SIO SILICA SUPPLEMENTAL INFORMATION

Document #1 – Silica Extraction Method

Vivian Sand Extraction Project

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Purpose

This document is provided to the Clean Environment Commission in response to inquiries received for additional information on the sand extraction method and operations for the proposed Vivian Sand Extraction Project (the "Project").

1.0 Production Operations

The Project will be developed as a sequential extraction well drilling operation with progressive annual closure/sealing of extraction wells and progressive annual rehabilitation of temporarily disturbed areas. Temporarily disturbed areas include land required to accommodate the extraction wells, drilling rig access trails, equipment laydown areas (within well cluster areas) and trails to accommodate the slurry lines and water return lines. Extraction operations will occur annually from April to November, weather permitting, and drilling and decommissioning activities will occur year-round, weather permitting.

When the original Vivian Sand Extraction Project Environment Act Proposal was filed (AECOM, July 2021), Sio Silica (Sio) anticipated extracting sand as a sand and water slurry from up to 467 extraction wells per year at an approximate depth of 61 m (200 ft) in the Winnipeg Sandstone aquifer. As a result of recent refinements in the Project plan aimed at improving efficiency and minimizing the Project footprint, Sio Silica has reduced the total number of wells required per year from 467 to 324 (a 30% reduction). Operations will start with lower numbers of wells (up to 280 extraction wells), with the number of extraction wells gradually increasing over the first few years of operation. Not all extraction wells during each year of operations will be operating simultaneously (i.e., at the same time).

During the initial ramp up phase of the Project approximately 1,176,000 tonnes of silica sand will be extracted annually. Over time, the production rate will increase from 1,176,000 tonnes of silica sand to 1,360,000 tonnes of silica sand produced annually at Sio's licensed Processing Facility. During each year of sand extraction operations, extraction wells were initially planned to be clustered in groups of seven (7) wells within 50- 60 m diameter well cluster areas. The current plan is that wells will now be clustered in groups of one (1) to five (5) wells within a 60 m diameter well cluster area based on refinements to the Project plan that have occurred since filing of the original EAP document. Extraction wells will be located approximately 18 m apart within these well clusters and their placement will abide by the Stantec Geotechnical Analysis (Stantec, 2022).

To produce the initial ramp up phase of 1,176,000 tonnes an average of 56 well clusters consisting of up to five (5) wells each will be sequentially developed and progressively decommissioned and rehabilitated each year. Once drilled, these wells will be producing for five to seven days. All wells within a well cluster are not planned to be operating at the same time. The objective is to keep the slurry supply continuously moving to the Processing Facility at an optimal and manageable rate. Therefore, up to seven extraction wells may be operating simultaneously in the Project area at any given time, this maximum number of wells operating simultaneously may be spread across two adjacent well clusters (e.g., four operating wells in one cluster and three in an adjacent well cluster). The operations will move in a pattern from one well cluster to the next, with wells being progressively sealed in accordance with Provincial regulations. This will occur sequentially over the April to November timeframe with all wells being sealed (decommissioned) sequentially and the disturbed areas rehabilitated annually.

A conceptual diagram illustrating how the extraction wells within each well cluster can be configured is shown in **Figure 1-1**.

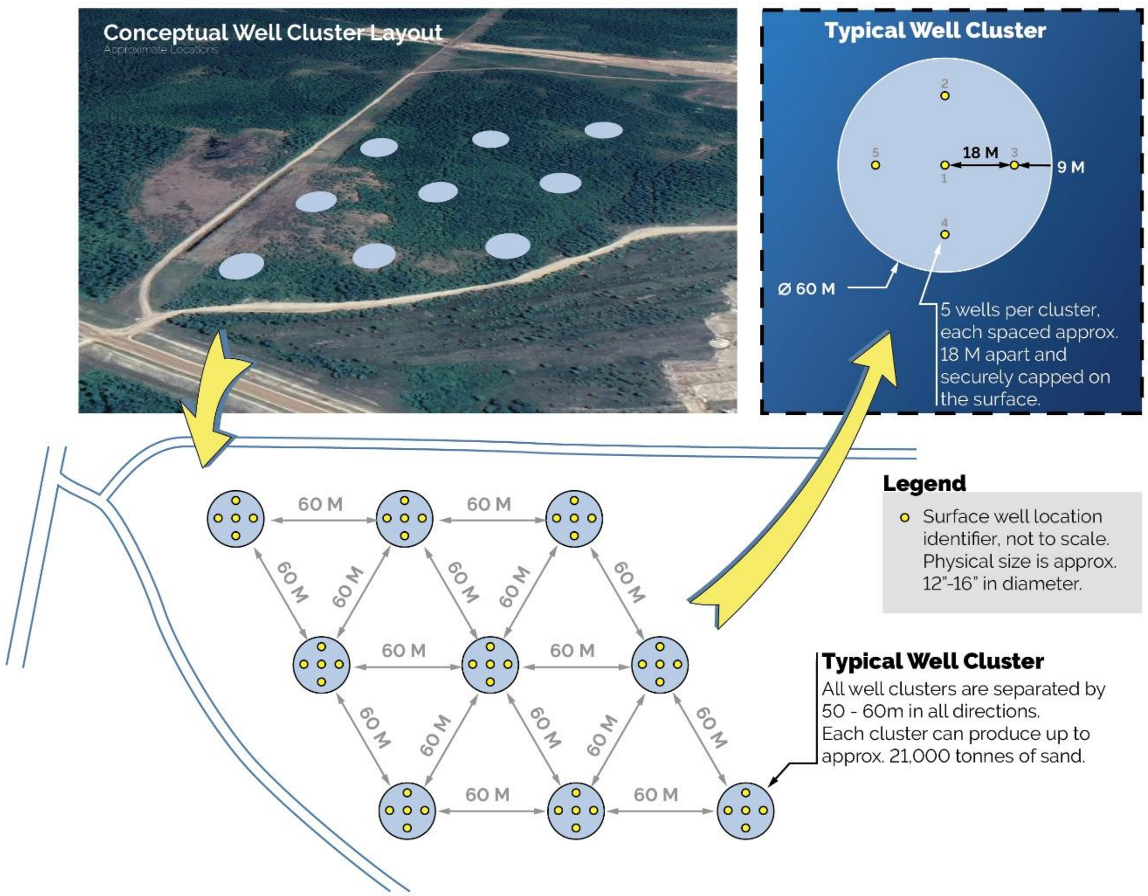

Figure 1-1: Updated Conceptual Extraction Well and Well Cluster Layout

2.0 Extraction Well Design and Drilling

Silica sand will be extracted from the Winnipeg Sandstone aquifer using an airlift extraction method which uses a dry screw compressor to circulate air into the bottom of the installed production pipe within each extraction well to extract the sand which is then placed in a slurry line for transportation directly to Sio's licensed Processing Facility. Extraction wells will first be drilled by a water well rig ahead of extraction activities. Wells are capped and secured once drilled while awaiting extraction. Extraction is performed with a different water well rig and once extraction is complete the equipment is removed, and the well is sealed (abandoned) in accordance with *The Groundwater and Water Well Act* and *The Mines and Minerals Act* requirements. Drilling of extraction wells will occur year-round.

In the original EAP filing, the Project plan considered clusters of seven wells in an approximate 60-70 m diameter area. Based on recent refinements aimed at improving efficiency and reducing the Project footprint, Sio is now able to complete sand extraction with five wells or less in a cluster, reducing the number of wells required per year from 467 to 324 (30% reduction, see Figure 1-1 for an example of the updated cluster layouts). These wells will be drilled in advance of extraction activities occurring using a water well rig and using standard industry practice water well drilling techniques. When each well is drilled, casing will be installed and cemented in place to create a barrier between the various formation layers to prevent vertical mixing of the different aquifers present in the area of sand extraction. This is the same process as with water well drilling. Additional detail on the cementing process is provided below.

The well drilling and design are as follows:

1) Establish access to the drilling location;
2) Advance borehole and casing through overburden using dual rotary drilling methods;
3) Install PVC surface casing into upper portion of Red River Carbonate;
4) Advance borehole through Red River Carbonate formation and underlying shale;
5) Install PVC casing from surface to Winnipeg Sandstone;
6) Cement borehole through shale and lower Red River Carbonate to prevent inter-aquifer mixing.

Wells will be drilled into the sandstone over one to two days. Once a well is drilled and casing is in place with cement as per *The Groundwater and Water Well Act* requirements, wells are securely capped until sand extraction activities begin. Wells are planned to be 12- 16” in diameter with expected efficiencies to reduce the size in the future. Wells that are capped and not active resemble a domestic water well with 1-3 ft of white PVC casing coming from the ground and a locked cap on top. An example of a standard domestic water well is seen in Figure 2-1 below:

Figure 2-1: Examples of a Standard Domestic Water Well.
Image Source: Constructing and Sealing Wells in Manitoba

Cementing practices follow the requirements of *The Groundwater and Water Well Act*, therefore, cement is pumped using a tremie line from surface. Cement is a predetermined mixture of cement and bentonite to create a reliable seal between the layers of the sandstone, shale, and carbonate to prevent inter-aquifer mixing. Cement is given the time it needs to set prior to extraction activities commencing and cement samples are collected from each batch and monitored for set up and quality (minimum of 12-24 hours).

