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Effect of Well Distribution on Dewatering Design for Regular and Irregular Wells Using MATLAB Software

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Abstract— The groundwater control is one of the initial geotechnical procedures performed on the site; therefore, before beginning any excavation, it is required to study site condition and hydrological state. Using MATLAB software created a program to design a dewatering system named DDS2021 to control the groundwater level before construction .it's presented the distribution of wells for the regular and irregular areas and presented the graphical shape of the water table drawdown induced by water extraction for all wells. Dupuit's assumption is the base for representing the dewatering curve. It may be possible to achieve the required lowering for the groundwater in the proposed pit by using a few wells pumped with high flow rates or a more significant number of wells with low flow rates. Similarly, varying the well locations surrounding (or within) the excavation may result in significantly different drawdowns in the area study. This search studied the effect of the regular and irregular distribution pattern wells on the lowering of groundwater levels for both regular and irregular areas.

Keywords— regular pattern wells, irregular pattern wells, design of dewatering, dewatering by MATLAB

1. Introduction

Some cities are featured for having high groundwater levels in various places and levels. As a result, lowering the water table is essential before beginning any construction project when a dry work condition is critical for excavating the site. One of the fundamental concepts for geotechnical engineers is that the soil properties will improve due to dewatering operations; this might also impact surrounding foundations that have been in place for a long period and any building or structure nearby. Because the dewatering process will be leading immediately to building instability, or some damages might occur. Therefore, groundwater rarely becomes a problem if treated appropriately during the investigation and design phase [8]. Control of groundwater level and management is a multidisciplinary technique requiring cooperation efforts by various specialists. in geotechnical engineering, hydrology, hydrogeology, hydrochemistry, geochemistry [3]. If not adequate control of groundwater, many problems maybe occur some of these problems. Firstly a piping failure or a base heave can occur in the base of the pits because of groundwater uplift pressures under the floor of the pits .secondary hydrostatic loads can increase due to the pressure of groundwater on the pit retaining structures, for example, pile-concrete walls. thirdly the pits may flood due to groundwater inflow from layers of soil or rocks that contain water .fourthly instability or seepage erosion on the sides of the excavation because of increased pore water pressures[10]. There are three classifications to control groundwater: firstly, extracting groundwater from the excavated area through ditch pumping and secondary using wells to lower the groundwater table under the excavation's bottom, thirdly separating the excavation from the inflow of groundwater that input inside the excavation[1]. Groundwater management is one of the most difficult issues encountered on a building site. If construction dewatering is ignored during project design, it may become expensive. The scale of the project, degree of difficulty, hydrological characteristics, prevailing soils, and associated cost all influence dewatering techniques; roads, bridges, tunnels, and canals are all-important transportation facilities in today's globe. To complete these projects safely and successfully, the degree of dewatering required corresponds with the scale of construction[12]. Matlab software is used to solve many geotechnical problems, such as it used to generate thematic maps with select depths and coordinates for changing the soil's bearing capacity in Al-Basrah city[9]. Prediction- ten years of groundwater level in Karaj plain (Iran) by three optimistic, pessimistic, and continuing current scenarios were described using the MATLAB interface to predict groundwater levels in the Karaj study area until the water year 2023–2024[5] . Programming was accomplished by using Matrix Laboratory (MATLAB) code and constructing an interactive screen user interface (SICOMED 2018). to describe software Simulation of Consolidation with Vertical Drains, a method for solving consolidation processes in heterogeneous soils with fully or partially penetrating prefabricated vertical drains (PVD), taking into account both the effects of the smear zone generated when integrating the drain into the ground and the drain's discharge ability limitation[4].In some cases, it is possible to design a dewatering system, but it is not effective in achieving the lowering of groundwater level, but when changing location wells for the same site, it is possible to reach the lowering groundwater level required. The study aims to study the effect of changing the locations of wells on the lowering of groundwater levels under foundations. By Programming and build a screen to communicate with the user via interactive screens was using Matrix Laboratory (MATLAB) code.The program presents as an easy-to-use and is viewed as simple with a primary graphical user interface that facilitates input characteristics of the soil and the geometry of the problem without depending on a complicated package software that necessitates complex programming. The software applications illustrate the program's flexibility as well as the accuracy of numerical results.

2. Principle of Groundwater Flow

French engineer Henri Darcy in the nineteenth century, first described groundwater flow through porous media explained the relationship between the flow rate through a soil specimen and the head differential as shown in Figure 1 illustrates the experiment of flow water during a sand-filled vertical column[11]. Darcy noted that the hydraulic head's reduction is related to a porous medium's flow per unit area. Also, noticed the elevation manometer entered the top of the soil column h1 is larger than the elevation bottom manometer h2. In this situation, the flow is downhill at a rate proportional to the hydraulic head or piezometric head difference Δh, and the flow is related to the hydraulic gradient. Therefore Underground, the groundwater flows in response to variations in elevation always downward and pressure different from high to low-pressure zones. This indicates that groundwater often flows 'downhill,' from a higher to a lower elevation [6].

