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Application of Side Scan Sonar to Disposed Material Analysis at the Bottom of Coastal Water and River

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Abstract : *Due to the growth of population and industrial development at the coastal cities, there has been much increase in necessity to effective control of the wastes into the coastal water and river. The amount of disposal at those waters has been increased rapidly and it is necessary for us to track of it in order to keep the waterway safe and the water clean. The investigation and research in terms of water quality in these regions have been conducted frequently but the systematic survey of the disposed wastes at the bottom was neglected and/or minor. In this study we surveyed the status of disposed waste distribution at the bottom of coastal water and river from the scanned images. The intensity of sound received by the side scan sonar tow fish from the sea floor provides information as to the general distribution and characteristics of the superficial wastes. The port and starboard side scanned images produced from two arrays of transducers borne on a tow fish connected by tow cable to a tug boat have the area with width of 22m~112m and band of 44m ~224m. All data are displayed in real-time on a high-resolution color display (1280 x 1024 pixels) together with position information by DGPS. From the field measurement and analysis of the recorded images, we could draw the location and distribution of bottom disposals. Furthermore, we could make a database system which might be useful for navigation and fundamental for planning the waste reception and process control system.*

Key words : *Side scan sonar, Disposed waste distribution, DGPS, Sea floor, Sound intensity, Tow fish*

1. Introduction

1.1 Background

The oceans and rivers are very important as the egg-laying site and the hatchery of marine and water wild ecologies. They should be preserved in clean so that they could keep their high productivity for the ecology and supply the amenity and resting place for the resident. However, they have reached at the level of dangerous beyond the self-cleansing limit due to various floating and bottom deposits of wastes from the large scale fishing and aqua-farming in these areas, increase of commercial and recreational use and expansion of the industrial complex near the waterfront. Especially in the ocean, it is well known that the main negative constraint for environment is disposal of the constructional wastes from the coastal zone development. In the river, on the other hand, so do wastes from the industrial production and consumption activities (Coe & Rogers, 1996).

The navigational hazards due to the disposed constructional and residential wastes scattered at the bottom of the coastal water and river have shown a rapid increase. Moreover, the physical and chemical changes of water and water pollution from this have become more serious social problem. In order to restore the blocked and contaminated water environment, it is necessary to identify rapidly the status of the bottom waste deposits and their distribution by a systematic survey. With this help we are able to set up the retrieval plan of the deposits and construct an effective operational system of cleaning the water by predicting the future dumping wastes.

1.2 Objectives and Methods

In this paper, we focused to supply the accurate data necessary for retrieval of the bottom waste deposits and control of water pollution in coastal water and river by surveying the status of the waste deposits, distributions and locations. The research and investigation related to the wastes into the coastal water and river induced by the economic development and improvement of human life had ignited on the year of 70's by London Convention and MARPOL and been continued to the year of 80's by the international organizations and developed countries. In Korea, the scientific research and investigation were started only at the mid of 80's (Kim et al., 1987; Korea National Science Division, 1989) but after the year of 90's in terms of actual survey and control (Korean Institute of Mechanics, 1998; MOMAF, 2001; Han River Operation Office, 2002). Most of the investigations up to now have been done mainly at the individual locations in the harbor by diving works or bottom cleaning vessels without scientific search equipment. For this reason, in this study

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we intended to investigate and analyze the status of disposed waste distribution selecting some coastal waters and river in Korea with the help of a side scan sonar survey system. We incorporated here a side scan sonar with DGPS (Differential Global Positioning System) to get a precise bottom profile and position of deposits.