An example of the Extraction well design is illustrated in **Figure 2-2** below:

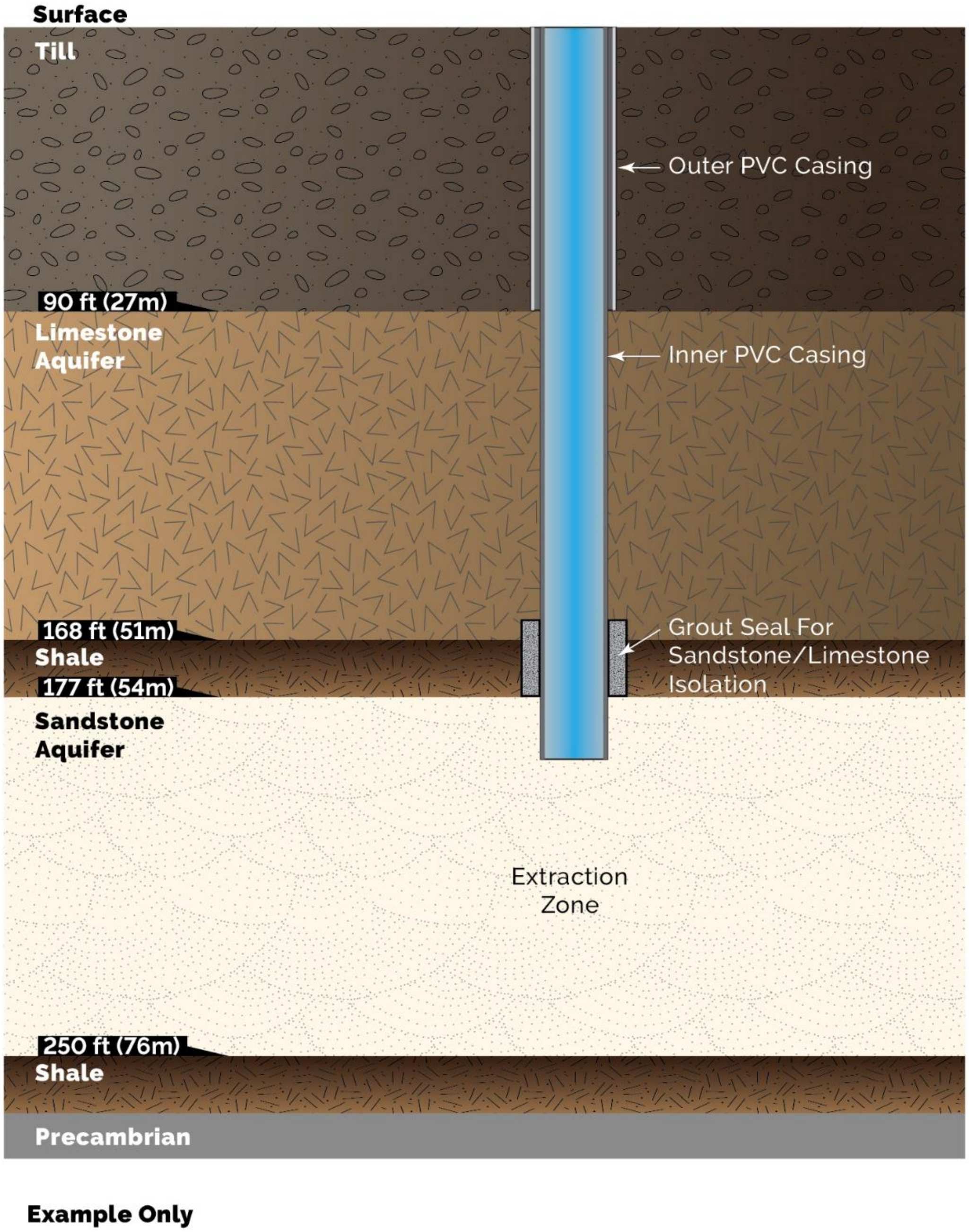

Figure 2-2 Example of Extraction well design

2.1 The Sand Extraction Method

Once the wells are drilled in one area, the extraction equipment will be set up and extraction will begin. All extraction equipment is designed to be mobile and therefore have less of an impact. Sound barriers will be used around the site to limit the sound. At any given time, up to seven extraction wells are the maximum number of wells expected to be operating simultaneously (i.e. at the same time). These seven active extraction wells will be spread across two adjacent well clusters. Wells will be brought online and shut off at different times. Therefore, wells will always be at different stages and will not be timed to all start and stop at the same time. Sand extraction activities will occur 24/7 from April through November (weather dependant).

Sio Silica will use an extraction method that has been developed using water well industry methods. This technique uses a dry screw compressor to circulate air at varying depths installed inside the production pipe within each extraction well to extract the sand which is then separated from the water at surface and placed in a slurry line for transportation directly to a sand Processing Facility. While this is occurring, water that is removed from the sand on surface is filtered and treated with UV and returned to the aquifer as the well is producing sand. This water is returned by gravity with no pressure applied at any time and is referred to as re-injection.

The extraction method combines the traditional method of airlift used to develop water wells and a dual rotary set up usually used to drill wells in unconsolidated formations to extract sand. The re-injection of water resembles that of the flood reverse water well drilling technique but is fed as water is available and by gravity flow only. Design changes and alterations to these techniques have been made to allow for sand to flow freely into the production pipe and be removed to surface over a longer period of time and a larger volume then that of just drilling a water well. This also allows for the return of the water that is brought to surface by this method, so that only sand is sent to the facility for processing which leads to little to no water removal from the aquifer due to the extraction activities.

To do this, the production pipe is installed to be movable in the wellbore independently. This means that while the extraction is occurring the pipe can be moved up and down as needed to collect sand. This requires the rig at surface to be able to move the production pipe as needed. In parallel with this, the compressor feeds an airline with a drill bit at the end of the airline which is inside the production pipe. This airline can also move up and down independent of the casing to allow the point of air injection to change. This ensures that the pipe does not become clogged with sand at any time. As the air is injected into the production pipe, it does not have anywhere else to go but to surface. Therefore, as the air comes to surface it creates a water flow that causes sand to come to surface.

In traditional sandstone water wells, casing is permanently installed and usually contains a well screen to keep sand out of the well. A pump attached to stationary piping is used to draw water from the sandstone aquifer. Over time it is not uncommon to see some sandstone wells with small amounts of sand pumped up by the well pump. In the case of Sio Silica's extraction method, casing is installed for the life of the well, and instead of a well pump, the production pipe and airline are used. In this case, the production pipe and airline are used to produce sand for several days and must be movable unlike a well pump that stays stationary. Typically, in a dual rotary design the airline can be used with air or mud and the casing will operate together, with the ability to make adjustments independently, then the airline will be removed, and the casing will remain. With Sio Silica's extraction method, the pipe moves freely allowing sand to infill in the void created when the pipe is lifted and be removed by the pipe as it is lowered. The production pipe is also not permanent and is removed after the extraction is complete on a well and re-used in the next well. Unlike traditional drilling methods, the extraction does not occur from top of the formation to the bottom. Extraction is commenced at a distance below the top of the sandstone and is moved only when needed. The production pipe does not extend to the very bottom of the formation at any time.

To increase the overall flow rate and volume of sand inflow, the production pipe is perforated with 1 - 2" diameter holes at the very bottom of the pipe to allow for a larger volume of water and sand to enter the pipe. This prevents clogging and increases the flow rate capabilities. Without these holes, sand will still come to surface, but at a very slow rate that may result in the pipe plugging up .

Step by step extraction steps are outlined below:

a) A production pipe will be installed in the extraction well with an air line installed inside the production pipe for air to circulate and facilitate movement of sand and water to the surface (Figure 2-3). This activity is a standard water well production method.
b) The sand and groundwater slurry brought to surface will pass through a coarse screen installed over a sump pit at the extraction site which will capture overs such as concretions (calcified sand) which are commonly encountered.
c) The sand and groundwater slurry will then move to a dewatering station at the extraction site where the sand will be separated from the groundwater.
d) This groundwater will then be filtered and treated with ultraviolet (UV) light, which is a water treatment technique commonly used in municipal water treatment facilities. After treatment, the water will be returned to the aquifer via the sand producing extraction well.
e) The construction method of the extraction well will prevent water that is returned to the sandstone from contacting any potential source of contamination.
f) The water that is returned to the sandstone aquifer comes from the sandstone aquifer and returns to the same place after filtration and UV treatment described above.
g) The sand will then enter a movable slurry transport system via a slurry line that will transport the sand slurry to the proposed sand Processing Facility located south of the hamlet of Vivian.
h) This slurry transport system will contain recycled water from the facility that is traveling in a continuous loop. The sand enters the loop at the extraction site, travels in the slurry line to the facility and is removed from the slurry line for washing and drying. The Vivian Sand Facility Project Environment Act Proposal (AECOM 2020) that has been granted an Environment Act Licence (No. 3367) describes how the sand is processed once it arrives at the facility.
i) Once the water no longer contains sand and has been through the treatment process (as outlined in the Facility Environment Act Proposal), the water returns back to the extraction site via a dedicated water return line. This water then feeds back into the sand slurry line to move more sand back to the facility in a continuous loop process.
j) Water well rigs that are the typical size used to install water wells will be used to install the sand extraction wells.
k) When a well is no longer producing sand, the production piping will be removed, the slurry line connection will be disconnected, and the well will be capped. All equipment will then be moved to the next well in the cluster and re-connected.
l) While this is occurring, the other wells (up to seven) will continue to operate so that the slurry loop system continues to supply sand to the facility for processing.
m) Once the production piping is removed from the extraction well, the well will be sealed as per *The Groundwater and Water Well Act* requirements to prevent movement of water vertically between the aquifers.

A diagram of the extraction method can be seen below in **Figure 2-3**.

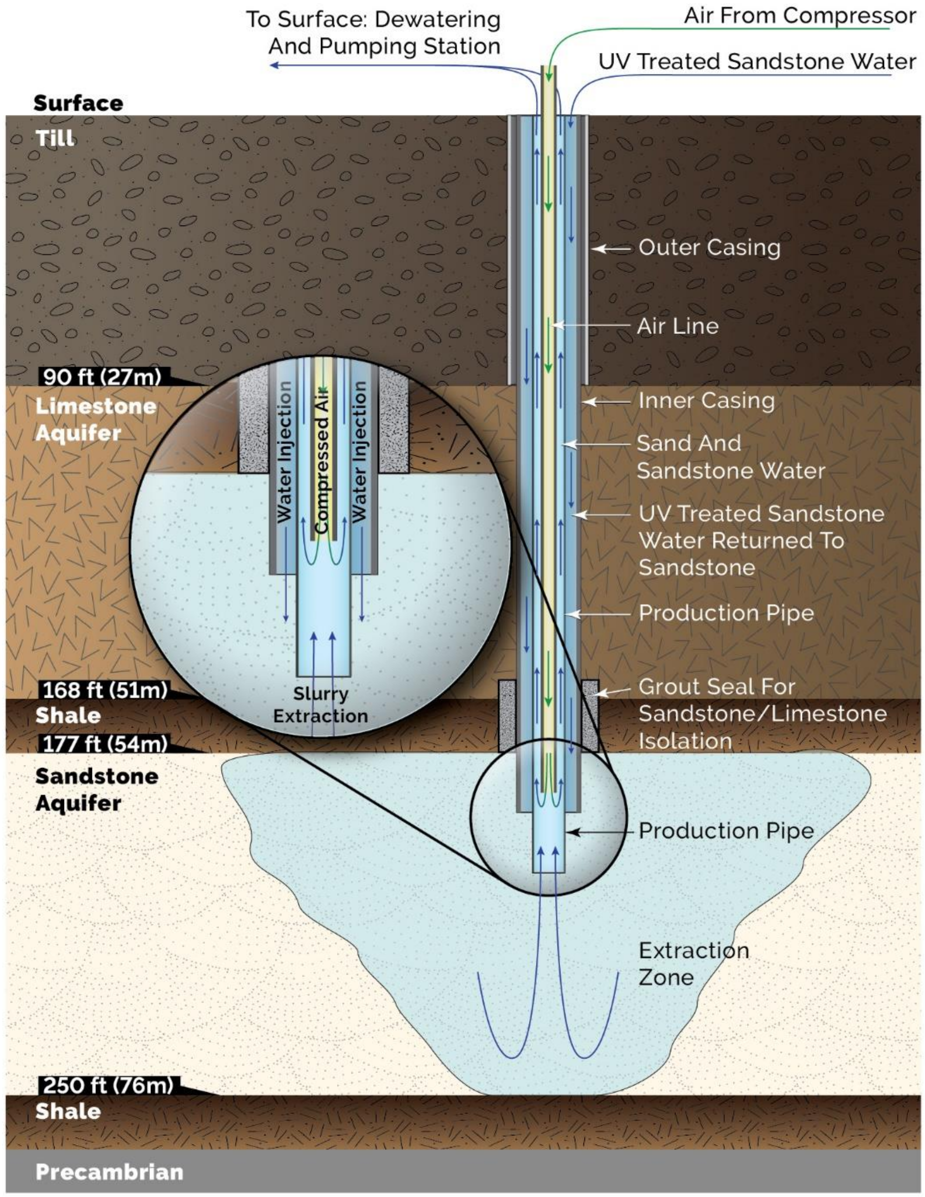

Figure 2 - 3 Extraction method example

2.2 Patent Pending

A copy of the patent pending application for the sand extraction method can be found in **Appendix A**. Please note that the patent describes some broad aspects of the method and materials that may or may not be used. The extraction method as described above is the method currently used and these aspects are contained in the patent application. This patent is pending.

