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Research article

MODELING FLUID PRESSURE VARIATIONS INFLUENCED BY PERMEABILITY AND POROSITY IN SEMICONFINED AQUIFERS IN OYIGBO, RIVERS STATE OF NIGERIA

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Abstract

Modeling fluid pressure variation influenced by permeability and porosity in semi confined aquifers has been developed**.** The models were derived through the formulated governing equation, an expressed equation was developed considering the variable that influence the system, this concept were to express the variation of fluid flow in semi confined aquifer under the influenced of porosity and permeability. Variation of fluid pressure were expressed with respect to period of flow and increase of ground water aquifers, this include distance travelled to ground water aquifers. The study is imperative because the rate of fast migration of other substances like solute to ground water aquifers are through the formation characteristics such as porosity and permeability. These two parameters were the variables that played major role to determine fluid pressure in semi unconfined aquifers , the degree of these two parameters determine the rate of variation of fluid pressure in soil, since variation in fluid flow determines ground water conditions in the study area.

Keywords: Modeling fluid pressure, permeability and porosity and confined aquifers.

1. Introduction

Groundwater is considered to be of excellent quality because of the soil barrier providing effective isolation of high quality source of water from surface pollutants. Groundwater is designed and constructed to meet up several demands; the quality for several uses has its criteria for different purposes and with various standards. Oyigbo is in Rivers State, situated at the deltaic environment, 80km way from the open sea; it lies between longitude of 60 55E to 70 10E of Greenwich Meridian and latitude of 40 38^{1}N to 40 54^{1}N of the equator. It covers a total distance of about 820km in terms of drainage; the area is situated on the Bonny River that transits its geological formation at Imo

River. It is entirely lowland with an average elevation of about 15m above sea level; the topography is under the influence of tides which result in flooding, especially during rainy season. Climatically, this site is situated within the boundary of Abia State and Rivers State, it is still within equatorial region of the tropical monsoon climate characterised by high temperature, low pressure and high relative humidity all the year.The annual temperature, rainfall and relative humidity are 30^0C, 2,300m and 90% respectively. The soil in this area is mainly silty-clay with interaction of sand and gravel, while vegetation covers a combination of mangrove swamp forest and Rain forest. The predominant formations are Benin formation and the aquifer thickness is on average of 2100 metres at the centre of the Niger Delta Basin. It consists of coarse to medium grains, sand stone, and gravel to medium grain sandstone, gravel and clay. The project site's geological setting may experiences homogeneous formation from aquitard to unconfined bed.

Among the many waterborne pathogens of humans, enteric viruses have the greatestpotential to move deeply through the subsurface environment, penetrate aquitard, andreach confined aquifers. Enteric viruses are extremely small (27-75 nm), readily passingthrough sediment pores that would trap much larger pathogenic bacteria and protozoa.Viruses have been found in groundwater at depths of 67 m (Keswick and Gerba 1980;Robertson and Edberg 1997) and 52 m (Borchardt et al 2003) and lateral transport has been reported as far as 408 m in glacial till and 1600 m in fractured limestone (Keswick and Gerba 1980). Several recent studies have demonstrated widespread occurrence of viruses in domestic and municipal wells in the United States(Abbaszadegan et al 2003; Borchardt et al 2003; Fout et al 2003; Borchardt et al 2004), and approximately half of waterborne disease outbreaks attributable to groundwater consumption in the United States have a viral etiology (National Primary Drinking Water Regulations, 2006). The US Environmental ProtectionAgency has listed several viruses on its drinking water Contaminant Candidate List, emphasizing that waterborne viruses are a research priority (http://www.epa.gov/safewater/ccl/index.html). Although the vulnerability ofgroundwater to virus contamination is now recognized, the occurrence of viruses inconfined aquifers has rarely been explicitly investigated. In the most comprehensivegroundwater-virus study to date, Abbaszadegan and others (2003) sampled 448groundwater sites in 35 states and found 141 sites (31.5%) were positive for at least onevirus type.Viruses must travel downward over 200 feet though the upper sandstone aquifer, an additional 10 to 30 feet downward through the Eau Claire aquitard to reach the top of the Mount Simon aquifer. Once in the Mt Simon aquifer the viruses must move laterallysome unknown distance to the production wells. Based on such a travel path, pathway seems very unlikely because travel times would likely be far longer than the six monthsto two years these viruses can survive in the environment (Yates et al 1985, Johnand Rose 2005, Schijven et al 2006). Transport pathways 2 and 3, through breaches in the aquitard or through fracture pathways, are more probable, but one must still account for the long travel distance through the upper sandstone aquifer above theAquitard.

