مجلة جامعة بني وليد للعلوم الإنسانية والتطبيقية

تصدر عن جامعة بني وليد – ليبيا

Website: https://jhas-bwu.com/index.php/bwjhas/index

المجلد التاسع، العدد الثاني 2024

دراسة نظام نزح المياه باستخدام التحليل العددي

أ. نجلاء فرج البعجة [1] ، أ. عائشة إبراهيم الزياني[2]

[1] قسم التقنية المدنية والمعمارية ، المعهد العالي للتقنيات الهندسية الماجوري ، بنغازي ، ليبيا

[2] قسم تقنية العمارة الحديثة ، المعهد العالي للتقنيات الهندسية ، بنغازي ، ليبيا

nagla@mei.edu.ly

A DEWATERING SYSTEM STUDY WITH A NUMERICAL SOLUTION

Najla F. Al-Baejah [1], Aisha I Alzayani [2]

[1] Department of Civil and Architecture Technology-The High institute for engineering Professions Majori Benghazi- Libya

[2] Department of Modern Architecture Technology -Higher Institute of Engineering Techniques- Benghazi- Libya

تاريخ الاستلام:22-05-2024 تاريخ القبول: 08-06-2024 تاريخ النشر : 25-06-2024

الملخص:

تعد إدارة مستويات المياه الجوفية والتحكم فيها من العمليات المهمة في عدة تخصصات التي تتطلب جهودًا مشتركة لعدد من المتخصصين في مجالات الهندسة المختلفة، وقد تم تطوير عدد من التقنيات المستخدمة لخفض منسوب المياه الجوفية أثناء الحفر والتي تشمل الطرق الأكثر شيوعًا لنزع مياه الأحواض والآبار بنقاط الآبار، والغرض منه هو التحكم في البيئة الهيدرولوجية السطحية والجوفية بطريقة تسمح ببناء الهيكل "في منطقة جافة".

وتعتبر معظم الإجراءات التحليلية المستخدمة في الدراسة لتدفق المياه الجوفية هي تدفق (حالة مستقرة) وتدفق (حالة غير مستقرة) للجريان في المرحلة الأولية من عملية نزح المياه.

ويمكن أن تتسبب المياه الجوفية غير الخاضعة للرقابة أو التي يتم التحكم فيها بشكل غير صحيح، عن طريق تأثيرها من حيث الضغط الهيدروستاتيكي، والتسريب أثناء إنشاء الأنابيب، والرفع، وتقليل استقرار منحدرات الحفر أو تربة الأساس غير أمنه لاستقرار ودعم أساسات المبنى الانشائي، حيث تعتمد أساليب التعامل مع مثل هذه المشكلات على: أبعاد الحفر، نوع التربة، ومتطلبات التحكم في المياه الجوفية، وعوامل أخرى.

ويتم تنفيذ أبسط عمليات نزح المياه بقليل من التخطيط وتتطلب العمليات الرئيسية في الظروف الصعبة أساليب هندسية وبناء متقدمة. ويمكن تصنيف الأهداف الرئيسية لهذه الورقة تحت العناصر الاتية:

a – استخدام التقنيات العددية (طريقة الفروق المحدودة) لتحليل تدفق المياه الجوفية عبر وسط مسامي.

b– عرض النتائج النظرية لمحاكاة تدفق المياه الجوفية في الخزان الجوفي للدراسة المقترحة.

c – تحديد التصريف وعدد نقاط الآبار والتباعد بين الآبار.

الكلمات الدالة : نزح المياه، المياه الجوفية، الآبار، نقاط الآبار.

Abstract

Groundwater level management and control is a multidisciplinary process that calls for the collaboration of several experts in geotechnical engineering, hydrogeology, hydrology, geochemistry, hydrochemistry, etc.

It is quite likely that some form of groundwater management is necessary for any new civil engineering project that involves building at altitudes below the water table. During excavation, a number of tried-and-true methods have been devised to decrease the groundwater table. The most often used techniques for dewatering include wells, sumps, and well points.

