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UTILITY APPLICATION

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**SYSTEMS AND METHODS FOR ASSESSING
AND CLEANING SUBMERGED STRUCTURES**

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The application claims priority to U.S. Patent Application No. 63/599,622, filed on November 16, 2023, entitled “WALL-MOUNTED SYSTEM AND REMOTE METHODS FOR CLEANING SUBMERGED STRUCTURES,” which is incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present invention relates generally to systems and methods for assessing submerged structures and cleaning of submerged structures of waste collection systems such as, but not limited to, sewers, sumps, wet wells, collection tanks, digesters, clarifiers, classifiers, and the like, and methods and processes for determining the location of submerged sediment and the volume within the tank or other submerged structure.

BACKGROUND

[0003] Water treatment facilities, e.g., water purification plants, sewage treatment plants, and the like, typically use one or more submerged water storage vessels or treatment vessels during the process of treating sewage and/or purifying water, which may be referred to as water treatment tanks. While such water storage vessels or treatment vessels at these facilities can be of any shape or size, an exemplary unit may include an oval-shaped and above-ground concrete tank that is squared off at one end. The facility may treat sewage using both anaerobic and aerobic processes within the same tank, with anaerobic processes predominating at one end,

and aerobic processes predominating in channels and at the opposite end. In an example, the tank may be approximately 200 feet long and 60 feet wide.

[0004] Water storage or treatment structures, such as tanks or vessels, storm water and other pipes, culverts, and the like, may periodically need to have one or more (or all) of debris, grit, sand, or sediment removed from them in order to continue to operate at a desired efficiency level. Accumulation of debris, grit, sand, and/or sediment in these structures may affect the design capacity and treatment efficacy of the structure or system. Such debris, grit, sand, and/or sediment can enter the structures through the collection system of pipes and lift stations. Any grit or sand that is not removed in the pre-treatment areas may eventually settle at the bottom of the structures and become sediment (for the purposes herein, these terms may be used interchangeably and sediment includes any debris, grit, or sand that may accumulate or exist in the system). As sediment accumulates, the volume and distribution of the sediment increases and may begin to effect the system. For example, the effectiveness of the treatment process may be compromised due to loss of volume in the structures and changes in waste water flow patterns and retention time due to the accumulation of sediment.

[0005] Prior to cleaning the structures, an estimate of the accumulated sediment volume may be made to estimate several factors including time needed to clean, costs associated with the cleaning process, and the volume of sediment that must be removed. Estimates desirably occur while the structures are submerged, thus allowing the structures and system to remain in service. To date, the amount, volume, and/or location of sediment removal is generally based on inadequate and imprecise estimation measures, including estimates based on experience and estimation methods including rod probing in accessible locations along vessel walls and cat walks. None of these measures, singularly or in combination, yield precise sediment volume measurements or provide meaningful data on sediment volume distribution.

[0006] As a result, most often, the sediment cleaning processes require draining of the structures intended to be cleaned to expose and visually quantify the accumulated sediment for subsequent removal. This methodology, while exposing and perhaps enabling sufficient cleaning of the drained structures, may not be ideal, however, as the structures, and sometimes the whole system, must be removed from service while these structures are drained and cleaned. Further, any undrained structures in the system would remain uncleaned or result in blind and inefficient cleaning if cleaned while still submerged. Treatment facilities with limited treatment capacity may not be able to drain, clean, and remove a structure from service, even temporarily, without disrupting their entire service to their service area.

[0007] For this reason, sediment removal while the tank remains submerged and operational may be preferred. Submerged cleaning, however, much like submerged estimation, can be inefficient, costly, and time-consuming as the precise location and volume of the sediment cannot be seen or otherwise accurately determined in the high turbidity water. As a result, cleaning of the structures while submerged is generally done blindly, without much data, and therefore is mostly governed by sheer luck as to whether such removal is actually effective. Alternatively, other methods of submerged cleaning may include lowering a hose into the undrained structure, conducting a “sweep” of the entire structure floor, and suctioning the sediment and water into a collection tank to ensure maximum recovery of capacity and efficiency of the system. In some cases, a submersible pump may be placed on the hose to increase collection efficiency. As the precise distribution of the sediment in the structure is unknown, the entire structure bottom must be “swept” with the hose to ensure all the sediment is removed. This methodology is inefficient and costly because it does not target areas of the structure that could most benefit from and that actually require cleaning and instead relies on high effort and overlapping cleaning across the entire structure to ensure no missed areas.

[0008] The distribution of grit in a structure, however, is rarely uniform across the bottom. Rather, the sediment accumulates in the physical form of hills, mounts, and reefs, and is subject to the hydrodynamics of the waste water flow within the structure and the system as well as the physical characteristics of the sand, grit, and sediment entering the structures and system. These realities of structure cleaning result in an inefficient removal process, that is unduly time consuming and expensive to the facility or that is ineffective and does not fully remove a desired or sufficient amount of sediment to operate at a desired capacity, efficiency, or for a desired length of time before the sediment accumulates and cleaning is required again.

[0009] Moreover, the amount of waste sediment that may be generated using current cleaning processes cannot be accurately estimated due to the fact that an accurate in situ volume and density of the sediment cannot be measured. Thus there is no empirical factor to calculate dry weight mass of waste from in-situ sediment volume once the sediment is cleaned or removed from the structure and system. This results in unexpected disposal costs for the facility if the waste is underestimated and uncertainty that the cleaning was sufficient if the amount of waste was underestimated, which cannot be readily determined.

[0010] As a result, it is currently not possible to efficiently and economically clean accumulated sediment from structures such as wastewater treatment tanks and vessels, storm water and other pipes, culverts, and the like, while the structure is filled. Additionally, devices used to give access into a water storage facility vessel and/or a water treatment vessel or that would facilitate mapping, monitoring, assessing, and/or cleaning a submerged structure often fall short, are bulky, inadequate, inefficient, or the like.

[0011] Accordingly, there is a need in the art for improved devices and methods by which to determine where and to what extent sediment has accumulated at the bottom of water storage facility structures or water treatment structures, such as the tanks and vessels therein. Further, there is a need in the art for systems and methods of cleaning sediment out of water storage

facility structures or water treatment structures, such as the tanks and vessels therein, while the structure is filled, without having to drain the vessel, remove it from its submerged location, or temporarily remove it from service.

SUMMARY

[0012] The following presents a summary of this disclosure to provide a basic understanding of some aspects. This summary is intended to neither identify key or critical elements nor define any limitations of embodiments or claims. Furthermore, this summary may provide a simplified overview of some aspects that may be described in greater detail in other portions of this disclosure. Any of the described aspects may be isolated or combined with other described aspects without limitation to the same effect as if they had been described separately and in every possible combination explicitly.

[0013] The present invention relates generally to devices, methods, processes, and systems of determining one or more properties in a water storage facility and/or a water treatment facility as well as the submerged estimation and/or cleaning of waste collection systems such as sewers, sumps, wet wells, waste water tanks, collection tanks, digesters, clarifiers, classifiers, and the like, and components and structures thereof.

[0014] The present invention relates generally to a wall-mounted systems and remote methods for assessing submerged structures and cleaning of submerged structures of waste collection systems such as, but not limited to, sewers, sumps, wet wells, waste water tanks, collection tanks, digesters, clarifiers, classifiers, and the like. The systems and methods may be used to determine one or more properties in a water storage facility or water treatment facility. The systems and methods may be used to determine one or more chemical and/or physical properties in a water storage facility vessel or water treatment facility vessel and then use such one or more chemical and/or physical properties to determine where and how much, if any, sand or other sediment may need to be removed and to assist in its removal.

[0015] Disclosed is a method for assessing sediment distribution in a submerged structure. In an embodiment, the method comprises collecting water chemistry data from contents in the submerged structure to determine the type of sediment in the submerged structure. In an embodiment, the method comprises conducting an remote survey of the contents in the submerged structure to determine sediment topography in the submerged structure. In an embodiment, the method comprises performing GEO data mapping of the contents in the submerged structure to determine volumes of the contents in the submerged structure. In an embodiment, the method comprises quantifying the amount of sediment in the submerged structure.

[0016] In an embodiment, collecting water chemistry data comprises collecting at least one sample of the contents in the submerged structure, wherein the collected water chemistry data is further analyzed to determine at least one physical or chemical property of the at least one sample of the contents in the submerged structure. In an embodiment, collecting water chemistry data comprises providing at least one on site-sensor positioned in the contents of the submerged structure, wherein the collected water chemistry data is further analyzed to determine at least one physical or chemical property of the sensor-measured contents in the submerged structure. In an embodiment, the at least one physical or chemical property includes one or more of the following: water temperature, salinity, dissolved oxygen, pH, oxidation reduction potential, turbidity, and presence of chosen ions or chemical constituents.

[0017] In an embodiment, the remote survey is an acoustic survey. In an embodiment, the remote survey uses LIDAR, RADAR, sonar, ultrasonic sensors, camera and image processing, or structured light 3D scanning technologies. In an embodiment, performing GEO data mapping comprises executing two or more scans at several frequencies using multi-beam transducers.

[0018] In an embodiment, the method further comprises carrying out a pre-survey site inspection. In an embodiment, one or more of the steps are performed remotely. In an embodiment, one or more of the steps are performed by an autonomous vehicle. In an embodiment, the autonomous vehicle is a drone, a surface vehicle, or a submerged vehicle. In an embodiment, one or more of the steps are performed prior to cleaning the submerged structure. In an embodiment, the method further comprises cleaning the submerged structure. In an embodiment, the method further comprises repeating one or more (or all) of the steps of claim 1 during cleaning of the submerged structure. In an embodiment, the method further comprises repeating one or more (or all) of the steps of claim 1 after cleaning of the submerged structure. In an embodiment, the method further comprises calculating the amount of sediment removed from the submerged structure and comparing the amount of sediment removed to the amount of sediment in the submerged structure prior to cleaning. In an embodiment, the method further comprises providing predictive maintenance estimations for the submerged structure.

[0019] The following description and the drawings disclose various illustrative aspects. Some improvements and novel aspects may be expressly identified, while others may be apparent from the description and drawings.

DESCRIPTION OF THE DRAWINGS

[0020] Operation of the present teachings may be better understood by reference to the detailed description taken in connection with the following illustrations. These appended drawings form part of this specification, and written information in the drawings should be treated as part of this disclosure. In the drawings:

[0021] FIG. 1 shows a side view of an embodiment of a wall-mounted system for mapping, monitoring, assessing, and/or cleaning a submerged structure in accordance with various aspects disclosed herein;

[0022] FIG. 2 shows a front view of the embodiment of a wall-mounted system of FIG. 1 in accordance with various aspects disclosed herein;

[0023] FIG. 3 shows a top view of the embodiment of a wall-mounted system of FIG. 1 in accordance with various aspects disclosed herein;

[0024] FIG. 4 is a flow chart showing an embodiment of a method of mapping and removing sediment in a submerged structure in accordance with various aspects disclosed herein;

[0025] FIG. 5 is an aerial view of an example of a viewable portion of a water treatment facility having a water storage or treatment tank that may be mapped and cleaned in accordance with various aspects disclosed herein;

[0026] FIG. 6 is a graph detailing turbidity data from turbidity stations 1-3 T;

[0027] FIG. 7 is a graph detailing turbidity data from turbidity stations 4-6 T;

[0028] FIG. 8 is a graph detailing turbidity data from turbidity stations 7-9 T;

[0029] FIG. 9 is a graph detailing redox potential data from stations 1-3 T;

[0030] FIG. 10 is a graph detailing redox potential data from stations 4-6 T;

[0031] FIG. 11 is a graph detailing redox potential data from stations 7-9 T;

[0032] FIG. 12 is a graph detailing dissolved oxygen data from stations 1-3 T;

[0033] FIG. 13 is a graph detailing dissolved oxygen data from stations 4-6 T;

[0034] FIG. 14 is a graph detailing dissolved oxygen data from stations 7-9 T;

[0035] FIG. 15 is a map showing an exemplary quantity survey of an oxidation ditch of the water storage or treatment tank located at the water treatment facility shown in FIG. 5;

[0036] FIG. 16 is an exemplary topography map of a floor of a water storage or treatment tank such as that located at the water treatment facility shown in FIG. 5;

[0037] FIG. 17 is a cross-section of the topography map of FIG. 16;

[0038] FIG. 18 is a view of an embodiment of an apparatus wherein a submersible pump and vacuum system is utilized to pump the waste slurry into the waste container;

[0039] FIG. 19 is a view of an embodiment of an apparatus wherein a vacuuming system and submersible pump is utilized to move the waste slurry into the waste container;

[0040] FIG. 20 depicts an apparatus such as a tank containing a solid and liquid mixture to be separated in accordance with aspects disclosed herein;

[0041] FIG. 21 depicts the system and method of separation of a solid and liquid mixture in an apparatus in accordance with aspects disclosed herein;

[0042] FIG. 22 depicts an tank of the apparatus of Figure 2 after separation of a solid and liquid mixture in accordance with aspects disclosed herein;

[0043] FIG. 23 depicts an example of how inorganic material, such as sand, impacts the dewatering of biosolids via a belt filter press; and

[0044] FIG. 24 depicts an exemplary wastewater treatment system.

[0045] The invention may be embodied in several forms without departing from its spirit or essential characteristics. The scope of the invention is defined in the appended claims, rather than in the specific description preceding them. All embodiments that fall within the meaning and range of equivalency of the claims are therefore intended to be embraced by the claims.

DESCRIPTION OF THE INVENTION

[0046] Reference will now be made in detail to exemplary embodiments of the present teachings, examples of which are illustrated in the accompanying drawings, wherein like numbered aspects refer to a common feature throughout. It is to be understood that other embodiments may be utilized and structural and functional changes may be made without departing from the respective scope of the present teachings. Moreover, features of the various embodiments may be combined or altered without departing from the scope of the present teachings. As such, the following description is presented by way of illustration only and should not limit in any way the various alternatives and modifications that may be made to the illustrated embodiments and still be within the spirit and scope of the present teachings.

[0047] In this disclosure, numerous specific details provide a thorough understanding of the subject disclosure. It should be understood that aspects of this disclosure may be practiced with other embodiments not necessarily including all aspects described herein, etc.

[0048] As used herein, the words “example” and “exemplary” means an instance, or illustration. The words “example” or “exemplary” do not indicate a key or preferred aspect or embodiment. The word “or” is intended to be inclusive rather than exclusive, unless context suggests otherwise. As an example, the phrase “A employs B or C,” includes any inclusive permutation (e.g., A employs B; A employs C; or A employs both B and C). Also, the articles “a” and “an” are generally intended to mean “one or more” unless context suggest otherwise.

[0049] Further, as herein disclosed, the terms “substantially,” “about,” and variations thereof describe features that are equal or approximately equal to a value or characteristic, as desired, reflecting tolerances, conversion factors, rounding off, measurement error, acceptable variation thresholds, and the like. For example, unless context or this disclosure suggests otherwise, the term “substantially” includes values or characteristics that are exact or within 15% of exact (or what is stated), for example within 10% of exact, or within 5% of exact. In another example, unless context or this disclosure suggests otherwise, the term “about” includes values within .5 of a degree to 1 degree of exact (or what is stated).

[0050] Further, unless context or this disclosure suggests otherwise, descriptions of shapes (e.g., circular, rectangular, triangular, etc.) refer to shapes meeting the definition of such shapes and general representation of such shapes. For instance, a triangular shape or generally triangular shape may include a shape that has three sides and three vertices or a shape that generally represents a triangle, such as a shape having three major sides that may or may not have straight edges, triangular like shapes with rounded vertices, etc.

[0051] As noted herein, the present invention relates generally to systems and methods to determine one or more properties in a water storage facility or a water treatment facility. In one

embodiment, the systems and methods may determine one or more chemical and/or physical properties in a water storage facility vessel or a water treatment facility vessel and then use such one or more chemical and/or physical properties to determine where and how much, if any, sand or other sediment may need to be removed and to assist in its removal.

[0052] In an embodiment, the systems and methods may give access into a water storage facility vessel or a water treatment vessel determine where and/or to what extent sediment or sand needs to be removed from a water storage facility vessel or water treatment vessel.

[0053] In an embodiment, the systems and methods may include a device mounted to or near a water storage facility vessel or a water treatment vessel and that allows for the mapping, monitoring, assessing, and/or cleaning a submerged structure. The device, and systems and methods thereof, may gather and determine data relating to one or more of water temperature, salinity, dissolved oxygen, pH, oxidation reduction potential and/or turbidity in a water storage facility vessel or a water treatment vessel to determine where and/or to what extent sediment or sand needs to be removed and to assist in its removal.

[0054] In an embodiment, the systems and methods may give access into a water storage facility vessel or a water treatment vessel and can create a 3-dimensional model of accumulated debris, sediment, grit, etc., within a submerged tank. The systems and methods may include using GPS and other mapping technology to create the 3-dimensional model.

[0055] Generally, the present invention may allow for the mapping, monitoring, assessing, and/or cleaning a submerged structure and may allow for access into a submerged structure and the waste water therein. The present invention may allow for the estimation and calculation of the amount of waste sediment that is in the area to be cleaned more accurately than current processes. The present invention may be able to measure and calculate a more accurate in situ volume and density of the sediment to use as empirical factors to calculate dry weight mass of waste from in-situ sediment volume. As a result, estimated and actual disposal costs or

estimated and actual waste removal may also be more accurate than current methods. In many cases the removal of waste from a structure, such as a waste tank or the like, may be charged by the amount of waste material removed from such structure. The present invention allows for a more accurate calculation of the material to be removed as well as identifying the location of the material to be removed, which provides a more accurate quote at the onset of the project.

[0056] Turning to FIGs. 1-3, shown is an embodiment of a wall-mounted system 10 for mapping, monitoring, assessing, and/or cleaning a submerged structure, which, in turn, may include a fluid such as waste water 2. The submerged structure, in an example, may include a tank or vessel 4 and the submerged structure and/or surrounding area may include a structure 6 that extends above the height of the tank or vessel 4.

[0057] The wall-mounted system 10 may include at least one attachment member, e.g., 20, 25, to selectively attach or secure the wall-mounted system 10 in a desired position or location. For example, the wall-mounted system 10 may include a first attachment member 20 and/or a second attachment member 25. The wall-mounted system 10 may include any number of attachment members, including 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 etc. attachment members. The wall-mounted system 10 may selectively attach or secure to a wall of a facility, to a wall of the submerged structure, such as to a portion of the tank 4 and/or structure 6, or may include a stand that allows the wall-mounted system 10 to free stand or stand independently. In an embodiment, the wall-mounted system 10 may be selectively attached or secured to the tank 4 and/or structure 6. Structure 6 may be a part of the submerged structure or structure 6 may be a part of a nearby wall or area of the facility, in proximity of the submerged structure.

[0058] The tank 4 and/or structure 6 may include corresponding areas of attachment, e.g., 7, 8, to which the attachment members 20, 25 may attach. In an embodiment, structure 6 may include at least one horizontal bar or other corresponding area of attachment 7 to which attachment member 20 may attach. For example, structure 6 may include a cage-like structure.