2. Equipments and Method for Survey

2.1 Survey Equipments

A fully integrated side scan sonar survey system with individually selected components was used here to meet specific survey requirements. Components include: tow fish, Signal processor unit, Power supply and Image processing unit as illustrated in Fig.1. This system manufactured by Sonar Tech Co., Ltd. (SeaView-400) has functions of each unit shown in Table 1. Each of the port and starboard side scanned image covers the bottom area with width of 22m~112m and band of 44m~224m, respectively at the same time. The negatively buoyant tow fish is tethered at the end of the tow cable which is connected at the stern of a survey boat. The length of tow fish is 140cm and the tow cable is 100m but adjusted depending on the water depth. The tow cable supplies power and returns the detected sonar signals. The whole detected signal is reproduced by the SDU (Signal Processing Unit) as shown in Fig.1(a) to get a raster formatted raw image and transmitted to the main computer. The SDU not only receives the signals from the tow fish but controls the horizontal detection width. The on-line or off-line processing module, SeaView, on the computer is specifically designed to process and accommodate the image data collected.

The acquired data from the system passed through the proper processes are then stored in a computer with the precise position information from DGPS. The system is incorporated with the beacon receiver of Trimble Co. Ltd., which has a position error of (±) 30cm.

Table 1 Function of the side scan sonar component

Unit	Function
Tow Fish	Two arrays of transducers mounted on the sides of the Tow fish Measurement of distance to the bottom by high resolution sonar signal
Signal Processing Unit	Amplification of the sonar signal transmitted from the Tow fish Real time recording the signal in PC
Power Supply	Power supply for the system operation
Image Processing Unit	Image recognition and visualization

2.2 Survey Method

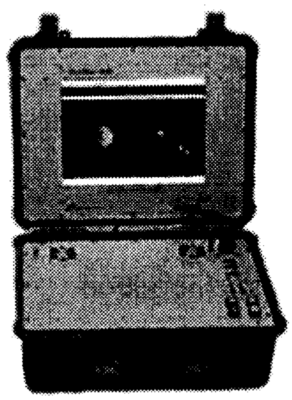
1) Pre-Processing Work

① Construction of investigation site plan on Numerical Chart

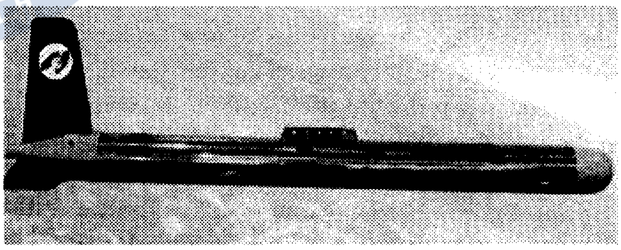
② Edition of NC (transform NC into DXF using U.T.M.)

③ Real time use of NC

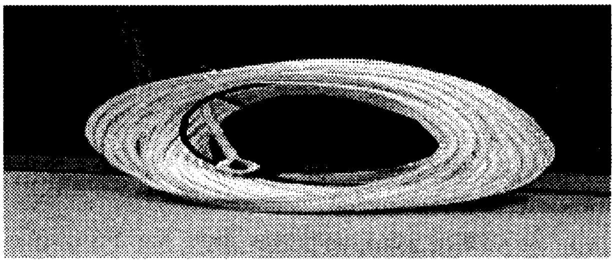
In order to use the completed investigation site plan on NC together with the side scan sonar system and DGPS in real time base, the NC is transformed into DXF file using internal edition tool. The real time scanned image by the side scan sonar operating system is displayed in the color monitor with the information of position (Latitude and Longitude by DGPS operating system), ship's heading, ship's speed and tracks.



(a) Image processing unit and signal processing unit



(b) Tow fish



(c) Line cable

Fig. 1 Component of Side Scan Sonar System

2) Main Processing Work

① Survey and monitoring by the side scan sonar.

After installation of the equipment on the survey boat and control of the tow fish through the sonar deck, the image content is obtained by transmitting and receiving the sonar signals under the sea surface as shown in Fig. 2.