Controlling the surface and subsurface hydrologic environment to enable "in the dry" building of the structure is the aim of construction dewatering. The majority of the analytical techniques for groundwater flow described in this handbook are for "steady-state" flow, not "unsteady-state" flow, which happens during the first stages of dewatering.

By hydrostatic pressure and seepage, uncontrolled or incorrectly managed groundwater can induce heave, leakage, or decrease the stability of excavation slopes or foundation soils to the point that they are unfit for sustaining the structure.

The methods used to address the resulting issues rely on a number of variables, including the size of the excavation, the type of soil, and the needs for groundwater control.

Even the most basic dewatering procedures are performed without any thought beforehand. Advanced engineering and construction techniques are necessary for large-scale operations in challenging environments.

The following categories best describe the primary goals of this paper:

a) Analyze groundwater flow via porous media using numerical techniques (finite difference method);

b) Present the theoretical findings of simulations of groundwater flow in the suggested research aquifer.

c) Calculate the discharge, the number of well locations, and the distance between each well.

Keywords: Dewatering, groundwater, wells, well points.

INTRODUCTION

"The separation of water from the soil" or "removing the water entirely from the specific construction problem" are two definitions of dewatering. This gives rise to ideas like pre-drainage of soil, groundwater management, and even enhancing the physical characteristics of soil. building dewatering, which entails temporarily lowering the ground water table to facilitate excavation and building within a reasonably dry environment, is rarely an issue if ground water concerns are addressed adequately at the research and design stage.[2]

The most common methods found in the literature for analysis of dewatering systems are the mathematical formulas method, the flow net method, and the numerical modeling method. There are a number of mathematical formulas found in the literature that can be used to predict the drawdown of groundwater table for simple cases of dewatering systems.[5]

The method of flow net can be successfully used to analyze the dewatering system with fully and partially penetrating wells in case of line source of seepage.[7]

Dewatering construction sites has long been a specialized market.

Dewatering construction: The groundwater may significantly aid in the building of subterranean buildings based on pervious soil strata under the water table by:

1. Catching seepage that would normally surface from an excavation's bottom or slopes.
2. Improving the stability of slopes that have been dug and avoiding material loss from the slopes or excavation bottom.
3. Lowering cofferdam lateral loads.
4. Reducing or doing away with the requirement for air pressure during tunneling.
5. Improving sandy soils' features for backfill and excavation.

The well point system is constructed as follows:

1. The well points are jetted into the earth.
2. Filter medium is inserted into the annular void.
3. A riser is used to link the well points to a header pipe.
4. Suction pumps are attached to the header pipe in order to pump. [1]

2. Method of solution and case study

2-1 Method of solution: Analytical solutions are always the result of simplifying assumptions. This is due to the fact that real-world scenarios are too complex to accurately replicate. Numerical approaches are preferred to solve the mathematical model in order to cope with more realistic scenarios.

With the advent of high-speed digital computers numerical models have been app- lied successfully for studying groundwater flow.

In this study, a two-dimensional numerical model using the finite difference method is applied for the ground water flow to a well in a circular island unconfined aquifer in steady state flow condition. The analysis in this method is based on the replacement of the partial differential equation which governs the water flow and subjected to boundary conditions by an equivalent difference. The procedure is to divide the study are with a grid network and to develop the difference equation at each grid intersection (i.e. nodal points). Thus, a partial differential equation can be converted into a set of N algebraic equation involving N unknown heads. The solution is obtained by repented arithmetic calculations known as the iteration or relaxation methods. We can test a numerical solution by comparing the head distribution generated by the computer with that determined from an analytical solution, if one is available, and check the simulated head distribution with the values observed in the field.[3]

When it comes to dewatering building sites, well point systems are usually the most sensible and cost-effective option when the necessary drop in ground water level is around six meters or less.[2]

2-2 Case study:

It is a land on located north of Benghazi, near the sea and in the ground water level is high significantly, which does not allow us to put the foundations and pillars of the building, but after getting rid of the amount of water that formed in the ground under the building that we want it was set up, there are several ways to reduce the water level in this land.