These temporal patterns and changes in the relative abundance of viruses and virus serotypes have been documented in wastewater for enteroviruses and adenoviruses (Sedmak et al 2003; Sedmak et al 2005; Carducci et al 2006). Add in all the other human enteric viruses that can be detected and sequenced and the viruses in wastewater shed by that population become a "virus signature" for that point in timeHunt et al (2005) used a similar conceptual approach for estimating the time of travel of river water through the riverbank to adjacent wells.

2. TheoreticalBackground

The pressure of fluid in soil are determined by several factor, soil are deposited based on different influence from geological setting, the rate of fluids pressure are subjected to influence from stratification through the disintegration of sediments at various grain sizes, the rate of fluid pressure also determines the stratification of the deposition of the formation, determines the aquifer flow in the semi confined aquifers: the condition of fluid pressure are also influenced by the porosity of the strata in soil formation. Several condition has developed lots of different fluid pressure flow in semi confined aquifers, there are tendencies of the soil formation experiencing slight overburden pressure in few regions. Such depositions may generate semi confined beds, in most cases the deposition of sand stone generate such type of depositions. But semi confine bed are not predominant in deltaic environments, rather semi confined beds were confirmed to deposit in few areas. Since the depositions are not predominant assumptions can be made by some experts that such geological setting are not in existence, thus applied the predominant geological setting result to abortive well construction. This development generated thorough investigation of semi confined bed in the study area, this is imperative because it will assist to observe the type of ground water design in those areas. To monitor this type of deposition, mathematical model were developed, the developed model are through the governing equation formulated , the variables were found to influence the deposition of semi confined bed , the variables are from formation characteristics. These variables play major roles in deposition semi confined bed, the depositions of sand stone in the formation generate consolidation in some regions of strata and developed sight overburden pressure in the soil, this independent variable are the stabilizer of the system and it was denoted by mathematical symbols, the conceptual framework developed the governing equation to monitor fluid pressure variation influenced by permeability and porosity in semi confined aquifers.

3. Governing Equation

$$Sop\frac{\partial^2 p}{\partial t^2} + \left[\varepsilon w\frac{\partial p}{\partial t}\right] w\frac{\partial p}{\partial t} - \frac{\partial p}{\partial x_1}\left[\frac{K_1 p}{\mu}\right]\left[\frac{\partial p}{\partial x_j} + pg\frac{\partial p}{\partial x_i}\right] = QP_z \qquad \ldots\ldots\ldots\ldots \qquad (1)$$

Taking Laplace transformation of (1)

$$\frac{\partial^2 p}{\partial t^2} = S^2 P_{(t)} - SP - P_{(0)} \qquad \ldots\ldots\ldots\ldots \qquad (2)$$

$$\frac{\partial p}{\partial t} = SP_{(t)} - P_{(t)} \qquad \ldots\ldots\ldots\ldots \qquad (3)$$

$$\frac{\partial p}{\partial t} = SP_{(t)} - P_{(t)} \qquad \ldots\ldots\ldots\ldots \qquad (4)$$

$$\frac{\partial p}{\partial x} = SP_{(x)} - P_{(x)} \quad \ldots \quad (5)$$

$$\frac{\partial p}{\partial x} = SP_{(x)} - P_{(x)} \quad \ldots \quad (6)$$

$$P = P_{(0)} \quad \ldots \quad (7)$$

Expressions from equation (2) to (7) were transformed into Laplace, this is to express their functions to the level where the variables will express their relation to each other at different ground water conditions, under the influence of fluid pressure variation at various soil formations generating semi confined bed.Subject to this transformation, an expression was generated through the substitution stated in equation (8).