$$q=kiA \tag{1}$$

Where:
i: hydraulic gradient
A: cross-sectional area
k: hydraulic conductivity

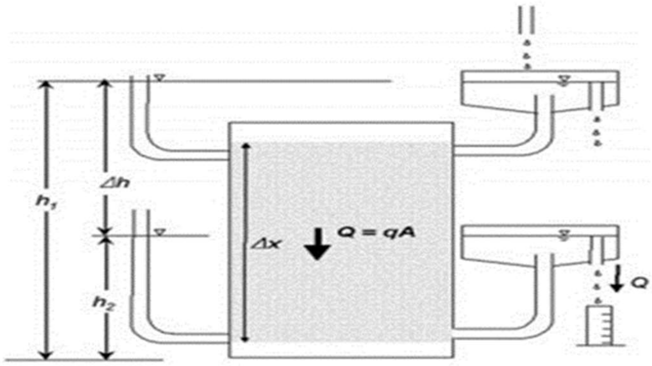

Figure 1: A laboratory permeameter configuration to determine the hydraulic conductivity

2.1 Equation of Lowering Groundwater

The equation for groundwater flow is a mathematical expression. It is used to describe groundwater flow through a confined and unconfined aquifer. The equation for groundwater flow is frequently derived by using a small typical elemental volume where the characteristics of the medium are constant. A mass balance of the water flowing into and out of this tiny volume is performed. By utilizing Darcy's law, the flux terms in the relationship are represented in terms of the head, which requires a laminar flow.

2.2 Radius Of Influence R_0 and Recharge Boundary

The typical aquifer does not recharge inside the pumping's zone of influence, but as shown in Figure 2, the principal natural aquifers are continually recharged and discharged. When dewatering is initiated, natural aquifer discharge decreases and generally, recharge increases. The rechargeable sources include the typical aquifer that does not recharge inside the pumping's zone of influence, but as shown in Figure 2, the principal natural aquifers are continually recharged and discharged. When dewatering is initiated, natural aquifer discharge decreases, and generally, recharge increases. The rechargeable sources include the seepage from bodies of water such as influent streams, ponds, lakes, and the sea, Vertical leaking via restricting beds on the higher or lower levels (aquitards), Infiltration through the surface caused by rainfall or flooding, and Horizontal connections to other aquifers.

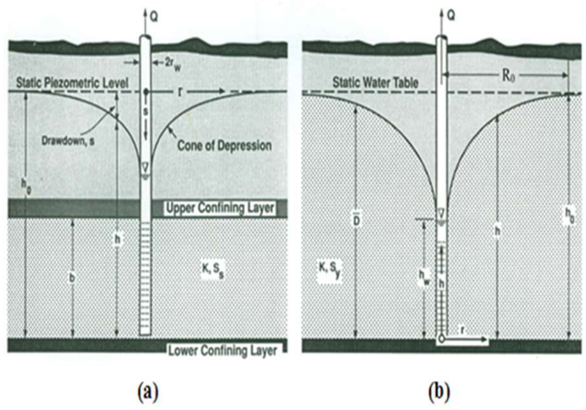

Figure 2: Drawdown pattern in (a) Confined aquifer (b) Unconfined aquifer. (Roscoe Moss Company, 1990)

For mathematical simplicity, we will consider all recharge sources as equivalent to a single large-capacity source operating on a vertical cylindrical surface positioned at a distance of R_0 from the center for pumping. The well's region of influence is determined by the outer boundary of the cone depression. The border of the region of influence is referred to as the influence circle. This circle's radius is known as influence's radius R_0, as shown in Figure 2. Sichart and Kryieleis established an empirical relationship that defines R_0 as a function of drawdown H-h and K as follows [7]:

$$R_0=3000(H-h)\sqrt{k} \quad (2)$$

Where:
R_0: influence of radius
H-h= drawdown level
K: permeability of the soil

2.3 Equivalent Radius r_e

Generally, the multiple-well systems that are used to lower groundwater levels can be categorized in form linear systems (designed to be installed alongside trench pits) or in form ring systems (designed to be installed around rectangular or circular pits). A convenient method is to consider groupings of wells as big equivalent wells, which enables the flow rate to be estimated by using simple equations. An equivalent well can be defined as a groundwater lowering system in which the flow of groundwater into the system is radial on a gross scale. Radial flow indicates that flow lines, dispersed water sources converge with the well from afar. The equivalent diameter theorem is used to simplify the mathematical solutions to estimate the flow rate. This technique involves estimating the system's equivalent radius re when dealing with the radial flow to rings of wells; re is the radius of the ring in the case of a circular ring of wells and assuming a well of the equal perimeter for a rectangular ring of wells with plan dimensions (a by b) as shown in Figure 3.[13]

