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PUBLIC WATER NOW

Andrew Barnsdale
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550 Kearny Street, Suite 800
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June 30, 2015

Dear Mr Barnsdale,

This letter and Attachment 1 contain comments by Public Water Now on the Cal Am DEIR for the Monterey Peninsula Water Supply Project. Attachment 2 is related. .

First and foremost are comments on several overriding concerns that have not been addressed in any substantive way in the DEIR, or have arisen after the publication of the DEIR.

1. Public Statements. This is a reminder of the many public comments about the nature of the "test" slant well. This indicates how widespread and pointed the expectations were, and how important it is that there be full follow through consistent with these public comments. It is obvious that everyone considers it an experiment. Thus it requires a detailed test period to be useful to the entire state and water industry. And it must be sufficient to justify the huge ratepayer liability for its implementation. Anything short of the full test period is a charade to the public, or a disingenuous promise by officials. Regardless it will be a crap shoot at ratepayer expense:
    1. "...slant test is an experiment..." Congressman Farr (Pine Cone 11-7-14)
    2. "...prove the feasibility of the state's preferred subsurface intake method." Jan Zimmer, member, CA Coastal Commission. (Herald 11-13-2014)
    3. "This will provide important information for the state." Steve Kinsey, Chair of CCC, (at permit hearing on Nov 13, 2014)
    4. "This is the right thing for Monterey and the right thing for the state." Rob MacLean, President, Cal Am, (Herald 11-13-14)
    5. "...further the state of knowledge with respect to alternatives to open ocean intakes." Mark Stone, Assemblyman, 29th District, letter of support.
    6. Research grant of $200,000 from WateReuse Foundation "This research is important to the entire water industry."
    7. "We're probably pushing the max as far as how large they (slant wells) can get." "How well the bearings will hold up over time is an area of concern." Rich Svindland, Cal Am Chief Engineer, National Driller July 2014.
    8. "...has only been done once..." "It's still a very rare method." Dennis Williams, president of GEOSCIENCE National Driller July 2014 (Cal Am, CPUC and ESA contractor).

2. Slant Wells, New and Unproven. Slant well technology for desal intake is new and experimental. Slant well technology is not in use for ocean desal projects anywhere in the world. There is no operational experience to draw upon. No experience with costs related to maintenance or replacement. Some similar horizontal directional drilling systems have been used, but mainly to pop out into the open ocean for intake. The lack of any operational use of slant wells in unconsolidated soils anywhere in the world should demand a thorough test period.. It should demand enormous attention in the DEIR. But it has not! The DEIR is notably and woefully incomplete for this omission. Will this complete omission of a discussion of its experimental nature be explained? Will other examples of its use be identified and translated for Cal Am's plan? Will ESA explore the unusual demands of slant well technology and include such research and reference material in the FEIR? No references to slant well success appears anywhere in the DEIR. Will ESA provide documentation of its success? Will it rely on citations of Geoscience for this? Will its FEIR comments be free of potential conflicts of interest generated by patents owned by Dennis Williams? If ESA will not research this, will it be a subject of discussion in the FEIR? If not, why not?

3. Feasibility of Subsurface Intake. The question of slant well feasibility has not been discussed in detail. The subject is raised in Chapter 2 with water rights, and is mentioned as an issue. But the subject - feasibility - is ignored. The State Water Resources Control Board had established guidelines that require the feasibility of subsurface intake for desal plants be determined before another option is pursued. Its definition in the newly adopted amendment to the Ocean Plan (May 2015) states:

   > FEASIBLE, for the purposes of chapter III.L, shall mean capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors.

   Furthermore the 16 Party Settlement Agreement states in Section 5.3: ("**As used in this paragraph, whether a source water project or program is feasible shall be determined by California American Water.")** Is Cal Am the sole arbiter of this definition? Doesn't the DEIR have a role in defining feasibility? Will it add comments on this?
   Also the concept of "risk" is not mentioned. Economic factors are not included in an EIR. However many of the site specific, design and technical factors are included, including migrations. So by not mentioning specifically the compliance to SWRCD requirements, the EIR is weak. Also by not mentioning other feasibility factors, the DEIR fails to cover key points surrounding slant wells. Its experimental nature is described in this letter (items 1 and 2). But the DEIR fails completely to mention the risks of a new and unproven intake technique, and the potential risk of litigation from water rights arguments The DEIR is deficient because of these omissions. Will the FEIR address these issues? Does ESA declare that it is feasible or not? What other factors, besides environmental, should be evaluated? .Did ESA think to include the feasibility question? If it was rejected, what were the reasons?