Submitting equation (2), (3), (4), (5), (6) and (7) into equation (1), yields

$$Sop\left[S^{2}P_{(t)} - SP_{(t)} - P_{(0)}\right] - \varepsilon w\left[SP_{(t)} - P_{(t)} - wSP_{(t)} - P_{(x)}\right] - \left[\frac{Kp}{\mu}\right] - \left[SP_{(x)} + Pg\frac{\partial p}{\partial x_{j}} + pgP_{(x)}\right] = QP_{z} \quad \ldots (8)$$

$$SoP_{(x)} - SoSP^{1}{}_{(t)} - P_{(0)} - \varepsilon w\, SP_{(0)}\, \varepsilon wP_{(0)} - wSP_{(t)} - P_{(0)} - \left[\frac{Kp}{\mu}\right] - \left[SP_{(0)} - P_{(x)} + Pg\, SP_{(x)}\right] = QP_{z} \quad \ldots \quad (9)$$

The expression from equation 8 were to correlate the variables in the system with the transformation from equation 2 to 7 as expressed above, the variables are to streamline the state of fluid pressure variation in several directions under the influence of formation characteristics in the system.

Considering the following boundary condition at

$$t=0, P^{1}{}_{(0)} = P_{(0)} \quad \ldots \quad (10)$$

$$P_{(t)}\left[Sop\, S^{2} - Sop - \varepsilon w - w - \frac{Kp}{\mu} + Pg\right] = 0 \quad \ldots \quad (11)$$

But considering the boundary condition

At $t > 0,\ P^{1}{}_{(0)} = P_{(0)} = P_{(0)}$ ………………. (12)

$$P_{(x)} - Sop\, S_{(t)} - \varepsilon w\, S_{(t)} - w\, S_{(t)} - \frac{Kp}{\mu}\, S_{(x)}\, QPz = Sop\, P_{0} + SoPPo + \varepsilon wP_{0} + wP_{0} + \frac{Kp}{\mu}P_{0} \quad \ldots (13)$$

$$\left[Sop - \varepsilon w - w - \frac{Kp}{\mu} - QPz\right]P_{(t)} = \left[Sops + Sop + \varepsilon w + w + \frac{Kp}{\mu}\right]P_{0} \quad \ldots \quad (14)$$

To monitor variation of fluid in the system, Boundary conditions were integrated in the equation, this to determine certain limits of fluid pressures in the formations through the geological setting in the study area. Subject to the variables in the system; they were to monitor the limit of fluid variation experienced in such stratification that developed slight deposition of semi confined aquifer zones.

This expression implies that the fluid flow experienced high degree of pressures,the variables in the system expressed the rate of variation through the influence of the deposition slight consolidation in some formations that

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resulted to sand stone deposition in the study area. Equations (13) and (14) through the boundary values expressed how the functions influence the variation of fluid in the system.

$$\frac{P_{(t)} = Sop + \varepsilon w + w - \frac{Kp}{\mu}}{Sop - \varepsilon w - w - \frac{Kp}{\mu} - QPz} P_0 \quad \ldots\ldots (15)$$

The rate of variation of the soil strata influenced variables in the system, integrating boundary values coupled the system mathematically, whereby the function variables of ground water conditions were expressed in detailed direction, but cannot produce a result that will ascertain the measurement of fluid pressure, to develop this expression, quadratic equations were introduced. Applying this expression was to descretize various variable functions as they influence the variation of fluid pressure. These applications are introduced to stabilize the system and streamline the functions of the variables that influence the variation of fluid pressure of flow in the study location.

