Construction of Oil-Spill Warning System based on Remote Sensing/ Numerical Model and Its Application to the Natural Resource Damage Assessment and Restoration System

Shintaro Goto and Sang-Woo Kim

Dept. of Environmental Systems
Faculty of GEO-Environmental Science
1700 Magechi Kumagaya-City Saitama, 360-0194, Japan
E-mail:got@risgw.ris.ac.jp

Abstract

From the lessons after the Nakhodka oil-spill in Jan. 1997, oil slick detection by using remote sensing data and assimilating the data to the simulation program is important for monitoring the oil-drift pattern.

For this object, we are going to construct the oil-spill warning system for estimating the oil-drift pattern using remotesensing/numerical simulation Model. Additionally we plan to use this system for restorating oil-spill damage domestically, such as estimating the ecological damage and making the priority for restorating the oil-spilled shoreline.

This report is intended to summarize the role of geo-informatics in the oil spill accident by not only paying attention to the effect of information provision/information management via the map, but also reporting the interim result in part based on the details discussed in the processes of recovery support and environmental impact assessment during the Nakhodka's accident.

Keywords: GIS, Remote sensing, Oil-Spill, Environmental damage assessment, System integration

1. Introduction

The oil spill accident of the Russian tanker "NAKHODKA" (hereinafter called the "Nakhodka's Accident") that occurred before dawn on January 2, 1997 caused serious damage to the territory of the coastal region where the rights and interests were involved intricately. Moreover, the recovery operation was never adequate from the stand point of the recovery operation and the consideration to the environment when evaluating the facts such as the major means of recovery were manually operated using a bucket and a ladle, and more volunteers than needed were thrown into the operation on some beaches during the recovery operation, or the wrong dispersing agent was used, the heavy machines were used for recovery, and the heavy oil recovered was buried in the beach, etc. In such a sense, this accident helped the people become aware in a drastic manner of how difficult it was to take the concrete measures to deal with the oil spill accident.

As is already shown in the oil-spill accident of the Exxon Valdez, it is necessary to recognize that this type of accident is an environmental disaster. By the same token, both measures taken to deal with this type of accident and environmental impact assessment are characterized by the wide-area, long-term, and complex assessment of the environmental impact of the accident, which requires the interdisciplinary scientific knowledge.

This report is intended to summarize the role of geo-informatics in the oil spill accident by not only paying attention to the effect of information provision/information management via the map, but also reporting the interim result in part based on the details discussed in the processes of recovery support and environmental impact assessment during the Nakhodka's accident.

2. Lesson learned from the heavy oil spill accident of the Nakhodka [1)]

The Nakhodka's accident is the greatest heavy oil spill accident on the Japan Sea side that Japan has ever experienced, and presents various problems. They are summarized as per the below.

1) The accident was an environmental disaster that occurred in the coastal region, and two or more competent authorities were involved in it. A local self-governing body had to conduct the actual operations upon the instructions given independently by such competent authorities, and became further confused all the more because of that. Moreover, even under the existing circumstances where there remains residual heavy oil, no comprehensive environmental assessment technique has been examined toward the measures taken in the future to deal with the heavy oil spill accident including the long-term environmental assessment of residual heavy oil.

2) Although the recovery operation supported mainly by a total of 770,000 volunteers played a central role, the information on the heavy oil recovery has yet to be summed up. Besides, there are few managers who have the professional knowledge of heavy oil recovery, and the wrong instructions are often given. Therefore, there still remain some regions where the problems are left unsolved in restoration of the coastal region.

3) The items of compensation for legal damages didn't include the item of legal damages for the non-utility value such as the environmental value, and the sightseeing value, etc. Therefore, the secondary and tertiary beneficiaries of such value were at a loss where to demand the legal damages.

4) The nationality of a ship sailing in international waters instead of calling at Japanese ports cannot be managed.