2.3 Well Abandonment and Sealing Additional Information

After sand extraction is complete at a well, the extraction piping is removed. The well is then sealed in accordance with industry standard practice that will meet or exceed the requirements of *The Groundwater and Water Well Act* and its supporting regulations, including the Groundwater and Water Well Regulation and the Well Standards Regulation.

Wells will be abandoned (also known as well sealing) in accordance with *The Groundwater and Water Well Act* and with guidance from the Construction and Sealing Wells in Manitoba – Information for Well Driller and Well Sealers document (Manitoba Government, 2018). The well sealing procedures will also meet borehole abandonment requirements of *The Mines and Minerals Act* and borehole licences issued under Part 3 of the Drilling Regulation.

The following procedures will be used to abandon or seal Project wells:

1. A mechanical plug will be placed at the predetermined depth to isolate the movement of water within the already cemented casing between the sandstone and limestone aquifers. Then a bentonite plug will be placed prior to cementing to ensure the cement does not dilute or leak into the water prior to setting.
2. Above this plug, a several foot-thick cement plug will be placed and allowed to set. Cement will be pumped into place using a tremie grout system and allowed to set overnight. The cement plug will be confirmed by manual contact prior to proceeding to the next step.
3. Once set, layers of bentonite and pea gravel or native material will be used, or a bentonite grout to 5 feet (1.5 m) below surface.
4. Where pea gravel or native material and bentonite are used, no more than 15 feet (4.6 m) of pea gravel will be used before another layer of bentonite. In addition, careful attention will be paid to the layering of bentonite across any interfaces between aquifers (e.g., the limestone to the till interface) to prevent vertical mixing of the aquifers.
5. A 5 feet (1.5 m) thick cement cap will be placed at the very top, allowed to set and then the topsoil/organics will be replaced on top of the cement to allow for vegetation regrowth/remediation of the surface land to occur.
6. Detailed logs will be kept of the well abandonment and depths of each layer, in addition to the GPS coordinates of each well.

This procedure will be used in all extraction wells and wells that exceed 2 inches (5 cm) in diameter. Where a monitoring well exists, these are often nested 5-inch (12.7 cm) and 2-inch (5 cm) PVC (polyvinyl chloride) casing sizes. As per the above referenced guidelines (Manitoba Government, 2018), the 2-inch (5 cm) casing will be grouted the entire length of the well as other sealing materials like bentonite chips can bridge off (expand and create a blockage) in the small diameter PVC casing.

Progressive decommissioning (well sealing) of annual extraction wells and well cluster areas will occur each extraction year in addition to progressive annual rehabilitation of temporary drilling rig access trails; equipment laydown areas; slurry line trails and return water line trails. Disturbed areas will be allowed to revegetate naturally and will be augmented using an approved native seed mixture and native plantings if required. Details of the progressive annual closure and rehabilitation of the extraction wells will be provided in a Closure Plan in accordance with the Manitoba Mine Closure Regulation 67/99 General Closure Plan Guidelines.

3.0 Follow up Plans and Monitoring

As outlined in the original EAP filing (AECOM, 2021), the follow-up plans and monitoring programs that will be implemented include, but are not necessarily limited to, the following:

- Waste Characterization and Management Plan;
- Water Management Plan;
- Progressive Well Abandonment Plan;
- Groundwater Monitoring and Impact Mitigation Plan;
- Erosion and Sediment Control Plan;
- Emergency Response Plan;
- Revegetation Monitoring Program;
- Heritage Resources Protection Plan; and
- Closure Plan

These follow up plans will contain the details, methods and procedures for critical items such as but not limited to:

- Aquifer quality and quantity monitoring before, during and after extraction activities;
- Waste management (including drill cuttings);
- Water management;
- Water monitoring (including domestic wells);
- Operations and well owner concerns and reporting;
- Site erosion and sediment control;
- Site rehabilitation and revegetation monitoring;
- Emergency response plans;
- Heritage resources and protection plans; and
- Closure plan details, including financial and operational commitments to site and well rehabilitation.

4.0 References

AECOM. 2020. Vivian Sand Facility Project Environment Act Proposal. Prepared for CanWhite Sands Corp. July 2020.

AECOM. 2021. Vivian Sand Extraction Project Environment Act Proposal. Prepared for CanWhite Sands Corp. July 2021.

Manitoba Government. 2018. Construction and Sealing Wells in Manitoba. Information for Well Drillers and Well Sealers. Retrieved from Government of Manitoba: https://www.gov.mb.ca/water/pubs/water/groundwater/publication/constructing_and_sealing_wells_contractors.pdf

Stantec Consulting Ltd. (Stantec). 2022. Geotechnical Analysis for Sio Silica Extraction Project. Report submitted to Sio Silica Corporation January 14, 2022.

SIO SILICA SUPPLEMENTAL INFORMATION

Appendix A – Patent Pending

Innovation, Sciences et Développement économique Canada
Office de la Propriété Intellectuelle du Canada

Innovation, Science and Economic Development Canada
Canadian Intellectual Property Office

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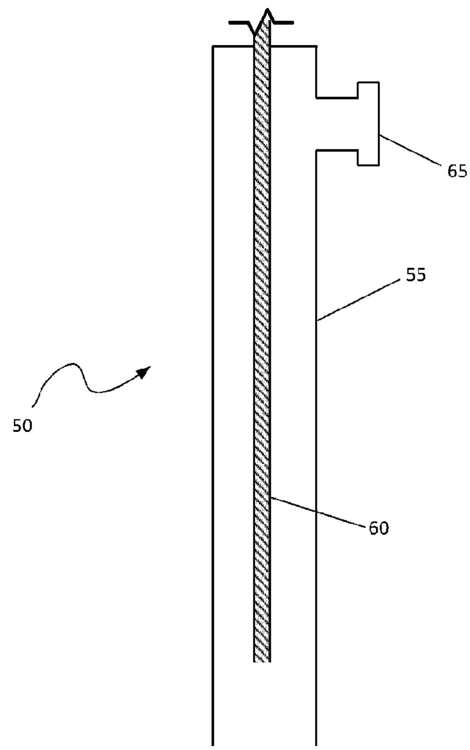
(54) Titre : SABLE DE REMONTEE PNEUMATIQUE
(54) Title: AIR LIFTING SAND



(57) Abrégé/Abstract:
An example of an apparatus is provided. The apparatus includes a conduit having a lower end and an upper end. The lower end is to engage a sandstone formation and the lower end opposite is the upper end. In addition, the apparatus includes a gas injection line to inject gas at an injection point proximate to the lower end. The gas injected at the injection point generates a low pressure region at the lower end to draw a sand slurry from the sandstone formation. Furthermore, the apparatus includes a collection port proximate to the upper end of the conduit. The sand slurry in the conduit is to be removed from the conduit via the collection port.

AIR LIFTING SAND

BACKGROUND

[0001] Unconsolidated sand may be found underground in certain formations. Such sand formations may have particular qualities, such as a high level of purity with silica content about 99% or more, which may be used in a wide variety of applications. The formations are generally found under layers of other types of rock. Accordingly, the removal of the sand may be carried out by mining for the sand and excavating the sand. For example, an open-pit mining technique may be used to remove the upper layer of rock so that the sand underneath may be recovered. The sand recovered may be used in a wide variety of applications. For example, the sand may be used as frac sand in the oil and gas industry for hydraulic fracturing to release oil and gas in a reservoir. Other uses for sand may include use for sand blasting, scouring cleansers, grinding media, grit for sanding and sawing, glass making, fiber optics manufacturing, foundry sand, silica metals, photovoltaic cells, and other applications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0002] Reference will now be made, by way of example only, to the accompanying drawings in which:

[0003]	Figure 1	is an example apparatus to extract sand from an underground sandstone formation in an underground water reservoir;
[0004]	Figure 2	is a diagram showing the apparatus of figure 1 installed in a well during operation;
[0005]	Figure 3	is a flowchart of an example of a method of extracting sand from an underground sandstone formation in an underground water reservoir;
[0006]	Figure 4	is another example apparatus installed on a well to extract sand from an underground sandstone formation;

[0007] Figure 5 is a diagram showing the apparatus of figure 4 in operation during an initial phase of removing sand from the underground sandstone formation in an underground water reservoir;

[0008] Figure 6 is a diagram showing the apparatus of figure 4 in operation during the removal sand from the underground sandstone formation after the formation of a void;

[0009] Figure 7 is another example of a lower end of a conduit used in an apparatus to extract sand from an underground sandstone formation; and

[0010] Figure 8 is another example apparatus to extract sand from an underground sandstone formation in an underground water reservoir.

DETAILED DESCRIPTION

[0011] As used herein, any usage of terms that suggest an absolute orientation (e.g. “top”, “bottom”, “up”, “down”, “left”, “right”, etc.) may be for illustrative convenience and refer to the orientation shown in a particular figure. However, such terms are not to be construed in a limiting sense as it is contemplated that various components will, in practice, be utilized in orientations that are the same as, or different than those described or shown.

[0012] Sand from sources such as glacial deposits as well as most beach and riverbank sand is low purity and may include impurities and sharp angles that may make it not suitable for some uses, such as hydraulic fracturing. Therefore, to obtain sand or other unconsolidated materials having target properties for specific applications may involve searching for such materials in limited locations. For example, high purity sand with a high proportion of silica may be typically mined from sandstone formations located near the surface at some locations where such deposits exist. These sandstone formations may be accessed by removing top layers such as topsoil and rock layers to expose a sandstone formation. These examples of sandstone formations may be typically a hard formation which may be blasted apart with explosives and collected and crushed to a suitable size for use.