$$r_e=\sqrt{(ab/\pi)} \quad \text{for circular} \quad (3)$$

$$r_e=(a+b)/\pi \quad \text{for rectangular} \quad (4)$$

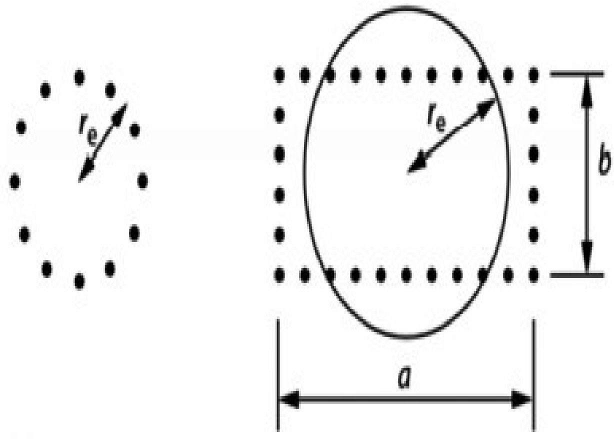

Figure 3: a) Radius-circle system r_e b) System of rectangles

2.4 Number of Wells

To calculate the number of wells needed for groundwater lowering in any site during the initial phase of dewatering is dividing the total discharge flow rate by the expected discharge for well productivity [13]

$$N = \text{Total discharge/discharge of well} \quad (5)$$

Where:
N: number of wells

There are some considerations for determining the number of wells; firstly, In aquifers with a permeability ranging from medium to high (i.e., the maximum output from a well is relatively high), the designer can include a greater number of wells with low productivity at close distances or reduce the number of wells with high productivity for longer distances .secondary when the productivity of the wells is large, pumps with high productivity may be unavailable, and pump performance may be used to control the output from each well; this should be taken into account while determining the number of wells and their spacing. Thirdly If the aquifer reaches a large depth, it may be conceivable to use a low number of wells with high capacity, and a large depth spaced several hundred meters. Fourthly, in poor-permeability strata, well productivity will be minimal. The designer will not choose a few wells with high productivity; therefore, the wells will be closely spaced to attain the overall discharge flow rate.

2.5 Distance Between Wells

After determining the number of wells, the possibility allows finding the spacing between them. For all systems, the spacing of the wells will affect the amount of time necessary to reduce groundwater levels to the target drawdown level. Generally, when the spacing between wells is closer, the drawdown achieves faster because the time is a factor essentially as cost in a building. Frequently, groundwater lowering systems are constructed with wells closer than is theoretically necessary to guarantee that the drawdown is completed in days or weeks. Calculating the distance between wells will depend on the equation coefficient of permeability in the field [2] illustrated in figure 4 . This method needs to determine the groundwater level inside the well during dewatering and the groundwater level that must be reached after dewatering. Two wells will be selected, the first which will have the water level during the dewatering process. The second will have the water level equal to the level required to lower groundwater after the dewatering process; then, implement the law of permeability in the field. The distance between the wells will be found, as shown in figure 4.

$$k = \frac{2.3q \log\left(\frac{r_2}{r_1}\right)}{\pi(h_2^2 - h_1^2)} \tag{6}$$

where:
k: coefficient of permeability
r_1: well radius
r_2: distance between two wells
h_1:water level during dewatering
h_2: maximum water level after dewatering

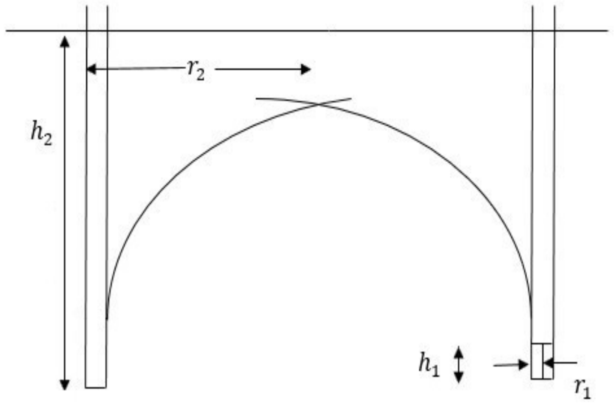

Figure 4: Distance between wells

2.6 Capacity of well

Each well should produce an adequate quantity of groundwater. All wells must work together to achieve the requisite flow rate and hence requisite lowering of groundwater under foundation[4].

$$q = 2\pi r l_w k i \tag{7}$$
$$l_w = 0.67L \tag{8}$$

where:
q: capacity of well
r: radius of the well
l_w: the length of the wetted screen under the reduced groundwater level
I: gradient hydraulic at the entry to the well
K: permeability of the soil
L: length of well

Although the designer has no control over the aquifer's permeability but can change the well's length and diameter within the constraints imposed by the site's geology and the cost of equipment for drilling wells. In 1928, Sichardt published determined the maximum capacity of well is empirically established to be constrained by a maximum hydraulic gradient (i max) which can be created at the face of a well in the aquifer

$$i_{max} = 1/(15\sqrt{k}) \tag{9}$$

By substituting Equation 9 in equation 7

$$q = \frac{2\pi r l_w \sqrt{k}}{15} \tag{10}$$

3. Simulation Program

Matrix Laboratory (MATLAB) code presented the program to design dewatering in any site need lowering groundwater level under foundation, and this program was named (DDS2020). It's an easy-to-use program for the user that can do complex mathematical computations; this need necessitates the graphical construction interface simple and practical in which data entry and option selection is done logically, intuitively, and guided. This program will offer the volume of water to be extracted, a number of wells, and the spaces between them; the expected settlement of soil surrounding the foundation pit due to dewatering and calculates the phreatic surface of the multi-well system, and present a 3D graphical shape of the water table drawdown induced by water extraction and distribution of wells. Dupuit's assumption is the base for representing the dewatering curve. Concerning the simulation capabilities, the user can be used this program to design a dewatering system. Because this program allows us to quickly learn about a wide range of results, engineers will be able to make the best choice decisions for their needs.

