A PERSPECTIVE OF SNOW COUNTERMEASURES IN URBAN AREAS

Snow-flowing (melting) Gutter Facilities for Snow Removal, Construction, Operation and Future Snow Countermeasures in Urban Areas

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Introduction

All across Hokkaido, a cold, snowy region, we are forced to deal with snow about one third of the year.

Snow-flowing (melting) gutters are one way of snow removal by melting snow on streets, the operation of which is carried out with the cooperation of the local residents. The start of this project marked a new epoch making it possible to secure a living space that is unchanged from summer to winter.

This paper reports on the outline of snow-flowing (melting) facilities, their effects on snow removal, characteristics of operating with the cooperation of the local residents, and how snow melting gutters utilize locally available energy.

On the other hand, after some time has passed since the initiation of use, and with the advancement of depopulation and aging, there are some problems surrounding snow-flowing gutter facilities. Other inherent matters of concern from the maintenance perspective have also become apparent, based on this consideration, we will survey future urban snow removal strategies.

1. Geography and History of Hokkaido

1.1. Area and Population

Hokkaido is the northernmost island of the north-south long Japanese archipelago with an area of 83,452 km^2 accounting for about 22.1 % of entire Japan. According to the national census in 2000, the population of Hokkaido is about 5.68 million, or 4.5 % of the population of Japan.

1.2. Climate

Hokkaido lies on the northern limit of the temperate zone and the southern limit of the subarctic zone. It has a cool and dry climate with an average temperature of 6-10℃ and an annual average precipitation of 800-1,500 mm. The climate is characterized by a large amount of snowfall. It is rare in the world for city as big as Sapporo, with a population of over 1.8 million, to have an annual snowfall of about 5 meters.

1.3. History

The history of full scale development of Hokkaido started in 1869 when the Meiji government established the colonization commission in Sapporo. Under government policy, immigration, road construction and cultivation of farmland by the colonial troops were promoted. The population of Hokkaido has increased from about 58,000 in 1869 to 5.68 million, achieving a hundredfold increase in only 130 years. Also, the total road length, which was only 54 km in 1871, reached a total of 18,000 km including national and prefectural roads only as of 2000. Thus, social infrastructure has been rapidly established.

1.3.1. Clearing of snow from roads in prewar days (until 1945)

Around 1933, snow removal by machinery using 2 tractors made in America was conducted in Sapporo, but only on a trial basis. In most cases, snow was cleared manually or by wooden ploughs drawn by horses. Consequently, traffic during winter in those days had to heavily rely on natural compaction of snow and it was taken for granted that traffic was interrupted by heavy snowfall for a long time.

1.3.2. Clearing of snow from roads after the war (after 1945)

It was not till the winter of the year when World War II ended (1945) that snow clearing by machinery was put into operation. The total length of roads from which snow was cleared rapidly increased from 55 km in 1945 to 2,500 km in 1955 due to the advancement of motorization and improvements in snow clearing machinery. In Hokkaido, whose whole area has a cold climate with much snow, clearing snow from roads is essential for securing smooth road traffic in winter while maintaining social economic activities in local communities and improving people's livelihood and safety. Today, the length of prefectural roads covered by snow clearing activity totals more than 10,000 km.

2. Present Situation Concerning Snow Control in Urban Areas

2.1. Clearing and removal of snow

Generally, methods of snow removal by machinery are divided according to the nature of operation into clearing fresh snow, smoothing out road surfaces, widening roads and removing snow by cutting snow piles along the road edge. As the road surface maintenance is an important factor in clearing snow from roadways in urban areas, graders are used in many cases. For sidewalks that often have attached structures such as tree-planting zones especially in urban areas, small-sized snowplows specially designed for sidewalks are necessary for snow clearing.

In urban areas, cleared snow is piled on the snow-piling space mostly utilizing attached structures of sidewalks. Considering these snow piles may block the driver's view and make it impossible to keep an effective enough width of roadways and sidewalks, snow piles need to be removed. Snow removal is the most expensive stage in snow clearing by machinery. The cost of snow removal varies greatly depending on how much snow needs to be removed for dumping.