[0013] In some rock formations, sand having a specific property may be found in sandstone formations that are unconsolidated and deep underground in water reservoirs or aquifers. The reservoirs may be about 200 feet below the surface, about 325 feet, about 650 feet, or even deeper, which poses challenges to removing the sand. The sand may be excavated by removing the material above the reservoir; however, such an excavation is a significant undertaking requiring several different types of machinery to remove the material. In addition, exposing an aquifer by removing layers above is environmentally dangerous and involve significant costs to contain the water that will be released once the aquifer is exposed. Furthermore, the material removed from above the reservoir is to be transported away from the site. Overall, a large amount of equipment and energy is used to move the material above the reservoir away so that the sand may be brought to the surface. Therefore, using conventional sand mining techniques may become prohibitively expensive when the sand is located at such a distance from the surface.

[0014] An apparatus to remove sand from an unconsolidated underground sandstone formation in a water reservoir is provided. The apparatus includes a conduit and a gas injection line to generate an area of low pressure near the interface with the sandstone formation to draw in unconsolidated sand to bring to the surface. The sand is brought to the surface in the form of a slurry with grains of sand and water.

[0015] Referring to figure 1, an apparatus 50 to extract sand from an underground sandstone formation in an underground water reservoir, such as an aquifer, is provided. The apparatus 50 is to be inserted into a well from the surface to the underground sandstone formation. It is to be appreciated by a person of skill with the benefit of this description that the depth to which the apparatus 50 is to be inserted is not particularly limited. Accordingly, the apparatus 50 may be applied to various sandstone formations at different depths. In the present example, the apparatus 50 includes a conduit 55, a gas

Date Reçue/Date Received 2020-05-01

injection line 60, and a collection port 65.

[0016] The conduit 55 is to engage a sandstone formation at a lower end of the well. The conduit 55 is not particularly limited and may be constructed from one of several different structures, shapes, and materials. In the present example, the conduit 55 is a steel conduit with a circular cross section having diameter of about eight inches. In other examples, alternative materials such as cast iron, copper, wrought iron, or galvanized metals, or plastics like polyvinyl chloride, acrylonitrile-butadiene-styrene, and/or polyethylene may be used In other examples, the conduit 55 may also have a different cross section or a varying cross sectional area along the length of the conduit from the sandstone formation to surface. Furthermore, the conduit 55 may include curves or changes in directions in applications where the well is not a vertical straight well. For example, the well may include horizontal portions or the conduit 55 may extend at an angle in the underground reservoir as a void is formed from the removal of sand to remove sand from the sides of the void.

[0017] The length of the conduit 55 is not particularly limited. In the present example, the conduit 55 may extend about 200 feet from the surface to the top of the sandstone formation. In other examples, the lower end of the conduit 55 may be positioned deeper to about 500 feet, about 715 feet, or even deeper to about 2000 feet in some applications. The conduit 55 may also be extendible in some examples during the extraction. For example, the conduit 55 may be moved while sand is extracted and flowing therethrough. The manner by which the conduit 55 is moved is not particularly limited and the range of movement may be limited by the position of the collection port 65. In particular, it is to be appreciated that if the collection port 65 is to remain above the surface as in the present example, a lower limit of movement is set by this restriction. The upper limit of movement may be restricted by the ability to provide support to the portion of the conduit 55 above the surface either by the strength of the conduit itself or with additional support structures on the surface to avoid collapse. In the present example, the range of motion of the conduit 55 is about 20 feet. In other examples, the range of motion may be up to about 50 feet or more. Once the limits of movement are reached, as the overall length of the conduit 55 may

Date Reçue/Date Received 2020-05-01

be extended or retracted by adding or removing sections, respectively.

[0018] The gas injection line 60 is to inject gas from the surface to an injection point proximate to the lower end of the conduit 55. The gas injected via the gas injection line 60 is not limited. In the present example, a compressor (not shown) at the surface may be used to inject air with a positive pressure and high volume flow rate, such as at a pressure within the range of about 30 psi to 90 psi with a flow rate of about 300 cubic feet per minute to about 600 cubic feet per minute. In other examples, a gas source, such as from a gas cylinder or a storage tank may provide the gas injection via a pressure regulator. In such examples, the gas injected at the injection point may include other types of gas, such as an inert gas.

[0019] It is to be appreciated by a person of skill in the art with the benefit of this description that by injecting gas that is eventually to flow upward in the conduit 55, a low pressure region will be formed at the lower end of the conduit 55 to draw a sand slurry from the sandstone formation into the conduit 55. The gas injection line 60 may inject gas at varying pressures and flow rates to maintain the low pressure region as a sand slurry is continuously extracted. Furthermore, in some examples, the gas injection line 60 may be used to further inject gas beyond the conduit 55 to generate a pressure vibration or pulsed air to agitate the sand in the sandstone formation from time to time.

[0020] The collection port 65 is disposed near the upper end of the conduit 55 generally above the surface. The sand slurry extracted via the conduit 55 is to be removed from the apparatus via the collection port 65. In the present example, the sand slurry may be forced out of a hole and discharged into a container or vehicle collecting the sand slurry and air. In some examples, the collection port 65 may be connected to downstream processing equipment via additional piping (not shown). In other examples, the sand slurry may be collected in a hopper or other container (not shown) and subsequently removed via the collection port 65.

[0021] The collection port 65 is not particularly limited. In the present example, the collection port 65 is perpendicular to the conduit 55 and ejects the sand slurry in a horizontal direction to be subsequently collected. In other examples, the collection port 65 may be oriented to eject the sand slurry in a different direction. In further examples, the collection port 65 may also be at the end of the conduit 55, such that the sand slurry is ejected in an upward direction or directed by an elbow in the conduit 55.

[0022] Referring to figure 2, the apparatus 50 is shown in operation at a well 100 above a sandstone formation 110. The composition of the sandstone formation 110 is not particularly limited and generally includes unconsolidated sand in an underground aquifer. In the present example, the sandstone formation 110 includes high purity sand having over about 99 percent silica and about 0.4 percent clay content. However, in other examples, the sand may include other minerals and be of a lower quality. Furthermore, the sandstone formation 110 is in an aquifer covered by another layer 120, which may include shale, limestone, till or any combination of these and/or other types of materials. Since the aquifer in which the sandstone formation 110 is found may be under pressure, the water level 130 rises above the formation upon the drilling of the well 100 to fill the well 100 with an amount of water to provide a hydrostatic head 125 and the water level 130. The height of the water level 130 is not particularly limited and in some examples where the water level 130 is too low, such as below the top of the sandstone formation 110, water may be added to the well from an external source to establish the water level 130 at a sufficient height to increase the water pressure within the sandstone formation 110 to facilitate the extraction of the sandstone slurry.

[0023] Referring to figure 3, a flowchart of extracting sand from a sandstone formation 110 via a well 100 is generally shown at 300. In order to assist in the explanation of method 300, it will be assumed that method 300 may be performed with the apparatus 50. Indeed, the method 300 may be one way in which apparatus 50 may be configured. Furthermore, the following discussion of method 300 may lead to a further understanding of the apparatus 50 and its various components. It is to be emphasized, that method 300 may not be performed in the exact sequence as shown, and various blocks may be performed in parallel rather than in sequence, such as blocks 320 and 330 discussed in more detail below.

Date Reçue/Date Received 2020-05-01

[0024] Block 310 involves lowering the conduit 55, which may be a steel pipe into a sandstone formation 110. In the present example, the conduit 55 is lowered into the well 100 drilled through a shale layer 120 into the sandstone formation 110, which may be aquifer with sand. It is to be appreciated that the well 100 is not particularly limited and may vary in depth. Furthermore, the well 100 may be a newly drilled well for the purpose of sand extraction or in other cases, the well 100 may be an old well that is repurposed for sand extraction. The manner by which the conduit 55 is lowered is not particularly limited. For example, the conduit 55 may include a plurality of sections of steel pipe where additional sections may be inserted above or near the surface to extend the conduit 55 into the sandstone formation 110. The depth into which the conduit 55 is inserted into the sandstone formation 110 is not particularly limited. In the present example, the conduit may be inserted about 20 feet into the sandstone formation 110.

[0025] Similar to the conduit 55, the gas injection line 60 is lowered into the well 100. The manner by which the conduit 55 is lowered is not particularly limited. In the present example, the relative position of the gas injection line 60 to the conduit 55 may be independently controlled. For example, the gas injection line 60 may be raised and lowered relative to the lower end of the conduit 55 to control or vary a low pressure region generated near the lower end of the conduit 55. It is to be appreciated by a person of skill in the art with the benefit of this description that the position of the gas injection line 60 is not limited and may be below the lower end of the conduit 55. In such an example, the sand near the lower end of the conduit 55 may be able to form a sufficient seal around the conduit 55 to allow gas from the gas injection line 60 to continue lifting material up through the conduit 55. By varying the low pressure region 200, the flow of sand slurry extracted from the sandstone formation 110 may be adjusted to achieve a stable rate to facilitate collection procedures. Furthermore, the gas injection line 60 may include a plurality of sections of tubing where additional sections may be inserted above or near the surface to extend the gas injection line 60 as the conduit 55 extending down the well 100 and into the sandstone formation 110.

Date Reçue/Date Received 2020-05-01

[0026] Next, block 330 involves injecting air from the surface into the conduit 55 proximate to the lower end. The manner by which the air is injected is not limited. In the present example, the gas injection line 60 enters the conduit 55 at the upper end and extends along the length of the conduit to the lower end. The gas injection line 60 may be connected to a pump delivering air at a rate of about 300 cubic feet per minute at in the range of about 30 psi to about 90 psi. The air is delivered to a region proximate to the lower end of the conduit 55. Although the present example illustrates the gas injection line 60 to be at approximately the center of the conduit 55, variations are possible. For example, the gas injection line 60 may be a separate tube or pipe external to the conduit 55. Accordingly, the gas injection line 60 may inject gas into the conduit 55 close to the lower end.

[0027] As the air enters the lower end of the conduit 55 via the gas injection line 60, the air rises back to the water level 130 where it rejoins with atmosphere. The movement of the air toward the surface caused by the injection of the air via the gas injection line 60 generates a low pressure region 200. The low pressure region 200 is not particularly limited. For example, the pressure differential between the low pressure region 200 and the aquifer may be about 20 psi to about 40 psi. The pressure differential draws a sand slurry into the conduit 55 from the sandstone formation 110. The sand slurry is then lifted up the length of the conduit 55 with the air injected from the gas injection line 60. It is to be appreciated by a person of skill with the benefit of this description that as material is lifted to the surface, the pressure at the low pressure region 200 is further decreased. Accordingly, the pressure differential between the low pressure region 200 and the pressure in the aquifer is increased, which in turn improves the drawing of sand into the conduit 55.