4. Shortened Test Well Schedule. Cal Am's schedule has always included an 18 to 24 month period of data collection from the test slant well. However the CPUC decision for a CPCN is scheduled after only about 12 months of testing. The test data will have to be consolidated and presented in a time frame that starts months shorter than 12 months. Also it is further complicated by the recent halting of the continuous testing. As of this writing, the test has been stopped for more than a week. This means even less data will be available for the FEIR. And the modeling designs may need further revisions. Will these gaps and changes be fully

discussed in the FEIR? The schedule for decision making is also further compressed with even less data. The announced 18 to 24 month test period is completely compromised. Will this be fully explained in the FEIR? Can ESA explain how a vastly shorter period of data collection meets ESA's interpretation of the requirements of CEQA? Can ESA explain how the incomplete data serves the purpose of informing the CPUC? Can ESA explain how the short time period for test well data collection provides a sound basis for judging the impacts of the extractions? Can ESA explain how the CPUC schedule for a decision is more important than a full evaluation of test well data? Can ESA explain why the CPUC allowed the schedule for the full EIR review to be inconsistent with Cal Am's own proposal for an 18 – 24 month test period? The contradictions of Cal Am proposed schedule, CEQA requirements, accelerated CPUC schedule for full review, inadequate data collection,, no time for due diligent analysis, and the rush to judgment on a decision, all contradict the public presentations for the longer test period? Can ESA explain how all this still meets CEQA requirements?

5. Patents and Conflicts of Interest. Dennis William, President, Geoscience, personally holds key patents for slant well technology and implementation. Research has revealed he holds three separate but related patents (US8056629 B2 in 2011 [attached], WO2011/020574 in 2011, and US8479815 B2 in 2013). Holders of patents stand to gain handsomely if their patents prove successful. Dennis Williams appears to have claimed to not be interested in making a profit from his patents. Then why has he sought to apply his patents across the globe - North America, South America, Europe, Asia, Middle east, and elsewhere! There is no reason to give any benefit of the doubt to Mr. Williams. He is a key, and we think, the most important key, to this slant well project going forward. As long as there is a cloud over the personal interest of Mr. Williams, or the economic interests of Cal Am, and their relationships, there must be an investigation. The credibilities of Mr. Williams, Cal Am, CPUC, and even ESA, are at stake. Will there be an investigation? Will ESA recommend an investigation? If not, why not? Will the results of this request be made public?

6. Lead Agency Responsibility. The CPUC role as lead agency includes the requirement to be deliberate and objective, and to meet the legal demands of CEQA. CPUC has retained Geoscience to lead its technical and modeling approach and analysis. Did ESA and CPUC know about the patent in the name of Dennis Williams, President of Geoscience Support Systems Inc, regarding slant well design and installation? Did ESA and/or CPUC vet the background to determine any potential conflict of interests? Did ESA and/or CPUC know that this fact has never been disclosed to the public in any of the work products of Geoscience? Or the work products of Cal Am? Or the work products of ESA? The appearance of a conflict is as important as a proven conflict of interest. Will Dennis Williams continue to be directly involved in the decisions of the hydro-geological working group? Within CPUC? Will this be explained in the FEIR?

7. Closed Loop Relationships Questioned. The appearance of a closed loop of the regulator (CPUC), the regulated (CAW) and common contractor (Geoscience) stretches the believability for objectivity and independent analysis. This applies to the CEQA process for environmental impacts and the separate CPUC tract for cost, economic, management, monitoring and implementation factors. The appearance of a conflict affects all three, but particularly the CPUC, which already has a problem of being way too close to its regulated utilities. Will the appearance of conflict of interest be addressed in the FEIR? Will the interconnected relationship (the closed loop) be explained? Will the public be informed of the procedure used by CPUC to select Geoscience to represent CPUC inputs to the CEQA process? Will the public

be informed of the vetting process that failed to reveal the patents and the potential of a conflict?

8. Role of Mr. Williams in HWG. The Hydrogeologic Working Group (HWG) has a critical role in applying modeling and evaluating data, for adequacy, significance, impacts, and drawing conclusions from its analysis. What is the role of Dennis Williams in this group? Who is the convener or leader? What procedure is used to render a conclusion? Is it a voting procedure? What is the mechanism to break a tie, since there are four members? The role of this group has now been compromised with the revelation of the patents held by Dennis Williams for slant wells. Will there be modifications to the relationships within HWG regarding Geoscience President Williams? Within the closed loop of Cal Am, CPUC and Geoscience? How about with other key project participant such as Office of Ratepayer Advocates, Settlement Agreement parties, Governance Committee, Mayors Water Authority, and Monterey Peninsula Water Management District? Will these parties be informed of a review of this potential conflict? Will there be changes to the working relationships of Williams within his contractor loop? If changes are made, will they be reported publicly?