3.1 Flowchart of Program

The flowchart Illustrates stages of the program as boxes of different types and their order by the employment of arrows to connect the boxes. This diagrammatic represented Clarify and simplify a resolving a particular issue, and in a variety of areas, flowcharts are used to analyze, manage processes, document, and design. Figure 5 shows a simplified scheme flowchart of the design dewatering system (DDS2021). Therefore when it comes to planning and designing for any operation, the use of flowcharts can be beneficial to determine the steps that are required and concurrently provide a broader picture for the operations; also, it classifies and arranges works by type. By this flowchart, all data (load) from a computer or entered manually in a (New) way from the program's window(DDS201)if it is not stored on the computer.

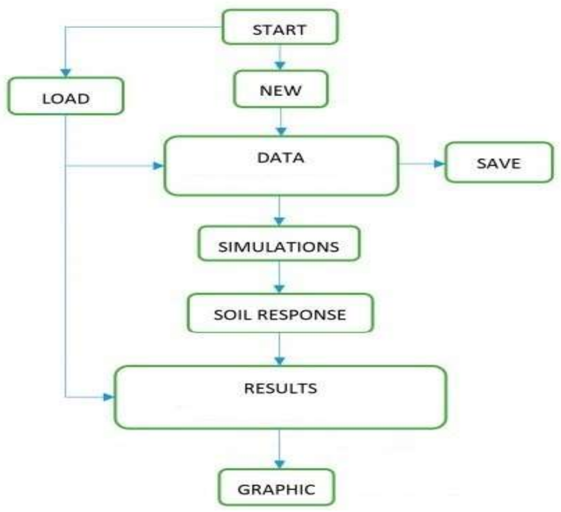

Figure 5: Scheme flowchart

3.2 Simulation Input Data

Data entered through the window that appears completed, as shown in Figure 6. The start-up screen allows the entrance of the problem geometry that includes (upload coordinate the site, select regular or irregular area, level of groundwater inside the well during dewatering in meter, required lowering groundwater under the foundation in meter, the permeability of soil in cube meter per second, the diameter of well in meter, Initial groundwater in meter, depth of well in meter). The user can prevent entering data by operating with a previously saved file to improve the program's stability and effectiveness. The software allows you to save and load data for this purpose. The simulation will begin once all of the data has been input or loaded. The program generates a network model file from a particular source code executed within the program to accomplish this.

3.3 Simulation output

The user can view the results at the end of the simulation and access the results given in Mathematically, as shown in Figure 7. The program offers up to total discharge in the site in cube meter per second, the number of wells for drawdown under foundation, equivalent radius for all location, level of groundwater after dewatering, site area, the distance between its well, influence radius (which represent the radius of equivalent area), discharge for each well, a figure that illustrates distribution wells . the geotechnical engineer can have all the necessary information in a simple. The end of the simulation can display the phreatic surface of the multi-well system and present the graphical shape of the water table drawdown induced by water extraction. This type of graphic shape is essential to Illustrates draw down the process by dewatering inside the soil and the end it possible the settlement that occurs in soil for any site.

4. Results and Discussion

One of the program's features firstly distributes the wells on a regular and compares whether the required lowered groundwater is achieved or not. If the level of lowering groundwater is completed, the program work will end. But if the necessary level of lowering groundwater is not achieved. In that case, the program will distribute the wells in a new pattern random distribution until the required level of reduction is completed. Still, it will maintain the distances between the wells, not exceeding (1.5 d) from the original distance. The wells will be distributed regularly and irregularly over a regular area noticed; the lowering of groundwater level in the irregular distribution of wells is more than 0.5 m from the distribution of regular wells. While when the wells distributed regularly and irregularly over an irregular area noticed the lowering of groundwater level in the regular distribution of wells is more than 0.8 m from the distribution of irregular wells.

4.1 Regular Area

An assumed case study for the regular area to study the effect pattern distribution of the regular wells on this area. The section of excavation is square (30x30) m in plan and 8 m in depth; the site profile consists of 20.0 m fine to medium sand overlying impervious deposits and design system requirements, as shown in Table 1

Table 1: Requirement of design

Initial groundwater level (m)	Permeability (m/s)	Diameter of wells (m)	Depth of wells (m)	Required lowering(m)
-1.5	0.000035	0.254	14	7

After designing the dewatering system by entering parameters into the program as shown in figure 6 . obtain the result of design dewatering as shown in Figure 7. By the push button (check lowering), the program will show the value for end lowering also download figure as shown in figure 8 that includes the locations and distances of the wells from the centre area also view phreatic surface as shown in figure 9. After checking for lowering groundwater level, the result was 7.3 m under foundation this value nearly to the required lowering that equal to 7 m; this indicates that the design of the dewatering system was successful and led to the required level of groundwater reduction for this pattern regular of distribution for wells.

