natural energy and orient settings to enhance human comfort, physically and psychologically, in both indoor and outdoor spaces.

The Chinese established the 'art of placement' - Feng Shui - about 7000 years ago, or possibly earlier, to identify the ways in which natural energy behaved and how energy affects humans.[6] The Chinese ideograms Feng and Shui mean wind and water. Together they symbolize the manipulation and utilization of the movement of energy from the universe. This practice takes into account the physical arrangement of cities, homes and workplaces; the internal arrangement of cities, homes, gardens and workplaces. It influences the timing of construction and other human activities; the shape, dimension and colour of structures and other materials; the magnetism of the polarities of the universe and humans, and the pervasive energy of the universe.[7] All of these aspects affect the establishment of favorable locations for human habitations and the confluence of forces for healthy, well-balanced living.

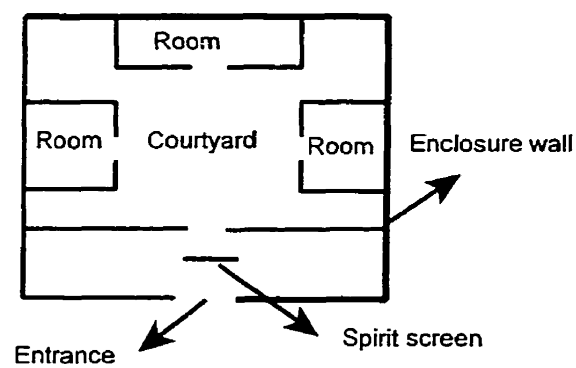

Figure 2.6: A traditional Chinese compound.

Source: Rossbach, S. (1983). Feng Shui The Chinese art of placement. New York: Penguin Books USA Inc. 75.

The traditional Chinese house compound (see Figure 2.6) represents a universe in itself. An enclosed courtyard depicts all nature in microcosm, where rocks can represent mountains and fish pools can represent oceans. The U-shaped enclosure wall of the compound mimics the dragon-tortoise-tiger armchair hill that protects the center of the house and provides a sense of security. The design turned inhabitants away form roads and from other people and, by virtue of its southerly orientation, is supplied a steady influx of solar energy and ventilation.[8]

From the modern western perspective, Kevin Lynch, a former professor of city planning at MIT, stated that: "Site planning is the art of arranging structures on the land and shaping the spaces between, an art linked to architecture, engineering, landscape architecture, and city planning. Its aim is moral and esthetic: to make places which enhance everyday life - which liberate their inhabitants and give them a sense of the world they live in."[9], Lynch also stated that "In nature, an integrated landscape is shaped by the consistent impact of well-balanced forces. In art, it is the result of comprehensive purpose skillfully applied."[10] As landscape architects, we should make outdoor space comfortable for people to enjoy by manipulating landscape elements and by utilizing natural energy to enhance human thermal comfort. The methods of capturing natural energy, the use of materials, structures and orientations of objects in space should not only respond to human habitation, but also to the inner feelings of people – how people perceive, interpret and generate a sense of place.

In a "winter city "like Winnipeg, the extremely cold and windy conditions make outdoor activities difficult. Nevertheless, people go outdoors to perform their daily routines such as going to work, to school or to shop. It is therefore critical to maintain human thermal comfort in outdoor spaces. The visual quality of space also affects psychological feelings and the willingness of people to go outdoors. Pedestrian walkways, public transportation waiting areas and parking areas with minimal negative climatic factors and sensitive landscape design can encourage people to go outside more often. In addition to daily routines, people go outdoors for relaxation and recreation. The design of parks and other outdoor activity areas should therefore provide protection for humans against adverse weather impacts. It is especially important to use landform, shelter belt planting and other types of barrier to reduce the effects on human comfort of the coldest (north-westerly) winter winds. Equally, designs should aim to a) reduce the impact of flowing downward (heavier) cold air masses into lower - lying areas, b) orient activities towards the south, thereby increasing exposure to the sun's warmth.

In summer, human thermal comfort can be enhanced by optimizing passive ventilation systems by increasing air movement for effective cooling. Careful planning and arrangement of vegetation can reduce the intensity of solar radiation reaching the ground. It can also help to reduce the impact of rain and hail and to provide shade. Similarly, seasonal changes in the colors of different plants can be used to advantage and the appropriate choice of different colors and textures of plants, paving materials and landscape structures can affect solar gain and heat radiation as well as creating visual qualities that increase the sense of identity and place.

Lynch stated that: " places should have a clear perceptual identity: be recognizable, memorable, vivid, engaging of our attention."[11] A successful outdoor space is determined by how people interact with the elements of the place, how they perceive it and how thermally comfortable they are within a place.

2.2.1 Human comfort zone

"An understanding of the thermal environment can best be developed by considering how it influences the ability of the human body to maintain a suitable rate of heat loss. Comfort may be regarded both physically and physiologically as a condition of thermal neutrality under which the body need not strain to reduce or increase heat loss."[12]

The human comfort zone is defined as:

> "those temperature and humidity conditions where 50% or more people feel comfortable."[13]

The human body produces about 250 BTU/hr[a] of excess heat during sleep and as much as 4400 Btu/hr when working or exercising. This excess heat must be dissipated to the ambient environment. Heat transfer from the human body to the environment is by radiation (67%), evaporation (23%) , conduction (10%), at an air temperature about 21°C (70°F), under conditions of still air and sedentary activities. Thermal discomfort will be experienced if excess body heat production and heat dissipation are not in equilibrium.

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[a] BTU (British Thermal Unit): a unit used to measure quantity of heat; Technically, the quantity of heat required to raise the temperature of one pound of water by 1°F. One BTU is equal to 252 calories. One BTU is approximately equal to the amount of heat given off by burning one kitchen match.

Human body extremities (fingers and toes) are more sensitive to the feeling of discomfort because they lose heat faster than the rest of the body and are difficult to insulate (see Table 2.1).[14] In general, if our body extremities feel warm, our body will feel more comfortable. Humans adapt to low ambient environment temperatures by adding clothing to maintain heat and by the use of mechanical heating systems.

Mean Skin Temperature °C		Degree of Discomfort
hands	feet	
20	21.5 - 22	uncomfortably cold
15	16.5 - 17	extremely cold
5	6.5 - 7	painfully cold

Table 2.1: Relationship of mean skin temperature and degree of discomfort.

Source: Feduniw, L. Human thermal comfort for interior designers and architects. Winnipeg: University of Manitoba, Faculty of Architecture. 114.

Effective temperature control allows a person to do extended work without raising or lowering his (or her) body temperature significantly within the human comfort zone.[15] Radiation, relative humidity, mean radiant temperature, air movement and landforms determine microclimate. Microclimate is an important consideration in landscape design because " this is the climate with which people are in contact, and it is the one that the designer can actually modify."[16] Therefore, the arrangement of buildings, landscape elements, planting materials and landforms can modify climate and optimize conditions to fall within the human comfort zone for outdoor activities.

2.2.2. Radiation

The amount of solar radiation reaching the earth's surface varies according to the time of day, time of the year and location (latitude, altitude and curvature of the earth's surface; and the length of atmospheric path to the sun).[17] These three variables allow us to determine the position of the sun and the shadow pattern on the ground at different times of the day throughout the year.

Not all solar radiation is intercepted by the earth; about 35% of the radiation is reflected back into space. The rest of the radiation which reaches the earth's surface can be divided into three component parts:[18]

1. Direct radiation: direct radiation from the sun and usually reflected and diffused by skycover (clouds) or absorbed by air pollutants and moisture.
2. Reflected radiation: solar radiation which is reflected onto adjacent surfaces, depending upon reflectivity on materials (albedo of different materials).
3. Diffused radiation: radiation that is diffused by skycover, clouds and air pollution.

The absorption and reflection of solar radiation by landscape elements is dependent on their albedo and conductivity. Lynch explained that " if the ground has a low albedo and high conductivity, then it produces a mild and stable microclimate. Excess heat is quickly absorbed and stored, and as quickly released when the ambient air temperature drops. Thus the sea, or grass, or wet ground, tend to even out the climate above them, while the weather over sand or snow or pavement is more violent because of their high albedo and low conductivity."[19] The use of vegeiation to control solar radiation through filtration, radiation and obstruction can provide shade in summer and allow more sunlight to reach the ground in winter. Also, vegetated ground absorbs heat during daytime and releases heat at night, thereby establishing a more stable microclimate. The information generated from sunpath diagrams and shadow patterns can be used to determine the arrangement of landscape elements, the location of sun pockets, planting materials and the placing of PV panels. In addition, the use of sunlight and shadow patterns can improve the quality of a space.

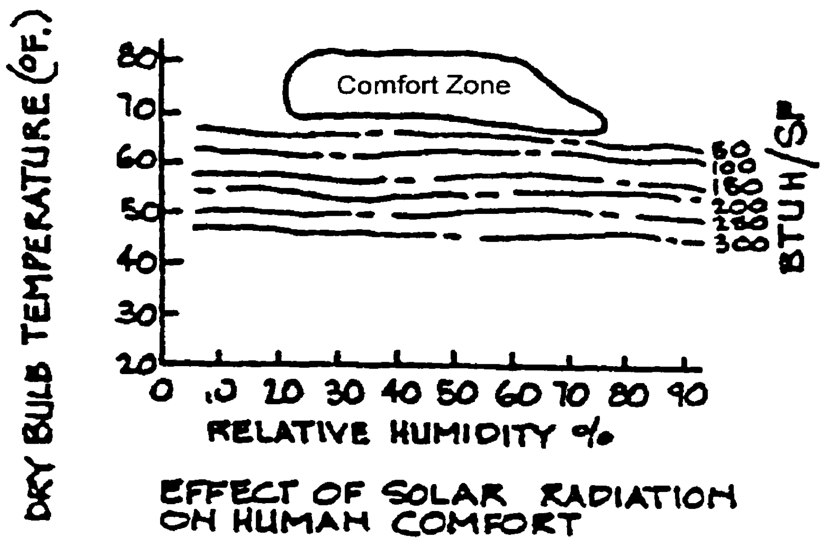

Figure 2.7: Effect of solar radiation on human comfort.
The values to the right indicate possible trade-offs between ambient air temperature and solar radiation at the lower fringe of the comfort zone. The use of planting materials can cut off excess solar radiation and prevent excess evaporation from the ground in summer time and allow more heat to reach and be absorbed by ground cover in winter.

Source: Feduniw, L. Human thermal comfort for interior designers and architects. Winnipeg: University of Manitoba, Faculty of Architecture. 23.

2.2.3. Relative humidity (degree of saturation of air)

A cooling effect can be experienced when moisture is added to the air in a drier environment due to the process of evaporation. The relative humidity of ambient air determines the evaporative loss of excess heat transfer (through perspiration and respiration) to environment. Relative humidity, together with air temperature, determines human thermal comfort (see Figures 2.8 & 2.9). Therefore it is necessary to have passive and/or active mechanical ventilation systems in an enclosed landscape structure (such as passenger shelters, kiosks or washroom facilities) in order to remove moisture and maintain a level of relative humidity within the human comfort zone.

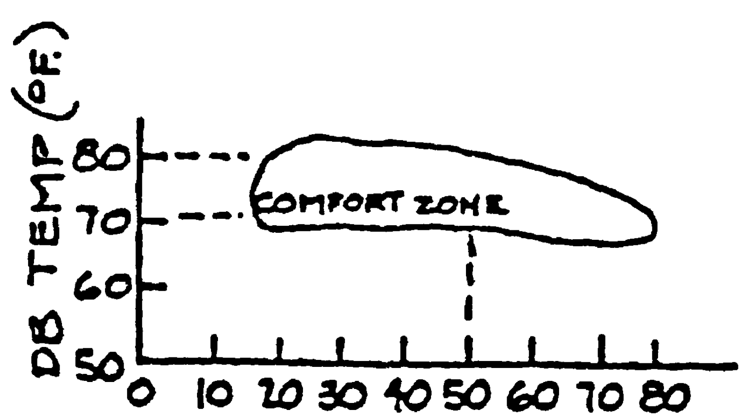

Figure 2.8: The human comfort zone in still air in relation to ambient air temperature and relative humidity.
In ambient conditions of high relative humidity and temperatures above 34°C (93°F), the human body will activate its control system (sweating) to increase heat dissipation. Air movement accelerates this evaporation process. Also, the balance of heat exchange will be more effective with a de-humidification process.

Source: Feduniw, L. Human thermal comfort for interior designers and architects. Winnipeg: University of Manitoba, Faculty of Architecture. 22.

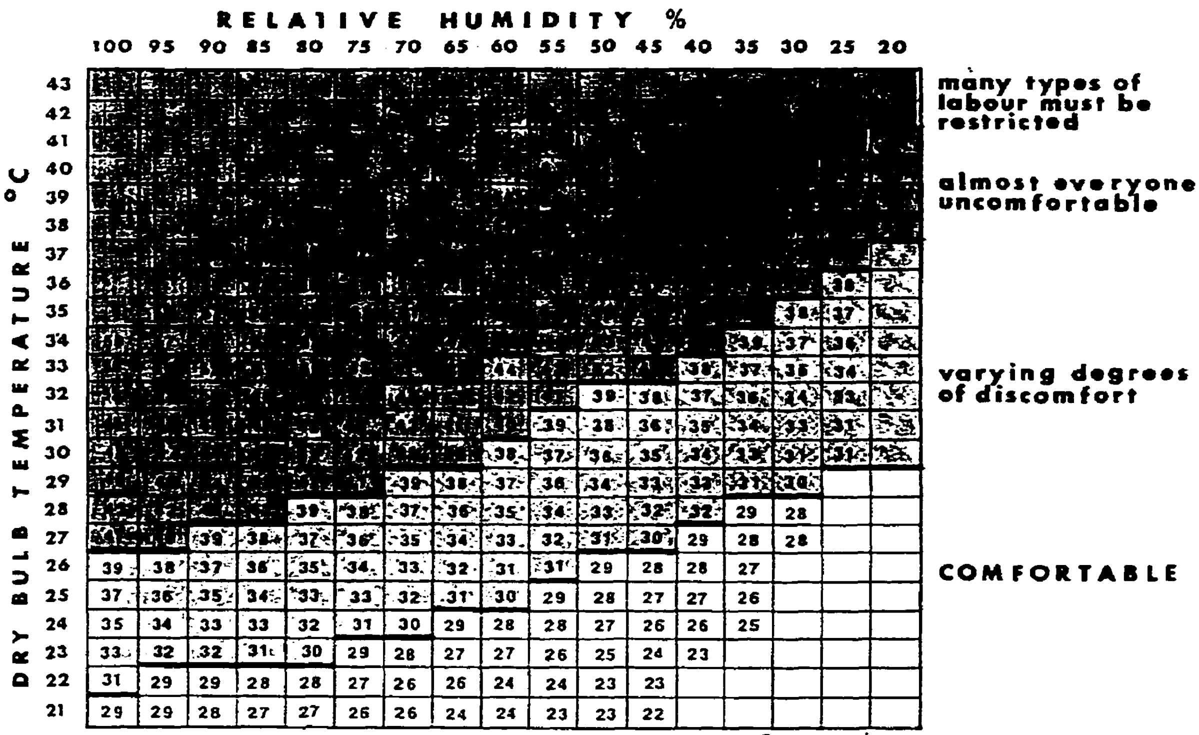

Figure 2.9: Relationship of ambient air temperature and relative humidity.
This chart indicates how temperature and relative humidity affect the human body's reactions. High temperature and high relative humidity inhibit human activities.

Source: Feduniw, L. Human thermal comfort for interior designers and architects. Winnipeg: University of Manitoba, Faculty of Architecture. 33.

2.2.4. Mean Radiant Temperature (MRT)

"Mean Radiant Temperature is a temperature unit, calculated by the weighted average temperatures of surrounding surfaces ."[20] This value indicates what a person's actual thermal experience is in various locations within a space as determined by the various inside surface temperatures. The MRT values are the mean temperature inside a space that people will experience at any specific location.

About 30-40% of human metabolic heat is lost by radiation to the surrounding surface. Heat loss and heat gain are different at any given location within an enclosed space, especially near entrances, windows and walls. Therefore MRT is even more important than air temperature. By raising the MRT, we can have a cooler air temperature and stay within the human comfort zone. On the other hand, lowering the MRT allows higher than normal air temperature within the comfort zone (see Figure 2.10). [21]

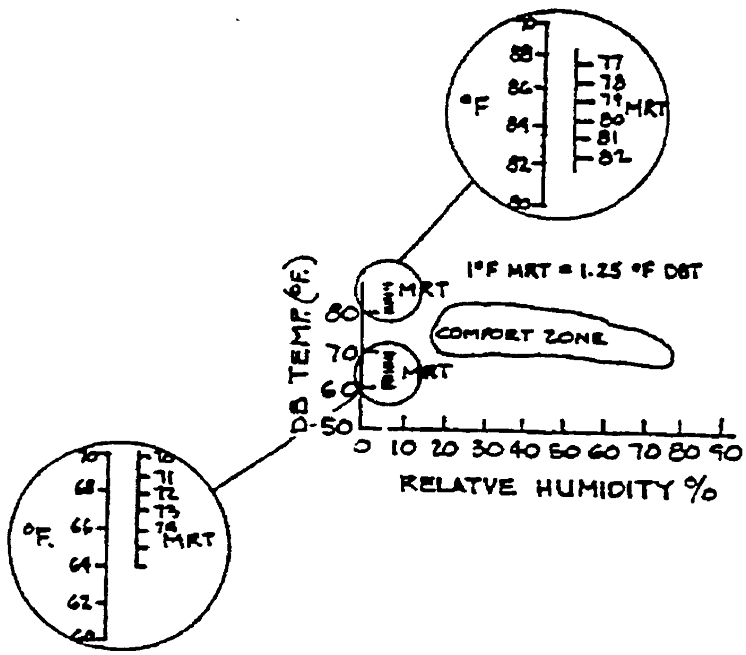

Figure 2.10: The effect of Mean Radiant Temperature on human comfort.
The circled areas shows possible trade-offs between ambient air temperature and MRT at the fringes of the comfort zone. In general, a raise in 1.0°F in MRT can offset 1.25°F decrease in air temperature.

Source: Feduniw, L. Human thermal comfort for interior designers and architects. Winnipeg: University of Manitoba, Faculty of Architecture. 21.

2.2.5. Air movement (wind)

Wind is caused by a temperature difference over a given area of the earth's surface. Air warmed by the earth's surface moves up and cooler air moves in to replace it. Wind also creates turbulence when it moves up and down from tall structures and trees. Wind increases evaporation of moisture from the surface of skin, thereby increasing heat dissipation.

In general, 10 to 20 feet per minute (f.p.m) of air movement help to remove stuffiness and air stratification. Air movement at 200 to 250 f.p.m. will accelerate body cooling through evaporation. Natural or induced ventilation can therefore improve an over-heated environment. Air movement above 250 f.p.m. will be noisy and drafty. Above 850 f.p.m. air movement causes discomfort [22] (See Figure 2.11).

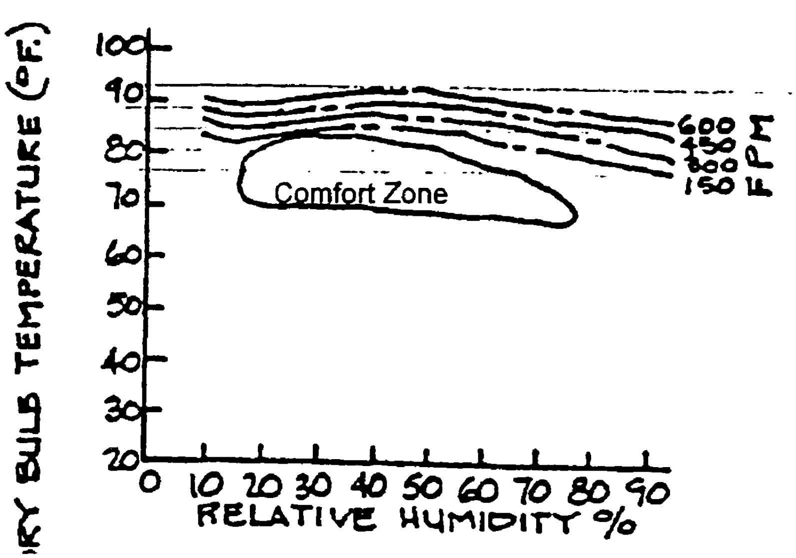

Figure 2.11: Effect of air movement on human comfort.
Figures to the right in F.P.M. indicate possible trade-offs between ambient air temperature and ventilation.

Source: Feduniw, L. Human thermal comfort for interior designers and architects. Winnipeg: University of Manitoba, Faculty of Architecture. 23.

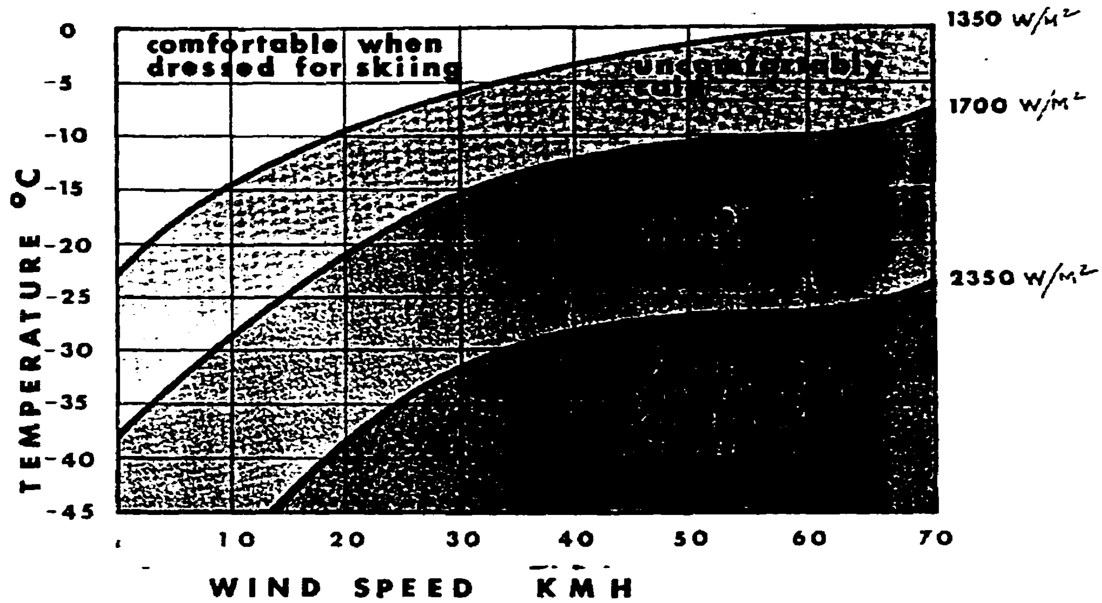

Figure 2.12: Effect on human activities in relation to wind speed and temperature.
W/M^2 indicates body heat loss for exposed area of the body surface in watts per square meter.

Source: Feduniw, L. Human thermal comfort for interior designers and architects. Winnipeg: University of Manitoba, Faculty of Architecture. 31.

The wind speed can have has an impact on human thermal comfort that may inhibit outdoor activities in cold climates. The "wind chill factor" refers to the effect of wind on exposed human skin as a given combination of temperature and wind speed (see Figure 2.12).

Wind moves moisture, pollutants, impurities, sand and snow. Wind speed and direction modified by landforms, structures and plants can improve ventilation and reduce or increase cooling effects. Trees and shrubs used as wind-breaks not only reduce wind speed but also filter pollutants and catch snow. Wind can also be used creatively, such as in wind sculpture, to improve the visual quality of a space.

2.2.6. Landforms

The landscape may be manipulated to utilize natural energy resources effectively. Landforms can be shaped to block unwanted wind or to modify the direction and speed of wind, to create sun pockets and to drain excess water.[23] Vegetation and landscape structures (as discussed in the previous sections) can be added.

The shapes of landforms, the organization of structures and landscape elements, the use of textures and materials, the colors and textures of vegetation can increase the visual quality of a space. They can be arranged to provide rhythms, visual clues and sequences, and to improve the identity of a place if they are designed according to their context.

2.3 Physical and psychological factors that affect human comfort

Factors that account for human comfort include: where people live and their cultural background, age, gender, types of clothing worn, effects of cold and warm surrounding surfaces, sensitivity and perception to color and materials, and the balance of heat exchange.

These factors are critical to the landscape designer's ability to consider suitable environmental conditions to accommodate different user groups according to their specific human comfort zone and their psychological responses.

2.3.1. National Geographic location and cultural preferences

People from tropical and warm climate regions prefer higher temperatures than people from colder climate regions. People adapt to cold weather through experience, by wearing appropriate clothing and by scheduling activities according to conditions. When moving from cold climate regions the human body, with time, will adjust to warmer conditions. Adaptation also determines the level of thermal comfort achieved.

People with different cultural backgrounds have different interpretations regarding landforms, shapes and colors. They also have different interpretations concerning landscape. A study of socially and ethnically diverse parks in Los Angeles found significant cultural differences in the use of parks.[24] By way of example, Francis and Marcus suggested that Latinos use parks more frequently for parties and celebrations. They change and add things to the landscape, such as balloons and blankets to help them to define and claim territory. By contrast traditional Chinese prefer an urban park that has well-organized planting areas, ponds, pavilions, etc., rather than an extensive green, open space.

2.3.2 Age[25]

In general, we tend to assume that, with age, people prefer warmer temperatures. However, with age, people tend toward more sedentary activities which produce less excess body heat and thus require a warmer environment. On the other hand, younger and more active people may prefer cooler surroundings and older people often have poorer circulation than younger people. This reduces their ability to keep warm. In short, different age groups have different requirements for the materials and organization of places to meet their needs.

2.3.3. Gender[26]

Generally women prefer warmer temperatures because they have a slightly lower metabolic rate than men and this factor is offset by slightly lower insensible perspiration; in other words, the rate at which womens' bodies must lose heat is lower than the rate for men.

Also, most women and men have different concepts of the use of open space. Francis and Marcus suggested that men tend to predominate in up-front, on-display locations in urban open spaces such as plazas and parks.[27] On the other hand, women tend to prefer backstage, quiet, secure and natural settings.[28] This suggests that designers should seek to integrate both types of space in a place.

2.3.4. Cold and warm floors [29]

As the skin temperature at the feet is lower than the rest of the body, people standing on a cool floor may perceive the floor to be uncomfortably cold. On the other hand, people standing on a warm floor may perceive the floor to be uncomfortably warm.

If, in winter, the passenger shelter floor (or the floors of other structures such as kiosks and washroom facilities) is heated to the appropriate temperature, the floor and the air near it will be more comfortable, and people inside the shelter will experience a more satisfactory level of thermal comfort.

2.3.5. Clothing

People driving vehicles tend to wear lighter-weight clothing in winter time when they go outside than those who walk or take the bus. Fashion trends, however, have an impact on what people wear in winter time - especially teenagers and young adults who want to be fashionable, regardless of weather conditions. Much of the clothing material for teenagers and young people is made from polyvinyl chloride (PVC), nylon and other synthetic materials, which do not regulate body heat and moisture dissipation effectively.

The type of footwear is critical to thermal comfort because body extremities lose more heat than the rest of the body. For light footwear, floor temperatures as high as 29°C (for low activity levels) are acceptable. The lower limit without feeling discomfort is 17 - 18°C on cold floors. For heavy footwear, the upper and lower limits of floor temperature are +10°C and -10°C.[30] Therefore, it is desirable to have a warm floor inside passenger shelters in Winnipeg in winter.

2.3.6. Color and material

The influence of color on thermal comfort remains something of a mystery. Faber Birren believes that the brain is affected by color before feelings develop. His research stated that:" the brain's electrical response to red is one of alerting of arousal whereas the brain electrical response to blue is one of relaxation... the aura, skin response, brain response - and also heartbeat, respiration, blood pressure - seem to be involved with color through electrical impulses."[31]

Generally, people feel warm when they perceive warm colors such as red, orange and yellow, while they feel cool when they perceive cool colors on the color wheel such as blue and green. Also the same color on different materials gives us different sensations on body temperature. For example, a metal handrail painted in red and red color brick paving give us two different feelings. Since our perception of metal is cold, we may still perceive the red-colored metal as cold and 'untouchable', especially in the winter time; on the other hand, red-colored brick paving gives a warmer feeling even in the winter, and lets people enjoy walking in the winter more. Also, it is noticeable that different age groups have different preferences for different colors. Generally children may prefer warm and intense colors while older people may prefer less intensive colors.

Colors and materials must therefore be selected carefully throughout the environment for different user groups. Selection must respond to our perception of color and its effects on thermal comfort.

2.3.7. Crowding [32]

In crowded conditions, heat generated by occupants will require a cooler environment. Lowering the Mean Radiant Temperature effectively increases heat flow from occupants to surrounding surfaces, thereby helping to balance heat exchange.

Crowding also affects us psychologically. When there is only one person waiting for the bus in winter, the individual would feel colder and perhaps even lonelier than when there is more than one person waiting.

To conclude, the above factors affect human thermal comfort and perception of a place. Therefore, they should be considered carefully in the process of landscape design. Without this consideration, the design will be in danger of failing to serve people in different conditions.

Endnotes for Chapter 2

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15.Hack, G. , Lynch, K. (1986). op. cit. 47.

16.Ibid. 49.

17.Feduniw, L.. op. cit. 1.

18.Ibid, 1 - 2.

19.Hack, G. , Lynch, K. (1986). op. cit. 51.

20.University of Manitoba, Faculty of Architecture, Department of Interior Design. (No date). Mean radiant temperature. [On line]. Available: Http://www.arch.umanitoba.ca/human_comfort/main.htm [2000, October 18].

21.Feduniw, L.. op. cit. 21 - 22.

22.Ibid, 23.

23.Robinette, G. (Editor). (1977). Landscape planning for energy conservation. New York: Van Nostrand Reinhold Company. 8.

24.Francis, C., Marcus, C. (Editors). (1998). People place. New York: Van Nostrand Reinhold Company. 88 - 89.

25.Feduniw, L.. op. cit. 163 - 164.

26.Ibid, 164.

27.Francis, C., Marcus, C. (Editors). (1998). op. cit. 27 - 28.

28.Ibid, 27 - 28.

29.Feduniw, L. op. cit. 170 - 171.

30.Ibid, 171.

31.Birren, F. (1978), Color and human response, aspects of ight and color bearing on the reactions of living things and the welfare of human beings. 80 - 81.

32.Feduniw, L. op. cit. 172.

Chapter 3: Transit Stop Design

3.1 Introduction

The Winnipeg Transit System wishes to upgrade passenger shelters across the city. It acquires 10 to 15 new shelters each year, as well as needing new transit terminals at major activity centers. It is therefore appropriate to investigate the redesign of transit stops and shelters so that they are safe, attractive and comfortable.

The elements within a transit stop (the passenger shelter, bus stop marker, bench, information panels, trash unit and retail vendors) should co-ordinate with the context of the site. Careful planning of vegetation and other site furniture can improve human comfort and provide a clear and obstacle-free transit stop.

This chapter examines, first, the existing transit stops throughout the city of Winnipeg, and identifies existing problems. It then analyses the existing transit stop and surrounding area of the stop located on Dafoe Road in the University of Manitoba Fort Garry Campus, Winnipeg, and it provides design proposals for the current situation. The last section of this chapter suggests a future development of the proposed site and an alternative design for the passenger shelter.

