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Sea water intrusion in coastal areas of Yellow Sea and Bohai Sea

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Abstract—This paper principally concentrates on the problems of sea water intrusion in the coastal areas of Yellow Sea and Bohai Sea and some proposals for prevention and control of the sea water intrusion. Sea water intrusion is very heavy at some places of the coastal area along Yellow Sea and Bohai Sea, and it is extending fast towards inland. It has caused underground water quality deterioration and short supply of fresh water at some places. It has resulted in the decrease of land productive capacity, limited industrial development and has destroyed landscape ecology in this area. In order to prevent and control continual extension of sea water intrusion in the area, several proposals, such as ecological agriculture and forestry, are suggested on the basis of ecological principle.

Keywords: sea water intrusion; coast; ecological agriculture.

1 Introduction

Sea water intrusion is a kind of environmental problems in some special areas. It is an aftermath that natural and artificial factors act on eco - environment. Scientists and political officials have paid close attention to the aftermath of sea water intrusion (Yin, 1992). Though the study on sea water intrusion has been carried out for many years, its systematic study has only begun in recent decades. Scientists from many countries, such as Belgium, Danmark, the Netherlands, Germany, Spain, the United States, Japan, Australia, former USSR, India and so on, have studied the problems, including formation, type and development of sea water intrusion. They pay particular attention to the effect of sea water intrusion on eco - environment. Theory, methodology and many models of sea water intrusion have been proposed by scientists (Breuch, 1983; Custodio, 1986; 1987; Gupta, 1982).

Study on sea water intrusion in China has been carried out by the Chinese Academy of Sciences, Geological Department, Nanjing University, Chinese University of Geology since 1975. The main areas studied are coastal areas of Shandong, Hebei, Liaoning and Zhejiang. Most studies before 1987 were devoted to investigate the status of sea water intrusion in these areas. Comprehensive studies have been conducted since then. Some of the proposals for the prevention and control of sea water intrusion have been suggested, and numerical modeling for simulating dynamic change at interface of fresh water to sea water and the regularity of the development and

extension of sea water intrusion have been developed (Chinese Association of Preventing Calamity, 1991; Zhao, 1991).

2 Status and factors affecting sea water intrusion in coastal areas of Yellow Sea and Bohai Sea

Sea water intrusion in the coastal area was discovered in 1970s, but it has begun to cause several disastrous problems in the coastal areas only since 1980s, especially in Shandong coastal zone where sea water intrusion is considerably heavy, and disasters are fast stretching towards inland. There is a large area of land that has been affected by sea water intrusion. The regional distribution of sea water intrusion in the coastal area of Yellow Sea and Bohai Sea is listed in Table 1. It is shown that there is about 1000 km^2 land that has been affected by sea water intrusion, up to the present, in which the largest area is in Shandong Province, which is about 70 percent of the total area. The heaviest place is Laizhou City in Shandong Province. There are about 388.9 km^2 land intruded by sea water from Laizhou to Yantai City, but there are only about 42.3 km^2 land affected by sea water intrusion from Yantai to Xiuzhen River. Although the coastal line from Laizhou to Yantai is about one third as long as that from Yantai to Xiuzhen River, sea water intrusion of the coastal zone from Laizhou to Yantai is about 9 times as large as that of the latter.

Table 1 Sea water intrusion distribution in coastal areas of Yellow Sea and Bohai Sea

Province	County/City	Area, km^2	Province	County/City	Area, km^2
Shandong	Laizhou	238.2	Shandong	Longkou	88.7
	Zhaoyuan	11.3		Penglai	5.4
	Changdao	5.3		Fushan	40.0
	Muping	2.0		Haiyang	2.0
	Jimo	1.8		Laoshan	15.0
	Jiaozhou	15.0		Jiaonan	4.5
	Huangdao	2.0		Pingdu	80.0
	Changyi	90.0		Hantin	61.5
	Shouguang	54.0		Guangyao	14.5
Hebei	Coastal areas of eastern and northeastern Hebei				24.0
Liaoning	Around Dalian				288.6
Sum		1043.3			

Sea water intrusion is principally discovered in various plains, such as piedmont plains, alluvial plains of river mouths and argillo-arenaceous plains near Bohai Sea. There are seven kinds of sea water intrusion based on hydrogeological conditions.