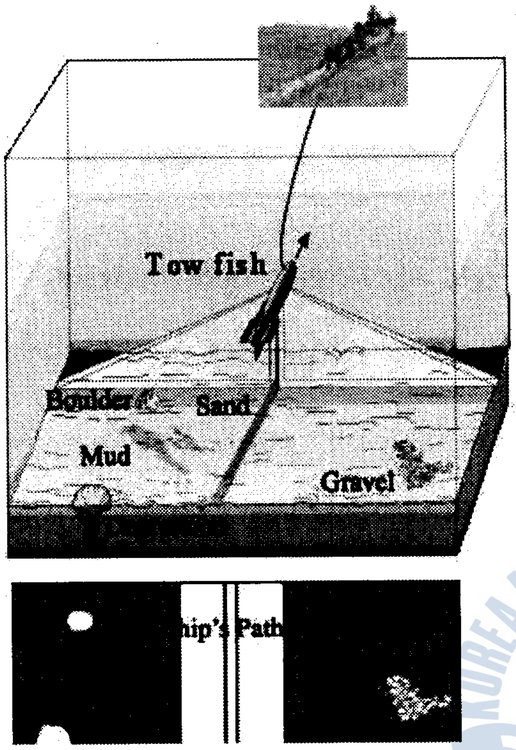


Fig. 2 Usage of tow fish and the image obtained

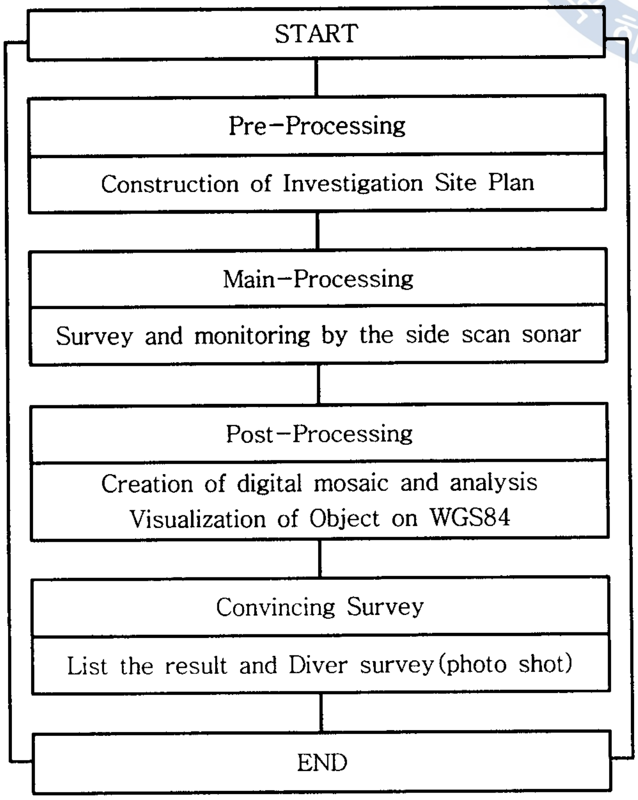


Fig. 3 Flow chart for investigation

② Investigation of the status of the disposed wastes along the track of survey boat.

In order to avoid the skip or overlap of the survey tracks, the real time ship's position by DGPS is monitored and the tracks are corrected interchangeably. This process is repeated sequentially throughout the survey work.

3) Post-Processing Work

The scanned data at the investigation site by the side scan sonar are stored in the computer with a constant interval. Therefore they are loaded into the SeaView software to make digital mosaic adding each image along the track as shown in Fig. 4.

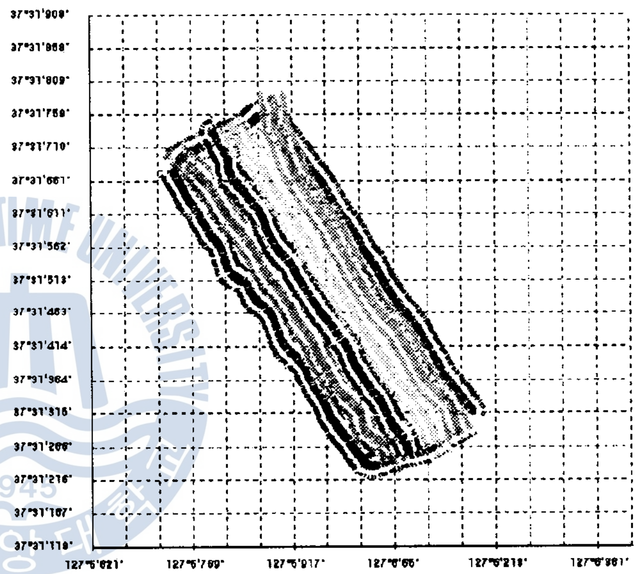


Fig. 4 Track diagram of site survey at Han-river(Site No.1)

4) Convincing Survey Work

For improvement of the survey result, this step of investigation is necessary for the case of difficult pattern recognition. Convincing survey work is done by sending divers under the water and taking photos of the object.