3.2 Transit stop in the City of Winnipeg

The basic requirement for a transit stop is a clear and obstacle-free stop platform. According to the Winnipeg Transit, the boarding platform should be a minimum of 2.1m (7') X 1.98m (6'6") to accommodate the deployment of a wheel chair ramp from a bus. Street furniture and other objects must be cleared from the platform. The typical layout of a bus waiting area in the city is to align the bench (if there is one), the bus stop marker and other site furniture (such as trash units, newspaper vendors and power pedestal), to the front edge of the shelter. This allows an obstacle-free area for pedestrians such as the one in front of the Legislative Building on Broadway (see Figure 3.1). However, in some locations, retail vendors (such as newspapers and beverages) are located in inappropriate locations such as the one on Osborne Street and Pembina Highway (see Figure 3.2, Page 50).

Figure 3.1: The transit stop on Broadway, in front of the Legislative Building.


Figure 3.2: Transit stop on Osborne Street and Pembina Highway. The retail vendors are randomly placed.

Planting materials are usually only used at transit terminals because of maintenance requirements (see Figures 3.3 & 3.4, Page 51). The selection of planting materials are determined by their maintenance requirements and tolerance to salt and other pollutants. Common shrubs planted at transit stops are *Juniperus* spp. (Juniper), *Viburnum trilobum* (High Brush-Cranberry), *Parthenocissus quinquefolia* (Virginia creeper), *Prunus maackii* (Amur Cherry), *Potentilla fruticosa* (Potentilla) and *Cornus* spp. (dogwood). Common trees are coniferous species and *Fraxinus pensylvanica* (Green Ash). Because of the low levels of maintenance, planting beds and planters appear to be empty or to contain dead plants for much of the time - even in summer in some locations. One recommendation is for Winnipeg Transit is to investigate opportunities to partner with private interests for adoption and maintenance of planting materials and other site furniture.

Figure 3.3: Transit terminal at Graham Avenue with well organized planting materials.

Figure 3.4: Transit terminal at St.Vital Shopping Center with empty areas in plant beds.

Vandalism to street furniture and bus shelters is found in most parts of the city. This includes graffiti and physical damage (see Figures 3.5 & 3.6).

Figure 3.5: Graffiti on bus stop marker at St. Vital Shopping Center transit terminal. It is common to see teenagers sitting on trash units and sometime on the roof of shelters.

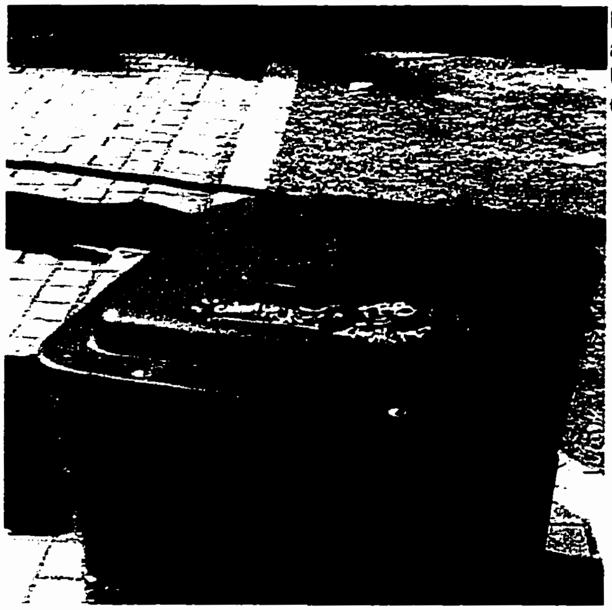


Figure 3.6: Graffiti on trash unit at the transit terminal of The University of Manitoba, Fort Garry Campus.

3.3 Site Analysis

After discussion with Mr. Alex Regiec, Operations Planner for the Winnipeg Transit System, it was agreed that the proposed landscape design to incorporate the passenger shelter prototype be located on Dafoe Road, east of the Music Building and south of the Architecture II Building at the University of Manitoba, Fort Garry Campus, Winnipeg (see Figures 3.7 - 3.9, Page 53 - 54).

This analysis was conducted by site observation. The analysis includes: primary and secondary users of the site, existing conditions, grading and drainage, utilities, circulation, views, existing vegetation, microclimate, sun angles and altitudes, and design opportunities (see Drawings 3.1 - 3.20, pages 56 - 76) .

Figure 3.7: The proposed site at University of Manitoba. The site lacks appropriate landscape elements, such as convenient and attractive sitting/waiting areas and vegetation to generate a comfortable microclimate. An improved landscape design for this site would generate a comfortable microclimate, and improve the appearance of the campus.

Figure 3.8: View of passenger shelter from north-west of Dafoe Road.

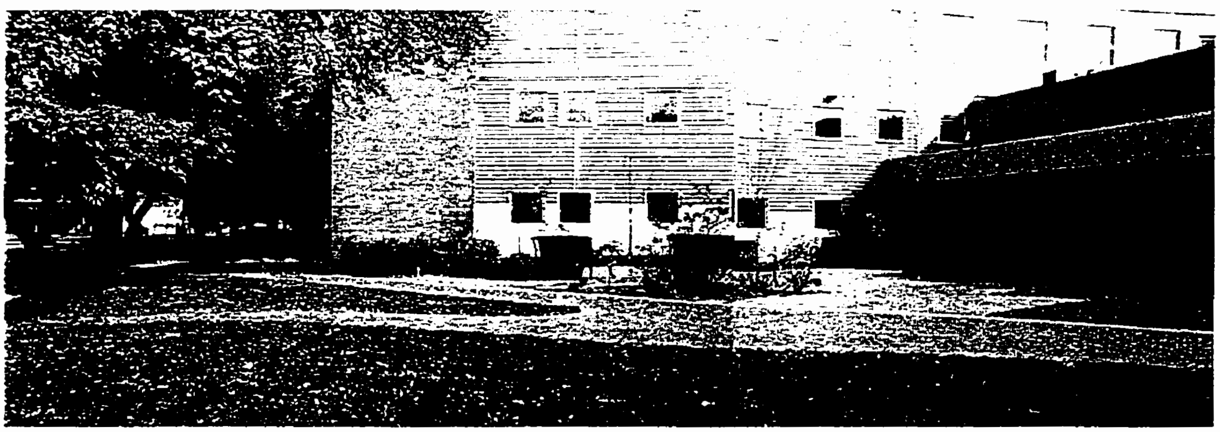


Figure 3.9: The use of native vegetation in agriculture building courtyard, south of Dafoe Road. There is a potential connection of the courtyard and transit stop by use of native planting.

List of Site Analysis Drawings

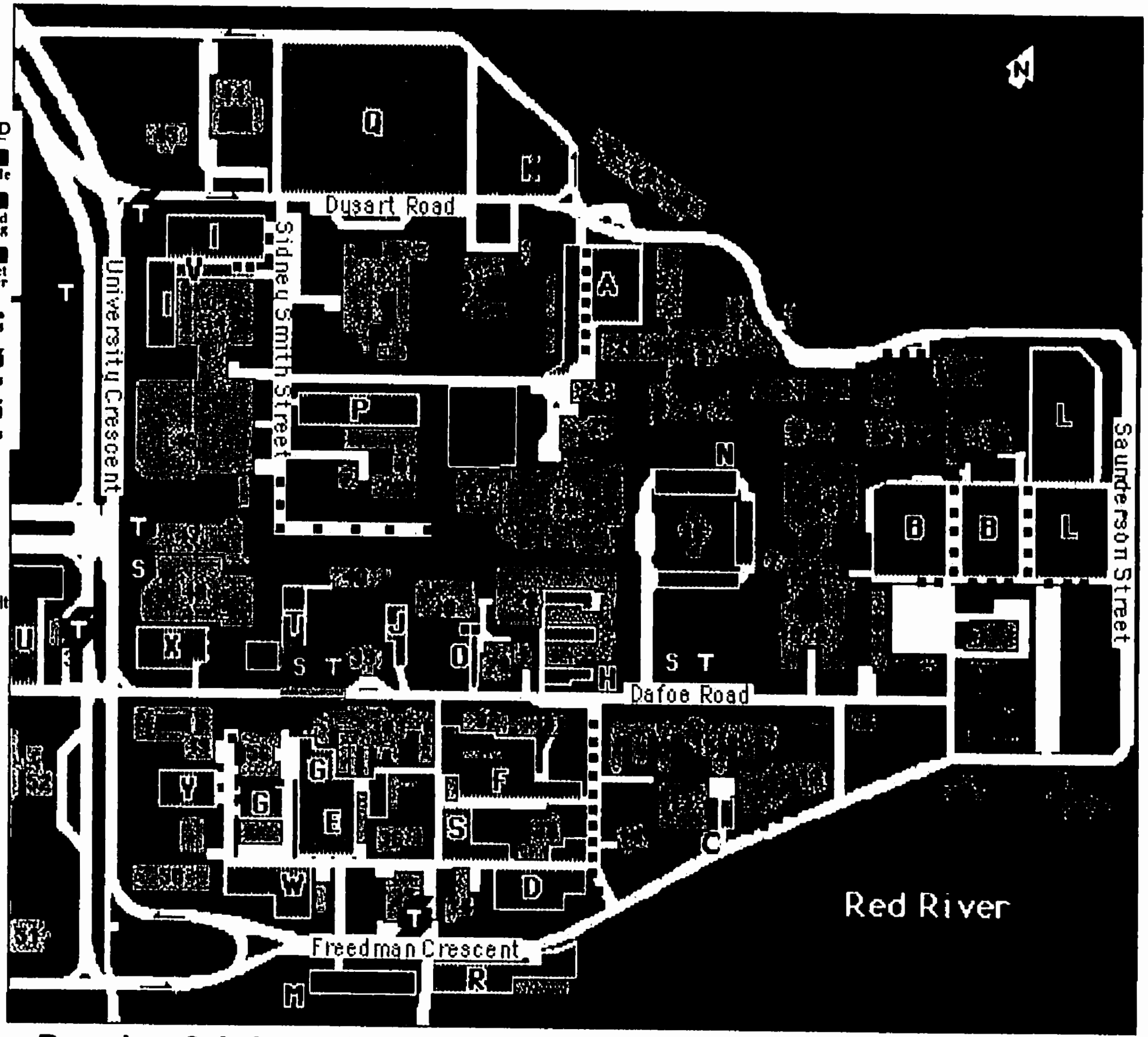
Fort Garry Campus Key
By number

1 Robson Hall
2 University College
4 Duff Roblin Building
5 Human Ecology
6 Elizabeth Dafoe Library
7 Fletcher Argue Building
8 Agriculture Canada Research Station
9 Isbister Building
10 Tier Building
11 Alumni House
12 Drake Cntre
13 Pembina Hall/University Club
14 Mary Speechly Hall
15 Tache Hall
16 Administration Building
17 Buller Building
18 Machray Hall
19 Armes Lecture Building
20 Allen Building
21 Parker Building
22 Wallace Building
23 ST. John's College
24 Pharmacy Building
25 Fitzgerald Building
26University Centre
27 Bison Building (Faculty of Nursing)
28 Engineering Building
29 Services Building (Campus Police)
30 Russell Building
31 Dairy Science
32 Agricultural Engineering
33 Powerhouse
34 Physical Plant/Energy Management
35 Stores Building
36 Ceramic/Sculpture Building
38 Agriculture Building
39 School of Music
40 Architecture II Building
41 Education Building
42 St. Paul's College
43 Sinnott Building (N.R.I.)
44 St. Andrew's College
45 Campus Day Care Centre
46 Max Bell Centre
47 Continuing Education Complex
48 Frank Kennedy Physical Education Centre
49 Animal Science/Entomology
50 Ellis Building
51 Agricultural Services Complex
52 Freshwater Institute
53 Information Centre
54 Investors Group Athletic Centre
56 Animal Science Research Unit

LEGEND

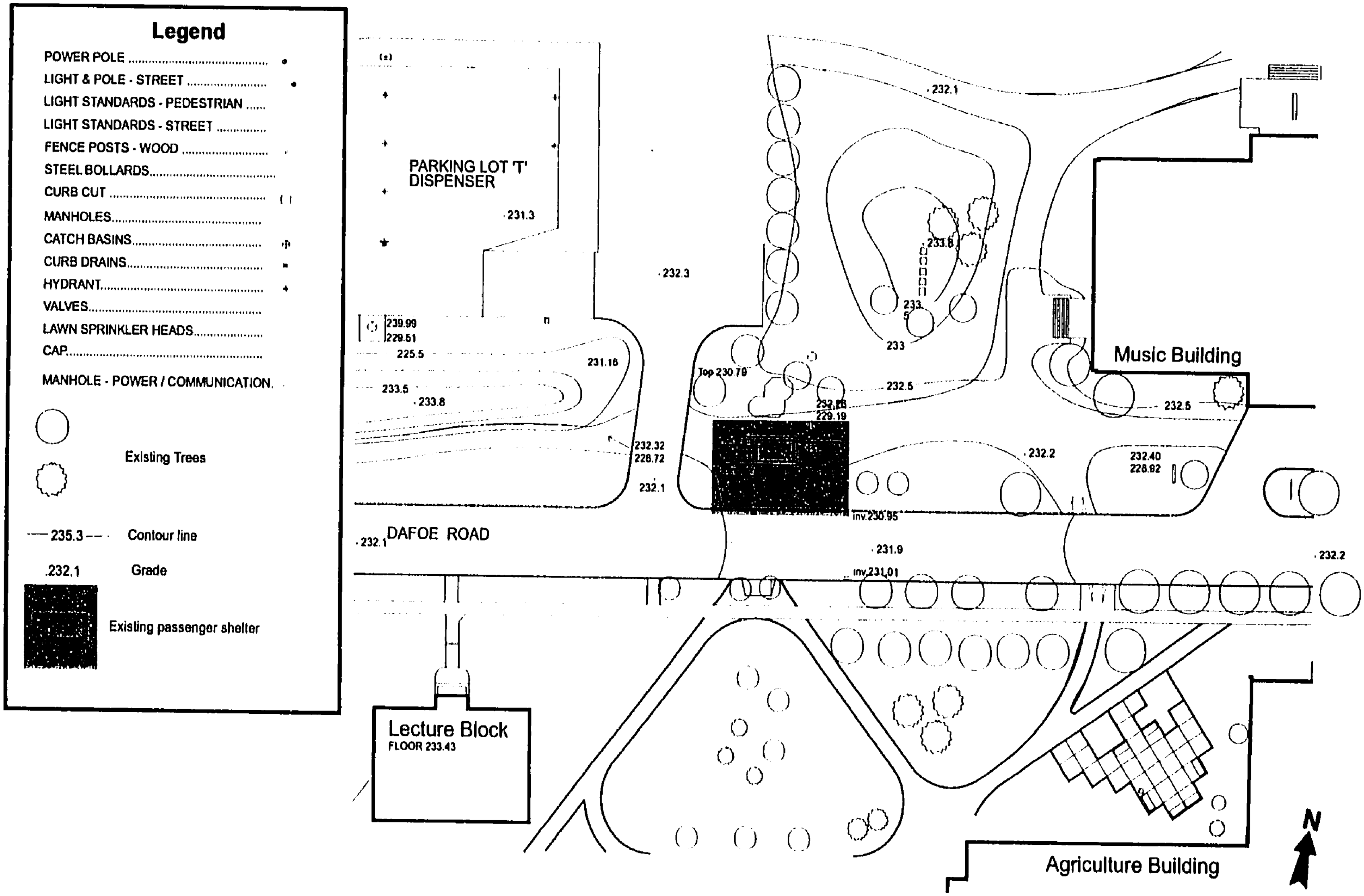
parkade
reserved parking
ticket dispenser
meters
bus stops
shuttle bus

Existing passenger shelter and proposed sit

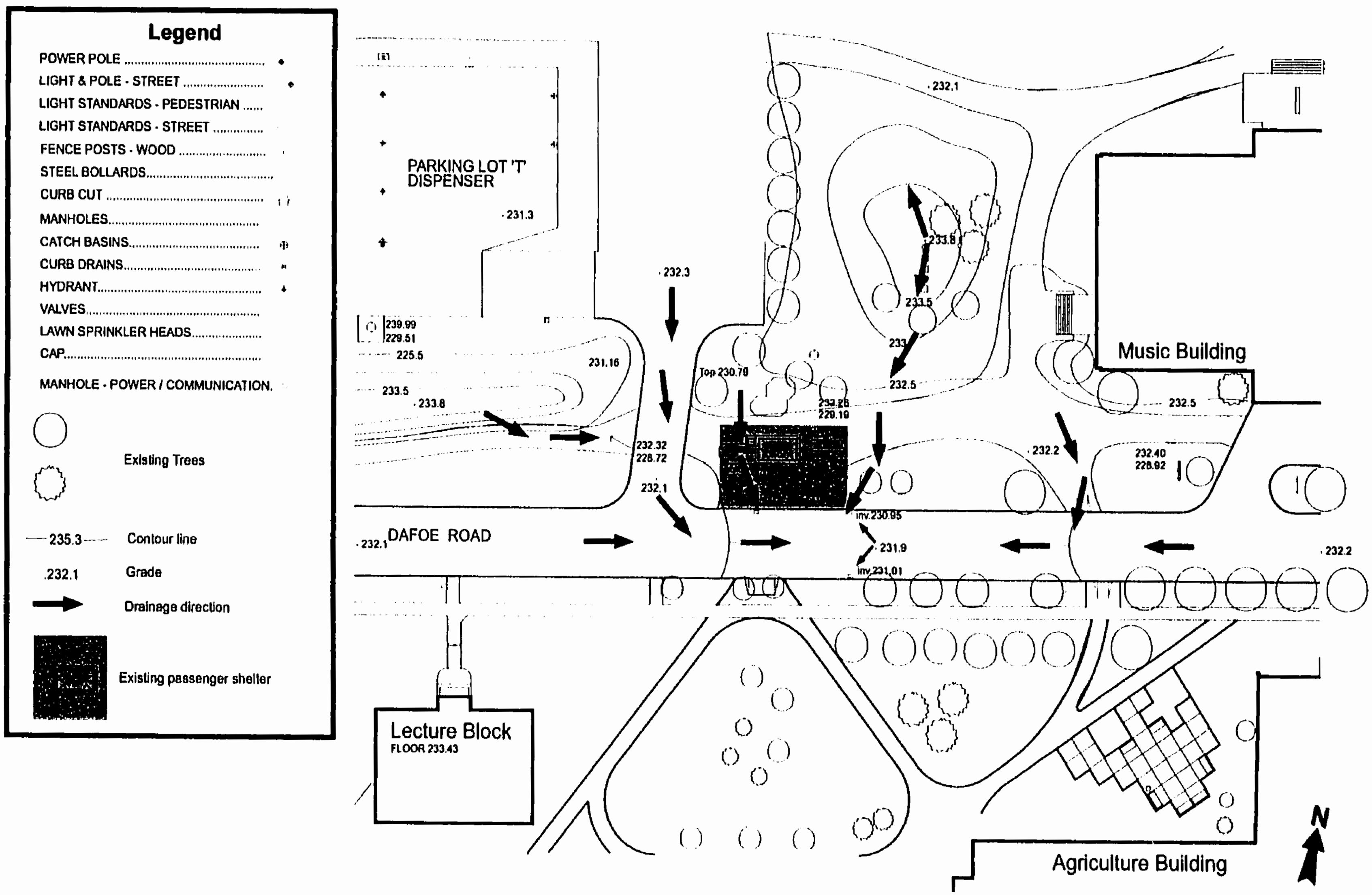


Drawing 3.1: Location of Proposed Bus Shelter and landscape design at the University of Manitoba, Fort Garry Campus
Scale: N.T.S

Drawing 3.2: Primary and Secondary Users from the Surrounding Buildings
Scale: N.T.S.

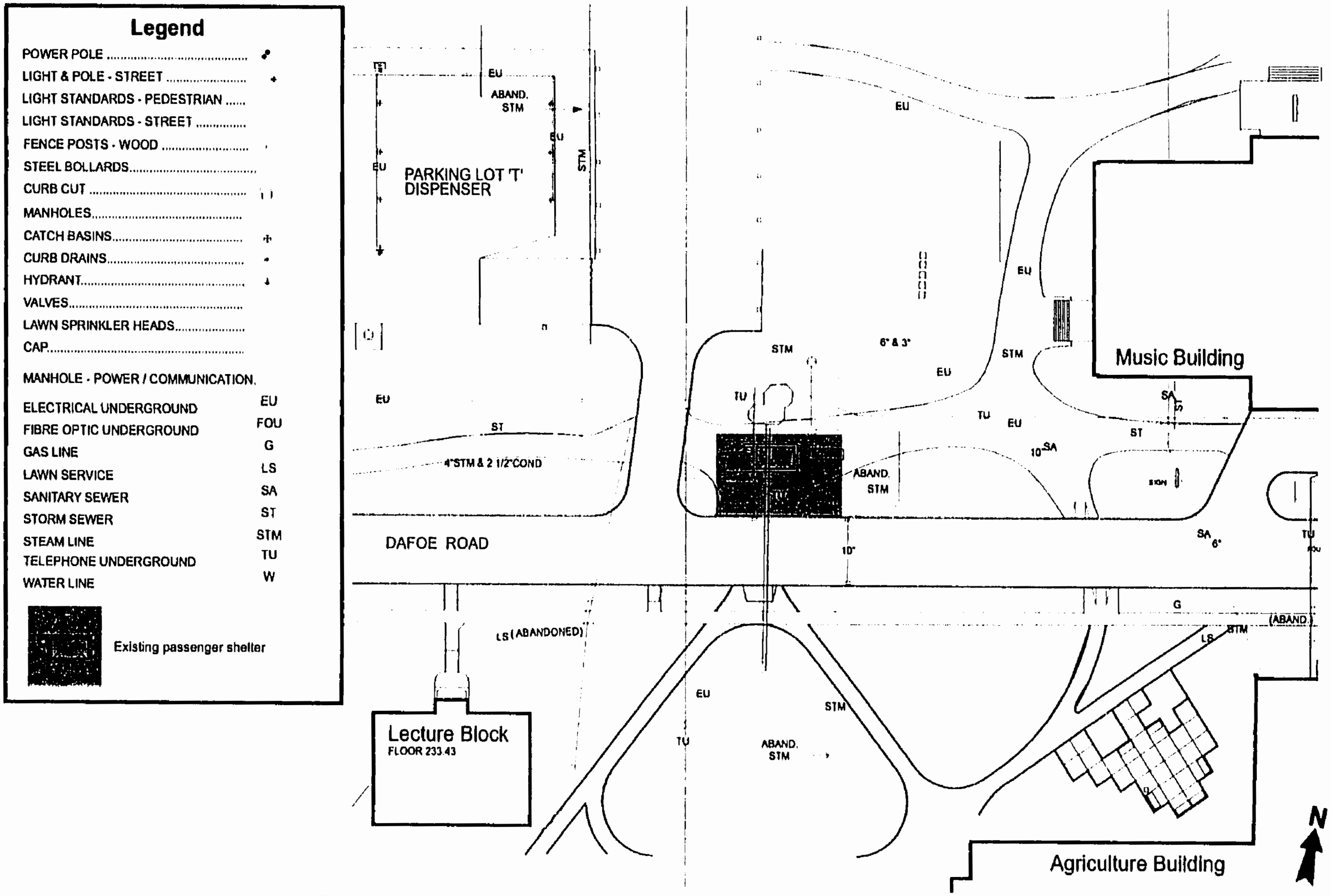


Drawing 3.3: Existing Conditions
Scale: N.T.S.

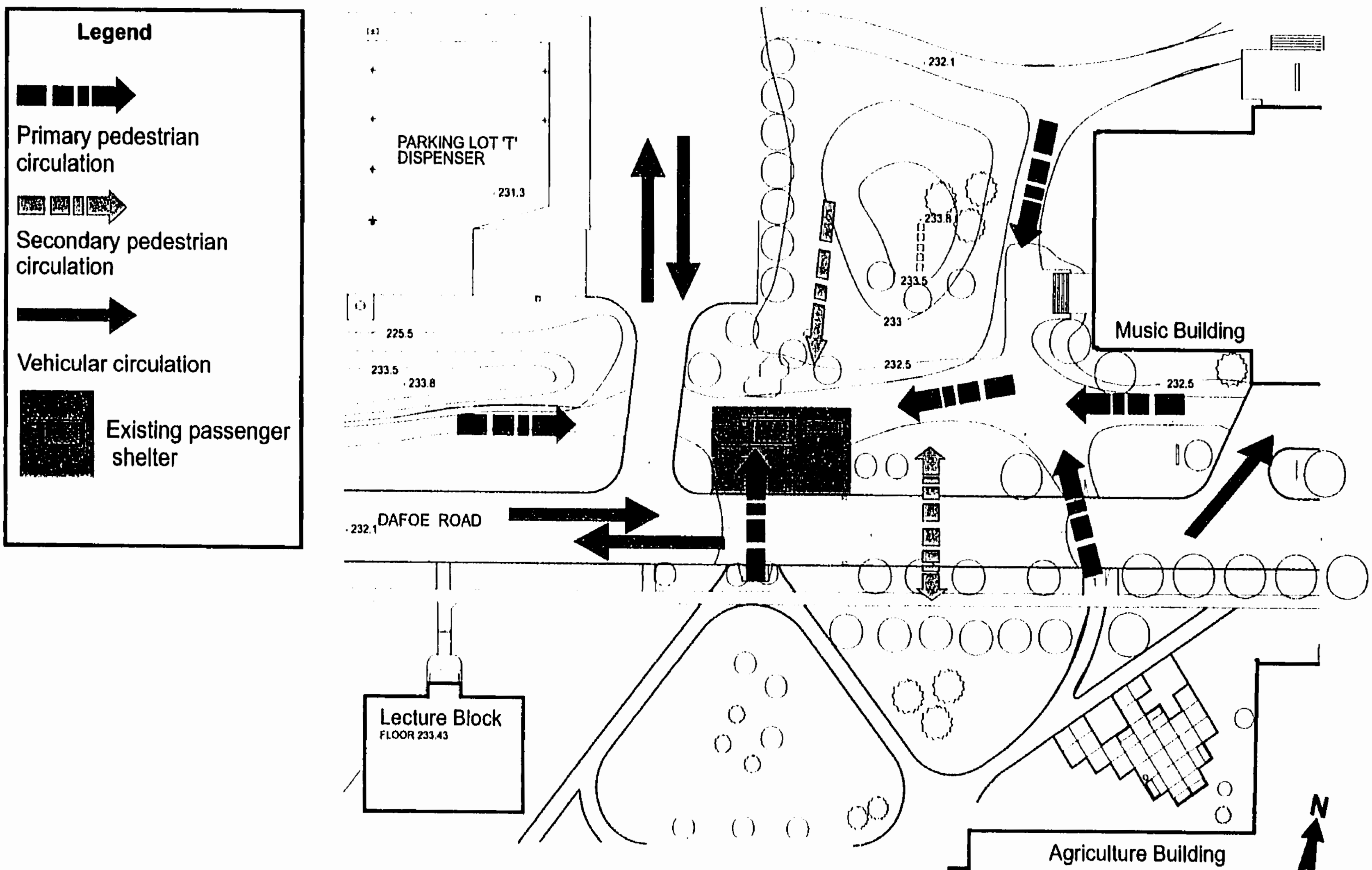


Drawing 3.4: Existing grading and drainage

Scale: N.T.S.



Drawing 3.5: Existing utilities -- overhead and underground structure
Scale: N.T.S.



Drawing3.6: Pedestrian and Vehicular Circulation
Scale: N.T.S.