The first one is the karst pattern along crevasses, such as sea water intrusion at Daweijia, Dalianpo and Nanganling. The second one is the porous pattern of cohesionless Quaternary sediment, like that discovered at Qinhuangdao, Laizhou and Penglai. The third one is the diffusive

pattern of piedmont plain, such as Shouguang, Hantin and Changyi. The others are mining pattern, such as at Laoshan, Muping and Dalian, and direct and indirect patterns.

Sea water intrusions related with increase in fresh water funnel and decrease in ground water table. The main increase in fresh water funnel and decrease in ground water table are due to the fact that fresh water demand continuously increases from economic development of cities, villages and towns in the coastal area. The increase in water demand has caused excessive mining of underground water so that the underground water quality is deteriorated by sea water intrusion. After the water quality at a place is deteriorated, a new underground water resource will be mined. In this case, sea water intrusion is extending little by little, so that disasters from sea water intrusion is also extending and becoming heavy. The typical area is the coastal zone in Shandong Province, especially in the cities of Dalian, Qinhuangdao and Laizhou. The area of sea water intrusion was only 15.8 km^2 or so in Laizhou City from 1976 to 1979, with an annual average velocity about 46m (Table 2), but increases in the area of sea water intrusion is 23.4 km^2 from 1980 to 1982, and 31.9 km^2 from 1983 to 1984. Annual average velocity was about 92m and 177m respectively, about 2 and 4 times as fast as that from 1976 to 1979. The area of sea water intrusion increases 98.5 km^2 from 1984 to 1987, and 32.3 km2 from 1987 to 1988. Annual average velocity was about 345m and 404.5m respectively. The highest velocity was about 9 times as fast as that from 1976 to 1979. The total area of sea water intrusion in Laizhou City was about 238.2 km^2 within 14 years, 80 percent of the littoral plain area of Laizhou City. The area of underground water table below sea level was 251 km^2 in 1988, and about the whole plain in 1989.

Table 2 Change of sea water intrusion in Laizhou City

Date	Area, km^2			Velocity, m/a
	Increase value	Sum	Average/a	
1976—1979	15.8	15.8	4.00	46
1980—1982	23.4	39.2	7.80	92
1983—1984	31.9	71.1	16.00	177
1984.6—1987.8	98.5	169.6	31.07	345
1987.9—1988.8	32.6	201.96	32.36	404.5
1988.8—1989.9	36.24	238.2	36.24	-
1984—1989	167.1	-	31.30	348
1976—1989	238.2	238.2	14.8	168

Sea water intrusion has taken place in mid 1960s in Dalian City, Liaoning Province. Sea water intrusion area was only 4.2 km^2. Two decades later, in 1986, the area increased to 288.6 km^2. Sea water intrusion makes this city heavily short of fresh water supply. This phenomenon will take place in Qinhuangdao City, Hebei Province, especially in Beidaihe area. At present, ground water table has been decreased to -18.6m, annual average velocity of sea water intrusion is about 16—22m. Large area of sea water intrusion will be found in the area if mining underground water is not abated.

Sea water intrusion is closely related with natural factors, especially with drought and sea level rising. The relationship between sea water intrusion and precipitation, and ground water table in coastal area of Laizhou Bay are listed in Table 3. In the last ten years, there was drought

in the area. The capacity of replenishing underground water from precipitation has decreased, so that the area of underground water below sea level has enlarged, and sea water intrusion has extended.

Table 3 Relationship between sea water intrusion and precipitation and change of ground water table at the typical coast zone along Laizhou Bay

Item*	Year				
	1976 1979	1980—1982	1983—1984	1985—1987	1988—1989
Precip. ,mm	571.3	429.9	312.3	482.5	486.2
Area,km^2	-	-	338.4	136.5	427.6
Darea,km^2	-	-	-	209.6	262.1
Sarea,km^2	15.8	23.4	31.9	98.5	68.6

*: Precip. is precipitation. Area is the area of the buried depth of underground water that is smaller than 15m. Darea is the area that ground water table is lower than sea level. Sarea is the area of sea water intrusion

Sea water intrusion is discovered principally in coastal plains with argillo-arenaceous stratum or sandy stratum. Generally there are characteristics in the plain with lower altitude, shallow ground water table and good water permeability. The permeable coefficient is about 30—150 m/a. Therefore, sea water extends easily to the plain when ground water table decreases.

