Message to colleagues in hydrogeology and petroleum geology. New turn.

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Scientific and technical association «Ecology imperative»

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Foreword

Dear colleagues, hydrogeologists and petroleum geologists. This memo was intended to inform you that I have completed my research in underground hydrodynamics with new methodology of hydraulic and hydrodynamic properties determination of aquifers and oil reservoirs. I have reached the desirable result and presupposed to finish my activity in this field and go to rest. My age does not give me a chance to promote it farther to seeing its implementation. At the same time, I cannot make the solution available to everyone. I would be happy if my great-grandchildren would continue my work. But they are too small for such problems. As the time come, they will choose their own way like their parents.

I turned out to be a loner researcher in this matter. I reached the main result of this research in the very late period of my life. My attempts to attract youth as partners to develop the software for customers had ended unsuccessfully. To my regret. My page at the LinkedIn website is actively visiting. I think it is due to the pilot version which is exposed there. This fact says that this topic is of interest to many hydrogeologists and experts in this field. It is quite understood. The modern knowledge in this field of hydrodynamics corresponds to fifty and even more years ago. It is time to upgrade it. The visitors hope to see the user's software. Alas, no such product for them yet. The investment company BHCO (Swiss) has sponsored the startup of the user software in 2007. The first version was shown at the International Exhibition Watec in Tel-Aviv, 2007 and at the International Symposium on Groundwater in Istanbul, 2008. Unfortunately, the global crisis of 2008 forced the sponsor to remain all his projects. I continued these developments by myself, but my own money was not enough.

A breakthrough in a science does not depend on the budget, it depends on the person who will appear with the interest to the problem to solve it. I turned out to be such a man. Many years ago. The further promotion needs money. Significant money. I was unable to attract them. I am missing such talent. So, my Odyssey's journey in science is over.

I began my search in a complete darkness, by touch, without any reference points. Only the Theis solution. It is the “home port” for underground hydrodynamics and various methods following of it. I have rejected all these known methods as not appropriating my interest to make the Theis' solution fully matching any reality. It was the revolutionary idea with the zero level of the prehistory. Therefore I have no references on beforegoing knowledge. I took up this problem at my own peril and risk. Few believed in this idea. I am proposing now a new methodology which the content is: "The set of commonly recorded data at a lonely well is now the sufficient resource for determining a complete set of hydrodynamic and hydraulic properties of aquifer, borehole, and environment for various projects". She intends for various reservoirs, well conditions in both hydrogeology and petroleum geology. She intends for various reservoirs, well conditions in both hydrogeology and petroleum geology. But it is absent for usage.

Good scientific ideas sometimes are living independently of the author. Suddenly the Ecology Imperative Association (Israel) proposed me its partnership to move farther. Great. Of course, I agree to delay my rest.

Introduction

Many years ago, I was passionate on development an alternative methodology for determining the reservoir hydraulic and hydrodynamic properties. Aquifers are standing closer to my basic education and science interest therefore the research was aimed firstly on these objects. The application of the obtained result to the oil-bearing objects is considered as the possible consequence of that. Under the term “alternative methodology” I'm meaning a new methodology for interpreting conventional transient hydrodynamic processes at a production well. They are initiated by the operator as the hydrodynamic test or are arising as a result of various activities on the well. For example, this can be due to intermittent schedule of pumping or ON and OFF the pump in connection with preventive or repair work.

The fundamental solution of Thies [1935] and its simplified version of Cooper and Jacob [1946] are the basic template for evaluation permeable formations through data of pumping well test. They are widely used since the mid-40s of the last century. The main requirement to use is that, the test site should respond the physical model the Theis-Cooper-Jacob solution is valid for. The local conditions of the well site may surprise the executor by different discrepancies with the basic model. These fundamental equations led to development of several technologies of hydrodynamic testing, in which one or another of the restriction could be overcome without changing the theoretical essence of the source. Following this principle, all known methods sought to consider the features of the object that distinguish it from requirements of the basic theoretical model in these specific circumstances. For example: geometry of the reservoir; leaky aquifer; unconfined aquifer, and few other. There were also suggestions of methods which only hypothetically satisfying the initial requirements. An eloquent example is the Horner's method, commonly used for interpretation the pressure/level recovery curve in a well. Strictly speaking, it is valid under the following conditions: the aquifer/layer is confined; top and bottom are impermeable; the aquifer/layer is an infinite in the plan; the sediments/rocks satisfy Hooke's law; and the entire thickness of the reservoir is