Pleasant Views

1. View to sculpture and trees

2. View to courtyard west of the Agricultural Building

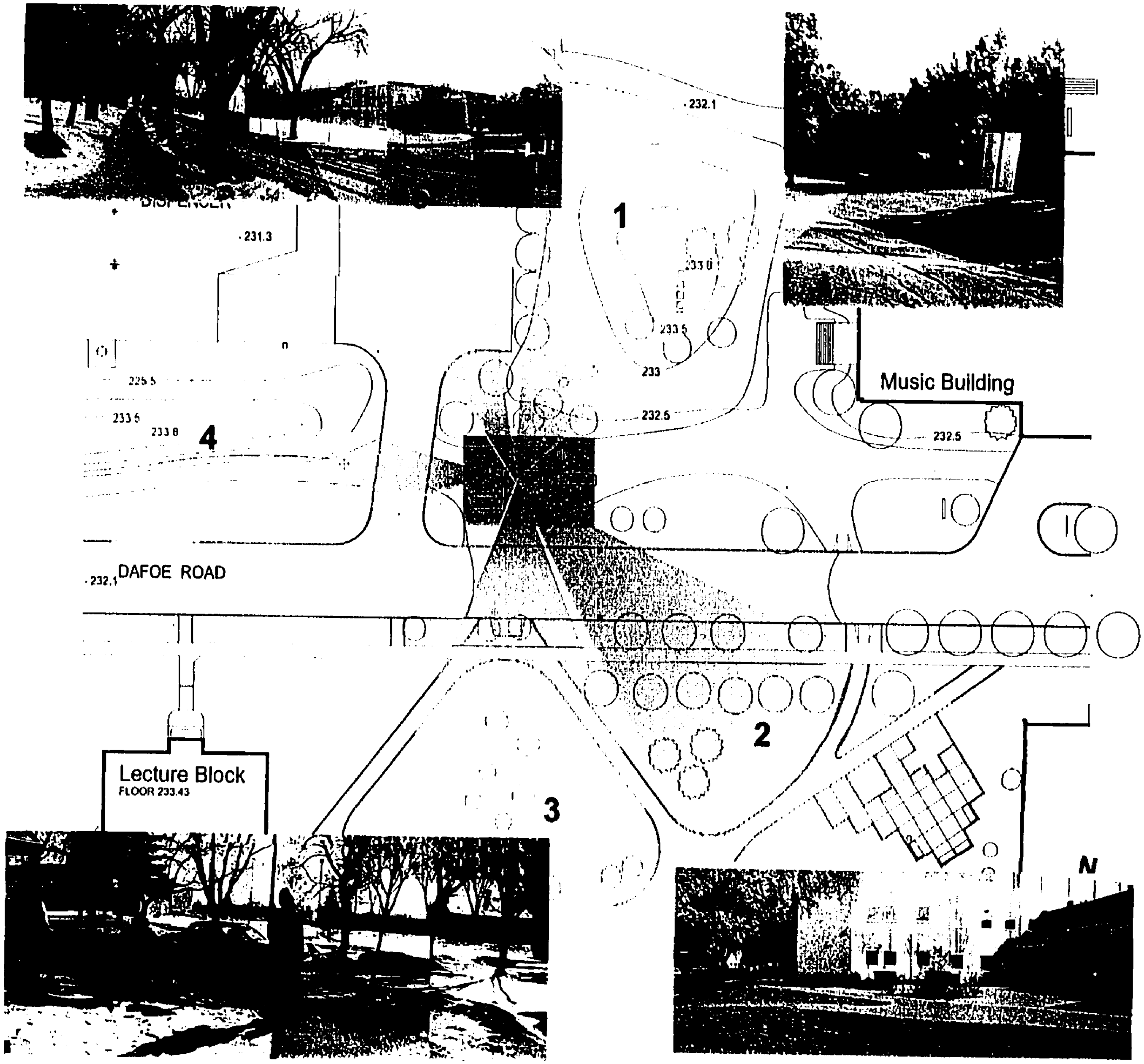
Unpleasant Views

3. View to parking lot G, looking to the parking lot in winter time.

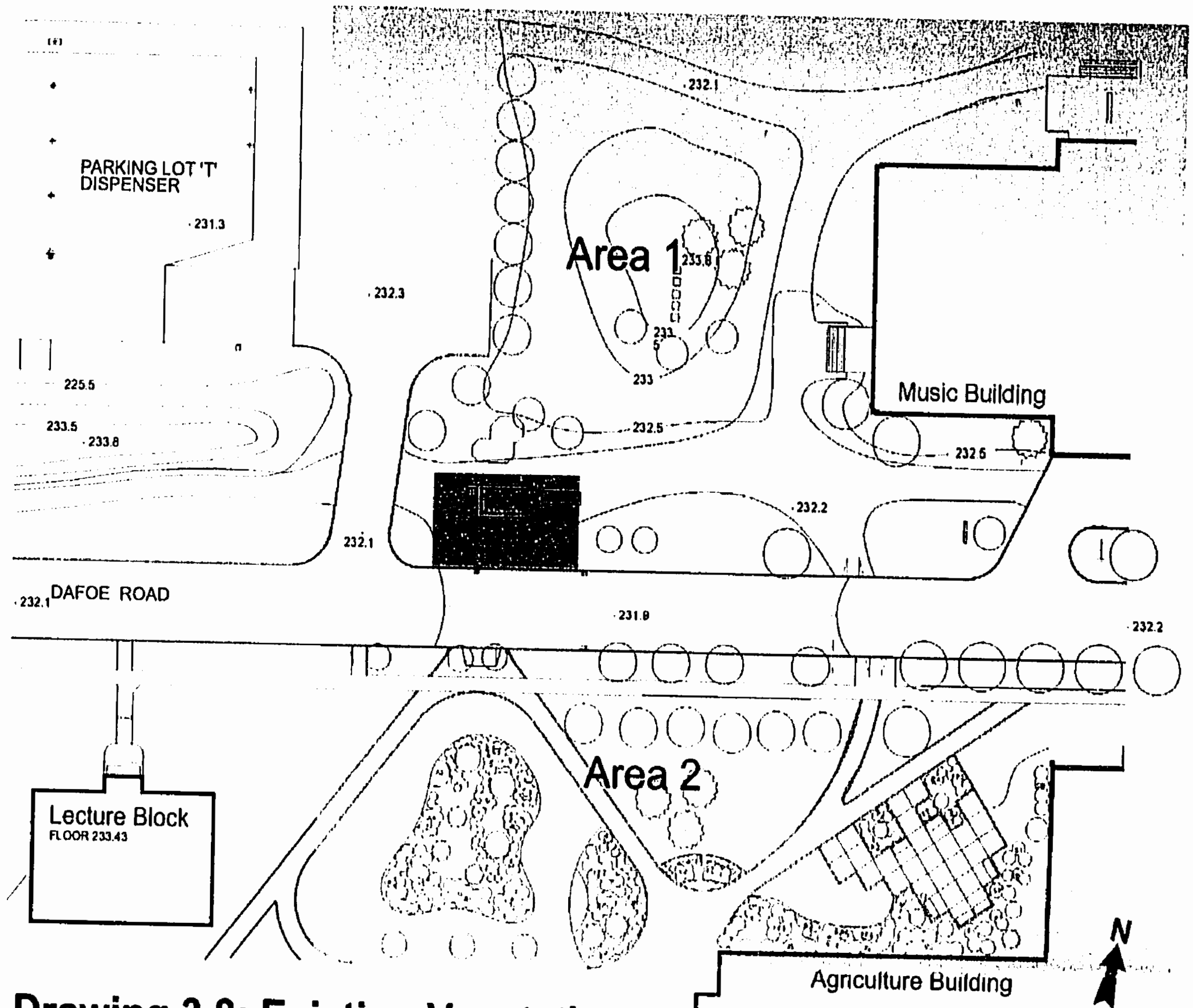
4. View to the berm of Frank Kennedy Physical Education Center

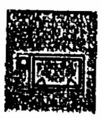
5. View to parking lot T and loading area

Existing passenger shelter



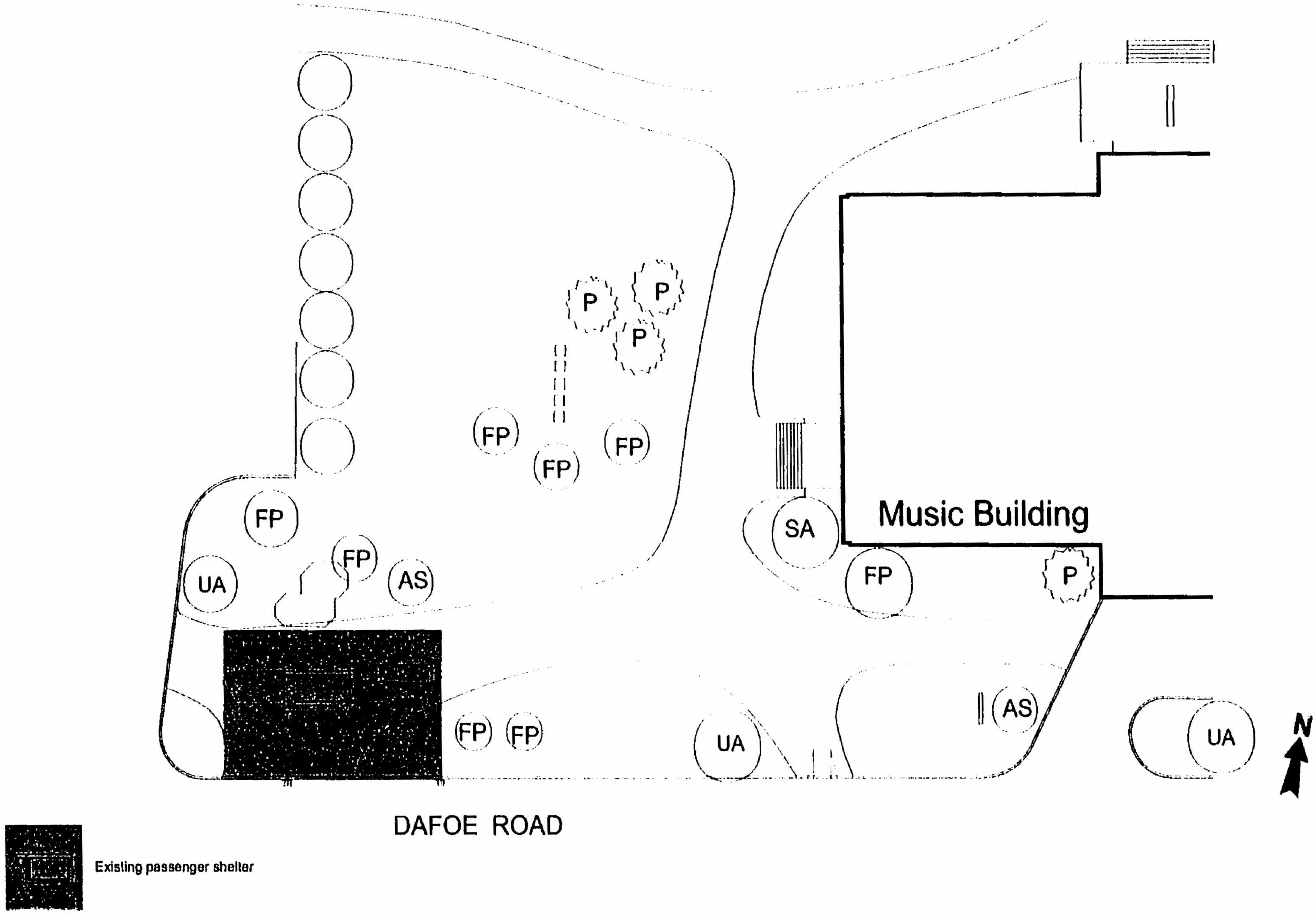
Drawing 3.7: Views
Scale: N.T.S.



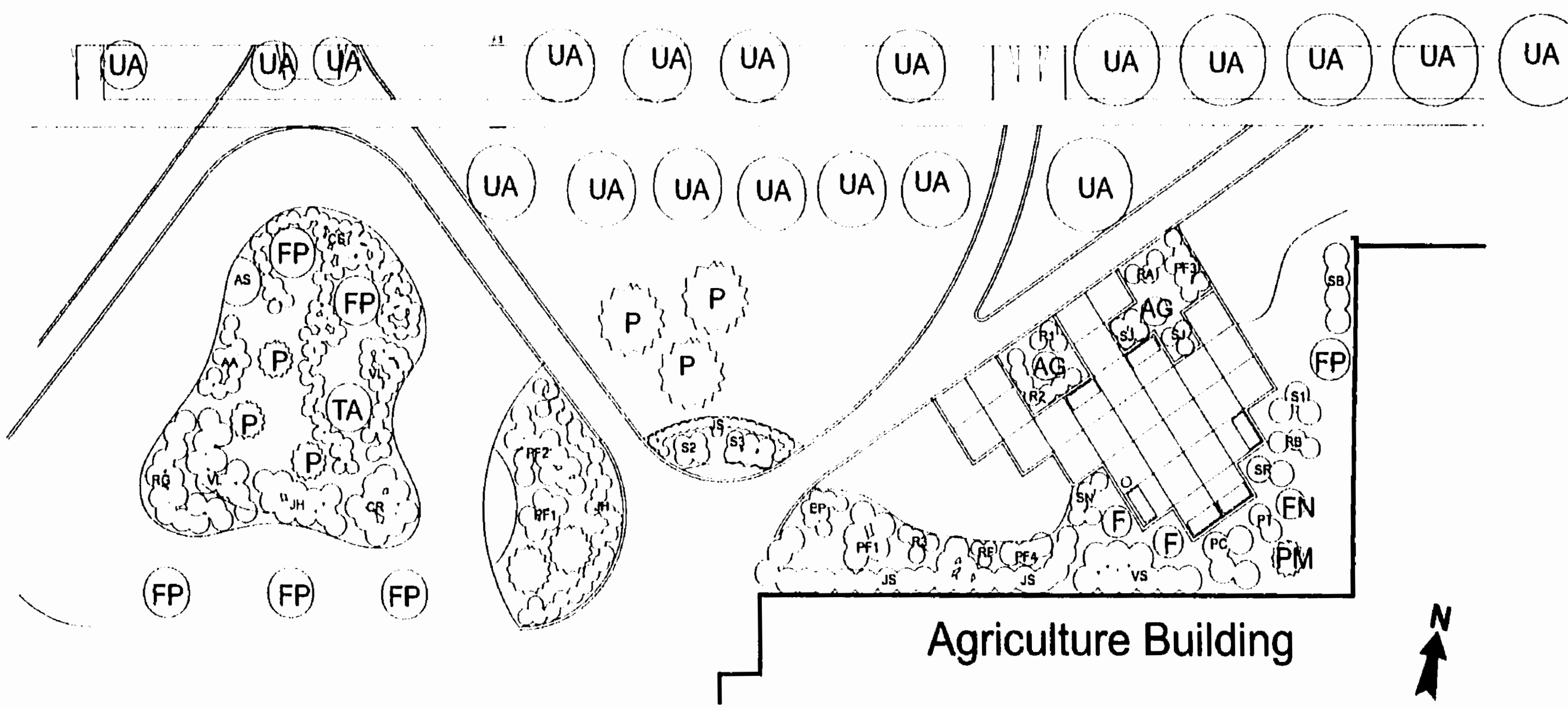


Existing passenger shelter

Drawing 3.8: Existing Vegetation - Key to shown in detail in Drawings 3.9 and 3.10
Scale: N.T.S.



Drawing 3.9: Existing Vegetation - Area 1
See page 66 for key to species
Scale: N.T.S.



Drawing 3.10: Existing Vegetation - Area 2
See page 66 for key to species
Scale: N.T.S.

Table 3.1: Key to Species

Shrubs and Flowers

Symbol	Scientific Name	Common Name
AA	*Amelanchier alnifolia*	Saskatoon
CS	*Cornus sericea*	Red -Osier Dogwood
CR	*Cornus racemose*	Dogwood
EP	*Echinacera* spp.	Purple Cone Flower
JH	*Juniperus horizontails*	Horizontal Juniper
JS	*Juniperus sbina*	Savin Juniper
PC	*Prunus* X *Cistena*	Cistena Cherry
PF1	*Potentilla fruticose* 'Pink Beauty'	Ptoentilla 'Pink Beauty'
PF2	*Potentilla fruticose* 'Yellow Gem'	Ptoentilla 'Yellow Gem'
PF3	*Potentilla fruticose* 'Coroation Triumph'	Ptoentilla 'Coroation Triumph'
PF4	*Potentilla fruticose* 'Modern Fireglow'	Modern Fireglow
PF5	*Potentilla fruticose* 'Orange Whisper'	Orange Whisper
PO	*Physocarpus opulfoius* 'Dart's Gold'	Ninbark 'Dart's Gold'
PT	*Prunus triloba* 'Multiplex'	Double Flowing Plum
R1	*Rosa* spp. 'Modern Blush'	Parkland Rose 'Modern Blush'
R2	*Rosa* spp. 'Winnipeg Parks'	Parkland Rose 'Winnipeg Parks'
RA	*Rosa arkansana* X 'Modern Cardinette'	Parkland Rose
RB	*Rosa blanda* X 'Therese Bugnet'	Parkland Rose
RF	*Rosa foetida* 'Persiana'	Persian Yellow
RG	*Rhus glabra*	Smooth Sumac
S1	*Spiraea* spp. 'Snow White'	Hybird Spirea
SB	*Spiraea* X *bumalda* 'Gold Flame'	Dwarf Pink Spirea
SJ	*Spiraea japonica* 'Little Princess'	Japanese Spirea
SN	*Spiraea nipponica*	Nippon Spirea
SR	*Sambuous racemose* 'Shtherland Golden'	Red Elder
VL	*Viburnum Lentago*	Nannyberry

Trees

Symbol	Scientific Name	Common Name
AG	*Acer ginnala*	Amur Maple
AS	*Acer saccharinum*	Silver Maple
F	*Fraxinus* X 'Northern Gem'	Ash hybird
FN	*Fraxinus nigra*	Black Ash
FP	*Fraxinus pensylvanica*	Green Ash
PT	*Pricea* spp.	Spruce
PM	*Pinus Mugo*	Mugo Pine, Swiss Mountain Pine
SA	*Salix alba*	White Willow, Silver Willow
TA	*Tilia americana*	American Basswood
UA	*Ulmus americana*	American Elm

Legend

Existing passenger shelter

Major direction of wind flow - Winter

Major direction of wind flow - Summer

1. Strong wind flow from west side of the campus.

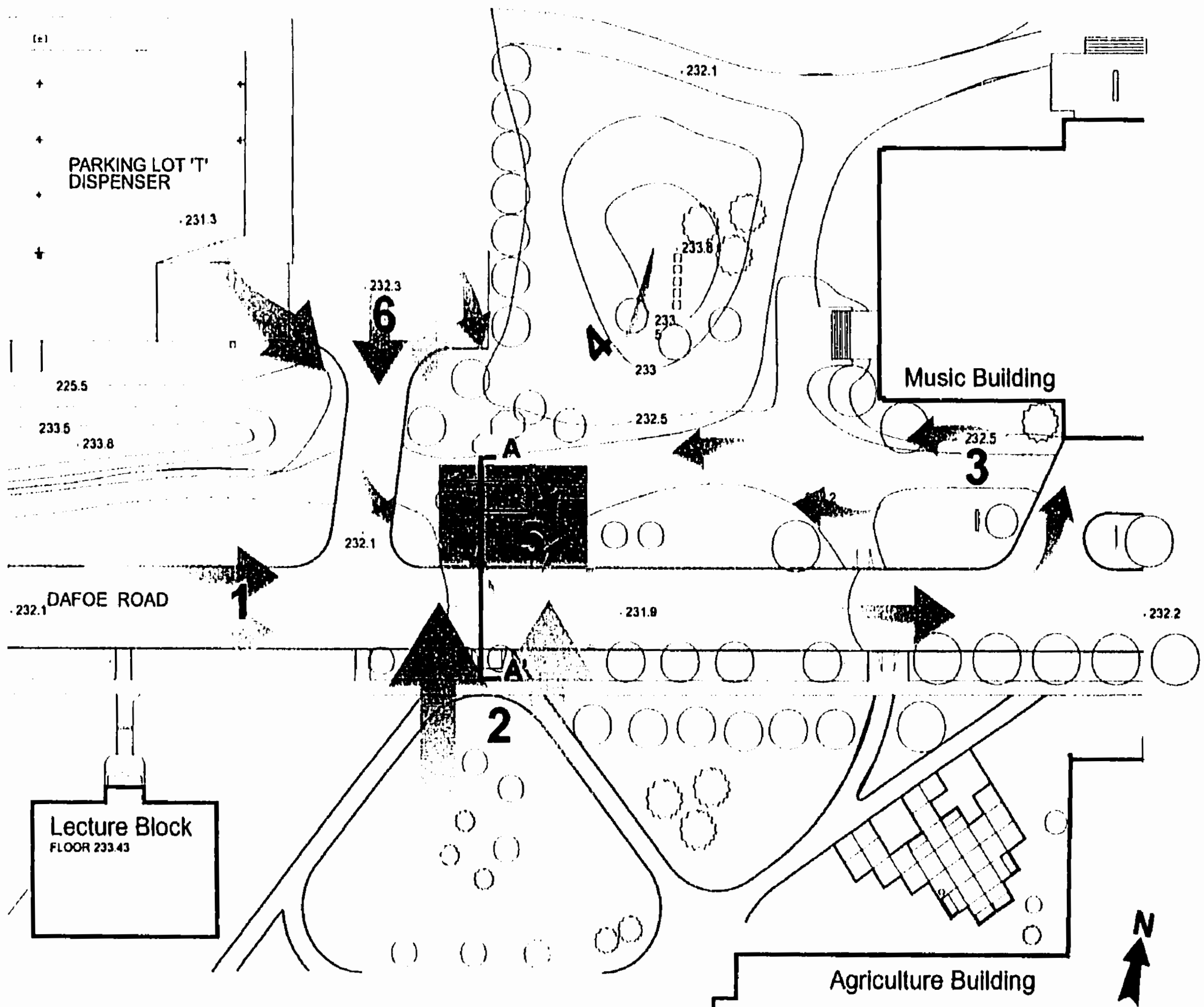
2. Wind from south parking lots G and E.

3. West wind flows to the loading area of Music Building and circulates in front of the wall.

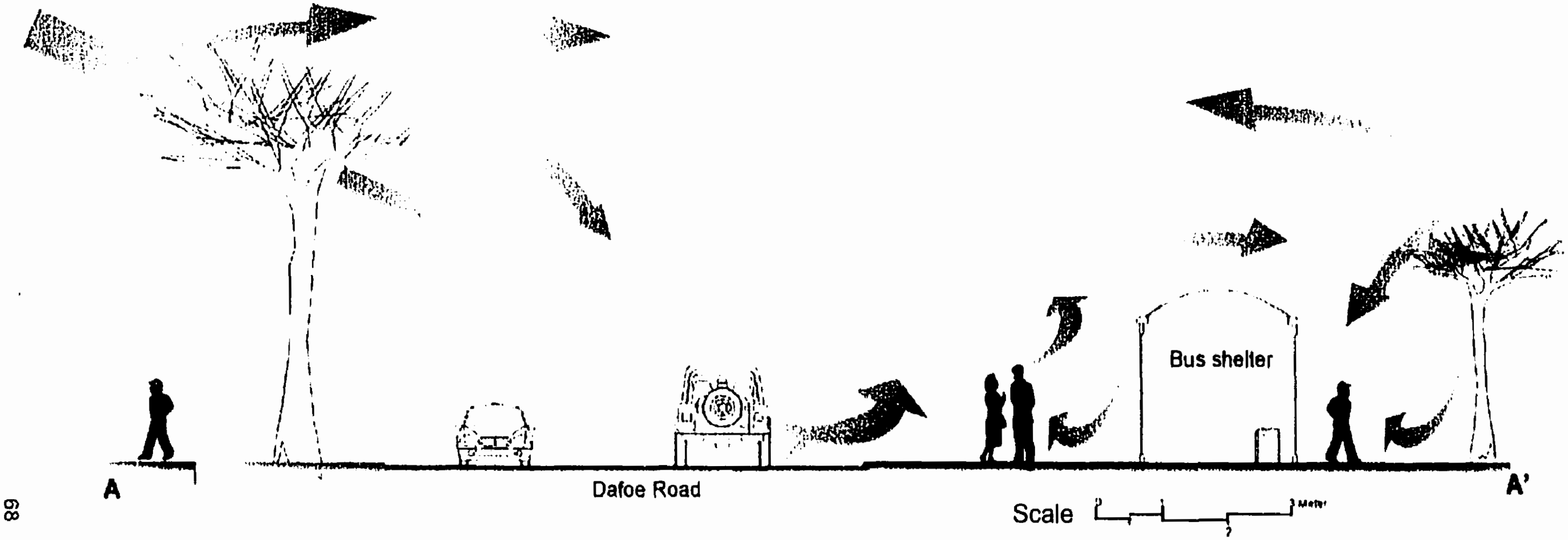
4. Wind from north side.

5. An eddy is formed as the result of converging wind flow from different direction. (Section A - A'- refer to Drawings 3.12 & 3.13, pages 68 & 69, seasonal nature of wind).

6. Strong wind from parking lot T.



Drawing 3.11: Wind
Scale: N.T.S.



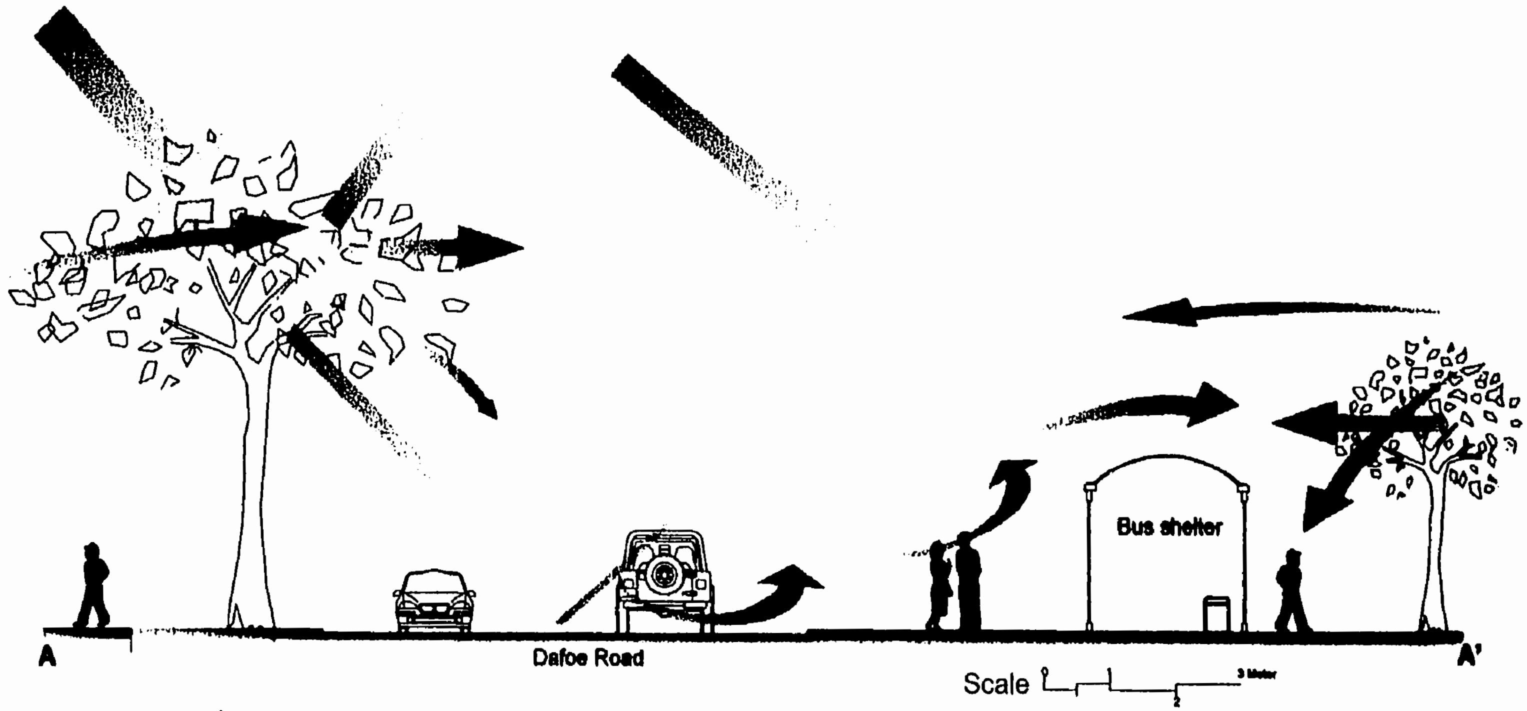
Wind flow

Wind blows from south to the passenger shelter. Turbulence is formed in front of bus shelter due to lack of trees to block-off the wind on the south side of Dafoe Road. Strong winds also blows from the north side and create turbulence at the back of shelter. Trees and tall shrubs are needed to reduce the effect of wind

Solar radiation

Low angle winter sun can filter trough the branches of the trees on the south side of Dafoe Road. Radiation reaches the ground and part of it is reflected back due to the high albedo value of snow. Also the low angle sun comes into people's eyes. The lack of vegetation around the shelter reduces the absorption of radiation by the ground and results in colder temperatures at night.

Drawing 3.12: Microclimate - section A - A' , winter



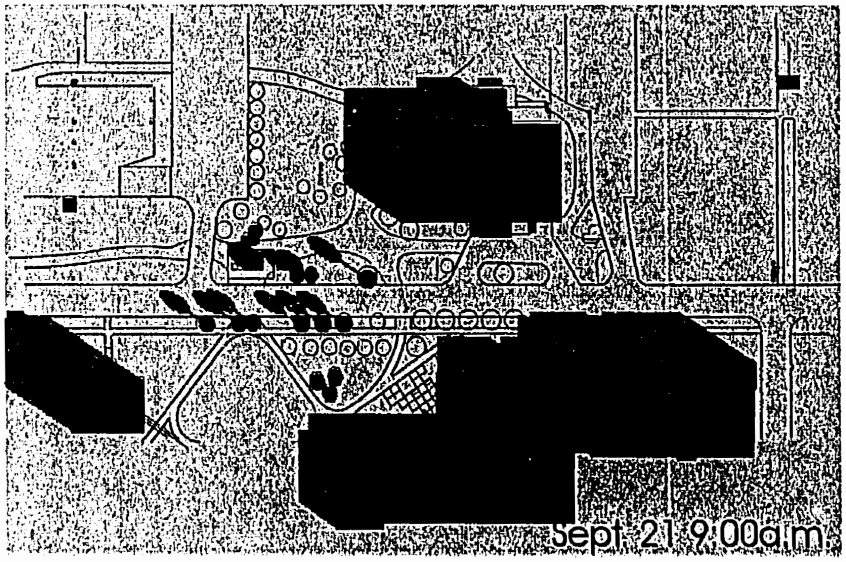
Wind flow

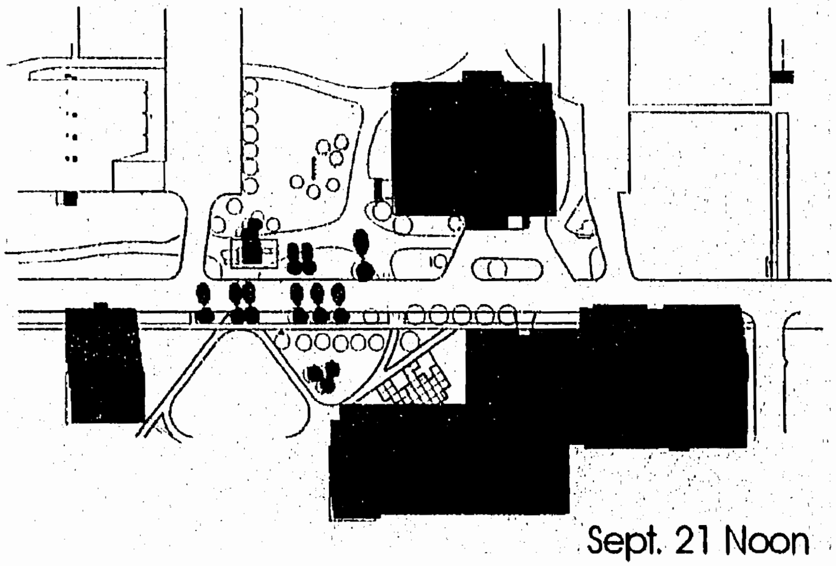
Wind blows from south and north is filtered by trees. As solar radiation is more intense and will heats up the concrete surface faster in summer, air is heated up and expands upwards; thereby reducing the cooling effect of wind.

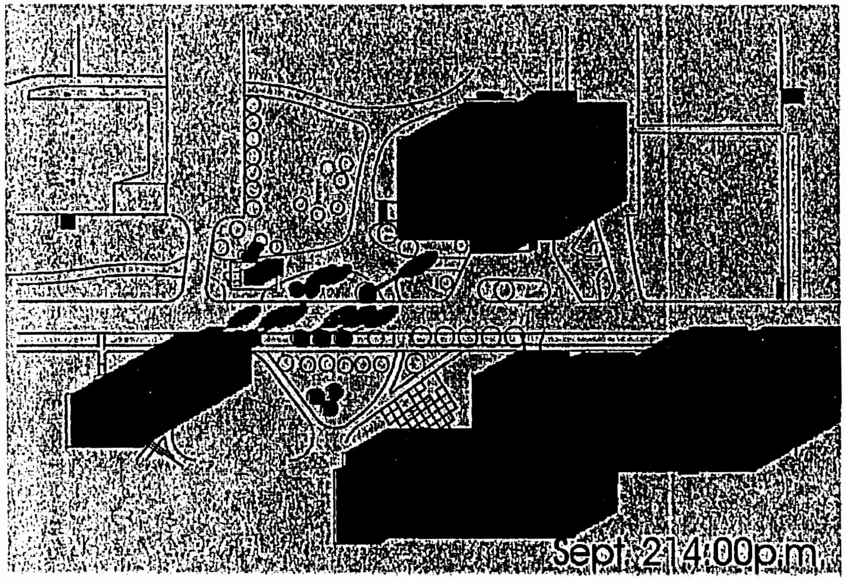
Solar radiation

High angle summer sun filter through the foliage of the trees. Also , radiation is blocked and reflected by trees; thereby reducing its intensity. Radiation reaches the ground and part of it is reflected back from concrete surface. The intense solar radiation may make people feel uncomfortable to sit inside the shelter. If there is not enough air movement, air will be stuffy. Vegetated ground cover can reduce the amount of radiation absorbed and reflected by the concrete surface.