9. Defying Common sense. Recent public comments by both Mr. Williams of Geosceince and Mr. Svindland of Cal Am state that there is no conflict of interest, because both assert the patents of Mr..Williams are not in use at the test slant well. However both assert they may be used in future slant wells in this project. So to deny conflict on one hand, and assert future use, suggests a future conflict. Just what is accurate? If the patents will be used, is there a current conflict, or is it only a future conflict. The appearance of a conflict is obvious. What are the facts and how do they apply to a potential conflict of interest?
   What we know is this. Geoscience (Williams) designed and supervised the installation and testing of a slant well at Dana Point from 2006 to 2012. His earliest patents were applied for in 2010 and 20111. What did he learn from the Dana Point experience? Did he apply it to the design of the test well for Cal Am? Did he use the patent information in the design and installation at the CEMEX site? Did he use any of the knowledge as a basis for evaluating his own work? Did this relationship of new knowle3dge, new patents, and a new project, miraculously not be used? This defies common sense. Will there be an investigation of this by the Energy Division of CPUC? By another office within CPUC?

This letter and the attachment represent Public Water Now comments on the Draft EIR for Cal Am's Monterey Peninsula Water Supply Project.

Respectfully submitted,

/s/ Geo T. Riley
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Attachments: 1. Additional PWN comments on DEIR
2. US Patent US8056629 B2

# Attachment 1 to PWN letter dated June 30, 2015
## Re: PWN on Cal Am DEIR, June 30, 2015

These additional comments supplement the cover letter which contains narrative questions on matters not contained directly in the DEIR, but which directly concern the adequacy of the DEIR.

| Page | Topic and Statements | PWN Comments |
|---|---|---|
| Ch 2 | **2. Water Demand, Supplies, and Water Rights** | Marina Coast Walter District is not mentioned once, yet it has contested the water rights of Cal Am, and has jurisdiction over the use of the CEMEX site. This omission makes it look like MCWD has no role in its own supply needs that are designed to use sites on or near the CEMEX site, perhaps in conflict with Cal Am's MPWSP. Will this be addressed in the FEIR? |
| | **3. Project Description** | |
| Pg 3-44 | Table 3-11, Cross-Section View of Subsurface Slant Well<br>It shows the well length extending beyond the shore line, beyond the demarcation boundary defined by the mean high tide line. | This is very misleading. In fact, the test well does not extend beyond that demarcation line. It stops on the landward side. Will this be corrected? Will the fact of the test well length be described.? The intent may be there, but the presentation is misleading. |
| | **4.4 Groundwater Resources** | |
| Overall | Marina Coast Water District is not mentioned once. This is a major omission, and significantly undermines the thoroughness of this DEIR. | |
| Pg 4.4-12 | "The Sand City desalinization plant produced 208.37 acre-feet (af) in 2012..." | The Sand City desal plant is designed to produce 300 afy. Is it true that Sand City is producing at less than 70% of designed capacity? Or is this the amount available for Cal Am? How is the Sand City allocation of 206 afy factored into this? Shouldn't only 94 afy be available for long term use? What amount did Sand City use? Is production at about 300 afy, or is it less? What is the production record of the Sand City plant? Will this be clarified in the FEIR? |
| 4.4-22 | "The total dissolved solids (TDS) concentration is 35,600 milligrams per liter | When the actual TDS is known, what is the value of using the average TDS along the |