In an embodiment, tank 4 may include at least one horizontal bar, ledge, rim, top surface, or other corresponding area of attachment 8 to which attachment member 25 may attach. While embodiments may describe attachment of the wall-mounted system 10 to both an area of the structure 6 and an area of the tank 4, it is noted that the wall-mounted system 10 may be attached to only one or more areas of the structure 6 (e.g., not to the tank 4), to one or more areas of the tank 4 (e.g., not to the structure 6), or a combination of areas of the structure 6 and the tank 4. It is further noted that while the structure 6 may be a part of the submerged structure and positioned above or on top of the edge of the tank 4, for example, extending from attachment area 8 as shown in FIG. 1, the structure 6 may also be positioned differently in respect to the edge of the tank 4, for example, attached to the side of the tank 4, may be located on an adjacent wall of the facility, may be included as a part of the wall-mounted system 10 as a stand or adaptor, or the like.

[0059] The at least one attachment member, e.g., 20, 25, may generally comprise a hook structure. For example, the at least one attachment member, e.g. 20, 25, may include an arm, e.g. 22, 27, and a hooked end, e.g. 24, 29. In an embodiment, attachment member 20 may include an arm 22 and a hooked end 24. In an embodiment, attachment member 25 may include an arm 27 and a hooked end 29. As shown in FIG. 1, each arm 22, 27 or the corresponding attachment member 20, 25 may be positioned over the corresponding area of attachment 7, 8 and the hooked end 24, 29 may hook around the corresponding area of attachment 7, 8 and secure the wall-mounted system 10 to the desired position on the tank 4 and/or structure 6. The attachment members 20, 25 may have the same size and shape, or may have different sizes and shapes that correspond to the size and shape of the corresponding areas of attachment 7, 8. For example, the attachment area 8 on the tank 4 may have a greater thickness, may include square edges, etc. and may require a longer arm 27 and/or hooked end 29. For example, the attachment area 7 on the structure 6 may have a smaller thickness, may be rounded, etc., and may require

a shorter arm 22 and/or hooked end 24. In an example, arm 22 may have a length that is adjustable to fit on the applicable structure. The length may vary depending on the location of the wall-mounted system 10 relative to the structure 6. The variability allows the wall-mounted system 10 to be positioned on a variety of different structures 6. The hooked end 24 may have an adjustable length so as to accommodate structures 6 of various sizes and configurations. In an example, arm 27 may have an approximate length ranging from 2 feet to 20 feet or more and hooked end 29 may have an approximate length ranging from ½ foot to 10 feet or more.

[0060] The attachment members 20, 25 may further include a tightening mechanism or lock, e.g. 28 to further secure or lock the wall-mounted system 10 to the desired position on the tank 4 and/or structure 6. For example, attachment member 25 may further include tightening mechanism or lock 28. The tightening mechanism or lock 28 may include, in an example, a screw that extends through the hooked end 29 and that may be tightened to engage the corresponding area of attachment 8 when the attachment member 25 is attached thereto so as to create a friction fit. It is noted that other types of tightening mechanisms or locks may be used as may be known in the art. It is noted that the wall-mounted system 10 may include a tightening mechanism or lock that corresponds to each of the attachment members or the wall-mounted system 10 may include a number of tightening mechanisms or locks that is different than the number of attachment members. For example, wall-mounted system 10 may include first attachment member 20 and second attachment member 25, where only second attachment member 25 includes a tightening mechanism or lock 28, or vice versa.

[0061] The wall-mounted system 10 may further include a bracing bar 30, a hanger 40, and an extendable member 50. The bracing bar 30 may connect to the at least one attachment member, e.g., 20, 25. The bracing bar 30 may connect to the hanger 40. The wall-mounted system 10 may further include a support member 35 connecting the bracing bar 30 to the hanger 40. The support member 35 may bear or redistribute some of the weight from the hanger 40,

extendable member 50, etc., to minimize or prevent entire weight of these aspects relying on the connection of hangar 40 directly to the bracing bar 30. In an embodiment, the support member 35 may have an adjustable length to accommodate the size and configuration of the tank 4 and/or structure 6. In an embodiment, the support member 35 may form a generally triangular shape with the hangar 40 and the bracing bar 30. The support member 35 may attach at any points along the hangar 40 and the bracing bar 30. In an embodiment, the support member 35 may attach at a point along the hangar 40 and the bracing bar 30 that opposite or further from the connection of the hangar 40 to the bracing bar 30.

[0062] The hanger 40 may generally connect to the bracing bar 30 at around the same height of the at least one attachment member, e.g., 20, 25. In an embodiment, the hanger 40 may generally connect to the bracing bar 30 at a height that is between the first attachment member 20 and the second attachment member 25. In an embodiment, the at least one attachment member, e.g., 20, 25 may extend in a first direction from the bracing bar 30 and the hanger 40 may extend in a second, opposite direction from the bracing bar 30. In an embodiment, the at least one attachment member, e.g., 20, 25 and the hangar 40 may generally extend from the bracing bar 30 at an approximate right or 90 degree angle.

[0063] The bracing bar 30 may include an upper and a lower portion. For example, the upper portion of the bracing bar 30 may be considered the top 1/3 of the length of the bracing bar 30. For example, the lower portion of the bracing bar 30 may be considered the bottom 2/3 of the length of the bracing bar 30. The upper portion or top 1/3 of the length of the bracing bar 30 may connect to the at least one attachment members, e.g. 20, 25, and the hangar 40 as described herein. The lower portion or bottom 2/3 of the length of the bracing bar 30 may extend from the upper portion of the bracing bar 30. This lower portion or bottom 2/3 of the length of the bracing bar 30 may also be referred to as an elongated or extended portion of the bracing bar.

[0064] When the wall-mounted system 10 is selectively attached to the submerged structure, the bracing bar 30 may generally align with central axis A. When the wall-mounted system 10 is selectively attached to the submerged structure, the bracing bar 30 may generally be inserted into the inner portion of the submerged structure where, for example, the at least part of the lower portion of the bracing bar 30 may extend into tank 4 and may insert into the waste water 2 therein. In an embodiment, the bracing bar 30 may have an adjustable length to accommodate the applicable size and configuration of the tank 4 and/or structure 6.

[0065] When the wall-mounted system 10 is selectively attached to the submerged structure, the hangar 40 may generally be perpendicular to central axis A. When the wall-mounted system 10 is selectively attached to the submerged structure, the hangar 40 may hang over the submerged structure and the contents therein, such as the waste water 2. In an embodiment, no portion of the hangar 40, unlike the bracing bar 30, may be submerged or come into direct contact with waste water 2. In an embodiment, hangar 40 may have an adjustable length to accommodate the applicable size and configuration of the tank 4 and/or structure 6.

[0066] While the present disclosure identifies that the arm 22, the hooked end 24, the support member 35, the hangar 40 and the bracing bar 30, may comprise adjustable lengths, each may also have a fixed length. Further, some of the arm 22, the hooked end 24, the support member 35, the hangar 40 and the bracing bar 30 may have an adjustable length while others may have a fixed length in any combination.

[0067] In an embodiment, the extendable member 50 may hang from hangar 40 at the end of the hangar 40 opposite the hangar's 40 connection to the bracing bar 30. The extendable member 50 may further connect to a device 60. Device 60 may be any type of device as desired for mapping, monitoring, assessing, and/or cleaning a submerged structure, for example, as well as for any data or sample collection. Device 60 may include sensors, measurement devices, sample collectors, and the like, or any other device that may be used to effectuate the methods

of assessing a submerged structure as described herein. Device 60 may include acoustic measurement devices, transducers, manipulators, etc. It is noted that various devices as described herein may be interchangeable as device 60 as desired and used with the wall-mounted system 10.

[0068] The extendable member 50 may selectively retract and extend device 60 into the waste water 2 in the tank 4 of the submerged structure and may direct or control the device 60 to different depths within the waste water 2 in the tank 4 of the submerged structure. The extendable member 50 may include telescoping members, a rope or line that may be wound and unwound, or the like. The wall-mounted system 10 may include a manual mechanism used to retract and extend extendable member 50 and device 60, may include an automated system, or electronic controller, etc.

[0069] Although the disclosure generally describes a wall-mounted device, it is noted that any device may be used with the disclosed system and methods. For example, the device may be free-standing, may be permanent or temporary, may be movable (e.g., motorized), may be controlled by an individual on site or remotely, may be automatic, and the like.

[0070] FIG. 4 is a flow chart of a method or process 100 of mapping and removing sediment in a submerged structure that may use wall-mounted system 10 or other system. Generally, the method 100 may include one or more (or all) of: (1) identifying the structure(s) to be cleaned, which may be done via a satellite analysis of the location; (2) conducting a pre-survey site inspection as described herein; (3) collecting water chemistry data of various types described herein; (4) analyzing the chemistry data to help make determinations regarding next steps; (5) pre-cleaning acoustic survey; (6) conducting GEO data mapping of sediment elevation (also referred to as geographic(al) mapping or geographical information systems); (7) determining tank floor sediment elevation map; (8) determining accumulated sediment volume calculation; (9) collecting sediment samples; (10) analyzing the samples; (11) completing and reviewing

sediment report; (12) determining intended sediment disposal volumes and weight; (13) submerged cleaning; (14) using GPS guidance for the downhole pump or vacuum device; (15) separating sediment from water; (16) conducting a post-cleaning acoustic survey; (17) conducting GEO data mapping of sediment elevation; (18) determining removed sediment volume calculation; and (19) completing and reviewing tank cleaning report based on comparing intended sediment disposal volumes and weight and removed sediment volume.

[0071] In an embodiment, the method 100 includes each of the above-listed steps in the above-listed order. It is noted that one or more of the above-listed steps may also be combined, reordered, excluded, etc. without departing from the disclosed method. It is also noted that the method 100 may be split into separate processes that may be completed at different times or in different phases or that may be used as a separate method entirely, including pre-cleaning surveys which can include evaluation of the water facility and system, evaluation and mapping of sedimentation; determination or calculation of desired sedimentation to be removed; removal of sedimentation, and post-cleaning survey which may can include reevaluation and re-mapping of sedimentation or comparison of actual sedimentation removed and desired sedimentation to be removed. In other words, the evaluation components of the above-listed steps may be performed separate and apart from the cleaning steps described. In fact, a different entity may perform the evaluation steps from the entity that performs the cleaning.

[0072] It is noted that one or more, or all, described steps may be performed by wall-mounted system 10 and the attachable devices 60 thereto. For example, different devices 60 may be used with the wall-mounted system 10 to complete any or all of steps 1-19 described herein. Devices 60 and wall-mounted system 10 may facilitate assessment, survey, cleaning, and maintenance of a submerged structure. It is also noted that one or more, or all, described steps may be performed by a different device as may be suitable or desired, such as a small remote-controlled boat or drone.

[0073] In an embodiment, the pre-survey site inspection may include assessing the submerged structure and site thereof to evaluate the submerged structure and the condition of the submerged structure. The inspection may include access point inspection, exterior assessment, and/or interior inspection. The inspection may be used to determine whether cleaning is needed and to what extent, diagnostics, time estimates, cost estimates, equipment needed, and the like. In an embodiment, the inspection may be carried out by persons on-site of the submerged structure or the inspection may be carried out by persons remote from the submerged structure (or may be carried out autonomously). The pre-survey site inspection may also be used to determine the most appropriate manner in which to collect the water to perform the water analysis and/or the most appropriate means to conduct the pre-cleaning acoustic survey.

[0074] For example, an aerial drone, remote controlled boat, or other remote operating, unmanned, or autonomous vehicle may be used to obtain information such as measurements or other information related to the submerged structure, site conditions and condition of the submerged structure, access point, exterior, and interior inspections, and the like. The drone may include an underwater transducer or overwater transducer (or both). The drone or remote controlled boat may utilize LIDAR or other remote sensing technology, such as RADAR, sonar, ultrasonic sensors, camera and image processing, structured light 3D scanning, etc. Data may be processed into an image or map. Data may be transmitted over a communication network or to a cloud for remote data analysis and evaluation. Data may be used to estimate and determine condition, cleaning or maintenance needs, diagnostics, job suitability, associated costs, and the like, without requiring a surveyor on site. In other embodiments, instead of a drone, a remote boat like device may be utilized. Such device may be controlled by a remote control (which may be at the site or remote thereto) that can drive the boat-like device around

the tank and/or structure. It is also noted that level trolls or other submersible pressure sensors may be used in the inspection and survey steps.

[0075] In an embodiment, the collection of water chemistry data may be carried out by persons on-site of the submerged structure or the collection may be carried out by persons remote from the submerged structure (or may be carried out autonomously). For example, an aerial drone or other remote operating, unmanned, or autonomous vehicle (such as a remote boat-like device or a submarine-like device) may be used to lower one or more containers into the submerged structure (e.g., into water/sediment within the submerged structure) to collect samples of the contents. For example, an aerial drone may be used to lower one or more sensors into the submerged structure (e.g., into water/sediment within the submerged structure) to collect data related to the contents. In an embodiment, a remote or autonomous surface vehicle may be used to collect samples or data through onboard or deployed sensors. The surface vehicle may be used within the submerged structure. In an embodiment, a collection or measurement instrument may be pulled through the water by the drone or surface vehicle. In an embodiment, the drone or surface vehicle may drag the sensor(s) over the water surface. The boat-like device or submarine-like device may include a sensor(s) that can be utilized immediately above the water or below the surface of the water.

[0076] It is noted that any sensors or combination of sensors may be used as desired to provide information relating to the water and contents within the submerged structure, including, for example, pH sensors which can measure the acidity or alkalinity of water by detecting the concentration of hydrogen ions, dissolved oxygen sensors that can measure the amount of dissolved oxygen in water, conductivity or salinity sensors, turbidity sensors which can measure cloudiness or haziness of water caused by suspended particles, temperature sensors, ion-selective electrodes which can measure specific ions such as chloride, fluoride, and nitrate ions, ammonium or nitrate sensors, total organic carbon sensors which can measure

the concentration of organic carbon compounds in water, redox or oxidation-reduction potential sensors that can measure the ability of water to undergo oxidation or reduction reactions; UV-Vis spectrophotometers which can analyze water samples for specific chemical constituents by measuring their absorbance or transmittance of light at different wavelengths, and the like. Data may be transmitted over a communication network or to a cloud for remote data analysis and evaluation. Data may be used to estimate and determine condition, cleaning or maintenance needs, diagnostics, job suitability, associated costs, and the like, without requiring a surveyor on site.

[0077] In an embodiment, the pre-cleaning acoustic survey may be carried out by persons on-site of the submerged structure or the survey may be carried out by persons remote from the submerged structure (or may be carried out autonomously). For example, an aerial drone or other remote operating, unmanned, or autonomous vehicle may be used to facilitate a survey of the condition and contents of the submerged structure, for example, an acoustic survey and/or survey to collect bathymetric data, including, without limitation a remote controlled boat. In an embodiment, a drone may be used to launch and retrieve a remote or autonomous surface vehicle which can execute the survey and data collection. The surface vehicle may be used within the submerged structure. It is also noted that level trolls or other submersible pressure sensors may be used in the survey steps.

[0078] The survey and data can be useful in determining the topography of underwater landscapes and terrain and may be used to determine presence and elevation of sediment or other debris layers in a submerged structure. The survey and data can be used to determine levels of layers across the entire interior of a submerged structure, substantially all of the interior of a submerged structure, greater than 50% of the interior of a submerged structure, at least $\frac{1}{4}$ of the interior of a submerged structure, and the like.

[0079] The survey and data can be used to determine levels of layers in a submerged structure with minimal or reduced estimation. For example, conventional methods may take depth measurements at discrete locations and then extrapolate the measurements across the submerged structure. The contents of the submerged structure, however, may not be uniform throughout its interior and the discrete measurements may not be representative of the whole, such that the extrapolation using conventional methods may result in both unpredictable underestimates and overestimates. The described survey and data may be used provide improved mapping and information related to the contents of the submerged structure. The described survey and data may be used provide more accurate mapping and information related to the contents of the submerged structure. Data may be transmitted over a communication network or to a cloud for remote data analysis and evaluation. Data may be used to estimate and determine condition, cleaning or maintenance needs, diagnostics, job suitability, associated costs, and the like, without requiring a surveyor on site.

[0080] In an embodiment, GEO data mapping of sediment elevation may be carried out by persons on-site of the submerged structure or the mapping may be carried out by persons remote from the submerged structure (or may be carried out autonomously). For example, an aerial drone or other remote operating, unmanned, or autonomous vehicle (such as a boat-like device or submarine-like device) may be used to facilitate GEO data mapping of sediment elevation within the submerged structure. In an embodiment, a drone may be used to launch and retrieve a remote or autonomous surface vehicle which can execute the data collection and mapping. The surface vehicle may be used within the submerged structure.

[0081] In an embodiment, the data collection and mapping may include executing two or more (or a plurality of) scans at several frequencies to determine contents of the submerged structure. The data collection and mapping at several frequencies may be used to determine in-situ volumes of biosolids and sand/grit. The frequencies may be carried out by transducers,

such as multi-beam transducers. Data collection from previous steps, such as the pre-survey site inspection, collection of water chemistry data, and pre-cleaning acoustic survey may additionally or alternatively be used to provide GEO data mapping of sediment elevation. Data may be transmitted over a communication network or to a cloud for remote data analysis and evaluation. Data may be used to estimate and determine condition, cleaning or maintenance needs, diagnostics, job suitability, associated costs, and the like, without requiring a surveyor on site. It is also noted that level trolls or other submersible pressure sensors may be used in the preceding and/or following mapping steps identified within this specification.

[0082] In an embodiment, determination of a tank floor sediment elevation map may be carried out by persons on-site of the submerged structure or the mapping may be carried out by persons remote from the submerged structure (or may be carried out autonomously). For example, an aerial drone or other remote operating, unmanned, or autonomous vehicle may be used to facilitate determination of the tank floor sediment elevation map within the submerged structure. In an embodiment, a drone may be used to launch and retrieve a remote or autonomous surface vehicle which can execute the data collection and mapping. In another embodiment, a remote controlled boat may be used to execute the data collection and mapping as described herein. The surface vehicle may be used within the submerged structure. In an embodiment, the elevation maps may be used to differentiate between organic and inorganic materials.

[0083] In an embodiment, a 3-dimensional map may be created. For example, conventional methods generally entail only a 2-dimensional map which is limited in the amount of data it provides. The described elevation maps can provide 3-dimensional information (e.g., in the x, y and z axes) that can allow of detailed visualization of space and show how objects relate to others in their surroundings. The elevation maps may provide improved or increased accuracy regarding sizes, heights, and distances, which may be useful in determining contents of the

submerged structure, levels of layers, needs for maintenance and cleaning, troubleshooting, and the like. Data collection from previous steps, such as the pre-survey site inspection, collection of water chemistry data, pre-cleaning acoustic survey, and GEO data mapping of sediment elevation may additionally or alternatively be used to determine the tank floor sediment elevation map. Data may be transmitted over a communication network or to a cloud for remote data analysis and evaluation. Data may be used to estimate and determine condition, cleaning or maintenance needs, diagnostics, job suitability, associated costs, and the like, without requiring a surveyor on site.

