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Review of Sand Production Control and Management

Mustafa Adil Issa[1,2*], Ali Nooruldeen Abdulkareem[3], Farqad Ali Hadi[2], Muntadher Adil Issa[2,4], Muhanad Al-moamen[1], Ahmed Jasim[1]
[1]*Basra Oil Company, Basra, Iraq*
[2]*Petroleum Engineering Department, College of Engineering, University of Baghdad, Baghdad, Iraq*
[3]*Petroleum Engineering Department, College of Engineering, University of Misan, Misan, Iraq*
[4]*Iraqi Drilling Company, Basra, Iraq*
*** Corresponding author:** Mustafa Adil Issa, Email: m.issa1908m@coeng.uobaghdad.edu.iq
Ali Nooruldeen Abdulkareem, Email: ali.nooruldeen@uomisan.edu.iq
Farqad Ali Hadi, Email: farqadali@coeng.uobaghdad.edu.iq
Muntadher Adil Issa, Email: muntadher.issa2008m@coeng.uobaghdad.edu.iq

Abstract: Production of the sand becomes a significant problem throughout the life of wells, especially in poorly consolidated reservoirs. This issue frequently leads to tube buckling and abrasion of the down-hole and surface equipment as a result of the inflow of sand. In addition, the costs associated with the loss of hydrocarbon production, work-over operations, and the processes related to the repair and re-installation of the electrical submersible pumps (ESP), and the need for disposal of sand in an environmentally acceptable manner. In this article, the difficulties with sand production that arise during drilling and production operations are thoroughly reviewed. The consequences and mechanisms of sand production, the factors influencing sand production capacity (i.e., sand production causes), as well as the remedial options were discussed. Eventually, this article can be utilized as a reference for any issue concerning sand production in oil and gas wells.

Keywords: sand production, pore pressure, flow rate, reservoir fluid, wellbore collapse.

1-Introduction

Sand production assigns to the transport of sand grains by producing reservoir fluid from the formation rock into the wellbore [1]. It is a critical case that affects the production of the well and casing stability. The primary reason for the production of the sand is the instability of the wellbore and the failure of the perforation tunnel in unconsolidated and poorly consolidated reservoirs [2]. The perforation tunnel's stability depends on far-field stresses, reservoir pressure, the strength of rock, wellbore pressure, and geometry of the perforation [3], [4]. Conventional sand control mechanisms are firstly based on installing sand screen, frac-pack, and gravel pack. It's desired to predict the stability of the perforation and the possibility of sanding before the completion engineers decide to determine which sand control procedures are needed [5].In reality, sand production can be divided into three categories:

Transient sand production: It indicates the concentration of the sand, and it declines with time under a constant production rate. It usually is observed through clean up after perforation, acidizing, and water breakthrough operations.

Continuous sand production: It is encountered through production from sandstone formations (i.e., unconsolidated reservoirs) that do not contain the sand control equipment.

Catastrophic sand production: It is the worst status and frequently takes place when the reservoir fluids are overmuch produced.[6].

Willson et al. (2002) utilized a new analytical model to prophesy the rate of sand production using the non-dimensionalized notions of Reynolds number and loading factor. They used the outcomes of sanding from laboratory experiments to create an empirical relation between Reynolds number (Re), sand production rate (SPR), and loading factor (LF), which integrates the impacts of water production. In other words, SPR = f (Re, LF, and water cut), [7]. Palmer et al. (2003) developed a new strategy for managing and predicting the production of the sand. This strategy is divided into three stages, including the onset, transient and steady-state sanding [8].Araujo Guerrero et al. (2014); Isehunwa & Olanrewaju (2010); Junmano et al. (2016); Pham (2017); Yi et al. (2004); and many others, conducted extensive research to develop models capable of predicting how much sand will be generated as a function of fluid types, flow rate, reservoir pressure, drawdown pressure, formation properties, formation strength and stress, and other crucial factors. These models could be helpful for a variety of field activities, such as controlling and monitoring sand production, improving well completion designs, and boosting productivity.[9]–[13]. Furthermore, no model can determine the danger of sanding under a specific set of field circumstances [12], [14].