open from the top to the bottom. There is no chance to meet such ideal conditions in the nature. Failure to perform at least one of listed conditions leads to an error in the result, in this case, is a water conductivity. This message has not a purpose to analyzing this method more comprehensively. Therefore, I will quote the Walton's conclusion to end this introduction. “Diverse results and vexations will arise if attempts are made to force the application of formulas to aquifer situations differing greatly from ideal conditions”, Walton [1983]. Following his statement, we can conclude: all applied methods do not provide a complete assessment of the object through the known hydrodynamic studies, and the parameters and characteristics that are formally calculated, do not have an enough accuracy. This is a direct consequence of the Walton’s analysis. The proposed method of mine reduces this uncertainty due to recognizing the hydraulically homogeneous area around the pumping well through the test data and yields the results that are pertaining to it. The method determines the hydraulic type of the aquifer (confined or unconfined) by default, and adapts the result considering this feature. And so on. Please scroll further.

Alternative knowledge

I believe the reader is quite familiar with the ability of all modern methods of aquifer and oil well tests for parametric evaluation of these objects. Therefore, let me right now to show the ability of the developed methodology.

The report for the user of the software comprises of two parts. First part presents the full set of hydrodynamic parameters and characteristics for three modes of filtration which are presenting in a space of depression cone at the time of the test. They are printed like a single table form of three parts of modes or three separate table forms. Modes of filtration get an identification symbolic. For elastic mode it is (j), for elastic-gravitational mode it is (jg), and for gravitational mode it is (g). Each table form has three columns for three aquifer nominations. They are shown by using the user's definitions.

Table 1. Report, part 1. Hydrodynamic features

Property	Symbol	Dimension	Target Interval of Aquifer	Effective Interval of Aquifer	Aquifer Genuine
Transmissivity	T	$m^2 d^{-1}$	+	+	+
Hydraulic conductivity	K	md^{-1}	+	+	+
Hydraulic conductivity effective	K_{ef}	md^{-1}	+	+	+
Diffusivity	D	$m^2 d^{-1}$	+	+	+
Storativity/ Storage (active water release)	S		+	+	+
Specific water release	S^*	m^{-1}	+	+	+
Porosity effective	m_{ef}		+	+	+

Hydraulic type			+	+	+
Thickness (virtual hydraulic image)	Mh	m	+	+	Geo
Porosity total	m_{tot}		+	+	+
Radius of the homogeneity area	R_j	m	+	+	+
Radius of the drainage area	R_{jg}	m	+	+	+
Radius of active runoff area	R_g	m	+	+	+
Response on the water withdrawal			+	+	+

Table 2. Report, part 2. Hydraulic features of the well, filter and its vicinity

Property	Symbol	Dimension	Formula
Transmissivity effective	T_w	m^2d^{-1}	
Transmissivity of filter	T_f	m^2d^{-1}	
Hydraulic conductivity of filter	K_f	md^{-1}	
Radius of turbulence	R_t	m	
Effective radius of well	R_{wef}	m	
Hydraulic imperfection index	Z_h	*share*	
Hydraulic imperfection head loss	ΔS_{hd}		
Partial penetration index	Z_p	*share*	
Partial penetration head loss	ΔS_{pp}		
Skin-factor structural	F_{st}	*share*	
Skin-factor effective	F_{ef}	*share*	
Formation loss factor	α	dm^{-2}	
Well loss factor	β	d^2m^{-5}	
Hydraulic efficiency of well	E_{ef}	%	

Note 1. Of course, it may seem that such report is overloaded with information, unnecessary for hydrogeologist engaged in some narrow segment of hydrogeology. Big cake always may be divided into parts. As required. This is the task of programming - the configuration of the report on request by the user. This comprehensive report will be kept on the file for another project with other need for information, without having to repeat the work physically.

Note 2. Please draw the attention on the effective and total porosity of the reservoir. They are determined in-situ. This is an especially important parameter for oil output industry to plan the best withdrawal. Total porosity is determined through use the step-drawdown test only. It is an additional characteristic to all other determinations.