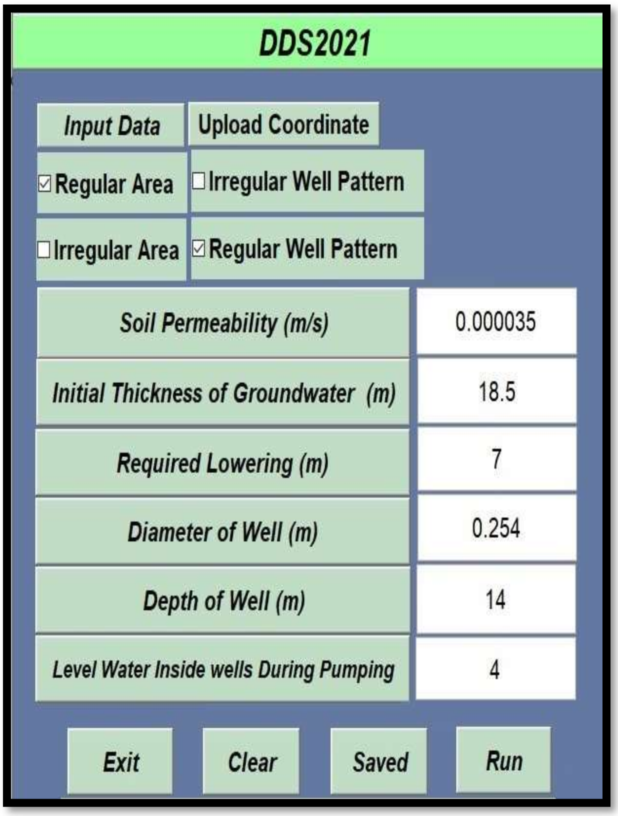

Figure 6: Input Data

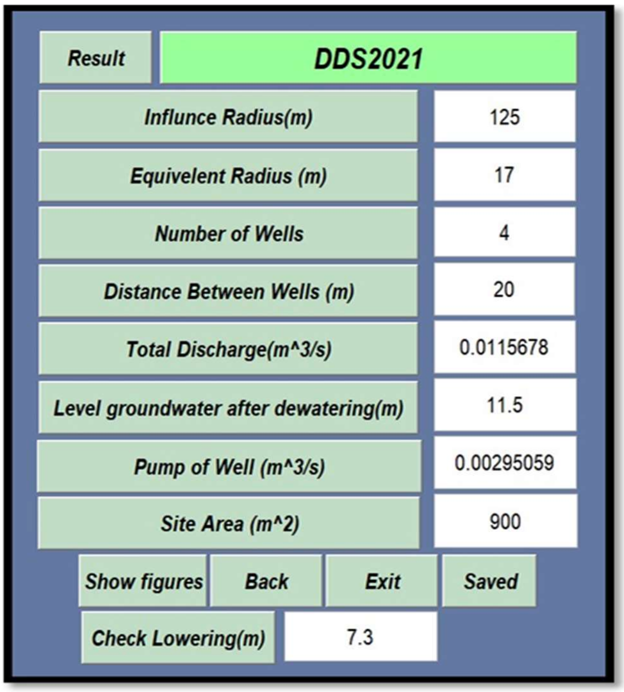

Figure 7: Results Design Dewatering

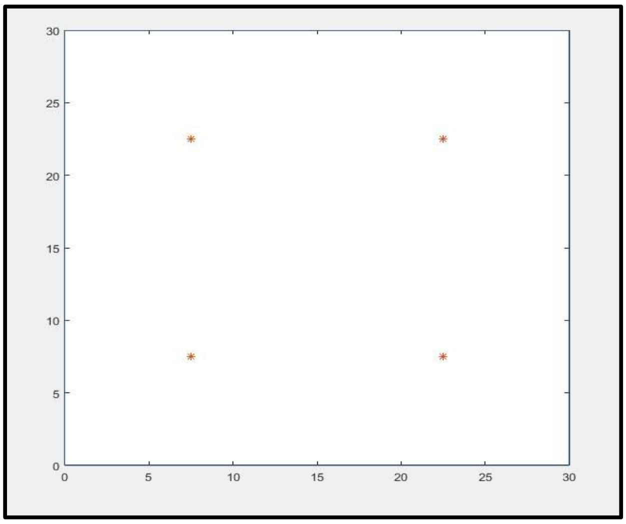

Figure 8: Regular distribution of wells

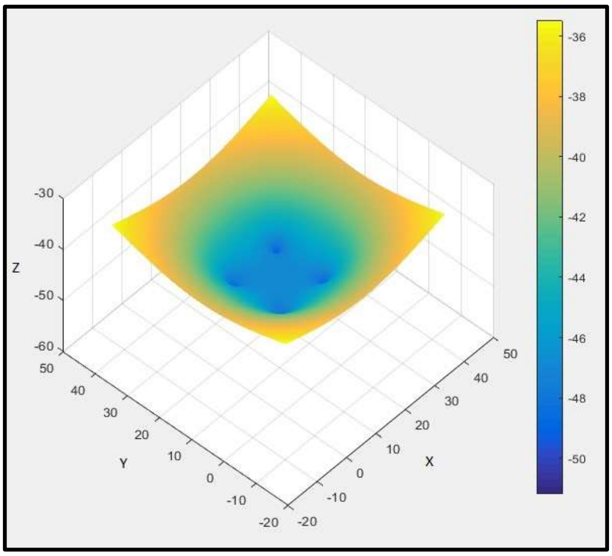

Figure 9: phreatic surface

But when the distribution of wells in irregular patterns for the case above this will be done by choosing the irregular well pattern button of the DDS2021; the program will distribute wells in the form irregular as shown in figure 10 .also, view phreatic surface as shown in figure 11.

After that select, the push button (check lowering), then the program will show the value for end lowering. The result of the lowering groundwater level is 7.8 m under foundation; this value is more than the required lowering equal to 7 m. This indicates that the design of the dewatering system by regular distribution pattern of wells lowers groundwater by increasing 0.8 m of required lowering.

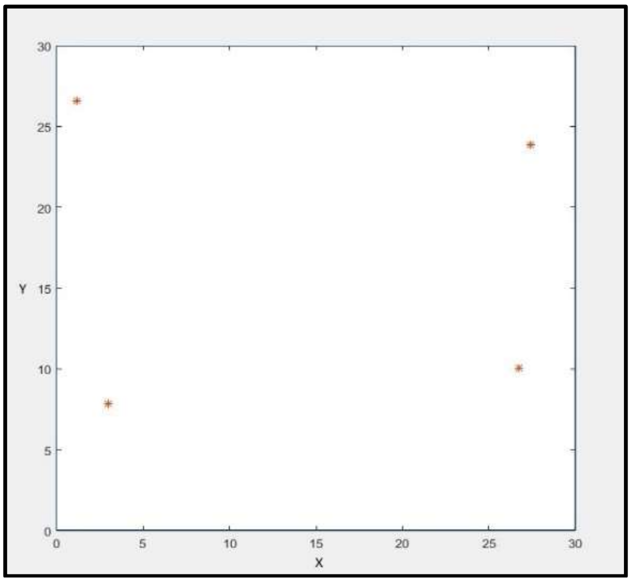

Figure 10: Regular distribution of wells

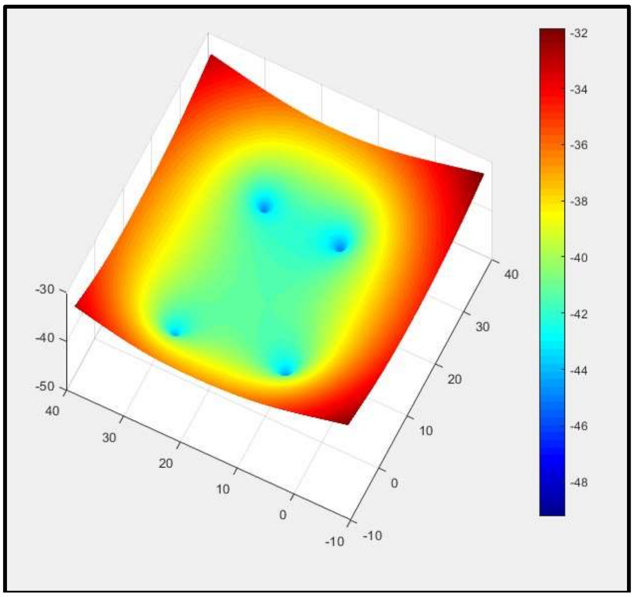

Figure 11: phreatic surface

4.2 Irregular Area

An assumed case study for the irregular area to study the effect pattern distribution of the regular wells on this area. The section of excavation is square 10 m in width and 5.5 m in depth, and 120 m long; the site profile consists of 20.0 m fine to medium sand overlying impervious deposits and design system requirements as shown in table 2

Table 2: Requirement of design

Initial groundwater level(m)	Permeability (m/s)	Diameter of wells (m)	Depth of wells (m)	Required lowering (m)
-2	0.000035	0.254	15	4

After designing the dewatering system, and by the push button (check lowering). Then the program will show the value for end lowering; also, download figure 12 that includes the locations and distances of the wells from the centre area also view phreatic surface as shown in figure 13. After checking for lowering groundwater level, the result was 5 m under foundation this value more than the required lowering equally to 4 m; This indicates that the design of dewatering system by regular distribution pattern of wells lowering groundwater by increase 1m from the required lowering.