5) The accident occurred in the Japan Sea during winter. For this reason, the restriction in the current monitoring technique of the heavy oil washed ashore ended up delaying the establishment of the system at the initial stage, or the data input to the drifting simulation intended to compensate for the observation result poor in time accuracy was reflected in the simulation accuracy, too. In particular, it was a restraint that the acquired data could not be disclosed due to the problem in the information disclosure system because the two-dimensional observation data was not available.

3. Application of geo-informatics to oil-drift monitoring

The oceanographic observation in the Japan Sea during winter heavily depends on the meteorological condition, and the continuous observation is impossible by using the visible sensor such as NOAA-AVHRR [2)]. It is necessary to establish the observation system independent of the meteorological condition through combined use of SAR and the H-F radar. The cases of using the above equipment are already put into practice in Canada and Norway in order to monitor the track line and the heavy oil lump, and should serve as a reference. Moreover, the drifting simulation must compensate for the monitoring by considering the restriction on monitoring with the optical sensor and SAR. Fig. 1 shows the result of oil-drift under the calculation condition of Tab. 1 and 2. Fig. 2 shows the simulated oil-drift washed ashore from the point of stranding off Tsushima and the point of drifting off Mikuni, respectively, under the condition of Tab. 1 and 2. From these it follows that the oil drifts about only before the Noto Peninsula instead of reaching the actual location of drifting. As shown in Fig. 2 and 3 show one of the result of drifting simulation by assimilating the data before the image is acquired by assuming that the heavy oil drifts from the heavy oil lump after the heavy oil lump is monitored with SAR. Fig. 3 shows the result using the outflow from the point 1 in the status of distribution shown in Fig.1 in part due to the constraints in the program used. From this result, it also follows that realistic drifting conditions are simulated. Although further investigation is required in the future, the data assimilation using SAR and H-F radar, etc. will become necessary. Oil-drift simulation program [3] used in this study is provided by Petroleum Association Japan.

Tab. 1 Condition of Oil-drift simulation used in this study

Item	Parameters used
Drift Condition	Current : mean Tidal current : not considered Wind effect : 5% Current from the river : not considered
Weather condition	Wind direction and wind speed : JMA-GPV data(per 3 hr.) Temperature : Jan. mean (per 1 hr.) SST : Jan. mean
etc.	Cell number : 5,000

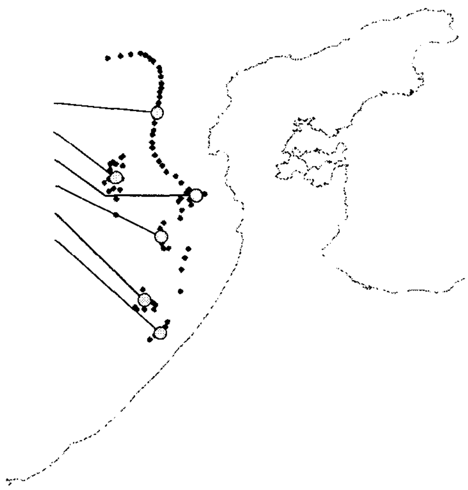


Fig.1 Oil-slickdistributiondetected by Radarsat.(Jan.11,1997)

Tab.2 Simulation Case

Case	Oil-source condition	Simulation Time
Case1	Oil-source Amount of oil : Point of running aground: 1000kl in 2 Jan.,1997 Mikuni : 5000kl in Jan.7,1997. Pattern of oil-outflow: at a moment	270hr. from Jan.2,1997
Case2	Oil-source Amount of oil : Point of running aground: no Mikuni : 6000kl in Jan.7,1997. Pattern of oil-outflow: at a moment	270hr. from Jan.2,1997
Case3	Oil-source : Oil-slick detected from the Radarsat data in Jan.11,1997.(See.Fig.1) Amount of oil: 6000kl Pattern of oil-outflow: at a moment	240hr. from Jan.11,1997