Note 3. The pilot version of the software was developed for research aims only and was not intended for commercial use. The one who wants to see its result welcomed to visit the link http://www.elektron2000.com/article/2056.html The customer version of the software is waiting of its developer. As the practice shows the volume of works with interference methods is shortened due to the mentioned and other reasons. At the same time, the number of exploration wells and running wells grows over the globe.

Alternative Technology

What the technology is being offered and which is becoming unnecessary? The Fig. 1. and Fig.2. show this clearly. A network of observation wells to monitor the water level dynamics at time of pumping and after it is no longer necessary. Only inside the pumping well.

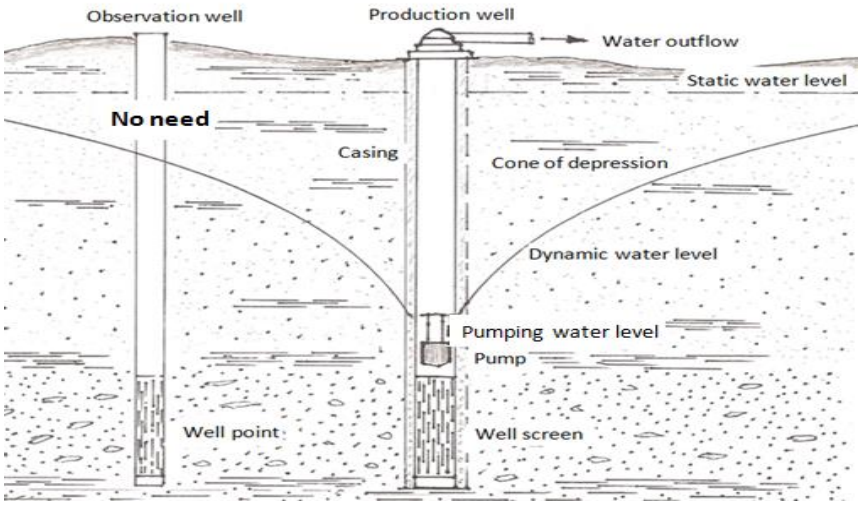

Fig.1. A piezometric well is now redundant

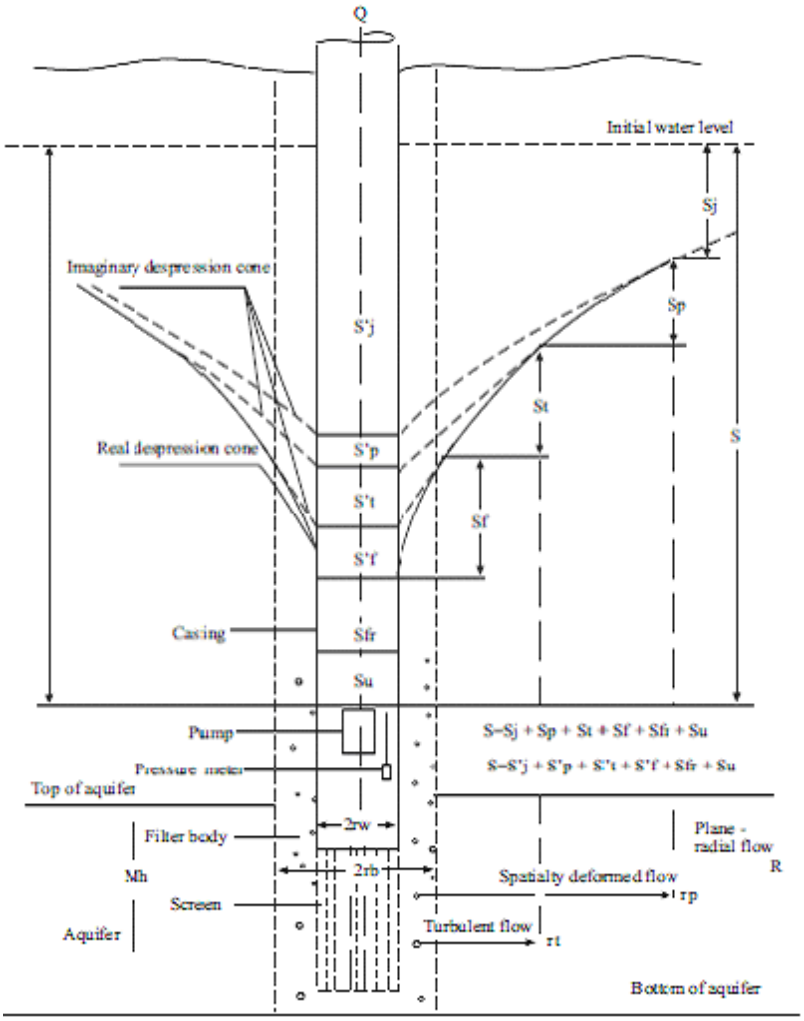

Fig.2. Schematic hydraulic model of a well-reservoir system.