2.3 Compensation of Distorted Data

Although we got the sonar data without any difficulties, it is possible to contain the distortion of data and interference from the noises. The reason for these are : ① Unstable of tow fish height due to heaving, pitching, and yawing, ② Variation of towing ship's speed, ③ Range data compression due to tow fish height. Most of these are due to the condition of ship handling and environmental condition. Among these, ② and ③ might be compensated by the digital side scan sonar, too. However, we need to consider the following facts when we analyze the obtained image data.

1) The Shadow

As the acoustic wave propagates straight, a tow fish, bottom line and the shadow end of an object forms a right-angled triangle as shown in Fig.5. The height of the object is an important parameter to calculate the amount of disposed wastes. Therefore, we need to get the height of each object. The height of an object H_T in Fig.5 can be calculated using the relationship of geometric similitude by the following formula:

H_T = (Length of shadow Ls x Height of tow fish)/(Distance from the tow fish to the shadow end of an object)

This fits well usually but incorrect when the sonar is operated under a special condition, such as the case of a large water density variation causing a curved propagation track.

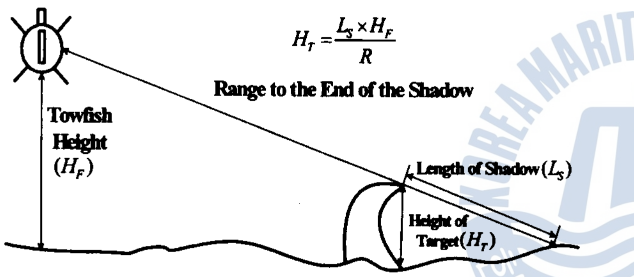


Fig. 5 Relation between the height of target and the length of shadow

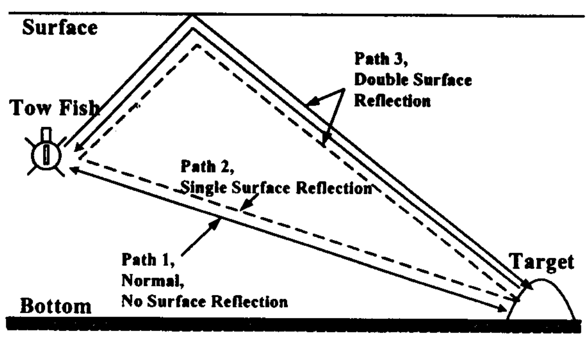


Fig. 6 Reception of echo through the multi-path

2) Surface Reflection

The side beam from the transducer of the tow fish propagates widely in vertical direction and reflects back containing information from the bottom, sea surface and target in the water through the multi-path as shown in Fig.6. In case of working in a calm and shallow water, the reflected acoustic wave from the target at the bottom is easily reflected again at the sea surface and the transducer receives this multi-path reflection. This causes several false echoes from an object. The most common structures for this are cylinder structures, pipelines, torpedoes, and sunken ships, etc.

In addition, there are many other side scan image processing and characteristics too numerous to discuss here for which the reader is referred to Kim et al. (1987), Fish & Carr (1990), and Johnson & Deaett (1994). Especially, Daniel et al. (1998)had developed an algorithm for side scan sonar image matching based on a hypothetical reasoning for the object shadows.