Applying Quadratic expression, we have

$$S = \frac{b \pm \sqrt{b^2 - 4ac}}{2a} \quad \ldots\ldots (16)$$

Where $a = Sop\varepsilon w, \quad b = \frac{wKp}{\mu}, \quad c = QPz$

$$S = \frac{\frac{WkP}{\mu}\sqrt{\frac{WkP^2}{\mu} + 4Sop\varepsilon w\, QPz}}{2Sop\varepsilon w} \quad \ldots\ldots (17)$$

$$S_1 = \frac{\frac{WkP}{\mu} - \sqrt{\frac{WkP^2}{\mu} + 4Sop\varepsilon w\, QPz}}{2Sop\varepsilon w} \quad \ldots\ldots (18)$$

$$S_2 = \frac{\frac{WkP}{\mu} + \sqrt{\frac{WkP^2}{\mu} + 4Sop\varepsilon w\, QPz}}{2Sop\varepsilon w} \quad \ldots\ldots (19)$$

$$S_1 = \frac{\frac{WkP}{\mu}\left[+ \sqrt{\frac{WkP^2}{\mu} + 4Sop\varepsilon w\, QPz}\right]}{2Sop\varepsilon w} S_2 + \frac{\frac{WkP}{\mu} - \left[\sqrt{\frac{WkP^2}{\mu} + 4Sop\varepsilon w\, QPz}\right]}{2Sop\varepsilon w}$$

$$\ell\left[\frac{\frac{WkP}{\mu}+\sqrt{\frac{WkP^2}{\mu}+4Sop\varepsilon w\, QPz}}{2Sop\varepsilon w}\right]\frac{L}{v}\left[-\frac{WkP}{\mu}-\frac{\frac{WkP}{\mu}\sqrt{\frac{WkP^2}{\mu}+4Sop\varepsilon w\, QPz}}{2Sop\varepsilon w}\right] \quad \ldots\ldots \quad (20)$$

Applying Laplace inverse of the equation, we obtain

$$P_{(t)}=\left[Sop\,\varepsilon w+Sop\,\varepsilon w+\frac{wKp}{\mu}\right]P_{(0)}\,\ell^{\frac{\left[\frac{WkP}{\mu}\sqrt{\frac{WkP^2}{\mu}+4Sop\varepsilon w\, QPz}\right]t\,+}{2Sop\varepsilon w}}$$

$$\frac{\left[\frac{WkP}{\mu}\sqrt{\frac{WkP^2}{\mu}+4Sop\varepsilon w\, QPz}\right]t}{2Sop\varepsilon w} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (21)$$

But if $t=\frac{d}{v}$

$$P\left[L,v\right]=\frac{Sop\varepsilon w}{L/v}+Sop\varepsilon w+\frac{WkP}{\mu}P_0\,\ell^{\frac{\left[\frac{WkP}{\mu}+\left[\sqrt{\frac{WkP^2}{\mu}+4Sop\varepsilon w\, QPz}\right]\right]\frac{L}{v}}{2Sop\varepsilon w}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (22)$$

Considering the following boundary conditions at

$$t=0,\ P^1{}_0=0,\ P_0=0 \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (23)$$

Boundary conditions were expressed on the application of quadratic expression; this is to monitor the variation of fluid pressures with respect to change and distance under the influence of formation characteristics to ground water aquiferous zone. These expressions are in line with other boundary values that were applied above. Subject to this relation, the expressions that determine the variation of pressure at this phase are based on variation of formation characteristics of soil stratification in semi confined bed.

$$P_{(x)}=\left[\frac{Sop\varepsilon w}{t}+Sop\varepsilon w+\frac{WkP}{\mu}\right]P_0\,\ell^{\frac{\left[\frac{WkP}{\mu}\left[\sqrt{\frac{WkP^2}{\mu}+4Sop\varepsilon w\, QPz}\right]\right]\frac{L}{v}}{2Sop\varepsilon w}}\ +$$

$$\frac{\left[\frac{WkP}{\mu}\left[\sqrt{\frac{WkP^2}{\mu}+4Sop\varepsilon w\, QPz}\right]\right]\frac{L}{v}}{2Sop\varepsilon w} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (24)$$