[Snow Clearing Activities (those managed by Hokkaido government)]
(FY 2000)

・ Total length of road plowed	
Total length of roads actually plowed:	11,365 km
Total length of roadways plowed:	10,247 km
Total length of road from which snow was tracked away:	967 km
Total length of sidewalk plowed:	5,391 km
・ Budget for snow removal	
Cost of snow clearing:	approx. 9.8 billion yen
・ Snow clearing machinery	
For roadways (graders, etc.):	1,901 machines
For sidewalks (small rotary snowplows):	199 machines
Total:	2,100 machines

2.2. Road heating

Road heating is a system whereby snow or ice on the road is melted by heat utilizing electricity and gas as well as local energy in some cases. Road heating systems are installed mainly on sloping roadways in the suburbs, while they are also installed in some parts of sidewalks in urban areas.

In the case of sidewalks in urban areas, road heating systems are installed for the purpose of securing safe walking space in winter, which means a higher standard of service is provided. Therefore, this system is basically maintained and managed by imposing some burden on residents along the road. Due to its high operating cost, such as electricity fees, this system is not generally used as a snow melting system in urban areas except for limited places.

[Installation of Road Heating System (those managed by Hokkaido government)]
(as of the end of FY 2000)

Place	Number of Places	Installed Area
Roadway	308 places	322,702 m^2
Sidewalk	120 places	36,206 m^2

Annual operating cost including electricity:
approx. 1.3 billion yen

Photo 1: Road heating on a sidewalk

2.3. Snow flowing gutter (snow melting gutter)

A snow flowing gutter is a channel built under the road along the edge of the sidewalk wherein snow removed from the road is dumped and carried by water flowing in it. Where this gutter is constructed, the road is almost always free of snow. From the viewpoint of securing walking space, this is an effective facility. This system is a good example of snow removal activity operated in cooperation with citizens who dump snow. Since snow is dumped on a daily basis, snow removed from roadways is also dumped along with snow on sidewalks. Thus, this system provides road administrators with the great merit that they do not need to transport snow to dumping sites.

[Construction of Snow Flowing Gutters (those managed by Hokkaido government)]
(as of the end of FY 2000)

Places where gutter was constructed	21 places
Length (total)	34.2 km
Annual operating cost including shared expenses	approx. 86 million yen

Photo 2: Dumping snow in a snow flowing

2.4. Snow dumping sites

Snow dumping sites are where snow removed and transported from urban areas is dumped. At one time, it was expected that the burden of transport and dumping of snow would be eased when improved snow removal facilities realize snow-free roads. However, given that the operating costs of facilities for snow-free roads are higher than expected and the burden of their maintenance and management is heavy, the need for transporting and dumping snow is rather increasing. In spite of these situations, there is a move to limit the use of places that have been used as snow dumping sites in urban areas such as rivers in consideration of the impact on the environment. There is a need to construct facilities where a large amount of snow can be dumped not far from urban areas.

2.5. Comparison among snow control methods in urban areas

Generally, snow control in urban areas is implemented by those methods described above. Here, we will compare snow clearing with the methods for realizing snow-free roads through the installation or construction of facilities.

Table 1: Comparison among Snow Control Methods in Urban Areas

	Level of Service	Burden of Local Residents	Operating Cost
Snow Clearing (removal by transport)	Piles of cleared snow are removed only several times a year and those snow piles left unremoved narrow sidewalks	It is carried out as a public service with no burden on the residents	Lowest, though varies depending on how often snow piles are removed
Road Heating	It provides the highest standard of service by keeping the road clear of snow	Basically, the residents share installation and maintenance costs	Highest at 3,000 yen per 1 m^2 of heated area
Snow Flowing Gutter	Although snow is almost cleared off, some snow is left on the surface of the road	Residents are required to cooperate in dumping snow in the gutter	About one third of that of road heating

3. Snow Flowing Gutter

Here, we will brief on the structure of snow flowing gutters, whose construction has been promoted in Hokkaido as a main snow control measure in urban areas, and give some typical examples.

3.1. Structure of snow flowing gutter

A snow flowing gutter is a snow removal facility whereby a gutter is constructed along the roadside wherein snow removed from the road and dumped by citizens flows down with stream. Usually, river water or ground water is used as the water source.