3. Field Application and Analysis

3.1 Survey of Disposed Materials at the Bottom of Coastal Water

The rapid identification of the bottom waste deposits in a confined water area due to development of coastal zone has grown in importance for the ocean going vessels to pass through the waterway safely. Survey with a side scan sonar provides a cost effective means of evaluating the amount of deposits and locating of the sunken obstruction. Here we describe a recent survey for such damaging deposits from the construction work at Jaseongdae Container Terminal in Busan City, Korea. We figured out the deposits by the side scan sonar and the position with DGPS system. In order to get high resolution images we set the side beam widths of the left and right transducers to 37m, respectively and surveyed the overlapped tracks with 20m intervals as shown in Fig.7. The length of tow cable and the ship's speed were set by 6m and 4kts, respectively.

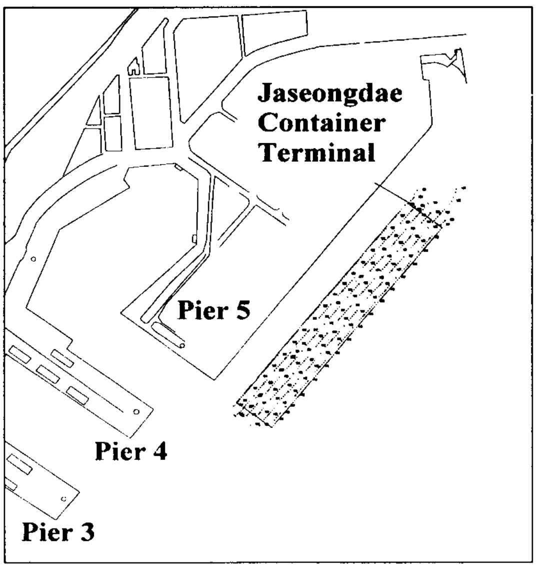


Fig. 7 Track of site survey at Busan North Inner Harbor

Table 2 The number of blocks found

Location	On the bottom	Buried	Assumption
Accuracy (%)	98%	70%	50%
No. of Blocks	33EA	37EA	27EA
Total No. of Block	97EA		

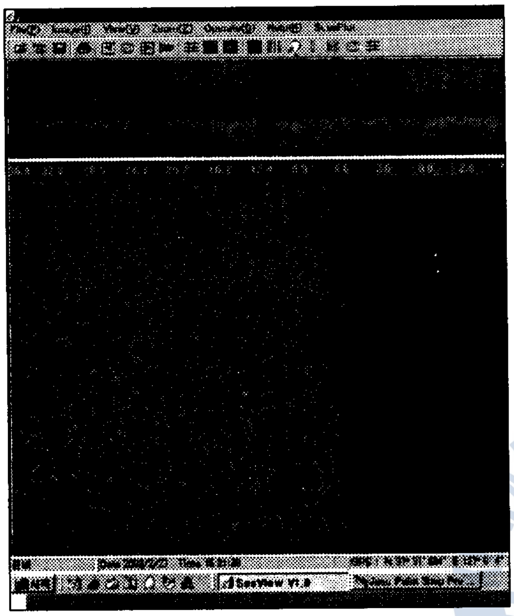


Fig. 8 Example of post processing by Seaview

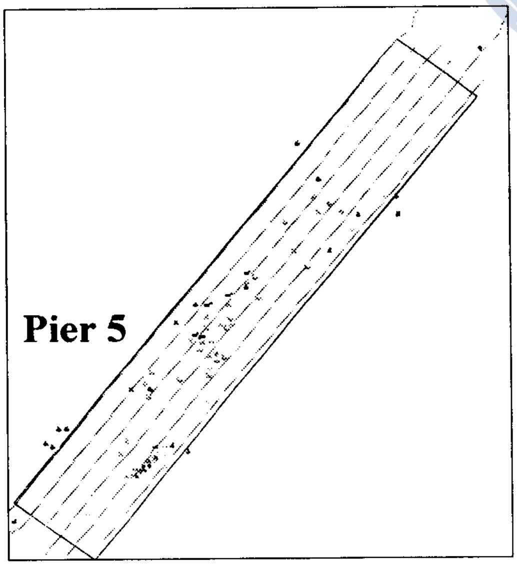


Fig. 9 Distribution of discarded concrete block on the bottom

Fig.8 is an example of the image processed by SeaView software, which is identified as concrete blocks used for the protection screen of suspended solids in Fig.9.From the post-processing, we could draw the status of the deposits within the area of 1,000m x 100m. We rearranged the number of the identified concrete blocks in three levels. As in Table 2, the sunken objects buried partially at the bottom are difficult to identify depending on the burying depth. Although the waste deposits due to construction work near the coastal zone might be used as construction materials but should be removed for safe navigation into the harbor, fishery activities, other construction and dredging works, etc.