[0028] The injection of air into the conduit 55 may be adjusted during the extraction process to maintain the flow of the sand slurry through the conduit 55 to the collection port 65. For example, the initial air pressure at which air is injected via the gas injection line 60 may be kept below the pressure of the sandstone formation 110. Once a flow of the sand slurry from the sandstone formation 110 is established, the injection point of the air may be adjusted by

Date Reçue/Date Received 2020-05-01

moving the gas injection line 60 relative to the conduit 55 in some examples. It is to be appreciated that by adjusting the injection point relative to the conduit 55, the flow of the sand slurry to the surface may be maintained as the sand and water interface moves during operation. In further examples, the pressure of the air injected via the gas injection line 60 as well as the volume of air injected may be adjusted to increase the pumping and lifting efficiency of the sand slurry through the conduit 55.

[0029] The movement of the sand slurry may be created by the pressure differential at the entrance to lower end of the conduit 55 as a low pressure region 200 is created and the higher pressure in the sandstone formation 110 around the bottom of the conduit 55 pushes water and sand into the conduit 55. Above the introduction point of air in the conduit 55 via the gas injection line 60, the pressure is higher but neutral to the formation due to hydrostatic head 125 in the surrounding wellbore. Once the sand slurry in the conduit 55 moves up past the static water level 130, fluid flow generates a conservation of momentum effect as the sand slurry is discharged from the collection port 65.

[0030] In some examples, as sand is removed from the sandstone formation 110, the lower end of the conduit 55 may be lowered further into the sandstone formation 110 so the bottom suction of the lower end of the conduit 55 follows the sand/water interface in the sandstone formation 110 as material is removed to the surface. Accordingly, this may allow for continued extraction of sand as voids are formed during the extraction process.

[0031] Block 330 comprises collecting the sand slurry exiting the conduit 55 via the collection port 65 at an upper end above surface. The manner by which the sand slurry is collected is not particularly limited. For example, the sand slurry may be ejected from the collection port into a hopper or dump truck for transportation. In other examples, the sand slurry may be transferred to downstream equipment for additional processing, such as a sump tank.

[0032] Referring to figure 4, another example of an apparatus 50a to extract sand from an underground sandstone formation 110 in a water reservoir, such as an aquifer, is provided. Like components of the apparatus 50a bear like reference to their counterparts in the apparatus 50, except followed by the suffix

Date Reçue/Date Received 2020-05-01

“a”. In the present example, the apparatus 50a may be inserted into a well 100 from the surface to the underground sandstone formation 110. The apparatus 50a includes a conduit 55a, a gas injection line 60a, a collection port 65a, a perforated wall 75a, and a cover 80a.

[0033] In the present example, the conduit 55a, the gas injection line 60a, and the collection port 65a are substantially similar to the conduit 55, the gas injection line 60, and the collection port 65, respectively. In particular, the conduit 55a is to engage a sandstone formation 110 near a lower end of the well 100. The gas injection line 60a is to inject gas inside the conduit 55a proximate to the lower end of the conduit. The collection port 65a is used to remove the sand slurry to be removed from the conduit 55a.

[0034] In the present example, the apparatus 50a further includes a perforated wall 75a at the lower end of the conduit 55a. The perforated wall 75a is to increase the surface area between the low pressure region 200 and the sandstone formation 110. It is to be appreciated by a person of skill in the art with the benefit of this description, that by increasing the surface area during the initial phase of extracting sand from the sandstone formation, additional sand will be drawn into the conduit to the collection port 65a to provide the conservation of momentum effect. In examples where the perforated wall 75a is continuously lowered into the sand, the benefits of the increased surface area may continue for the duration of the extraction process as long as the perforated wall remains below the sand/water interface.

[0035] The cover 80a is disposed at an upper end of the conduit to provide a seal. It is to be appreciated by a person of skill with the benefit of this description that the cover 80a is not particularly limited and is to direct the flow of the sand slurry to the collection port 65a. Accordingly, the material from which the cover 80a is constructed is not limited. In the present example, the cover 80a is a made from steel with a flexible membrane seal to seal the upper end of the conduit 55a. In other examples, the cover 80a may be constructed of other metals, rubber, cork, or a plastic (e.g. polyvinyl chloride or similar material). The cover 80a is to be secured at the upper end of the conduit 55a with sufficient strength to withstand the pressure forces from the impact of the

Date Reçue/Date Received 2020-05-01

sand slurry moving at high velocity toward the upper end of the conduit. The manner by which the cover 80a is secured is not limited and may involve using a fastener such as a clamp or screw. In other examples, the cover 80a may be affixed with a sealant such as epoxy. In further examples, the cover 80a may also be friction fitted to an opening of the conduit 55a.

[0036] In the present example, the cover 80a includes an opening for the gas injection line 60a to pass through. In the present example where the cover 80a is formed from a rubber material, the opening may be slightly smaller than the outside diameter of the gas injection line 60a such that the cover 80a forms an airtight seal at the upper end of the conduit 55a.

[0037] In some examples, the cover 80a may slidably engage the gas injection line 60a such that the gas injection line 60a may able to move within the conduit 55a in a vertical manner. The movement of the gas injection line 60a allows for the gas injection point within the conduit 55a to be controlled to adjust the flow rate of the sand slurry drawn into the conduit 55a. Furthermore, the gas injection line 60a may also be lowered beyond the lower end of the conduit and into the sandstone formation 110 to generate a pressure vibration or inject a pulse of air to agitate the sand from time to time.

[0038] Referring to figure 5, the apparatus 50a is shown in use during the initial phase of extraction. In this example, the apparatus 50a is lowered into the sandstone formation 110. The perforated wall 75a is to be in the sandstone formation 110. As a gas is injected into to the conduit 55a near the lower end, the low pressure region 200 is formed to draw in additional sand slurry into the conduit 55a via the perforated wall 75a. As the sand slurry drawn from the sandstone formation 110 moves up the conduit 55a to the surface, the sand slurry may be collected or further processed after passing through the collection port 65a.

[0039] Referring to figure 6, the apparatus 50a is shown in used and further along the process of removing material from the sandstone formation. In the present example, a void 140 is formed and filled with water. It is to be appreciated as the void forms and sand moves away from the perforated wall 75a, the advantages of the perforated wall 75a are negated since water may

Date Reçue/Date Received 2020-05-01

pass through the perforated wall. However, in some examples, the conduit 55a may be extended to maintain the perforated wall 75a below the sand to continue receiving the advantages of the perforated wall 75a. Alternatively, the gas injection line 60a may be used to generate a pressure vibration or pulse air to agitate the sand such that the void 140 is partially filled by settling of the sandstone formation 110 to cover the perforated wall 75a.

[0040] In the present example, a compressor 85a is shown connected to the gas injection line 60a to provide air pressure into the gas injection line 60a. The compressor 85a is not particularly limited and may provide a wide range of pressures as well as flow rates. In the present example, the pressure provided by the compressor 85a may be variable between about 30 psi and about 90 psi. Furthermore, the compressor 85a may provide a flow rate of about 300 cubic feet per minute to 600 cubic feet per minute.

[0041] A separator 90a may be connected to the collection port 65a to receive the sand slurry. The separator 90a is to separate the sand component from the water component as well as remove the air that is received from the collection port 65a. In the present example, the air is released into atmosphere. The water component and the sand component from the sand slurry may be separated by allowing the sand component to settle. In other examples, the separator 90a may use a filtration system.

[0042] Upon separating the water component from the sand component, the separator 90a may return the liquid component to the sandstone formation 110 by releasing the liquid component into the well 100 to maintain the static water level. In other examples, the sand component may be collected while the liquid component is discarded. For example, due to local regulations, it may not be possible to reintroduce the liquid component into the well 100 to reduce the possibility of contaminating the water in the aquifer.

[0043] Referring to figures 7A and 7B, a lower end of another example conduit 55b is illustrated. In the present example, the conduit 55b includes a perforated wall 75b configured to have two states. The first state shown in figure 7A is an open state where the perforated wall 75b includes opening from the inner portion of the conduit 55b to the outside sandstone formation. The second state shown in figure 7B is a closed state where the opens are closed effectively converting the perforated wall 75b into a solid wall. The manner by which the perforated wall 75b is converted from the open state to the closed state is not particularly limited. For example, the conduit 55b may include an inner wall 77b that fits within the inner diameter of the exterior wall of the conduit 55b. The inner wall 77b may include matching openings with exterior wall to provide the perforated wall 75b with openings between the interior of the conduit 55b and the exterior sandstone formation. To change the state of the perforated wall 75b, the inner wall 77b may be rotated so that the openings are no longer aligned as shown in figure 7B to close the openings. Similarly, the inner wall 77b may be rotated to open the perforations to return to the state shown in figure 7A. The inner wall 77b may be rotated automatically with controller and motor near the surface or manually rotated. In other examples, the openings of the perforated wall 75b may be manipulated via other mechanisms, such as longitudinally sliding inner wall 77b. In further examples, the inner wall 77b may be omitted and valves or other gate devices may be disposed on each opening of the perforated wall 75b.

[0044] It is to be appreciated by a person of skill with the benefit of this description that by increasing the surface area of a low pressure region to the sandstone formation at the lower end of the conduit, it is easier to draw in the sand slurry to start the extraction process during the initial phase. Accordingly, to initiate the extraction of sand from the sandstone formation, the perforated wall 75b may have the openings in the perforated wall 75b opened to be in the open state. Once a flow of sand slurry is established, the openings may no longer provide an advantage to toward maintaining the flow. This may be especially true when a void, such as the void 140 develops which causes any openings to draw water without sand. Accordingly, once the flow of sand slurry is established through the conduit 55b, the openings at the perforated wall 75b may be closed such that the suction of sand slurry from the main opening at the end of the conduit 55b where most of the sand is located will be increased.

[0045] Referring to figure 8, another example of an apparatus 50c to extract sand from an underground sandstone formation in a water reservoir, such as an aquifer, is provided. Like components of the apparatus 50c bear like reference to their counterparts in the apparatus 50, except followed by the suffix “c”. In the present example, the apparatus 50c may be is to be inserted into a well from the surface to the underground sandstone formation. The apparatus 50c includes a conduit 55c, a gas injection line 60c, and a collection port 65c.

[0046] In the present example, the conduit 55c and the collection port 65c are substantially similar to the conduit 55 and the collection port 65, respectively. In particular, the conduit 55c is to engage a sandstone formation near a lower end of the well. The collection port 65c is used to remove the sand slurry to be removed from the conduit 55c.