This article provides a comprehensive overview of sand production problems, concentrating on the consequences and causes of sand production that may arise during different activities. Additionally, the factors affecting sand production were explained. Finally, sand control and management methods were addressed to reduce the sand issue.

2- Sand Production Consequences

2.1. Formation Subsidence

Production of a large volume of formation sand can cause a collapse of the formation around the wellbore. Over time, avoid or an empty area is increased gradually and becomes large enough behind the casing as more formation sand is produced. The overlying formation sand or shale above the void or an empty area may subside into the hole due to the lack of the provided materials used for support. Moreover, the sand grains can be accumulated and then reduce the formation's permeability to a value lower than initially existing. Eventually, the collapse of formation can lead to filling the perforation tunnels with formation material. Thus, at a given flow rate, the pressure drop is increased near the wellbore.

2.2. Subsurface Accumulation

Sand accumulation takes place when the velocity of production fluid is not adequate to transport the grains up to the surface. Over time, the grains are accumulated in the tubing or casing. Consequently, the production rate will reduce or cease due to the perforation intervals filled with formation sand. In such circumstances, the work-over operations are usually required for the well to restart production.

2.3. Down-hole and Surface Equipment Erosion

In high productivity wells, the sand produced with reservoir fluid at high velocities can generate excessive erosion in down-hole equipment and surface facilities. Consequently, maintenance works are required to change the equipment that has been damaged.

2.4. Accumulation in Surface Facilities

Sand accumulation occurs when the velocity of production is sufficient to move sand to the surface equipment. Sand grains are usually settled in surface facilities such as flowline systems, separators vessels, heaters, condensers, and pumps. If the amount of sand is large enough in one of these facilities, disposal of accumulated sand becomes inevitable. In this situation, the well is shut-in (deferred production), and the cost associated with clean-up activity should consider [15], [16].

3- Causes of Sand Production

The parameters that impact formation capability to sand produce can be divided into fluid flow and formation strength effects [17].

3.1. Tectonic Stress

Tectonic stress is more significant near the top of the structures and the faults and results in joints or micro-cracks created as a result of breaking the internal framework of the original rock. The strength of the stone for these locations is weak, and sand production happens quickly and severely. Thus, more caution should take for these locations [18].

3.2. Pore Pressure Reduction

Production of reservoir fluid over time depletes the reservoir pressure due to the formation of pore pressure reduction. In general, lowering the pressure of the reservoir can lead to an increasing amount of stress that is applied to the sand formation. In other words, the vertical stress increases. The grains from sandstone formation at some point may be crushed or loose from their matrix. Subsequently, the sand grains are possibly produced along with hydrocarbon fluids. In addition, the formation might collapse when the effective stress overrides the formation strength due to reservoir rock compaction resulting in pore pressure reduction [19].

3.3. Degree of Consolidation

Refers the ability to remain the perforation tunnels is open (i.e., closely tied to how strongly the individual solid particles are bonded together). Commonly, the formations with young tertiary age have a tenuous cementation material connecting the grain particles; these formations are typically unconsolidated. The

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property of the rock mechanical related to the consolidation degree is named unconfined compression strength (UCS). In general, the magnitude of compressive strength for the poorly consolidated sandstone reservoirs is less than 7 MPa. Fig.1 show the failure of sand due to the weak strength of rock [20].

