A New Probe into the Evaluation indicator for the Suitability of Recharge Engineering

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Abstract. Recharge measures can effectively eliminate the potential environmental risks caused by the loss of groundwater. It is a commonly used groundwater control measure and is widely implemented nationwide. However, at present, there is no clear judgment method for whether certain projects are feasible to recharge. This article classifies and summarizes the evaluation indicators in terms of the necessity, feasibility and economy of recharging, and provides a basis for the decision of recharging projects.

1. Introduction
Due to the design or construction of the water-stop curtain during the excavation of the foundation pit, the dewatering in the foundation pit may cause the drop of groundwater level especially the confined water level around the foundation pit, which may cause the subsidence of the surrounding soils. There are certain environmental risks, threatening property and safety greatly.

At present, the integrated method of pumping and recharge, has been implemented in many projects across the country and has achieved good results. This method uses recharging water to control the surrounding water level of the foundation pit and to avoid the adverse impact of deep foundation pit dewatering on the surrounding environment. However, there is no systematic analysis and research about the application condition. There is no authoritative recharge suitability standard to respond to this question and is lack of quantifiable discrimination methods. It is more likely determined based on experience. Whether recharge engineering is carried out often depends on the subjective judgment of experts or construction units. The entire decision-making process is not clear and transparent, and the suitability evaluation of recharge in one pit cannot be directly transplanted to other foundation pits.

Therefore, it is necessary to mathematicalize and systematize the decision-making process, select the indicators for evaluating the suitability of reinjection, and turn the decision-making problems with multiple objectives and multiple criteria that are difficult to quantify into multi-level single-objective problems. After the quantity relationship of the level elements relative to the elements of the previous level, calculation, comparison and screening are performed to obtain a decision.

At present, there are few studies on the evaluation of recharge suitability, so there is neither unified naming nor clear classification of the evaluation indicators of recharge suitability. What’s more, these influencing factors of recharge suitability are related to each other, which adds the difficulty for classification.
2. Existing evaluation indicators
Du Xinjiang studied the recharge of underground water quality control indicators and make recommendations related standards, think recharge water quality must be better than categories IV of drinking water indicators.

Wang Guofu selected the recharge water quality, the distance of the building from the foundation pit, the risk loss level, the permeability of the aquifer, and the ratio of the total pumping quantity of the foundation pit to the water storage of the aquifer as the evaluation indicators. According to the different aquifer permeability and the need for recharge, the geological condition suitability classification evaluation matrix is established; according to the different risk loss levels and the recharge protection building necessity, the building protection rating evaluation matrix is established. In short, the evaluation indicators are divided into three categories: the suitability of geological conditions, the quality of recharge water and the suitability of building protection.

Wang Guofu discussed the impact of the recharge scheme on the hydrogeological conditions of the recharge site, the quality of the recharge water source, and the economic and social benefits of the recharge scheme during the evaluation of the suitability for the dewatering and recharge of the foundation pit of the Jinan rail transit line R1. He believes that the main factors affecting the hydrogeological conditions of the recharge site are groundwater pressure, the permeability of aquifer, aquifer thickness, compressive modulus of aquifer. Underground recharge water quality control targets include mainly turbidity, acidity (pH), microbial indicators (such as the BOD), heavy metal content. The economic and social evaluation indicators of recharge can be summarized as: the cost of implementing recharge, the protection of surrounding buildings, and the balance of water resources.

In the existing recharge suitability evaluation system, each suitability factors recharge is not fully independent, for instance, hydro-geological indicators and recharge water quality indicators will affect the recharge costs.

Therefore, a new type of recharge suitability evaluation system is needed. In this system, the recharge suitability evaluation indicators are grouped into three categories: necessity, feasibility, and economy. Necessity means whether a recharge measurement is needed, feasibility means whether recharge is possible in existing technical conditions; economy means whether recharge is high cost.

3. Necessity indicators for recharge
The necessary indicators mainly focus on the economic risk loss and environmental damage that may be caused if the water level outside the pit is out of control without recharge, including the amount of ground subsidence, the differential subsidence, the allowable values of subsidence and differential subsidence of the building (structure), and loss of groundwater resources. The allowable value of subsidence and differential subsidence of the structure is related to the severity and probability of risk loss. For example, there are ancient protected buildings or subways and tunnels that need to be protected in the surroundings of pit. Once the danger caused by dewatering occurs, the consequences are more serious and there is an irreversible loss. In this case, the recharge is very necessary. If the construction technology of the ground wall can be guaranteed, and the hydraulic connection between the inside and outside of the pit can be cut off, and the water level outside the pit does not drop significantly, the necessity of recharge is weak. If the loss of stratum water resources is considered to have an adverse effect on the environment, such as salinization caused by a large amount of pumping or protection of the springs in Jinan, recharge is very necessary.

The indicators that affect the necessity of recharge include but are not limited to: the importance of the structure, the distance from the structure to the foundation pit, the drop of the water level inside and outside of the pit, the sensitivity of ground subsidence, the reliability of the construction technology of the water-stop curtain, and the requirements of water resources protection.

