Research on construction for the clarification of groundwater reserve based on underground structure visualization and a practical discharge well model
-on Proper investigation and management of groundwater as environmental resources -

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Summary

Chapter 1   Aim and background of study

In regional groundwater basins nationwide, the groundwater level is recovered by groundwater extraction regulation and the land subsidence tends to decrease in recent years. But, the water in deep well is often used as the water for a life or the water for agriculture and industry at present and also, there is the situation that the land subsidence has occurred with the groundwater use for melting snow in the heavy snowfall area and the rapid increase of the groundwater use in the dry season. Considering them, the re-maintenance about the groundwater management for preserving a sound water cycle is essential with the rationalization of the groundwater use and the change of the needs in the future. Moreover, from point of water environmental preservation, groundwater contamination prevention is also important for regional groundwater management. To that end, not only extraction regulation, but also the simulation of the groundwater flow with pumping water or under a nature flow and grasp of cultivation function is needed. Therefore, the aim of groundwater preservation is maintenance of the groundwater level in overall area, water quality preservation and prevention of land subsidence, etc. For the purpose, it is necessary to note how much proper pump discharge is. The proper pump discharge means generally the pump discharge which is the maximum quantity(critical discharge) of the groundwater pumped from well in laminar flow area, which the groundwater flows serenely multiplied by the safety ratio. Moreover, the value of that is reduced according to regulation of ordinance in an area and it is supposed that the value is just the proper pump discharge in the area. Discharge quantity exceeded critical discharge is   made it deteriorate well structures from to disturb aquifers and to close a gap around well.

Different from this damage,   this discharge quantity is caused land subsidence by the water level is lowered in regional groundwater basins. This is the cause of the land subsidence nationwide in recent years.

The cause of the damage caused by pumping is that is not led correctly. critical discharge which becomes the foundation ,and formal well theory and foundation composition model are not fulfilled conditions of the natural foundation. It is an author's judgment that the analysis technique is not established practical proper pump discharge. Therefore, in this study, first of all, based on investigation means to elucidate structures of some underground basins and state of groundwater reserve and instances utilized it, the hydraulic theory which should be utilized on groundwater and well and problem points is shown. And the aims of study are proposing and constructing pumping model on regional groundwater environmental preservation and well loss formula and contributing to groundwater management for preservation of sound water cycle. Moreover, because form of groundwater flow is various that is wide area, middle and partial region, the simulation model which has high practicality is needed to grasp state of groundwater around pumping water. To that end, before everything, the fundamental model is constructed and practicality of the model concerned is estimated.

Chapter 2   Methods of study

In the first half of chapter 2, on wells in deep layer which are influenced by ground-water flow based on well theory about groundwater, the practical and significant items and the problem points found with theoretical development of equilibrium theory, in which laminar flow is realized and non-equilibrium theory are shown. As both of these theories have simple monolayer model, it is difficult to apply for construction of the practical model corresponding to the various geological construction which shape actual underground structure. Therefore, in the latter half, the characteristic and precision limit of means to investigate various geological underground structure more accurately is clarified and vertical electric prospecting methods, electromagnetic prospecting methods and so on as underground structure visualization technology, the boring survey which extracts the actual geology sample and the pumping test to know the amount of groundwater are described. It is thought that those give the ideal groundwater investigation means which can grasp structure of various regional groundwater basins and quantity of groundwater reserve.

Chapter 3   Groundwater   reserve of typical basin structure

In chapter 3, Underground structure and groundwater reserve of typical small basin in Shiga Prefecture Kohoku as regional groundwater basin is elucidated with the vertical

electric prospecting methods, the boring survey and the pumping test which are shown in chapter 2. In this region, author inquired previous geology data beforehand. This result is judged worthy vertical electric prospecting methods, that is possible which investigated 100m inside of the foundation.

And the value of electrical resistivity （result of investigation means to elucidate structures of some underground basins） as measured physical constants in geology constructed underground structure, or Mesozoic sedimentary rocks, igneous rocks and the stratum in Pleistocene and Holocene era is found out because of underground structure visualization and regional geological construction is shown by the value and the boring survey. Moreover, hydraulic constant in aquifer is grasped by the boring survey and the pumping test. Furthermore, on the potential of groundwater and the groundwater cultivation which are necessary to groundwater flow model, relation between pumping water and water cycle system is elucidated by grasping influence of precipitation, evapotranspiration and water requirement in depth.