Building project (Zhou Benghazi) north of Benghazi. **Figure 1**.

General information on the public site:

The total area of land for the project = **16234.274 m^2**

The total area of the land on which the building trade = **2400 m^2**

The total area of the land on which the tower is built = **2530 m^2**

The total area allocated to green spaces = **2678 m^2 of land**

The total area of the land allocated to stations and parking = **4830 m^2**

Figure 2. well points in (Zhou Benghazi tower).

3.Theory and Calculation

Relationships using the language of science − mathematics. We then try to solve the resulting mathematical equations in order to describe and understand the behavior of the system under study. In general, a full mathematical equation too complex to solve exactly, so we will make approximations which we judge the impact will be negligible for the problem at hand. Even equations usually draw well. Difficult to solve analytically, so we resort to numerical approximations for this set of simplified equations. The approximate numerical production systems algebraic equations which are solved using computers.

The most common methods are:

- The method of finite differences
- The technique of finite elements

In this paper we will use the **finite difference method** because it can be easily used of systems having regular boundaries as is the case in our study. [3]

3-1 Finite Difference:

Finite difference method is a numerical approach to solve partial differential equations. And can be used to describe a large number of problems in the field of groundwater hydrology. Spreadsheet applications may readily implement the finite difference technique and partial differential equations in the case of problems with constrained basic geometry and boundary constraints. The technique may be used in anisotropic situations and with numerous layers.[6]

Taylor Series: Whose values and derivatives are continuous in the function $y = f(x)$.

$$f(x) = f(a) + \frac{f'_{(a)}}{1!}(x - a) + \frac{f''_{(a)}}{2!}(x - a)^2 + \ldots\ldots + \frac{f^{(n)}(a)}{n!}(x - a)^n + \ldots\ldots \qquad [1]$$

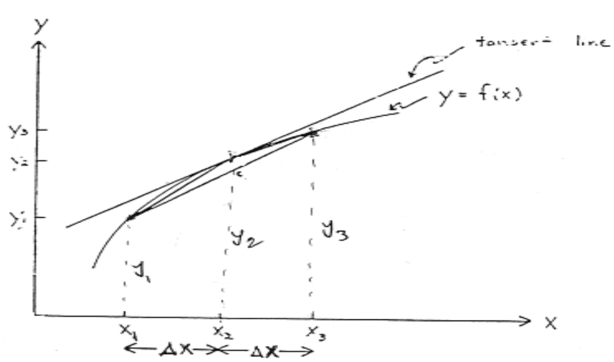

Figure3. Graph showing the function *f (x)*

3.1.1 Finite Difference model based on steady-state flow

- **Laplace's equation:**

when water has an anisotropic permeability and flows continuously through a two-dimensional porous soil.[4] $(k_x \neq k_y)$,

$$k_x \frac{\partial^2 h}{\partial_{x^2}} + k_y \frac{\partial^2 h}{\partial y^2} = 0 \qquad [2]$$

Eq. [2] becomes Laplace's equation in the case of isotropic permeability $(k_x = k_y)$

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = 0 \qquad [3]$$

- **Poisson's equation (confined aquifer):**

Which is the finite deference from Laplace's equation. Consideration of discharge or recharge wells can mathematically be represented by the use of Poisson's equation. For a two-dimensional flow in a confined aquifer whose thickness is constant and equals b. Let R (x,y) be the volume of water disc- charged or recharged per unit time per unit aquifer area. For steady state conditions, the continuity implies that the volume rate of out flow must equal

R (x,y) Δx ,Δy. Therefore,

$$\frac{\partial q_x}{\partial x} \Delta x(b\Delta y) + \frac{\partial q_y}{\partial y} \Delta y(b\Delta x) = R(x,y).\Delta x\Delta y \qquad [4]$$