Drawing 3.13: Microclimate - section A - A' , summer



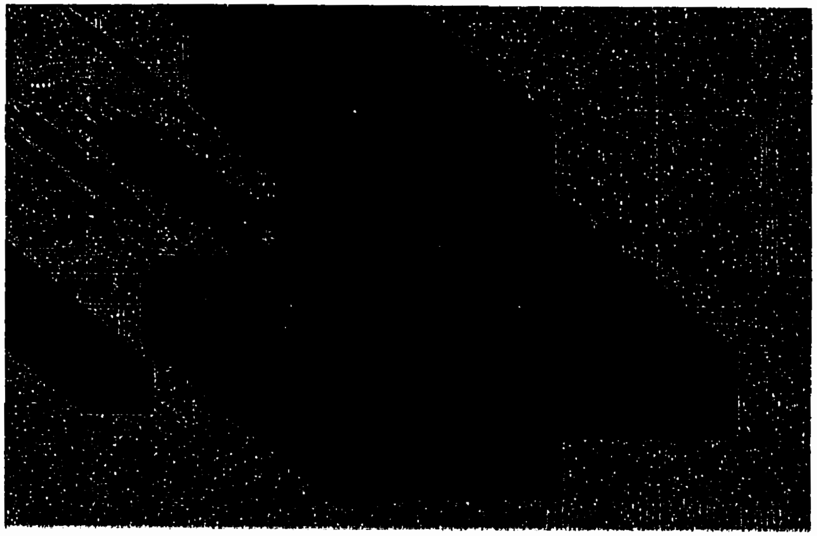


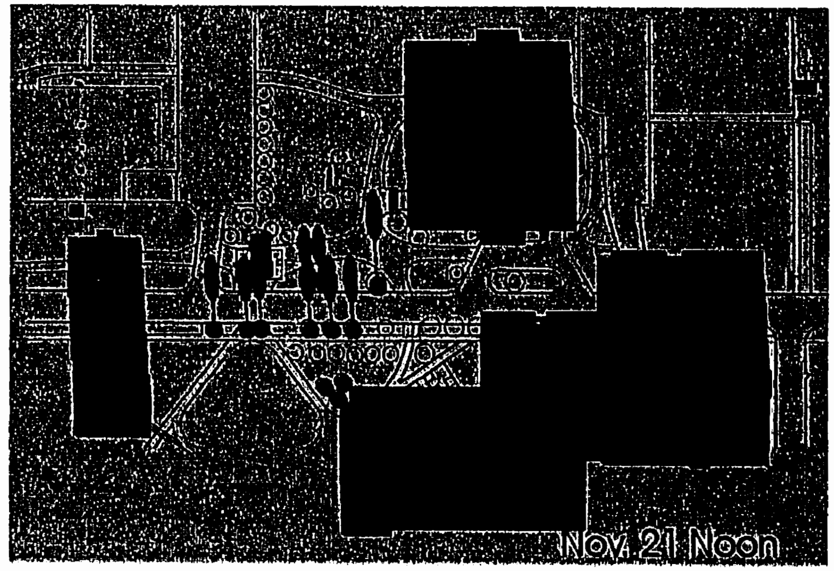


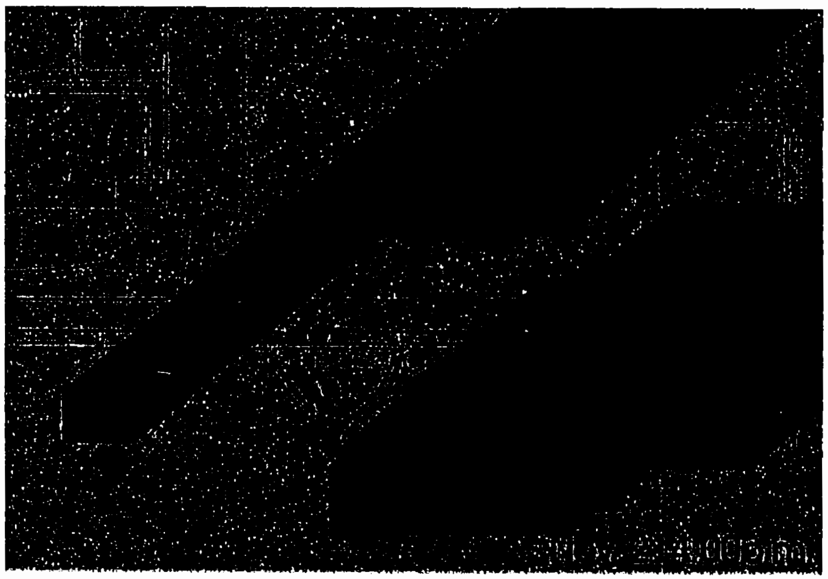
Existing passenger shetler

As shown in the diagrams, the shelter receives direct solar radiation most of the time. Solar energy will be used to operate a ventilating fan inside the shelter. Vegetation is use to shade the shelter during over-heating periods.

Drawing 3.14: September 21st shadow diagrams **Scale: N.T.S.**



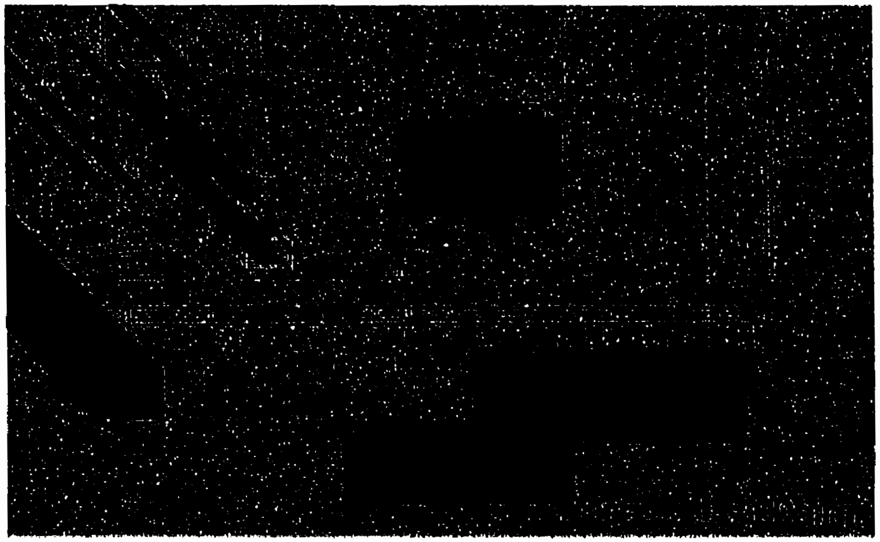


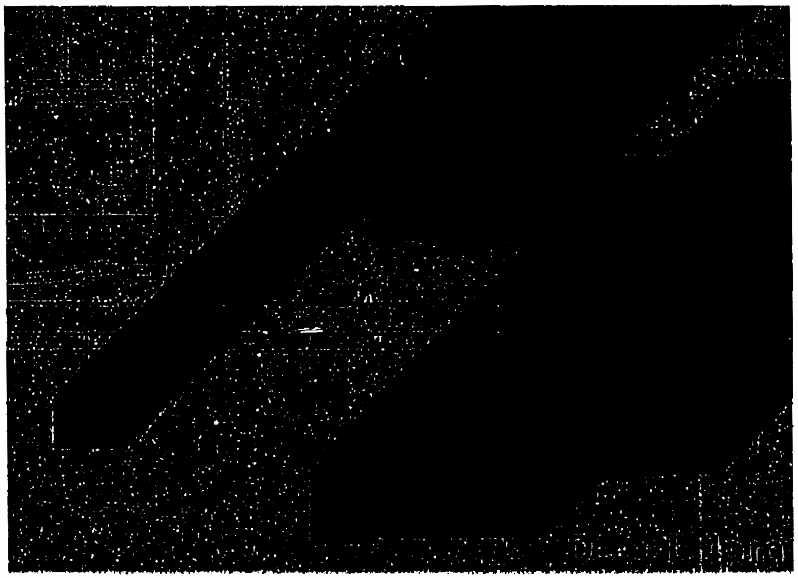


Existing passenger shelter

As shown in the diagrams, the shelter is shaded by adjacent buildings in early morning and late afternoon. It receives direct solar radiation that is filtered through the branches of the trees from late morning to early afternoon.

Drawing 3.15: November 21st shadow diagrams **Scale: N.T.S.**

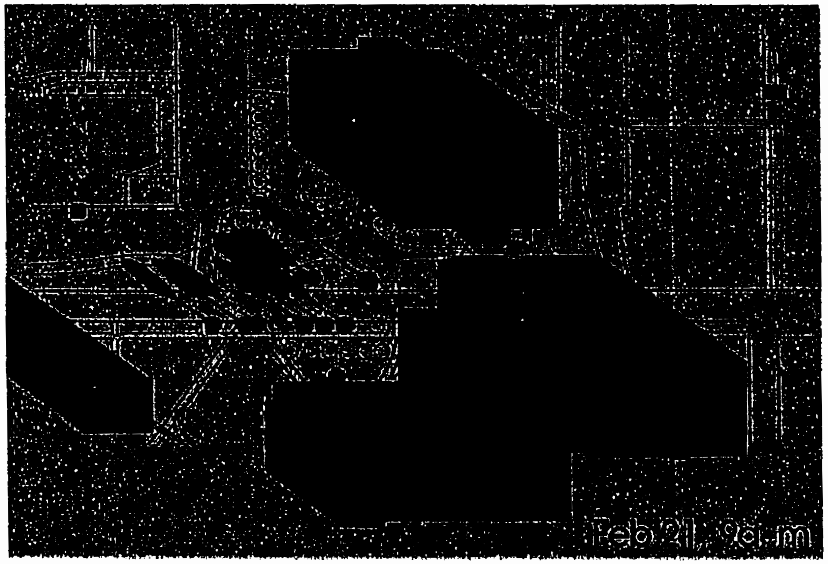


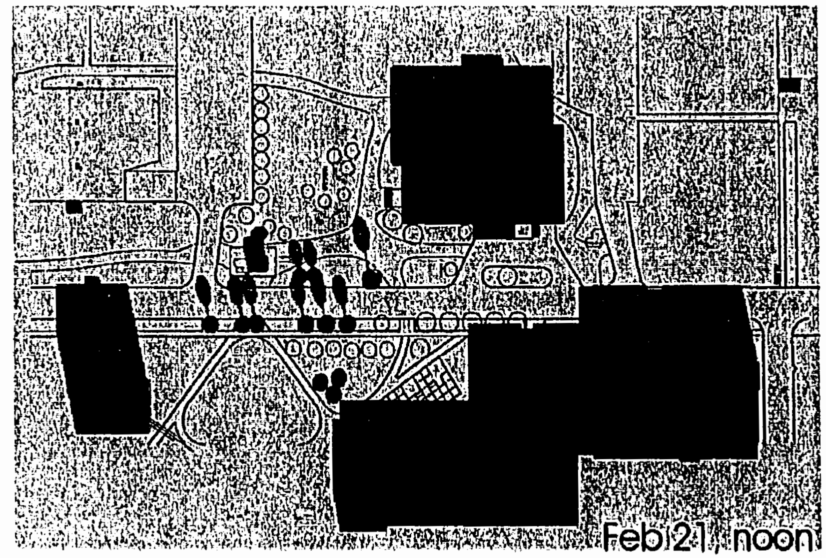


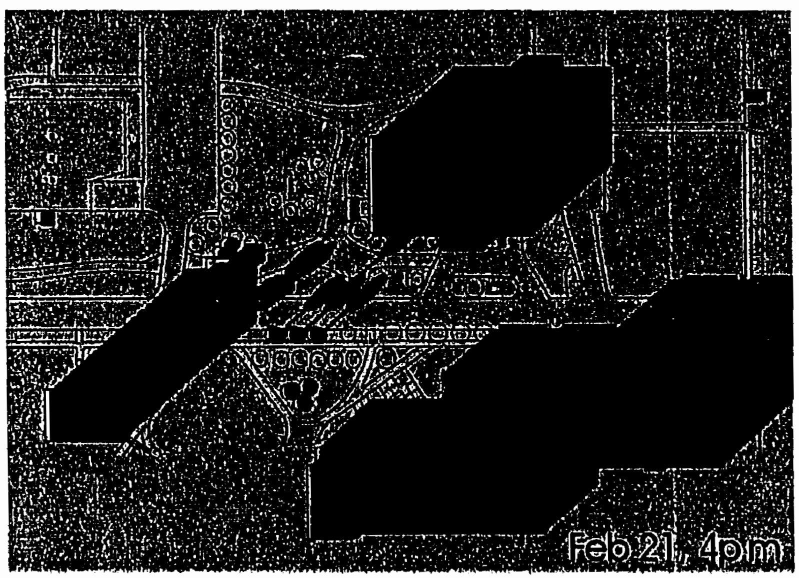
Existing passenger shelter

As shown in the diagrams, the shelter is shaded by adjacent buildings in early morning and late afternoon. It receives direct solar radiation that is filtered through the branches of the trees from late morning to early afternoon. Trees and tall shrubs reduce the effect of wind on the north and west side of shelter.

Drawing 3.16: December 21st shadow diagrams **Scale: N.T.S.**



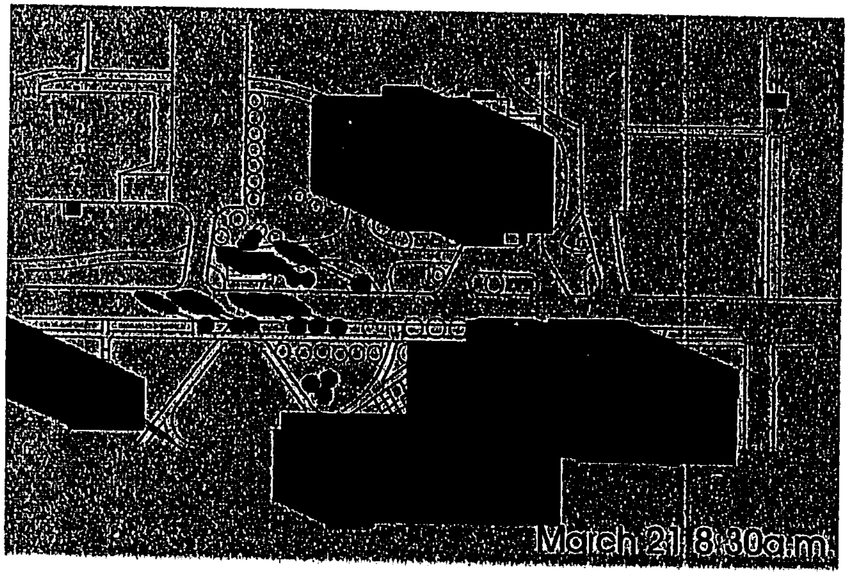


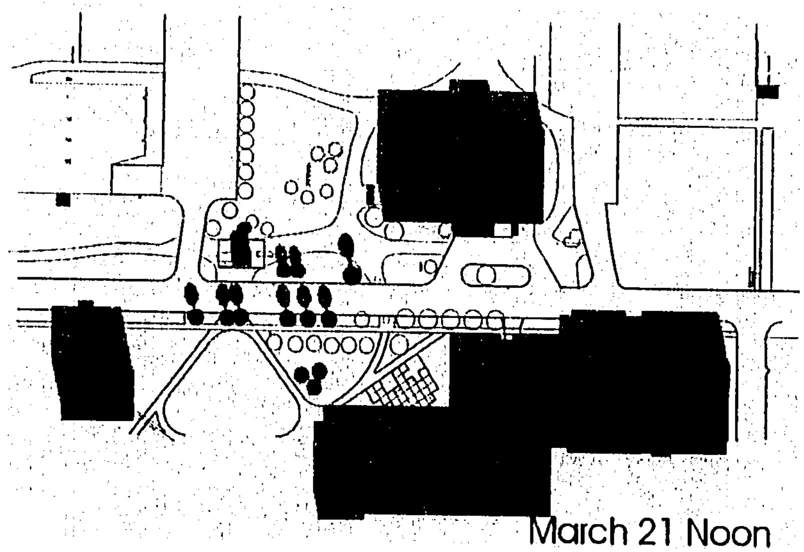


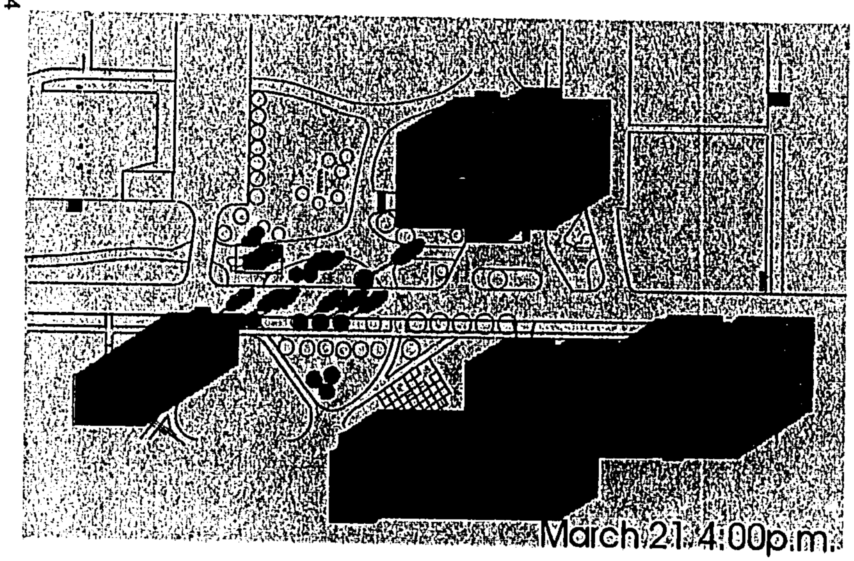
Existing passenger shelter

As shown in the diagrams, the shelter is shaded by adjacent buildings in early morning and late afternoon. The shelter receives direct solar radiation at noon. Low angle winter sun filters through the branches of the trees from late morning to mid-afternoon.

Drawing 3.17: February 21st shadow diagrams **Scale: N.T.S.**



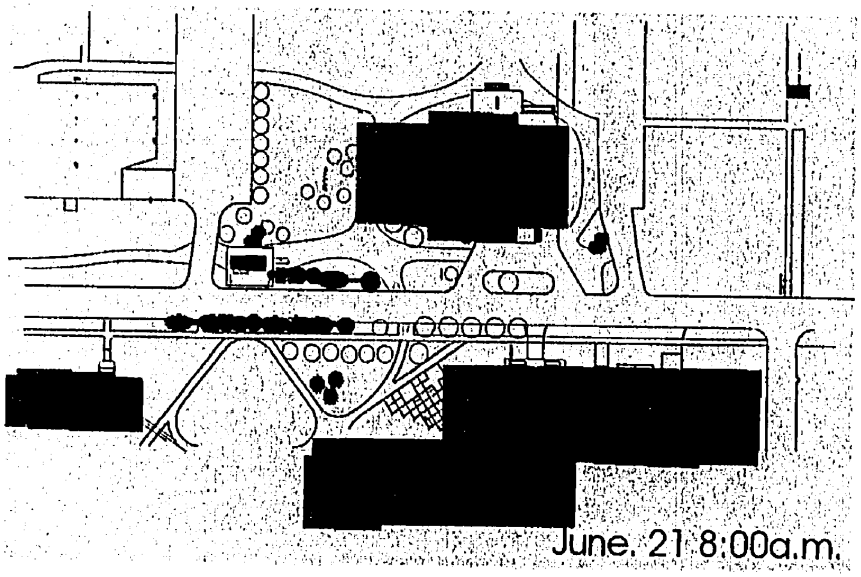


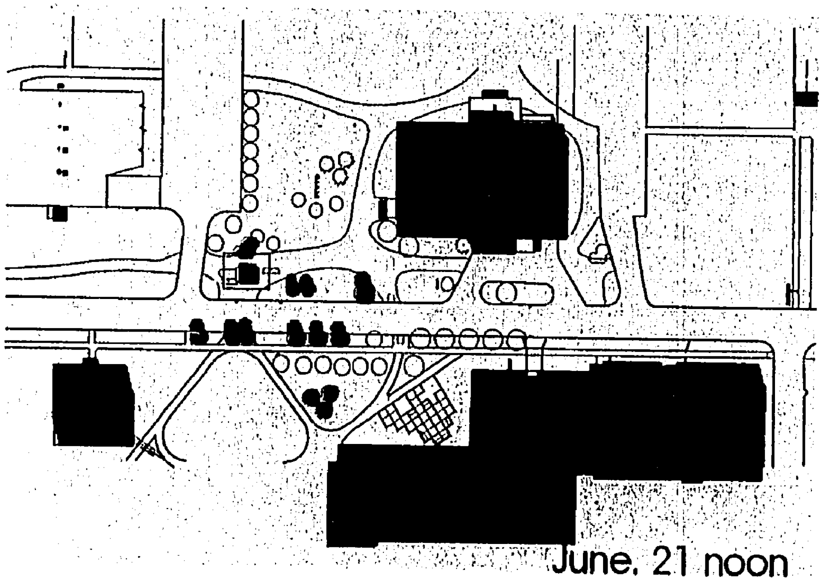


Existing passenger shelter

As shown in the diagrams, the shelter receives filtered solar radiation in early morning. The shelter receives direct solar radiation during daytime.

Drawing 3.18: March 21st shadow diagrams **Scale: N.T.S.**

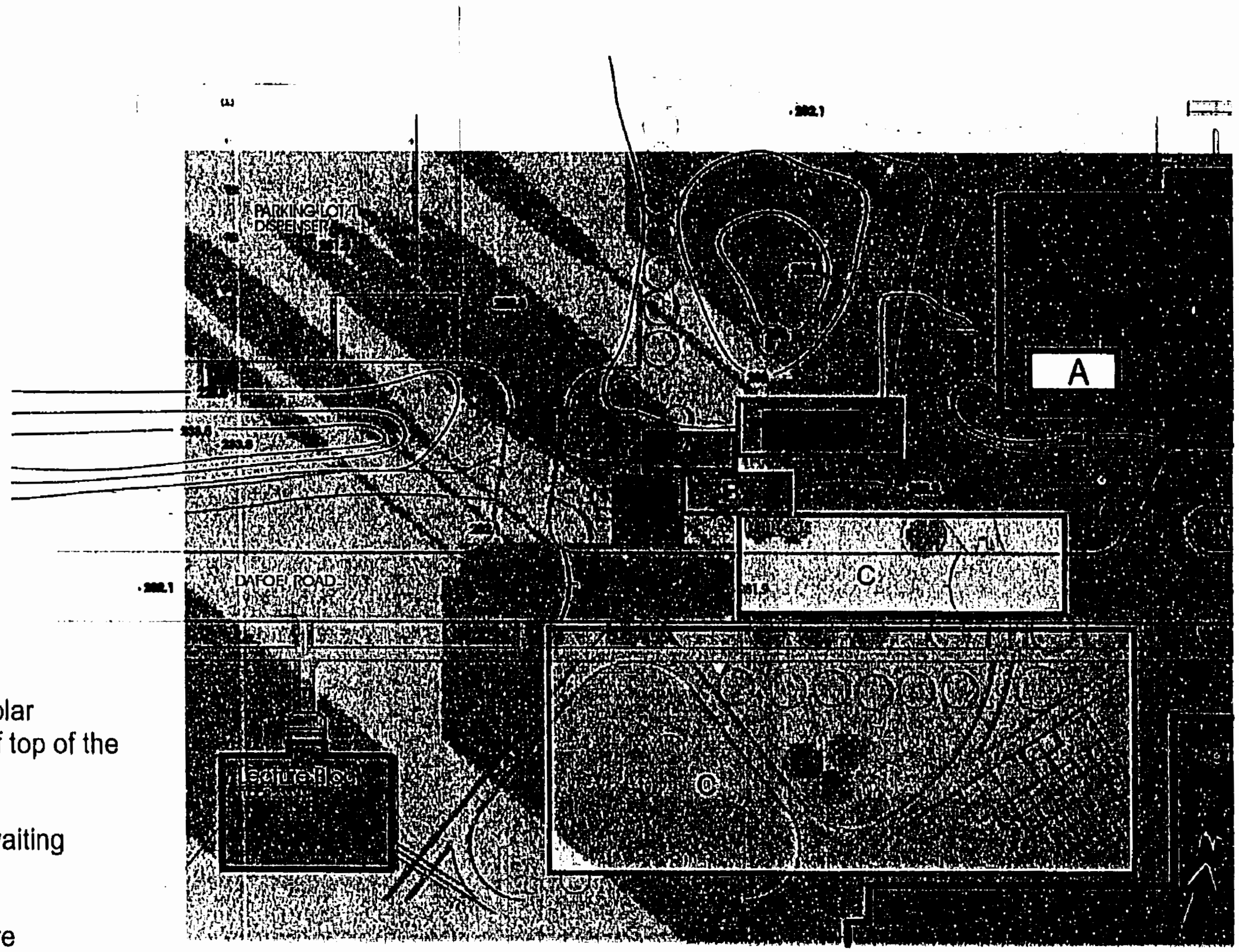




☐ Existing passenger shelter

As shown in the diagrams, the shelter receives direct solar radiation during daytime in summer. Photovoltaic operated is a ventilating fan inside the shelter to increase air circulation.

Drawing 3.19: June 21st shadow diagrams **Scale: N.T.S.**



Existing passenger shelter

*January 21st, 9 a.m. Shadow diagram is overlaid on top of the plan

A. Potential locations for installing solar collector systems. Including the roof top of the Music Building.

B. Sun pockets - potential seating/waiting area.

C. Potential connection of Agriculture courtyard and transit stop by use of native planting.

Drawing 3.20: Design Opportunities **Scale: N.T.S.**

3.4 The proposed transit stop design

The purpose of the proposed design (option A) is to provide a more comfortable microclimate (-particularly in winter) and to enhance the visual quality of the site. The arrangement of vegetation and other site furnishings aims to create continuity with the nearby areas (Drawings 3.21 - 3.25, pages 79 - 83).

Strong winter effects are caused by north and west winds. The wind carries snow and deposits it on the north sides of structures. In order to achieve a more comfortable environment and to minimize adverse winter effects, tree and shrub planting is proposed on the north side of the passenger shelter in order to reduce snow deposition and to reduce the speed of strong winter winds. Shrubs (less than one meter high for clear visibility of the shelter) are also proposed adjacent to the west side of the shelter in order to reduce heat loss. The east side of the shelter remains clear for an unobstructed view oncoming buses.

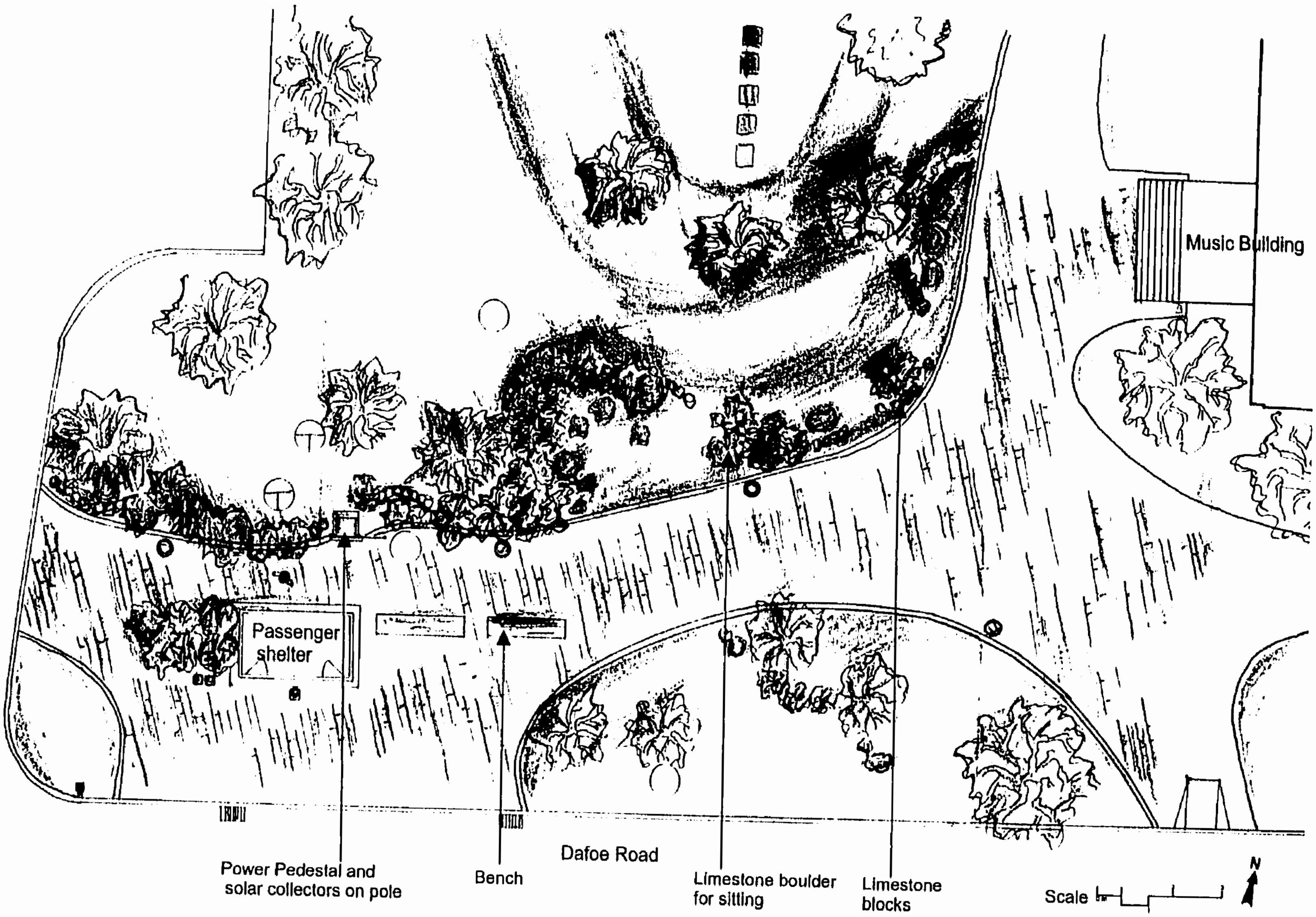
The solar panels and solar thermal collector are proposed to be located 2.3 meters from the north side of the shelter, and three meters above the ground in order to have maximum access to solar radiation and to avoid vandalism. The power pedestal is located beneath the solar panels and solar thermal collector.

The arrangement of vegetation is in a curved form. This arrangement gives continuity of the organic form of landscape on the west and north side of the Music Building. Also, the vegetation forms pocket areas for informal outdoor space for students from nearby buildings. Limestone blocks and boulders are proposed to refer to the context of the campus (the use of limestone for buildings, such as Tier Building and Engineering Building, and on base of virtually every subsequent building). The boulders also can be used for seating. The colour changes of foliage in different seasons are an accent to the landscape.

Proposed design - Option B (Drawing 3.26, page 84) shows the preferred design of the site. This is similar to the design shown in Drawing 3.21 (page 79). Except that design option B accounts of the shuttle bus stop in front of the Music Building. The extended arrangement of planting to incorporate the shuttle bus waiting area would create a unified transit stop on this section of Dafoe Road.

3.4.1. The Landscape plan proposed by the Winnipeg Transit System

The landscape plan proposed by the Winnipeg Transit System (Drawing 3.27, page 85) is a standard layout for a transit stop. Solar collectors will be installed on the roof of passenger shelter and the power pedestal will be located on the west side of the shelter. The existing bench on the east side of the shelter will be removed and relocated at the west side of the shelter. The layout of this transit stop will provide a clear and obstacle-free stop platform. The Exterior Environment Committee of the University will provide project funding for extending the paving units from the transit stop to the front of the Music Building.



