ISSN: 0974-5823 Vol. 7 No. 1 January, 2022

*International Journal of Mechanical Engineering*

# A geomechanical model to predict the start of sand production, a case study

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## Abstract

**This research presented a model to predict the production of sand in any type of oil reservoir. In this model, the geomechanical aspects (the deformation of rocks and their failure due to instability) that cause the problem of sand production. A comprehensive form is presented, while developing sand production prediction models, we note that the primary purpose is consistent with sand production models for other applications. This ensures an anticipation of research continuity is an approach amid anticipating start sand production and continuation as soon as it happens. One of most economic problems facing the production of hydrocarbons from oil reservoirs with incoherent sandstone is the production of sand. Once the production of hydrocarbons begins, the sanding start prediction model is very important, in order to identify areas where sand production occurs and to make a decision to control sand in the future, including whether the sand. Control should be used or not, or when sand control is used. We have developed an easy-to-use mathematical model to determine the starting sand production sites in the driven area, this model is based on the estimation of the critical pressure drop that occurs when sand production starts. The results were plotted as a function of free sand production with allowable critical flow rates as a function of tank pressure drop.**

**Keywords: Logging data, rock mechanics parameter, sand prediction, interface drawdown pressure.**

**نموذج جيوميكانيكي للتنبؤ ببدء إنتاج الرمال، دراسة حالة**

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الخلاصة

قدم هذا البحث نموذجاً للتنبؤ بإنتاج الرمل في أي نوع من مكامن النفط. في هذا النموذج، درس الجوانب الجيوميكانيكية (تشوه الصخور وفشلها بسبب عدم الاستقرار الطبقي) التي تسبب مشكلة إنتاج الرمال. تم تقديم نموذج شامل. أثناء تطوير نماذج التنبؤ بإنتاج الرمال، يجب ان يكون الغرض الأساسي يتوافق مع نماذج إنتاج الرمال للتطبيقات الأخرى. استمرارية البحث وهو نهج توقع بدء إنتاج الرمال واستمرارها بمجرد حدوثها. يعتبر إنتاج الرمال من أكثر المشاكل الاقتصادية التي تواجه إنتاج الهيدروكربونات من مكامن النفط وخاصتا ذات الحجر الرملي غير المتماسك. بمجرد أن يبدأ إنتاج الهيدروكربونات. فإن نموذج التنبؤ ببدء الصنفرة مهم جدًا، من أجل تحديد المناطق التي يحدث فيها إنتاج الرمال واتخاذ قرار للتحكم في الرمال في المستقبل، بما في ذلك السيطرة على الرمال. يجب استخدام التحكم أم لا، أو عند استخدام التحكم بالرمل. لقد طورنا نموذجًا رياضيًا سهل الاستخدام لتحديد معدل بدء إنتاج الرمال في المنطقة المدفوعة، ويستند هذا النموذج إلى تقدير انخفاض الضغط الحرج الذي يحدث عند بدء إنتاج الرمال. تم رسم النتائج كدالة لإنتاج الرمال الحرة مع معدلات التدفق الحرجة المسموح بها كدالة لانخفاض ضغط الخزان.

## INTRODUCTION

During oil flow sand production is considered due to interrelated mechanisms in primary production (rock failure). Mass production of sand may cause adverse effects and problems on well and production equipment. However, the procedures followed to control sand production tend to reduce the rate of oil production. Numerical studies and research were conducted to predict the start of sand production in oil reservoirs, depending on the stability and failure of the reservoir rocks **(Willson et al., 2002)**.The following equation was used in this model to start the sand production calculations. Calculation of downhole critical flow pressure that causes sand granule production to occur. It is based on a simple clear standard, along the assumption that it is flexible behavior. The hole can be considered as a well (to complement the open hole). The direction of the well or well is reflected in the calculation of the main pressures be perpendicular to the bore direction and variation of the main causative stresses that affects the site **(Willson et al., 2002)**. This systematic method calculates a parameter called load factor (LF), which ultimately indicates the ratio of the maximum effective girth stress to the effective rock strength. When for LF > 1, the reservoir rock collapse will occur and sand production may be expected. For LF < 1, the rock will be stable and the well should produce free sand **(Willson et al, 2002 , Rahman et al 2010)**.

### Application of geomechanics in oil and gas industry

Geomechanics is an important discipline and plays a major economic role in the petroleum industry. It also becomes an essential and integrated section for each field stage from the initial stages of exploration to abandonment, as shown in **(Figure 1)**. Geomechanics used for forecasting and estimating in-situ core and pore pressures, evaluating drilling performance, estimating safe mud weight window, wellbore stability, well course optimization, shear and collapse of casing, forecasting and controlling sand production, feasibility of unbalanced drilling, and characterization of broken reservoir, and maximizing production which is affected by natural fractures, hydraulic fracturing, fluid vapor injection, reservoir pressure. Therefore, the geomechanical model is an essential essential part of future planning for field development **(Soroush, 2013).**

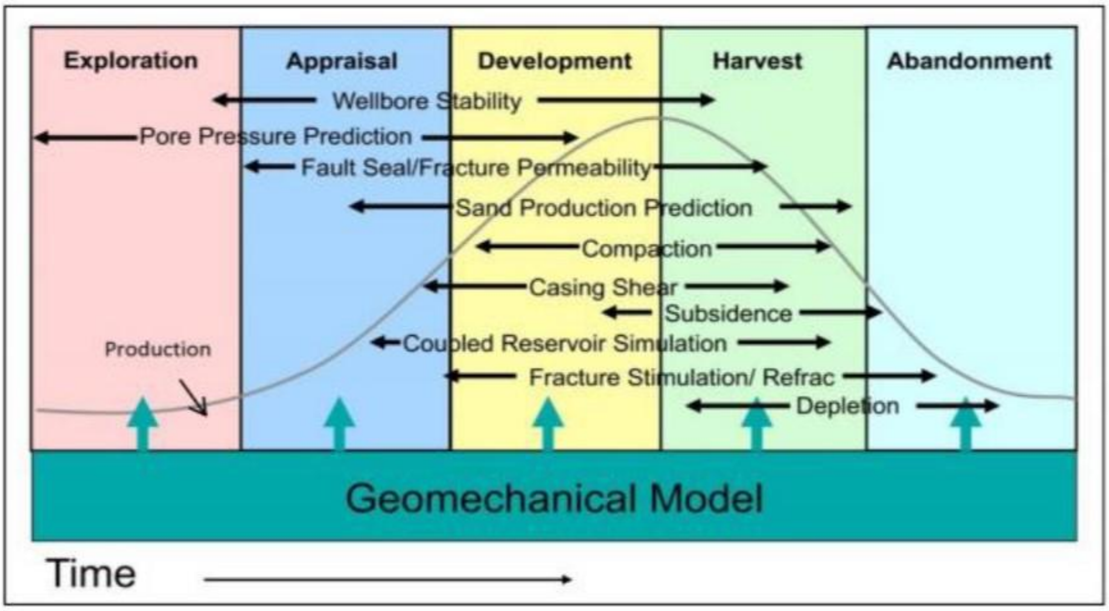

Figure (1). Geomechanics role during the field life **(Zoback, 2007)**.

### Sand Production from Reservoir

Formation stability is a major concern in petroleum engineering. Failed formation around the well may cause major and serious problems during various conditions of production of hydrocarbon fluids due to failure problems in well rocks in incoherent sandstone reservoirs during the production of hydrocarbon compounds, a process called sand production, sand production erosion damage occurs to the bottom of the well and to the surface. A better understanding of the failure mechanisms of weakly cohesive sand formations is extremely important for sand production management, which in turn enables cost-effective production of oil and gas resources. The term sand production refers to the production of solid particles from oil reservoirs with effluent hydrocarbons. The term "solid production" is often used instead of "sand production" because chalk or coal bed formations can also produce solid materials while the term "sand production" only refers to production from weak sandstone layers.