But after studying the irregular distribution pattern of wells for the same case above. This will be done by choosing the irregular button of the DDS2021 program. When selecting this button, the program will distribute wells in the form irregular, as shown in figure 14. After that, select the push button (check lowering), then the program will show the value for end lowering; also download figure 15 that includes view phreatic surface and view all calculations required for lowering groundwater in this point. After checking for lowering groundwater level, the result was 4.2 m under foundation; this value is nearly from the required lowering that equal to 4 m. this indicates that the design of the dewatering system was successful and led to the required level of groundwater reduction for this pattern irregular of distribution of wells.

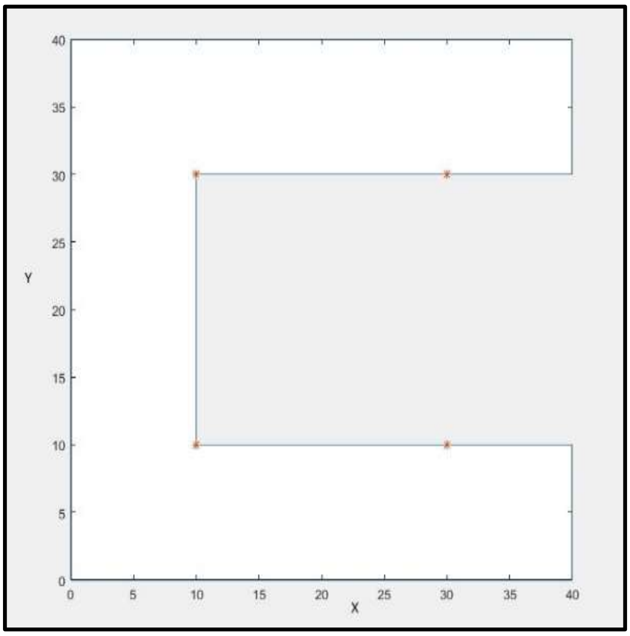

Figure 12: Regular distribution of wells

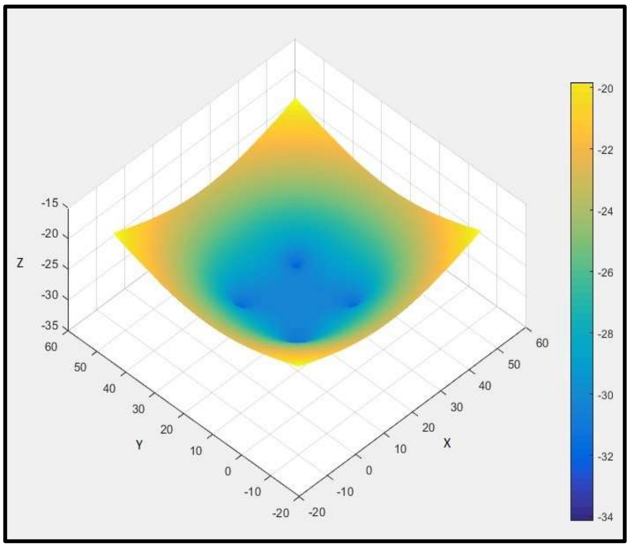

Figure 13: Phreatic surface

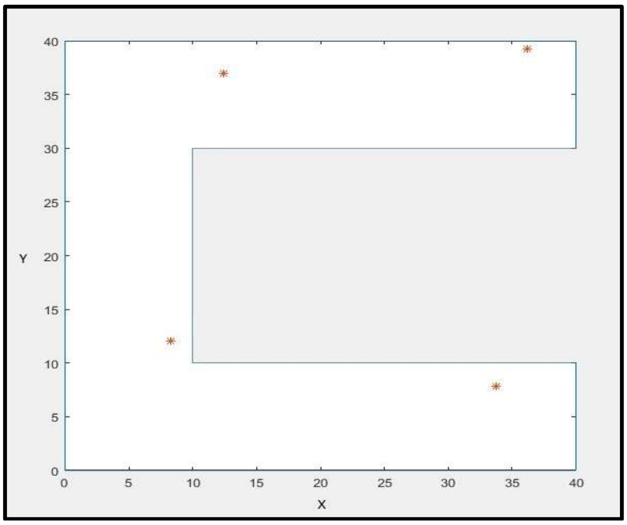

Figure 14: Irregular distribution of wells

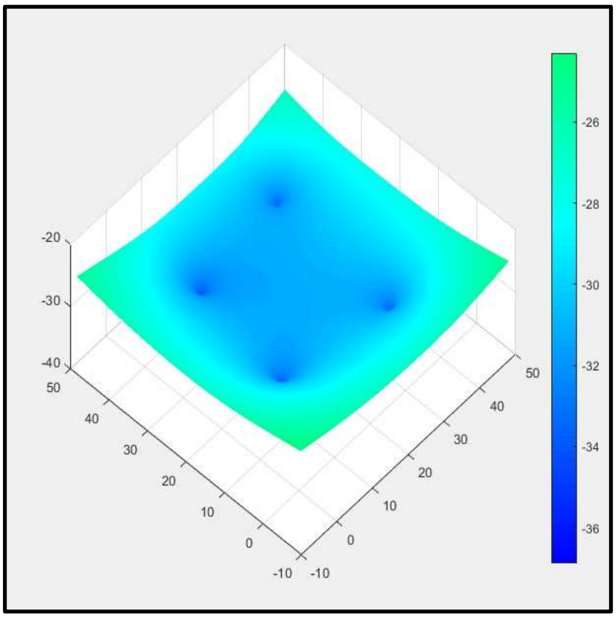

Figure 15: Phreatic surface

5. Conclusion

1- The results of the suggested program(DDS2021) showed good agreement with lowering the groundwater table to a required depth.
2-Changing the locations of wells has a significant effect on the lowering of groundwater levels.
3- The groundwater level's lowering for the regular wells' pattern distribution on the regular area equals 7.3m under foundation. While the lowering of groundwater level for the same case with the irregular distribution pattern of wells equals 7.8 m under foundation, this indicates the pattern distribution of the regular wells with the regular area is closer to the required lowering of groundwater level that equals 7m.
4- The lowering of groundwater level for the pattern distribution of the regular wells on the irregular area equal to 4.2m under the foundation. While the lowering of groundwater level for the same case with the irregular distribution pattern of wells equals 5 m under the foundation, this indicates the pattern distribution of the irregular wells with the irregular area is closer to the required lowering of groundwater level that equals 4m.
5-The shape of the phreatic surface obtained from the program notice depends on the position of the wells.

6. Acknowledgements

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References

[1] B.El-Garhy, A. Youssef and K. Roshdy "Evaluation of Three Analysis Methods of Dewatering System, "*Tunnelling and Underground Space Technology*, vol. 23, no. 5. pp. 481–491, 2008.

