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Engineering Geology for Society and Territory – Volume 5

Urban Geology, Sustainable Planning and Landscape Exploitation

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Part X Experiences and Potentialities of Data-Driven Modeling in Earth Science Issues

Part XI Geohazard in Urban Scenarios: Forcasting and Protective Monitoring

Discussion on Geological Hazards Caused by Exploitation of Deep Groundwater in North China

130

Xiuyan Wang and Lin Sun

Abstract

The depression cone and its extent expansion formed by over-exploitation of deep groundwater were the main causes inducing a series of geological disasters such as land subsidence, ground fissures, seawater intrusion etc. in many large and medium-sized cities. The land subsidence and related disasters caused by groundwater over-exploitation are a kind of geological hazard that the people face globally and that mark one of serious geo-environmental disasters in China. Basis on the overview of ground subsidence, earth fissures and related geological disasters in North China, the paper analyzed the regional distribution and characteristics of these geological disasters, discussed the relation between ground water exploitation and some causes of geological environment hazard's formation, such as land subsidence, ground fissure. The conclusion is the cone caused by overexploitation is the main induction of the land subsidence and related geological environment problems, that earth fissure is the result of geological tectonic activities belongs to different periods, prevention and control the ground subsidence and other disasters, we must first try to restore underground water level.

Keywords

Deep ground water • Groundwater depression cone • Earth fissure • Land subsidence • Geological environment hazard

130.1 Introduction

The depression cone and its extent expansion formed by over-exploitation of deep groundwater were the main causes inducing a series of geological disasters such as land subsidence, ground fissures, seawater intrusion etc. in many large and medium-sized cities. The land subsidence and related disasters caused by groundwater over-exploitation are a kind of geological hazard that the people face globally and that mark one of serious geo-environmental disasters (Miyabe 1970; Holzer and Pampeyan 1981; Adrian et al. 1999; Li et al. 2000; Yun et al. 2008; Chen et al. 2011). The northern cities usually take deep groundwater as a unique water resource for water supply in China, due to the abundance of deep groundwater quantities and its excellence uneasy to be contaminated, especially those in the arid and semi-arid areas where the surface water is scarce. What problems may occur as deep groundwater is exploited? The regional groundwater union funnels have formed and land subsidence and related disasters has been induced. The negative effects have taken place by exploiting deep groundwater in North China with the rapid development of industry and agriculture in the latest 30 years. These geological disasters cause substantial damage, including the loss of ground surface altitude, cracking of buildings, farmland water leakage, etc. This damage results has not only disturbed people's life but also brought huge economic losses.

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The North China belongs to the temperature zone with semi-arid and sub-humid climate, the surface freshwater is seriously lacking. In addition, as the shallow groundwater may be salt water, bitter water or have bad water quality etc., the deep groundwater becomes the only water source for agricultural production, life and economic development. And the average groundwater exploitation for many years exceeds the average groundwater recharge for many years that is over-exploitation of groundwater. The burial depth of the bedrock ranges from 624 to 1,700 m in North China plain, and can be divided into four aquifer groups from the top to the bottom: the burial depth of the first aquifer group bottom limit is 40–60 m; the burial depth of the second aquifer group bottom limit is 120–170 m, the burial depth of the third aquifer group bottom limit is 250–350 m, and the burial depth of the fourth aquifer group bottom limit is 350–550 m. As the first and second aquifer groups are the shallow aquifer system, which are the main groundwater exploitation layers for agricultural water in this area with bad water quality or limited water quantity. The third and fourth layer of confined water is extracted in most areas.

130.2 Geological Environment Hazard

130.2.1 Depression Cone of Deep Groundwater

Exploitation rate goes much faster than the recharge to deep groundwater due to its slow recharge nature (Zhang and Wang 2002). Therefore, the depression cones have been formed and enlarging in the industrial and agricultural developing areas where the urbanization and economy is rapidly increasing. In the North China plain overexploitation of groundwater for years has led the local cone areas of Hebei, Tianjin and Dezhou in Shandong to become one big depression cone. The area of depression cone had been up to