Sea water intrusion is related with sea level rising. According to statistic results of 48 hydrographic observatories, sea level has risen about 5 cm in last 100 years, but it rose 1.01 cm in 1989 alone. Sea level rising makes relative ground water table decrease and sea water intrusion increase.

Sea water intrusion is principally related with artificial factors. In recent years, fresh water demand increases continuously with city's, village and town's industrial development in the coastal area. Mining of underground water rapidly increases, with a decrease in ground water table: At some places, ground water table is often kept between -20m and -25m. For example, minable amount of underground water was about 1.62 Gm^3 between 1976 and 1989 in Laizhou, but the amount actually mined was about 2.46 Gm^3. The excessive mining amount was about 0.84 Gm^3 in 14 years. Along Laizhou Bay, excessive mining underground water was about 3.8 Gm^3 from 1976 to 1989 in six counties of Shouguang, Changyi, Hantin, Pingdu, Laizhou and Longkou.

Another reason that causes sea water intrusion is that sea water has been elevated up to 3—5m and sent to 5—15 km away from coast by canals and ditches to be used for developing sea water breeding and enlarging salt pan. These kinds of limitless human actions have resulted in local sea water intrusion. The problem has been discovered in the coastal area of Laizhou City, Tangshan City and Qinhuangdao City for several years.

Many reservoirs have been built since 1958 in upper and middle streams of each river which flows into sea to be used for fresh water storage and for local economic development. The water storage method makes flowing surface water decrease and underground water supply abated in the areas of the down streams, so that it causes ground water table decrease and sea water intru-

sion extension.

Mining sand in river beds near a sea is also a way to cause sea water intrusion increase. A large amount of sand got from river bed has caused many river - beds decrease so that they are lower than water level of tide. Their decrease is advantageous to sea water intrusion towards inland.

These natural and artificial factors have caused sea water intrusion and extension, and several disasters have appeared. Limitless excessive mining of underground water and sand near river mouths must have made the coastal area of Yellow Sea and Bohai Sea move along the way: economic development — increase in fresh water demand — excessive mining of underground water and sand near river mouth — breaking of water equilibrium — extension of sea water intrusion — underground water salinization — mining of new underground water resources — increase and extension of sea water intrusion — eco - environment deterioration — limitation on economic development. Unless measures of prevention and control of excessive mining of underground water or sea water intrusion are taken the whole coastal plains of Yellow Sea and Bohai Sea will become salt plains.

3 Effect of sea water intrusion on eco - environment

Sea water intrusion resulted from natural and artificial factors has caused many disasters. Some disasters in Shandong Province from sea water intrusion are listed in Table 4. It is shown that there are about 45000 hectares cultivated land salinized, about 7103 irrigation wells scrapped.

Tale 4 Disasters caused by sea water intrusion in the coast in Shangdong Province*

City/County	Tilling, ha	Well	Village	Population
Laizhou City	18000	2361	132	107000
Longkou City	6667	1000	35	30000
Penglai	333	15	18	36000
Changdao	400	42	13	5000
Fushan	2667	200	20	20000
Muping	333	10	2	1000
Haiyang	333	18	2	1000
Jimo	133	16	7	10000
Laoshan	1200	300	20	60000
Jiaozhou City	1200	200	20	60000
Jiaonan City	333	19	10	4000
Huangdao	133	6	2	1000
Pingdu	400	40	5	15000
Changyi	5067	1530	40	35000
Hantin	2200	288	16	15000
Shouguang	4667	558	51	40000
Guangrao	867	230	11	5000
Sum	45000	7103	404	445000

* : Tilling is the area of cultivated land damaged by sea water intrusion; well is the number of irrigation wells scrapped by sea water intrusion; village and population are the number of villages and population suffering from sea water intrusion disaster.

After the coastal area was intruded by sea water, content of Cl^- in underground water was very high. In the coastal area of Laizhou Bay, content of Cl^- in underground water was 80—100 mg/L before the sea water intrusion, the highest content was about 150 mg/L. One year after sea water intrusion, the content of Cl^- increased to about 450 mg/L, and about 5520 mg/L five years later, the highest content was about 10000 mg/L. In Qinhuangdao City, the type of hydrochemistry was HCO_3—Ca. Na before 1960. Content of Cl^- was 130—170 mg/L. Sea water intrusion began in early 1970s in the city. Hydrochemical type in the city became HCO_3. Cl—Ca. Na since 1986, content of Cl^- increased to 500 mg/L. In other places of sea water intrusion, content of Cl^- in underground water was also very high.