[0084] In an embodiment, calculations of accumulated sediment volume may be carried out by persons on-site of the submerged structure or the calculations may be carried out by persons remote from the submerged structure (or may be carried out autonomously). Data collection from previous steps, such as the pre-survey site inspection, collection of water chemistry data, pre-cleaning acoustic survey, GEO data mapping of sediment elevation, and tank floor sediment elevation maps may additionally or alternatively be used to calculate accumulated sediment volume.

[0085] In an embodiment, predictive maintenance calculations may also be carried out. For example, surveys performed and associated collected data on the same submerged structure over time may be used to predict when cleanings of the submerged structure should be performed or would be recommended. In an example, episodic surveys and data collection may be used to monitor the submerged structure and determine status for cleaning. In an example, the submerged structure may be continuously monitored to determine status for cleaning. Recommended cleanings may be performed automatically so as to avoid delay in cleanings and overuse of the submerged structure. Recommended cleanings may be performed automatically to adhere to a preventative maintenance schedule based on the preventative maintenance calculations. Recommended cleanings may be performed based on only the predictive

maintenance calculations and without one or more (or all) of the prior steps of pre-survey site inspection, collection of water chemistry data, pre-cleaning acoustic survey, GEO data mapping of sediment elevation, and tank floor sediment elevation maps so as to avoid delay in cleanings and overuse of the submerged structure.

[0086] Calculations may be carried out remotely using data, which may be transmitted over a communication network or to a cloud. Calculations may be used to estimate and determine condition, cleaning or maintenance needs, diagnostics, job suitability, associated costs, and the like, without requiring a surveyor on site.

[0087] In an embodiment, the collection of sediment samples may be carried out by persons on-site of the submerged structure or the collection may be carried out by persons remote from the submerged structure (or may be carried out autonomously as described above). For example, an aerial drone or other remote operating, unmanned, or autonomous vehicle (such as a small boat) may be used to lower one or more containers into the submerged structure (e.g., into water/sediment within the submerged structure) to collect samples of the contents. In an embodiment, a sediment core sampler may be used to take samples of the contents. An improved sediment core sampler may be used which may take more accurate samples faster. For example, an aerial drone or remote controlled boat may be used to lower one or more sensors into the submerged structure (e.g., into water/sediment within the submerged structure) to collect data related to the contents. In an embodiment, a remote or autonomous surface vehicle may be used to collect samples or data through onboard or deployed sensors. The surface vehicle may be used within the submerged structure. In an embodiment, a collection or measurement instrument may be pulled through the water by the drone or surface vehicle. In an embodiment, the drone or surface vehicle may drag the sensor(s) over the water surface.

[0088] Generally, the described methods and steps may be carried out remotely. In an embodiment, all steps except for the actual cleaning of the submerged structure may be carried

out remotely. For example, signals may be transmitted and received through water and air. For example, the measuring and collection devices can receive instructions remotely and may transmit feedback and data to a remote location while the measuring and collection devices are on-site the submerged structure. In an example, data may be transmitted over a communication network or to a cloud. The data may be analyzed and evaluated from a remote location. The data may be analyzed and evaluated in real-time from a remote location. For example, software may be used to adjust the pitch and yaw to produce smoother images. For example correlations may be generated between the chemical and physical parameters through mapping or other charts. Additives such as polymers, coagulants, and flocculants may be used to treat the submerged structure prior to or after any of the described methods and steps to improve visibility, accuracy in measurements, and the like. The described methods and steps may be used to estimate and determine condition, cleaning or maintenance needs, diagnostics, job suitability, associated costs, and the like, without requiring a surveyor on site. In an embodiment, only a technician may be needed on-site or no person may be needed on-site to carry out one or more (or all) of the described steps and methods (aside from the actual cleaning of the submerged structure).

[0089] In an embodiment, a working or cleaning crew may be given direction from a remote crew that analyzes the collected data in real-time. In an embodiment, an operator on-site may be given instructions and guidance based on the collected and/or analyzed data. In an embodiment, estimates relating to the expected qualities and quantities of materials to be removed, contents, levels or layers and locations of different levels, and the like, may be made using the described methods and steps.

[0090] For example, the expected disposal weight or volume in cleaning the submerged structure may be provided. Further, the amounts of inorganic materials (e.g., sand) and organic materials (e.g., biosolids) may be provided. The density of each amounts of inorganic materials

(e.g., sand) and organic materials (e.g., biosolids) and the expected weight of each to be removed during cleaning may be provided. The differentiation of the types of materials may be useful in determining loss of volume calculations by type of material, equipment needed, future maintenance recommendations, and the like. The differentiation of the types of materials may be determined by one or more (or all) of the data collection and processing steps (e.g., pre-survey site inspection, collection of water chemistry data, pre-cleaning acoustic survey, GEO data mapping of sediment elevation, tank floor sediment elevation maps, collection of sediment samples, etc.).

[0091] In an embodiment, the processing data steps may be carried out separately from the data collection steps. In an embodiment, the processing data steps may take into consideration how the various data is collected and account for the methods of data collection or the processing data steps may be universal and be agnostic to how the data is collected. Generally, the described methods and steps may provide improved data collection and analysis. For example, the described methods and steps may facilitate taking more accurate samples faster (of water, sediment, and the like).

[0092] It is noted that any of the described methods and steps may be combined or used sequentially. For example, the data collected in a preceding step may be used in a following step. For example, sample collection and data collection steps may provide information that can be used to create the mapping steps and calculation steps. It is noted that any of the above methods may be used pre-cleaning to assess the condition of the submerged structure and to estimate cleaning needs and costs, during cleaning to assess progress and efficacy of cleaning, post-cleaning to evaluate the success of cleaning and to create a baseline, during maintenance to evaluate additional cleaning needs, etc.

[0093] In an embodiment, the method 100 may combine several processes and methodologies in a specific sequence. The method 100 may, in a mapping stage, generate and

utilize a 3-dimensional model of the accumulated debris within the structure. The method 100 may, in a cleaning stage, remotely guide the cleaning equipment using GPS and the generated 3-dimensional map. For example, from the 3-dimensional model, the exact, near exact, or approximate volume of accumulated sediment in a structure can be calculated, and its location within the tank determined. Using GPS to guide the submerged cleaning equipment in the structure, only those areas with significant accumulations of sediment or that are desired to be cleaned may be cleaned and the progress monitored by comparing how much sediment is removed from an area to the calculation of how much sediment was in the area. This selective and intentional cleaning may both reduce the time required for cleaning and the cost to the facility, and may also ensure sufficient cleaning of the structure for increased efficiency and capacity of the system. Also, a more precise estimate of the amount of the sediment can be made prior to cleaning the structure to better estimate disposal costs. Further still, knowing the location of the sediment can help the party conducting the cleaning pick the most appropriate cleaning apparatus to conduct the cleaning. By way of a non-limiting example, if the sediment is in a location that is a way from the side of the structure being cleaned, the entity cleaning the structure may choose to use a combination downhole pump/vacuum truck with a dripless tube that is expandable a distance. An example is disclosed in U.S. Patent No. 9,796,003, which is incorporated herein by reference.

[0094] The method 100 includes identification of a suitable structure 1 to which the invention can be successfully applied. Suitable structures may include, but are not limited to, storage or treatment tanks, water treatment tanks, vessels, or basins, pumping systems, screening, separation, or filtration chambers, clarifiers, digesters, aeration systems, treatment, disinfectant, and additive chambers, storm water and other pipes within the storage or treatment system, culverts, drainage areas, and the like. Suitable structures may also include any kind of holding device that includes a liquid or liquids, solid or solids and/or biosolid or biosolids. The

structure to which the present teachings can be applied isn't limited to just those described herein. Any kind of holding device that possesses any of the foregoing attributes may be a suitable structure hereunder. For various reasons, such as not having access to critical areas of the tank to take measurements, not all submerged structures may be appropriate for the process and methodology of mapping and cleaning.

[0095] The method and identification of a suitable structure 1 may further include application of criterion the has been developed to rank a suitability of a potential structure using aerial or satellite images, which can be performed without having conduct a physical site visit, or may include conducting a physical site visit. When reviewing aerial or satellite images or conducting a physical site visit, the potential structures should be evaluated by criterion which includes accessibility of equipment and rolling stock, water depth, height of tank walls above ground level, location of catwalks and railings, and the like, to determine suitability of the various structures for mapping and cleaning. Suitable qualities of structures for mapping and cleaning include, for example areas with greater accessibilities, areas known to have more accumulated sediment, areas known to be generally representative of the composition in the tanks, and the like. Unsuitable qualities of structures for mapping and cleaning may include, for example those that don't have any liquid or don't have enough solids or biosolids to clean. It should be noted, however, that a suitable structure may also include a cover or top and isn't limited to the open tank shown in the drawings.

[0096] Once a suitable structure is identified, a pre-survey site inspection 2 may be conducted to confirm the suitability determination and identify contents of the submerged structure and any potential problems that may arise during cleaning. For example, the pre-survey site inspection 2 can be used to determine one or more of access, dimensions for sizing and spacing sonar imaging, water quality, solids sampling, and the like. The pre-survey site inspection may comprise collection 3 of and analysis 4 of various water chemistry measurements as described

herein to assess sediment in the structure. For example, one or more of the following measurements and analyses of the water in the structure may be used: temperature, pH, salinity, oxidation-reduction potential, turbidity, and the like. Additionally, a pre-cleaning acoustic survey 5 may be conducted via various methods, equipment, processes, and analyses. The pre-cleaning acoustic survey may be performed using specialized commercial equipment and may comprise acoustic surveying equipment, remote-controlled surface vessels, software and data processing devices, and the like. The described-samples may be collected through use of a remote controlled boat, which may be placed in the applicable tank or other water holding device and driven out to the appropriate location. The sample may be able to utilize a collection device that is on the remote control boat that can collect these items and bring them to a location to be tested. For example, the remote-controlled boat may have an arm that extends with a container that can collect the appropriate sample from the appropriate depth. The arm can bring the container back on the remote-control boat and seal the container. The container can then be stored on the remote controlled boat and then brought back to a user that can provide the container with the sample to the appropriate lab or can conduct the analysis described herein at the facility location.

[0097] Chemistry analysis may also provide specific insight as to the relationship between water chemistry and acoustic survey measurements. For example, chemistry analysis may provide insight as to the relationship between turbidity and sonar range. The chemistry analyses may include one or more of salinity, temperature measurements, pH, oxidation reduction potential (which if too low may suggest anaerobic process and the production of undesirable nitrogen gas that can interfere with the processes of the facility and/or could negatively impact the ability to measure the material in the structure), oxygen levels, turbidity, and the like. The turbidity level may be useful in that a high turbidity level can negatively impact the present system's ability to measure the amount of material in the structure. Knowing the turbidity can

help determine the accuracy of the information or allow the user to adjust the system to account for the higher turbidity.

[0098] The variation of each measurement going down predefined dimension (e.g., each foot of height from the surface) may provide insight into the discontinuity of layers in the tank as well as insight into the composition and layering of the sediment and biosolids, as well as the amount of each and the locations. The chemistry analyses may be carried out by lowering a probe through the waste water and to take point measurements and varying depths or take a continuous measurement at increasing depths. A chemistry analysis report may be generated and compared to past data to further understand the relationship between water chemistry and acoustic survey measurements. Other analyses may also include grain size analyses of the solids and/or biosolids found in the structure. Knowing the grain size can help determine the overall weight of the material in the structure that needs to be removed. The grain size can be determined through either collecting a sample and/or through an acoustic survey. This can help knowing how much material is to be removed and the total cost to the owner/manager of the facility to remove the material from the structure. Knowing the density of the material helps determine the weight, which is essential to knowing the cost of removing the material.

[0099] Following the described data collection, collected data may be processed, evaluated, analyzed, and mapped 6 using software so as to produce and transform the data into a 3-dimensional topographic image or tank floor elevation map 7 of the accumulated sediment in the structure and on the structure floor. The 3-dimensional topographic image or tank floor elevation map 7 may include elevation information related to the higher and lower accumulated sediment areas within the tank and may also be converted into a sonar map. The elevation information may include coloring, such as red for the highest elevations and blue for the lower elevations (and orange, yellow, green, etc. to indicate varying elevations in between) and these elevations can be used to target specific cleaning of sediment so that only the higher elevations

are cleared. This can increase efficiency of the cleaning process and decrease the effort and time needed to complete requisite cleaning to get the tanks to a working capacity. This may also allow a user to more easily identify problem areas or areas with more solids/biosolids than other areas. This may help focusing the cleaning effort make the structure easier to clean with the analysis than otherwise. The aforementioned analysis may be conducted by a software program or app that takes the information data points assesses them and then outputs the information. The software program may be utilized in the non-transitory memory of any known computing device.

[00100] The chemistry analyses and/or elevations maps may also provide more accurate removal estimations compared to current measuring processes which often can be both much lower and much higher than the actual removal. An example 650 of the tank floor elevation map 7 is shown in FIG. 16 and a cross-sectional view 700 is shown in FIG. 17. This 3-dimensional topographic image or tank floor elevation map 7 may be then overlaid on an as-built scale drawing of the structure and an accumulated sediment volume calculation may be determined 8. As a result, the data collected from GEO mapping (also referred to as geographic(al) mapping or geographical information systems) may be used to produce a tank floor elevation map 7 and to determine an accumulated sediment volume calculation 8. The accumulated sediment volume calculation 8 may be determined by using software that computes the volume of the 3-dimensional information.

[00101] The tank floor elevation map 7 may then be used to determine locations of collecting sediment core samples 9. As an example, the sediment core samples 9 may be collected from areas identified through the tank floor elevation map 7 as having significant accumulation of sediment. Specialized equipment designed to remove intact sediment core samples from waste water tanks may be used to collect the sediment core samples 9. Such specialized core sampling equipment may include a “sludge judge” that has been modified to take an intact sediment

sample. The sediment core samples 9 may then be filtered in the field to remove excess water, with the remaining sample stored on ice to preserve the sediment core samples 9 for analysis. The sediment core samples 9 may then be processed for further data analysis 10. In one aspect, the processed sediment core samples 9 may be taken to a quantitative analysis laboratory for analysis in accordance with a specific protocol. The analyses may include analyses for grain size distribution and other physical property characteristics. This information may assist with determining the in situ density and the resultant removed material to be disposed. Other analyses may include percent H₂O, percent organics, and percent inorganics. In another aspect, the processed sediment core samples 9 may be analyzed in the field using a portable lab brought to the site.

[00102] The resulting data may include calculations for determining sediment density, percent volume, and mass of the inorganics and organics contained within the sediment. A sediment analysis report 11 may be generated and used to estimate the sediment disposal volumes and weights 12 after cleaning operations 13 occur. These volumes and weight may be particularly useful in understanding the materials and composition of the waste tank so as to target efficient cleaning. The sediment disposal volumes and weights 12 measured after cleaning operations 13 occur may indicate when sufficient or desired cleaning has been accomplished and the sufficient or desired sediment has been removed from the structure or that the desired sediment in a specific location has been removed.

[00103] Cleaning of the structure may be carried out using customized equipment designed to efficiently remove sediment from a submerged structure, such as a submersible pump. An example of which is described below. In an example, the cleaning operation may be precisely guided using a GPS transponder 14 in connection with the tank floor elevation map 7 so that the areas of the structure having significant accumulation of sediment are selectively targeted and cleaned. During the cleaning process, waste water and organic materials may be separated

from the sediment using gravity separation and filtration equipment, or any other technique or process that is known or otherwise may become known in the art. The wastewater and organic materials, free of sediment, may then be returned to the structure for further processing. The collected solid sediment may then be dewatered to a “paint-filter” dry condition before disposal of such material. Disposal may be accomplished in a variety of manners including disposal on-site or via transport to a landfill. Prior to disposal, the volume and/or weights 12 of the solid sediment material is collected and recorded for further analysis.

[00104] Following cleaning of the structure and removal of the sediment, a post-cleaning acoustic survey may be conducted to verify that the measured loss of capacity has been restored in accordance with the agreed upon plan 18 with the facility. The accumulated sediment volumes 8, removed sediment volume calculations 18, and sediment disposal volumes and weights 12 may be utilized to prepare a final tank cleaning report 19.

[00105] Additionally, the acoustic reports and analyses described herein may also allow for the customer and facility specific estimations of future cleanings and provide a schedule based on when the facilities are expected to hit a 10% loss of capacity, which would interfere with the facility’s functions. For example, it is noted that facility and plant interruptions can occur at accumulation levels below 10%, especially in structures using certain types of aeration systems. This analysis and estimation may allow a facility to have a preventative maintenance schedule developed for it. This would prevent unnecessary cleaning of a structure that isn’t in need of such, allows for only that portion of a structure that needs to be cleaned being cleaned or prevents a structure from reaching a level of undesired material rendering ineffective or inoperable. The system will allow an operator to sell this as a service to structure owner/manager. The owner/manager is able to use the system to know when this preventative maintenance is required to prevent their structures from becoming inoperative, presents conducting unneeded cleaning all of which can help the owner/manager save money and time.

[00106] One example of how the method 100 of the present invention operates was conducted at an exemplary facility shown in FIG. 5. The facility is an oval-shaped above-ground concrete tank that is squared off at its northern end. The facility treats sewage using both anaerobic and aerobic processes within the same tank, with anaerobic processes predominating at the northern end, and aerobic processes in the channels and at the southern end. The tank is approximately 200 feet long and 60 feet wide.

[00107] Water Column Profiles: Water circulation and aeration was shut down at 0900 so that a series of nine water column profiles 210 could be taken from various stations, for example, (1) from the northern end of the tank, (2) along the western channel wall, and (3) at the southern end of the tank (see FIG. 4). These sites were chosen due to the ease in accessibility for these site-specific structures. However, the water column profiles 210 could have been taken from any location and from any amount of locations. The present teachings aren't limited to just these exemplary locations.

[00108] Measurements of pH, redox potential, salinity, turbidity and dissolved oxygen were taken at 1 foot intervals from the water surface to the bottom of the tank (or in some cases, to the top-of-the-sediment) at each of the nine stations 210 indicated in FIG. 4. It should be understood that the 1 foot interval is merely exemplary. Any appropriate interval may be chosen and may change such as based on the depth of the structure from which the sample is being taken.

[00109] Stations STA 1-3 – T are in the anaerobic basin area over the time from 0913 through 0946 (33 minutes). Stations STA 4-6 – T are located along the west channel wall in an aerobic digestion area over the time from 0957 through 1022 (25 minutes). STA 7-10 – T are in the southern turning basin, also aerobic, over the time from 1334 through 1356 (22 minutes).

[00110] Temperature and Salinity: Temperature and salinity are nearly uniform from the surface to the bottom at all stations during the sampling period, indicating the water column was well mixed without the development of either a thermocline or halocline.