The importance of framing structures can be referred to the Geotechnical Engineering Investigation Code, and the framing structures are divided into three engineering importance levels:
1. First-class project, important project, with serious consequences, important industrial and civil buildings; high-rise buildings with more than 20 floors; high-rise buildings with more than 14 floors
with complex shapes; those with special requirements for foundation deformation, single column load above 4000 KN.

2. Secondary engineering, general engineering, serious consequences, general industrial and civil buildings.

3. Tertiary engineering, minor engineering, minor consequences, minor buildings.

In order to judge whether the protected building is enough far away from the pit, Construction Excavation Engineering Technical Specification is referred. Usually, buildings which are 2H (H is the excavation depth) away from the pit are barely affected; for soft soil area, the distance expands to 4H.

The drop of the water level in the pit has a direct impact on the change in the water level outside the pit. If the water level in the pit drops greatly, the hydraulic gradient inside and outside the pit will be large, which may lead to a large drop in the water level outside the pit, which will lead to the subsidence of the soil outside the pit, causing more serious social impact.

The sensitivity of ground subsidence indicator reflects the volume change after the effective stress of the stratum is reduced. The compression modulus of the sand pebble layer is 5 to 10 times that of the weak clay soil. Therefore, in the same water level drawdown, the amount of compression in sand layer is 1/5 to 1/10 that in clay layer. Under the same stratum type with the same water level drawdown, the thicker the aquifer is, the greater the corresponding aquifer subsidence occurs.

The reliability of water-stop curtain directly determines the pits strength and hydraulic connection. Once the enclosure deforms greatly or fails, the side walls will be flooded with water and sand, and the water level outside the pit will drop significantly, which will cause great environmental risks and loss.

The water resource protection requirement indicator refers to whether the loss of stratum water resources has an adverse impact on the environment, such as the massive water withdrawal causing seawater intrusion to cause land salinization or the massive water withdrawal to cause underground runoff changes, affecting the spouts of spring, etc.

![Figure 1. Necessity indicators](image)

**Figure 1. Necessity indicators**

**4. Feasibility indicators of recharge**

The feasibility indicator mainly focuses on whether the recharge can meet the requirements of water level control, subsidence and water quality. Feasibility indicators include stratum permeability, stratum water storage, stratum pressure, stratum resilience, site conditions and water quality.

The permeability of the stratum directly affects the recharge effect. When the other parameters are the same, the greater the permeability coefficient is, the more water can be recharged. That is, the greater the aquifer permeability coefficient, the greater the recharge/pumping ratio, the easier the groundwater recharge is, avoiding recharge water resting in the recharge well.
Water storage ability of targeted recharge layer also affects the feasibility of recharge implementation. The water storage coefficient and thickness of the stratum determine the capacity of water storage. If the water storage capacity of the stratum is large, the corresponding recharge volume is large, and the rechargeability is large.

The stratum pressure is the head pressure of the aquifer. Submerged recharge fills aquifer pores, and confined water recharge expands the aquifer volume, so under the same conditions, submerged water is easier to recharge than confined water. Aquifers with low head pressure are easier to recharge than aquifers with higher head pressure.

Formation resilience refers to the ratio between the vertical rebound deformation of the stratum caused by recharge and the subsidence deformation caused by precipitation at the same position after the water level rises back to the original water level. The closer the resilience of the stratum is to 1, indicating that the structure of the stratum has not undergone irreversible changes after water loss.

The site condition refers to whether there are conditions for recharging. For example, when encountering construction red lines or underground obstacles, the recharging wells cannot be arranged, or the amount is insufficient, which cannot achieve good results.

The water quality standards for the recharge of groundwater to underground aquifers have not been determined. If pumping water in one layer and recharging in another layer, it may lead to changes in groundwater quality and even pollution, affecting residents and industrial water.

![Feasibility indicators](image)

5. Economic indicators of recharge
The economic indicators mainly revolve around the cost of recharge engineering, including the cost of forming a recharge well and the operating cost of a recharge well, as well as the cost of other measures saved due to the implementation of recharge.

The cost of recharging wells is related to the depth of recharging wells, the material of recharging wells, the diameter of recharging wells and the number of recharging wells.

The operation cost of the recharge well includes electricity, water, labor, equipment, etc. required for recharge.

The cost savings of other measures such as the reduction of the depth of the ground continuous wall, the cost savings of the surrounding house reinforcement, etc.
Figure 3. Economy indicators

6. Conclusion
This article analyses the existing evaluation indicators of recharge suitability, summarizes the advantages and disadvantages of the existing evaluation indicators, and summarizes the evaluation indicators into three categories: necessity, feasibility, and economy.

Necessity indicators mainly focus on the economic risk loss and environmental damage expansion that may occur if the water level outside the control pit is not recharged. The feasible indicators mainly focus on whether recharge can reach the control water level, volume, and water quality requirements. Economy indicators focus on the costs incurred by the recharge project.

These three types of indicators are independent of each other, and the scores are evaluated within each type of indicator, and then the evaluation results of the three types of indicators are integrated to determine whether to recharge. This new type of recharge suitability evaluation system can avoid opacity in the decision-making process, and has a high degree of portability, which provides a quantifiable reference for similar engineering decisions.

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