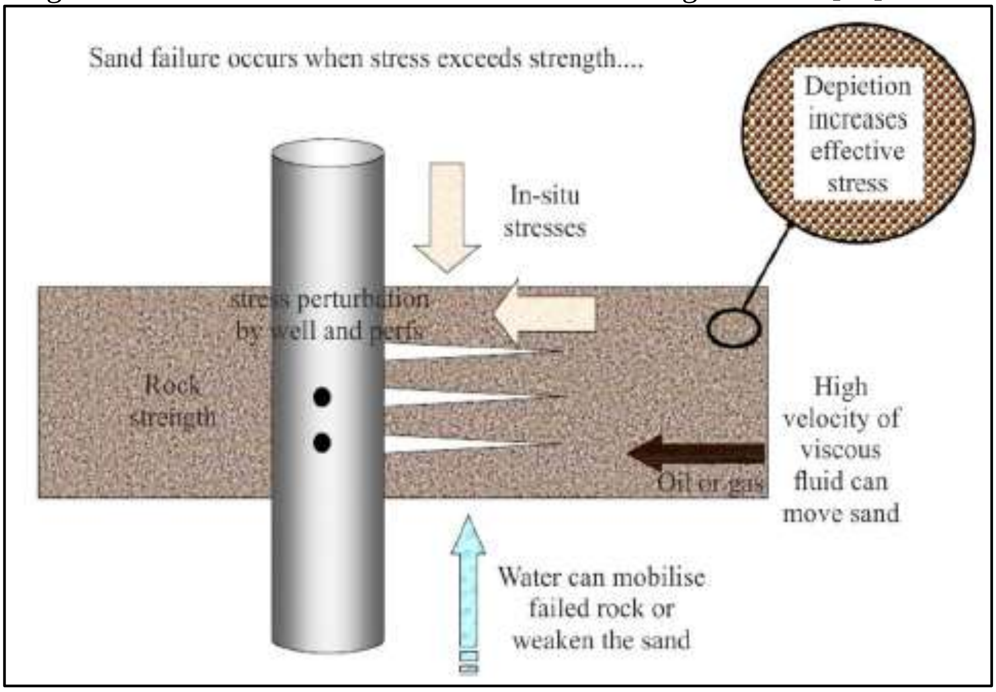

Fig. 1. Show failure of sand due to weak strength of rock [20].

3.4. Heterogeneity of Formation

The effect of heterogeneity involves significant two aspects: far-field stress and permeability. In-situ stress covers rock stress, overburden stress, formation pore pressure, production drawdown, and frictional force on rock result in fluid flow. There are diverse rocks with various failure modes and different stress effects under the same force due to some parameters such as developmental conditions and diagenetic environments. For unconsolidated sandstone formations, heterogeneity of stress results in the formation shear yield in some orientations is more accessible than other orientations and subsequent the pay of original structure will fail, production of sand will take place [18].

3.5. Production Rate

Increasing of the production rate due to high drawdown pressure (i.e., the difference between the pressure of the reservoir and bottom-hole flowing pressure) can lead to sand production. Typically, the production of the hydrocarbon fluid generates differential pressure and drag forces that may override the compressive strength of the formation. As a result, most of the production wells have a critical flow rate; below this rate, the drag forces and the pressure differential are insufficient to overcome the strength of the rock and lead to sanding. A critical rate is determined via increasing the rate of production slowly till the sand production is revealed. Furthermore, one technique utilized to minimize sand production is a choke size surface valve. Using this technique, the critical flow rate can be achieved, in which the sand does not happen or has a reasonable level [19], [21].

3.6. Increasing water production

The sand production is increased as the water cut increases. Two mechanisms explain this incidence. First, when the wettability of the sandstone reservoir is water-wet. In this case, the cohesiveness among some grains is supplied through the surface tension force of irreducible water around each grain particle. The connate water (irreducible water) can adhere to produced water at the beginning of the production. Consequently, the cohesion force between the sand grains is decreased due to the reduction of the surface tension force. As shown in Fig.2, the sand arch stability around perforation tunnels is bounded by water production resulting in the production of the sand grains [22]. A second mechanism that influences sand production is relative permeability that relates inversely to the water cut. It can increase the differential pressure needed to produce the reservoir fluid at the same flow. Thus, increasing the differential pressure close the perforation tunnels generates higher stresses across the sand formation. This condition may cause the unstable sand arch surrounding perforation; consequently, the production of the sand will occur [15], [19].