Content of Cl^- in underground water decreases with distance increases away from the sea side. Results of Laizhou hydrographic observatory shows that the content is about 1000 mg/L in the coastal plains 1600m away from the sea side in 1989, and about 100 mg/L 1660—2100m away.

Sea water intrusion has caused a decrease in productive capacity of land. The main reason is that soluble salt in underground water of high salinity can move into tillage layer along capillary vessel of soil and concentration on the layer. When the salt in soils accumulates to some extent, soil structure will be destroyed, physicochemical properties of soil changed and fertility decreased.

There are about 46700 hectares of cultivated land which have been affected by sea water intrusion in coastal areas of Shandong Province, in which there are about 33000 ha land that have been salinized because of irrigated underground water of high salinity. There are 3300 ha cultivated land that have become wasteland. In the whole area, grain yield goes down 20% in normal years, 40% in drought years and down to zero in very heavy drought years. Grain yield drops 200—300 million kg/a in this area, total drop is about 3—4.5 million tons in the last 14 years. The heaviest area of salinization is Laizhou City and the neighboring counties. About 80 percent of the coastal plain of Laizhou City has been salinized, and grain yield abates about 75 million kg/a. There has been some 3000 ha cultivated land affected severely by sea water intrusion in Shouguang County, in which 2000 ha has become salinized soil. Grain yield abates about 25 million kg/a. There are many disasters of cereal crops caused by sea water intrusion.

Sea water intrusion has affected not only agriculture in the coastal area of Yellow Sea and Bohai Sea, but also affected industrial production in the area. In Laizhou City, because of high content of Cl^- in water, paper quality of paper mill is low, chemical plant has to change water pipe every 3—5 years. There are 79 factories in Laizhou City, in which there are about 20 factories suffering a loss of about 150 million Yuan/a each factory. Three gold mines in northern Laizhou and three salterns of Shouguang County that is next to Laizhou City have been heavily affected by inadequate fresh water. According to statistic data, coastal areas of Shandong Province lose income about 200—300 million Yuan each year because of sea water intrusion, and accumulated loss amounts to 3—4.5 billion Yuan in recent 14 years.

It is known that sea water contains a large amount of soluble salts. The main salts are NaCl, $MgCl_2$, $MgSO_4$, K_2SO_4, $CaSO_4$ and so on. Salts can deposit in soils because of sea water intru-

sion, but concentration and kinds of salts in soils change with the distance from the sea side. Concentration of salts in soils is decreased little by little from sea side to inland, solubility of salts is on the contrary. Therefore, degree of soil salinization and kinds of salts in soils appear as belt zones, and change of landscape ecology also appear as regional belt zones. Generally, the zone nearest the sea side is salt marsh. It is about 3. 5m high above sea level (Zhao, 1991). The depth of the underground water is about 1. 0—1. 5m. In the zone, content of salt in soils is about 2% or more. The rate is often higher than 90% for Cl^- to total content of salt in soils and underground water, equal to 80% or more for the amount of potassium and sodium to total soluble cations and more than 4% for Cl^- to SO_4^{2-}. Therefore, the area is a barren land under natural conditions (Table 5).

The second zone from sea side is about 3. 5—6. 5m above sea level. The buried depth of the underground water is 0. 5—3. 0m. Content of salt in soils is more than 1%. The main anion is Cl^-. The rate is about 80% for Cl^- to total amount of salts, about 70% for potassium and sodium to total soluble cations. Content of salts changes for different seasons. Salts are generally concentrated in soils in dry season and washed out in rainy season. In the zone, the land is often covered by some salt-tolerant plants, such as *suaeda salsa*, *Aeluropus littoralis*, *Artemisia* and *Limonium*, and by other anti-salt plants.