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| | (mg/L), and thus closely compares with the average seawater TDS concentration of 33,694 mg/L found along the central coast of California." | central coast of California? Table 4.4-5 on page 4.4-23 uses the average TDS for comparison purposes. The lower TDS in the average may conceal the actual mix of sea and fresh water being pumped. Will this be explained? Will the actual TDS be included in the modeling? If not, why is it not used? If both are used, will it be explained? For statistical clarity, will this avoid the appearance of a manipulation of comparisons? |
| 4.4-41 | Figure 4.4.11 Monitoring Well locations. No monitoring wells south of CEMEX site, which could impact known MCWD plans for expanding its water supply with subsurface intake for its desal production. s | Why are there no monitoring wells south of the CEMEX site, where Marina Coast Water District has wells.. And where MCWD plans to install new desal intakes for future water supply. ESA is aware of these plans, and the controversy over water rights and access to well sites. Why is this key issue - Cal Am intakes vs MCWD intakes - omitted? What rationale exists to justify leaving out this discussion? Will this discussion, and transparency regarding it, be included in the FEIR? If not, why not? |
| Pg 4.4-43 | "...the models used for the analysis of the proposed project used hydrology and climatic conditions spanning a 63-year time period from 1949 to 2011. ….While applying the historical record into the future may not precisely mimic future climatic conditions, it provides a reasonable method to estimate future climatic trends over a model period." | There is much disagreement with the baseline data. Too many recent climate studies and projections suggest far greater diversity of extremes. Will this report add comments to that effect? Will the word and concept of "reasonable" be quantified or qualified? Will the current drought be factored in? Will sea level rise be factored into the modeling? Has it already been factored in? Can you state exactly what assumptions have been included in the modeling? |
| 4.4-58,59 | "Impacts from groundwater pumping at the proposed slant wells were analyzed by reviewing the <u>modeling</u> output from the NMGWM. This analysis compared the <u>modeling</u> output …. The <u>modeling</u> shows that project pumping from the slant wells would cause a response ...The <u>model</u> outputs are presented as maps and ..." | Emphasis added. Will the importance of the 18 to 24 month test period be compared to the importance of modeling? Real data is superior to modeling. Will ESA dispute this? Why short-cut real data when it was planned all along? Why does the schedule depend on modeling when actual data has been planned? |
| -65 | "The slant wells would extract groundwater from the offshore portion of the Dune Sand and 180-Foot Equivalent Aquifers and not | Such statements are negated by the areas of influence and cone of depression charts. The wells will extract substantial |

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| | the 400-Foot Aquifer." | groundwater from inland. To insist on this definitive language is misleading, and seems self serving to the intended outcome of an acceptable project. Why not be honest and make the qualifying statement that it will extract the majority of water from offshore. Will this be corrected, or explained in the FEIR? |
| 4.4-67 | "The NMGWM estimated the volume of inland water would be about 7 percent under 2012 land use conditions after the pumping has started and the cone of depression has stabilized after a few months." | Where is the evidence that the cone of depression will stabilize in a few months? This is self-serving to the DEIR, Cal Am and the CPUC. Why is this statement made with no facts to support it? Where does the actual test period of 18 to 24 months come into the picture? Why has the test period not been mentioned? Does it have relevance in the eyes of the consultants? |
| 4.4-67 | "Over the life of the proposed project, this would be an average …".(re amount of inland water extracted) | This reference to 'the life of the proposed project' is used often. But the DEIR fails to designate such a useful life span. Where are the years mentioned? Does the DEIR address replacement components to apply to "the life of the project"? Are there different "lives" re pipelines, desal facility, intake wells, and more? Where does the 'life of the project" get addressed? Is this a proper subject for a DEIR? How does the "life" relate to an EIR for project approval? There is a mention of a 25 year payback of Cal Am's overdraft of the Seaside GWB, but that is it. |
| Pg 4.4-68 | "The first Phase of the test slant well investigation commenced with the construction of a 724-foot long test well drilled at an angle of 19 degrees below horizontal at the CEMEX site. " | The DEIR does not reveal the fact that the test slant well has not reached the sub-ocean floor. It's terminus is landward of the mean high tide line. What justification is there that this is adequate for the test? All statements by Cal Am, and contained in permitting applications, was that the test well was to extract from under the ocean floor. The facts are not reported here. Will they be reported? Will the FEIR contain justifications for this oversight, and the fact that the terminus is landward of the application and the permit from CCC? |
| Pg 4.4-68 | "The long-term pumping test began in mid-April 2015, and results will be provided in the Final EIR, as available. " | "Long-term" is not defined. How long is this? Cal Am schedule calls for an 18 to 24 month period. CA Coastal Commission |