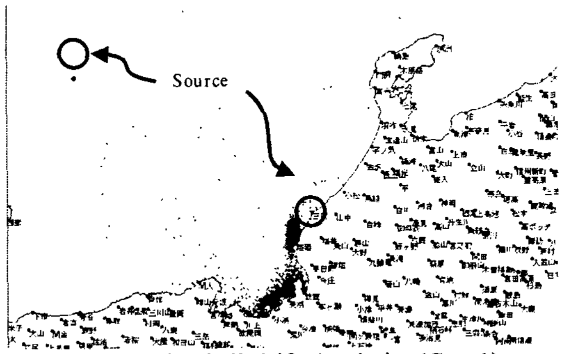
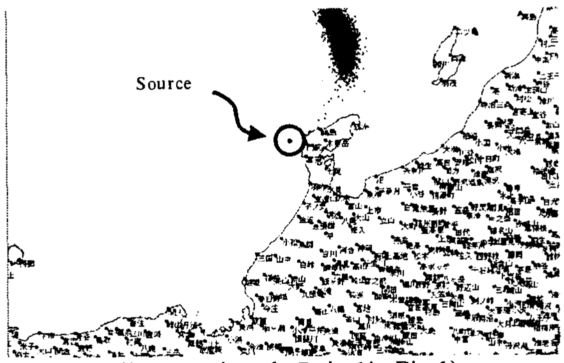


Fig.2 Result of oil-drift simulation(Case1)

Fig.3 Result of oil-drift simulation(Case3)



(Oil-source is only Point1in Fig.1)

4. Application of geo-informatics to support of decision-making process during oil restoration act

Until the first termination of accident was declared, the information on the conditions of heavy oil washed ashore was available only fragmentarily, and no linear or

Until the first termination of accident was declared, the information on the conditions of heavy oil washed ashore was available only fragmentarily, and no linear or surface relationship was provided where it was not clear as to which place should be given priority in recovery operation. Therefore, people devoted themselves solely to removing the heavy oil. GIS that can enable us to catch the entire situation and visualize the data on each individual scene will be effective for making sure of the above situation, too. Moreover, it gives an advantage both to the volunteers and the local people because they can prevent the possible confusion if the manpower pertaining to the existence of volunteer operations, recovery of heavy oil washed ashore again, cleaning, and monitoring operation in addition to the above information can be input as data so that the proper measures taken to deal with the recovery, etc. can be presented. Further, it is conceivable that the same location may be observed by a different study group in the related study, too. For this purpose, the role of Bulletin Board for unifying the study information such as the Kobe Network that started during the Great Earthquake of Hanshin/Awaji Regions will be necessary.

The function necessary for GIS during disaster is summarized in the following based on the experience of the Nakhodka's accident by assuming that the time required until the first termination of accident is declared is an emergency.

1)Function to provide data to the public.

2)Function to provide the information on the distribution of damages/information related with recovery linked with the map.

3)Function to centralize the information on the distribution of damages/information related with recovery.

4)Linkage function to the detailed (more technical) information over the ordinary GIS.

It is impossible to train the general users on a daily basis so that they can own and utilize the GIS in an emergency toward the realization of 1) – 3).

Such function has been provided to Web-GIS because it is deemed more realistic to use the homepage of internet whose users are increasing day by day. In the meanwhile, the function mentioned in the above 4) requires the system where the GIS software on the client's side can manage the Environment Sensitivity Index (ESI) intended to determine the priority of recovering the heavy oil washed ashore during the accident so that the client can use it by linkage as occasion demands. Fig.4 shows the system configuration of the Web-GIS prototype. Fig. 5 shows its Graphical User Interface (GUI).