Substitute Darcy's low for q_x and q_y and let the transmissivity. q_x T equals the product of hydraulic conductivity K and the aquifer thickness b. Making this substitution in Eq. [4] and dividing through by −T Δx Δy yields Poisson's equation

$$\frac{\partial^2 \mathrm{h}}{\partial \mathrm{x}^2} + \frac{\partial^2 \mathrm{h}}{\partial \mathrm{y}^2} = -\frac{R(x,y)}{\mathrm{T}} \qquad [5]$$

The finite difference form of Poisson's equation can be obtained after substitution of second differences for the second partial derivatives, then

$$\frac{h_{i-1,j} - 2h_{i,j} + h_{i+1,j}}{(\Delta_x)^2} + \frac{h_{i,j-1} - 2h_{i,j} + h_{i,j+1}}{(\Delta_y)^2} = -\frac{R(x,y)}{T} \quad [6]$$

where Δx the nodal spacing $\Delta x = \Delta y$

$$R(x,y) = \frac{-Q}{\Delta x . \Delta y} \quad [7]$$

and Q is the pumping rate from the well. For a two-dimensional flow in an unconfined aquifer Poisson's equation takes the form:

$$\frac{K}{2}\left(\frac{\partial^2 h^2}{\partial x^2} + \frac{\partial^2 h^2}{\partial y^2}\right) = -R \quad [8]$$

which is the **Poisson Equation in** h^2, or making the variable transformation $v = h^2$. The solution is first obtained in terms of v and the heads are then obtained by taking the square root of v.

where h: The water head in unconfined aquifer and Δx and Δy are the nodes spacing in the x and y directions, respectively, the discredited from of Eq. [8] at Point i,j is [4]

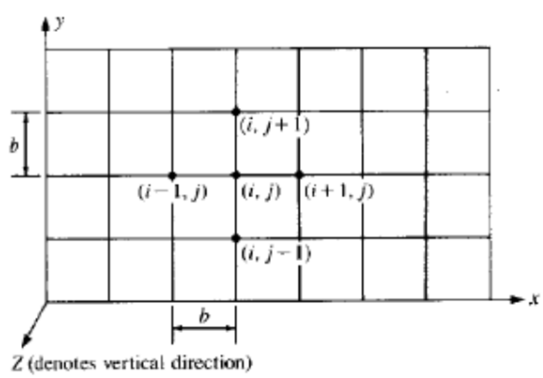

Figure 4. five-point operator [4]

$$\frac{k_x}{\Delta x^2}\left(h_{i+1} + h_{i-1,j} - 2h_{i,j}\right) + \frac{k_y}{\Delta y^2}\left(h_{i,j+1} + h_{i,j-1} - 2h_{i,j}\right) = 0 \quad [9]$$

As shown in Figure 4.(Δx =Δy = 5 m and $k_x = k_y = 14 m^2 / day$)

$$h_{i,j} = \frac{1}{4}(h_{i+1,j} + h_{i-1,j} + h_{i,j+1} + h_{i,j-1}) \quad [10]$$

Usually, the dewatering pumps that are utilized are made especially for that purpose. A typical system has well points spaced one to three meters apart. The kind of underlying soil has a major role in determining how deep a well point is buried. [2]

3.2 Calculation

The optimization solver available in Microsoft excel can be used for solving the groundwater management problem. In this paper, we will solve a dewatering problem using excel solver.

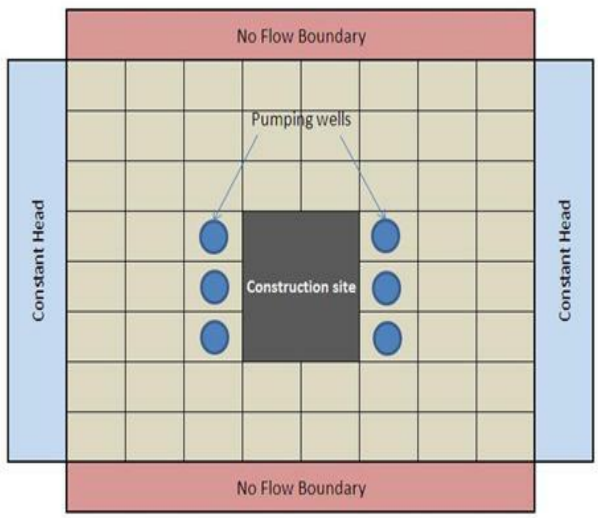

Figure 5. Schematic diagram of a dewatering problem [3]

Consider a two-dimensional unconfined aquifer shown in Fig. 5. The left- and right-hand sides of the aquifer have constant head (h = 100 m). The other two sides of the aquifer have no flow boundary. Some construction is proposed in the area shown as construction site. To facilitate the construction, the water table has to bring down to certain desirable level.