Drawing 3.21: Transit Stop Design - OptionA

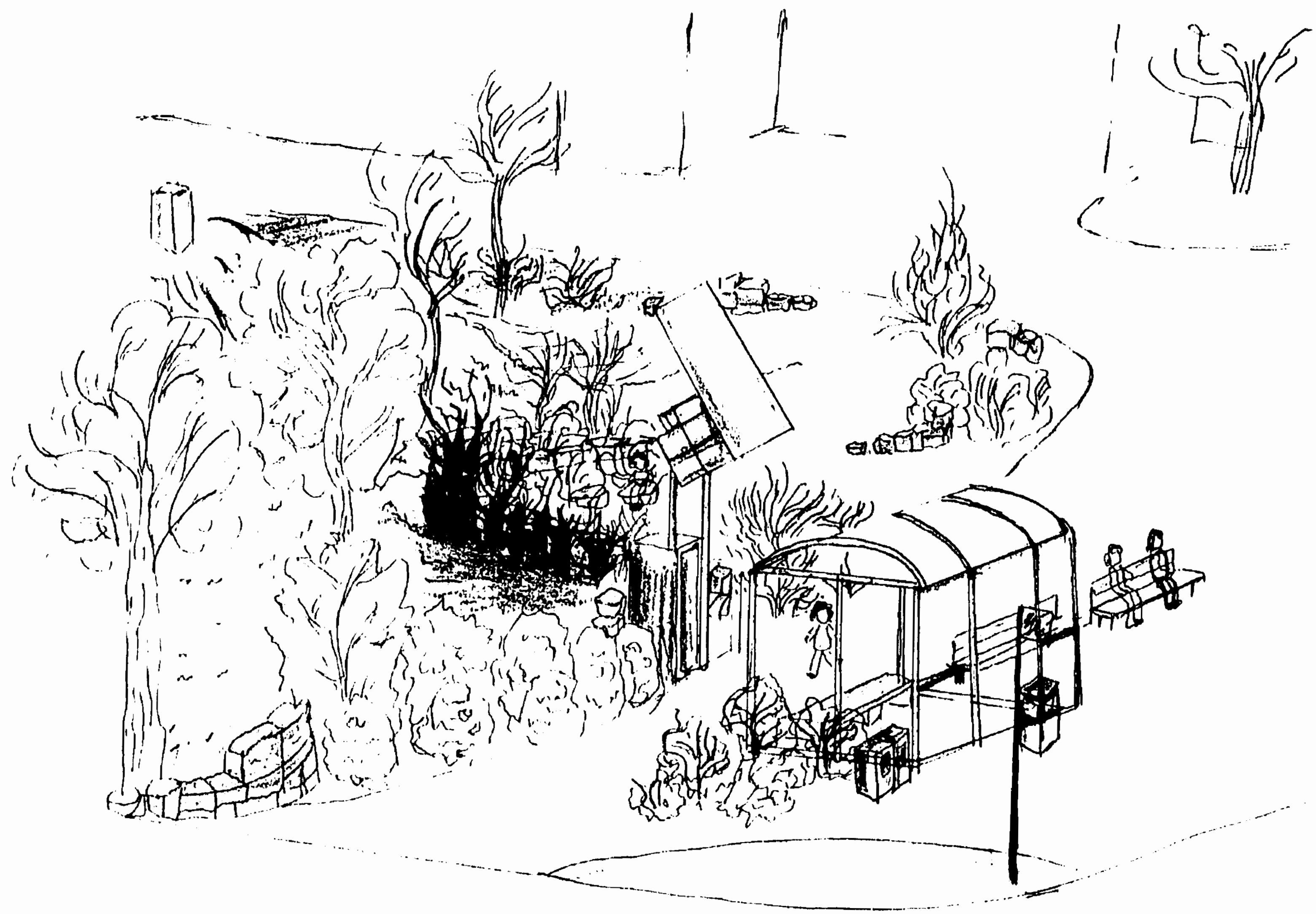
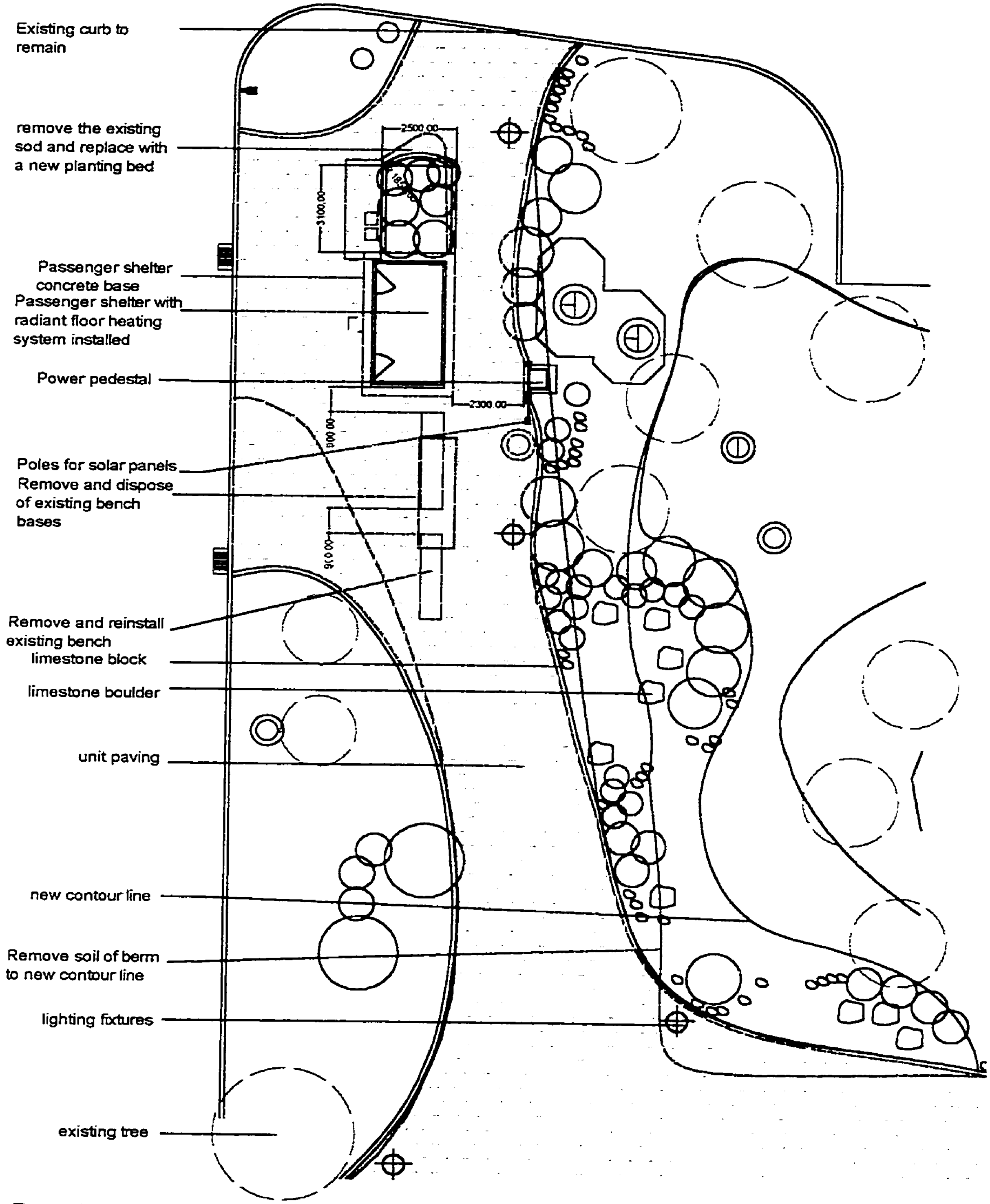


Figure 3.22: Option A - View to the transit stop from the west side of Dafoe Road

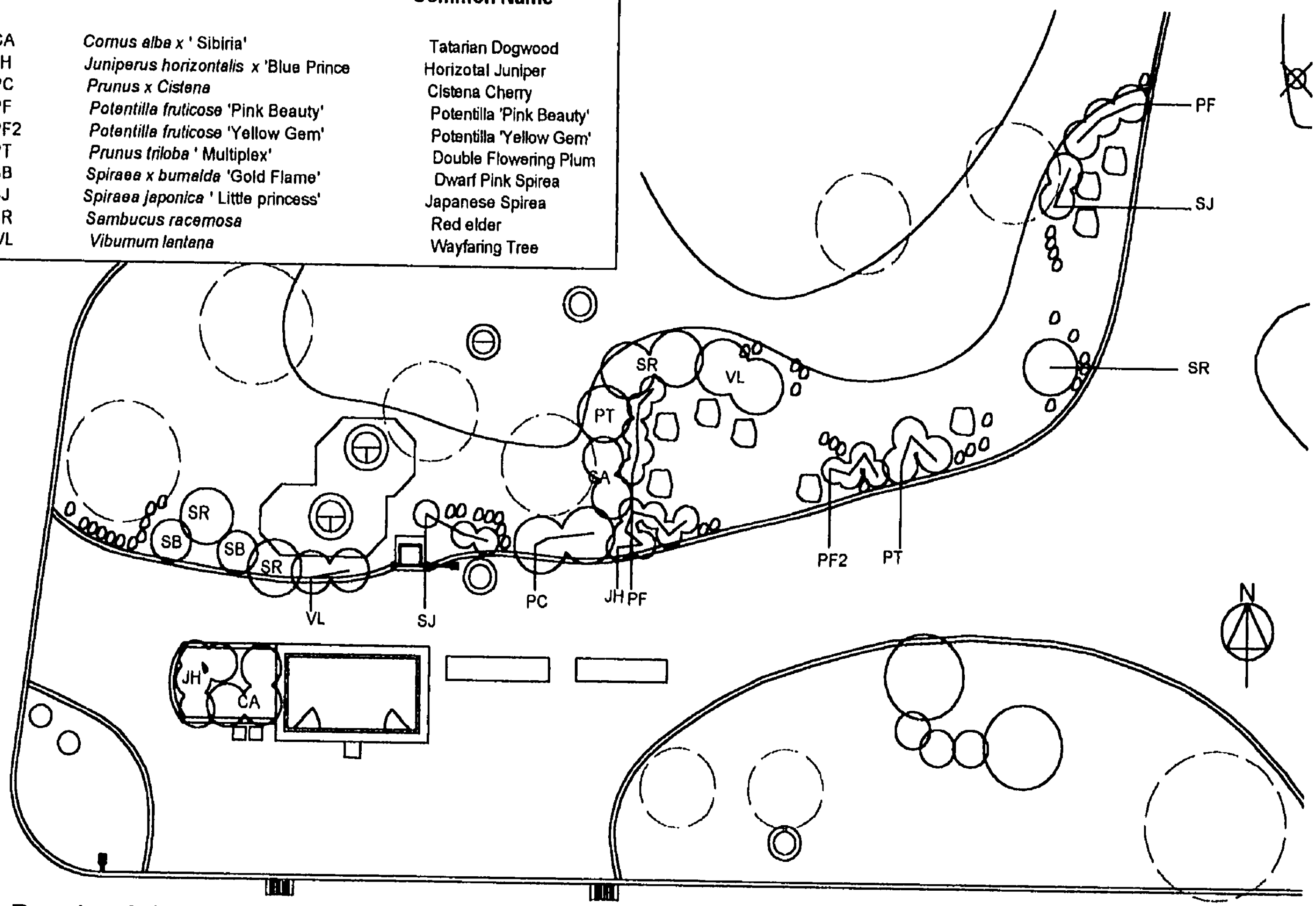
Drawing 3.23: Option A - View to the transit stop from the east side of Dafoe Road



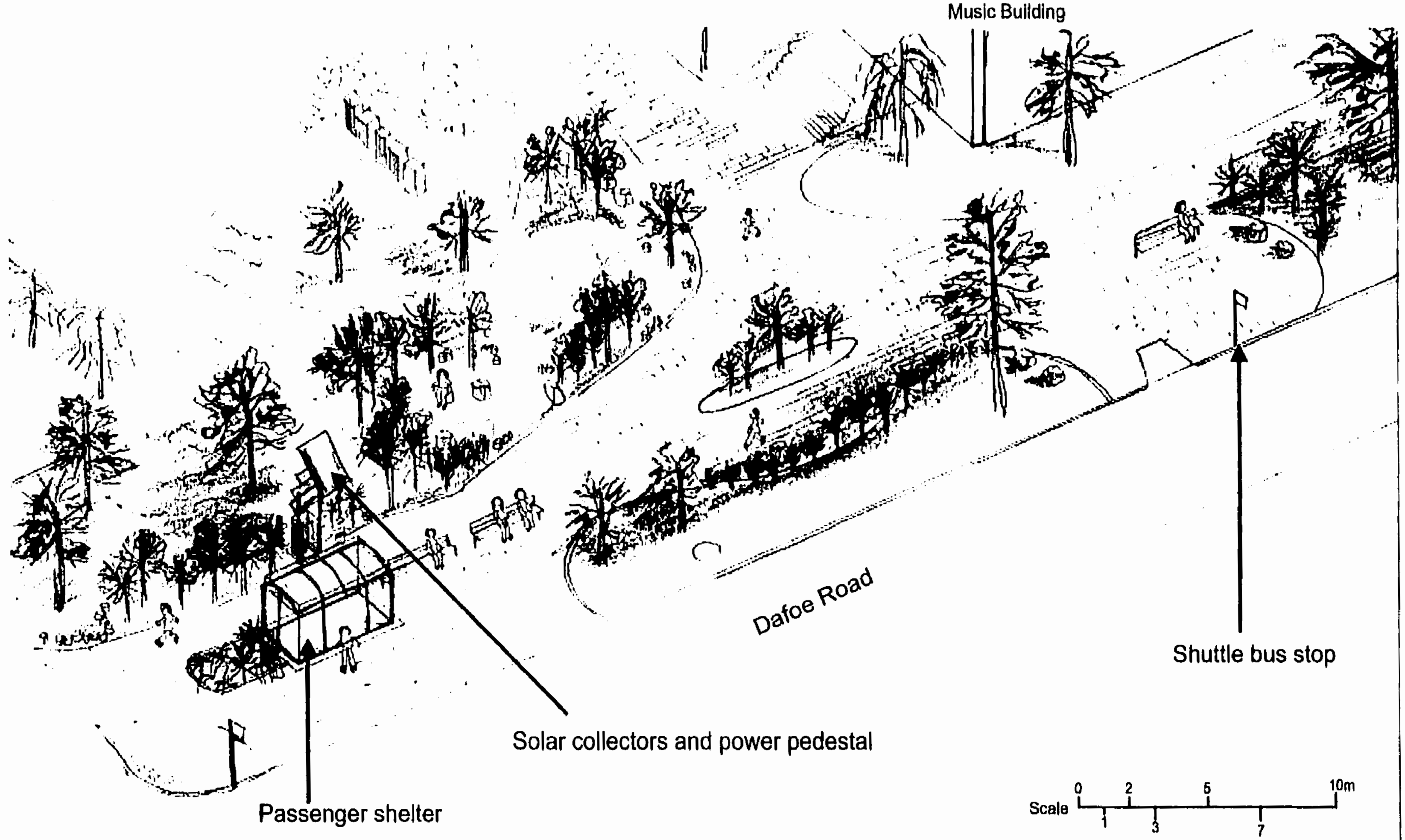
Drawing 3.24: Proposed landscape plan (Option A) - layout
Scale: N.T.S.

Key

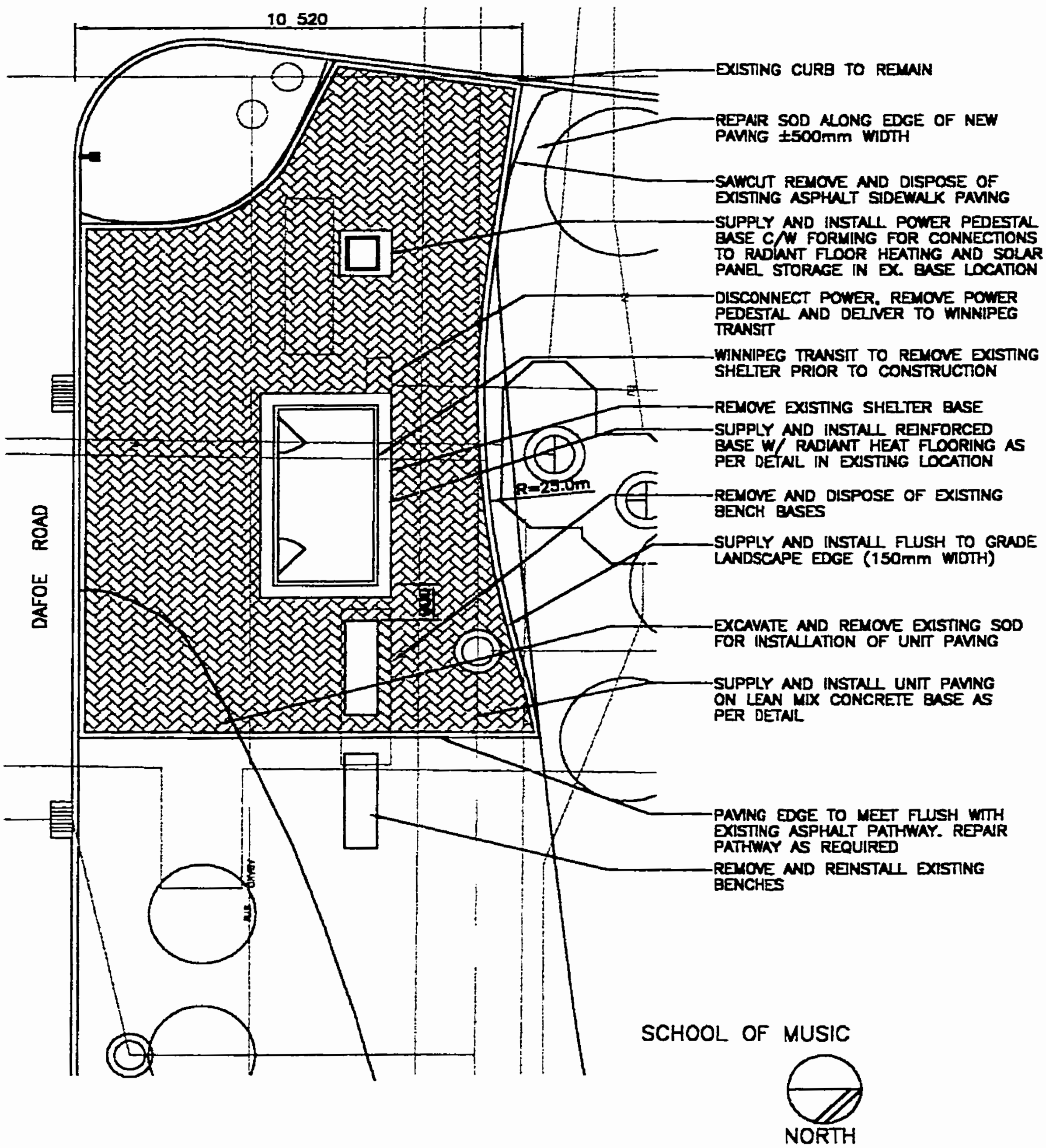
Symbol	Scientific Name	Common Name
CA	*Cornus alba x* ' Sibiria'	Tatarian Dogwood
JH	*Juniperus horizontalis* x 'Blue Prince	Horizotal Juniper
PC	*Prunus x Cistena*	Cistena Cherry
PF	*Potentilla fruticose* 'Pink Beauty'	Potentilla 'Pink Beauty'
PF2	*Potentilla fruticose* 'Yellow Gem'	Potentilla 'Yellow Gem'
PT	*Prunus triloba* ' Multiplex'	Double Flowering Plum
SB	*Spiraea x bumalda* 'Gold Flame'	Dwarf Pink Spirea
SJ	*Spiraea japonica* ' Little princess'	Japanese Spirea
SR	*Sambucus racemosa*	Red elder
VL	*Viburnum lantana*	Wayfaring Tree



Drawing 3.25: Planting Plan for landscape design option A
Scale: N.T.S.



Drawing 3.26: Transit Stop Design - Option B



Drawing 3.27: Landscape plan by Winnipeg Transit System (provided by McGowan Russell Design Group, Winnipeg) Scale: N.T.S.

3.5 Future development

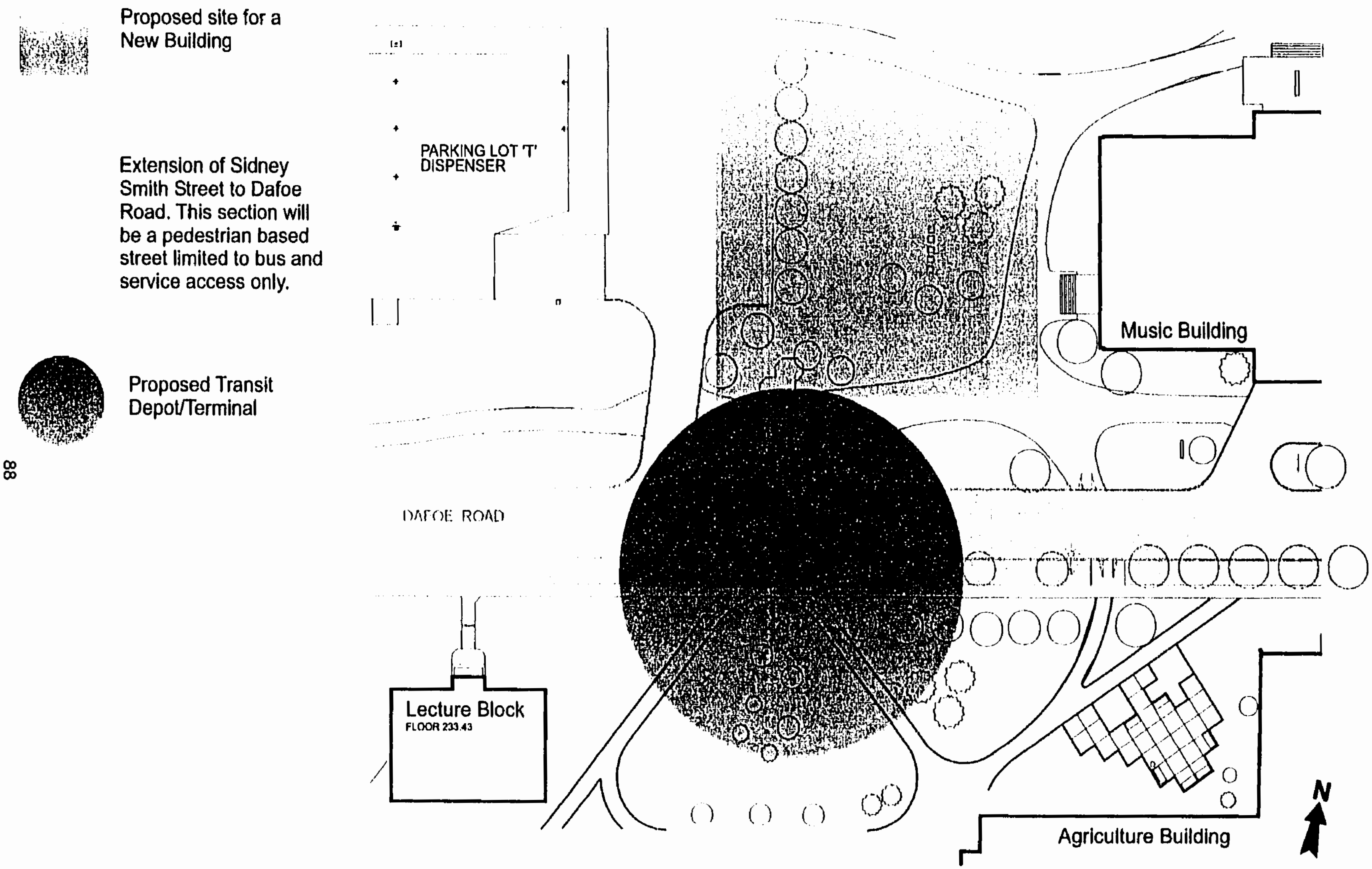
Current solar technology allows photovoltaic panels to be installed on the facades of buildings (Figure 3.10). With this technology, the application of solar systems for passenger shelters would not limit the orientations of shelters across the city. Solar collectors can be installed on surrounding buildings for maximum access to the sun. Therefore the design of individual transit stops and passenger shelters could respond to context, microclimate and the volume of passengers to any given location.

Figure 3.10 : Public library (1995) in Pompeu Fabra, Mataró, Barcelona by Miquel Brullet i Tenas. The building is oriented so that the main facade faces south. The main energy souce is the PV system which has been installed on the south facade and the roof.

Source: Herzog, T. (editor), 1998. Solar Energy in Architecture and Urban Planning. Munich: Prestel. 140.

The proposed site has the potential for the application of this technology. The Master Plan Committee for the University is allowing for construction of a new building west of the Music Building, and north of the existing transit stop. This Committee and the Winnipeg Transit System are considering expansions of the existing transit stop into a transit depot/terminal (see Drawing 3.28, Page 88). Solar collectors could be installed on the south facade of the proposed building in order to provide electricity for the transit depot and the building itself (see Drawing 3.29, Page 89). The energy could be used for the passenger shelters, and also for the surrounding. This might include a radiant heating system on sidewalks to melt snow or the supply of power for lighting fixtures.

Remote solar systems would allow passenger shelters to be free from considerations of orientation. This would allow new possibility for the design of passenger shelters with different configurations and materials relating to their contexts . It is recommended that the Winnipeg Transit System should investigate new landscape furniture designs (such as benches, bus stop markers and information kiosks) which would co-ordinate with the shelter's design.



Drawing 3.28: Future development on Dafoe Road

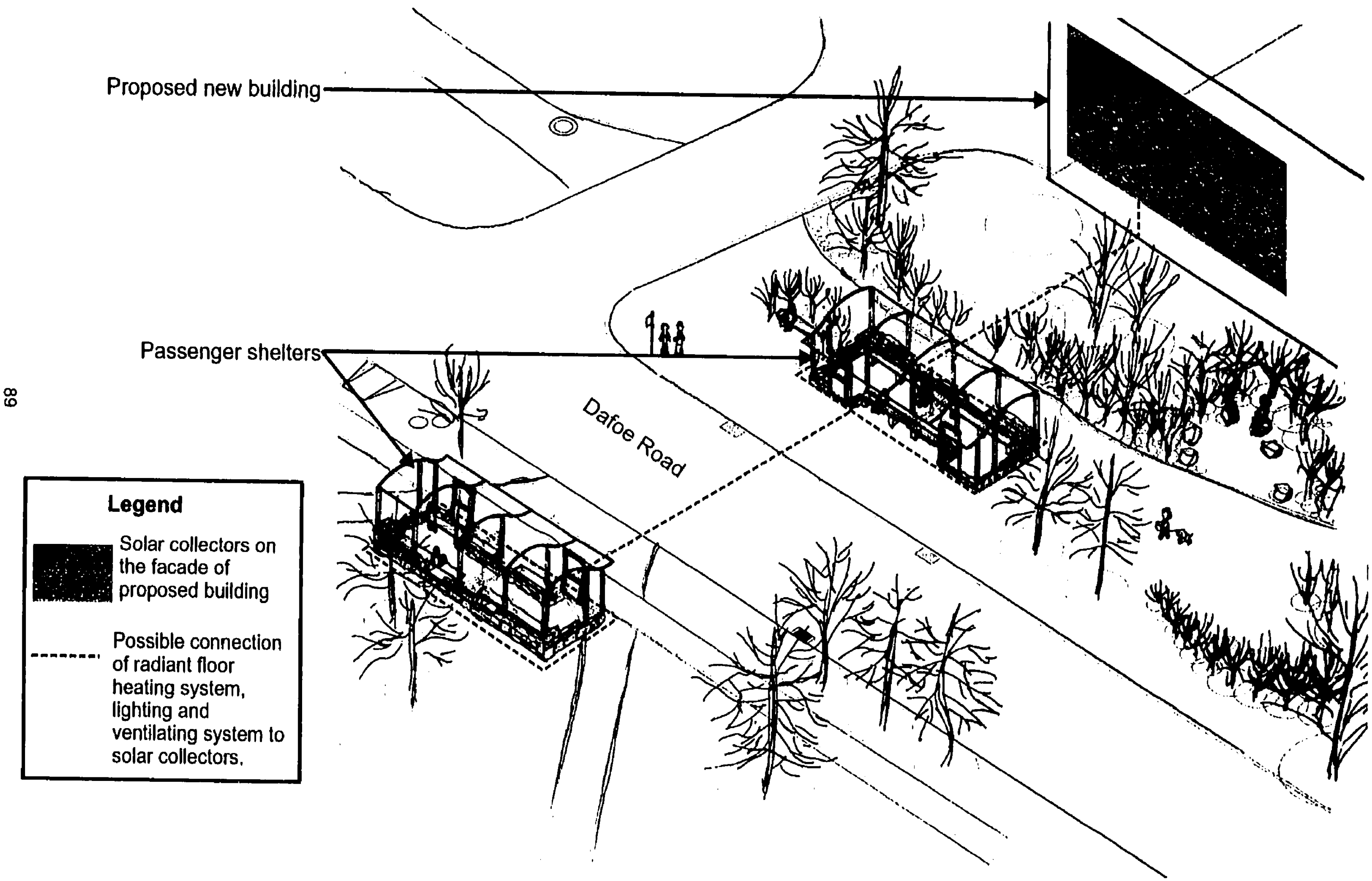
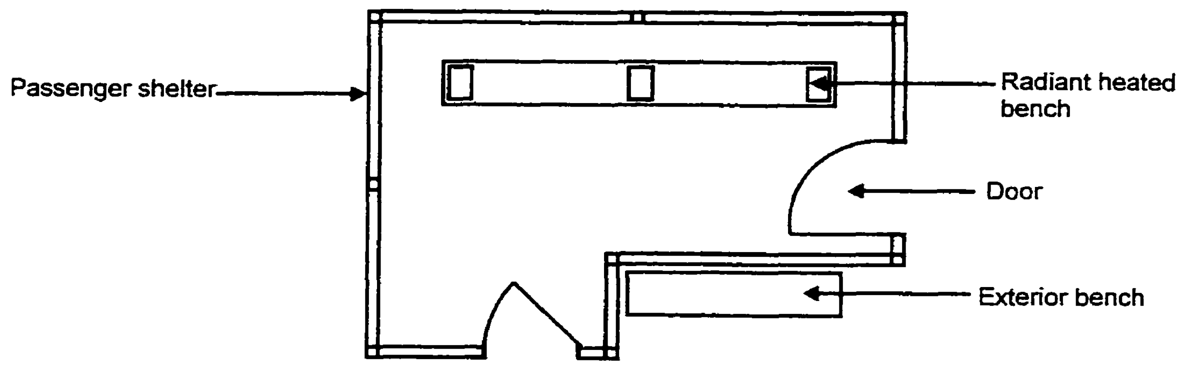


Figure 3.29 : Future Transit Depot/Terminal Opportunity on Dafoe Road, University of Manitoba, Fort Garry Campus

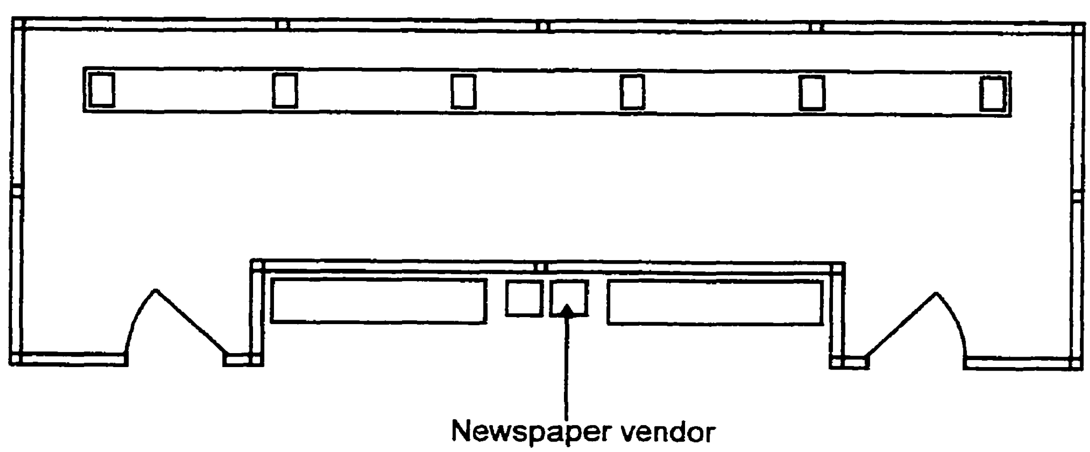
The shape of new passenger shelters should respond to the demands of human comfort and passenger circulation. L-shaped shelters have a greater flexibility as a modular unit than other shapes. Drawings 3.30 and 3.31 (Page 91) illustrate possible configurations of L-shaped shelters.

A basic L-shaped shelter has an indented exterior space for passengers who do not want to stand inside the shelter (see Drawing 3.30, page 91). This exterior space can be oriented according to wind direction at the site in order to reduce its effect on waiting passengers. The doors can be located according to the distance from the shelter to the road, and should respond to wind directions in order to minimize heat loss and to reduce air movement within the shelter in winter, or to allow wind enter the shelter in summer.