[00111] Turbidity: Turbidity measurements 300, 330, 360 showed high values (1,000 to 4,000 FNU) varying by depth and time from aeration shut down (see FIGS. 6 through 8). Clearing of the upper water column is fairly rapid and dramatic, indicating the floc mass is well formed with a greater density than the water. Within four hours after aeration shut down, the water is less than 1 FNU from the surface to 8 foot in depth. Turbidity levels in the lower water column increase over time indicating the settling rate of the floc is significantly slower in the upper water column. One explanation for this could be the formation of pin floc from the denitrification of nitrate to nitrogen gas, trapping bubbles in the floc increasing their buoyance. "Popping," the phenomena of nitrogen bubbles breaking the surface scum is observed in this area at that time, providing visual confirmation of denitrification. By 1334 a very sharp turbidity cline forms at the depth of 8 foot to 10 foot where turbidity went from less than 1 to over 2,000 FNU.

[00112] Redox Potential: Redox potential measurements 400, 430, 460 range from a high of approximately 150 mV to a low of -30 mV over all Stations (see FIGS. 9 through 11). In STA 1-3 – T, from the anerobic area of the tank, the redox potential indicates bacterial processes are predominately cBOC degradation and denitrification. STA 4 – T is also in identification, with STA 5-6 – T primarily in nitrification. STA 7-9 – T show the development of a strong redox cline at a depth of 6 to 8 feet below the surface. Bacterial processes went from strong nitrification in the surface waters, to robust denitrification in the deeper waters.

[00113] Dissolved Oxygen: Dissolved oxygen measurements 500 are relatively high in the anerobic area of the ditch (see FIG. 12) with values ranging from 10 to 3 mg/L from the surface to the bottom of the tank. Results 530 from STA 4-6 – T (see FIG. 13) show similar high

oxygen saturation levels. Oxygen levels 560 in the area of STA 7-9 – T (see FIG. 14) show the water column is super-saturated with oxygen, particularly in the upper half of the water column.

[00114] Sedivision Results: The geophysical survey is able to survey 600 approximately 90% of the Oxidation Ditch tank bottom (see FIG. 15). The tank bottom area beneath the two mixers at either ends of the tank could not be surveyed due to equipment limitations at the time of the survey. The survey of the oxidation ditch shows a loss of capacity of 251 cubic yards, with the largest accumulation being in the northern (anoxic) section of the tank. In this area the accumulation is highest along the western and eastern walls, with a high of 4.2 feet. The remaining area of the tank bottom sediment is fairly uniform, with the accumulation ranging from 0.1 to 1 foot. As a point of comparison, if the area surveyed had a uniform 1-foot accumulation the total accumulation would be 454 cubic yards. Percentage loss of capacity is calculated to be 3.64 %. The geophysical survey may be conducted by any appropriate device. In a non-limiting example, an acoustic survey device may be utilized. One example of an acoustic survey device comprises using vector acoustic sensors. In another example, a sonar device that is capable of generating a survey may be utilized. This may be similar to the technology used in other sonar devices, such as a fish finder and the like. It should be understood that these are merely exemplary acoustic survey devices and that any configuration of an acoustic survey device that is capable of operating in water or liquid can be utilized.

[00115] As noted above, the facility shown in FIG. 5 uses a combined anaerobic/aerobic treatment process with pretreatment of the influent to remove large solids and sand. Water chemistry measurements indicate the treatment process is performing within good treatment specifications. Stable temperatures overtime indicates a uniform mixing of the water column. Oxidation Reduction Potential values provide a direct indication of the types of critical chemical processes occurring with the wastewater.

[00116] Turbidity measurements demonstrate rapid clearing of the upper half of the water column, beginning immediately after aeration/circulation shut down, indicating swift sinking of the floc mass. Most interesting is the development of an extremely sharp turbidity cline at the 8 to 10 foot depth, concurrent with sharply increasing turbidity in the 10 to 17 foot depth. Normally this would be assumed to be associated with a water density discontinuity. However, uniform water column values of temperature and salinity (the two primary controllers of water density) demonstrate no such discontinuity existed. Therefore, in one non-limiting example, it can be concluded that while the upper layer floc is sinking into the lower half of the tank, the floc in the lower half remained suspended, or at least had a much lower sedimentation rate. The material from the rapidly sinking floc from the upper water column, combined with the slower sedimentation of the floc in the bottom half, results in the higher turbidity levels in the 10 to 17 foot depth range.

[00117] At the same time as the development of the turbidity cline, redox potentials in the same area are rapidly falling with depth, from relatively high positive values (strongly nitrifying conditions) to moderately low negative values (strongly denitrifying conditions). During denitrification, bacteria convert nitrate to nitrogen gas (N_2), forming nitrogen bubbles. If the bubbles are large enough to rise to the surface and break through the scum, "popping" will be observed. This phenomenon is observed in this area at the time of the measurements, confirming denitrification in the bottom waters was well underway at the time, as indicated by the chemical measurements that determined the concentration of dissolved oxygen in the waste water.

[00118] In previous wastewater tank surveys, and confirmed by this survey, that turbidity concentration was unrelated to SediVision or acoustic/sonar survey range in the tank. This leads to a conclusion that residual air bubbles (which are a strong attenuator of sonar signals) from the aeration process (either bubblers or circulators) limited the sonar range. These

bubbles would be expected to both rise to the surface and dissolve in the wastewater over time, gradually increasing the sonar range to see the floor and sidewalls of the tank. Previous studies did not completely bear this out, with sonar range being limited to about 25 foot in the best cases. While it is likely that air bubbles play an important role in limiting sonar range, it is clear other limiting factor(s) must also be in play.

[00119] The facility shown in FIG. 5 and results from the conducted experiments provide compelling evidence that nitrogen bubbles resulting from denitrification are an important factor in sonar range limitation in at least two ways. First, free rising nitrogen bubbling (popping) will increase over time as the denitrification process predominate in the lower portion of the tank and as measured by the decreasing redox potential. This will offset the reduction of air bubbles (from the aeration/circulation process) by dissolution to maintain a more constant bubble concentration. Second, small nitrogen bubbles will enmesh in floating floc masses, increasing their buoyancy and reducing their settling rate. Overtime, one would expect a high concentration of micro-bubble laden floc suspended in the water column. As this applies to SediVision or acoustic/sonar survey range, one would expect to see increasing range as the air bubble dissolve, then the range obstructed (or possibly reduced) as nitrogen bubble concentrations increase. This information can be applied to the system to generate an acoustical/sonar survey that is more accurate than other versions because it can account for the various factors that previously degraded the quality. Accounting for these factors allows for a more accurate survey, which in turn allows for a more accurate location and calculation of the amount of sediment, solids, biosolids and the like in the structure. Knowing this will help removal thereof in a more efficient and cost effective manner.

[00120] Referring now to FIGS. 18 and 19, the system of the present invention comprises a high pressure water pump assembly 1010 for generating high pressure water, a high pressure water hose 1012, a hose reel 1013, a cleaning head 1014 for receiving high pressure water and

cleaning a sewer, a submersible pump 1016 for pumping a slurry of solids and liquids out of the sewer when the slurry contains a large amount of liquid, a power source 1017 for the submersible pump 1016, a slurry hose 1018, a waste container 1020 for receiving the pumped slurry, a decant water hose 1022, a decant water outlet 1024 for releasing the water from the container, main supply water line 1032, and main supply water source 1034. The invention may be mounted to a truck 1040 as seen in FIGS. 18 and 19, or to an immobile unit that must be towed to and from a jobsite. For consistency, the unit will be described as a truck throughout this document. It should be noted that while water is mentioned as the liquid in which the submersible pump 1016 operates, the present teachings are not limited to such. The submersible pump 1016 may operate in any kind of liquid.

[00121] The high pressure water pump assembly 1010 and pump power source 1017 are mounted on, for example, a truck 1040 and may use the truck engine for power. The purpose of the pump assembly 1010 is to pressurize water for use in washing sewer lines 1042 by means of cleaning head 1014 attached to and in communication with high pressure water hose 1012. The source of water for pump assembly 1010 may be derived from any water source 1034, including a fire hydrant, a tank on the truck 1040, or from the sewer 1042 itself. Further, the high pressure water pump assembly 1010 may be of any appropriate configuration and type. By way of a non-limiting example, the high pressure water pump assembly 1010 may be configured as a hydraulically driven down-hole (submersible) pump. While a single water pump assembly 1010 is shown and described, any number of water pump assembly 1010 may be utilized without departing from the present teachings, e.g., two, three, four, etc. In some embodiments, four water pump assemblies 1010 may be attached to a single truck.

[00122] The cleaning head 1014 may be bullet-shaped with a front and rear face. The rear face of the cleaning head 1014 may include water jet outlets 1015 directed backwardly. The truck 1040, high pressure water hose 1012 and cleaning head 1014 may be of any suitable

conventional equipment. When the cleaning head 1014 is lowered through a manhole 1041, and into a sewer 1042, high pressure water, such as 2000 psi may be applied through the hose 1012 to the cleaning head 1014. The high pressure water applied to the cleaning head 1014 has several functions. First, the water sprays out of the outlets 1015 and the exiting high pressure water washes the solid material from the walls of the sewer 1042 and suspends the sewer pipe solid material in a slurry. Additionally, the high pressure water being applied to the cleaning head 1014 moves the cleaning head 1014 in a direction 1043. After cleaning the sewer 1042, the cleaning head 1014 may be retrieved by retracting the high pressure water hose 1012 by means of hose reel 1013.

[00123] If conditions dictate that a submersible pump 1016 should be used, i.e., if a relatively high volume of liquid exists in the sewer 1042, a submersible pump 1016 is provided with a capacity of more than the total flow of water being injected to the cleaning head 1014 as well as any normal sewer flow. It is desirable to have a large water content in the sewer 1042 for efficiently cleaning the sewer 1042 by suspending the solid particles and material in the sewer 1042 in a liquid slurry. The submersible pump 1016 is capable of pumping a slurry having up to 80% solids.

[00124] For example only, if the high pressure water pump provides a flow of 60 gallons per minute, a suitable submersible pump 1016 capable of removing 2000 gallons a minute of 80% solid material is desirable for allowing the present invention to clean an operating sewer having flowing fluids therein. While any suitable submersible pump 1016 may be provided, pump series 53, sold by Garner Environmental Services, Inc., is satisfactory. Such pumps can be powered hydraulically and powered by diesel, electric motors, gasoline engines or any other available power source. Additionally, a jetter type sewer pump is contemplated herein. In an embodiment, two jetter sewer pumps may be utilized having a rating of 180 GMP.

[00125] The fluidized slurry from the submersible pump 1016 may be transmitted through the slurry hose 1018 to a waste container 1020. The fluidized slurry enters the top of the container 1020, where the solids and water separate and the solids settle to the bottom of the container by gravity. If desired, baffles may be provided in the container 1020 to assist in the separation. The water is then decanted from the container 1020 and as the container 1020 fills up, the decanted water is released from the container 1020 by means of the positive pressure forcing the water through a decant water hose 1022. The waste container 1020 may be of any appropriate configuration and type. By way of a non-limiting example, the waste container 1020 may be pressurized as described in more detail below. While a single submersible pump 1016 is shown any described, any number of submersible pumps 1016 may be utilized, e.g., two, three, four, etc.

[00126] The waste container 1020 may be either permanently affixed to the truck 1040, or may be removable therefrom. If the waste container 1020 is removable, when the container 1020 is substantially filled up with solid particles, it may be removed and a replacement container 1020 may be rolled into place and connected to hoses 1018 and 1022. The filled container 1020 may then be removed to a dump site while the truck 1040 remains on site and continues the cleaning operation. If the waste container 1020 is permanently affixed to the truck 1040, the truck 1040 must go to the dump site each time the waste container 1020 becomes substantially filled up with solid materials. Further, still multiple waste containers 1020 may be utilized without departing from the present teachings. In such embodiments, the waste containers 1020 may be operatively attached with one another, such as in a series. In these embodiments, if one of the waste containers 1020 is filled with solid materials, the adjacent waste container 1020 may then become filled with the slurry as described above. If multiple waste containers 1020 are used, each of the waste containers 1020 may be continuously filled such that the pump 1016 need not stop running

once one of the waste containers 1020 fills. Any appropriate tubing may be attached between the plurality of waste containers 1020.

[00127] When the submersible pump 1016 is used, the more water that flows through the cleaning head 1014 and sewer 1042 the better the cleaning operation. In the present system, the decanted water can be used to provide additional washing by injecting it upstream of the cleaning head 1014 and pump 1016. This allows keeping the solid materials in the sewer in suspension so that they can more easily be removed by the pump 1016. The decanted water is transmitted through decant water outlet 1024 to decant waterline 1022 and then to a manhole 1041 into the sewer 1042 upstream of the cleaning head 1014 for increasing the water in the sewer flow.

[00128] This additional water, applied to the sewer 1042 aids in more efficiently cleaning the sewer 1042, and the pump 1016 has the capacity to completely remove the water in the system. Thus, the present embodiment is in effect a closed loop and the decanted water, all water injected or decanted, is utilized in cleaning the upstream portion of the sewer. Furthermore, the water need not be disposed of by trucking. After the sewer 1042 is cleaned, the cleaned decanted water may be disposed of in the sewer 1042. For example, present systems utilize 60 gallons of water per minute for injection from the cleaning head 1014. If additional water is available for supply to the cleaning head 1014, a better water injection system and cleaning system can be provided. When cleaning a fully charged sewer, i.e., sewer capacity at maximum, the decanted water may be disposed of in a downstream sewer.

[00129] Referring now to FIG. 19, the system comprises a truck-mounted high pressure water pump assembly 1110 for generating high pressure water, a high pressure water hose 1112, a hose reel 1113, a cleaning head 1114 for receiving high pressure water and cleaning a sewer, a vacuum system comprising a vacuum tube 1118 held in place by a boom 1119, an air pump 1150 used to create the vacuum, generally located at or near a silencer 1151 and

a discharge point 1152 where air is released to the atmosphere. The system further comprises a waste container 1120 for receiving the pumped slurry, a main supply water line 1132, and a main supply water source 1134. The boom 1119 may be used to control the position of various devices and the movement of a pressure water hose 1112 to inject pressurized water through the waste collection system.

[00130] The high pressure water pump assembly 1110 is mounted on, for example, a truck 1140. The purpose of the pump assembly 1110 is to pressurize water for use in washing sewer lines 1142 by means of cleaning head 1114 attached to and in communication with high pressure water hose 1112. The source of water for the pump assembly 1110 may be derived from any water source 1134, including a fire hydrant, a tank on the truck 1140, or from the sewer itself. The pump assembly 1110 may be equivalent to the pump assembly 1010 as described above.

[00131] The cleaning head 1114 may be bullet-shaped with a front and rear face. The rear face of the cleaning head 1114 has water jet outlets directed backwardly. The truck 1140, high pressure water hose 1112 and cleaning head 1114 may be of any suitable conventional equipment. When the cleaning head 1114 is lowered through a manhole 1141, and into a sewer 1142, high pressure water, such as 2000 psi is applied through the hose 1112 to the cleaning head 1114. The high pressure water applied to the cleaning head 1114 has several functions. First, the water sprays out of the outlets and the exiting high pressure water washes the solid material from the walls of the sewer 1142 and suspends the sewer pipe solid material in a slurry. Additionally, the high pressure water being applied to the cleaning head 1114 moves the cleaning head 1114 in a direction 1143. After cleaning the sewer 1142, the cleaning head 1114 may be retrieved by retracting the high pressure water hose 1112 by means of the hose reel 1113.

[00132] If conditions dictate that a vacuum system be used, i.e., if a relatively small volume of liquid exists in the sewer 1142, a vacuum system comprising a vacuum tube 1118 held in place by a boom 1119, an air pump 1150, generally located at or near a silencer 1151 and a discharge point 1152 where air is released to the atmosphere, is provided. The air pump 1150 creates a negative pressure in the system, causing slurry to be sucked up through the vacuum tube 1118 and into the waste container 1120. The solid material in the waste slurry then falls to the bottom of the waste container 1120. The air pump 1150 continues to pull the air in the container 1120 through the air pump 1150, and through the silencer 1151 before being released to the atmosphere through the discharge point 1152.

[00133] Use of a submersible pump allows for decanting of water simultaneously while performing the cleaning operation. This may not be possible with a vacuum system. However, because a submersible pump cannot be used effectively when little or no water exists in the pipe to be cleaned, the vacuum system is necessary to deal with these types of situations. In these embodiments, the submersible pump may not be capable of use when the vacuum system is in operation or it may be capable of use simultaneously with the vacuum system. Similarly, the vacuum system may not be capable of being used simultaneously with the submersible pump or it may be capable of being used simultaneously.

[00134] Loosening solid materials, i.e. debris, mud, etc. from the walls of the waste collection system and getting the solid materials to the submersible pump 1016 requires a high pressure stream of water. A pressurized water pumping system as described above is not always available or practical for cleaning the waste collection system.

[00135] Further still, a separation process for separating and removing solid components in a mixture or slurry may be utilized. In an example, the method comprises removing inorganic material such as sand, grit or other solids having a similar or greater density from a digester, clarifier, wastewater apparatus, collection tank, process tank, etc. Removing the inorganic

material may prevent subsequent clogging and bridging of the filters used to separate the remaining biosolids (where the biosolids are one or more of sewage, sludge, animal waste, etc.) and water.

[00136] In one embodiment, the apparatus of the present invention comprises a wastewater treatment system and/or tank 100 of Figure 1 that may be operatively connected to one or more of one or more sewers, one or more sumps, one or more wet wells, one or more digesters, one or more clarifiers, one or more classifiers, one or more wastewater apparatuses, one or more collection tanks, one or more process tanks, and the like, that generally comprise a mixture of liquids and solid components. In one embodiment, a treatment system such as tank 100 of Figure 20 may house a solid and liquid mixture or slurry including water 102, biosolids 104, sand 106, and other deleterious materials (not pictured). It is noted that the treatment system, or other apparatus, may include more solid and/or liquid components. However, if the treatment system contains more water the present teachings may be more efficient and effective – the material should be wet enough to run through the submersible pump as described below. The mixture may be fully mixed, partially mixed, or layered as shown in Figure 1.

[00137] Figure 21 depicts system 200 according to one embodiment of the present invention and a method of separation of solids in a mixture housed in the tank of apparatus 200. For example, at least one submersible pump 202 may be submersed into a mixture of at least water, biosolids and/or sand in tank 204 in apparatus or treatment system 200 and designed to pump the mixture from the bottom of tank 204 of treatment system 200, or other depths as required, to remove the mixture from tank 204 of treatment system 200. The removed mixture may be run from submersible pump 202 into a pressurized debris tank 206 via debris hose 208. In one embodiment, pressurized debris tank 206 may be portable. For example, pressurized debris tank 206 may be, but does not have to be, located on a vehicle, such as a truck, as shown in Figure 21. Pressurized debris tank 206 settles the components of the mixture from tank 204

based on the density and/or buoyancy of the various components in such a mixture, such that the more dense components settle on the bottom of pressurized tank 206, and the more buoyant components do not fall as quickly as the more dense components within pressurized tank 206. The more buoyant components are essentially allowed to move, or striate, to the top of pressurized tank 206 via positive pressure from submersible pump 202 and the action of the settling of the heavier components such as the level of sand as it rises. An example of a system that may be utilized with the present teachings is the system and truck disclosed above.