### Relationship of the force of the formation, U, to force measured.

During the study of sand production models, effective pressure called collapse pressure is used and this process is called thick-walled hollow cylinder (TWC) test and collapse pressure is used as a measure of the force acting on wells and holes. This is identical to the original study. The specimen used has usual dimensions for TWC specimens measuring 1½" OD x" ID x 3" long **(Veeken. et al.1991).**

It was noted that the relationship between the applied force TWC and the effective effective force in the site of the well rocks, U, is essential because the TWC test is not done directly on the reservoir rocks, but rather takes place in the laboratory. The efferent effective force can it is represented by TWC force where the OD / ID ratio tends to infinity. There is also a problem with identifier scaling, as sample dimensions may exceed 0.5 inch when using a bore sample in low strength sandstones (Willson et al., 2002). The relationship between the size and thickness of the samples was also studied and this difference was shown by **(van den Hoek 2000)**. They found it for Castlegatesandstones, with OD/ID ratio, the max size effect is between (3.0 and 3.8), an in-house research was conducted by BP in TWC for a number of sized sandstones with different OD/ID ratios, results were obtained as in the figure **(Figure 2).**

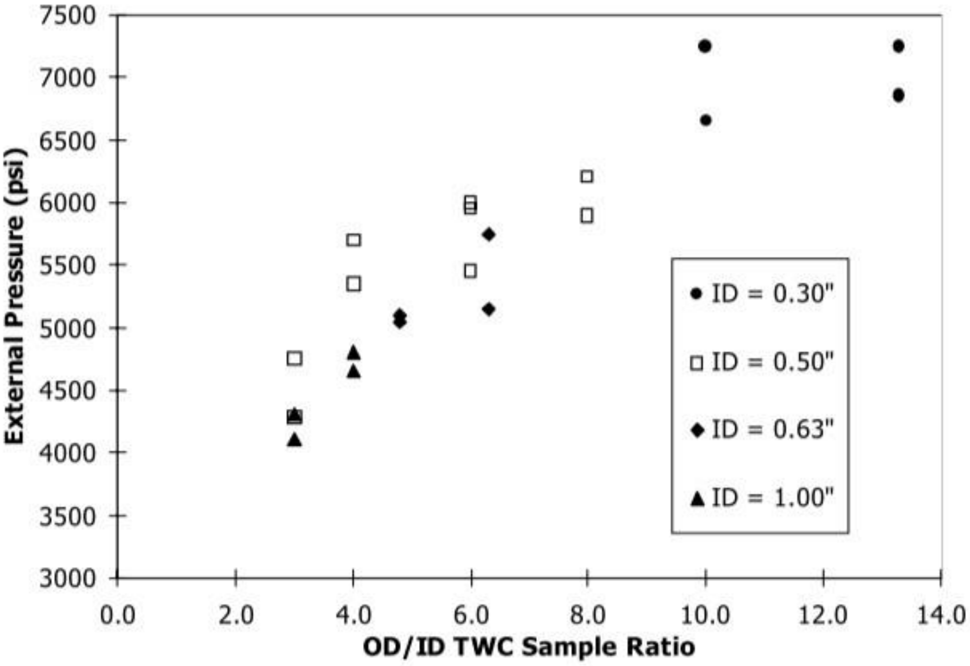

Figure 2. Relationship of TWC collapse pressure for each sandstone model and with varying OD/ID ratios (Willson et al., 2002).

**Sand production mechanism**

In sandy layers with poor cohesion and hardening, the beginning of sand production occurs in two stages: the first stage is failure and the second stage is transfer. If the stresses generated in the stratum and around the well exceed the bearing strength of the formations surrounding the well, the sandstone will eventually fail. Then, as the hydrocarbon flows from the reservoir to the well, it carries with it the failed sand **(Figure 3)**. Sand production can be prevented or reduced by finding a prediction of the failure stage and thus mitigating its severity. Most of the sand production problems that occur are in unconsolidated sand deposits, caused by the sand arc formed around the well **(Younessi et al., 2013)**.

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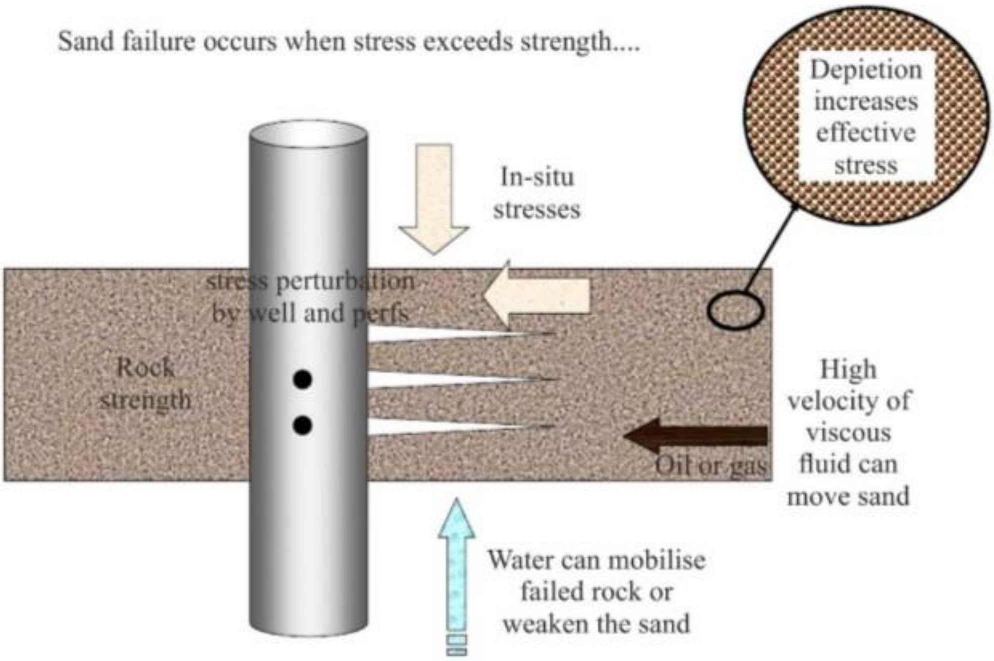

Figure 3: Shows failure of sand due to weak strength of rock (Abass et al., 2002).

Once the sandy stratum fails, fluids flowing from the stratum into the well causes a pulling force of the sandstone causing some sand particles to separate into the borehole and fall into the bore. Fine sand grains, especially in formations with weak cohesion, begin to flow due to the force of pulling pressures happened because of hydrocarbon oil flow into the well. Moreover, sandy grains that settle in the porous medium near the wellbore, can it redirect fluid flow state and changes the direction and amount of stress applied, creating additional stresses. Generally, as soon as the exceed induced stress effect of the reservoir rock strength, we will notice an increase in the production quantities of sand **(Matanovic et al., 2012)**.

### Sand production from experimental operations

It was observed necessary to perform in vitro experiments on cylindrical samples under isotropic strain conditions and compared with real triaxle strain conditions **(Mogi, 2006)**. Several laboratory sand production experiments were conducted on industrially manufactured samples that simulate well conditions. It was found through the best laboratory research to conduct these experiments on sand samples taken from natural sandy rocks, but this is subject to some basic limitations. First, it is practically difficult to take a sample from the well that is intact without being damaged, especially if the sandstone is weak and not cohesive. Second, the physical properties and mechanical properties of the reservoir rocks from which they are taken may not be homogeneous, while it is possible to work in the laboratory models with homogeneous properties and qualities that may be acceptable **(Perkins and Weingarten, 1988)**. During the geomechanics case study, the state from the pressures of acting around borehole is resulting the occurrence of three basic stresses; One of them has a vertical pressure effect, and the other one be horizontal. As a result of the research, different patterns of failure were observed around the well bore. Failure patterns were categorized by the state of stresses near the well **(Bratton et al., 1999)**.