Chapter 4　　Groundwater reserve of typical small basin in granite belt

In chapter 4, underground structure and groundwater reserve under the plateau in the center of Hyogo Prefecture Awaji island,　 which represents small basins in granite belt are elucidated by electromagnetic prospecting methods shown in chapter 2. The under-lying data on groundwater management and regional environment preservation related the deep well which has water for agriculture is arranged. In this region, Osaka group beds had sediment relatively, namely it was inserted to between east and west granite belt went up by author's exploration. On account of this base ups and downs, author adopted electromagnetic prospecting methods that official announcement example of underground water survey is almost no it. Electromagnetic prospecting methods used in this region provided forms of groundwater basins, fault and lineament. This is a most groundwater-head development point that is concave portion in basement rock and adjoined fault or flexure. And author checked abundant groundwater reserve. Moreover, the data is analyzed with the register of the existing well and the regional property that source of pumping water in compartmentalized small basin is subject to geology and topography is found. In the in-situ test of source of pumping water, configuration of groundwater basin, site of dislocation and lineament and geohistorical tectonic activity is discussed, and as a result, increase and decrease of amount of the groundwater reserve is elucidated. Furthermore, on the potential of groundwater and the groundwater cultivation, the relation between pumping water and water cycle system is elucidated by grasping influence of precipitation, evapotranspiration and

water requirement in depth with the similar way in chapter 3.

Chapter 5　Proposal of the pumping water model and the well loss formula on regional groundwater environmental preservation

The well formula is represented as fully penetrating well model whether steady theory or non-steady theory is used. But, according to national well database, a lot of deep well are non-fully penetrating well with multilayered screen based on the geological construction of aquifer. It is based on thought that it is possible to obtain abundant pump discharge from various aquifers because of drilling of wells and the depth in which it is possible to obtain target pump discharge is enough as depth of drilling of wells in consideration of the cost of construction. Only the well formula in laminar flow was shown and the concrete index of hydraulic constants effective in groundwater management was not shown in the many papers and reports of overseas or domestic in early the 20th century. Because, primarily, it is necessary to represent change of groundwater state and anisotropy of permeability coefficient, but it is very difficult to measure their values with high accuracy. Therefore, in this chapter, from average permeability coefficient and depth of well hole, new water pumping model to which use of calibrating coefficient as permeability coefficient is basic is constructed. As a result, practical and reasonable analytical methods are found. As theoretical analysis of monolayer model was not suited to actuality and thickness of aquifer was semi-infinite and was not definite actually according to many instances of researchers on groundwater relation and others, the monolayer model which is not suited to actuality is improved practical bilayer model. Non-linear laminar flow formula which is able to distinguish the laminar flow area from the turbulent flow area in non-equilibrium theory representative until now is invented according to equilibrium theory, which can reflect on element of well structure and regional peculiar hydraulic characteristic value. The safety desired pump discharge which doesn't cause excessive pumping water in any deep wells in regional groundwater basin is able to be drawn by using this formula. In short, it is elucidated that this pumping water model and well loss formula are practical and are able to contribute to establishment of long-term use of deep well and regional groundwater preservation.

Chapter 6　Hydraulic preservation according to regional groundwater flow simulation and how to carry out pumping test in the future

In the area which needs water environmental preservation and development of new water source, it is desired that the aquifer model in which monitoring and simulation is

possible is created. Because of this, it is necessary to prevent mutual interference of existing well and new constructed well, the permanent fall of water level, incline of stratum and deterioration of well capacity and take into enough consideration of proper pump discharge management which doesn't spoil regional water environment. Therefore, in this chapter, the various factors which are applicable to regional groundwater basin about aquifer to be fundamental model are arranged. And groundwater simulation by finite element method is performed to fundamental model to grasp water environmental condition from operation condition of well. This simulation is thought to be effective in estimating influence on existence of groundwater problems, such as drying up of well and land subsidence, project of new well construction and the excavation from water head change, groundwater flow and so on. The monitoring system of regional ground water must be constructed based on high accuracy of boundary condition in the future.

Chapter 7   Conclusions

The technique which is able to apply to any pumping test is not established at present. Primarily, it is thought that pumping test doesn't have equilibrium state not only in groundwater flow caused by pumping water, but also in natural groundwater flow and has non-equilibrium state and the stratum which is definite to semi-infinite. At that time, it is necessary to judge whether the groundwater of pumping test is in laminar flow area or in turbulent flow area and decide marginal pump discharge. Especially, improvement of the technique about stepping pumping test is required. The improvement methods of that are verification of the fall speed of water level around the end of step of pumping, finding marginal pump discharge with derivative of the formula representing specific capacity by non-linear curve of well loss proposed in this paper and estimate and grasp of speed change of groundwater flow according to pump discharge. In this paper, pumping water model, well loss formula and so on are proposed on fundamental investigation and management of groundwater as fundamental guideline of this difficult judgment from positive point of view mainly. It is thought that the fruits of them contribute to investigation and proper management of groundwater as environmental resource.