3.2 Survey of Disposed Materials at the Bottom of River

The river has some of the most productive and valuable habitats of the biosphere, including lakes, lagoons, estuaries, and wetlands. It is a place of high priority interest to commerce, to navigation, to agriculture, to housing, to recreation, and to a variety of industries. Because it contains dense populations and undergoes great contacts with the people commercially and industrially, we expect that there are lots of disposed wastes and contaminants into the river. We investigated here seven distinct locations along the Han-River in Seoul as shown in Fig.10. The site includes the places under construction of bridges, landfill and dredging, and a wide band of green parks and grounds where the civilians visit frequently. As the water depth was good for using the side scan sonar and more precise survey was required for retrieval of the wastes, we set the overlapped tracks with 22m intervals. The length of tow cable and the ship's speed were set by 4m and 4kts, respectively. Fig.4 indicates one of the sample tracks at Site 1. The survey data at seven sites were analyzed and classified in terms of shape, size, type, and event. The expected numbers of these by image processing are shown in Table 3. It was difficult to identify the deposits when they had been buried on the bottom. However, we were able to predict the amount when they are protruded above the bottom face. In order to get comparatively accurate numbers, we had sent divers to take photos for those locations and made comparison with the results of image processing.

1) Type and Amount of the Waste Deposits

Classification of waste deposits by type and shape includes tire, rope, timber, iron, concrete block, and plastic, etc. Table 3 indicates the expected amount from the horizontal distribution of each survey items after the analysis. Based on the information at 7 survey sites, we made prediction of total waste deposits in the Han-River under the jurisdiction of Han River Operation Office as follows.

① Considered only 33㎢ for the basin area of the Han-River excluding the small island (Dunchi-Do) of

Table 3 Calculation table for waste deposits. (Unit : kg)

Item / Site N	Tire	Rope	Timber	Iron	Concrete block	Plastic	Sum
Site 1	893.2	4,325.0	10,157.4	22,483.6	24,319.6	194.4	62,373.2
Site 2	111.0:		812.5	5,105.0	759.0	1,544.4	8,331.9
Site 3	255.5		758.3	44,936.1	616.4		46,566.3
Site 4	421.8		2,179.4	106,902.7	4,606.4		114,110.3
Site 5	696.4		533.8	17,969.6	738.3		19,938.1
Site 6	440.4		516.3	51,169.0	2,242.5		54,368.2
Site 7	560.6	28.0	976.6	30,552.4	2,012.5		34,100.1
Sum	3,378.9	4,353.0	15,879.9	279,087.5	35,294.7	1,738.8	339,788.1
Total amount of Site 1 through 7	339,788 (339.7ton)						
Predicted amount in the Han-River in the limit of Seoul City	7,376ton						

6.9㎢:

- near the river bank (Site 2,3,4): 0.413㎢ → deposits of 169ton (409ton/㎢)
- at the center of the river (Site 1,5,6,7): 0.850㎢ → deposits of 171ton (201ton/㎢)

② Area for river bank and river basin center in the limit of Seoul City: total area of 33㎢

- area of the river bank: 71.5㎞ (both sides) 0.05㎞ = 3.575㎢ (11%)
- area of the river basin center: 33㎢ - 3.575㎢= 29.425 ㎢ (89%)

③ Calculated waste deposits in the Han-River in the limit of Seoul City

- near the river bank: 409ton/㎢ 3.575㎢ = 1,462ton
- at the center of the river: 201ton/㎢ 29.425㎢ = 5,914ton

From this calculation, we arrived that the total amount of waste deposits in the Han-River in the limit of Seoul City is 7,376ton.