This is the basic model. Inside the figure there are shown the balance equations of the pressure loss on the various virtual fragments of the depression.

The following figures show possible sources of data. All of them equally provide the same result in completeness.

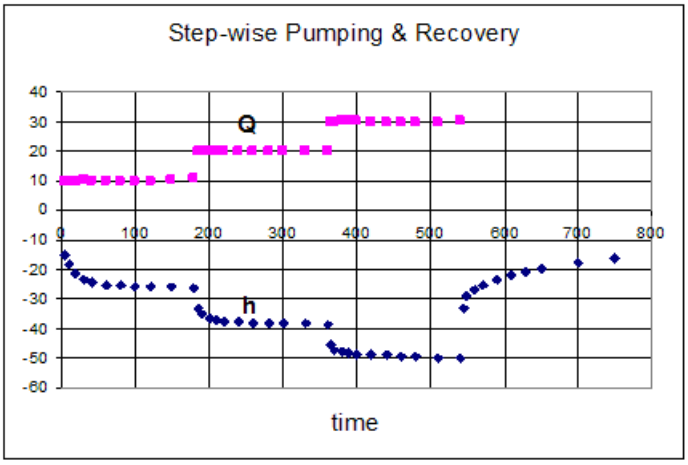

Fig.3. Multi rate pumping & Recovery test. It is accepted as a full version of the test.

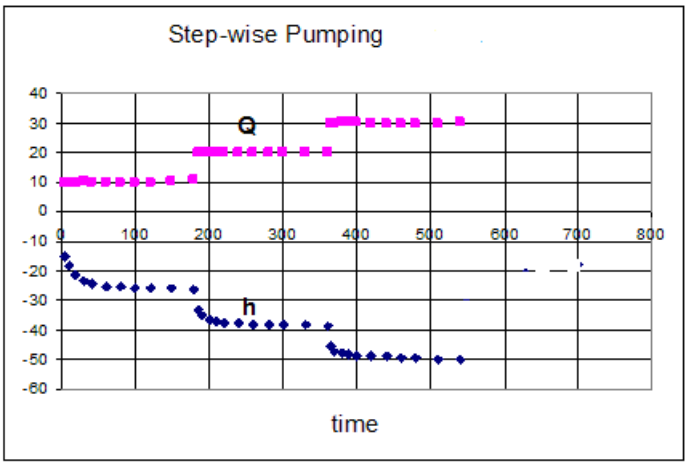

Fig.4. Multi rate pumping test.

This case presents a stepwise set of performance pumping at the production well. Recovery function, that is missing, is reproduced virtually through new theoretical findings. All other, including result, is the same as in the basic version.

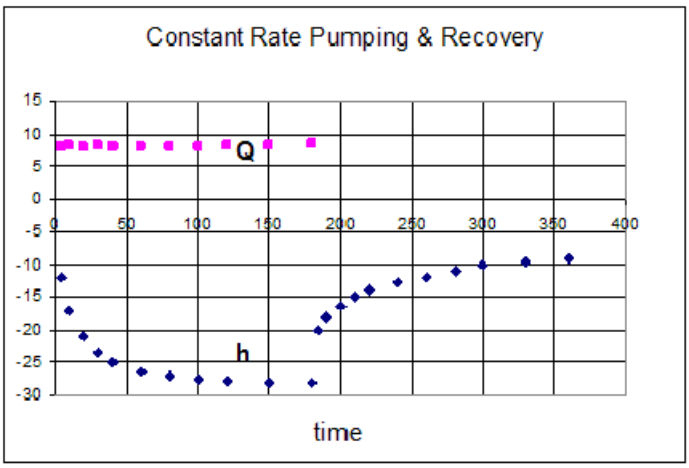

Fig.5. Constant rate pumping & Recovery test.