Several cases will be considered here in order to calculate the drawdown which will result in the study area in response to the proposed abstractions. The discharge rate was changed and the corresponding heads (and drawdown) were calculated. For each case drawdown.

4. Results and Discussion

In our study we set the number of well in which a draw to 5 wells. In first case, which was attributed **96.41015 m** when the withdrawal **rate 0.5 m3/day** and including that attributable required to establish a less than the level of groundwater, was necessary to increase the rate of withdrawal as shown in following table.

Table 1. All types of cases

Case No.	Q (m3 / day)	h (m)
1	0.5	96.410
2	0.6	95.692
3	0.7	94.974
4	0.8	94.256
5	1.0	92.820
6	6	56.922
7	10	28.203
8	13	6.664
9	14	-0.516

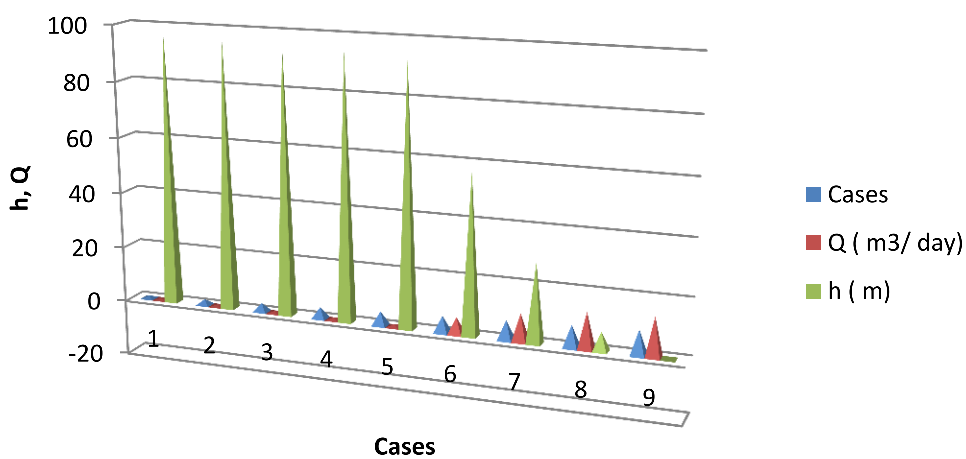

Figure 4. Cases vs.h,Q

5. Conclusions

In the first eight states the level of the water was upper than the construction level. We started changing the Q, which is the value of Dewatering unit we reached to the ninth state in which the level of the subterranean water become less than the construction and that what we really need to build the bases and then we stopped dewatering.

References

[1] Hack Barth, D. A, "Application of the drill – stem test to hydrology Ground water", vol. 15, no. 15, pp.5-11 (1978).

[2] Johnson Drillers Journal, "Deep wells for dewatering offer real advantages", part I: UOP Johnson, January –February, pp. 1-11 (1977).

[3] Mount, J. R, "Application of computer in design and operation of dewatering project": presented at the annual meeting of the Association of Engineering Geologists (1968)

[4] Universal Oil Products Johnson," Ground water and wells" Saint Paul, Edward E. Johnson Inc., p.107 (1972).

[5] Powers, J.P., "Construction dewatering: new method and applications" 2nd edition Wiley & Sons, Inc., New York, (1992).

[6] U.S Army," Dewatering and Groundwater Control" TM5-818-5, (2004)

[7] Youssef, A. A., "Report for Lowering the Groundwater Table at Sidi-Krir", Egypt (2006)