### Geometry of failed zone

he geometry of the failure area (i.e. width and depth) means the shape of the failure area is affected by the pressure sizes and pore pressures the extent of stress around the wellbore is a function of the extent of unchanged original stress, stress perturbations related to well completion, and the effects of pore medium pressure depletion associated with fluid flow during long-term production **(Risnes et al., 1982)**.

### Rock Strength Criterion

There are four commonly used criteria for estimating rock strength by analyzing well bore stability and its use in predicting sand production. Several shear failure criteria such as von Mises criteria, Mohr-Coulomb, modified Lade criteria, and Drucker- Prager, and others have been suggested in literature **(McLean and Addis 1990; Simangunsong et al., 2006; Maury and Sauzay 1987; Zhang et al., 2006; Morita and Ross 1993).**

### Standards for wellbore stability and sand failure

There are a group of factors causing the instability of the wellbore, which can be considered on a specific scale either to be controllable or to be naturally uncontrollable in the first place. Uncontrollable factors are caused by natural ground movements such as natural faults or fractures, tectonic stresses, high in situ pressures, and mobile formations, natural collapse of oil shale caused by overpressure or overpressure, unconsolidated formations, etc. The factors that can be controlled are downhole pressure (drilling fluid density) or valve opening changes during production, transit pore pressure, well slope and physical/chemical interaction of rocks with fluids, erosion and temperature **(Bowes and Procter 1997; McLellan 1994; Mohiuddin et al. 2001; Chen et al. 1998)**. Beforehand starting to mention a variety of models that are used in predictive calculations of the occurrence of sand production, it is important at determine the main cause of well rock failure. Therefore, is not necessary when the rock grains are eroded and separated from the wall of the well bore, it does not necessarily mean that the borehole rocks have failed and that they have become subject to the sand grain production process. This results in a deformation of the wall, which does not mean that the well has failed **(Matanovic et al., 2012).**

Before starting the borehole drilling process, the rock in stress equilibrium state. ground stresses in under these conditions field stresses define in situ or remote pressures ($\sigma_V, \sigma_h, \sigma_H$. During the well drilling process, the pressures around the bore of the borehole as the pressures it is redistributed as follows firstly provided excavated rock being replace it with hydraulic pressure. for clay) **(Gaurina-Međimurec 1994)**. The stresses can be represented as perpendicular or heavy stress$\sigma_V$, as for the horizontal stress $\sigma_H$, it will be two, (maximum horizontal stress in-situ), and $\sigma_h$ (minimum horizontal stress in-situ), which are generally unequal stresses **(McLean and Addis 1990)**. the tensile strength surpasses the compressive state, which is redistributed, the strength of the rocks, whether under pressure causing instability or tension. **(Figure 4)** shows that the pressures distributed around the borehole after the drilling process. It is described as tangential stress$\sigma_t$ , radial stress, or circumferential stress$\sigma_r$, axial stress $\sigma_a$. The radial stress is effective at all directions around well and perpendicular to the bore wall of wellbore, and tangential stress surrounds borehole and axial stress is acting similar to the bore axis of the wellbore. Likewise, wellbore pressures quickly changes with depth the well, shifting to far field pressures. This is because it will be far from the well. So the effect of radial stress changes to a minimum the effect of horizontal stress$\sigma_h$, and the tangential stress is approximately equal with the maximum horizontal stress$\sigma_H$.

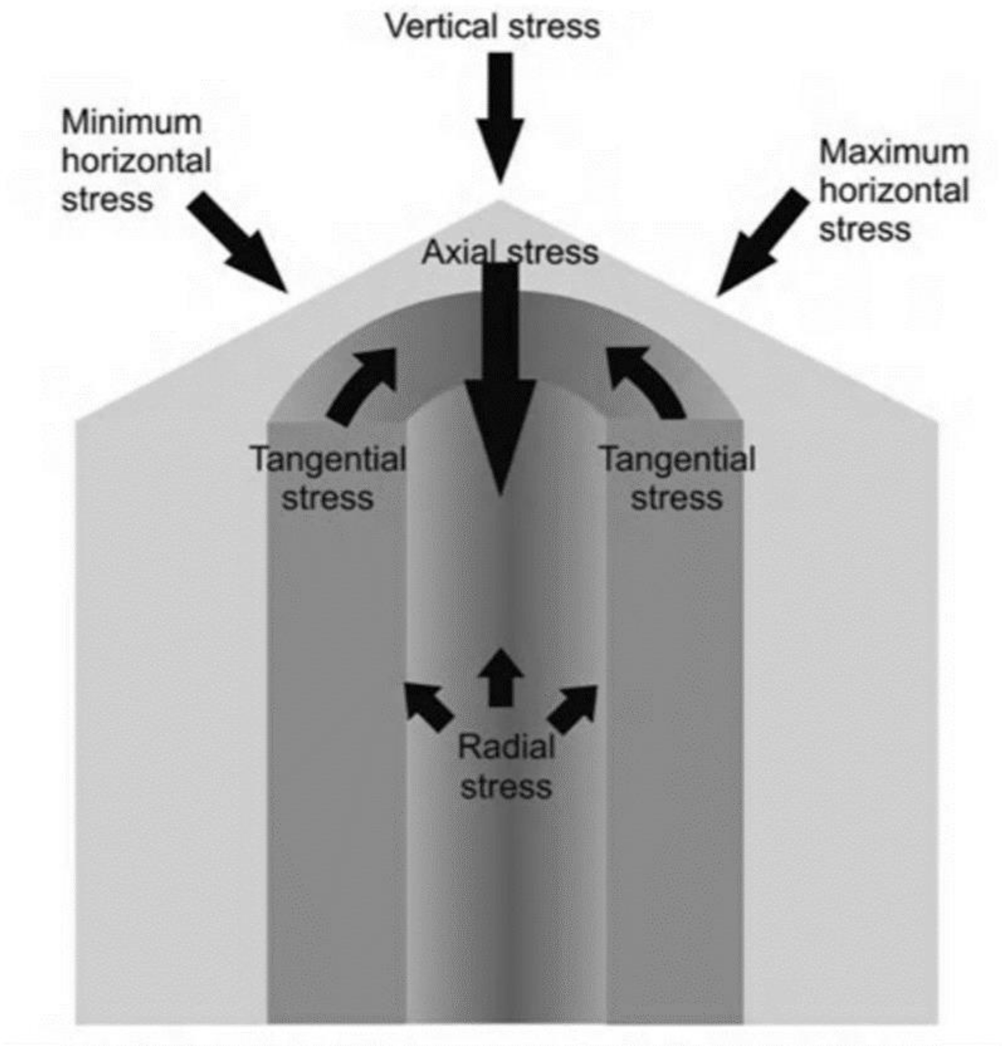

Figure 4. Stresses affecting the borehole (Matanovic et al., 2012).