[00138] For example, the inorganic material such as sand or grit, having a greater density, will settle on the bottom of the pressurized tank, whereas the biosolids and water, having a lower density and higher buoyancy, will not settle on the bottom of the pressurized tank and will instead rise to the top of the pressurized tank, above the sand. Due to the positive pressure inside the pressurized debris tank, the supernatant of the pressurized mixture, comprising the water and/or biosolids, is then transmitted out of the pressurized debris tank, into a return debris hose, or decant hose, 211, and back into tank 204 of system 200. As the supernatant is routed back into tank 204 of system 200, the mixture in tank 204 of system 200 is agitated, causing a slurry formed from all, or some, of the components (i.e., water, biosolids and/or sand) as the various components are mixed together. In one embodiment, this may be necessary in order for the water portion of the mixture in tank 204 to carry the sand and/or grit portion out of tank 204 and into pressurized tank 206 via pump 202 and hose 208. In one example, at least the sand and water need to be mixed together to carry the sand out of tank 204 and into pressurized tank 206 by being carried with the water. The slurry may be partially mixed, fully mixed or separated but removed together. The method of de-sanding may not need a separate water supply and, instead, the water within tank 204 may be utilized to remove the sand and grit therefrom. The method may be accomplished with system 200 and/or tank 204 being online (i.e., operating) or being offline (i.e., not operating). It should be noted that while a tank 206 is illustrated in

connection with system 200 any device or item that can hold water and/or one or more solids or slurries can also be used in system 200.

[00139] All, or some of, the components are mixed together, may be needed for the water to carry the sand and/or grit out of the treatment system and into pressurized tank 206. In one example, at least the sand and water need to be mixed together to carry the sand out of at least tank 204 and into pressurized tank 206. The slurry may be partially mixed, fully mixed or separated but removed together. The method of de-sanding may not need a separate water supply and, instead, the water within treatment system 200 (e.g., in tank 204) may be utilized to remove the sand and/or grit also located in at least tank 204 or some other liquid/slurry holding device. The method may be accomplished with treatment system 200 and/or tank 204 being online (i.e., operating) or being offline (i.e., not operating).

[00140] As way of a non-limiting example, the present teachings may be utilized in cleaning lift stations and pump stations. Lift and pump stations may be used to pump wastewater from a lower to higher elevation, particularly where the elevation of the sewer pipe is not sufficient for gravity flow. Wastewater will collect inside a well which is part of said lift/pump station, once the wastewater reaches a certain level, the pumps are activated to transmit the wastewater from the low elevation of the well, to the higher elevation of another sewer pipe. In such systems inorganic material may accumulate that needs to be removed. The present teachings may be applied to remove such inorganic material from the lift and pump stations.

[00141] In an embodiment, one process of routing a solid and liquid mixture from a tank, or other liquid/slurry holding device, 204 in treatment system 200 into a submersible pump 202, may be transmitted via a debris hose 208 to a pressurized tank 206 and back into tank, or other liquid/slurry holding device, 204 of treatment system 200 via the positive pressure from submersible pump 202 and a decant hose 211. This process can be repeated until all or the desired amount of the sand or other dense components are removed from the mixture. Figure

22 depicts the de-sanded mixture or supernatant in a tank 204a of treatment system 200 after the sand, grit and other similarly dense components have been removed. As before, the de-sanded mixture, comprising water and/or biosolids, may be fully mixed, partially mixed, or layered as shown in Figure 3. In an embodiment, the supernatant including biosolids and water is further separated using a dewatering process, such as a belt filter press, filter, or centrifuge, as a full cleaning process to capture the biosolids. An example of a belt filter press is shown in Figure 23. In this embodiment of the belt filter press, the biosolids are being separated from the liquid within the treatment system. Specifically, Figure 4 displays how sand or other inorganic material 401 may create a bridge for the biosolids 404 to pass through a belt filter press without being dewatered.

[00142] In an embodiment, computations may be performed to determine the estimated amount of sand, grit or other components of the same or similar density to be removed from a treatment system. Once the volume of sand, grit or other components to be removed has been determined, a slurry concentration may be estimated to determine the rate of sand, grit or other components removed. Thereafter, the amount of liquid required to move the material may be determined and, finally, the amount of times the solid and liquid mixture of the treatment system will need to be cycled through the de-sanding process to remove the sand, grit or other components may be better quantified. As a non-limiting example, the steps of such a calculation may comprise: (1) estimate quantity of sand, grit or other component to be removed; (2) apply pumping concentration; (3) estimate volume of water to transport inorganic material (sand, grit or other components) via slurry to pressurized container; (4) compute volume of liquid in a tank or other holding system of treatment system; and (5) estimate amount of time to recirculate liquid in tank to remove inorganic material (sand, grit or other components). An exemplary embodiment of the present application is as follows. It should be understood, however, that this calculation is merely exemplary and is not intended to be

limiting. Figure 24 depicts the wastewater treatment system utilized in this exemplary embodiment.

[00143] Exemplary embodiment: First, compute volume of contents inside the wastewater treatment system: (a) in a rectangle wastewater treatment system multiply the length by width by the depth of the contents inside the wastewater treatment system; and (b) example: volume of contents: 100 feet by 200 feet by 15 feet = 300,000 cubic feet.

[00144] Second, compute volume of inorganic material within the contents of the wastewater treatment system by: (a) in a rectangle wastewater treatment system multiply the length by width by the depth of the inorganic material inside the wastewater treatment system; and (b) example: volume of inorganic material: 100 feet by 200 feet by 5 feet = 100,000 cubic feet.

[00145] Third, compute the volume of liquid required to remove the inorganic material from the wastewater treatment system by: (a) divide the volume of inorganic material inside the wastewater treatment system by the percentage of solids in a liquid that the submersible pump is capable of removing (where for example a submersible pump will be able to pump a liquid that contains, for example, 10 percent to 20 percent total suspended solids; and (b) example: volume of liquid required to remove the inorganic material from the wastewater treatment system: 100,000 cubic feet divided by 0.10 = 1,000,000 cubic feet.

[00146] Fourth, determine the number of times that the liquid contents of the wastewater treatment system will need to cycle through the pressurized debris tank in order to remove the inorganic material from the wastewater treatment system by: (a) divide the volume of liquid required to remove the inorganic material from the wastewater treatment system by the difference between the volume of contents inside the wastewater treatment system and the volume of inorganic material within the contents of the wastewater treatment system; and (b) example: number of times that the contents of the wastewater treatment system will need to cycle through the pressurized debris tank in order to remove the inorganic material from the

wastewater treatment system: $1,000,000 \text{ cubic feet} \div (300,000 \text{ cubic feet} - 100,000 \text{ cubic feet}) = 5 \text{ times}$.

[00147] Fifth, determine the amount of time it will take to remove the inorganic material from the wastewater treatment system by: (a) convert the volume of liquid required to remove the inorganic material from the wastewater treatment system from cubic feet to gallons. One cubic foot is approximately 7.48 US liquid gallons. Divide the gallons of liquid required to remove the inorganic material from the wastewater treatment system by the pumping capacity of the submersible pump in gallons per minute (GPM); and (b) example: the number of hours it will take to remove the inorganic material from the wastewater treatment system: (i) $1,000,000 \text{ cubic feet} \times 7.48 = 7,480,000 \text{ gallons}$; and (ii) $7,480,000 \text{ gallons} \div 2500 \text{ GPM} = 2,992 \text{ minutes}$ or 49.87 hours.

[00148] Although the embodiments of the present invention have been illustrated in the accompanying drawings and described in the foregoing detailed description, it is to be understood that the present invention is not to be limited to just the embodiments disclosed, but that the invention described herein is capable of numerous rearrangements, modifications and substitutions without departing from the scope of the claims hereafter. The claims as follows are intended to include all modifications and alterations insofar as they come within the scope of the claims or the equivalent thereof.

CLAIMS

What is claimed is:

1. A method for assessing sediment distribution in a submerged structure, comprising:
collecting water chemistry data from contents in the submerged structure to determine a type of sediment in the submerged structure;
conducting an remote survey of the contents in the submerged structure to determine sediment topography in the submerged structure;
performing GEO data mapping of the contents in the submerged structure to determine volumes of the contents in the submerged structure; and
quantifying an amount of sediment in the submerged structure.
2. The method of claim 1, wherein collecting water chemistry data comprises collecting at least one sample of the contents in the submerged structure, wherein the collected water chemistry data is further analyzed to determine at least one physical or chemical property of the at least one sample of the contents in the submerged structure.
3. The method of claim 1, wherein collecting water chemistry data comprises providing at least one on site-sensor positioned in the contents of the submerged structure, wherein the collected water chemistry data is further analyzed to determine at least one physical or chemical property of the sensor-measured contents in the submerged structure.
4. The method of claims 2 or 3, wherein the at least one physical or chemical property includes one or more of the following: water temperature, salinity, dissolved oxygen, pH, oxidation reduction potential, turbidity, and presence of chosen ions or chemical constituents.

5. The method of claim 1, wherein the remote survey is an acoustic survey.
6. The method of claim 1, wherein the remote survey uses LIDAR, RADAR, sonar, ultrasonic sensors, camera and image processing, or structured light 3D scanning technologies.
7. The method of claim 1, wherein performing GEO data mapping comprises executing two or more scans at several frequencies using multi-beam transducers.
8. The method of claim 1 further comprising carrying out a pre-survey site inspection.
9. The method of claim 1, wherein one or more of the steps are performed remotely.
10. The method of claim 1, wherein one or more of the steps are performed by an autonomous vehicle and wherein the autonomous vehicle is a drone, a surface vehicle, or a submerged vehicle.
11. The method of claim 1, wherein one or more of the steps are performed prior to cleaning the submerged structure.
12. The method of claim 1 further comprising cleaning the submerged structure.
13. The method of claim 12 further comprising repeating one or more (or all) of the steps of claim 1 during cleaning of the submerged structure.

14. The method of claim 12 further comprising repeating one or more (or all) of the steps of claim 1 after cleaning of the submerged structure.

15. The method of claim 12 further comprising calculating an amount of sediment removed from the submerged structure and comparing the amount of sediment removed to the amount of sediment in the submerged structure prior to cleaning.