[Design Requirement for Snow Flowing Gutter]

① It needs to slope at an angle of 1/50-1/500 degree (1/300-1/500 is desirable)
② The speed of flow is about 1m/s
③ It has the water depth of at least 30 cm in order to float and flow lumps of snow
④ A flow rate of 0.2m^3/s or more is desirable
⑤ In principle, the culvert method is adopted and the cross section of the gutter should be 0.6m wide and 0.8m high at the minimum

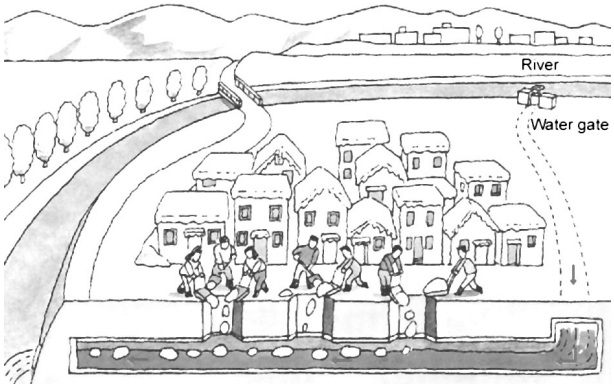


Figure 1: Structure of Snow Flowing Gutter

3.2. Construction of snow flowing gutter in Hokkaido

Since the first snow flowing gutter in Hokkaido was constructed in Kimobetsu town in 1979, a total of 147.7 km of snow flowing gutters and snow melting gutters have been put in service in 25 municipalities by the end of March 2001. In addition, construction projects are now under way in 11 places with the total length of 28.3 km. The increase in the total length of snow flowing gutters in Hokkaido is shown below.