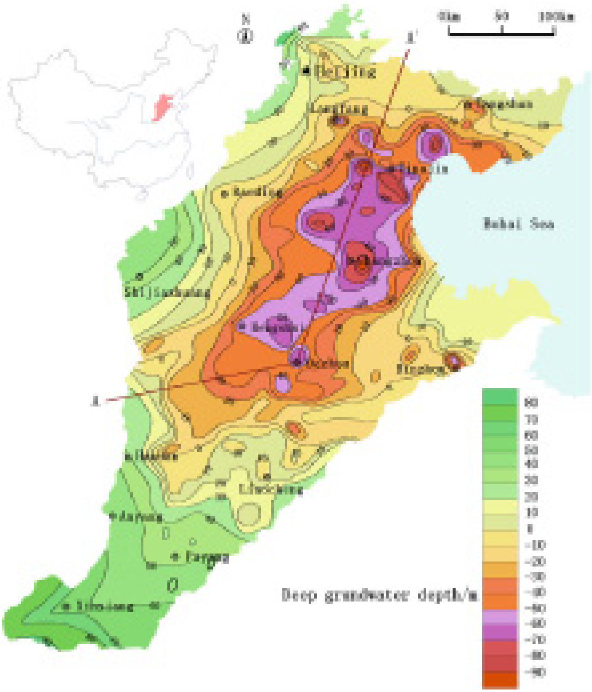

Fig. 130.1 Contours of ground water level in North China Plain, 2000

43,915 km^2 by 2002. The center of the cone went down 1.5–2.3 m yearly from 1980 to 2000 (Wang et al. 2013).

Up to 1980, the depression funnel of groundwater area have been formed a certain scale, and gradually expanded. Up to 2000, the groundwater funnel area have been even synthetic one, forming a combined depression large funnel, from north to south, the funnel included Tianjin-hangu Tianjin, Hejian-Suning, Changzhou, Hengshui, Dezhou, For details is showed in Figs. 130.1 and 130.2 (Zhang and Wei 2005; Zhang et al. 2009).

130.2.2 Land Subsidence

Based on statistics in 2010 (Liu et al. 2001; Ma et al. 2006; Shi et al. 2007; Zhao et al. 2009; Yi et al. 2011), 17 provinces have been hit by subsidence, 112 cities have been hit by subsidence. The North-China Plain area has the largest number of cities that are hit by subsidence, accounting for 47 % of the total (Wang et al. 2013), the center of land subsidence has been found in large and medium-size cities, the land subsidence situation in North China can be seen in Fig. 130.3, from north to south, the center of land subsidence include Tianjin, Changzhou, Hengshui, Dezhou.

130.2.3 Earth Fissures

Many earth fissures have been observed in North-China Plain since 1963, and it is in the growing. Seven earth fissures occurred near to the big 'funneled depression' associated with groundwater withdrawal in the Hengshui area during the period of 1998–2007 (Hengshui area is located in the central part of North China), the distribution of ground fissures is showed in Fig. 130.4, Three of the f earth fissures were investigated by means of field survey and geophysical prospecting including shallow seismic refraction method and high density resistivity prospecting method.

The characteristics of these earth fissures can be seen in Table 130.1.

130.3 Analysis Discussions

130.3.1 Depression Cone of Deep Groundwater and Land Subsidence

Under the over-exploitation of deep groundwater and level depression conditions, the deep, thick unconsolidated formation of North China provides a material basis for the land

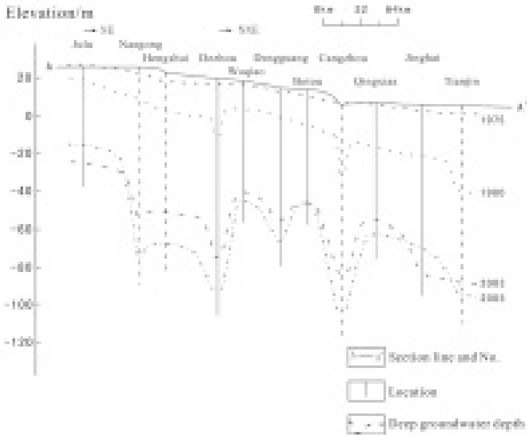

Fig. 130.2 The deep groundwater cone development in North China Plain

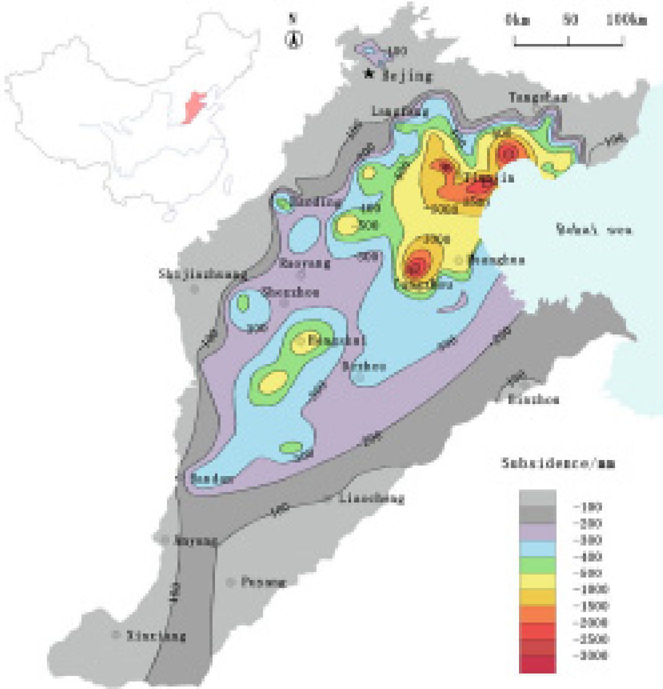

Fig. 130.2 Contours of land subsidence in North China Plain, 2002

subsidence. More serious subsidence cities: Tianjin, Cangzhou, Hengshui and so on, deep buried rock, the thickness of soil layer are more than the 400 m witch effected by exploiation groundwater .