16. The method of claim 1 further comprising providing predictive maintenance estimations for the submerged structure.

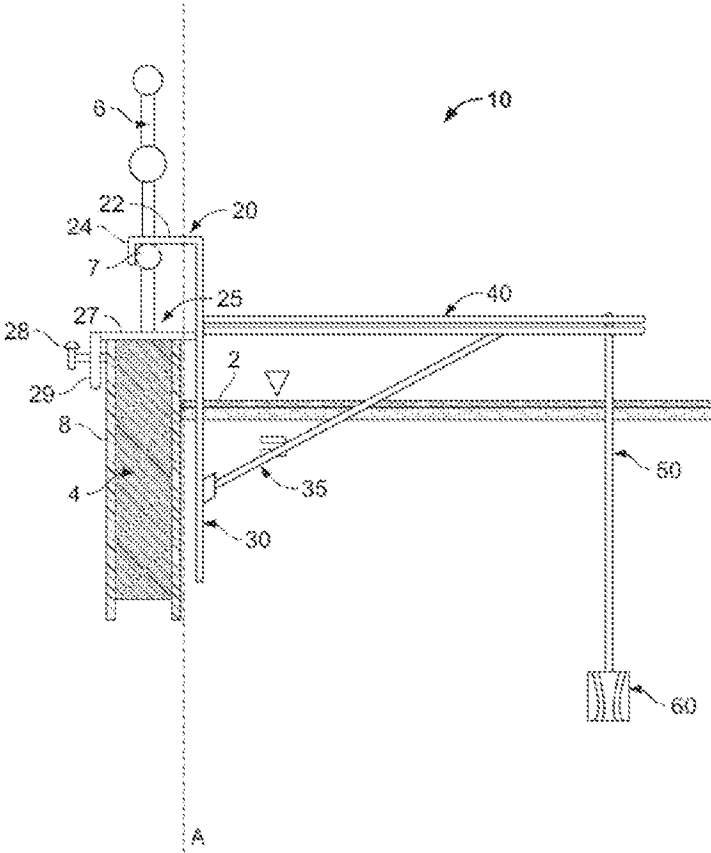


FIG. 1

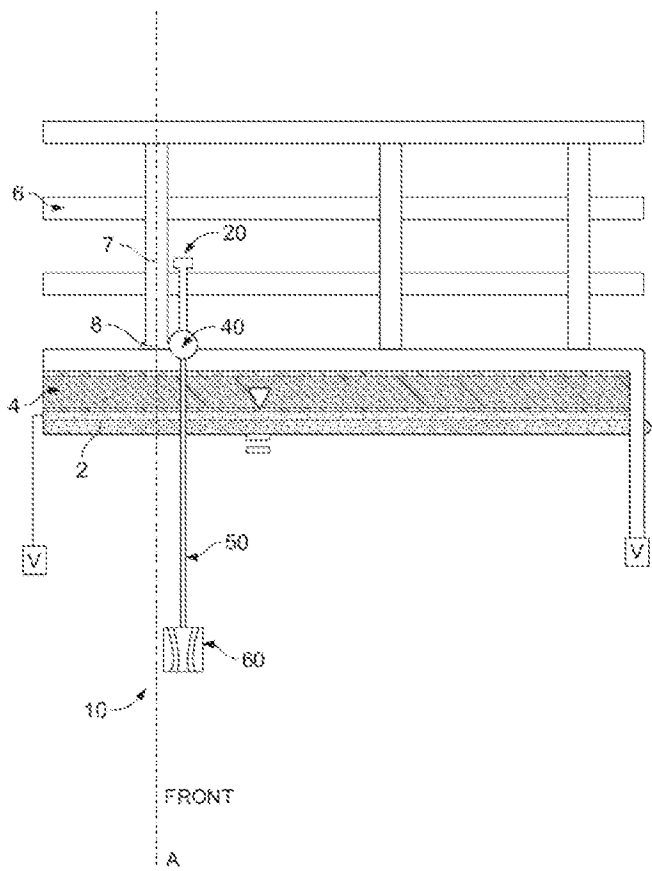


FIG. 2

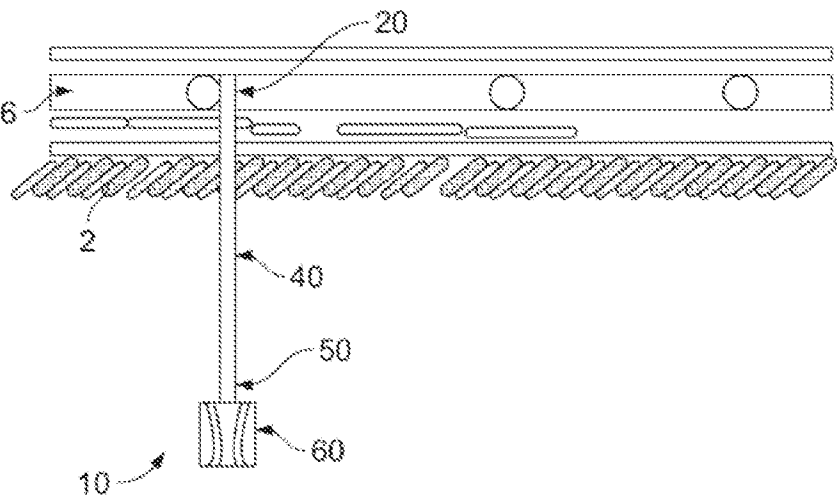


FIG. 3

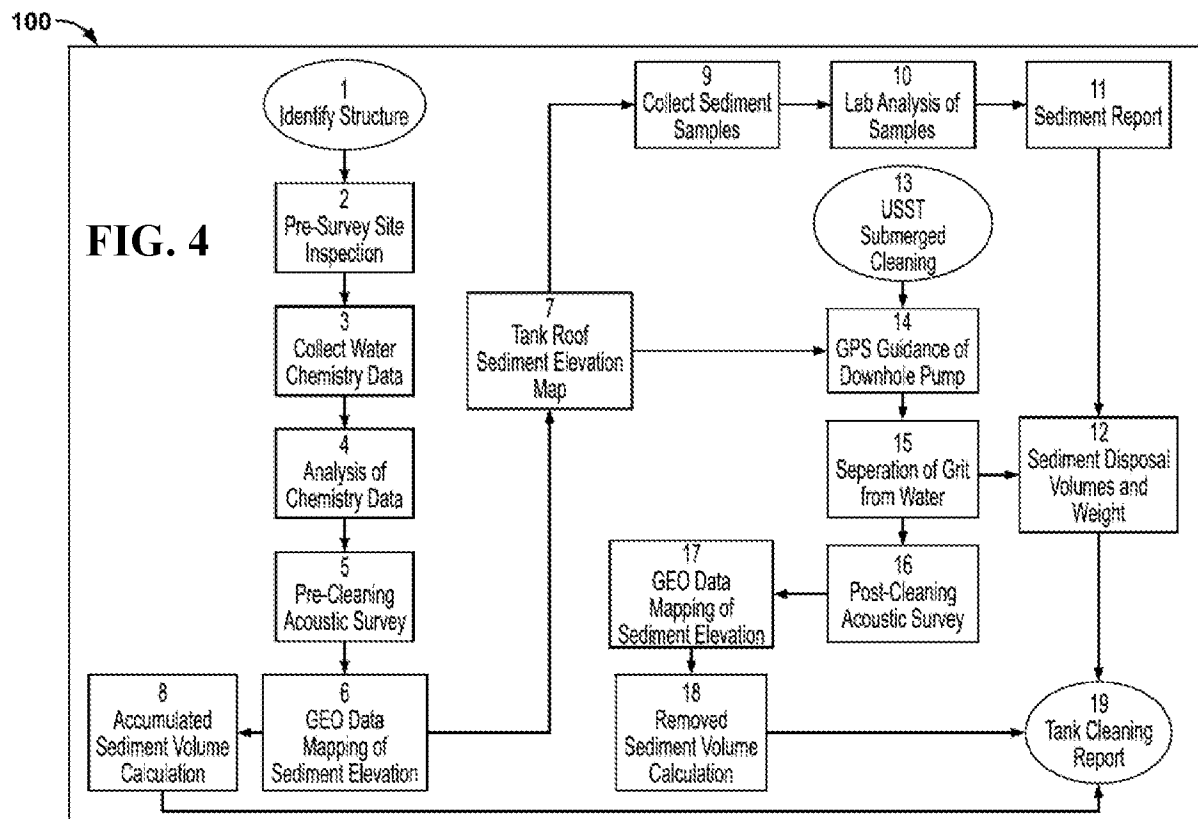




FIG. 5

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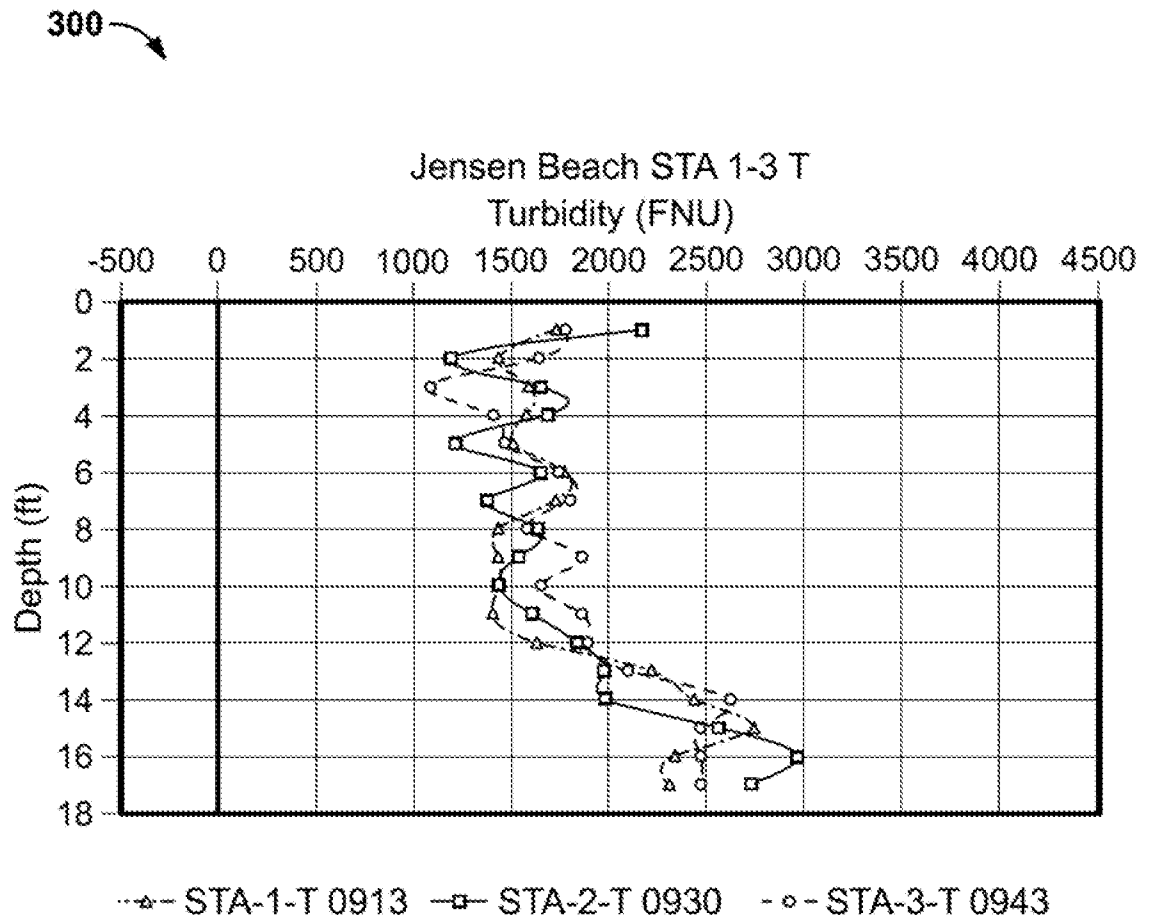
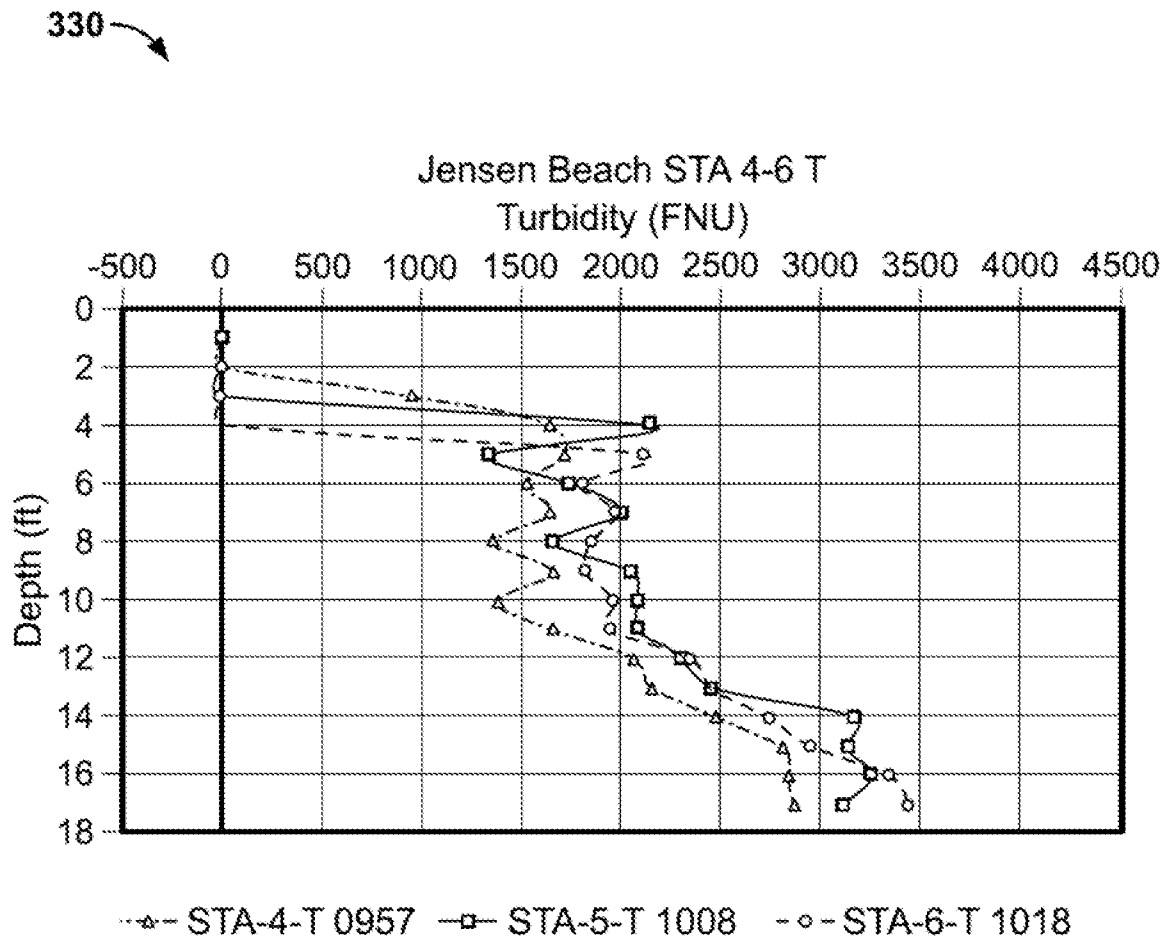


FIG. 6

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**FIG. 7**

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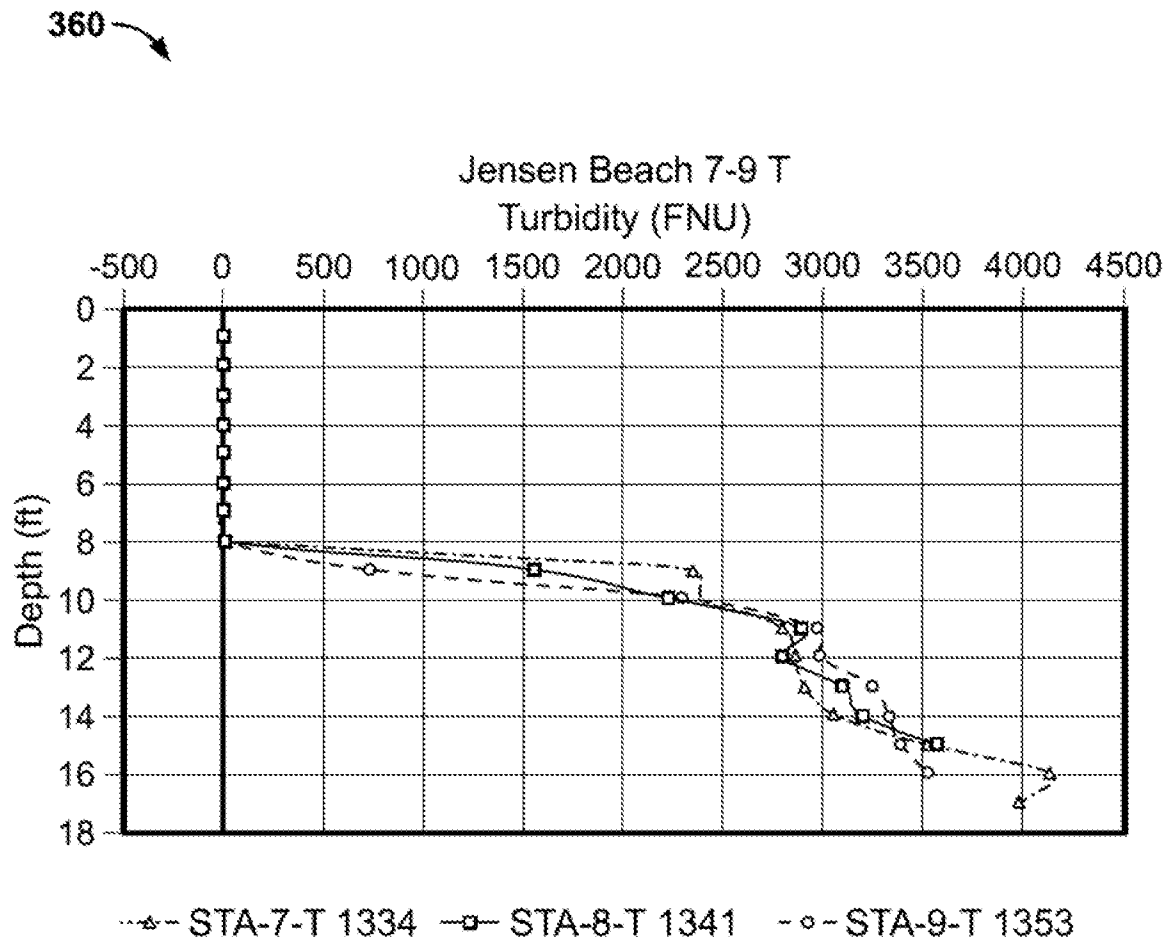


FIG. 8

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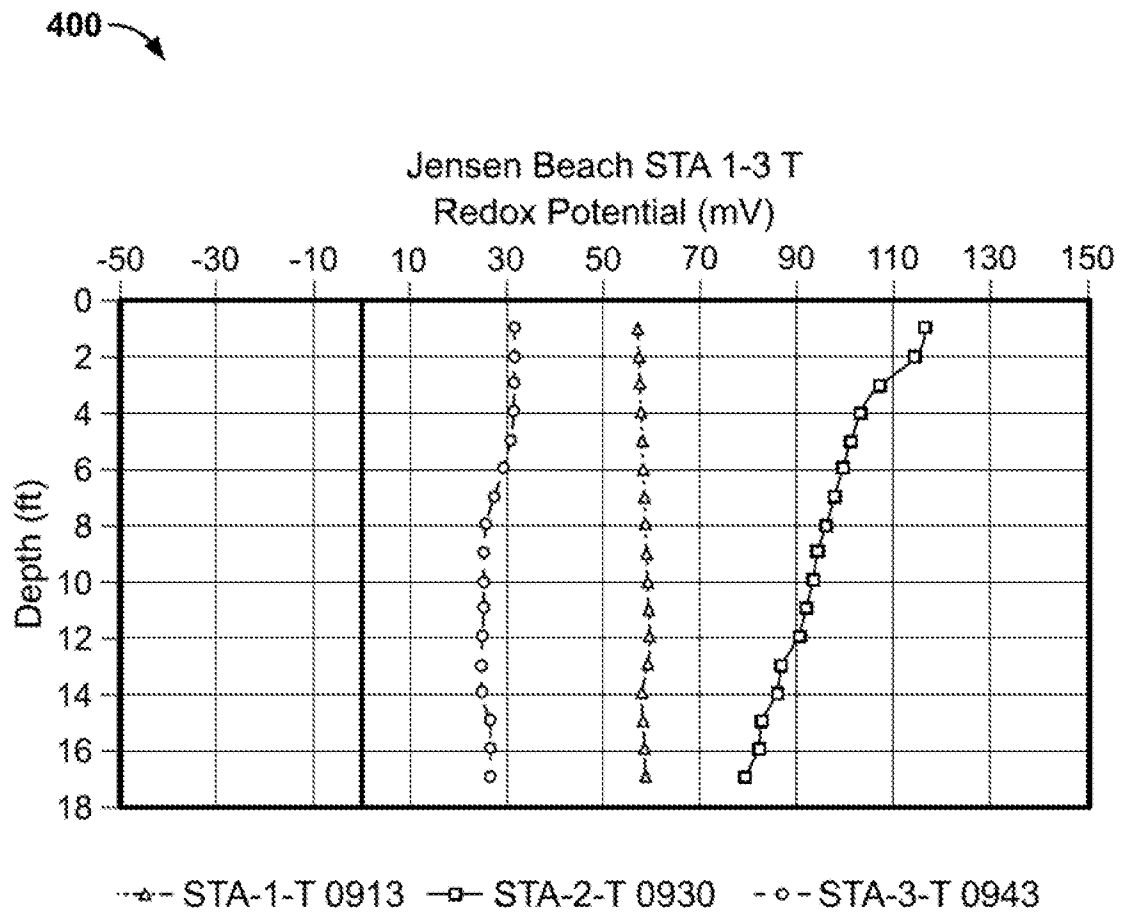
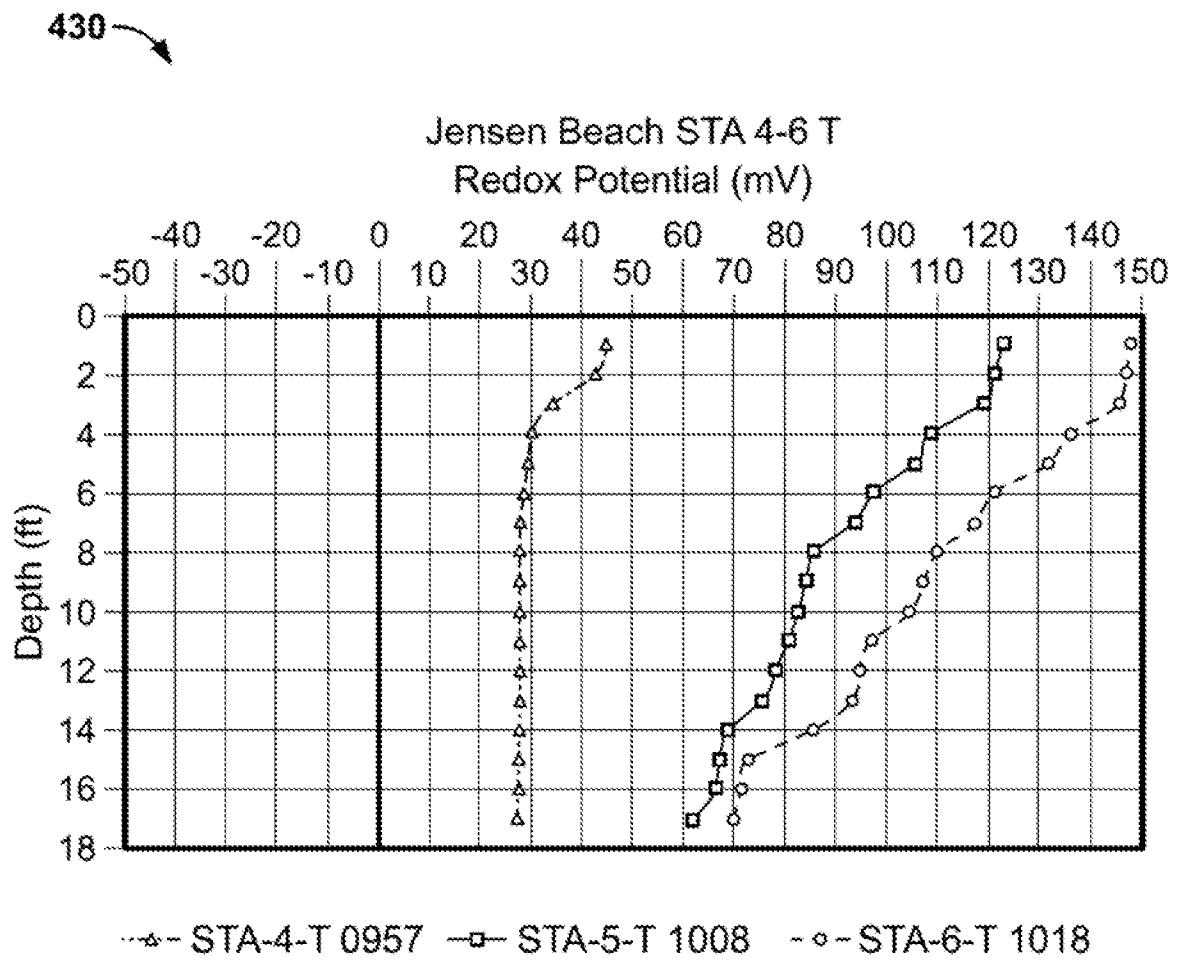


FIG. 9

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**FIG. 10**

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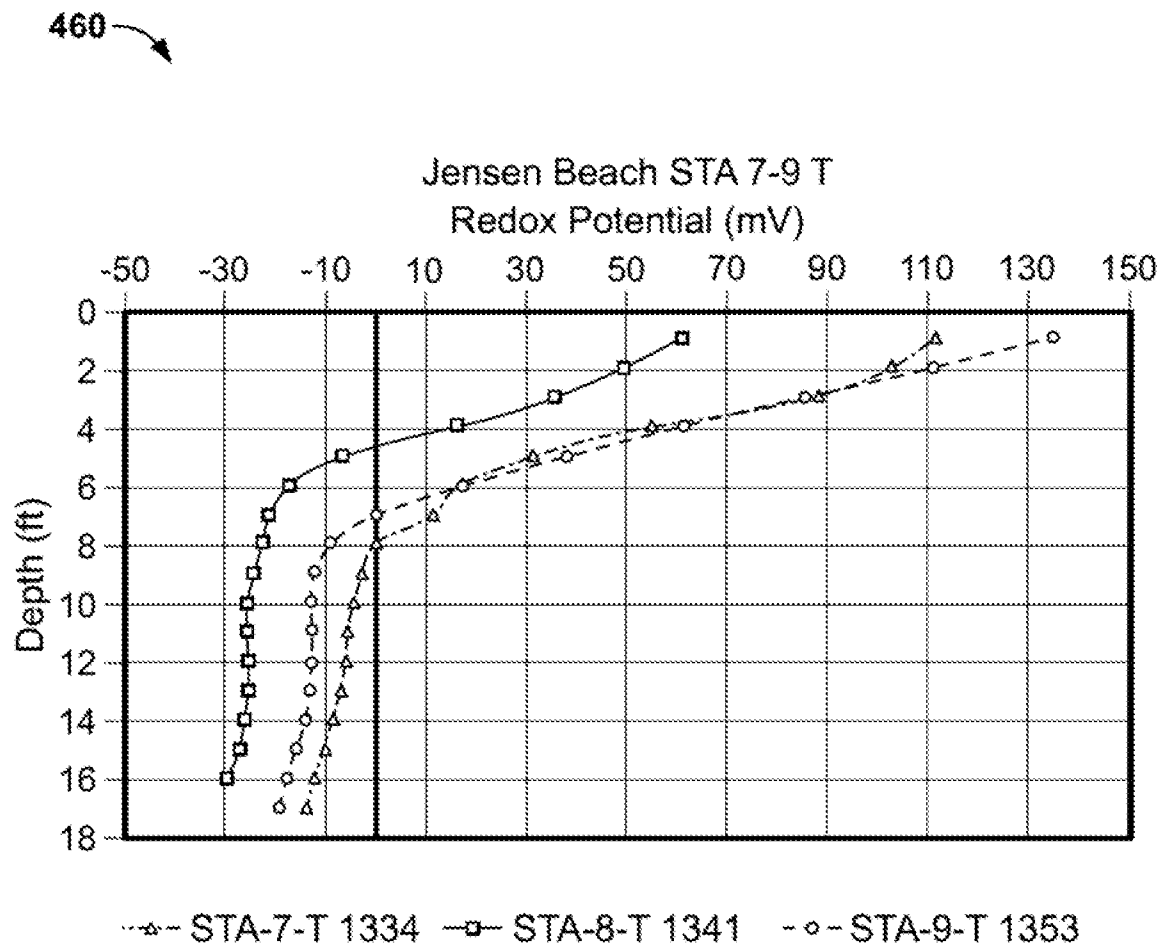