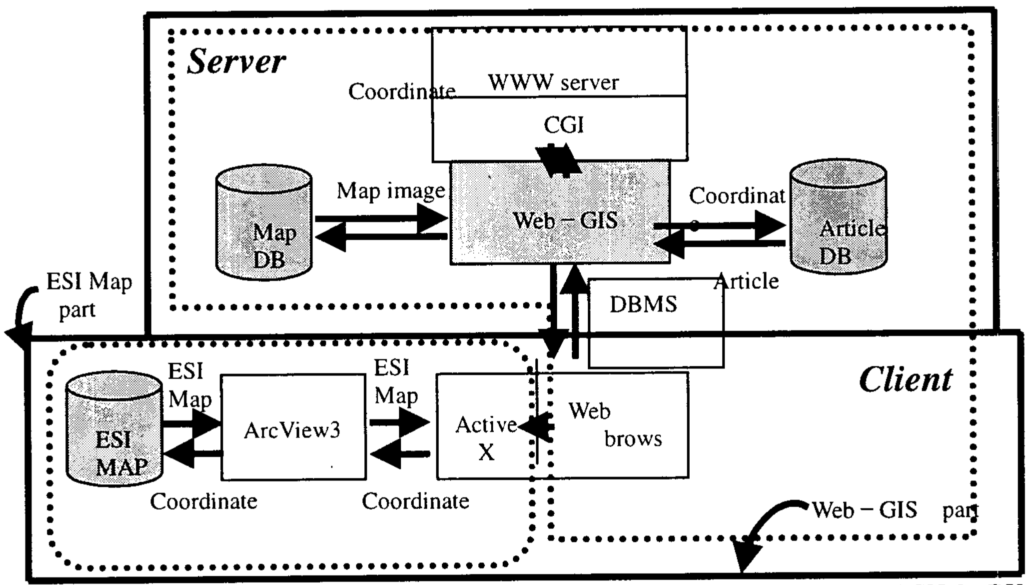


Fig. 4. Schematics of the linkage of Web-GIS for Near shore Environmental Management and GIS for ESI-map