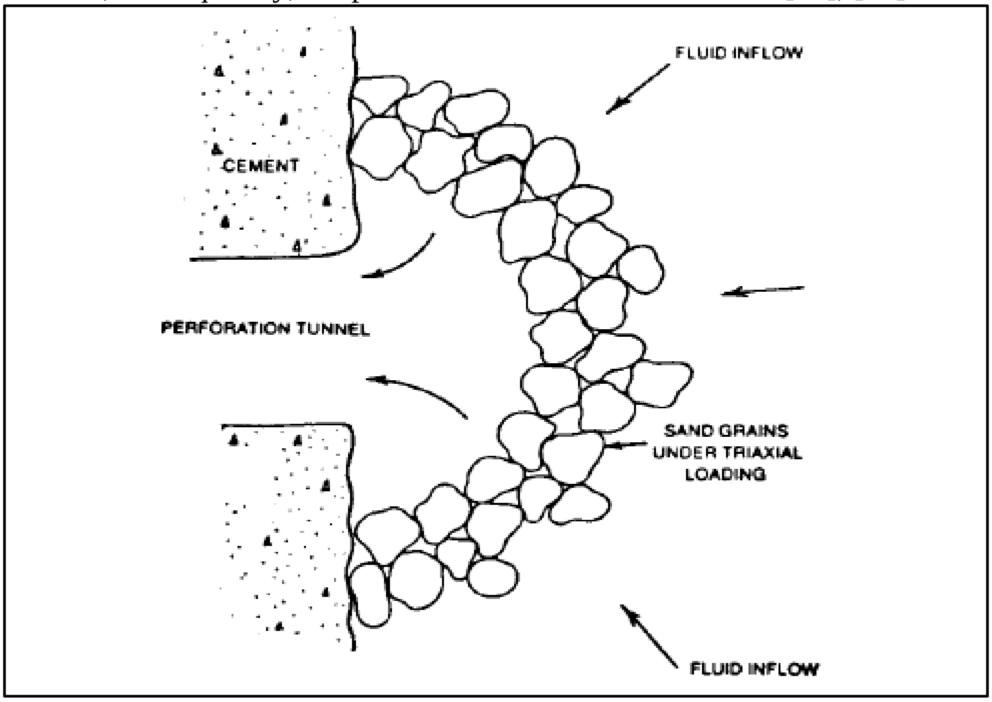

Fig. 2. Stable arch geometry around a perforation [15].

3.7. Viscosity of Reservoir Fluid

The flowing of hydrocarbon fluids in sand formation can generate the frictional force associated with the velocity and viscosity of the reservoir fluids. A more significant drag force will apply to the sand formation when the viscosity of hydrocarbon fluid is high and vice versa. In reservoirs with heavy oil, i.e., low API and higher viscosity, the viscous drag force can lead to sand production even at low velocities [19].

4- Sand Production Mechanisms

The sand production from oil wells attributes to the original pressure surrounded the wellbore or perforation is broken, resulting in the formation rock's failure. There are two types of rock failure mechanisms: mechanical and chemical failures [18].

4.1. Mechanical Failure Mechanism

The process of sanding begins with the mechanical rock failure near a perforation or wellbore. In this process, the key essential factor in the production of sand is the formation failure that is governed by in-situ stresses and the mechanical rock properties. Stresses around a perforation or wellbore are further concentrated, and unconsolidated formation rocks are apt to distortion under these circumstances. Excavation and completion operations can lead to damage in the region close the wellbore. Consequently, the production of the reservoir fluid and the associated frictional force exerted on the unconsolidated reservoir produce erosion at the sand face. As shown in Fig.3, once sand particles are loose from its matrix, it transports up the wellbore [23]. The most common kinds of mechanical failure mechanism of sand production are:

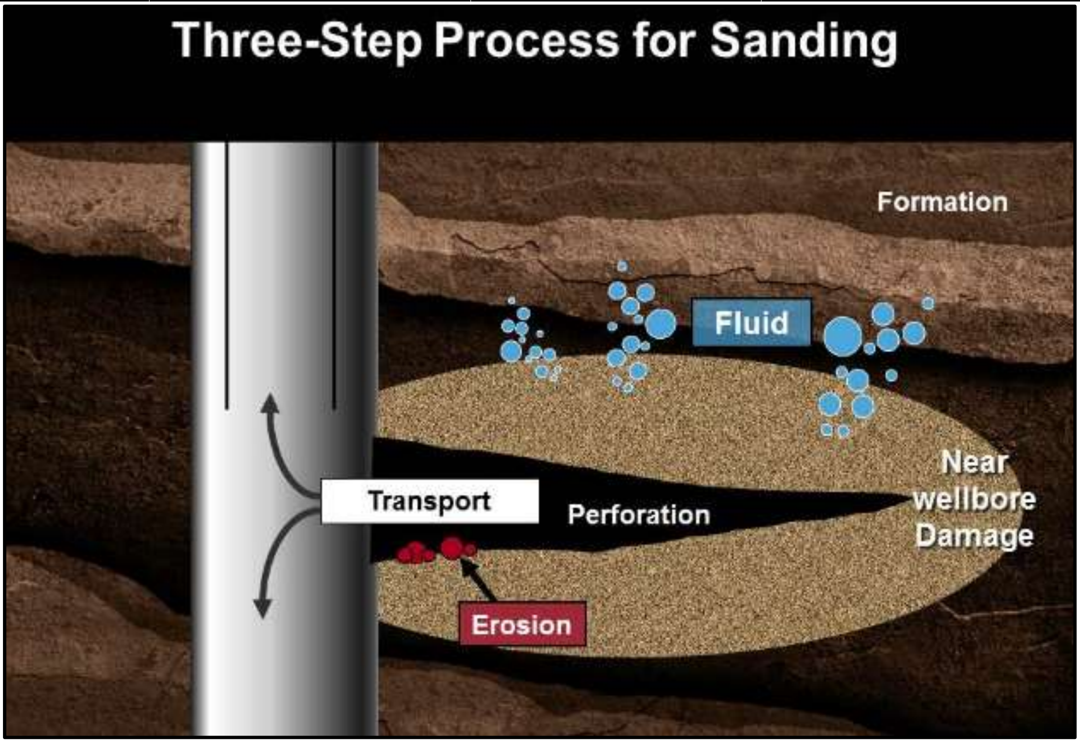

Fig. 3. Process of sand production [23].

a. Shear or Compressive Failure

In the layers below the surface of the earth's, many parameters control whether a reservoir rock will mechanically fail. These factors include rock strength (UCS), in-situ stress, differential pressure due to drilling and production, and stress distribution near the wellbore [24].Compressive rock failure happens predominantly in tight sandstone formations, and it indicates to extravagant tangential stress close the wellbore wall, which can lead to shear rock failure [25].

During production, the shear failure occurs due to the effective stresses being increased in the formation due to the depletion and /or drawdown. This failure has an adverse impact, i.e., a large amount of sanding. On the other hand, the greater drawdown will cause evident more significant effective tangential stress around the wellbore or perforation tunnel. When the stresses overcome the strength of intact sandstone formation, shear failure will occur, and subsequent sand production will occur. Pore pressure declines during production activity will worsen position as it can alter the far-field stresses exerting on the rock formation. Thence, the event will produce larger shear stress surrounding the perforation holes and borehole; consequently, the high possibility for sanding will manifest [11], [18], [26].