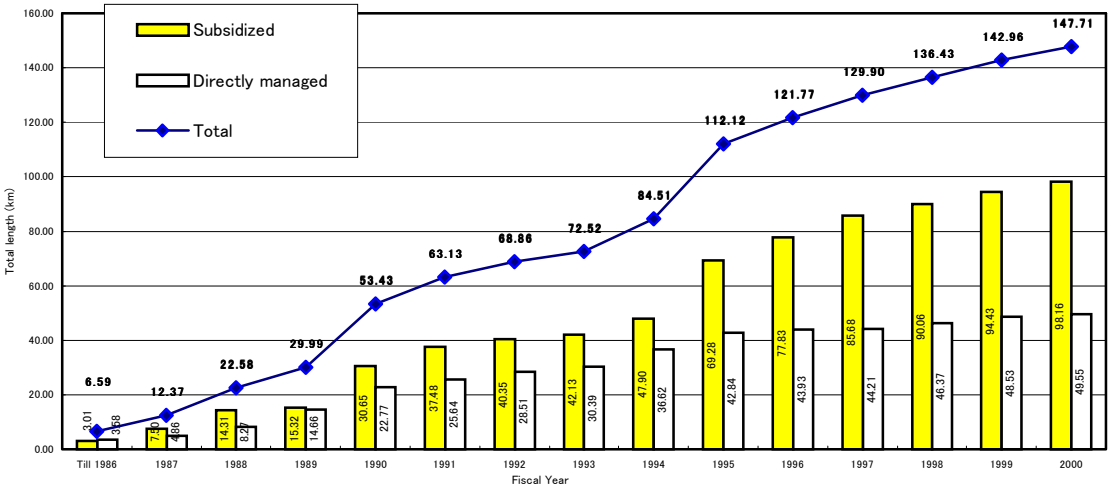


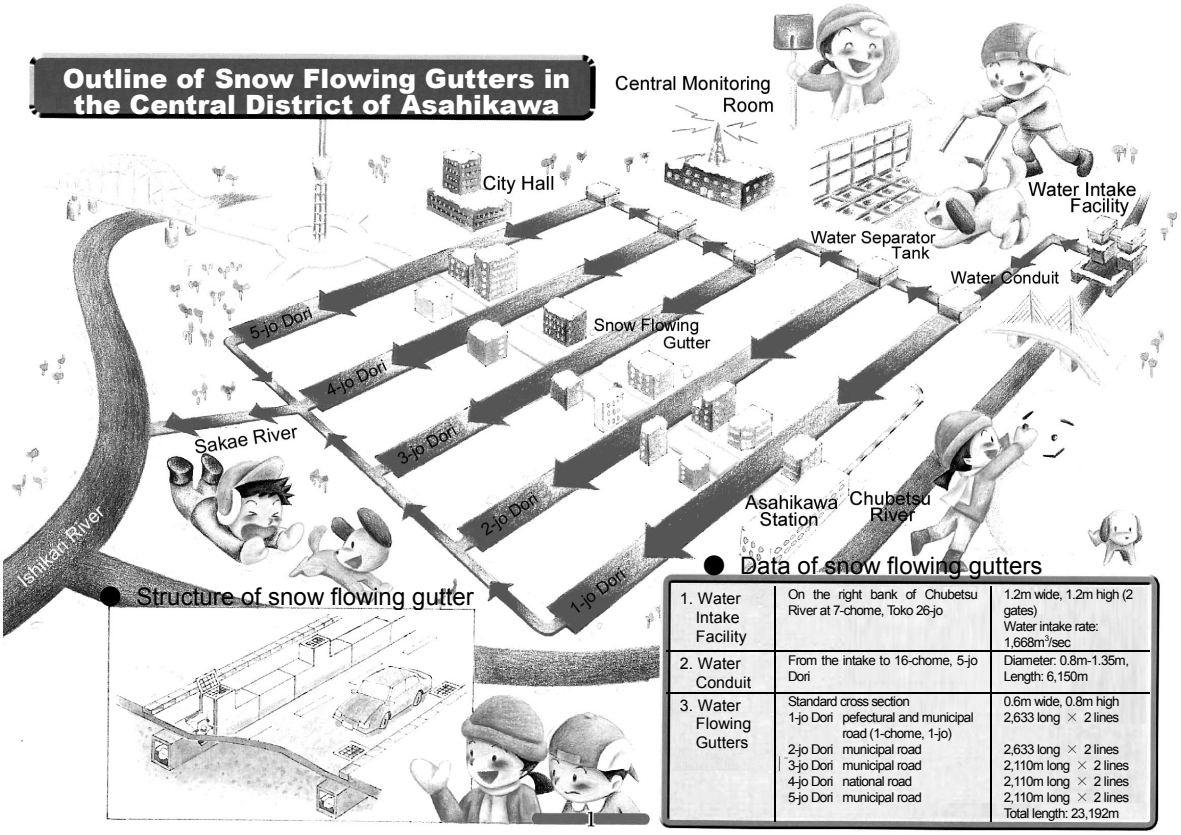
Figure 2: Increase in Total Length of Snow Flowing Gutters in Hokkaido

3.3. Examples of snow flowing gutter in Hokkaido

3.3.1. Construction of snow flowing gutters in Asahikawa

Asahikawa is the second largest city in Hokkaido with a population of 360,000 situated in the center of Hokkaido. It has a snowfall of 7m annually. Based on the "Basic Plan for Snow Melting and Removal in Asahikawa" established in March 1988, the city of Asahikawa has been promoting construction of snow flowing gutters in 10 lines totaling 23km in length, the largest scale in Hokkaido, covering the central business district as the snow dumping area. The completion of all lines is scheduled for 2001 (8 lines have already been put into operation).

Snow flowing gutters are constructed by the national, prefectural and municipal road administrators. As for the maintenance and management of shared facilities, the city of Asahikawa takes charge of the actual works and the national and prefectural governments share the costs under the Maintenance and Management Agreement.



Before the construction of a snow flowing gutter (National Route 12)

After the construction of a snow flowing gutter (National Route 12)

Figure 3: Outline of Snow Flowing Gutters in Asahikawa

3.3.2. Snow flowing gutters utilizing hot spring water in Naganuma

Naganuma is an agricultural town located on the southwestern end of Sorachi subprefecture,

30 km east of Sapporo. In recent years, it has been making efforts to construct urban resort facilities utilizing the hot spring.