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| | | agreed when it issued the test well permit. Will the test period be that long before it is considered by the CPUC? How long is an appropriate time for such a test? No operational slant well is in place anywhere in the world. Will the FEIR contain specific justification to proceed without the long-term data for a full analysis? What justifications support the lack of a full;l test period? |
| “” | “...results will be provided in the Final EIR, as available.“ | Will the full evaluation period of 18 to 24 months be discussed in the FEIR? Will any shortcuts to that time frame be explained? Will the most recent data be included in the FEIR? Will the public have an opportunity to review and comment? How? On what schedule? Locally or at the CPUC in San Francisco? Can you explain how the DEIR is a complete record of environmental impacts when key teat data is not included here? Why are no suggestions offered for an incomplete data record? What mitigation, monitoring or follow up suggestions could the FEIR contain to cover this deficiency in the DEIR? |
| 4.4-73 | “The impact analysis of the Seawater Intake System was based primarily on the NMGWM model simulations and the response of monitoring wells to the 5-day constant-discharge pumping test discussed above.” | Is it adequate to base the impact analysis on only “the 5-day constant discharge pumping test”? When Cal Am, CPUC, CCC, Settlement Agreement parties and others are very well aware of Cal Am,'s proposed 18 to 24 month test period, what is the justification to draw such precise conclusions? Why has the DEIR not mentioned the longer and planned test period? |
| -73 | “None of the wells located in the area of influence would be adversely impacted by the draw-down...” | Will the omission of the Ag land Trust well(s) be addressed? Too much public attention has been focused on this. Will there be an explanation? |
| pg 4.4-74 | Mitigation Measure 4.4-3 re Intake System “Immediately following project approval, the project applicant, working with the MCWRA, shall fund and develop a groundwater monitoring and reporting program that expands the current regional groundwater monitoring network to include the area near the proposed slant wells.” | Why is MCWD excluded. The site is located where MCWD has water rights, not MCWRA.. “Shall fund” means a cost. Is cost ever tied to EIR recommendation? When and how? In what format and what forum? |

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| -74 | "Area of groundwater monitoring shall be determined by MCWRA and the MPWSP Hydro-geology Working Group (HWG). " | Has this been agreed to by MPWSP HWG? This is an expense. Is Cal Am to pay? Is this a shared cost with MCWRA? What agreements are there by MCWRA and MPWSP HWG? Is it in writing? Is a budget set? Is it budgeted? |
| -74 | "The voluntary groundwater monitoring program shall include retaining an independent hydro-geologist to evaluate the conditions and characteristics ...of participating wells prior to the start of slant well pumping." | Who engages the independent hydro-geologist? Who pays? Why is MCWD excluded? It is in MCWD jurisdiction with its own authorized water rights.. |
| -75 | "...identify areas lacking adequate groundwater data and if deemed necessary, install new monitoring wells (in 180 ft aquifer).". | Who identifies? Who makes the call? Who installs? Who pays? On what time frame? Are such wells forever? Or can they be converted to deeper wells ever? |
| -75 | "...evaluate whether project pumping is causing a measurable and consistent draw-down of local groundwater levels in nearby wells that is distinguishable from seasonal groundwater level fluctuation." | Who evaluates? Reported to whom? Who determines the impact? Who enforces mitigation? Another obvious cost issue to be acknowledged |
| -75 | "In the event that a consistent and measurable draw-down is identified, determine if the observed degree of draw-down would damage or otherwise adversely affect active water supply wells." | "Determine" how? By who? What if a determination is challenged? What resolution format applies? Litigation? Other options? What are the plans for this? |
| -75 | "If it is determined that a nearby active groundwater well has been damaged or otherwise negatively affected by the project pumping of the slant wells, the project applicant shall coordinate with the active well owner to arrange for an interim water supply and begin developing a mutually agreed upon course of action to repair or deepen the existing well, restore groundwater yield by improving well efficiency, provide long term replacement of water supply, or construct a new well." | Does this exclude the MCWRA from participation? How long is "interim"? How long is the fix to last. How do differences as to the appropriate fix get resolved? Litigation? A deeper well could be more damaging to the basin, or conversely be more advantageous to the owner. Where is the MCWRA in reviewing or arranging for a course of action? Who pays for litigation? Is it in Cal Am's budget? How long is "long term?" |
| -74,5 | Various mentions of impacts | There is no mention of the proposed 18 to 24 month test well data collection period. Why not? It is contained in every Cal Am schedule and all updates. What assumptions would be challenged or modified with data from the extended data |