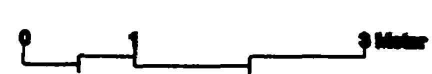
Two or more shelters could be attached to accommodate more passengers (see Drawing 3.31, page 91). Benches and other site furniture, such as newspaper vendors and trash units, could be placed in the indented exterior space to keep pedestrian circulation areas free from obstacles. Planting materials can be arranged to modify microclimate of the site and thereby contribute to the comfort of passengers using the transit stop.



Drawing 3.30: Basic L-shaped shelter - Plan view

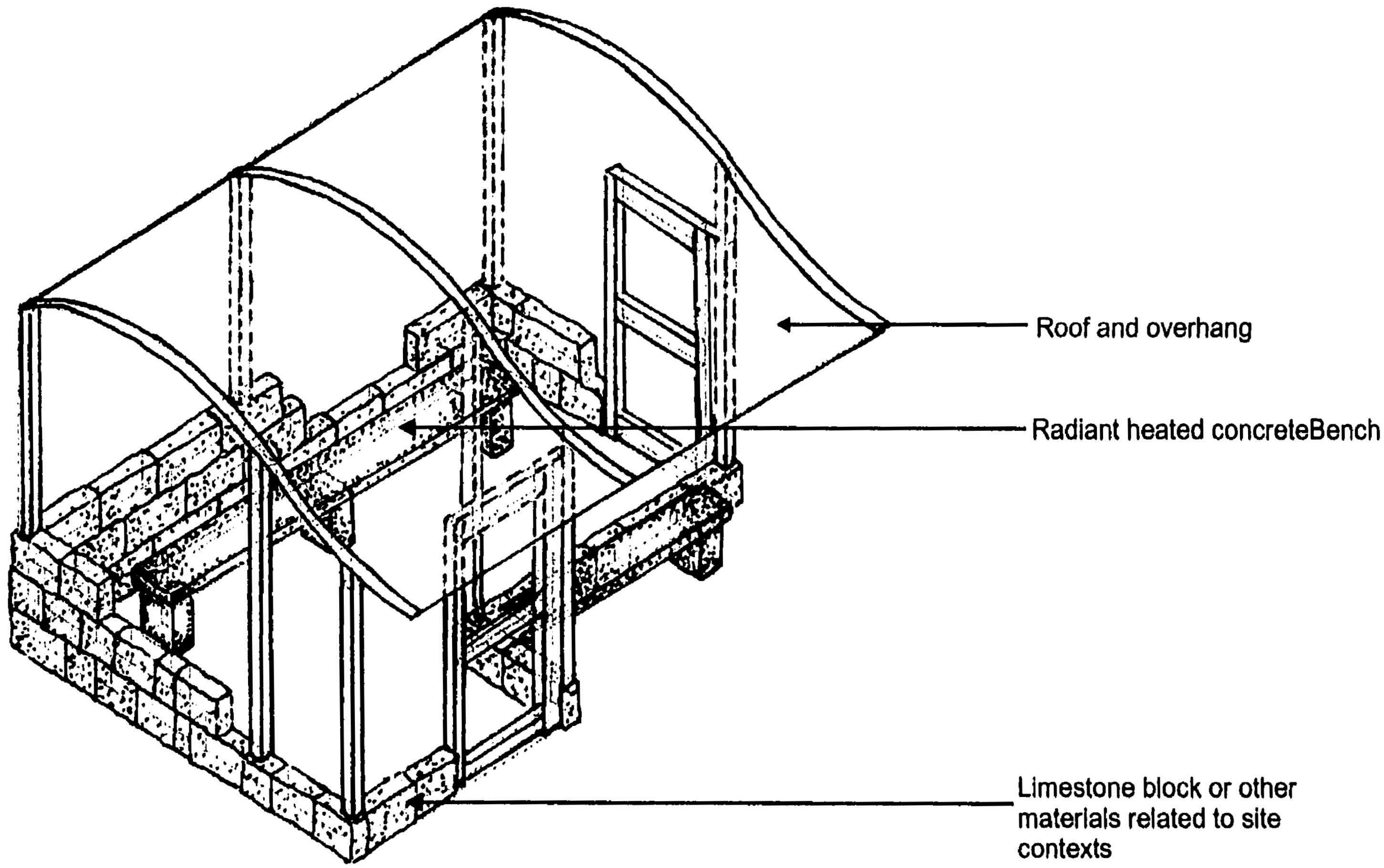


Drawing 3.31: Two attached L-shaped shelter - Plan view

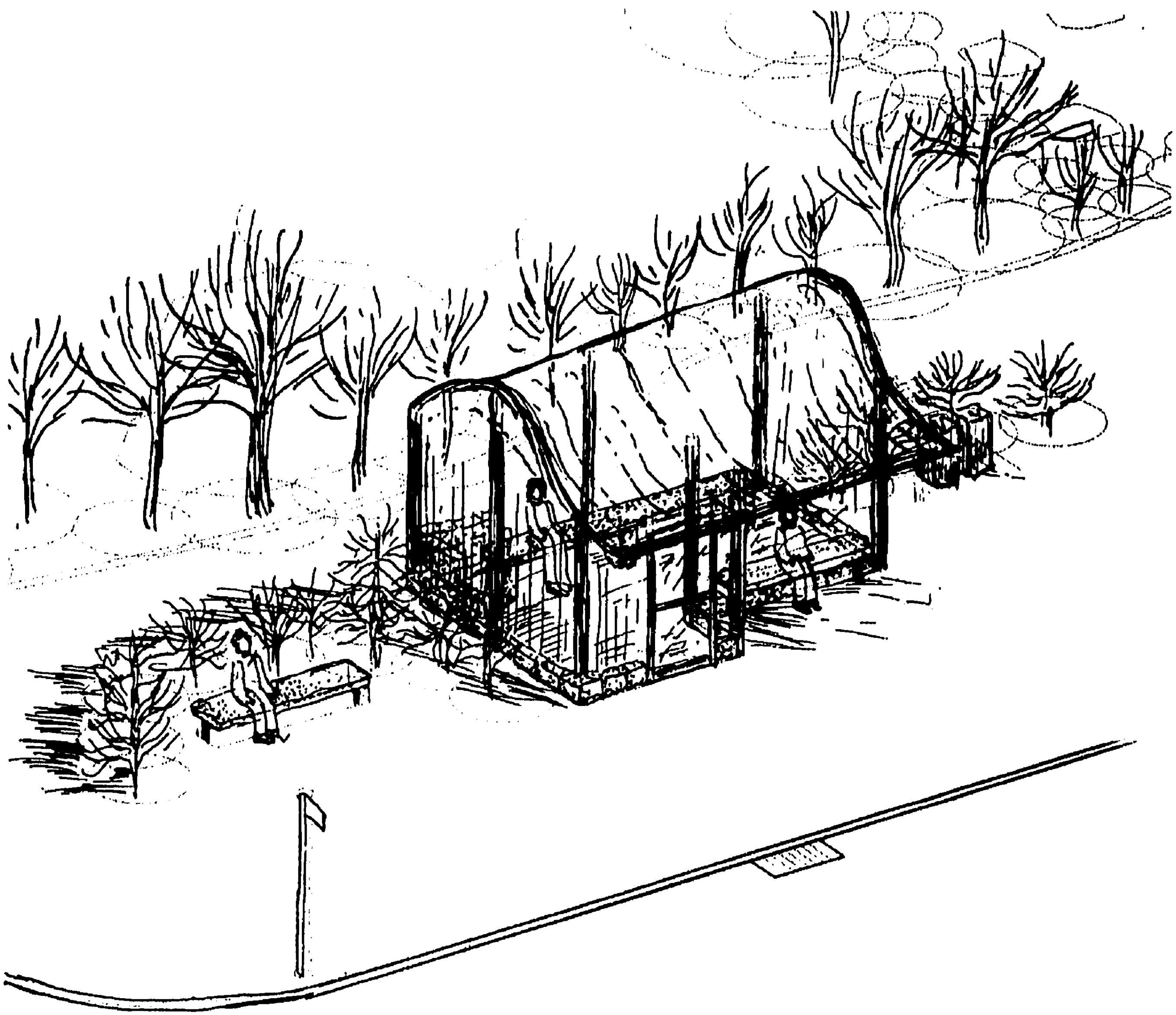


The structural materials of the shelter could be changed in relation to the site context. For the proposed site on Dafoe Road, the base framing material of the shelter should be limestone or other building materials that are common on the campus (see Drawing 3.32, Page 93). This would create continuity with the campus. The height of the stones (or other materials) should not exceed 0.9m (3') for security reasons to provide clear visibility to incoming buses.

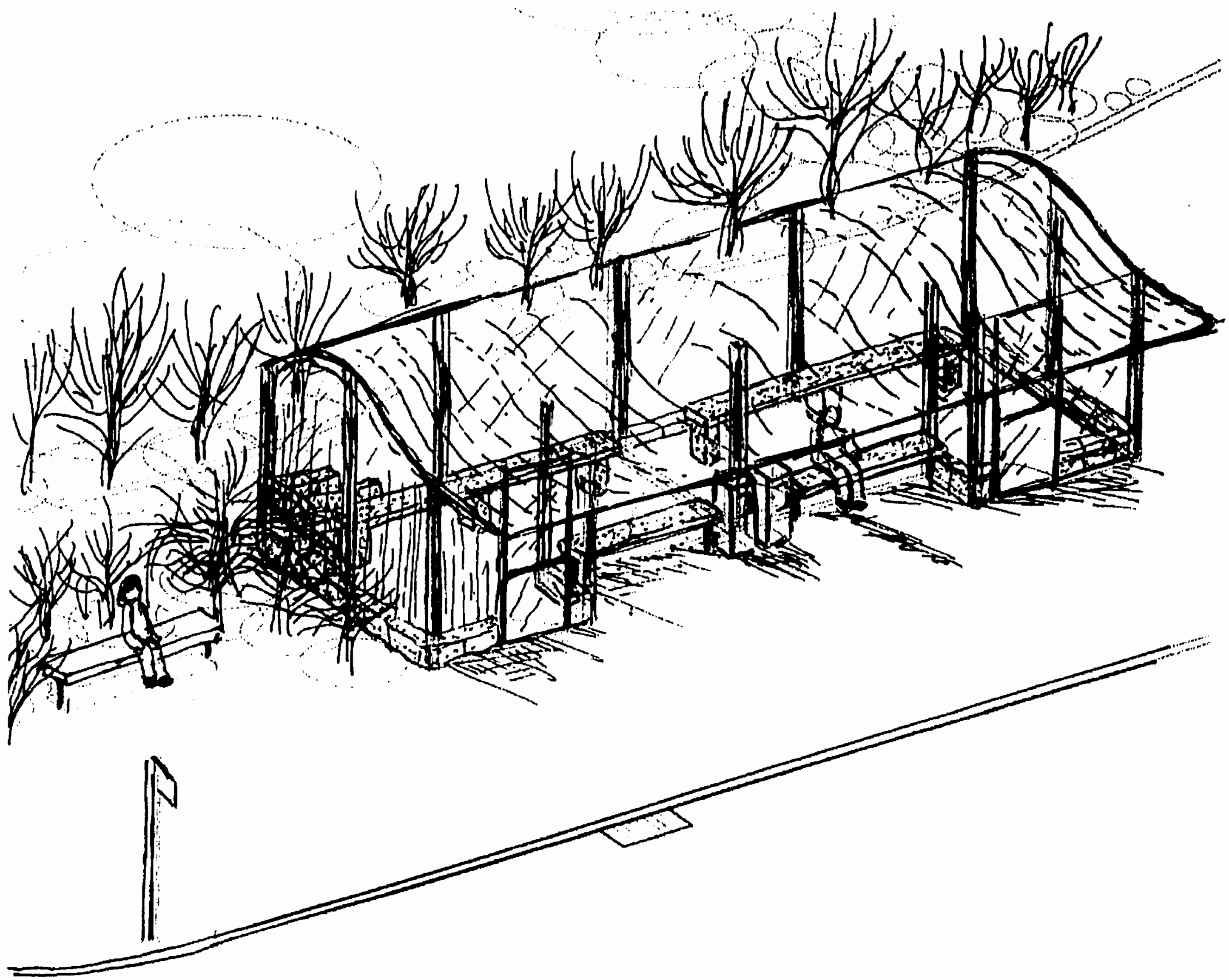
The arched roof could be extended beyond the edge of the shelter to provide shading and protection from rain and snow for people waiting in the indented exterior space. The curved roof would also improve the appearance of the shelter (see Drawings 3.33 & 3.34, Page 94 & 95).



Drawing 3.32: Isometric view of the L-shaped shelter



Drawing 3.33: Sketch of L-shaped shelter on proposed site



Drawing 3.34: Sketch of two attached L-shaped shelters on proposed site

Chapter 4: Passenger Shelter Prototype

4.1 Introduction

The basic function of a passenger shelter is to keep passengers safe and to protect them against snow, wind, sun and rain. Existing passenger shelters in Winnipeg are marginally effective in performing these functions. Many people complain about heating systems not warming up the shelter effectively and, in summer, air inside the shelter can be very hot and stuffy. In addition, the metal benches inside the shelters can be too cold to sit on in winter and too hot to sit on in summer.

The design for the passenger shelter prototype is intended to improve thermal comfort. The concept examined in this study is to replace the conventional heating system with radiant heating for the floor system and bench seat. Solar radiation will provide energy for the radiant system, lighting and ventilation, thereby reducing operation costs and minimizing the need for energy from other sources.

This chapter examines, first, the existing various types of passenger shelter throughout the city of Winnipeg and then analyses shelter design, in terms of heating/cooling systems, lighting, materials and human comfort. The last section of this chapter proposes a prototypical passenger shelter incorporating solar energy.

4.2 Location of the prototype

The passenger shelter prototype replaces the existing passenger shelter which is located on Dafoe Road, east of the Music Building and south of the Architecture II Building, at the University of Manitoba, Fort Garry Campus, Winnipeg.

The Winnipeg Transit System and the University of Manitoba are working in partnership on this project, with Winnipeg Transit System providing capital funding and professional design support. The University of Manitoba will provide some maintenance support for the bus shelter and Professor Leon Feduniw (Department of Interior Design, Faculty of Architecture) and his students will monitor the efficiency of the radiant floor heating system for a period of one year. If the efficiency level of the system meets expectations, Winnipeg Transit will consider installing more of these passenger shelters across the city.

4.3 Passenger shelters in the City of Winnipeg

In Winnipeg, there are about 4,475 bus stops and 800 passenger shelters, of which approximately 80 are heated with electric convective heaters. Shelters are usually located at bus terminals, in the downtown area, at major activity centers (such as shopping malls, post-secondary institutions, hospitals, seniors' homes and at other high transit usage locations), and along major arterial routes.

4.3.1. Small non-heated passenger shelter

The dimensions of the current standard small passenger shelter are:

a) 1.2m wide X 2.4m length, non-heated, one-opening and no door.

b) 1.5m wide X 3.8m length, non-heated, one-opening and no door.

This type of passenger shelter is usually located along major transit corridors and adjacent to busy transit usage locations. The basic structure of the small passenger shelter is a metal frame with single-paned half inch float tempered glass on four sides, and a curved LEXAN semi-transparent plastic roof (see Figures 4.1 to 4.3, Page 99) or flat wooden frame roof. Some of the shelters have a metal or plastic bench inside which allows only two people to sit at the same time. The shelter can accommodate about three or four people standing comfortably. Lighting is provided by sunlight during the day and by surrounding street lights at night.

The primary function of this type of shelter is to protect passengers from wind, snow and rain. However, this non-heated type of shelter does not protect passengers from cold air temperature. When sunny, heat is provided by direct solar radiation through the glass walls and roof. These shelters lose heat from the opening and the two inch drainage spaces under the glass walls. In summer, the opening of the shelter can provide some air movement inside the shelter but, intense solar radiation often increases air temperatures inside the shelter to a level of discomfort. As a result, in summer, passengers often prefer to stand outside and use the shelter only when it is raining, hailing, very windy or when the outdoor air temperature is low.

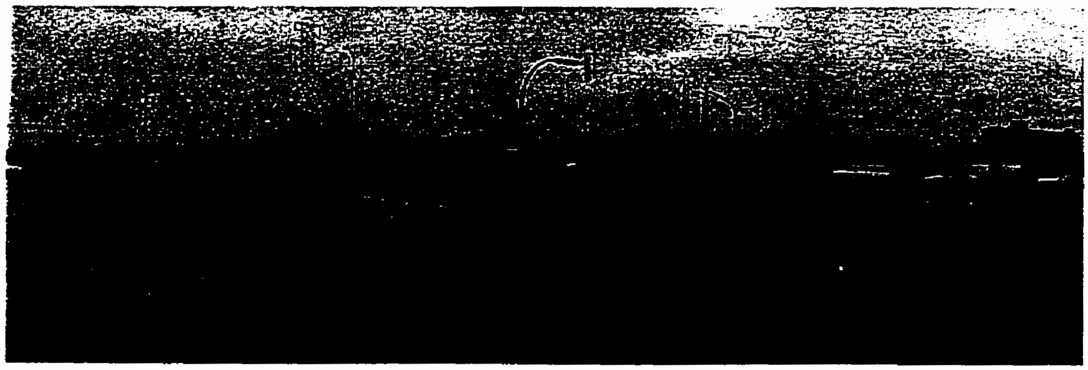


Figure 4.1: a small non-heated bus shelter at Bishop Grandin Avenue and St. Mary Avenue.

Figure 4.2: small non-heated shelter on Nassau Street and Corydon Avenue. It is common for most of shelters to get dirty in winter because of the salted sand and dirt.

Figure 4.3: This is one of the old design shelters on Nassau Street and Pembina Highway. It is built from aluminum and glass.

4.3.2. Heated passenger shelter

The heated passenger shelters vary in size. Two typical sets of dimensions are:

a) 2.4m wide X 4.5m length, heated, two doors.

b) 2.5m wide X 7.0m length, heated, two door.

The basic structure of this type of bus shelter is similar to the small, non-heated bus shelter, except that the top and the bottom of the tempered float glass walls are attached to the metal frame (see Figures 4.4 to 4.6, Page101). There is a half inch gap under the door. A flat wooden frame roof variation can also be seen throughout the city. Larger shelters of the same basic design are used at terminals to accommodate more people (see Figures 4.7- 4.8, Page 102).

These shelters use electrical energy for heating lighting and ventilation. Heating is provided with two electric convective heaters located behind or under the metal benches. Some shelters have ventilating windows on both roof end walls while others are equipped with ventilating fans on one end, and one or two ventilating windows (depending on the size of shelters) on the other end wall near the roof plane. Sunlight provides sufficient light during the day, and two caged orange lamps are located on each end of the long axis of the shelter to provide light at night. These lights are automatically switched on and off between dusk and dawn by sensors on top of the lamps.

Figure 4.4: Large, heated passenger shelter on Osborne Street and Pembina Highway. The sign on the roof provide clear information.

Figure 4.5: Large, heated passenger shelter at the bus terminal at the University of Manitoba, Fort Garry Campus.

Figure 4.6: Standard heated passenger shelter on Portage Avenue.

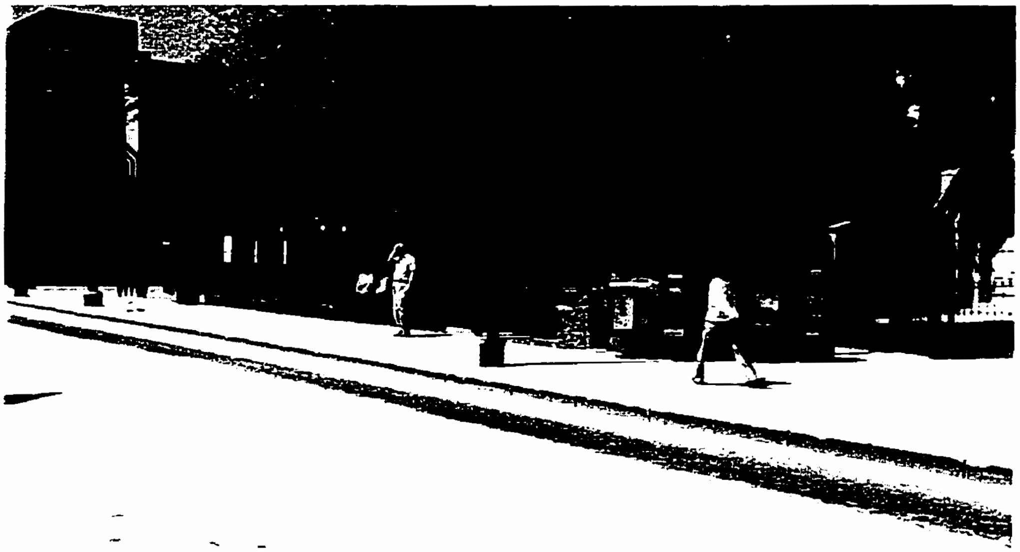


Figure 4.7: A larger shelter at downtown bus terminal on Graham Avenue.

Figure 4.8: Bus terminal at St. Vital Shopping Center.

These types of shelter can accommodate up to twenty people standing comfortably inside them. In winter people tend to stay inside the shelters even though the electric heating system does not provide an adequate level of comfort because the shelters provide protection against wind and snow. In summer, people prefer not to use the shelters because they are often hot and stuffy.

4.3.3. Innovative passenger shelter

Innovative passenger shelters demonstrate a different approach from conventional bus shelters. They vary in form, dimensions and materials and are better integrated with their surroundings.

The passenger shelter located at the corner of Portage Avenue and Memorial Boulevard, in front of the One Canada Center Building in Winnipeg , is a good example of contextual integration (see Figure 4.9). This shelter was designed in the same materials as the building and becomes an extension of that building.

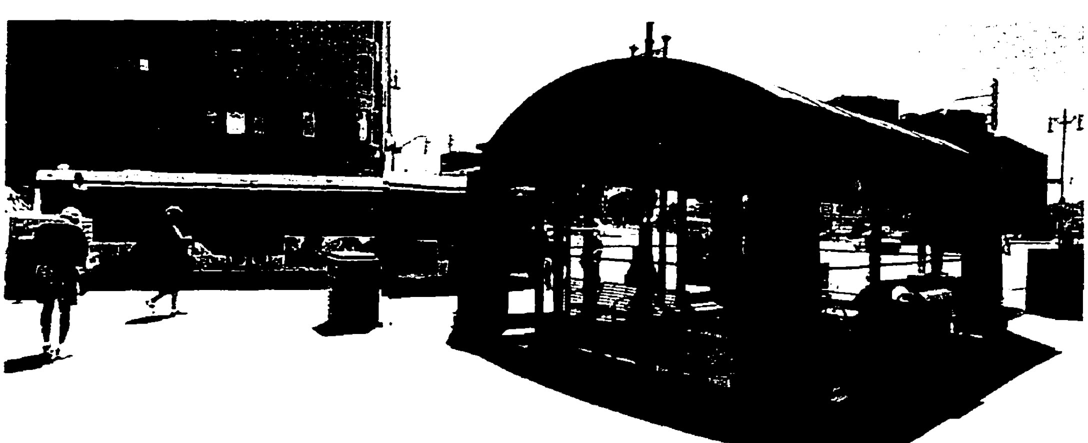


Figure 4.9: Bus passenger in front of One Canada Center Building on Portage Avenue. The shelter and site furnishing are an extension of the building's design.

A less successful design is the shelter at the corner of Portage Avenue and Smith Street (see Figure 4.10). This consists a canopy roof which is attached to the wall of the building and a wooden bench, also attached to the wall. The canopy roof above the bench offers some protection from direct sun but does not provide any protection for passengers against rain, snow and wind because it is too high.

Figure 4.10: Bus passenger at Portage Avenue and Smith Street in downtown. This shelter provides minimal protection for passengers from rain and snow. Primary intent is to mitigate down drafts from adjacent building.

Both shelters described above were designed by different architects who were trying to improve comfort for waiting transit passengers.

4.4 Analysis of passenger shelter

This section consists of an analysis of heating and cooling systems, lighting and structural materials for a passenger shelter which is to be a retro-fitted prototype on Dafoe Road, University of Manitoba. Some of the information in this analysis was taken from a report prepared by a group of University of Manitoba students in 1995 [1]. The previously existing shelter had a pedestal on the west side for controlling the electrical power supply and distributing it for lighting and heating (see Figure 4.11) . The shelter was dismantled in September 2000 in preparation for installation of the prototype.

Figure 4.11: Passenger shelter structure to be retro-fitted with a radiant-floor heating system on Dafoe Road, the University of Manitoba, Fort Garry Campus.

4.4.1. Mechanical Heating System

There were two conventional electric convective heaters located between the glass wall and the benches (see Figure 4.12, Page 106). Air warmed by the heaters rose to the arched roof, then fell to the floor as it cooled, creating a loop with the coldest air at the floor level. As a result, the air temperature at the floor was cold. In addition, drafts were created and the air was stratified with the warmest air at the ceiling (see Drawing 4.1, Page 107).

Additional air movement was induced by the opening and closing of the doors and by minor activities of the people inside the shelter. At night, electric lights inside the shelter added about 409.44 BTU/hr source of heat [2] (see Figure 4.13)

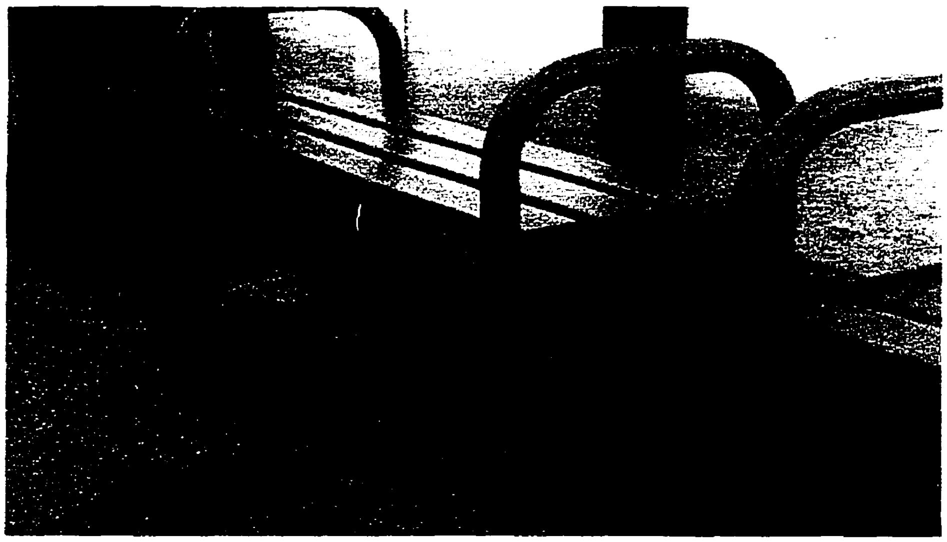
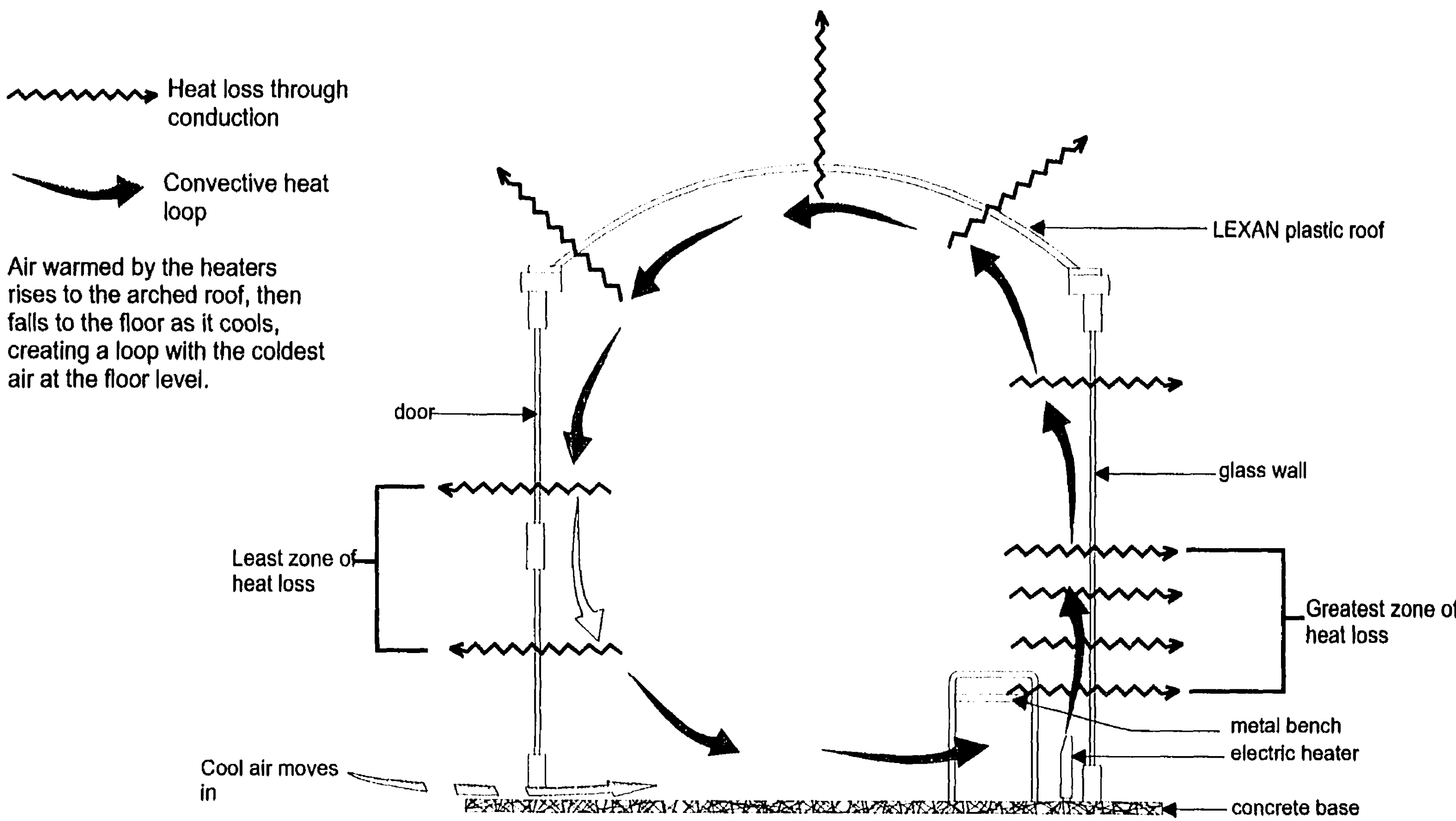


Figure 4.12: Metal bench and electric convective heaters inside the shelter

Figure 4.13: Passenger shelter at night. The intensity of the orange/yellow lamps is high. However, there is no other artificial light source on either side of the shelter.



Drawing 4.1: Convective heat loop **Scale: N.T.S.**

4.4.2 Passive Heating System

A passive heating system utilizes solar radiation and heat gain from occupants. The basic material of the shelter is glass; therefore, long-wave radiation is trapped creating a greenhouse effect. This effect is more pronounced in summer because of increased radiation intensity and duration. However, since the single-paned glass walls are highly conductive to heat flow and the greenhouse effect is considerably lessened in winter. The rate of heat lost by conduction increases with increases in inside and outside temperature differences.

Sensible heat generated by one person while seated is only about 450 BTU/hr. Therefore only a small amount of heat is generated by occupants. With the shelter generally and seldom having more than ten occupants at any one time, the heat that they generated was not a significant consideration.

4.4.3 Cooling systems

Since there was no mechanical system cooling was through natural ventilation by opening of doors. An electrically powered fan would provide ventilation in summer, as well as in winter, and removing moisture which accelerates body heat loss and which obscures the view by condensing on the interior surfaces of the shelter.