A change in the local pressure distribution (in-situ pressures) around the borehole can occur by a combination of mechanical, hydraulic, chemical and thermal effects. **(Figure 5)** illustrates the coordinate referral system used to calculate and distribute the pressure around the borehole, which can be subject to the influence of on-site pressures as well as other hydraulic influences. The local stresses due to the effect of site stress and hydraulic belongings acting on wellbore wall can be described by (r = rw), and the vertical well can represented at follows **(Fjær et al. 2008).**

$$\sigma_t = \text{pw} \tag{1}$$

$$\sigma_t = (\sigma_t + \sigma_t) - (\sigma_x - \sigma_y)\cos 2\Theta - \text{pw} \tag{2}$$

$$\sigma_a = \sigma_z - 2(\sigma_x - \sigma_y)v\cos 2\Theta \tag{3}$$

**Where**:

| | |
|---|---|
| $\sigma_x$ | Normal stress with x-direction. |
| $\sigma_y$ | Normal stress with y-direction. |
| $\sigma_z$ | Normal stress with z-direction. |
| $\sigma_a$ | Axial stress in wellbore. |
| $\sigma_t$ | tangential stress. |
| $\sigma_r$ | radial stress. |
| $v$ | Poisson’s ratio. |
| Pw | pressure wellbore. |
| Θ | Point location angle, degrees |

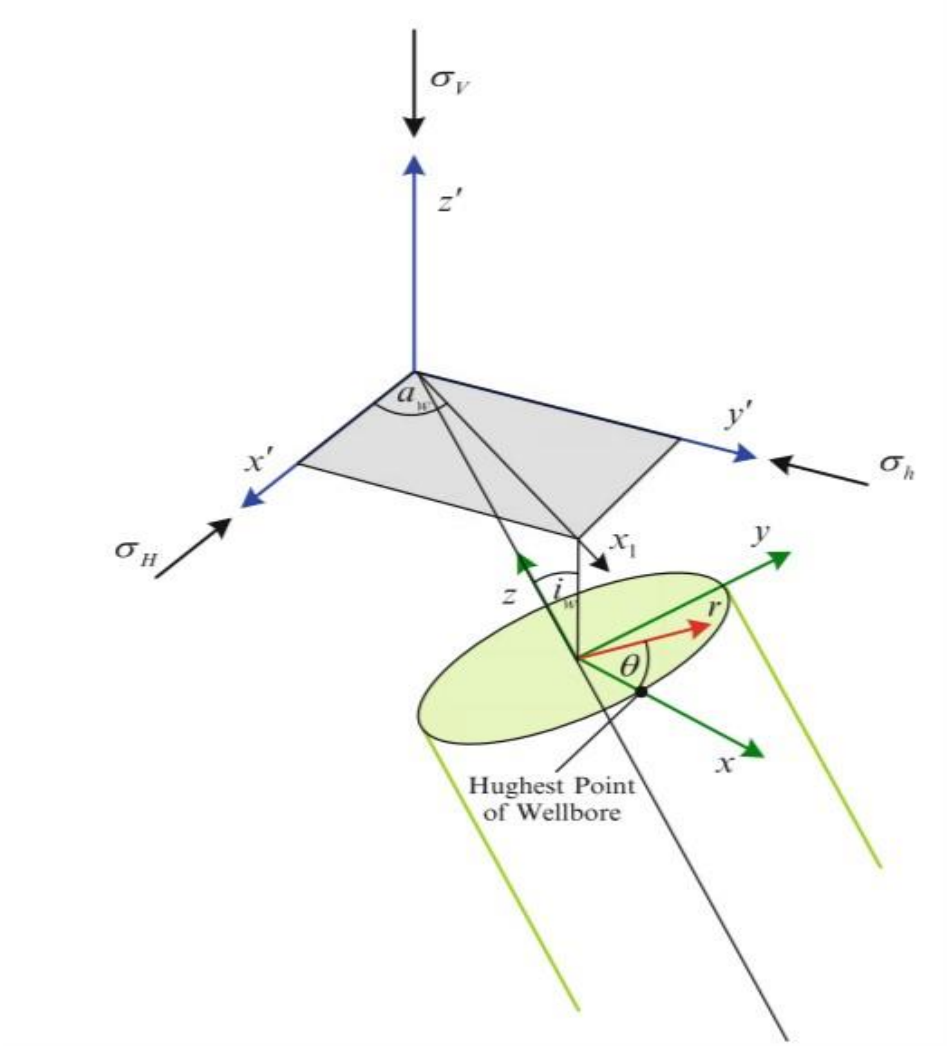

Figure 5: Well Formation Coordination System **(Pasˇic´ et al. 2007)**.

It can be concluded from the previous equations, that the radial stress$\sigma_r$ is due to wellbore pressure or depends on the weight of the service liquid. The case of tangential pressure depends on the state of the normal pressure, which is in (x) direction x, and the normal pressure depends in (y) direction y, the slope of the angle between the anchor on the wall of the well and the direction of maximum horizontal stress y and bottom pressure and the amount at horizontal pressure the minimum stress , the $\sigma_a$ axial stress depends on the $\sigma_z$ amount of standard stress acting in the z- direction, the$\sigma_x$ normal stress in the direction x, the amount of $\sigma_y$normal stress in the (y) direction , and either the Poisson ratio of the rock (v) , the angle between a point at wall of the well , in the direction of $\sigma_H$maximum horizontal stress **(Matanovic et al, 2012)**.The case of local pressure acting at well (r = rw) due to various influences can be expressed as:

$$\sigma_r = 0 \tag{4}$$

$$\sigma_t = \frac{\alpha_P(1-2\mathrm{V})}{1-\mathrm{V}}(pw - Pp) + \frac{E\,\alpha t}{3(1-2\mathrm{V})}(Tw - Ti) \tag{5}$$

$$\sigma_a = \frac{\alpha_P(1-2\mathrm{V})}{1-\mathrm{V}}(pw - Pp) + \frac{E\,\alpha t}{3(1-2\mathrm{V})}(Tw - Ti) \tag{6}$$

Where:

$Pp$ pore pressure.
$Ti$ formation initial temperature
$Tw$ wellbore wall temperature.
$\alpha t$ volumetric-thermal-expansio.
$\sigma_a$ Axial stress in wellbore.
E Young’s modulus
$\sigma_t$ tangential stress.

$\sigma_r$ radial stress.
$v$ Poisson's ratio
Pw pressure wellbore.
$\alpha_P$ Biot's constant.

It is necessary to calculate the stress around the borehole caused by thermal and chemical belongings. Pore pressure change can be done by the movements of liquid in or from oil rock strata due to hydraulic pressure, electrical, chemical influences. Pore pressures can be estimated using the available equations mentioned in the relevant literature **(Awal et al. 2001; Lomba et al. 2000; Ottesen and Kwakwa 1991; Zhang et al. 2006)**. In order to study the possibility of stability of the well bore, and that the search and establishment are realistic and logical. Therefore, an accurate and appropriate the form must be used for calculate stress or pressures around the borehole. The calculated then the stresses must be compared using an accurate specific failure criterion. Several large shear failure criteria for rock stratums, such as Drucker- Prager, Mohr-Coulomb, modified Lade criteria, von Mises, etc. have been proposed in literature**. (Simangunsong et al. 2006; Zhang et al. 2006; Maury and Sauzay 1987; Morita and Ross 1993; McLean and Addis 1990).**

**Mohr Coulomb criteria**
The Mohr-Coulomb model is the most commonly used and most important model to assess well rock collapse. But this model ignores the main intermediate pressure but includes the case of the influence of the directional force of the shale. The shear failure criterion includes the pore pressure and the maximum principal stress $\sigma_1$, the constant $\alpha_P$of Biot, it sums the relationship with the cohesive force of Co, internal friction angle, and minimum principle stresses $\sigma_3$ , the following equation illustrates this

$$\sigma_1 - \alpha_P * Pp < \mathrm{Co} + (\sigma_3 - \alpha_P * Pp) * tan^2 \varphi \qquad (7)$$

Where:

$Pp$ initial pore pressure.
$\sigma_1$ maximum stress.
$\sigma_3$ minimum stress.
$\sigma_r$ radial stress.
Co cohesive force.
$\alpha_P$ constant of Biot.
Φ internal friction angle.