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| | | collection period? Why no mention of its relevance? Is this DEIR intended to seek approval without the test data? What is the rationale for this? How can the extended test period be ignored?. Will it have relevance to future actions, mitigation monitoring, follow up? What id the effect on the project if new data proves relevant? Has this been accounted for in the DEIR? Where? Will it be included in the FEIR? Would mitigations change if relevant data emerges? What, for example? |
| -80 | "With the implementation of the proposed project, a portion of the intruding seawater would be removed from the coast through pumping at the seawater intake system. Once removed, the pressure on the seawater flowing landward at the coast would be reduced within the localized area affected by the proposed project pumping. The pressure reduction would interrupt the inland flow of seawater instead of allowing the seawater to continue to migrate inland. This would cause the seawater/freshwater interface to migrate back towards the ocean, thus reducing the extent of the area currently affected by seawater intrusion." | Figure 4.4-9 (pg 4.4-28) shows an 11-mile front of seawater intrusion. Figures 4.4-13, -14 and -15 show about 4 miles of ocean front for potential impacts on groundwater levels. Figure 4.4-16 shows particle tracking data, also over about a 4-mile front. The particle tracking shows a trend of close-in water flows that circle toward the cone of depression, but does not show the circular loop of other water particles that follow in the larger 11-mile front of seawater intrusion. Logic says that the larger circle of particle tracking would fill in behind the flow toward the cone of depression, and stabilize about 4 miles inland. Where is the data to show that seawater intrusion will be affected at the more inland areas? Where is the proof that circular pattern of particle tracking actually extends farther than about 4 miles inland?. Where does it stabilize and how far inland? The DEIR cannot say there is an inland reduction of seawater intrusion without more definitive data to support it. Will this be corrected? Will this be explained in the FEIR? |
| Pg 4.4-88, -89 | Mitigation Measure 4.4-4 Following a discussion of toxic plumes and injection and extraction from ASR wells, the DEIR makes not one mention of the role of MPWMD. Reporting requirements and remediation actions are discussed. MPWMD was totally omitted here. | ASR is a partnership between Cal Am and MPWMD. To exclude the MPWMD from a role in monitoring the effectiveness and production of ASR facilities is a distinct oversight. What is the reason for placing all responsibility on Cal Am? What it the rationale for this? Where does MPWMD fit into this component? Was it omitted intentionally? Why? There needs to be an |

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| | | explanation. |
| **Ch 5** | **Cumulative Impacts** | |
| Table 5.1, page 5-4 | Cumulative Projects<br>ESA failed completely to include the Marina Coast Water District plan and obligation to expand its water service for future Ord development. It intends to use wells sited very close to the CEMEX site. To overlook this plan is to ignore a fundamental conflict in the north Marina area. It overlaps the fight over water rights. The DEIR recommends a preemption of MCWD plans, rights and obligations for its customers and its jurisdiction. ESA knows all about this issue, having participated in the permit arguments at Marina City Council earlier in 2015. ESA is obligated to address MCWD plans. | This is a substantial omission. No reference to MCWD is contained in the entire chapter. How can this be? This is a huge oversight or omission, and considerably weakens the DEIR. Will the MCWD plans be described and discussed in the FEIR? Will the MCWD plans be acknowledged in the FEIR? Will its plans be included in the analysis of cumulative impacts? Will any modeling inputs be made to account for MCWD plans? |
| **Ch. 7** | **Ch. 7. ALTERNATIVES** | |
| Entire | GEOSCIENCE is mentioned 36 times. It is referenced 12 times with cited data or comment from 2012 through 2015. This is the period that Dennis Williams of Geoscience had patents for slant well technology and implementation. The CPUC role as lead agency is required to be deliberate and objective, and it will meet the legal demands of CEQA. CPUC has retained Geoscience to lead its technical and modeling approach and analysis.<br>The appearance of a conflict of interest is as important as a proven conflict of interest. | Did ESA and CPUC know about the patent in the name of Dennis Williams, President of Geoscience Support Systems Inc, regarding slant well design and installation? Did ESA and/or CPUC vet the background to determine any potential conflict of interest? Did ESA and/or CPUC know that this fact has not been disclosed to the public in any of the work products of Geoscience or Cal Am? Will ESA report on its knowledge of the patents, and its concern for potential conflicts of interest? Will Dennis Williams continue to be directly involved in the decisions of the hydro-geological working group and decisions within the CPUC? Will Williams recuse himself from key decisions? Will this be addressed in the FEIR? |
| Pg 7-3 | "The selection of alternatives is limited to those that would avoid or substantially lessen any of the significant effects of the project, <u>are feasible</u>, and would attain most of the basic objectives of the project." " An EIR need not consider every conceivable alternative, but must consider and discuss a <u>reasonable range of feasible alternatives</u> in a manner that will foster informed decision- | Why has ESA not addressed the question of "if feasible"? The SWRCB has used that phrase consistently, but ESA fails to mention the implied question 'if'. Why not? What factors of the SWRCB definition of 'feasibility' have ESA considered? What factors in SWRCB definition does ESA not address? Will this be discussed in the FEIR? |