[2] B. Das "Advance Soil Mechanics,", 2008.

[3] F. El-Nahhas, "Geotechnical Aspects of Controlling Groundwater Levels in Urban Areas," In Conference proceeding article. vol.6, 2003.

[4] G. Ros, I. Alhama and M. Cánovas "Powerful Software to Simulate Soil Consolidation Problems with Prefabricated Vertical Drains," Water, vol. 10, no.3, pp.1-20,2018.

[5] H. Yousef, M.H. Niksokhan,S. Zahedi and M. Momeni "Ten-year prediction of groundwater level in Karaj plain (Iran) using MODFLOW2005-NWT in MATLAB," Springer, vol.343,no.78,pp. 1-14,2019.

[6] J. Wiley and Sons, "seepage in soil." 2003

[7] J. POWERS, A. CORWIN , P. SCHMALL,W. KAECK"Construction dewatering - new methods and applications," 2007.

[8] M. Samaaneh and A. Al-Gadhib, "Modeling Impact of Dewatering on Soil Structure Interaction Using SAP," In the Conference proceeding article, 2013.

[9] M. Karkush, M.Ahmed, A. Abdul-Hassan Sheikha and A. Al-Rumaithi " Thematic maps for the variation of bearing capacity of soil using SPTs and MATLAB," Geosciences, vol.10,no.9, pp. 1-17,2020.

[10] N. Calin, C.Radu and I. Bica "Dewatering system of a deep of excavation in urban area – Bucharest case study,"Procidia Engineering, vol.209, no.4, pp.210-215, 2017.

[11] N.Ahmed, S.Taylor and Z.Sheng "Hydraulics of Wells." 2014.

[12] O. Kenechukwu Simeon "Groundwater Control Issues in Transportation Engineering: A Short Review of Dewatering Methods and Lessons Learned, " Journal of Engineering Science and Technology Review, vol.8, no.3, 2015.

[13] P. Cashman and M. Preene, "Groundwater Lowering in Construction." p. 429, 2021.

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الخلاصة – يعتبر التحكم في المياه الجوفية أحد الإجراءات الجيوتقنية الأولية التي يتم إجراؤها في الموقع لذلك قبل البدء في أي أعمال حفر يجب دراسة حالة الموقع والحالة الهيدرولوجية. باستخدام برنامج الماتلاب تم إنشاء برنامج لتصميم نظام نزح المياه يسمى DDS2021 للتحكم في مستوى المياه الجوفية قبل البناء ، حيث قدم توزيع الآبار للمناطق المنتظمة والغير المنتظمة وقدم الشكل البياني لانخفاض منسوب المياه الناجم عن استخراج المياه لجميع الآبار . افتراض دوبويت هو الأساس لتمثيل منحنى نزح المياه. قد يكون من الممكن تحقيق التخفيض المطلوب للمياه الجوفية في الحفرة المقترحة باستخدام عدد قليل من الآبار التي يتم ضخها بمعدلات تدفق عالية أو عدد أكبر من الآبار ذات معدلات التدفق المنخفضة. وبالمثل ، فإن تغيير مواقع الآبار المحيطة (أو داخل) الحفريات قد يؤدي إلى انخفاضات مختلفة بشكل كبير في دراسة المنطقة. درس هذا البحث تأثير توزيع الابار بشكل منتظم وغير منتظم على انخفاض مستويات المياه الجوفية لكل من المناطق المنتظمة وغير المنتظمة.

الكلمات الرئيسية – نمط الابار المنتظم , نمط الابار الغير منتظم , تصميم نظام نزح المياه , نزح المياه ببرنامج ماتلاب