b. Tensile Failure

Mechanism of the tensile failure is an uncommon occurrence while in production in several oil fields and triggered typically via a high production flow rate [26].This mechanism happens at the perforations where the radial stresses are controlled through wellbore pressure and reservoir pressure. When an abrupt alteration in pressure overcomes the formation tensile strength, production of sand will occur, and subsequently, the perforation hole will enlarge. Sanding will take place when effective stress surrounding the wellbore is larger than the rock tensile strength. Generally, tensile failure may happen at the tip and the wall of the perforation holes [11], [18], [24]. Tensile failure near the wellbore yields small volumes of sanding, and it will stabilize over time [26].

c. Cohesion or Erosion Failure

The mechanism of cohesion failure is essential in poorly consolidated reservoirs. Erosion of the formation surface is controlled via the strength of cohesion; it refers to the production or gradual removal of individual sand grain from its locations like perforation hole, fracture surface in hydraulic fracture, and the wellbore surface in open-hole completions. The frictional force is associated directly to the velocity of the fluid flow. Hence, erosion will occur when the frictional force applied on a face grain overrides the cohesive strength between surface grains, production of sand will take place in formations. In unconsolidated sandstone

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reservoirs, the strength of cohesion approach zero, and the sand production occurs due to cohesion failure [11], [18], [25].

d. Volumetric Failure

This type of failure happens when the pressure of the reservoir is decreased. Reduction of pore pressure within the reservoir can increase the effective stress, causing pore collapse [11], [24].Mechanism of pore collapse typically can be seen in the formation with high porosity like chalk and sandstone. Pore collapse occurs due to excessive hydrostatic stress exerting on the grainy rock. The broken or loosen grains can push into pore spaces, the porosity will decrease, and subsequent compaction will occur. Furthermore, excessive localized shear stresses exerting on the grain-to-grain contact can lead to failure [26].

4.2. Chemical Failure Mechanism

The strength of the rock is controlled via the following parameters: drag force, the contact force between grain particles, and cohesion strength between cement and grain particles. When moveable water with a specific volume exists in reservoirs and starts to flow, this movable water can lead to chemical reaction with other materials and dissolve cement portions. Consequently, the strength of rock will decrease. The level of failure of sandstone formations as a result of chemical reaction may only be determined by estimation of the cement of sandstone [18].

5- Sand Control

Conventional methods of sand control, including frac-pack, gravel packing, wire wrapped screen, expandable screen, chemical consolidation, etc., are executed rely on the absolute sand exemption philosophy [27]. Any sand grains in the production facilities cannot accept [19]. The sand inflow should be avoided entirely. The traditional techniques minimize the rate of production in order to decrease the entering quantity of sanding in the wellbore. The procedure used to eliminate or control the production of the sand relies on analyzing the prophecy of sand. Consequently, it leads to the improvement of diverse numerical and/or analytical approaches to prophesy the onset of sanding [25], [28].Thence, sand flow is commonly considered a factor that restricts the production rate. The restrictions of the production occur due to the mounting mechanisms of sand control, workover operations and failures of equipment, and low rate limits of maximum sand-free. Nevertheless, mechanical rock failure and expansion of the formation rock are associated with sand inflow [19], [29], [30].

6- Sand Management

Sand management is considered one of the major issues during oil and gas reservoirs development. It points out the concept of the operation process in which the conventional mechanisms of sand control are generally not utilized. The process of production managed by controlling and observation the pressures of the well, rates of fluid flow, and sand inflow [31]. Sand management is an equilibrium of the hazards (i.e., safety, environmental, cost, and process) associated with sand producing from the reservoir up to the surface. Also, it is attempting to reduce the dangers related to holding the sands in the reservoir. Consequently, the elections are not straightforward or constantly easy to perform [19]. The rational analysis of the life cycle of the sand beginning from forecast the circumstances of the formation that contributory to sand production and finishing with extreme elimination of the sand produced at the surface. This analysis is achieved by risk management [31]. Fig.4 displays the events' path after assessing risk to investigate the better-fit mechanisms of the sand management.