FIG. 11

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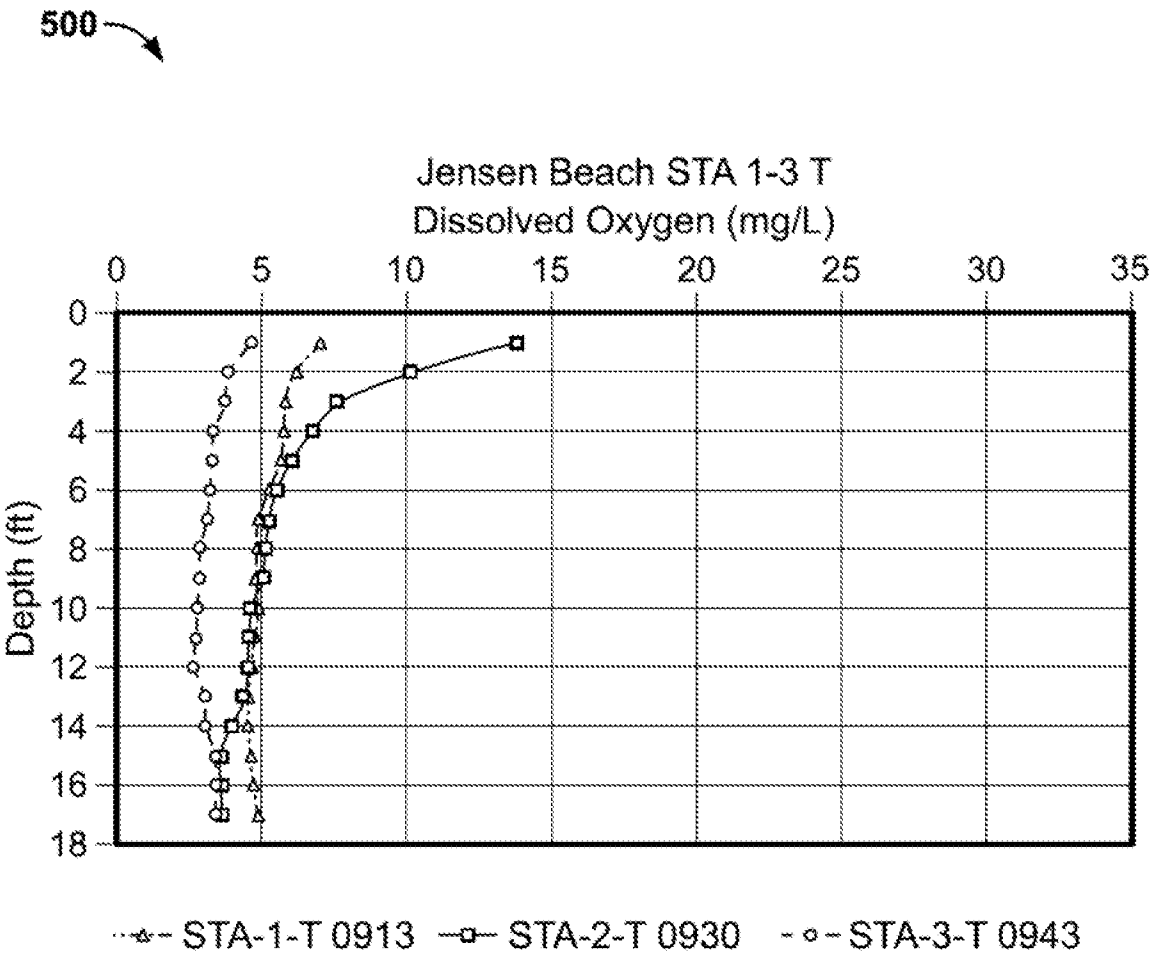
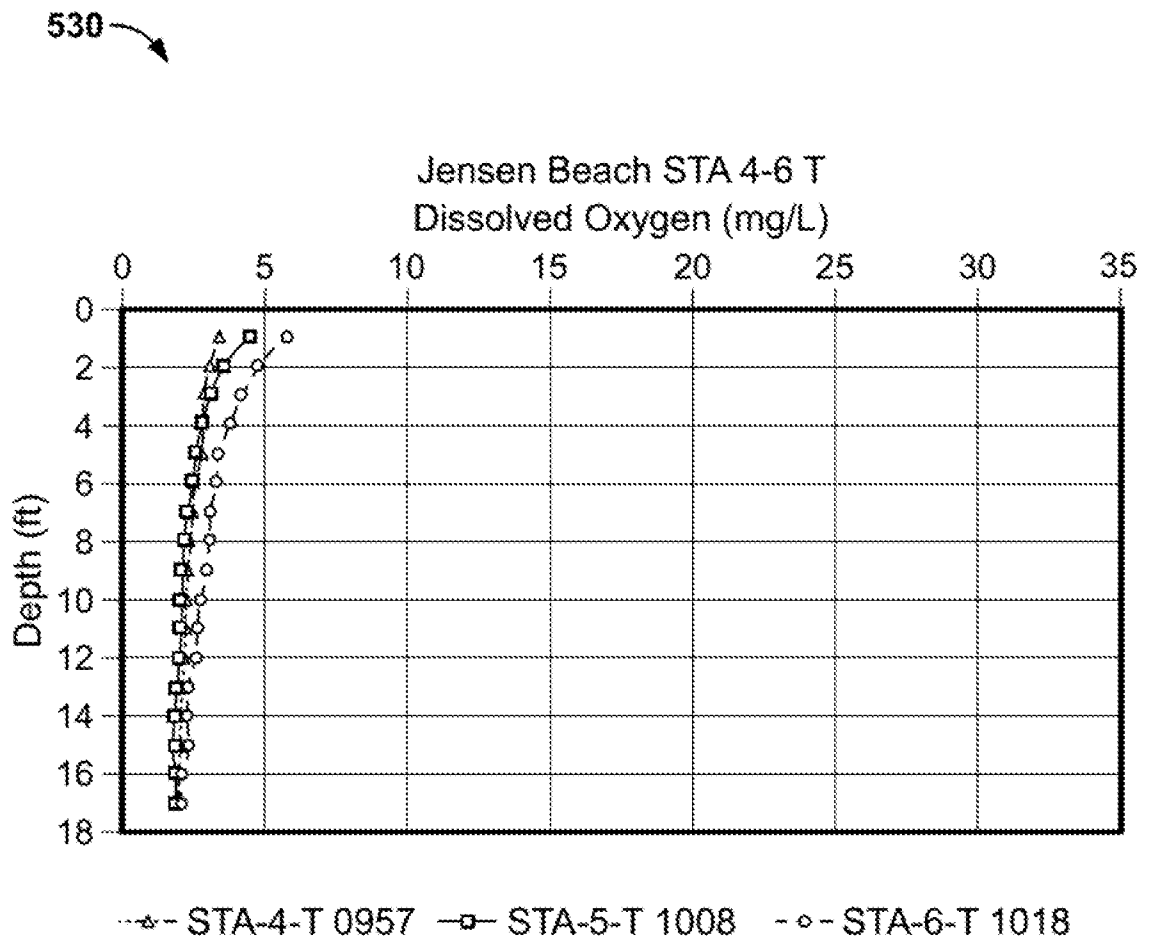


FIG. 12

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**FIG. 13**

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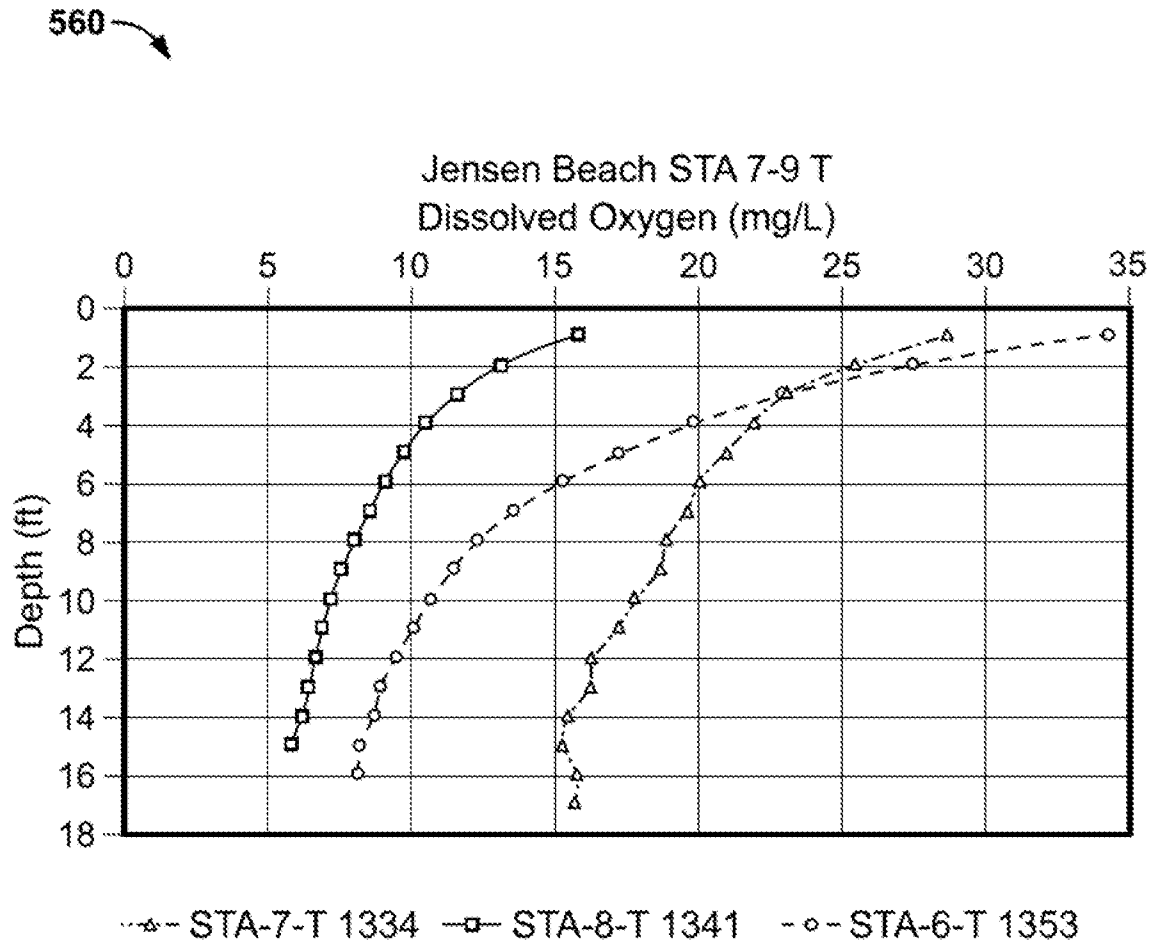