Table 5 Relationship between landscape and eco-environment

Plant community	Status of eco-environment		Distance
	salt content, %*	situation	
Barren land	≥2. 0	bad	near
Suaeda salsa, *Nitraria schoberi* and *Temarix chinensis*	-1. 5		
Aeluropus littoralis, *Artemisia anethifoclia* and *Statice bicolor*	-1. 0		
Aeluropus littoralis, *Imperata cylinderica* and/or *Phragmites communis*	0. 3—0. 6		
Phragmites communis and *Imperata cylinderica* or *Imperata cylinaderica* and *Phragmites communis* and Plantation	<0. 3		
Crops	<0. 2	good	far

* : salt content is content of salt in soils

The third zone is the district of the desalinized salty alluvial soil. The height above sea level is about 6. 5—7. 5m. The depth of the underground water is about 3—4m. The distribution of salts in soils is the type of inverted "T". General content of salt in soil layer of root system is less than 0. 3%. The main type of the component of salts is sulfate-chloride or chloride-sulfate. The zone is a transitional area where the soil may be brought under cultivation and improvable. The main surface landscape plant is mixed *Phragmites communis*, *Imperata cylinderica* and planted plants.

The outside zone of sea water intrusion is the district of crop community. The district is higher, 7. 5m above sea level. The buried depth of the underground water is more than 4m. Content of salts in soil is lower than 0. 2%. The hydrochemical type is HCO_3-Mg. Ca. Na, or

HCO_3. SO_4- Mg. Ca. Na and/or HCO_3. Cl. SO_4- Na. Mg. Ca. The surface landscape is the crop district where main crop is dry but part of crop is both dry and water ones.

Sea water intrusion not only causes soil salinization and plant community evolution but also menaces man's and animal's living. Sea water intrusion causes inadequate drinking water for people and animals and water quality deterioration. Men and animals drink the deteriorated water for a long time, many diseases will be brought about. In the coastal area of Yellow Sea and Bohai Sea, there are about 404 villages in which drinking water is heavily inadequate at present, about 0. 45 million people who drink low quality water for a long time so that they have suffered from different endemic diseases. The main diseases are thyroid, dental fluorosis, skeletal fluorosis, brucella, distomatosis and chronically endemic fluorosis, and main district of the diseases coming on are Changyi, Shouguang, Hantin and others, about 7 counties. In recent years, the number of people suffering from chronically endemic fluorosis is greatly increasing in Changyi, Shouguang and Hantin. It increases from 0. 2 million to 0. 4 million in Shouguang County , and from 3076 to 15000 in Laizhou City. It is shown that sea water intrusion can bring many disasters to whole ecosystem and that sea water intrusion can not only cause terrestrial ecology degeneration, with people suffering from different kinds of diseases, but also damage industrial and agricultural production.

4 Proposals for the prevention and control of sea water intrusion

Some of the proposals to be suggested are based on the situation of the sea water intrusion in the coastal area of Yellow Sea and Bohai Sea, on the sea water intrusion is principally caused by natural and anthropogenic factors, and on ecological principles. The proposals are as follows:

4. 1 Overall planning and treatment

On the basis of the distribution of the different zones mentioned above, the zones are treated respectively from inland to sea side.

On salt marsh of littoral zone, mixed coniferous and scrubby forest should be planted to decrease sea wave and/or stormy tide damage to ports, salt pan and breeding run, to prevent damage to building and to decrease coast erosion. At the same time, environmental pollution must be controlled, grass - covered area must be formed. In this area, halohytic plants, such as *Suaeda salsa* and *Tamarix chinensis*, must be planted, and salt - tolerant plants should be planted. In addition, salt - tolerant forage grass - "Lumu one" should be spreaded, and livestock farming should be developed at the same time. Sea water breeding, such as prawn and shellfish breeding, and saltworks can be developed.

Different functional forest should be developed in the district of salinized Chao soil, it can be used for windbreak, sandbreak and conservation of water supply. Additionally, economic wood such as timber and fuelwood should be included in the forests. At the same time, natural mixed community of *Aeluropus littoralis*, *Artemisia anethifoclia* and *Statice bicolor* has to be protected and developed. The forest can improve eco - environment of district.

In the district, reasonable saltworks and chemical industry taking salt as raw material can be developed. Grass land should be enlarged and herbivorous animals should be bred to supply com-

mercial nonstaple. Another method to treat salinization may be to wash out salts from soils with fresh water, that is rain, by artificial collection and full utilization, and is diverted from other water resources outside of those in the district.