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| | making and public participation." (pg 7-3) "The EIR must evaluate the comparative merits of the alternatives and include sufficient information about each alternative to allow meaningful evaluation, analysis, and comparison with the project " (pg 7-4) | |
| 7-9 | "Subsequent to approval of the Regional Project, Cal Am withdrew its support for the Regional Project in January 2012....." | Suspicious activity with various participants, both public and private officials, still festers. Ethics violations still are in open cases at the federal level. The conflicts still hover around this project. The complications overlap, but the DEIR fails to even mention it. As ESA winds its way through the maze of concerns, this failure still haunts this process,, especially because ratepayers have had to pay over $35 million for this failure by Cal Am. Would it be appropriate to at lease mention this? |
| 7-10 | 7.4.5 MCWRA Interlake Tunnel Project | EIR has wasted energy and time to use this as comparison. It never had relevance to water demand on the Peninsula. Other alternatives not considered have more relevance, i.e., the bypass pipeline directly from ASR to Cal Am's Forest Lake distribution system.. |
| 7-10,11 | 7.4.6 Other Desalination Proposals at Moss Landing | Again the word "feasible" is used, but not defined. Cost and risk are overlooked in this analysis. Will the word' feasible' be defined for the FEIR? Will it include the concepts of cost and risk? |
| 7-12 | Re DWD. "At the discharge point, a high velocity five-jet linear diffuser would be attached to the end of the outfall pipeline.' | Is the high velocity jet diffuser a better system than Cal Am's gravity system? Where has this comparison been made? Is this not a better alternative for brine dispersal? Why has ESA not made this clear? Will it be clarified in the FEIR? |
| " | Re DWD: "This desalination proposal has not been carried forward as an alternative to the MPWSP b<u>ecause the CPUC has no jurisdiction</u>, ...." | Why is 'no CPUC jurisdiction' a factor? Does it matter? Why is this a reason for not carrying it forward? Will this 'reason' be explained? Most water services throughout California are outside the CPUC jurisdiction. To make this statement shows a bias toward a corporate provider. Is this the intent? Please explain. |
| 7-13 | Re Peoples: "The preferred intake site is an | It is not abandoned. Why make this |

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| | abandoned intake pump structure... ." | statement? What is the evidence that it is abandoned? It has had recent permits and was used. Why the reference to "abandoned"? |
| 7-14 | RE Peoples: "This desalination proposal has not been carried forward as an alternative to the MPWSP because the CPUC has no jurisdiction, ...." | Again, why is this reference to 'no CPUC jurisdiction' relevant? All alternatives should be considered, regardless of CPUC jurisdiction. |
| 7-18,19 | Open Ocean Intakes | Nowhere is there a mention of the rapidly improving technology for OOI that reduce entrainment and impingement. Why is its technical feasibility omitted? Especially since two alternatives (DWD and Peoples) propose its potential use. The EIR is deficient with little discussion of its widespread use and usefulness. Why is OOI feasibility shortchanged? Will this be addressed? |
| 7-19, and later | Operations and Maintenance Considerations for Open-Water Intakes | This entire narrative is self-serving for subsurface intakes. It points out negatives and demands for its use, without offering a fair description of newer technology, especially with passive intakes. Will a fuller explanation of the feasibility of OOI be included in the FEIR? Will improved technologies be acknowledged? |
| 7-19,20 | "However, the magnitude of potential entrainment of marine species into the bottom sediments caused by continuous subsurface intake operations has not been systematically and scientifically studied to date (WateReuse, 2011)." | Why has there not been notice of no operating slant well anywhere in the world? Therefore there are many events not experienced, and therefore the risk is high, yet ignored. Why omit this information? Will it be corrected? |
| 7-21 | Approximately 10 to 12 horizontal wells would be needed ... | Why 10 to 12 horizontal wells, and only 8 to 10 slant wells? Similar technology, similar locations, similar depth, so why the difference? Also the length can be longer, thus avoiding the aquifer and water rights issue altogether. Why is this not the superior alternative? What supports the statement that HDD is not superior, when certain facts clearly show the avoidance of water litigation, avoidance of extra cost for dealing with inland water, and no contrary opinions about the effect on seawater intrusion? Will this be explained? |
| 7-22 | (3) HDD would not avoid or minimize any | This is a gross exaggeration, if not outright |