4.4.4. Materials

The glass walls were a poor insulation material but needed to be transparent in order to increase the sense of safety for occupants. There was a problem of condensation on the interior surfaces in winter as a result of higher moisture content (relative humidity) in warm air. Much of it was generated by occupants. Moisture reached its dew point on the cold glass surfaces and created fogging on the glass walls.

The concrete floor without insulation underneath could not retain stored heat. Furthermore, the metal frame was highly conductive to heat flow. Consequently, there was a high level of heat loss at the bottom edge of the shelter. In summer, the metal bench was too hot to sit on because metal is a good conductor of heat and was cold in winter because metal has a low capacity for storing heat energy.

4.5 Preferred passenger shelter prototype

The initial proposal was to design a solar-powered bus shelter which would be different from "typical " bus shelters. A prototype installed adjacent to the existing bus shelter on Dafoe Road would compare thermal performance and energy efficiency with the existing shelter (see Figure 4.14, Page 110). However, due to limited project funding, Winnipeg Transit System, in consultation with the University's Exterior Environment Committee decided that the existing bus shelter should be retro-fitted with a conventional radiant floor heating system, a radiant-heated bench, and solar powered lighting and ventilating systems.


Figure 4.14: Looking at the shelter from south side of Dafoe Road.

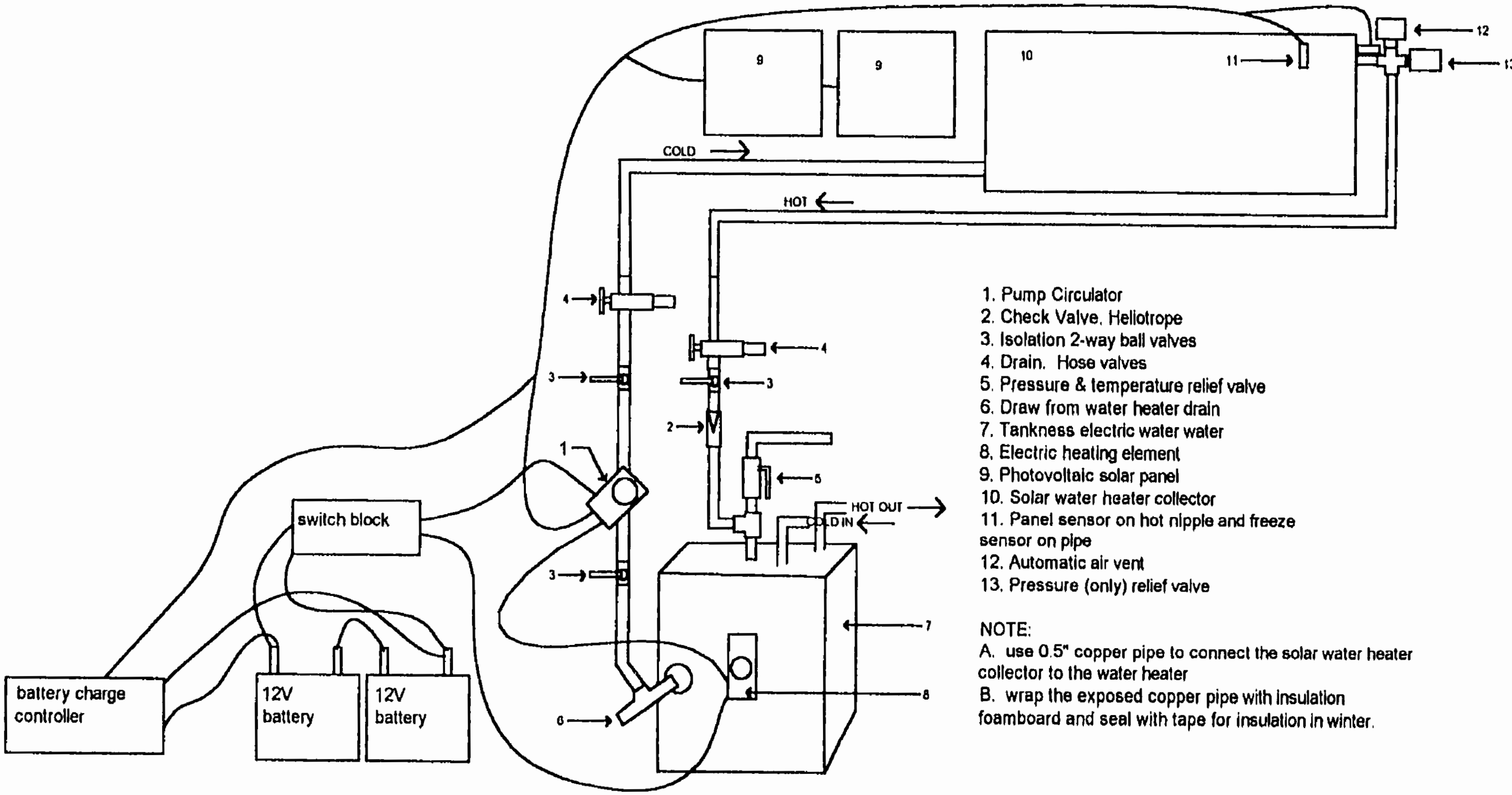
The site is ideal for installing a solar-powered bus shelter prototype because it faces south, has full access to the sun (refer to shadow diagrams: Drawings 3.14 - 3.19. Pages 70 - 75), and it is not overshadowed by buildings on the south side of the Dafoe Road. This will allow the collectors to receive maximum solar energy. Even though there are tall trees on the south side of Dafoe Road, solar radiation can reach the collectors through the empty branches in winter. The passenger shelter prototype will reinforce the image of the University of Manitoba as an innovative and unique place for study and research.

The advantages of a radiant floor heating system over the existing conventional electric heaters are summarized in Table 4.1 (Page 111).

Table 4.1: Radiant floor heating system vs. Conventional electric heater

Conventional electric heater	Radiant floor heating system
• The electric heater heats air creating gentle convective currents. Heated air is stratified with the warmest air at the ceiling and the coldest air at the floor level. As a result, energy is wasted because more energy is required to maintain higher temperatures at the lower levels.	• A radiant floor heating system heats the floor material which in turn heats the air above it resulting in a relatively evenly heated volume of air from floor to ceiling (moisture is removed by the photovoltaic powered fan).
• Because the convective heater cannot heat up the air evenly, it uses electrical energy inefficiently. Regular maintenance add to the cost.	• The system requires less energy because it operates at a lower temperature while providing required air temperature in the space. It is maintenance free.
	• Ideal for the distributions of solar and other forms of alternative energy. • The system can be used both indoors and outdoors.

The solar-powered bus shelter prototype has three photovoltaic panels to collect solar energy. The photovoltaic panels will charge direct current (DC) batteries with electrical power for lighting and ventilating systems at night and on overcast days. With the preferred prototype liquid collectors will provide heat for the radiant floor heating system. The water is then circulated from a tankless conventional electric water heater through the floor system and the bench (see Drawing 4.2, Page 112).



Drawing 4.2: Solar Hot Water Collector System

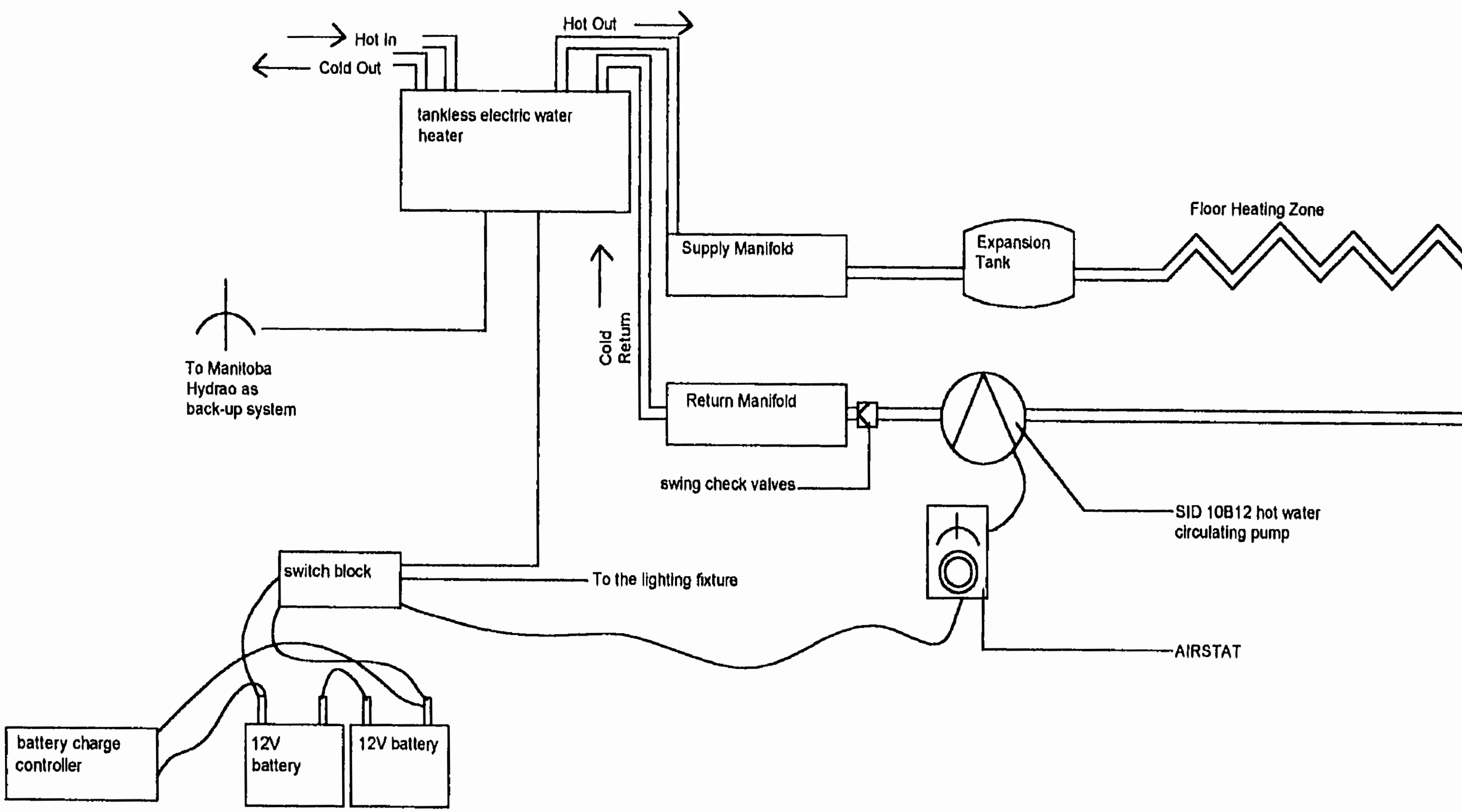
4.5.1. The radiant floor heating system

The radiant floor heating system proposed in the preferred prototype is a closed loop system with glycol added to prevent freezing. Heated water from the collectors is circulated through the tankless electric water heater to the floor heating zone by means of a small electric-powered pump (see Drawing 4.3, Page 114).

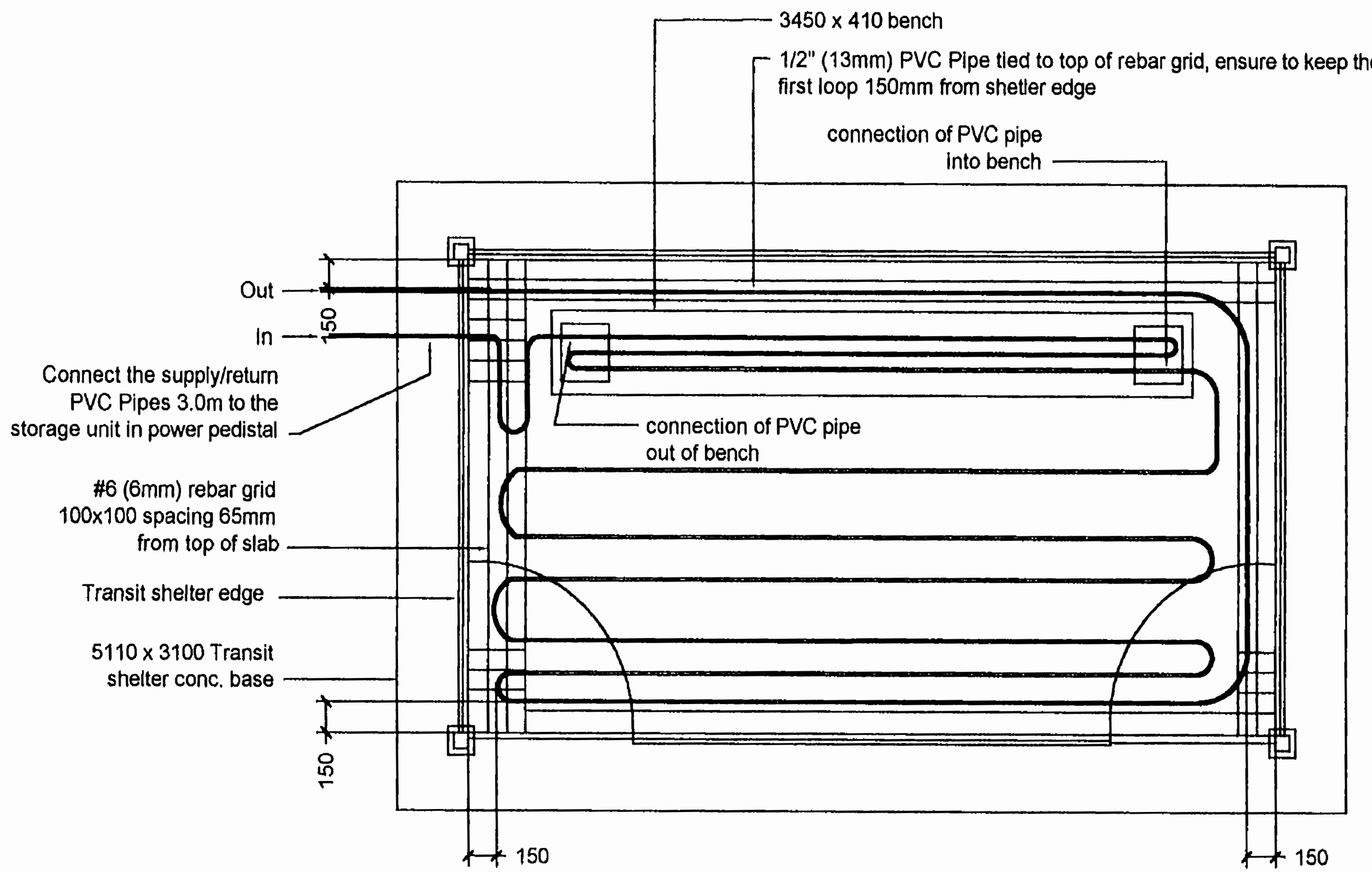
The system uses PVC tubing embedded in the concrete floor to distribute the glycol-water mixture. The heated fluid is first routed through the concrete floor slab then through the bench. Tighter looping along the edges of the door and walls balances heat-loss at the perimeter of the shelter. From the concrete bench the heated liquid returns to the floor system and completes the loop at the collectors. (See Drawing 4.4, Page 115)

The radiant floor slab 'floats' on top of the shelter's structured concrete base. Four inches of rigid foam insulation (R15) is placed between the shelter's concrete structural base and the four inch thick 'floating' concrete slab. The PVC tubing is laced to the integrated rebar grid. A third pouring of concrete forms the bench. The shelter is then installed with the gaps between the shelter structure and the floor caulked to minimize heat loss.(see Drawing 4.5, Page116)

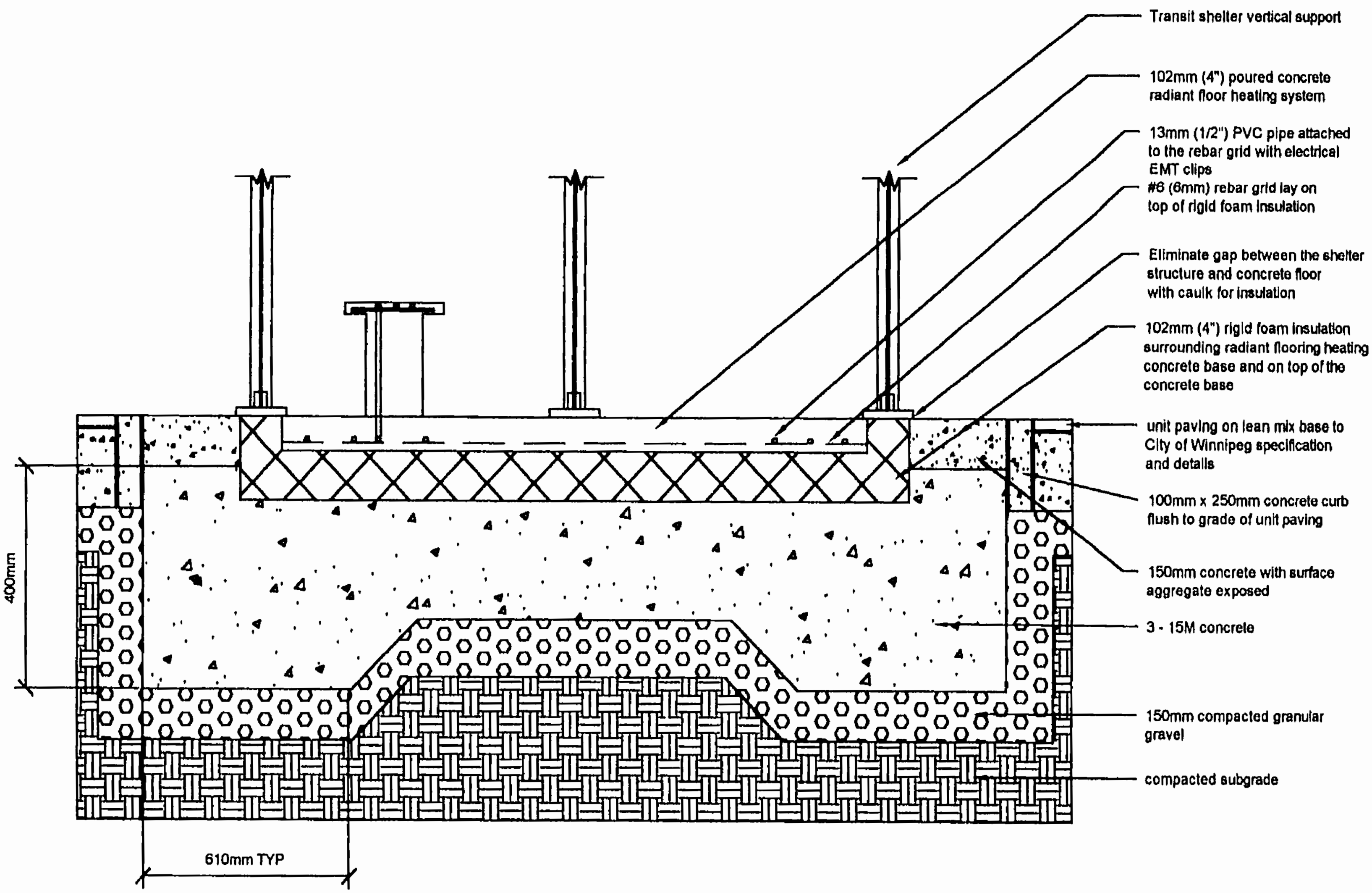
Because heat loss through a single-paned glass wall drastically reduces the efficiency of the system through conductive heat losses, insulated glass is recommended.



Drawing 4.3: Close Loop Radiant Floor Heating System



Drawing 4.4: Plan of Radiant Floor Heating System   Scale: N.T.S.



Drawing 4.5: Section of Radiant Floor Heating System Scale: N.T.S.

Professor Leon Feduniw will supervise student monitoring of the prototype over a 12 month period. Temperature sensors under and in the center of the insulation and five sensors in the concrete slab inside the shelter (one at each corner and one in the center of the concrete slab) have been installed. Several other sensors will be located inside and outside the shelter.

If the prototype performs effectively and efficiently, the temperature inside the shelter will be 10°C to 15°C above the ambient outdoor temperature in winter temperatures of -30°C. Waiting passengers will feel warm when they enter the shelter because the floor radiates heat to the feet first and then evenly to other parts of the body. As discussed in Chapter Two, when passengers feel cold and enter the shelter, they will perceive the floor to be comfortably warm, warm feet will help people to feel warmer overall. Unlike the electric heater, the radiant-heated floor does not create convective air flows, thus air movement is minimized and air movement surrounding the occupants is minimal thereby reducing heat lost.

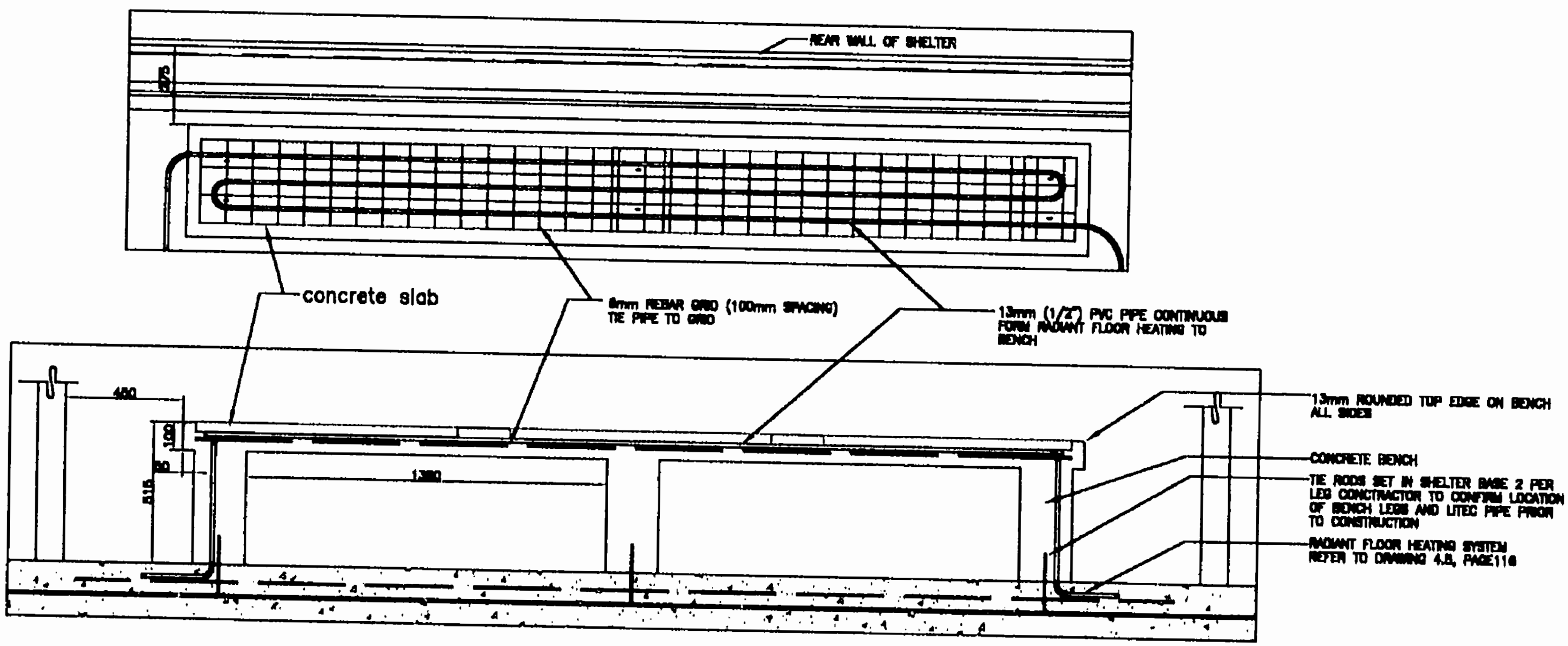
4.5.2 Radiant-heated bench

The bench is 3450mm (long) x 410mm (wide) x 500mm (high). It is located 450mm away from the north wall of the shelter. The bench and the radiant floor heating system operate in the same 'loop'. The PVC tubing runs through the bench as the last loop of the floor system so that the temperature of the bench will not be as high as the temperature of the floor, and it will be more comfortable to sit on (see Drawing 4.4 Page 115). The structure of the bench is connected to the floor structure by re-bars through its legs . The casting of the bench is done after the casting of the floor.

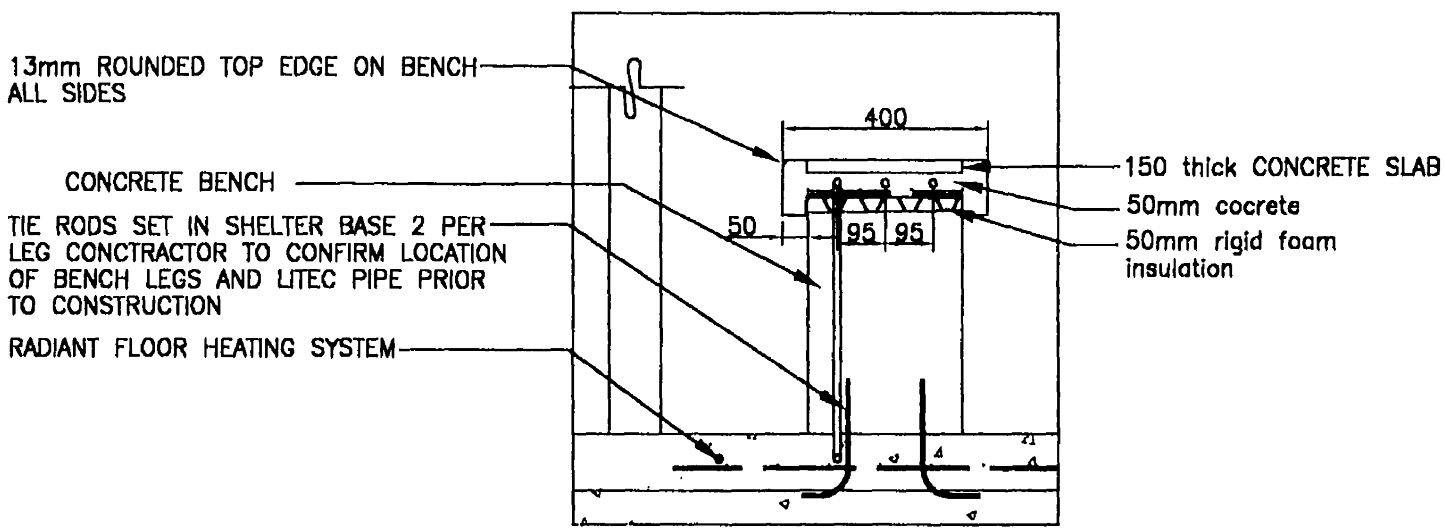
An important feature of the bench is the surface finish. Three different concrete slabs (15mm thick each) will be placed into the slots of the bench in order to find out which material will be the best for the bench surface (see Drawings 4.6, 4.7, Pages 119 - 120). Sensors can be put inside the slabs to monitor the temperature. The types of slab include:

3. same materials as the bench - this slab is the control unit for the other two slabs.
4. aggregate concrete with coarse surface - a coarse surface can retain more heat because air is trapped inside the tiny spaces at the surface
5. mixed-color glass cullet as a substitute for aggregate in concrete - recycled-glass cullet screened into a consistency of a coarse sand or pea gravel and mixed with concrete to create a textured and multi-colored finish. This material can retain heat and make the bench more attractive.

The concrete slabs can be replaced by other types of slabs for testing purposes.



Drawing 4.6: Plan View and Elevation of Radiant Heated Concrete Bench   Scale: N.T.S.



Drawing 4.7: Section through Radiant Heated Concrete Bench Scale: N.T.S.

4.5.3. Ventilating system

The ventilating system has a low voltage ventilation fan and a standard Winnipeg Transit ventilation window. They are installed on the roof end pieces (one on each side).

The fan is solar-direct operated which means that the fan operates with the direct current (DC) generated from a 10 watt solar panel. The fan is switched on as long as the sun in present, thus saving the cost of a battery. The fan is connected to temperature sensors and a controller to automatically switch on and off according to thermal conditions inside the shelter. The fan is caged inside and outside the bus shelter to avoid vandalism. DC batteries charged by the PV arrays operate the fan on overcast days and at night.

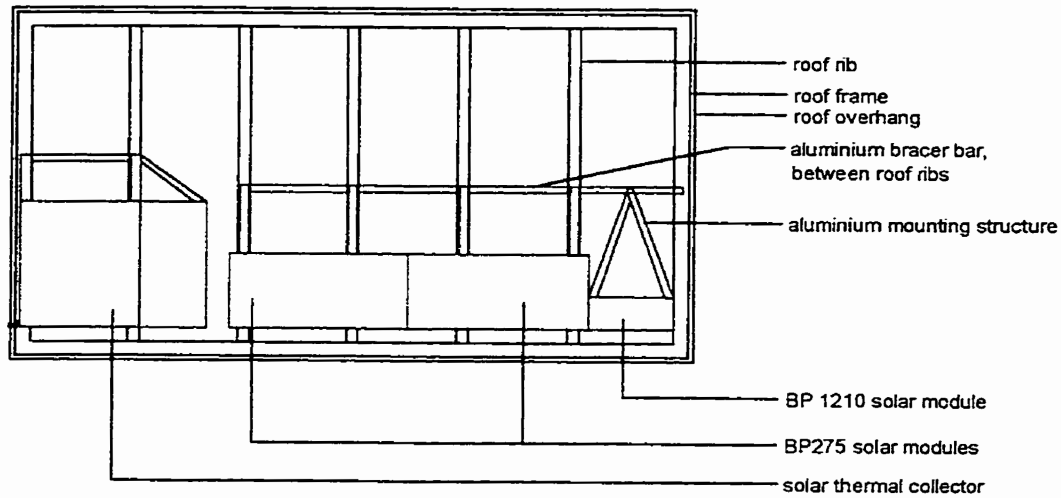
4.5.4. Lighting system

Two caged LED lighting fixtures are installed on each end of the long axis of the structure. Light sensors on top of the lights allow the lights to switch on and off automatically between dusk and dawn. DC batteries charged by the PV arrays operate the fan on overcast days and at night.

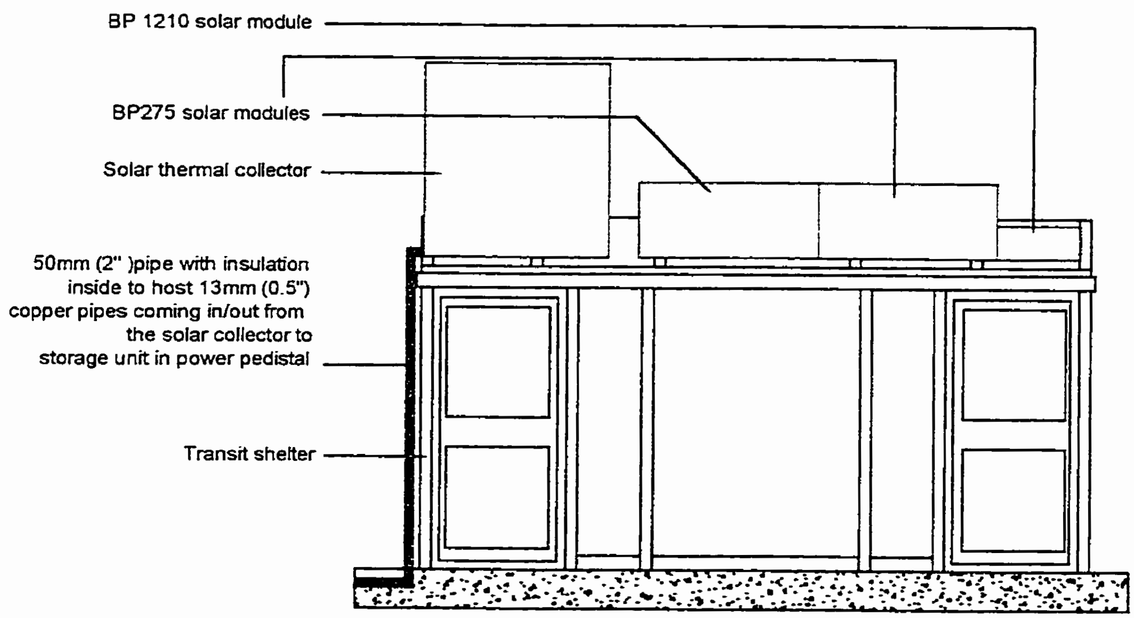
4.5.5. Solar panels and solar thermal collector

Two options are provided for the placement of three solar panels and one solar thermal collector. The first option is to install all panels on the roof of the bus shelter (see Drawings 4.8, 4.9, Pages 123 -124). The second option is to mount panels on poles, away from the bus shelter with a power pedestal installed between the poles (see Drawing 4.10,4.11, Pages 125 -126). For both options, the solar panels and solar thermal collection is set at 55° to the horizontal for optimum year-round performance.