Under the snow flowing gutter system in Naganuma, hot spring waste water conveyed from Naganuma Hot Spring 2.5 km from the downtown at the flow rate of 1,500 litters per minutes is stored in snow flowing gutters installed along national, prefectural and municipal roads, extending for 2,450m in total. Snow dumped in gutters melts slowly. This system is unique in that it makes up for the small quantity of water flow with the high temperature (22℃) of waste water from the hot spring. Annual snowfall depth in Naganuma is 2-3 m.

Each project to construct a snow flowing gutter was implemented independently by the national, prefectural and municipal governments who administer the respective parts of roads for which gutters are constructed. All snow flowing gutters were put into full operation in December 1999.

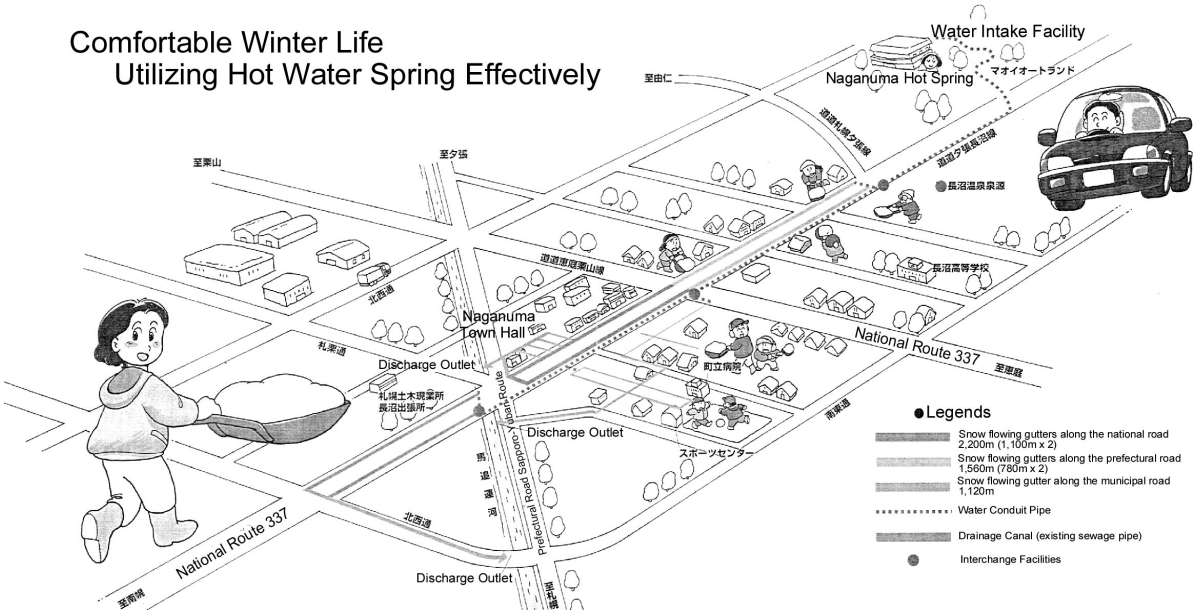


Figure 4: Outline of Snow Flowing Gutters in Naganuma

3.3.3. Snow flowing gutters utilizing treated sewage in Naie

Naie, an inland town in central Hokkaido, is one of the heaviest snowfall towns in Hokkaido with the annual snowfall reaching over 6m. In 1989, the town of Naie settled on "Naie Snow Control Plan" with a view to promote establishment of a snow disposal system using snow flowing and snow melting gutters.

This system is to let sewage treated at the Naie Center for Purification of Sewage from Ishikari River Basin flow into snow flowing gutters constructed along the national and prefectural roads and snow melting gutters constructed along municipal roads, wherein citizens dump snow. In addition, electric snow melting tanks are installed for by-streets to which treated sewage is not conveyed in an effort to realize an efficient snow disposal system in the whole downtown.

The great feature of this system is the utilization of treated sewage. In the gutter along the municipal road where the flow rate is not enough, dumped snow is melted slowly by the thermal energy of treated sewage (water temperature: 10℃).