[0047] In the present example, the gas injection line 60c includes a directional injection point 62c at the lower end of the gas injection line 60c. It is to be appreciated that the directional injection point 62c is not particularly limited and may be to inject gas into the conduit 55c in any direction. In the present example, the gas injection line 60c includes an elbow to direct the gas or air in an upward direction and in the same direction as the flow of the sand slurry. In other examples, the directional injection point 62c may include directed the flow of gas at an angle. In further examples, the gas injection line 60c may include a mechanism where the directional injection point 62c may direct the flow of gas and have the capability of changing directions during operation. In such an example, the direction of the injected gas may be another variable that can be adjusted to increase the flow of the sand slurry.

[0048] It should be recognized that features and aspects of the various examples provided above may be combined into further examples that also fall within the scope of the present disclosure.

What is claimed is:

1. An apparatus comprising:

   a conduit having a lower end and an upper end, wherein the lower end is to engage a sandstone formation, and wherein the lower end opposite the upper end;

   a gas injection line to inject gas at an injection point proximate to the lower end, wherein the gas injected at the injection point generates a low pressure region at the lower end to draw a sand slurry from the sandstone formation; and

   a collection port proximate to the upper end of the conduit, wherein the sand slurry in the conduit is to be removed from the conduit via the collection port.

2. The apparatus of claim 1, wherein the lower end of the conduit includes a perforated wall to increase surface area at the sandstone formation.

3. The apparatus of claim 2, wherein the perforated wall is to be in one of a closed state or an open state.

4. The apparatus of any one of claims 1 to 3, wherein the injection point is adjustable relative to the lower end of the conduit to maintain a flow of the sand slurry.

5. The apparatus of any one of claims 1 to 4, wherein the gas injection line is to inject a pulse of gas to agitate the sandstone formation.

Date Reçue/Date Received 2020-05-01

6. The apparatus of any one of claims 1 to 5, wherein the conduit is extendible to be lowered further into the sandstone formation as the sand slurry is removed.

7. The apparatus of any one of claims 1 to 6, further comprising a cover at the upper end of the conduit.

8. The apparatus of claim 7, wherein the cover is made of steel with a flexible membrane seal.

9. The apparatus of claim 8, wherein the cover includes an opening for the gas injection line to pass therethrough, the cover forming an airtight seal at the upper end of the conduit.

10. The apparatus of claim 9, wherein the cover is to slidably engage the gas injection line, and wherein the gas injection line is slidably moveable within the conduit to control the injection point.

11. The apparatus of any one of claims 1 to 10, further comprising a separator connected to the collection port to receive the sand slurry, wherein the separator is to separate a sand component from a liquid component.

12. The apparatus of claim 11, wherein the separator is to return the liquid component to the sandstone formation to maintain a static water level.

13. A method comprising:

lowering a lower end of a pipe into a sandstone formation;

injecting air into the pipe proximate to the lower end to generate a low pressure region at the lower end to draw a sand slurry from the sandstone formation; and collecting the sand slurry at a collection port proximate to an upper end of the pipe.

14. The method of claim 13, further comprising opening perforations on a wall of the pipe to increase surface area between the low pressure region and the sandstone formation.

15. The method of claim 13 or 14, further comprising injecting a pulse of air to agitate the sandstone formation.

16. The method of any one of claims 13 to 15, further comprising extending the pipe to lower the lower end further into the sandstone formation as a void forms.

17. The method of any one of claims 13 to 16, further comprising moving a gas injection line within the pipe to adjust an injection point, wherein adjusting the injection point is to vary the low pressure region.

18. The method of any one of claims 13 to 17, further comprising drilling a well through a shale layer to the sandstone formation.

19. The method of claim 18, further comprising adding water to well to establish a static water level at a predetermined height above the sandstone formation.

20. The method claim 19, further comprising separating a sand component from a water component in the sand slurry.

21. The method claim 20, further comprising returning the water component to the well to maintain the static water level.