This is the basic version. This technology consists of transitional period of water level lowering after the pumping ON at the specified rate, and the recovery of water level after the pumping OFF.

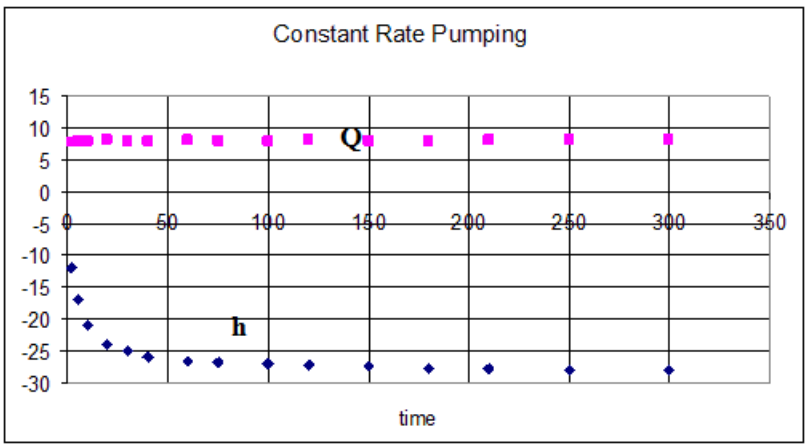

Fig.6. Constant rate pumping test (transition period at the beginning).

This version of the technology can be observed as a transitional process at the production well after the pumping ON. Data that are missing are reproduced virtually via new theoretical findings. All other, including result, is the same as in the basic version.

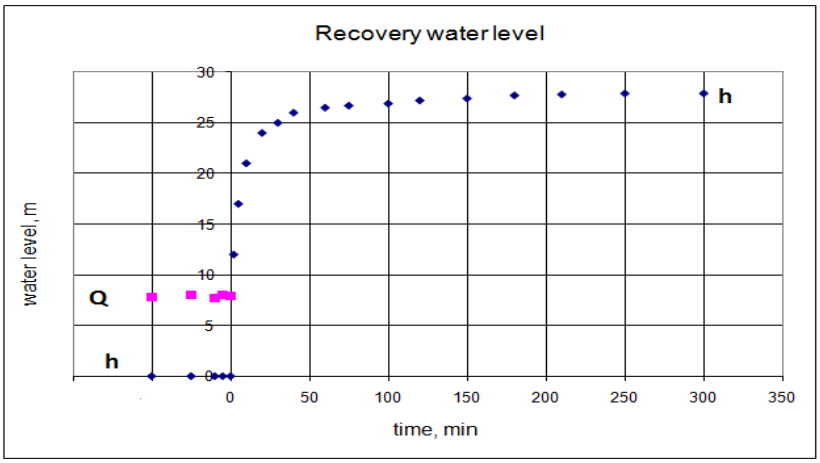

Fig.7. Recovery of water level after long-term pumping (transition period at the beginning). This version of the technology may be available on a production well which was running for a long time. Every case the pumping is stopped for any reason gives the opportunity to get data for calculation. Data that are missing for full set are reproduced virtually via new theoretical findings. All other, including result, is the same as in the basic version.

How has it become possible?

The fundamental Theis' solution is kept as the hydrodynamic template. But unlike known approaches the restrictions of this fundamental solution are not ignored. The clue to overcome this discrepancy was found through consideration of well-aquifer hydraulic system as a self-regulating system. As a closed physical system, it has steady laws that govern it. These laws were discovered via few novelties that were introduced in. Few of them are:

- The inflow function into a well was expressed as a function of variable mass motion.

- The forces of inner and outer spaces of the pumping well were 'bridged' via introduction of a new variable named "filtration viscosity".

- Fragmentation of depression cone onto virtual fragments of different modes of filtration was found out by theoretical means.

-Virtualization of drawdown and recovery functions one via another was found by theoretical means.

- Joint interpretation of drawdown and recovery functions was introduced into the method as the pioneering invention in this field of investigation.

-Formation loss factor determination was also the novel finding of ours as the functional characteristic.

These are only a part of the theoretical findings. The algorithm is analyzing the initial field data and adapts them to the Theis' model to keep it as the recognized template.