Image of Snow Disposal System in Naie

Naie Center for Purification of Sewage from Ishikari River Basin

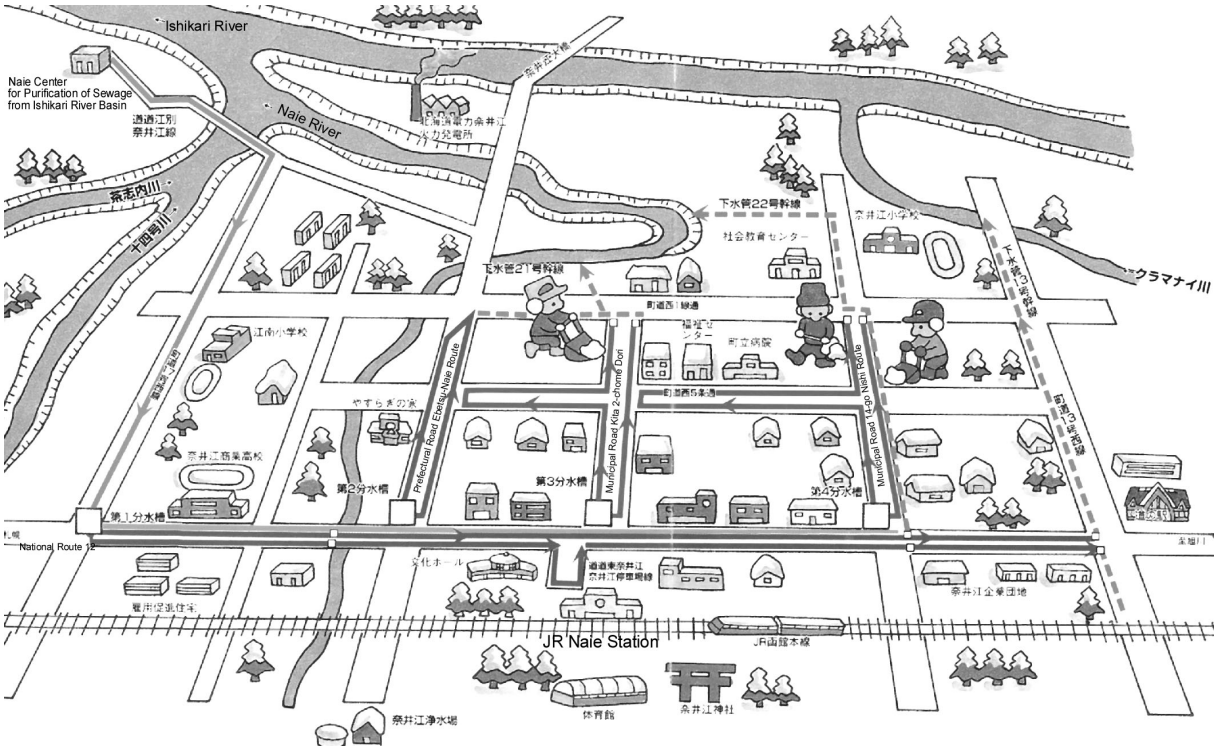


Figure 5: Outline of Snow Flowing Gutters in Naie

4. Problems Concerning Snow Flowing Gutter

In Hokkaido, the first priority in snow control policy in urban areas has been put on the construction of snow flowing gutters. However, there arise various problems, making it difficult to proceed with the construction of new gutters. Problems involved in the construction of snow flowing gutters are shown below.

Problem	Details
Increase in maintenance and management costs	・ High cost for driving pumps where water does not flow naturally ・ Handling of unexpected troubles such as clogging ・ Cost for renewing machines such as pumps

Cooperation of citizens and the burden shared by the community	・ Increase in the number of places where snow is not dumped by citizens due to depopulation and aging population ・ User's lack of morals (snow dumping in masse by machines, snow dumping out of designated hours, etc.) ・ Sense of unfairness based on the fact that the system benefits only limited areas
Problems in securing water sources and problems related to structure and function of facilities	・ Difficulty in securing new water sources ・ Improvement of facilities to prevent clogging of water pipes and sticking of snow to snow inlets ・ Traffic safety measures during snow dumping activities

5. Future Direction of Snow Control in Urban Areas

We have reported on snow control measures in urban areas in Hokkaido, with a special focus on snow flowing gutters. Snow control in urban areas such as snow clearing is one of those fields where citizen's demand for public service is the highest. In Hokkaido where a decline in birth rate and the aging of society are expected to further accelerate, it is undeniable that this is an important issue that must be tackled by the administration. However, with respect to snow flowing gutters and road heating, as mentioned above, increased costs and difficulty in securing water source make it difficult to construct new facilities. Here, we will report on the study of more effective snow control that is currently underway and future prospect of technological development.