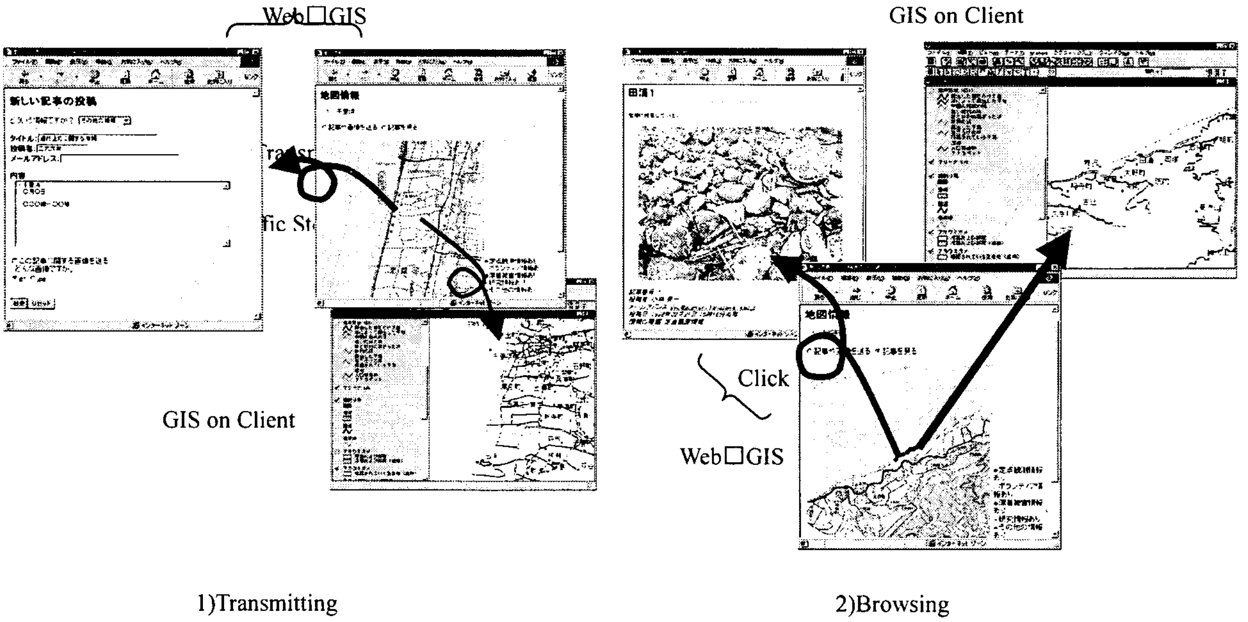


Fig.5 GUI of Web-GIS

5. Application of geo-informatics to the overall environmental assessment [4)]

In the case of the Exxon Valdez's accident, the State of Alaska claimed 2.3 billion dollars as compensation for ecological loss from Exxon, and the court decided that 900 million dollars should be paid as legal damages. However, even the damages against the reduction in sightseeing value have not been compensated for properly, not to mention the damages to the eco-system in the case of the Nakhodka's accident. The Contingent Valuation Method (CVM) represents the technique for calculating the non-utility value such as eco-system. This method has been rapidly investigated since the Valdez's accident, and is used for measuring the value of Yakushima Island in Japan, too. It is necessary to prepare the base so that the above methods can be used for accounting the damages of the environmental disaster. For this reason, it becomes necessary to discuss, etc. who will take care of the environment as the Commons in addition to the technical issue. Moreover, this is a common problem required for reviewing the public works centering on the dam construction in Japan. The problem of conflict between development and environmental protection is the common issue in the some wetland such as Isahaya Bay, Fujimae wetland, some mitigation project in the development of the coastal region, and the cost/benefit analysis in the measures to deal with the oil-spill, too.

In the meanwhile, our colleague,.Mr.Sawano and Dr.Yokohata, are now identifying the symbolic creatures on the beach in Ishikawa prefecture where the heavy oil was washed ashore on an independent basis in order to assess the environmental damage using the alternative method. We are attempting to estimate the damages to the eco-system at the expenses required for restoring the symbolic creatures equivalent in portion to those that retreated from the baseline due to the heavy oil washed ashore by arranging in order the distribution of the symbolic creatures and their environmental carrying capacity by using GIS. These are still under way, and will be reported elsewhere.

6. Conclusion

Based on the results of our study so far, we have shown the support of decision-making process during the oil recovery, monitoring of the heavy oil washed ashore, and the role of geo-informatics played in the overall environmental assessment.

The operation scenario that considers the utilization during the normalcy will be required for ensuring that the systems including the coastal GIS whose construction has started at the initiative of the Maritime Safety Agency can be utilized smoothly during the disaster. The future problems can be summarized in the following.

- Utilization by training during the normalcy and smooth cooperation during the disaster.
  *Application to the training (Contingency Plan) that presupposes the disaster during the normalcy.
  *Linkage to the guidelines for recovering oil spilt.
- Strengthen the observation system that presupposes the disastrous condition.

While the satellite data was also utilized in the case of the Nakhodka's accident, such data failed to be utilized effectively at the civil and NGO levels because it took time until the data was provided, etc. The following matters must be examined including the countries related to the area of sea around Japan based on the above.

  *Installation of portable receiving and processing equipment of satellite data.
  *Sharing of observation data by networking.
- Improvement in oceanographic observation in the stormy weather.

References

1)H.Oyama: Near Shore environmental management using GIS in oil-spill disaster, Proc.of JSPRS, pp.11-16,1998. (in Japanese)

2) Y.Mukai et al: Status of the remote sensing data acquisition related oil-spill accident in the sea of Japan,Journal of remote sensing, Vol.17, No.1, pp.70-82, 1997. (in Japanese)

3) Petroleum Association Japan: Manual of oil-drift simuration,Vr. 4.0, 1998.(in Japanese)

4) S. W. Kim, S. Goto etal: Estimation of environmental damage assessment in the shoreline after the NOKHODKA Oil-spill Using Geoinformatics, Proc. Of ISRS, 1999. (in printing)