Owing to long-term groundwater overexploitation, groundwater level continuously declines and imposes additional stress on soil mass, leading to the deformation of soil layers.. The range of ground subsidence is consistent with the scope of groundwater funnel that can be seen in Figs. 130.1 and 130.3.

130.3.2 Development of Earth Fissures Due to the Withdrawal of Deep Groundwater

It was subjected to frequent earthquakes in the past, North China plain. The core-drilling results indicate that the fissure planes occur in deep soils, especially in the hard cohesive soil, buried fissures or fissure planes formed by tectonic stresses activity in soils, that is, a lot of fracture exist in the deep hard soil (Xiuyan et al. 2006).

Data on the groundwater level variations in the funneled depression and areas where earth fissures occur in the Hengshui area during 1970–2005 show that shallow groundwater level has varied little in the range of 4.8–25.4 m, on average 11 m, whereas the deep groundwater level has varied significantly in the range of 24.33–71.37 m, on average 77.6 m. The correlative curve of groundwater level variations in different areas with the depths of earth fissures is shown in Fig. 130.5 (Xiuyan et al. 2006). When we follow-up investigation the Zhangjiazhuang earth fissure in 2010, the investigation shows that no sign of land fissure development can be seen on the surface, due to the groundwater level recovery.

Of course, due to the formation and development of the funnel of groundwater exploitation, in addition to the ground subsidence, ground fissure disasters, there are other related disasters, such as karst collapses in Tangshan, seawater intrusion in coastal areas and so on.

Fig. 130.4 Schematic diagram of earth fissures in the Hengshui area

Table 130.1 Characteristics of earth fissures in the Hengshui area

Location	Occurrence time	Latitude and longitude	Damages and loses	Geophysical prospecting and survey
Zhangjiazhuang Village in Shenzhou	2003.9	N37° 54′57.6″-N37° 54′59″ E115°40′ 31.8″- E115°40′ 38.3″ trending N12°E	Cracking in farmland, leaking during irrigation	The fissure trends N 12° E and dips southwards at an angle of 85°–88°, width: 20–40 cm, width of crack zone: 10 m, Extend: 500 m, depth: 60 m
Hanguan village —Fucheng County	1998.3–2000.8	N37°50′20.7″-N37° 50′11.2″, E116° 06′20.4″-E116° 05′54.2″ trending N22°E	Cracking and leaking in farmland; the walls and classrooms were cracked through the Hanguancun Primary School, the direct economic losses is over 200,000 RMB	The fissure axis dips southwards at an angle of 75°, width: 30–80 cm, width of crack zone: 18 m, Extend: 4000 m, depth: 120 m
Nanqinglin village in Wuyi County	1999.3	N37°49′33.9″, E116° 04′22.7″, trending N62°E	Farmland cracking, irrigation leaking, cracking in the house walls, no direct economic losses	The fissure trends N62°E. Its axis dips westwards at an angle of 75°. width: 10–80 cm, Extend:4000 m, depth: 96 m
Shuipocun	2002	N37°05′54.3″, N37° 05′58.9″ E115° 50′54.4″-E115° 50′55.9″, trending N66°E	The walls and floors of the school classrooms were cracked, no pupil was hurt, and the school was moved. Direct economic loss is 200,000 RMB	The fissure axis dips westwards at an angle of 75° width: 5–15 cm, width of crack zone: 34 m, Extend: 300 m, depth: 72 m

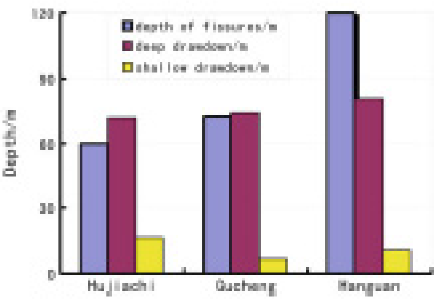

Fig. 130.5 Curves between earth fissure depth with groundwater drawdown (The location of the crack can be found in Fig. 130.4)

130.4 Conclusion

(1) The range of ground subsidence is consistent with the scope of groundwater funnel. The compressible soil provided the material conditions for land subsidence.

(2) The earth fissures in the Hengshui area extend along with geological structures, which are responsible for producing the hidden fissures. Buried Fissures or Fissure planes Formed by Tectonic Stresses in soils.

(3) It is a good correlation between the depth of ground fissures with the drawdown of deep groundwater in the Hengshui. Development of earth fissures due to the withdrawal of deep groundwater.

(4) The cone caused by overexploitation is the main induction of the land subsidence and related geological environment problems. Prevention and control of ground subsidence and other disasters, we must first try to restore underground water level.

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