Fruit tree should be developed in the area of desalinized Chao soil, in addition to developing functional forest just like that in the area of salinized Chao soil. The area of rice plantation should be increased to decrease salinized soil area. The communities of *Phragmites communis* and *Imperaata cylinderica* are developed and protected to decrease salinization, evaporation capacity and increase organic matters in soil. Salt-tolerant plants should be developed, including salt-tolerant green manure, such as *Sesbania cannabina*, *Meliotus suaveolwna* and *Medicago sativa*, and salt-tolerant crop, such as *Echinochloa crusgallic*, *Sorghum vulgare*, *Helianthus annuus*, and *Gossypium herbaceum* and *Cimicifuga foetida*. Intercropping woods, grain and fruit is good for development in the area.

Various functional forests have to be planted in the area of cultivated land. At the same time, irrigation pipeline system should be mapped out and laid, and some techniques for economizing the use of water have to be carried out, such as transmission water under low pressure, furrow irrigation and drip irrigation, and quota irrigation are necessary measures, so that water resource can be fully utilized. In addition, drought-enduring and salt-tolerant crops should be bred or introduced, and a kind of high and stable yield planting model should be spread.

4.2 Developing ecological agriculture of retentive water

It is very important for frail eco-environment of interface of sea and land to find and develop a kind of ecological agriculture of retentive water on the basis of the negative relationship between sea water intrusion and fresh water resource in coastal area.

According to the present conditions in the coastal area of Yellow Sea and Bohai Sea, crops adapted to saline water, semi-saline water, micro-saline water and fresh water should be introduced and developed respectively, so that salt in salinization soils can be decreased, and organic matter in soil increased. The relationship among living beings is arranged and coordinated by applying ecological principles and systems engineering method. The plan for forest, cultivated land and road is reasonably arranged systematic. It is possible to achieve the goal in completing the plan, and the plan should be completed by stages. It is the most important thing that environmental protection must be carried out at the same time. The network of systematic monitoring should be founded to monitor dynamic environment changes so that measures can be adjusted in time.

4.3 Diverting water from outside water resource

Yellow River, Haihe River, Luan River and Liao River are not far from the coast of Yellow Sea and Bohai Sea, and their water capacity is more than adequate. Part of water can be diverted from these rivers to the coastal area. Water may be diverted from Yangtze River under the permissive condition of NE (national economy).

4.4 Construction of underground cut-off wall

When ground water table decreases or sea level rises, sea water goes into land through various pores and extends towards inland. Underground cut-off wall may be built, on the basis of

investigation of coastal stratum and lithological characters, to block various passageways that sea water seeps into inland. The material used for building the wall may be cement or clay. The buried depth of the wall and its thickness should be based on the requirement that intrusion of sea water may be prevented. The function of the wall is to form an underground fresh reservoir so that sea water intrusion may be controlled. But considerable sum of money is to be paid for building the wall.

4.5 Building water conservant facilities

In the coastal area of Yellow Sea and Bohai Sea, 70% of precipitation is concentrated in the rainy season of which two thirds precipitation is concentrated within 20 days, and it is rainstorm. About 60%—70% rain water of rainstorm flows into sea in the form of surface water. Therefore, there is only 20%—30% rain water utilized. Building different kinds of water conservant facilities, such as seepage well, seepage canal and sewer, may keep rain water longer time on land so that more rain water can seep into underground to replenish underground fresh water. Moreover, floodgate and dam should be built along rivers and low-lying land to decrease flowing velocity and discharge of floodwater into sea.

4.6 Building tideproof groyne

Storm tide is one of common natural disasters. Storm tide not only destroys sea water breeding and saltworks, but also causes sea water intrusion near sea side as well. The heaviest sea water intrusion caused by storm tide can extend several tens of km towards inland. Tideproof groyne may control and decrease storm tide damage.

Two other measures are available for controlling sea water intrusion. One is to pump salt water and inject fresh water at the same time near the interface of salt water and fresh water under ground. The other is artificial rainfall.

5 Conclusion

Sea water intrusion has appeared in the coastal area of Yellow Sea and Bohai Sea since 1970s. At present, the heaviest areas are in Laizhou City and its neighborhood. The velocity of sea water intrusion towards inland was 46 m/a at the end of 1970s, but it was about 404 m/a at the end of 1980s, an increase about 8 times in 10 years. There are several factors causing sea water intrusion. The main factor is excessive mining of underground water, in addition to precipitation decrease caused by climate change.

According to geographic position and geological condition of sea water intrusion occurring, 8 measures for controlling sea water intrusion are suggested. The main measures are ecological agriculture, diverting water and building water conservant facilities.

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