It was found that tensile failure occurs when the amount of pressure resulting from the weight of drilling mud used during drilling operations exceeds the amount of tensile strength of the formation rocks. Excessive weight produced by drilling mud causes hydraulic pressure condition, deforming the rock matrix. Thus, tensile failure occurs when amount of the effective core stresses is s3 and is reinforced by the pore pressure through reservoir rock that exceeds the amount of the tensile strength of the formation. Mathematically, this parameter can be summed and expressed in the following equation (8), **(Zhang et al. 2006; Simangunsong et al. 2006)**:

$$\sigma_3 - Pp < T_O \qquad (8)$$

Where:

$Pp$ initial pore pressure.
$\sigma_3$ minimum principle stress Pa
To tensile strength

It can be assumed that tensile strength is zero, in theory, a fracture begins in an existing defect, joint, or breakage. To apply the standards in the equation (8). The major stress is subject to stress shifts. The tensile stress magnitudes **(Bowes and Procter 1997)**. The production of sand of different composition is a non-aggregated or incoherent result. sand grains around the borehole. These formations typically contain low rocks or medium cohesion strength with petite or no intergrading adhesive/ bonding materials but in practice, sand granules can also be produced from high strength reservoir rock formations with the good bond of the grain. In either case sand production begin proximately or it can later lead to the life cycle of the well.

When any decision is taken during the production operations management as to whether or not to follow which method to controller sand production, is implemented based the integrated geomechanical model used to control sand production. **(Rahman et al. 2010)** proposed a universal standard for the collapse of reservoir rocks, which is a function of reservoir pressure and changes in rock strength as a result of impacts, hole spacing and direction, and well bore path. The aim is to estimate the sand production problem through the approach shown in the workflow in (**Figure 6**).

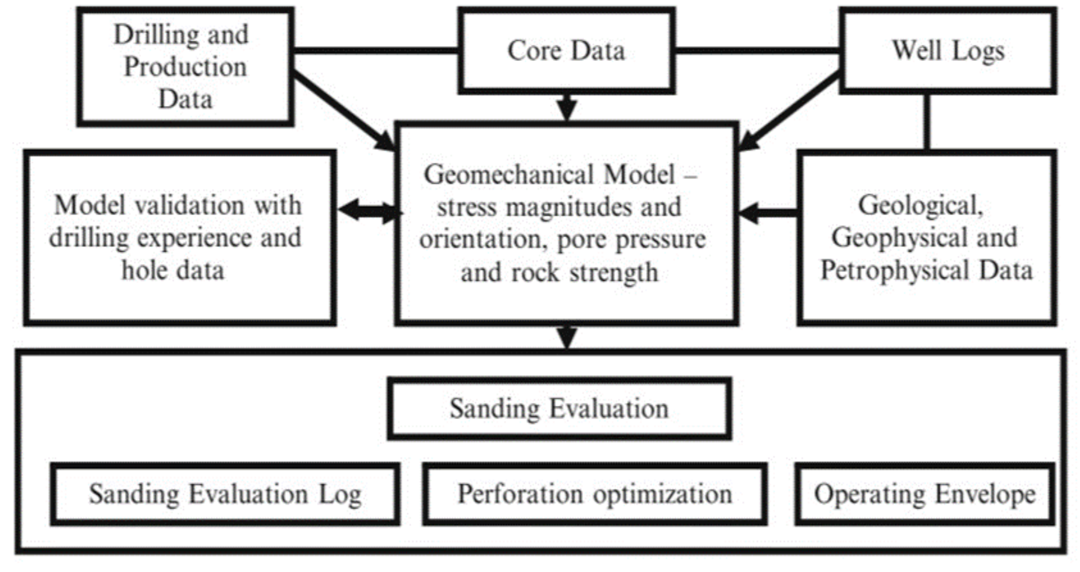

Figure 6: Workflow of sand assessment **(Rahman et al. 2010)**.

A decent model to choose with appropriate control of sand production provides combination from geomechanical representation (LF rating), Well improvement condition limits such as (well trajectory depending on the direction of maximum effective pressure and direction of the well).
For the purpose of avoiding sand production, the tangential pressure (t2), relative to the total far field pressures$\sigma_{t2}$ $\sigma_1 > \sigma_2$ , with downhole pressure, it must be smaller than effective force of U formation Wilson et al. (2002).

$$\sigma_{t2} - Pw < U \qquad (9)$$

Where:

Pw wellbore pressure. Pa
$\sigma_{t2}$ largest effective tangential stress. Pa
$U$ effective strength formation.

The location of the tangential stresses at the edge of the well wall can be considered as in **(Figure 7)**. The tangential stress acting on surface of well wall, maybe you can be follows as:

$$\sigma_{t1} = 3\sigma_2 - \sigma_1 - pwf(1 - A) - A\,Pe \qquad (10)$$

$$\sigma_{t2} = 3\sigma_1 - \sigma_2 - pwf(1 - A) - APe \qquad (11)$$

Where:

Pw wellbore pressure.
$\sigma_{t2}$ largest effective tangential stress.
$\sigma_{t1}$ tangential stress at wellbore.
$\sigma_1$ maximum stress.
$\sigma_2$ minimum stress.
$Pe$ reservoir pressure (far field).
$pwf$ bottom hole flowing pressure.
A poro-elastic constant.

These equations give the relationships between the transverse stresses at surface of the hole wall st1,2, and the reservoir pressure downhole flow pressure pwf, and the poroelastic constant A (defined in equation 12):

$$A = \frac{(1-2*V)\,\alpha_P}{1-V} \qquad (12)$$

Where

| | |
|---|---|
| A | poro-elastic constant |
| $v$ | Poisson’s ratio for rock. |
| $\alpha_P$ | constant of Biot |

$$\alpha_P = 1 - \frac{cr}{cb} \qquad (13)$$

Where

| | |
|---|---|
| $\alpha_P$ | constant of Biot. |
| cr | bulk compressibility rock. |
| cb | grain compressibility. |

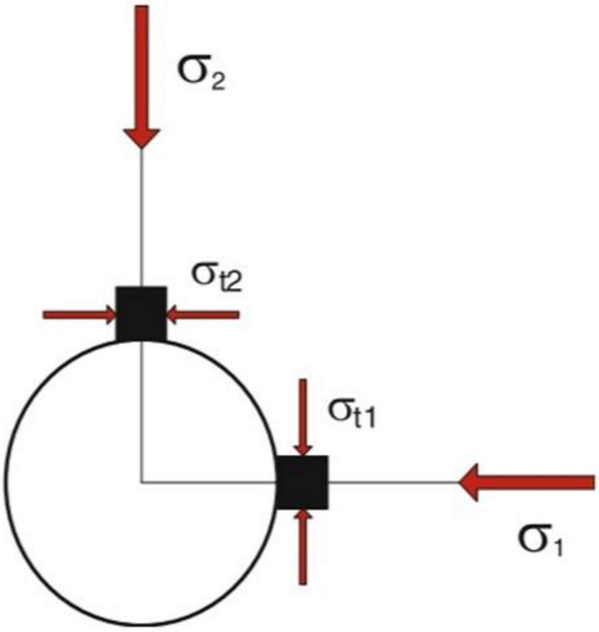

Figure 7. Tangential of stresses on wellbore wall **(Wilson et al. 2002)**.