FIG. 14

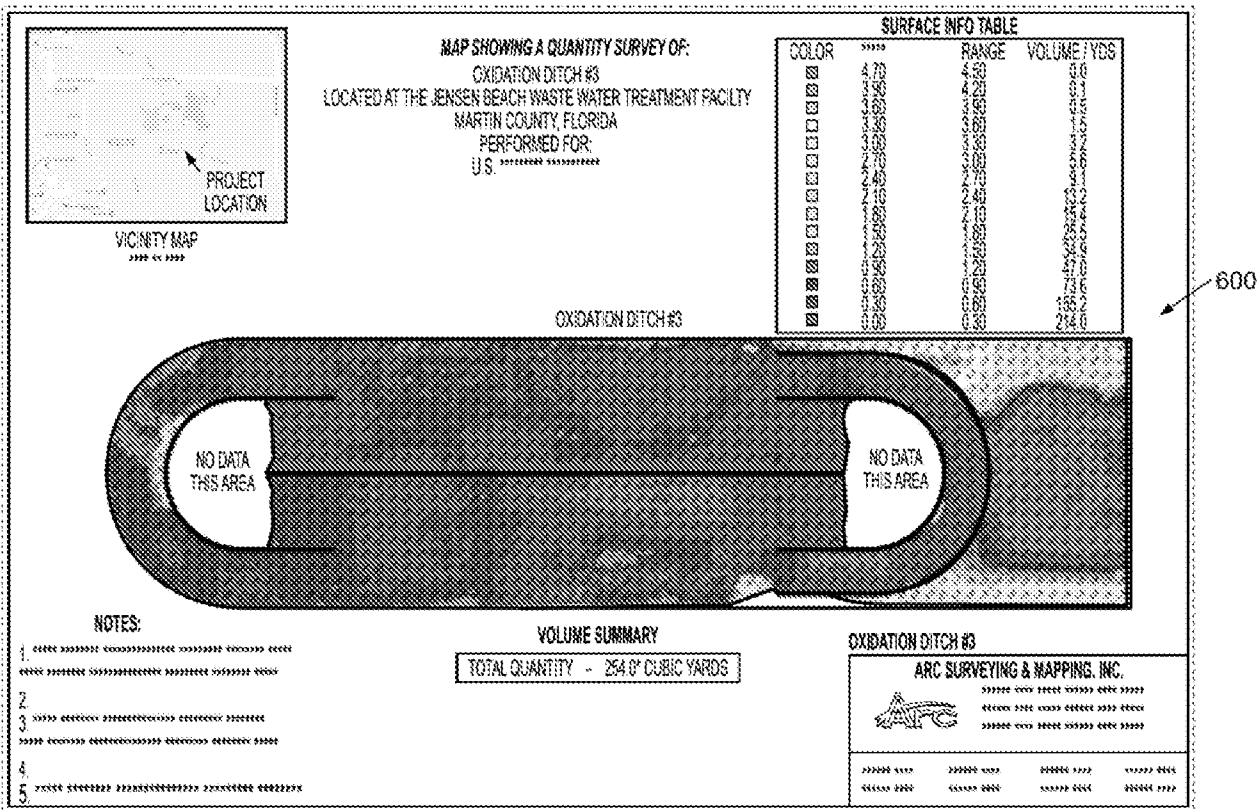


FIG. 15

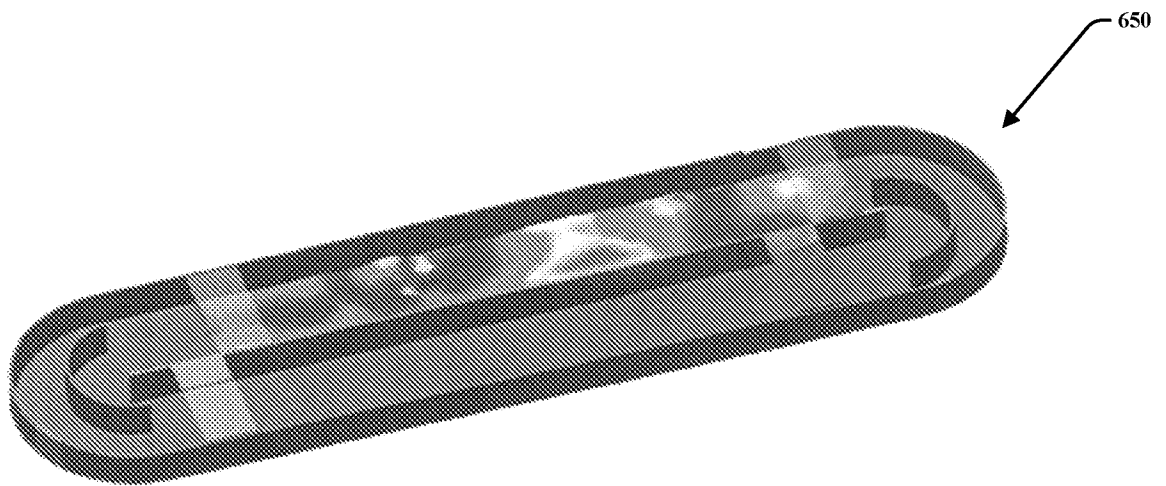


FIG. 16

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700

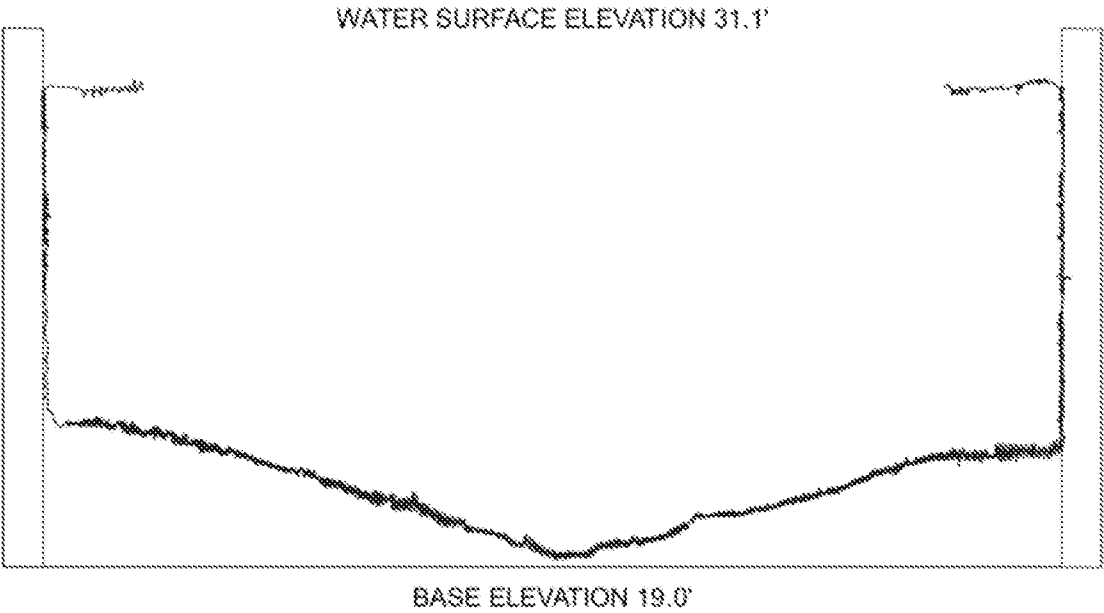


FIG. 17

FIG. 18

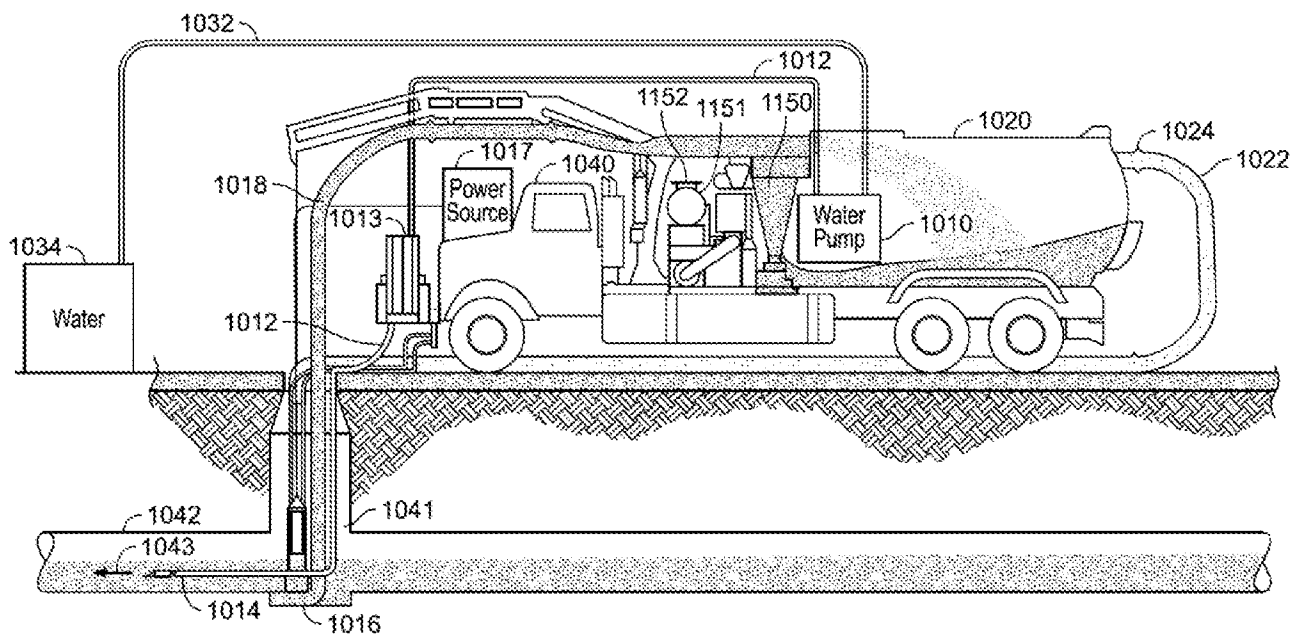
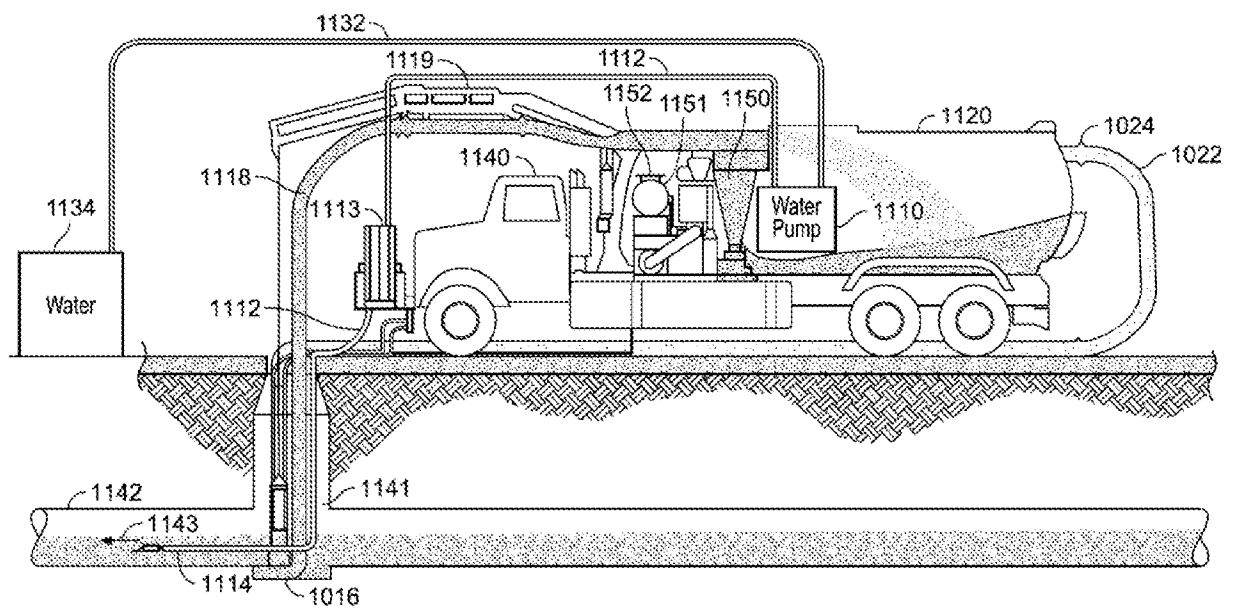


FIG. 19



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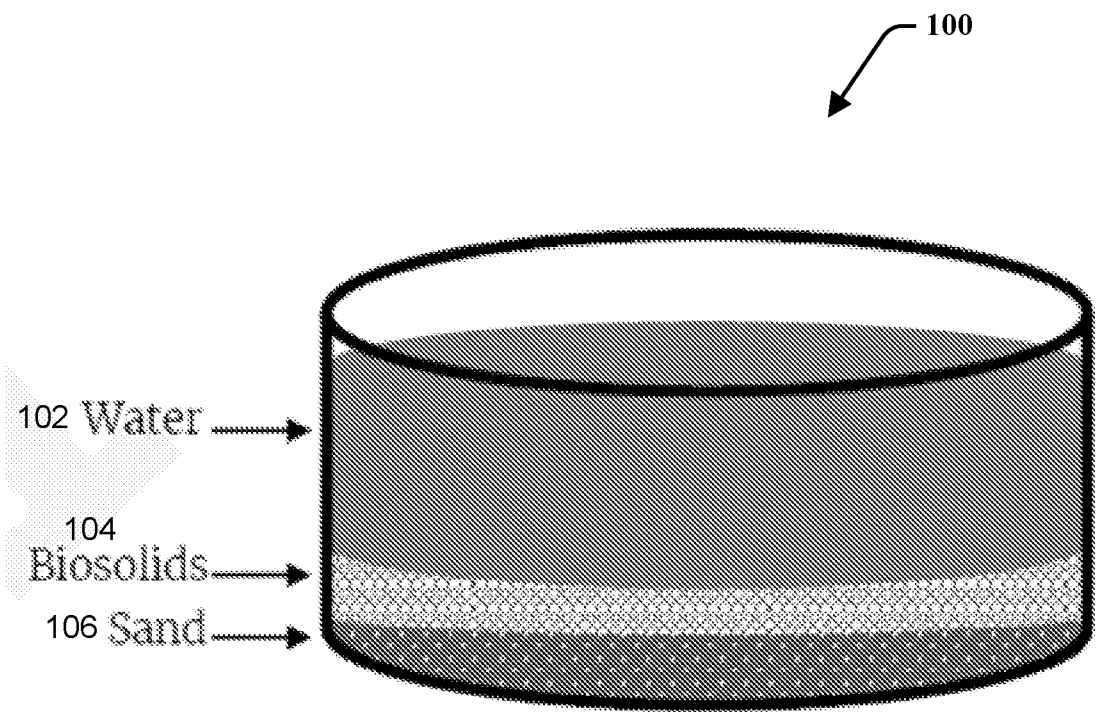


FIG.20

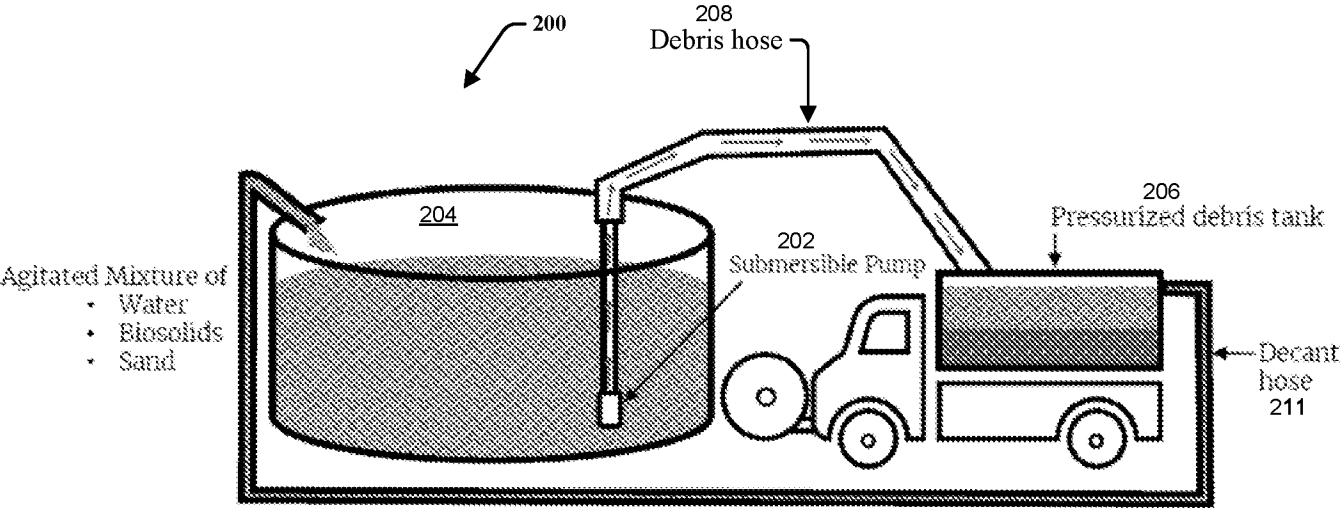


FIG. 21

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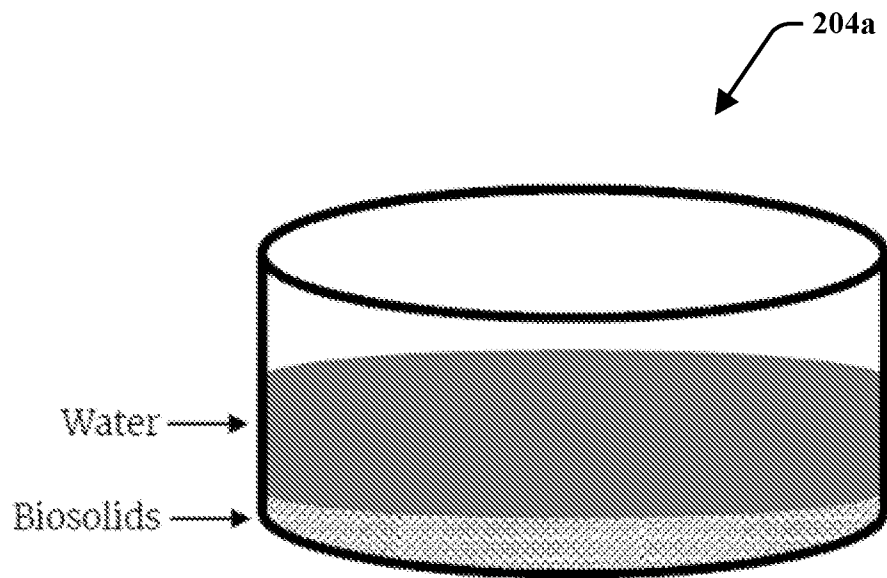


FIG. 22

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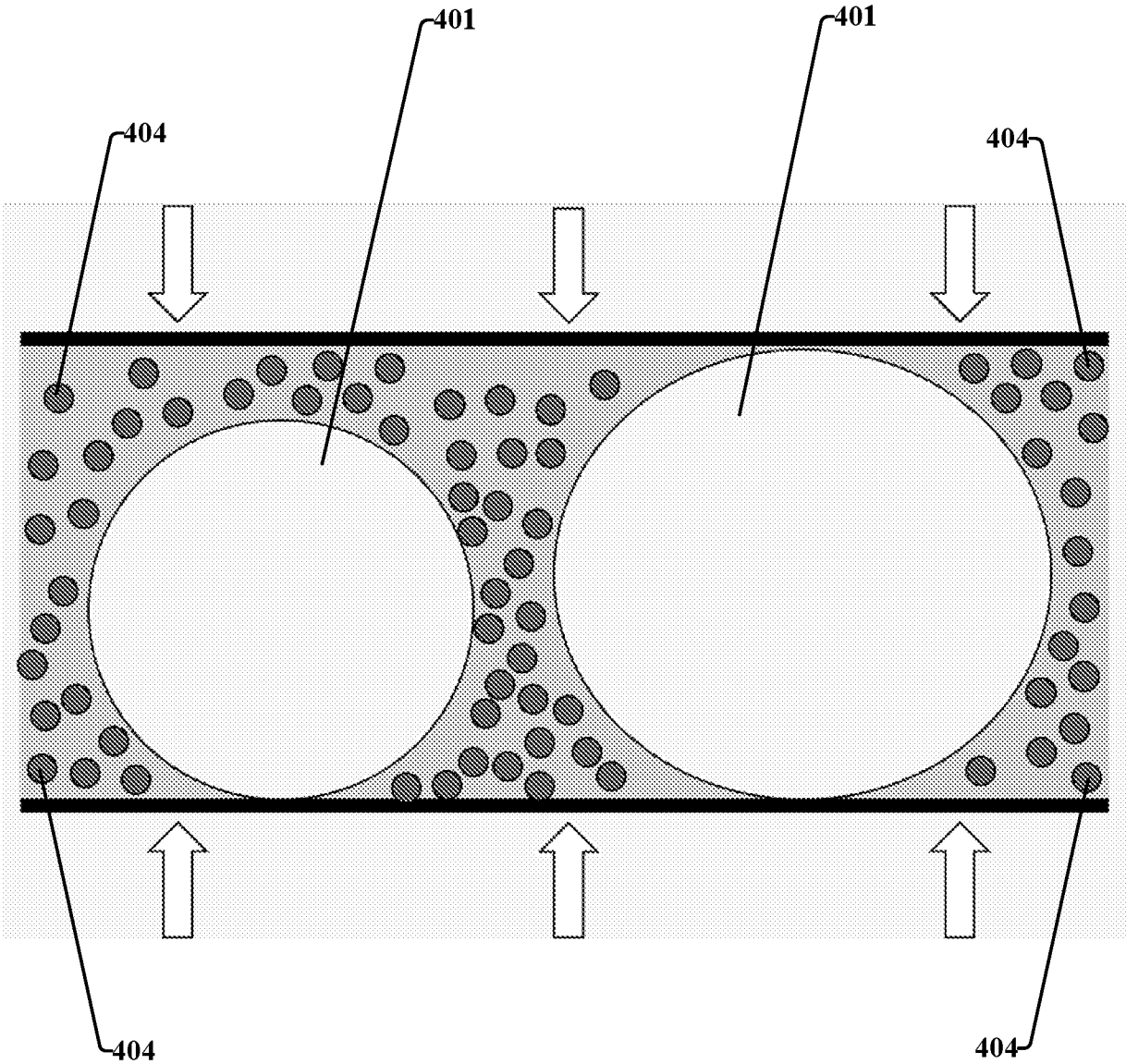


FIG. 23

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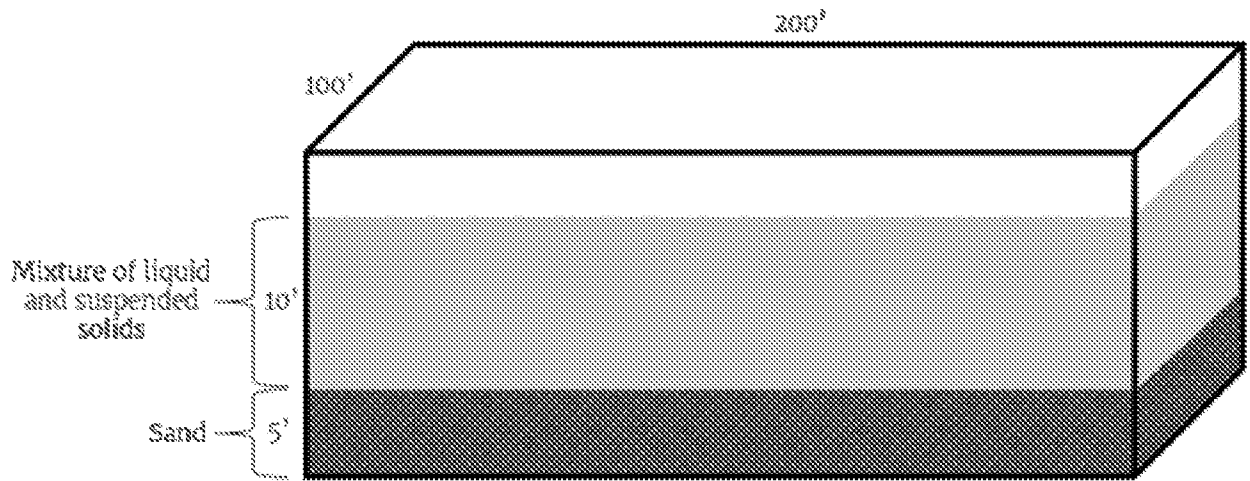


FIG. 24

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2024/056370

A. CLASSIFICATION OF SUBJECT MATTERIPC: **B08B 13/00** (2024.01); **G01N 33/18** (2024.01); **G01N 27/00** (2024.01); **B08B 9/46** (2024.01); **B08B 9/08** (2024.01); **B63G 8/00** (2024.01)CPC: **B08B 13/00**; **G01N 33/18**; **G01N 27/00**; **B08B 9/46**; **B08B 9/08**; **B63G 8/00**; **B08B 2209/08**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

See Search History Document

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

See Search History Document

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

See Search History Document

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2022/0395872 A1 (U.S. SUBMERGENT TECHNOLOGIES, LLC) 15 December 2022 (15.12.2022) entire document; especially para [0013]-[0019], para [0046]-[0052]	1, 5, 6, 8, 9, 11-16
Y	entire document; especially para [0013]-[0019], para [0046]-[0052]	2-4, 7, 10
Y	US 2020/0017372 A1 (SOURCEWATER, INC.) 16 January 2020 (16.01.2020) entire document; especially para [0005]-[0008], para [0049]-[0051]	2-4
Y	US 2018/0136329 A1 (R2SONIC, LLC) 17 May 2018 (17.05.2018) entire document; especially para [0013], para [0017], para [0032]	7, 10



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See patent family annex.

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“O” document referring to an oral disclosure, use, exhibition or other means

“P” document published prior to the international filing date but later than the priority date claimed

“T” later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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“Y” document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

28 December 2024 (28.12.2024)

Date of mailing of the international search report

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