The first option keeps the panels and the bus shelter as one unit. However, the large size of the liquid collectors is generally considered unsightly. Mounted on the roof the collectors could also be a target for vandalism. The second option addresses these problems by locating them away from the shelter and mounting them high above the ground. Shading from trees and buildings will also be reduced. Heat losses are minimized with insulating materials.

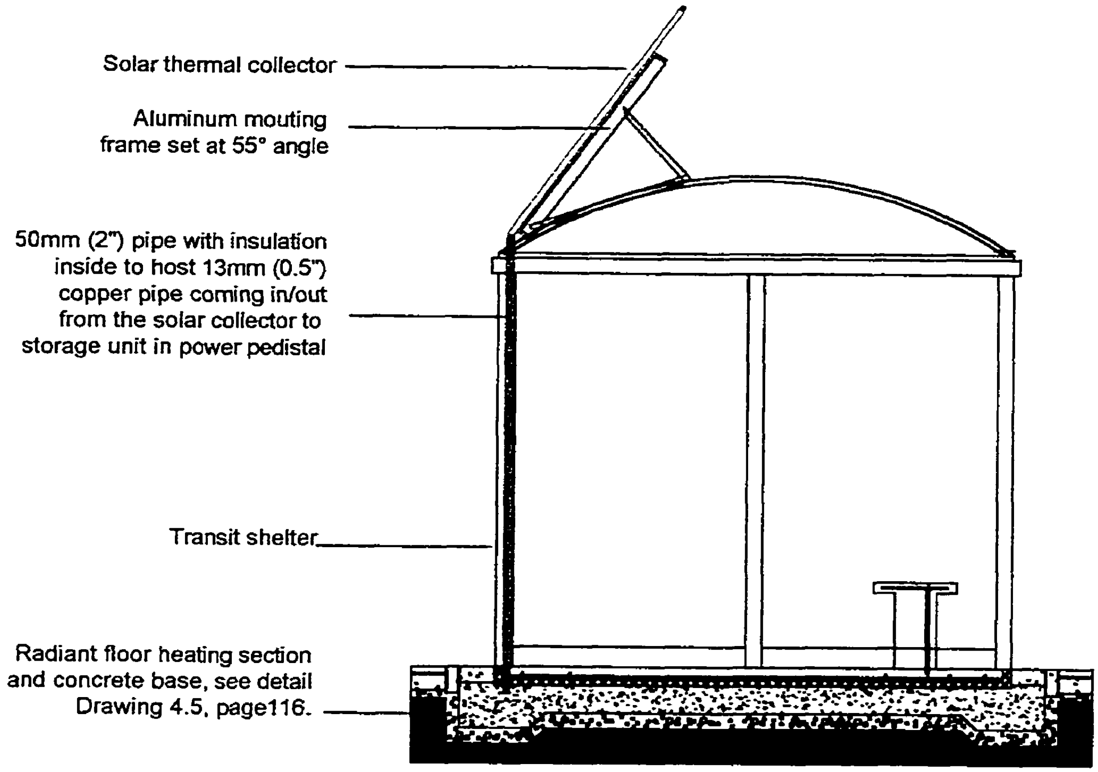


Plan of Shelter Roof - Option 1 Scale: N.T.S.

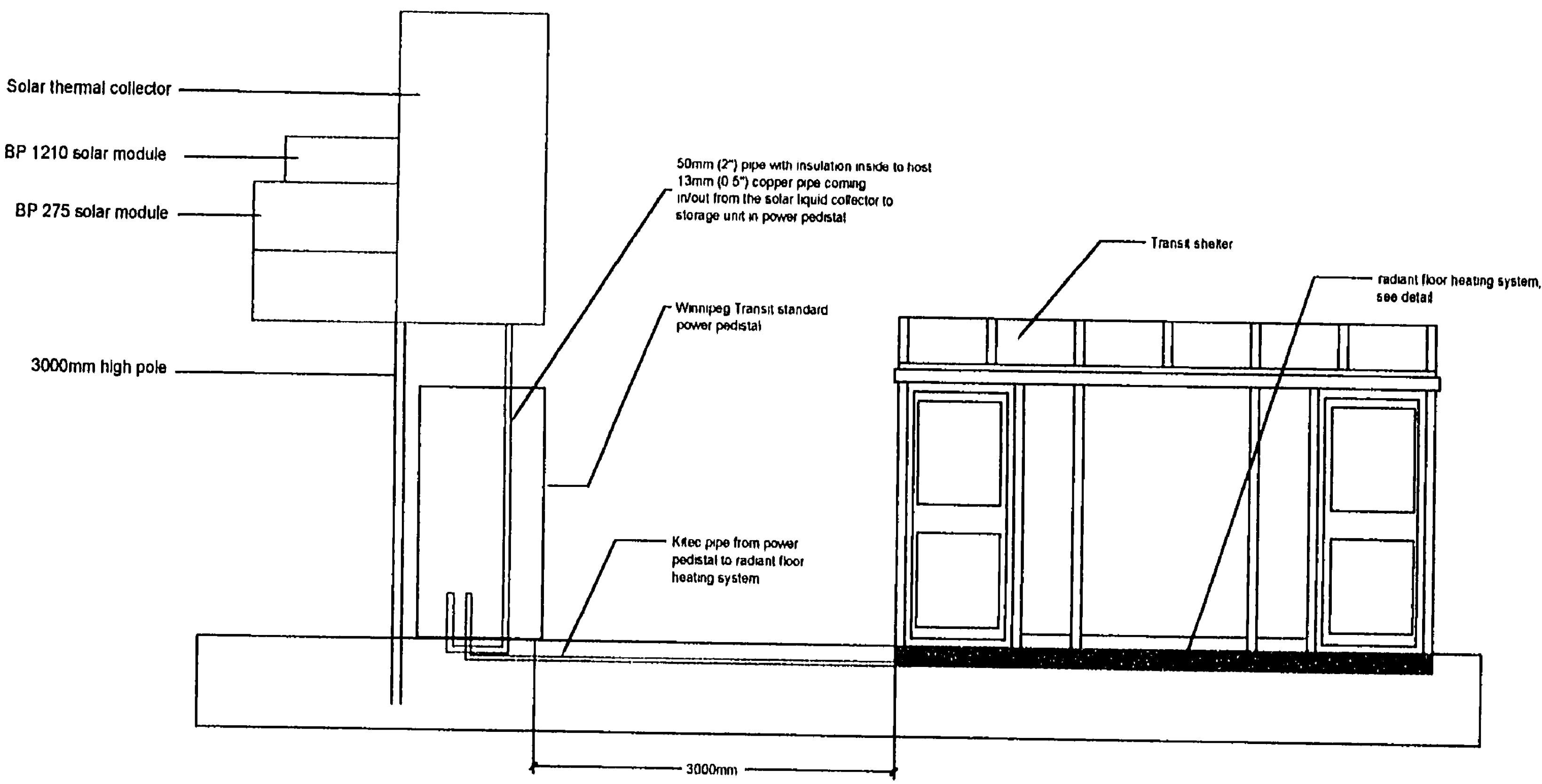


South Elevation of Option 1 Scale: N.T.S.

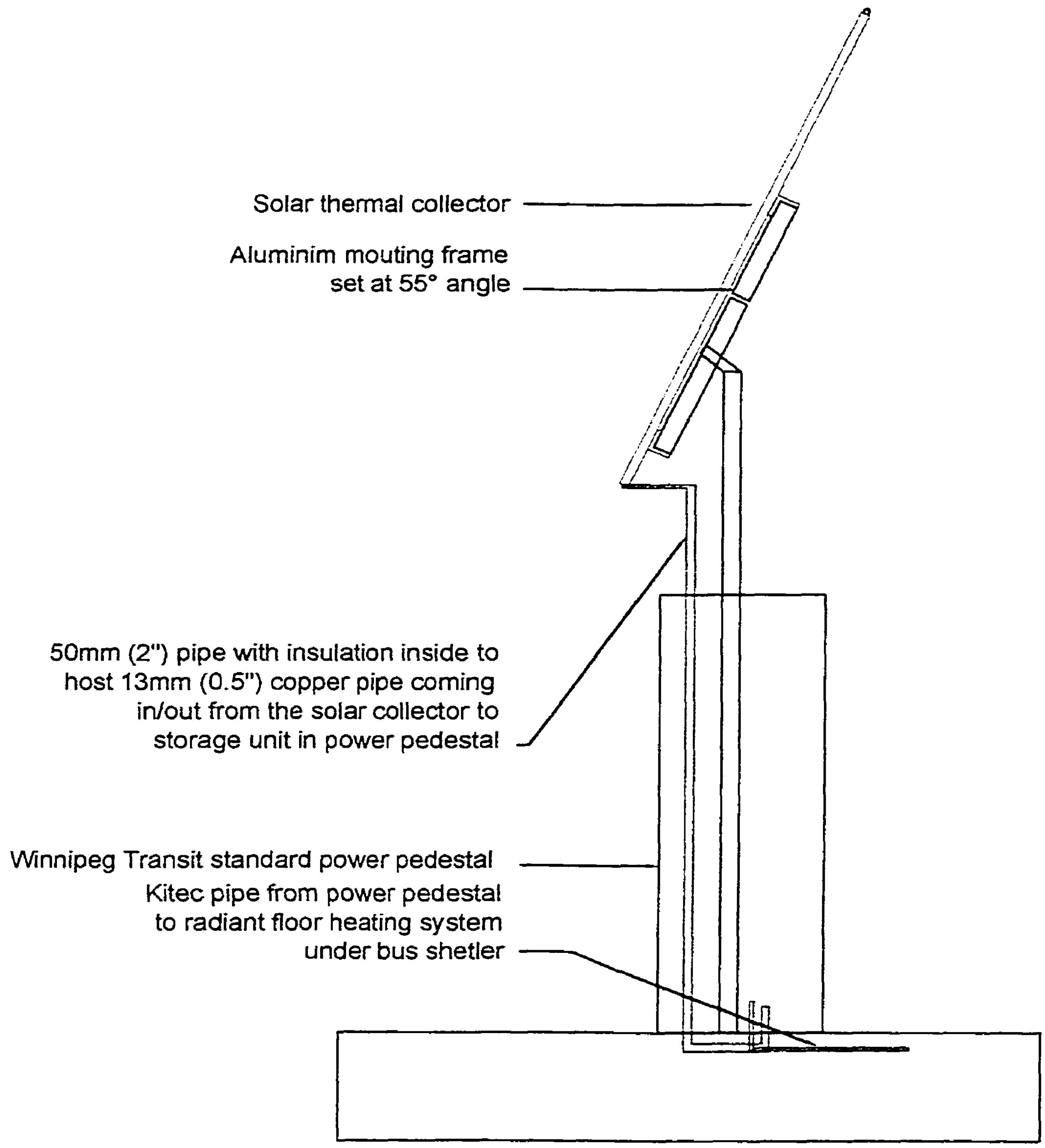
Drawing 4.8: Solar Collectors Roof Assembly Scale: N.T.S.



Drawing 4.9: Shelter Section - Solar Thermal Collector - Option 1
Scale: N.T.S.



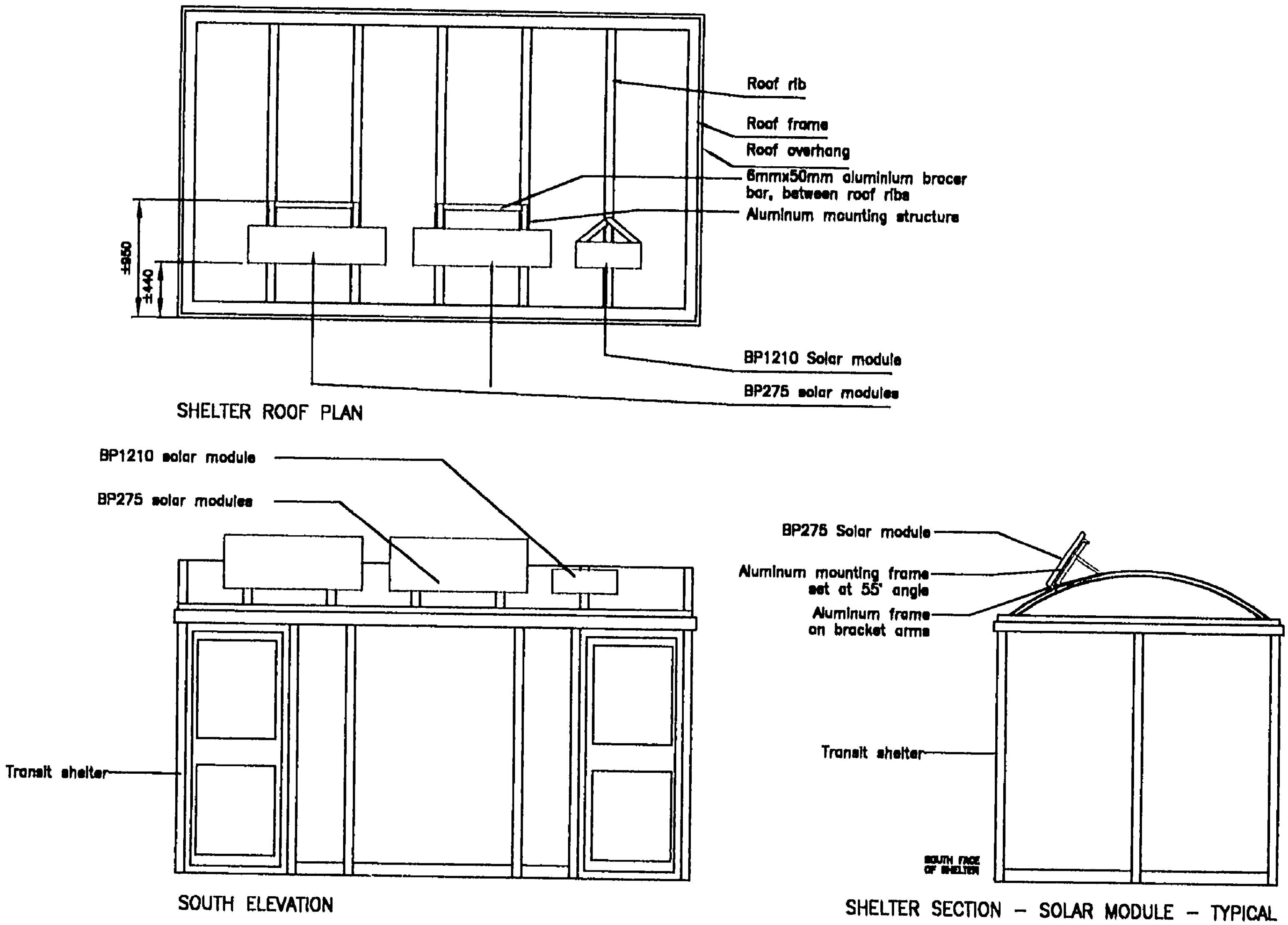
Drawing 4.10: Elevation of Solar Collectors on Pole Scale: N.T.S.



Drawing 4.11: Section of Solar Collector on Pole Scale: N.T.S.

4.6 Winnipeg Transit System prototype

Winnipeg Transit system opted to mount the solar PV panels on the roof to keep the structure as a single unit (see Drawing 4.12, Page 128 and Figures 4.15 & 4.6, Page 129). The actual built prototype had a few changes from the preferred design. First, Winnipeg Transit opted not to use a solar liquid collector because the Exterior Environment Committee of the University of Manitoba considered the solar thermal collector to be intrusion on the campus landscape. Consequently, the energy supply for heating the water is from the existing electrical energy source. It is disappointing not to be using the solar liquid collector because it would have been valuable to have the whole system integrated without the use of any external energy source. Second, the structural foundation and radiant floor slab are not separate entities. Poorly installed rigid insulation surrounded the base but exposed the edges of slabs, and would have resulted in major heat losses to paving units and to air on the perimeter of the shelter (see Figure 4.17, Page 130). There is a one inch gap between the shelter and the floor, this would increases convective air currents resulting in further increases in heat loss (see Figure 4.18, Page 130). Thereby seriously reducing the overall thermal performance of the prototype. Cold winter temperatures can lead to poor construction procedures. It is therefore recommended that construction for the shelter base be done in summer. Third is the bench design - the different types of concrete slabs on top of the bench to test for the efficiency of materials were omitted (Drawings 4.13 & 4.14, Pages 131 -132).



Drawing 4.12: Final Solar Panel Roof Assembly Scale: N.T.S.
(Provided by McGowan Design Group, Winnipeg)

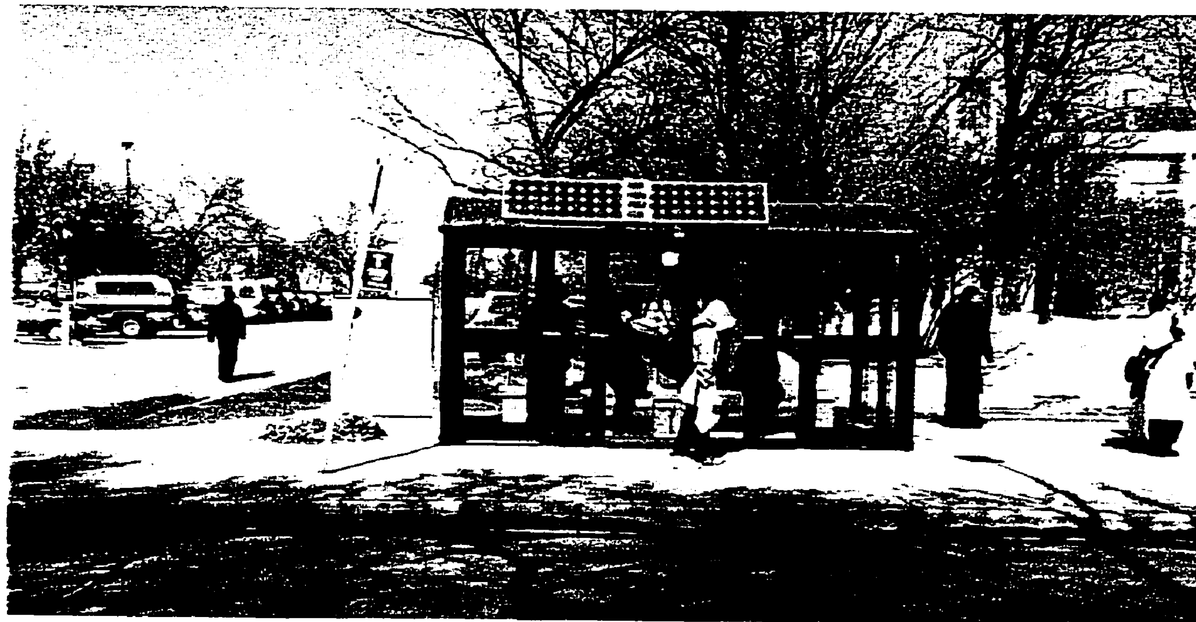
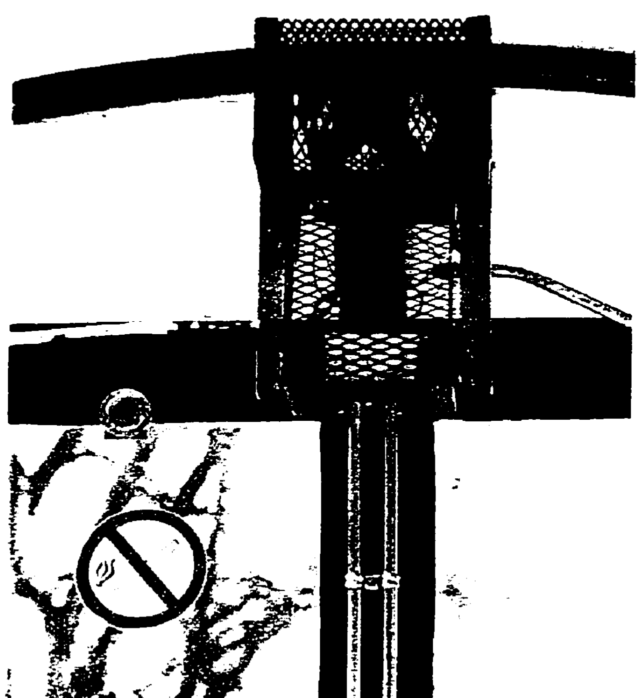


Figure 4.15: Winnipeg Transit System prototype. Solar panels mounted on the roof to keep the structure as a single unit.

Figure 4.16: LED lighting fixture and ventilation fan inside the shelter.



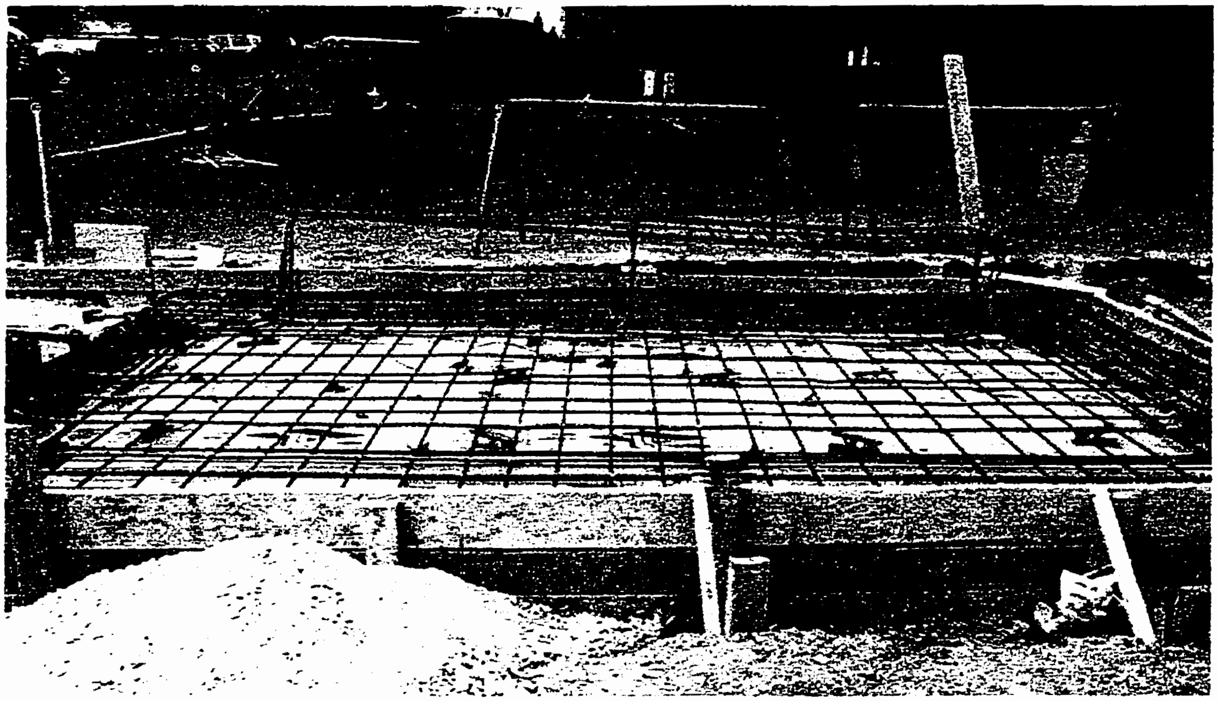
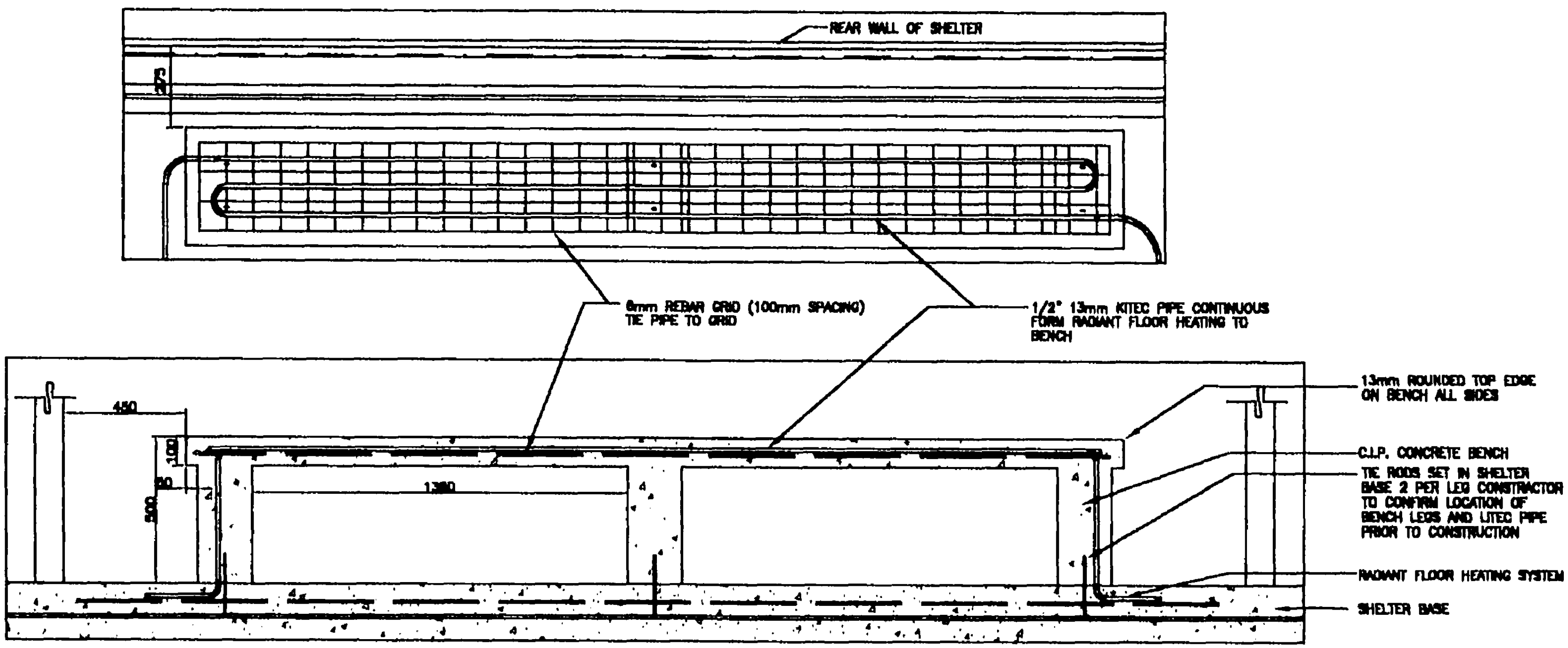
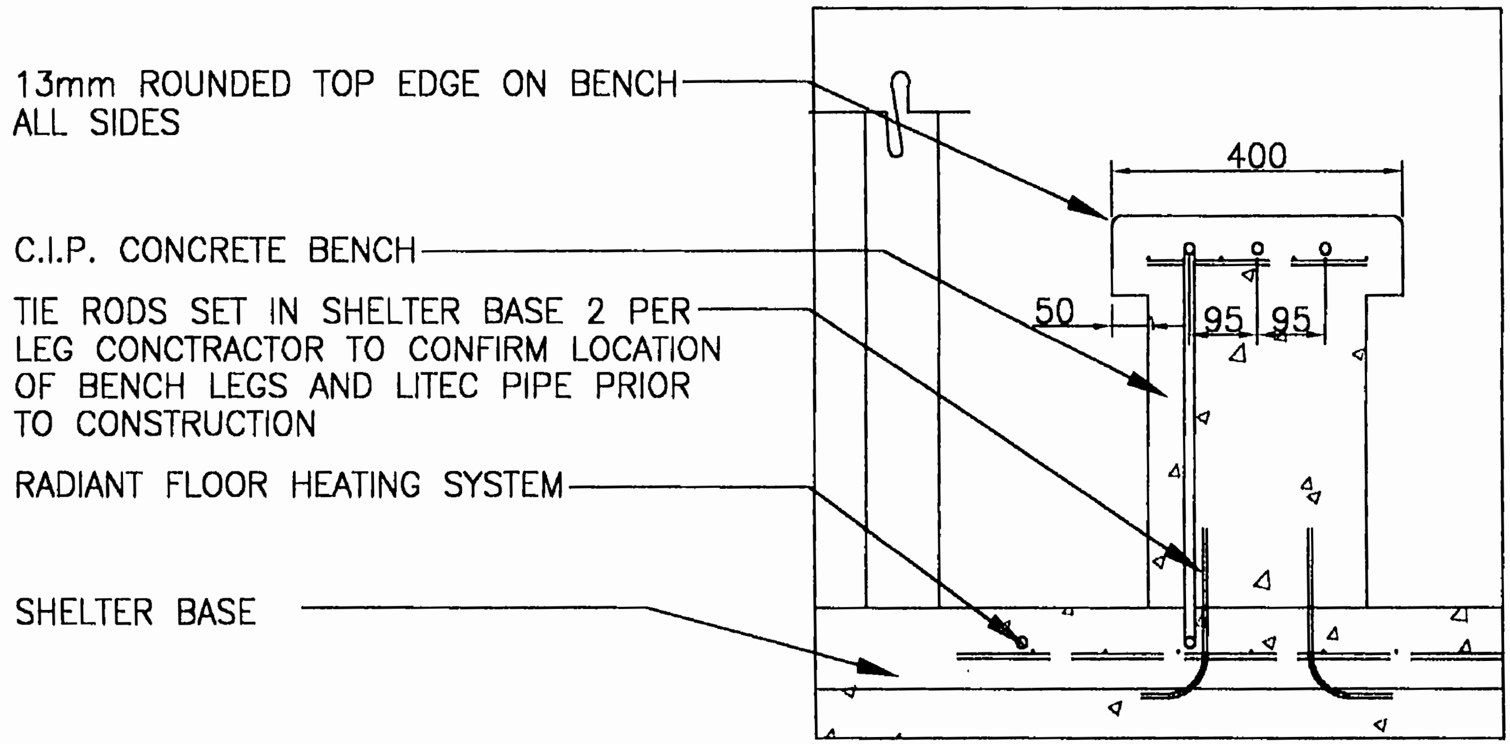


Figure 4.17: Front view of (incorrectly insulated) casting of foundation.

Figure 4.18: One inch gap under the shelter



Drawing 4.13: Radiant Heated Concrete Bench Scale: N.T.S.
(Provided by McGowan Russell Design Group, Winnipeg)



Drawing 4.14: Section through Radiant Heated Concrete Bench Scale: N.T.S.
(Provided by McGowan Russell Design Group, Winnipeg)

Endnotes for Chapter 4

1.Astolf, J., Fernandez, F., Haque, M., Ng, K. (1995). Man-made Environmental lighting, acoustics and mechanical sytems. A report to Professor Leon Feduniw, University of Manitoba.

2.Ibid, 5.

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