The critical bottom hole flow pressure (CBHFP) causing sand production can be estimated as:

$$pwf \geq \text{CBHFP} = \frac{3\sigma_{t1}-\sigma_{t2}-U}{\rho_{ma}-\rho_{fl}} - Pe\,\frac{A}{2-A} \qquad (14)$$

Where:

| | |
|---|---|
| Pw | wellbore pressure. Pa |
| $\sigma_{t2}$ | largest effective tangential stress. Pa |
| $\sigma_{t1}$ | Tangential stress at wellbore, Pa |
| $Pe$ | reservoir pressure |
| $pwf$ | bottom hole flowing pressure |

A poro-elastic constant
$U$ effective strength of the formation.
CBHFP Critical bottom hole flowing pressure, Pa
$\rho_{ma}$ density of mass gm/cc
$\rho_{fl}$ density of liquid gm/cc

The sand production process is caused by the pressure difference mechanism between the reservoir pressure and the well pressure i.e. (pwf = pe - CDP); CDP is an expression for effective intake pressure, you can find a relationship amid CDP and Reservoir pressure:

$$Pe = 0.5(3\sigma_{t1} - \sigma_{t2} - U + \text{CDP}(2 - A)) \qquad (15)$$

or

$$\text{CDP} = \frac{1}{2-A}\left(2\,Pe - (3\sigma_{t1} - \sigma_{t2} - U)\right) \qquad (16)$$

Where:

$\sigma_{t2}$ effective largest tangential stress.
$\sigma_{t1}$ Tangential stress at wellbore.
$Pe$ reservoir pressure.
A poroelastic constant.
$U$ effective strength of the formation.
CDP Critical drawdown pressure.

The effective strength U, of rock formation can be calculated at numerous ways, but often use called thick cylinder test (breakdown pressure of sample TWCsp). In the laboratory specimens of various sizes are used and subjected to laboratory testing, one of which has a size of 31.8 mm [1.5 in] OD out diameter, 12.7 mm [0.5 in] ID in diameter 76.2 mm [3 in]. The acceptable relationship is:

$$U = 2 * 1.55 * TWC_{SP} = 3.1TWC_{SP} \qquad (17)$$

Included term load factor (LF) as:

$$LF = \frac{\sigma_{t2} - pwf}{U} \geq 1 \qquad (18)$$

Where:

$\sigma_{t2}$ largest effective tangential stress.
$pwf$ bottom hole flowing pressure.
$U$ effective strength of the formation.
LF Loading factor, dimensionless.
$TWC_{SP}$ collapse pressure of the specimen.

This means at LF < 1, formation rock will not fail then for LF > 1, formation rock fail and sand is produced.
load factor, LF = f (in-situ pressures, well trajectory, reservoir pressure, retreat and exhaust, TWC force).

**Field case for sand production rate forecast:**

The sand production rate prediction model was applied to a number of wells in two fields. first field has two wells and petroleum production rates range between 2000-20000 barrels per day. The second field has four wells and high production rates reaching 38000 barrels per day. Over time, the well records showed that the total production rates decreased to nearly half The initial production quantity, with an increase in water production of more than 90%. For the fields that were studied, the effect of force on the reservoir rocks was studied by making thick-walled and unconfined cylindrical measurements.

Thus, it is possible to determine the extent of the impact of the different pressures. In situ stresses were estimated using the previous steps. The results of the study analyzes predicting the sand production rate for wells are presented at Figures (8, 9), for field A wells. (Figures 10 to 13) for field B wells.
The comparison of (Figures 8, 9) can be seen simply in terms of the change in the expected sand production rates for the production of. (Figures 10,11,12,13) also showed the effect of cut off the measured water, where it was noticed that there is a difference in

some cases clearly during the period studied. In (figures 8,9,10,11,12,13), a well-defined flow condition is observed. Thus, good measurements of oil, sand with water production rates, as well as surface flow through downhole pressures, were made. The field data used to validate sand production model it is the best available. In general, sand production prediction model is able to give sand production good results, although it is limited in its prediction, and it is measured when two to four factors are available. Good results were obtained for oil-producing wells (figures 8 and 9). Expected rates 3000 to 4000 barrels per day usually provide a limit to those measured. In those wells. The water cut-off in the figures (figures 10-13) is still somewhat acceptable, due to how representative the water produced is in the model. For example, if a well is produced with a cut-off of 50% water, the 50/50 oil-through model is assumed in the measured model. This increases the "boosting agent" used to produce the water shown in (figure 6). (Figure 14) shows a sand flow distribution for well B/1 for the following specific production terms: 77% cut with water and 29.690 bbl/d of total oil production; The drop is 592 psi and the pressure drop is 265 psi. The total sand production projected full perforation period is 119 lbs/day, equivalent to an average sand yield of 4ppm. In this figure there is a formation permeability distribution. Porosity is associated with shaping strength (low strength, high permeability). figure shows a line whose transmittance ranges from 9,927 ft to 9,930 ft and is expected to yield 12