Advantages

The advantages of this new method are:
-it uses routine data of pumping rate and water level inside the pumping well;
-it processes data for pumping period and after it turns off jointly;
-it is applicable to any geological environment, type of reservoir, hydraulic type of aquifer, etc.;
-it is independent on well depth and well diameter.
Additional advantages to the above described ones herein are follows:
The method defines and evaluates parametrically (qualitatively and quantitatively): (a) target segment of aquifer where the screen installed; (b) effective segment of the aquifer's thickness that supplies water to the well screen. And also: hydraulic type of aquifer in regards of interaction with surface; sanitary protection areas (hydraulic definition) for planning; hydraulic features of the well's filter and its vicinity in situ (hydraulic conductivity, skin-factor, area of turbulence, and others). And at last, it can be adapted to the remotely monitoring systems of operating wells to obtain the same set of aquifer and well features automatically in time.

Benefit for user

This new software will provide a prompt practical benefit for the user if he will ask "why this method & software is superior to other available methods?" Table 3 and Table 4 below answer this question.

Table 3. Special data the explorer must have/know for

For use traditional method	**For use proposed method**
Pumping well	Pumping well
Lithological section	Lithological section
Observation well	No need
Hydraulic type of aquifer	No need
Reservoir type	No need
Boundary condition	No need
Homogeneous area	No need
Long time pumping	Short time pumping
Budget on pumping well plus	Budget on pumping well only

Table 4. The information that the explorer extracts from

From traditional method	From proposed method
Transmissivity of unidentified thickness of the aquifer	Transmissivity of separate parts of the aquifer for different types of water release
Unable	Hydraulic conductivity of separate parts of the aquifer for different types of water release
Diffusivity of unidentified origin within the aquifer's space	Diffusivity of separate parts of the aquifer for different types of water release
Storativity/Storage of unidentified origin within the aquifer's space	Storativity/Storage of separate parts of the aquifer for different types of water release
Unable	Specific storativity/storage of separate parts of the aquifer for different types of water release
Unable	Porosity and effective water release factor for separate parts of the aquifer and different types of water release
Unable	Thickness of aquifer separated relatively to the space and type of water release
Unable	Hydraulic type of aquifer
Unable	Area for sanitary protection
Unable	Set of hydraulic features of well-aquifer system

And finally

I started this science direction in Applied Hydrogeology at the end of 70-s of the past century in the former USSR and finished completely in Israel with a good result. I should thank colleagues of the Water Company of Israel (Mekorot), Water Planning for Israel (TAHAL), and the Israel State Water Service for support. This research has taken a lot of time as any pioneer idea. It is true that I was a lone conceptualist and the idea developer, but many assistants accompanied me in many related works, such as laboratory research and seminar experiments, field research, programming, computational work, etc. I am incredibly grateful them.

In science, you can say "done", but you cannot say "that's over." I see few new tasks for aquifer heterogeneity assessment. It seems me the concept of modeling is desirable to be modified too. Now it is a virtualization of the object's properties as the response to the observed effect. And the opposite approach is also possible: the virtualization of the effect as the reflection of the natural picture of properties distribution in a space of the object. The combination of these two approaches in one is the path to the reliability of intellectual modeling, it seems to me.

The developed methodology provides the opportunity to reinterpret the old data which are storing in archives without use.

Or another problem that seems me as an urgent one. It is a parametric monitoring of existing wells equipped by automatic devices for flow rate and water level recording. Any change in the operating mode of the well is accompanied by a transient process. This is quite enough to compute the hydraulic state of the wellbore zone and the environment itself on-line.

Note. Somebody may ask why I did not publish these results for acknowledgement of the professional community. This is a natural question. But the answer is not so simple. I'm an emigrant in Israel since 1991. Here I was engaged as a freelancer with small income. I had no affiliation to any university. That time it was unlikely. So, this research here became my hobby. This restricted me for application for grants or discount in payments for publication in leading journals. From another side. All this work was like folding a mosaic carpet with vague stencil and an incomplete set of pebbles. How can this be published in parts? And who will agree to this? When the carpet took shape, it became oversized. For example, my attempt to publish the theoretical article on parts in the Water Resources Research ended unsuccessfully. So, if someone wants to get full content of this development, he will find a road to the place where it will be stored.

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underground hydrodynamics, reservoir properties, hydraulics of well-aquifer-environment system, pumping withdrawal influence, depression cone fragmentation.