5.1. Expansion and improvement of snow clearing system jointly implemented by public and private sectors

Although the administration has steadily enhanced the standard of snow clearing service, people's demand for and complaints against snow clearance never decrease. Under the present severe financial situation of local governments, there is a limit to the improvement of the standard of public service. For further improvement, cooperation of local citizens is essential. Among many forms of citizen's cooperation are snow removal in the community, support for snow clearing around the houses of elderly citizens by volunteers, the use of local funds in snow removal, sharing of maintenance cost by the community, and so on. It is important to have various discussions between the administration and citizens.

5.2. Effective utilization of waste heat

The most effective way of maintaining smooth and safe traffic and securing walking space during winter is the installation of a road heating system that melts snow at the moment it falls on the ground. However, this system is not practical because of its high maintenance cost such as electricity fee. Also, it is undesirable from the viewpoints of controlling global warming and saving energy. Based on this situation, utilization of natural energy and local energy including waste heat is strongly needed. However, it is difficult to solve the issue of location and time such as "the source of local energy is far from where it is needed" or "there is a gap between the time zone in which energy is generated and it is used". These are the factors preventing adequate utilization of local energy. Here, we will state our expectation for "utilization of waste heat through the introduction of locally dispersed power generation system" and "storage of seasonally available heat utilizing ground water and underground space".

5.2.1. Utilization of waste heat through introduction of locally dispersed power generation system

One of the most prospective sources of local energy to be used for snow control in urban areas is waste heat from power generation which is made available through the introduction of a locally dispersed power generation system. If a low-pollution and high-efficiency power generation facility which supplies both heat and electricity using fuel cells or gas turbines is built in a city, it would be possible to use a huge amount of heat that used to be dumped in the form of hot waste water for improving the urban environment during winter.

Before introducing this system, comprehensive study and simulation need to be conducted taking into account various factors including not only road management but also energy supply as a part of city management policy and improvement of the urban environment. The framework for such study needs to be established jointly by public and private sectors.

5.2.2. Storage of seasonally available heat utilizing ground water and underground space

We can feel the benefit of exuberant solar energy especially in spring when snow thaws. A couple of warm days in a row is enough to make snow piles smaller and smaller. If some of the solar energy available in summer can be used for melting snow in winter, it would contribute to improve the urban environment in winter. There is high expectation for the establishment of technology for storing seasonally available heat.

Such technology includes utilization of heat stored in ground water and the ground, heat conveying systems using inexpensive and easy-to-built heat pipes, and development of heat storage materials that can store huge amount of heat throughout the year.

5.3. Location planning of snow dumping sites

There is no denying snow clearance and snow removal are the mainstream of snow control in urban areas. Improvement of winter road conditions in urban areas relies on the efficiency of snow removal. It is very important to have snow dumping sites at well-planned locations so that the snow does not need to be transported a long way.

At the same time, development of a snow transport system as a substitution for snow flowing gutters is expected. Construction of new snow flowing gutters is difficult due to difficulty in securing water source for flowing snow and the limits of manual snow dumping. If a new snow transport system or mechanized snow dumping method is developed as a solution to these problems, it would be possible that snow transport system will be established as new social infrastructure.

6. Conclusion

In snowy and cold Hokkaido, the battle with snow never ends. We have made various efforts as road administrators. However, there is a limit on what road administrators can do because of financial and technological restrictions. We believe it is important to consider new measures by seeking the cooperation of local residents or developing a snow disposal system as part of the urban management system. Environmentally friendly and sustainable snow control measures are strongly needed. To this end, we hope to pursue our study in wide-ranging field through cooperation between public and private sectors.