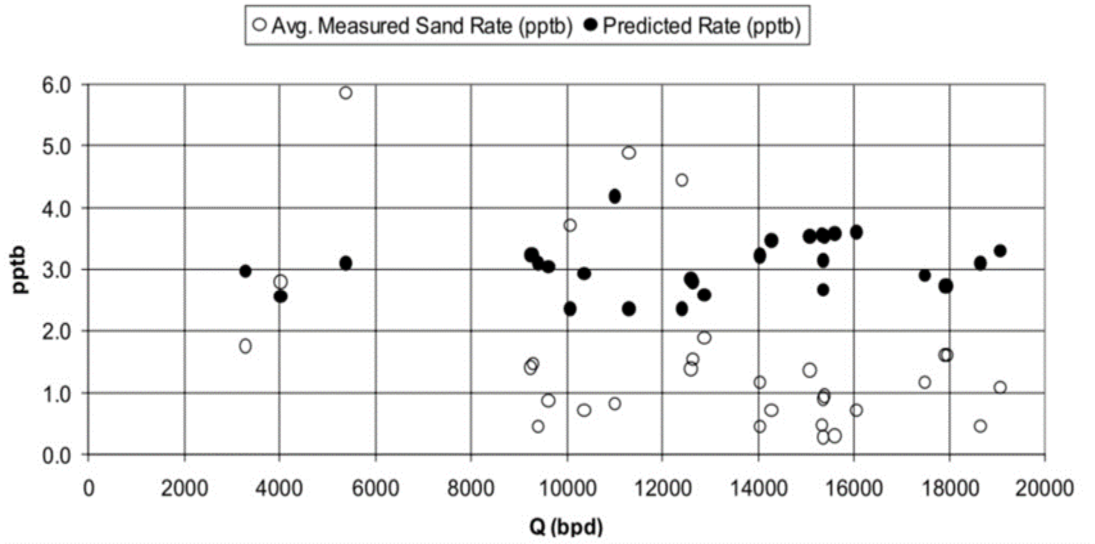

Figure 8. Sand Production Rate vs. Predicted Measured, Field -A, Well NO-1

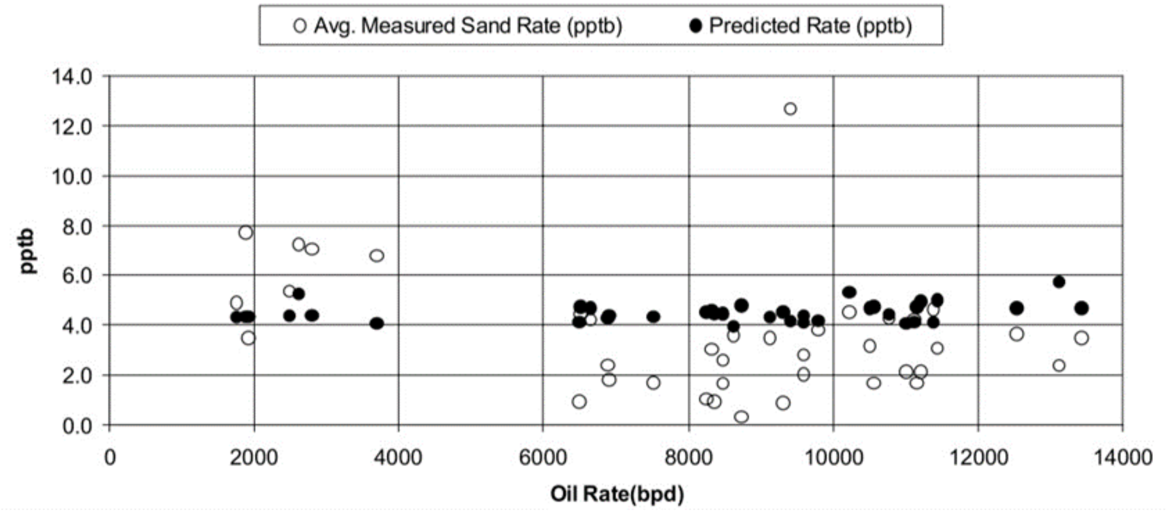

Figure 9. Sand Production Rate vs. Predicted Measured, Field -A, Well NO- 2.

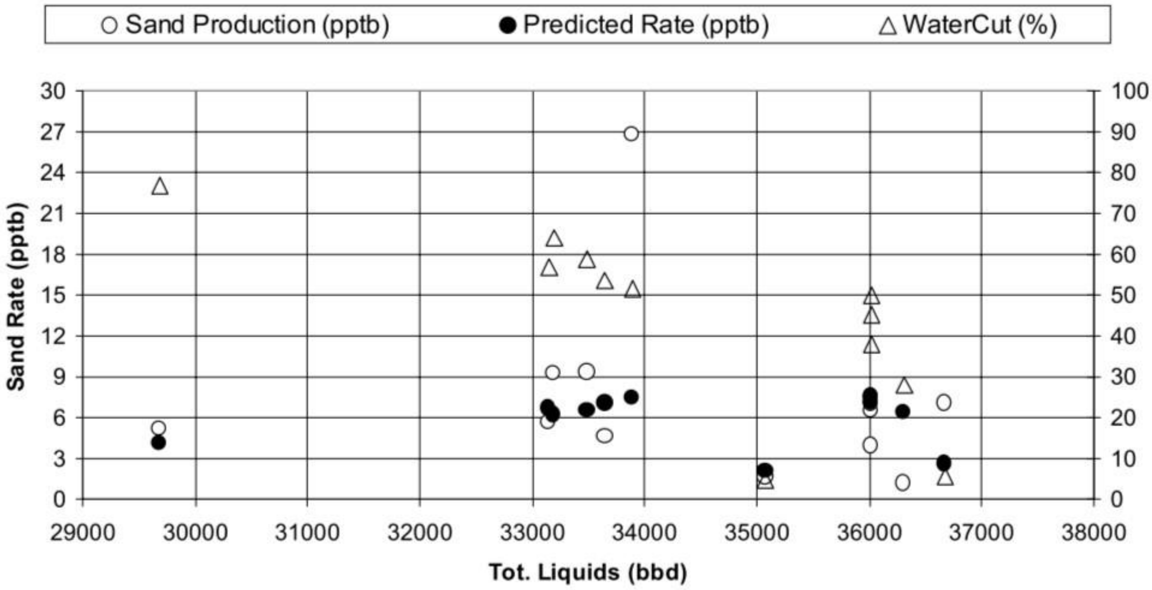

Figure 10. Predicted vs. Sand Production Rate, Field B, Well 1.

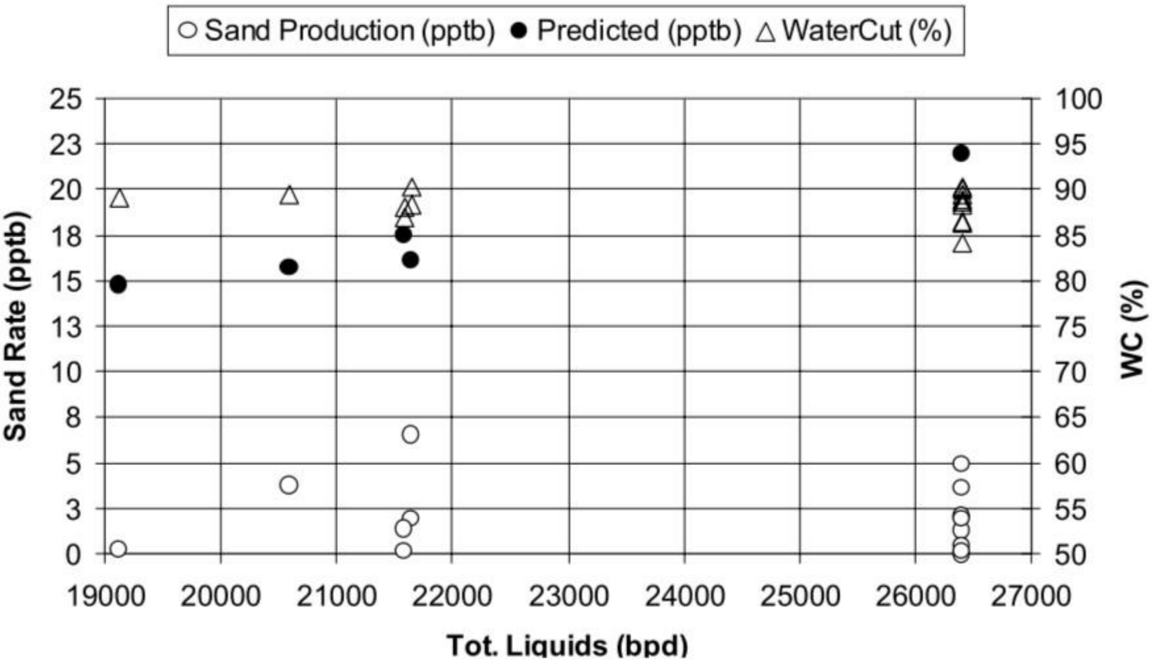

Figure 11. Sand Production Rate vs. Predicted Measured,Field B, Well NO-2

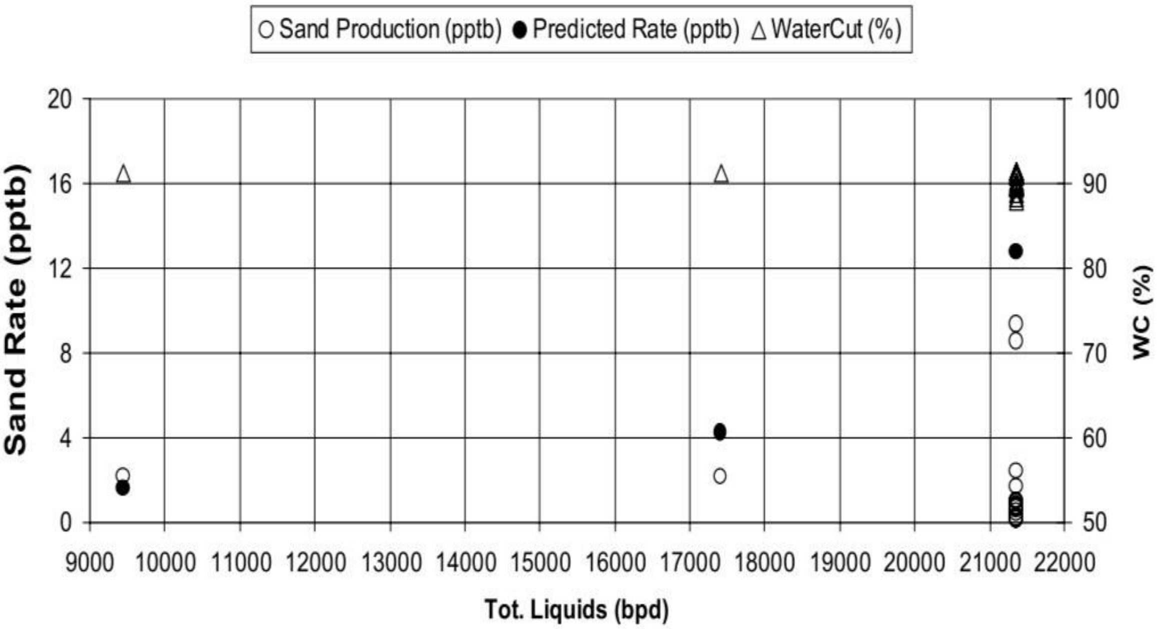

Figure 12. Sand Production Rate vs. Predicted Measured, Field B, Well NO- 3.