At $P^1{}_0=t\neq 0$

Again, $P_0 = P_{(0)}$ so that

$$P_0\left[Sop\varepsilon w + \frac{WkP}{\mu}\right]P_0\,[1 + 1]\,i.e.\;0 = \left[0 + \frac{WkP}{\mu}\right]2 \quad \text{.................. (25)}$$

$$\Rightarrow \quad \frac{WkP}{\mu} + \frac{WkP}{\mu} = 0$$

$$P_{(x)} = \left[2\frac{Sop\varepsilon w}{2}\right]\;P_0\,\ell^{\frac{\left[\frac{WkP}{\mu}\left[\sqrt{\frac{WkP}{\mu} + 4Sop\varepsilon w + QPz}\right]\right]\frac{L}{v}}{2Sop\varepsilon w}} + \frac{\left[\frac{WkP}{\mu}\left[\sqrt{\frac{WkP}{\mu} + 4Sop\varepsilon w + QPz}\right]\right]\frac{L}{v}}{2Sop\varepsilon w} \quad \text{.................. (26)}$$

Moreover, $e^{x} + e^{-x} = 2Cosx$ therefore, we have

$$P_{(x)} = \left[2\frac{Sop\varepsilon w}{t}\right]\;P_0\,Cos\frac{\left[\frac{WkP}{\mu}\left[\sqrt{\frac{WkP}{\mu} + 4Sop\varepsilon w + QPz}\right]\right]\frac{L}{v}}{2Sop\varepsilon w} \quad \text{.................. (27)}$$

The expression in (26) is the final model equation that will monitor the variation of fluid pressure, fast migration of contaminants to groundwater aquiferous zones are in line with this direction of ground water system. The derived mathematical equations were generated through the governing equation that will monitor the variation of fluid pressure to groundwater aquifers. Variation influence from several formation characteristics within a short period of time has expressed the behaviuor of fluid flow in deltaic environment that deposit semi confined bed. This is because a lot of ground water condition in flow behaviour are not observed, there should be thorough examination of fluid pressure to examine various aquifer condition and determine there thickness and yield coefficients. The migration of a pollutant may be observed through fluid pressure. The study of fluid variation is imperative because knowing the rate of these pressures through mathematical model will prevent any sources of pollution. The negligence from this direction has also resulted to lots of abortive wells, investigation of the cause were ignored in the study location. Variation of fluid pressure are were found to play some roles in the migration of solute, therefore the rate of fluid pressure variation are through the structural deposition of the soil formation, therefore the modeling for fluid pressure variation under the influence of permeability and porosity has a subject relation with the migration of solute in soil formation, the direction of fluid pressure variation engineer the rate of solute deposition resulting to the victims of pollution source causing illness, groundwater are the major source of water for human utilization. Thousands of people in the study area get their water from public water supply and private boreholes. Subject to this relation, there should be thorough examination to monitor fluid pressure, this will enable experts determine aquifer thickness and yield rate in design of ground water system in the study area.

4. Conclusion

Variation of fluid pressure are determined by several factors, the rate of fluid pressure are through soil geological deposition of soil stratification, they are influenced by the degree of porosity and permeability of the formation. The study areas are predominantly with deltaic formation, this condition implies formation has a lots of environmental influence through climatic condition including the activities of man. Fluid pressure variation is one the major influences in aquifer yield rate; the yields rate from water well through ground water aquifer is a subject of concern in the study area. And this are influenced by fluid pressure variation, it may also determine Fast migration of solute through fluid dynamics, more so, formation characteristics through the micropoles degree depositions were also confirmed to influence variation of fluid pressure. This condition determines the rate of fluid pressure variation in strata to ground water aquifers, these were expressed in the study through hydrological studies in the study location, information from hydrological studies were confirmed to be semi confined bed in the study area. Semi confined bed deposits several fluid pressures thus, presented shallow aquifers, the deltaic nature of the study location deposit homogenous soil formation, this condition implies that the fluid dynamics in soil are determine predominantly by the expressed deltaic environment.To monitor the rate of variation of fluid pressure in the study area mathematical models were found to be the absolute concepts that determine the rate of fluid variations.. The models were derived through the governing equation developed to solve the problem, the governing equation were derived considering several conditions that influenced the variation of fluid pressure in deltaic environment.The derived mathematical model will monitor the variation of fluid pressure in semi confined bed.

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