Date Reçue/Date Received 2020-05-01

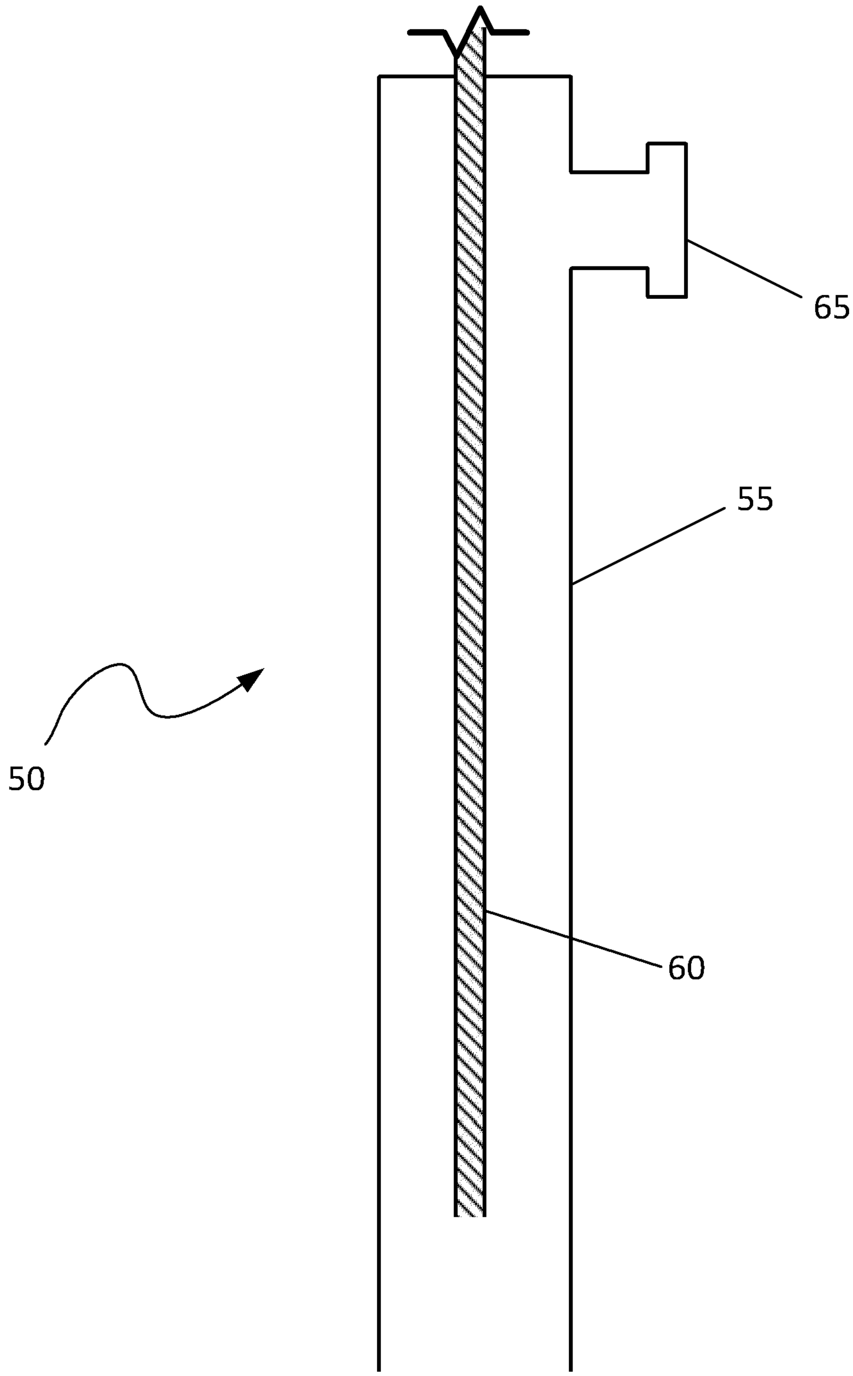


Fig. 1

Date Reçue/Date Received 2020-05-01

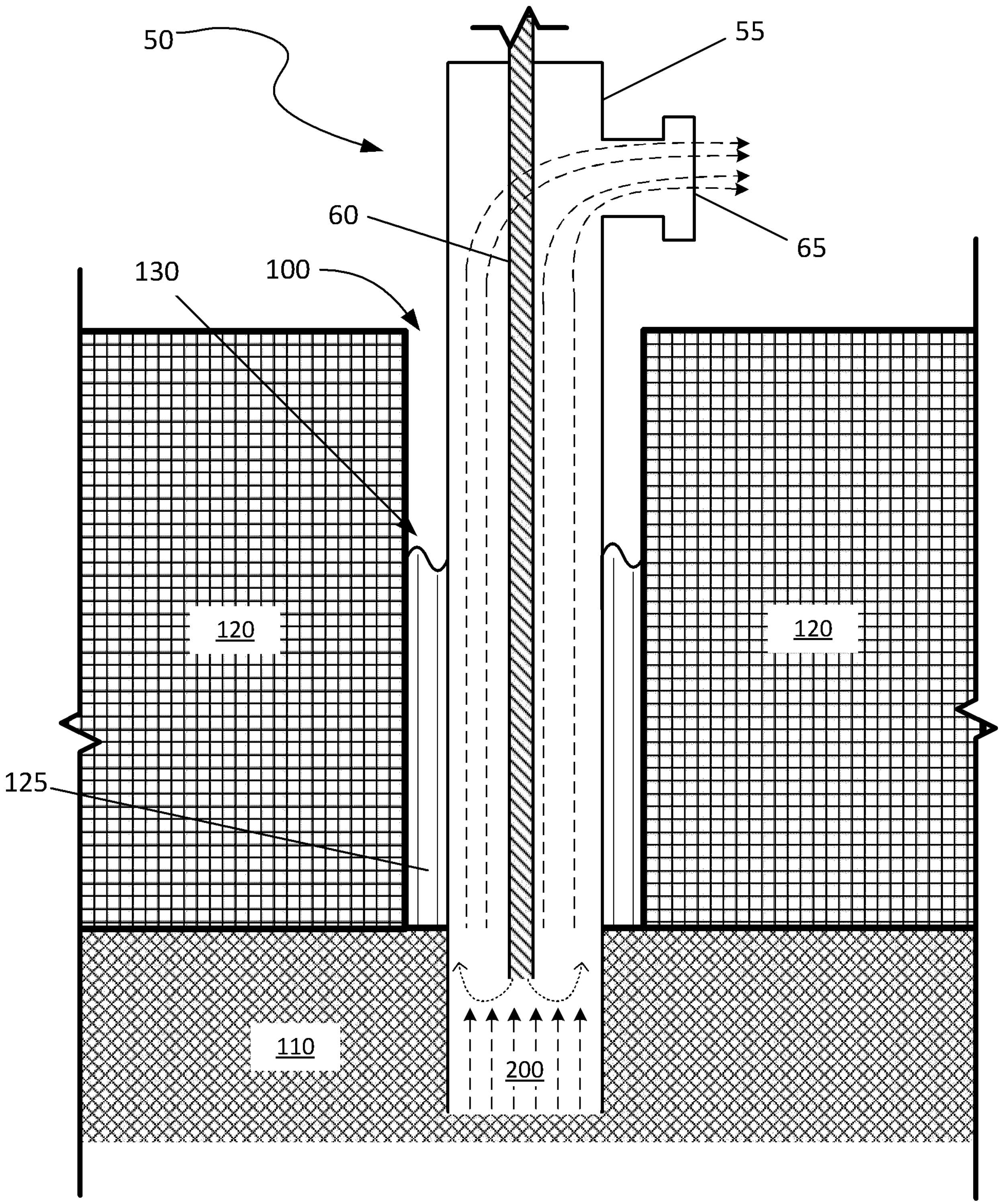


Fig. 2

Date Reçue/Date Received 2020-05-01

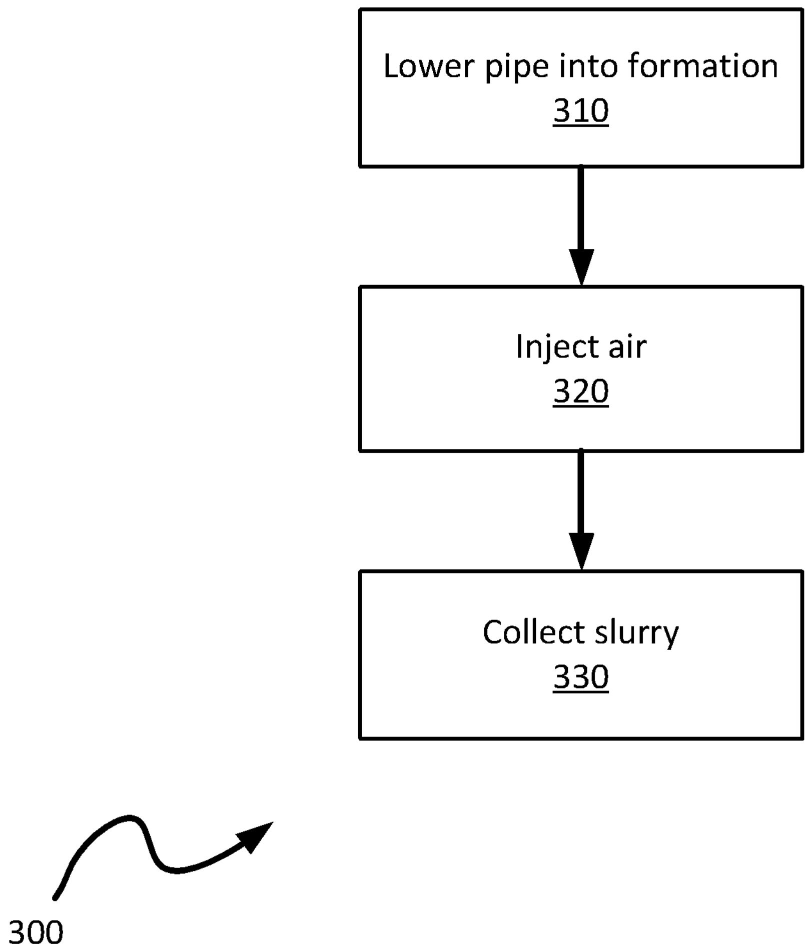


Fig. 3

Date Reçue/Date Received 2020-05-01

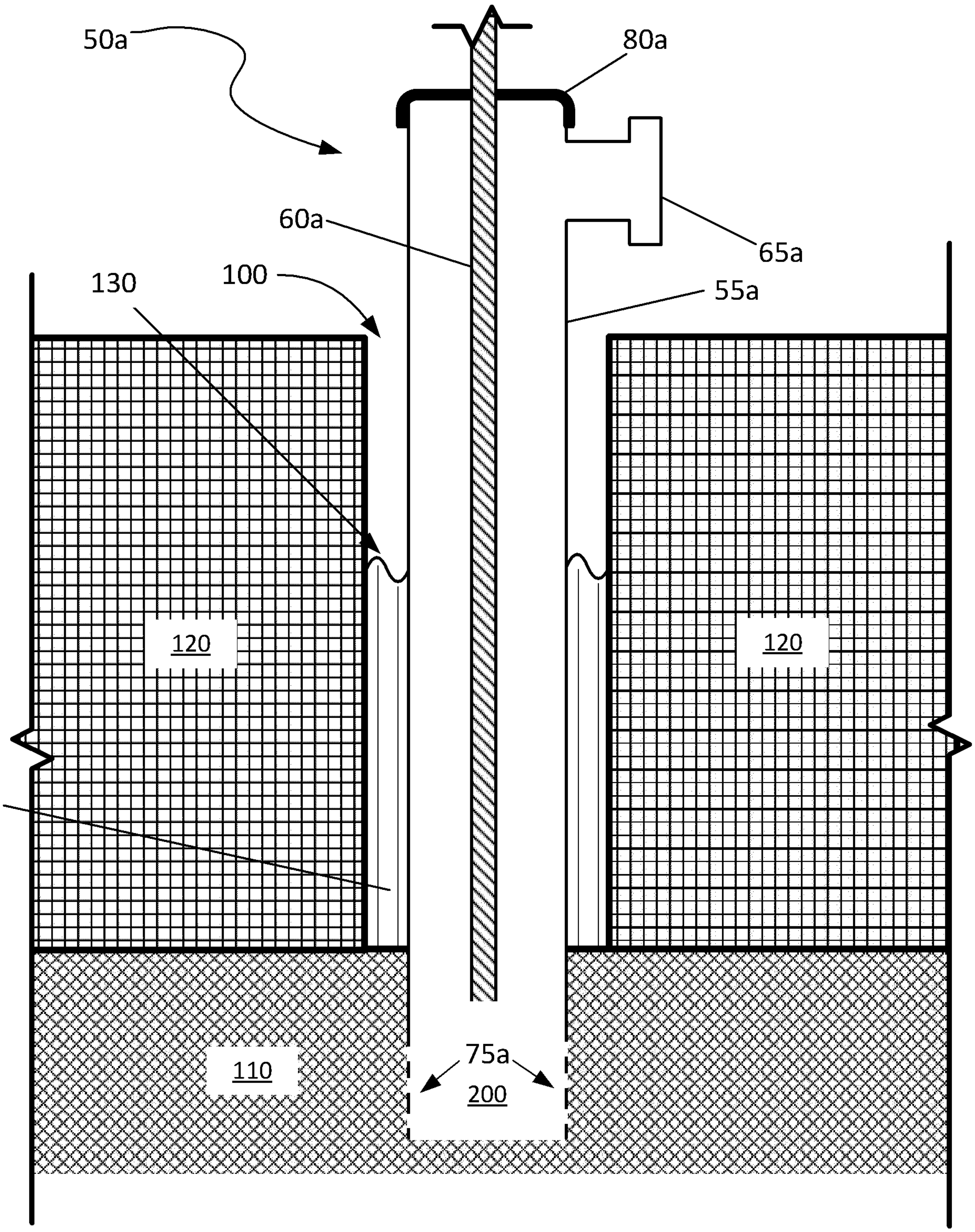


Fig. 4

Date Reçue/Date Received 2020-05-01

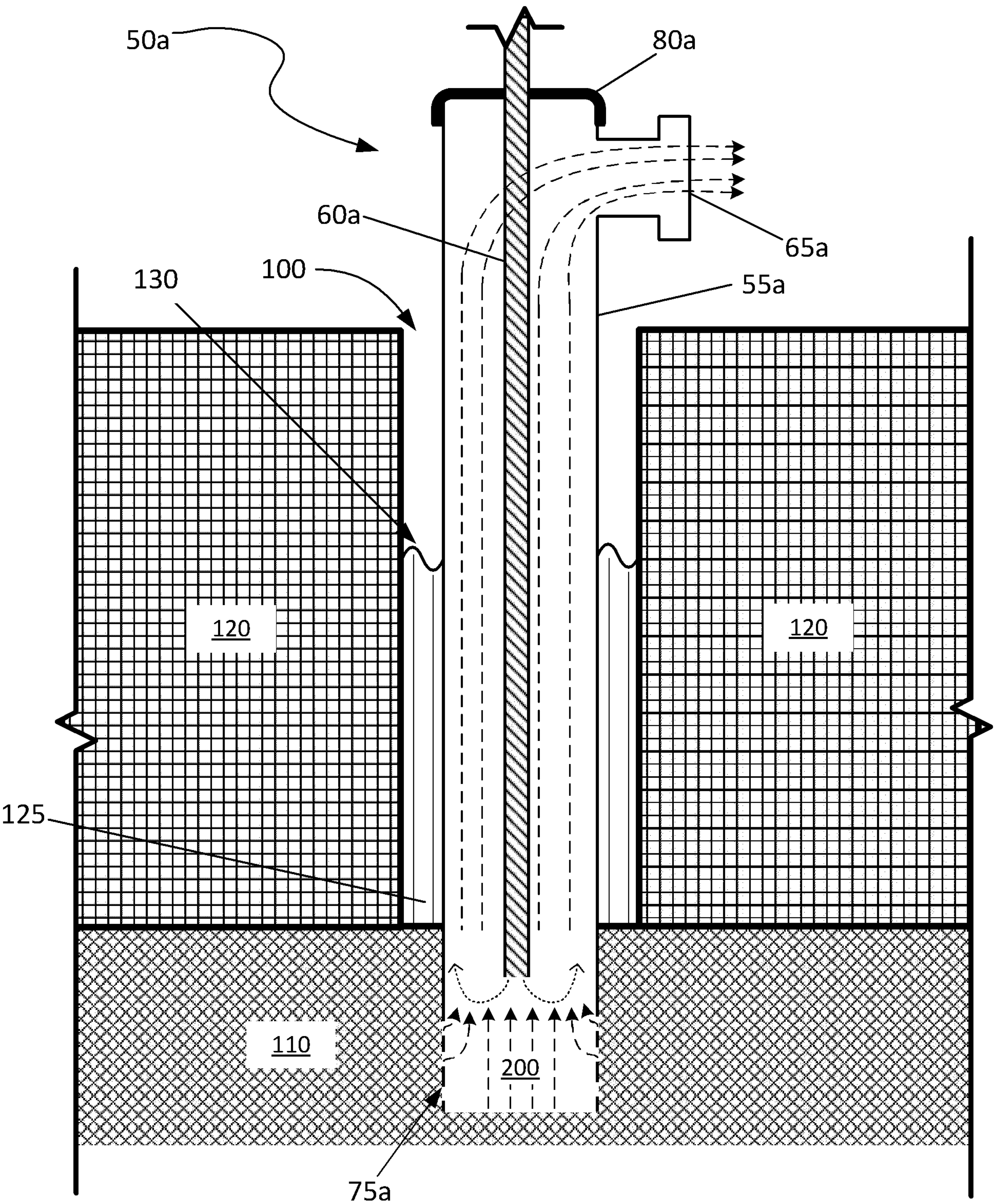


Fig. 5

Date Reçue/Date Received 2020-05-01

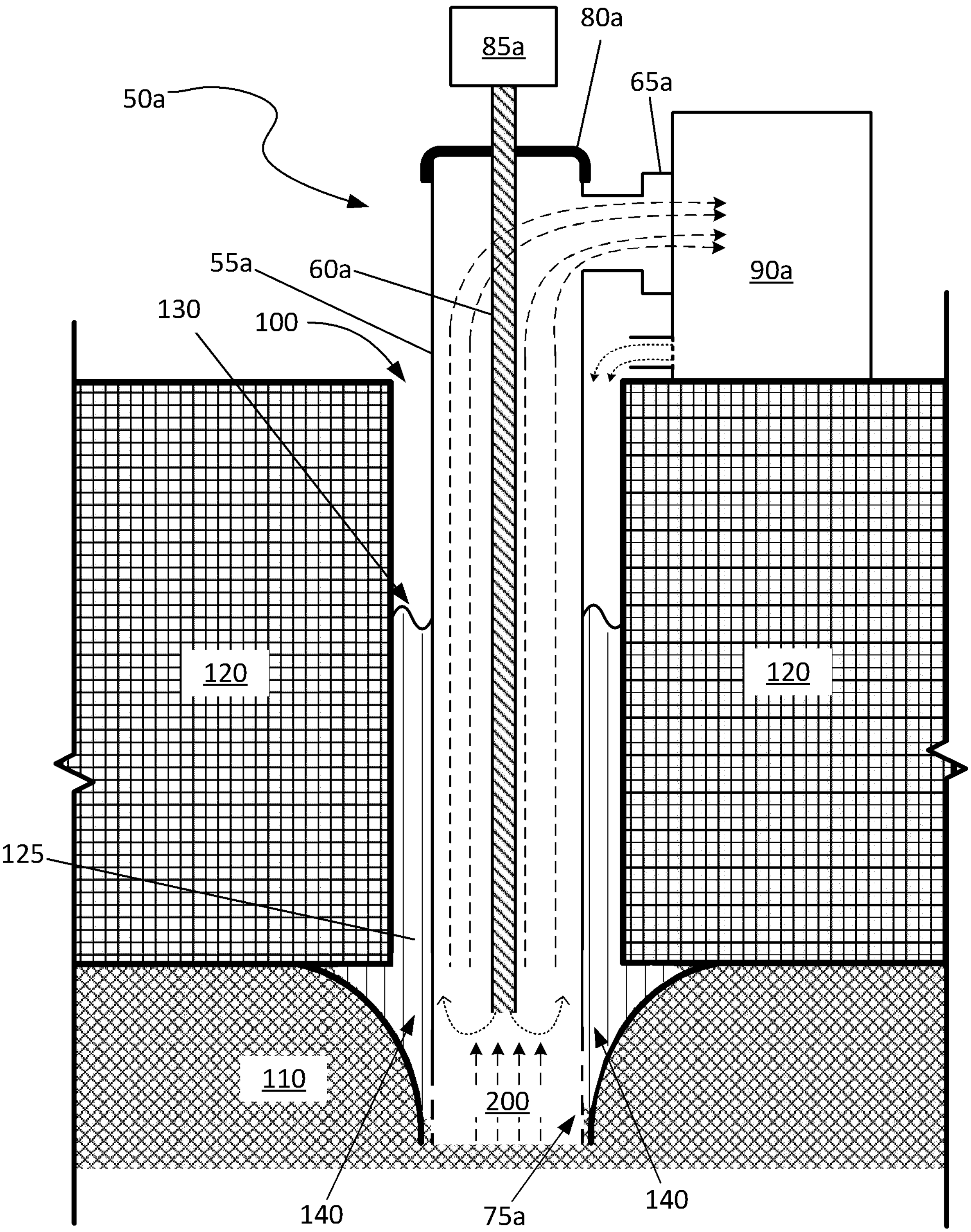


Fig. 6

Date Reçue/Date Received 2020-05-01

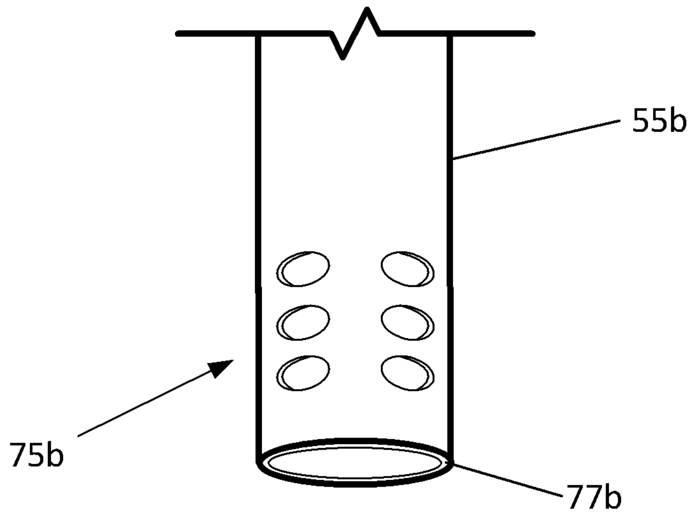


Fig. 7A

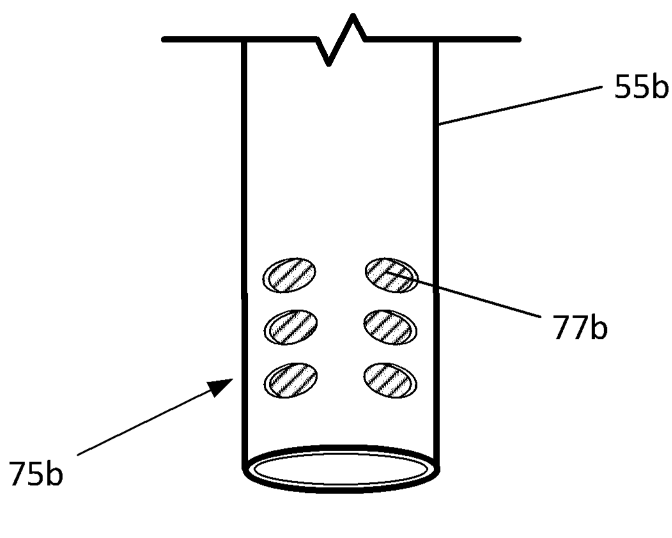


Fig. 7B

Date Reçue/Date Received 2020-05-01

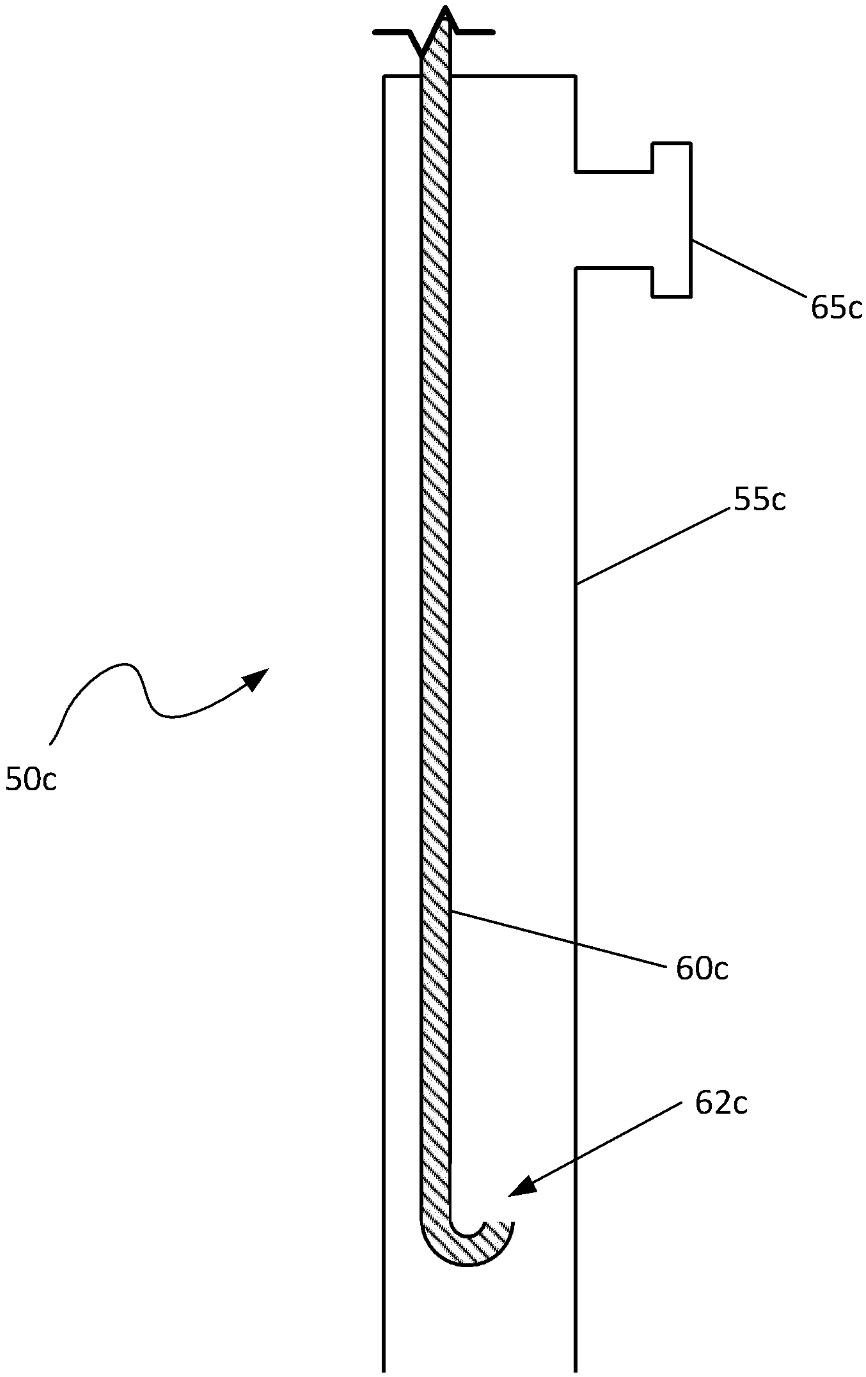


Fig. 8

Date Reçue/Date Received 2020-05-01

ABSTRACT

An example of an apparatus is provided. The apparatus includes a conduit having a lower end and an upper end. The lower end is to engage a sandstone formation and the lower end opposite is the upper end. In addition, the apparatus includes a gas injection line to inject gas at an injection point proximate to the lower end. The gas injected at the injection point generates a low pressure region at the lower end to draw a sand slurry from the sandstone formation. Furthermore, the apparatus includes a collection port proximate to the upper end of the conduit. The sand slurry in the conduit is to be removed from the conduit via the collection port.

Date Reçue/Date Received 2020-05-01