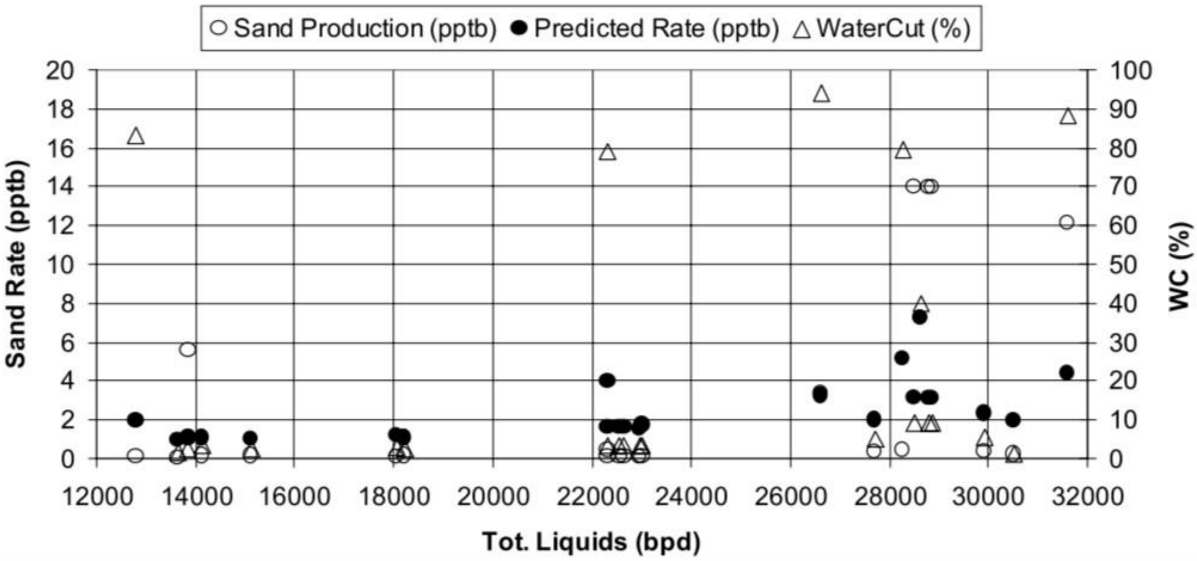

Figure 13. Sand Production Rate vs.Predicted Measured, Field B, Well NO- 4

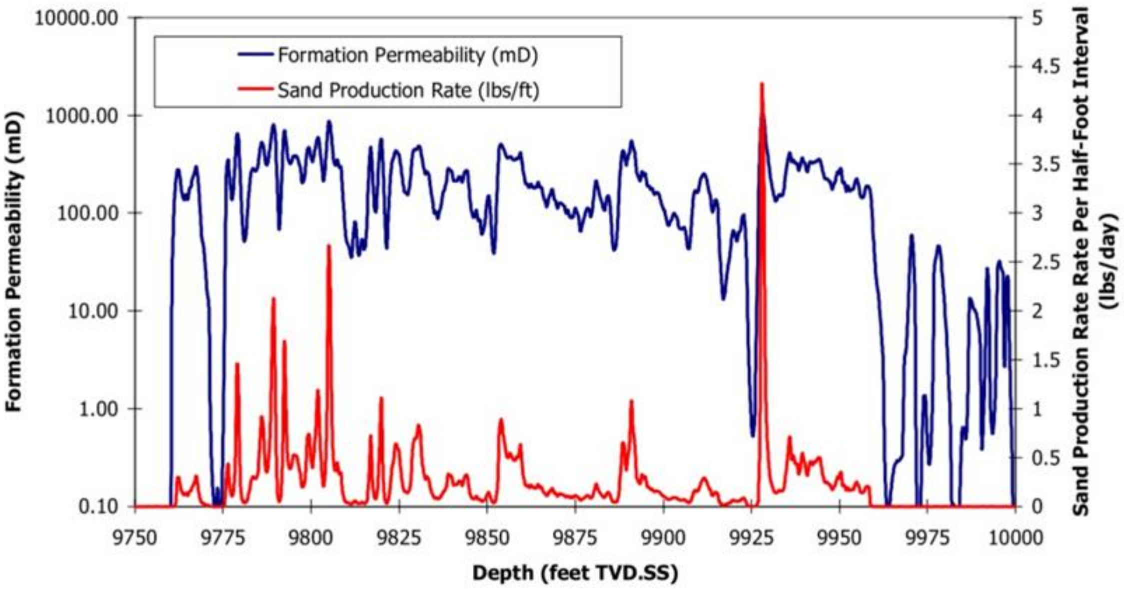

Figure 14. The expected distribution of sand production for Field B, Well NO- 1, under specific production conditions.

## Conclusions

1- Description of the empirical method and interpretation of field data on sand production that can be used as a rationale for finding reliable methods for predicting sand production.

2- The concept of a "load factor" can have a sand production rate model derived from being consistent with existing models used to predict sand production.

3- The production engineer can calculate sand prediction analysis, in a specific area need a lot of field data, the engineer can also take advantage of the easy calculator programs that facilitate the task.

4- This method is used to calculate the critical flow rates for the productive layer. It was observed that the expected critical flow rate is in good agreement with the data. However, the most accurate forecasts are based on accurate field data for each region during the production period.

## Nomenclature

A: Poro-elastic constant,
Aw: Well azimuth. Dimensionless
Ap: Biot’s constant, dimension-less
At: Volumetric-thermal-expansion-constant, K?1
Co: Cohesive strength, Pa
cb: Grain compressibility,
cr : Bulk rock compressibility, pa
CBHFP: Critical pressure bottom hole flow, Pa
CDP: Critical drawdown pressure, Pa
DH: Vertical- compaction, m
De: Change at void ratio, dimension-less
Eo: Original void, dimensionless
E: Young’s modulus, Pa

h formation thickness, f

Iw: inclination Well, degrees
LF: factor Loading, dimensionless
Pe: Reservoir pressure, Pa
Pp: Pore pressure, Pa
Ppi: pore pressure Initial, Pa
Pw: bottom hole pressure, Pa
R; Near wellbore position, m

Rw: radius of Wellbore, m
Ti: Initial temperature of formation, K
To: Tensile strength of rock formation, Pa

Tw: temperature bottom hole, K
TWCsp: Collapse pressure of the specimen, Pa
U: strength Effective, Pa
n Poisson ration, dimension-less
$\sigma_{t2}$ effective tangential stress largest, Pa
$\sigma_{t1}$ Tangential stress at wellbore, pa

$\sigma_1$ maximum stress, pa
$\sigma_2$ minimum stress, pa

σx, σy, σz principal stresses along the Cartesian coordinates

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