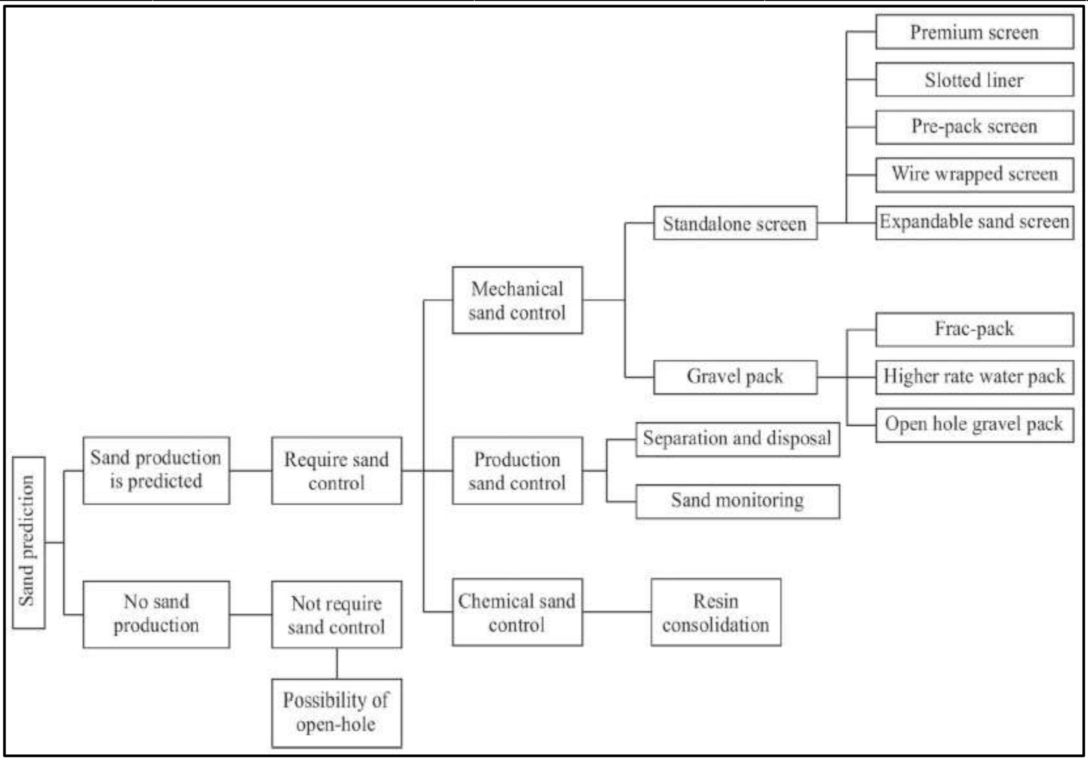

Fig. 4. Flow chart of sand management strategy [19].

7- Conclusions

The following points can be used to summarize the outcomes of the research:

- It's possible that sand production will be related to reservoir fluid production in weakly cemented strata.
- Production of the formation sand can lead to minimized well productivity, premature failure of the wellbore, and damage of the downhole and surface equipment.
- Sand is produced as a result of the formation rock failure, which develops when applied force exceeds the formation's strength.
- Tectonic activity, drilling-induced stress, formation pore pressure, vertical stress, and drag force during production are all factors that contribute to rock collapse.
- Unconfined compression strength (UCS) is a mechanical rock property that is related to the degree of rock consolidated, and its value for weakly cemented sandstone reservoirs is typically less than 1015 psi.
- A choke-size surface valve is a method that is used to reduce sand generation. Using this method, the critical flow rate may be reached, where the sand either does not occur or has a manageable amount.
- Traditional sand control techniques are executed relying on the absolute sand exemption philosophy. Any sand grains in the production facilities cannot be accepted.
- The solutions to the sand control point out the minimum hazard and high cost where the sand management can be utilized to decrease the cost issue.

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