2) Convincing Survey of the Waste Deposits

As per the survey with the side scan sonar, it was found that there were various shapes and several different types of waste deposits at the bottom of the Han-River. For convincing the deposits clearly, we had sent divers to take photos for those locations and made image analysis to get the status of distribution. Table 4 and Table 5 show the comparison between the diver's camera image and sonar image. We figured the positions of the objects and found both images are identical.

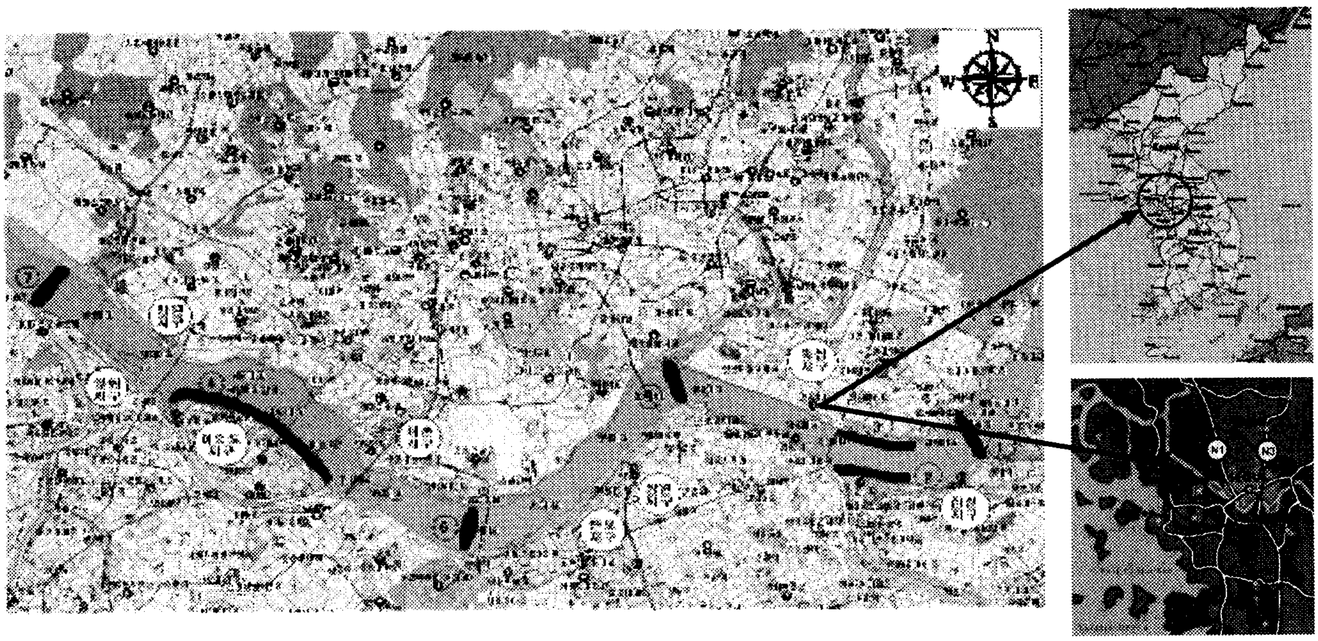
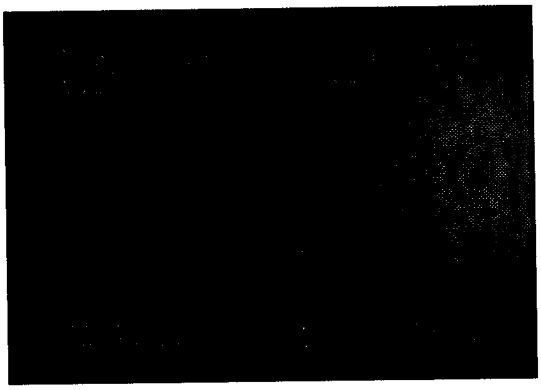


Fig. 10 Location map and track of site survey for Han-River

Table 4 Comparison between camera image and side scan sonar image (1)

Image No	Coordinate(U.T.M)	Lat. & Lon.(WGS-84)
2-2-4	X:4153427.941 Y:330514.559	37-31-127N 127-04-787E
Illustration	Rowing boat (filled with other sweepings)	



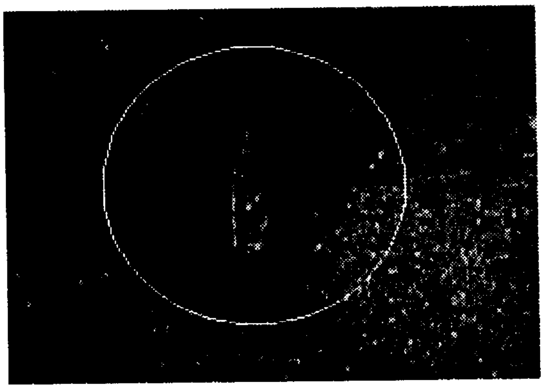
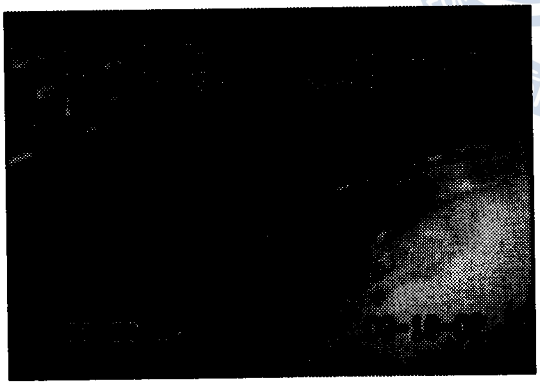
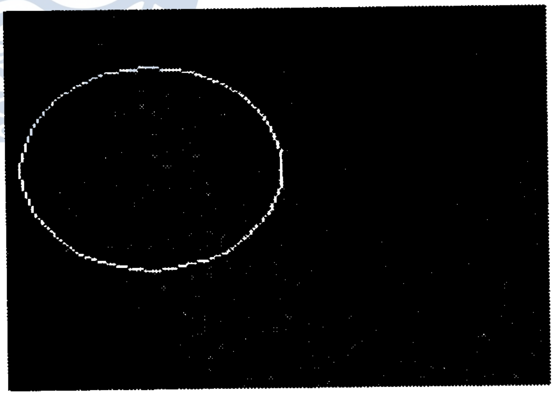


Table 5 Comparison between camera image and side scan sonar image (2)

Image No	Coordinate(U.T.M)	Lat. & Lon.(WGS-84위도)
4-13-1	X :4154924.149 Y : 317624.381	37-31-788N 126-56-018E
Illustration	Large Tire (For Dumper truck)	





4. Results and Discussions

Most countries recognize the coastal water and river as distinct region with resources that require special attention. We believe that they are the basin for human daily life today and that our future depends on the way how we use those areas. For better and rapid identification of bottom waste deposit, acoustic surveys with a side scan sonar provide a cost effective means of locating the wastes on the chart, and it must be a proper tool for removal of waste deposits and keeping the waterway safe and clean. We came to the following findings:

1) Most of the waste deposits in the harbor were constructional materials used for port development.

2) Various urban wastes and constructional materials are evenly distributed on the bottom along the river and we could predict the approximate amount of total waste deposits within a given area from the basis of surveyed sites

3) We are able to supply the necessary information for removal of waste deposits distributed at the bottom of coastal water and river.

Besides of the above mentioned visible results, it might be used to supply the basis for establishment of the environment protection policies and applied to construction of fish breeding ground, dredging, investigation of wrecks and obstructions, environmental monitoring, hydrographic mapping, beach profiling surveys, offshore jetty and groin surveys, and channel clearance surveys, etc.

However, all the surveys are being done on the ship and therefore, it should be noted and prepared for the following aspects:

1) Recognition of the position error of DGPS in terms of winds, currents, waves which is connected to dynamic motion of the survey ship and tow fish.

2) Compensation of the relative position between tow fish and DGPS position.

3) Difficulties of positioning divers and equipments for convincing survey after acoustic scanning work.

All these facts can be managed and improved with the help of experienced operators and the use of precise software.

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