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| | of the impacts associated with the proposed action. | misleading and wrong. All sorts of impacts would be avoided if this were the choice. All sea water for intake. No inland water. No water rights issue. Why say it is possible up to 2400 and 2500 feet, then call it challenging? Either it has impacts or not. But 'challenging" is subjective, and not supported by facts. What justifies such a self-serving statement in support of slant wells? What comparisons were made and from what sources? |
| 7-23 | "...slant wells can be screened at greater distances offshore..." | Same with HDD wells, but the EIR fails to mention this fact. Shows a bias toward slant wells, and an incomplete evaluation of HDD wells. Why this bias? Why the omission? Will this be corrected? This bias for Cal Am's slant wells is becoming too obvious. Will this bias and the omissions be addressed? |
| " | "Slant wells can be drilled from behind sand dunes or from the active beach area..." | So can HDD wells. Why the bias? Why the continuous omissions and scarce accuracy about the HDD option? |
| " | (slant well) "wellheads can be buried beneath the sand or installed flush with the ground surface." | Again same with HDD wells. The bias and omission of a full evaluation of HDD wells should be embarrassing. Will this be addressed? |
| 7-26 | Re CCC policies: "There may be differences in applying the Coastal Act policies to public or private desalination facilities." | Two competing desal proposals are in the works..Both are expected to be publicly owned. EIR consultants know this. Why is there not some explanation for such differences, if the DEIR is expected to be a thorough document? Will those omissions be corrected or explained? |
| " | "Before the CCC will consider permitting an open-water intake, it must first be demonstrated that a subsurface intake is infeasible." | The DEIR does not contain the definition of "infeasibility" nor "feasibility. This is a key question raised by ratepayers over and over again, but there is no insight shared in this DEIR. This omission fails to inform the CPUC and the public about a key condition for the entire desal project. Where is it? Will this be explained in the FEIR? Will the relevance of 'feasibility' and test slant well and the test period be discussed? This omission is appalling. |
| 7-27 | " The CCC requires a 1-year feasibility study to evaluate the potential entrainment | What requirements apply to subsurface intakes? Are there no requirements at all? |

| | | |
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| | impacts expected from open-water intake operations (CCC, 2004)." | Do you mean a tried and true ocean intake system requires a one year study, but an experimental slant well system with no recorded history anywhere in the world will not require any specific study? This is a bothersome summary. It is a serious omission. The consensus is in support of the 'idea' of slant wells, but no proof exists of an actual operating history. Why is this issue omitted? Will this be addressed? |
| " | Re MBNMS Guidelines: "Where subsurface intakes are not feasible, open-ocean intakes should be sited with existing pipelines of acceptable structural integrity." | It is appropriate that this is pointed out, but is is not appropriate for the consultants to not mention this in its evaluation of Peoples with its existing infrastructure. Will the evaluation of Peoples be modified? |
| 7-28 | Re State DWR Water Desal Task Force Findings: "One of the primary findings was that <u>economically</u> and environmentally acceptable desalination should be considered as part of a balanced water portfolio to help meet California's existing and future water supply and environmental needs." | Numerous mentions of "feasibility" and "economically acceptable" are made, but the definitions are missing. Surely the cost and risk factors are important. Why does this DEIR fail to mention the second track for dealing with costs and risks?. Continuous mentioning of these phrases glosses over the separate and critically important cost side of "feasibility" and "economically acceptable." Will there be a distinct narrative in the FEIR on the cost and risk track for CPUC consideration? |
| -29 | "...Desalination Feasibility Study for the Monterey Region (AMBAG, 2006). The purpose of the <u>Feasibility</u> Study was to investigate the environmental, <u>economic</u>, and social impacts of seawater desalination project implementation..." "Subsurface intakes should be used where they are found to be feasible and beneficial." | Again, the economic feasibility is identified. Will the FEIR specify what economic factors are considered appropriate? |
| 7-29 | **7.6.2 INTAKE OPTIONS**<br>General | What will be included in the FEIR if any of the two competing desal proposals initiate an NOP before this DEIR is finalized? |
| 7-84 | **7.8.1 CONCLUSIONS RE INTAKE OPTIONS** | |
| -85 | "...the CCC, Monterey Bay National Marine Sanctuary, SWRCB, and other resources agencies will not consider permitting an open-water intake unless a subsurface intake has been deemed infeasible or would result in greater environmental impacts." | The issue of feasibility, or infeasibility, is not defined. The Settlement Agreement leaves it up to Cal Am to determine feasibility. (Section 5.3 states "<u>**As used in this paragraph, whether a source water project or program is feasible shall be**</u> |

| | | |
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| | | **determined by California American Water.")** With all the research and comparisons, isn't it appropriate to define, or suggest a definition, for feasibility or infeasibility? Will the FEIR contain such suggestions? Will the FEIR address feasibility factors? Will the CPUC have a role in reviewing 'feasibility factors"/ |
| 7-184 | 7.11.1.2 No Project Alternative 2 | The following questions are based on comments from the narrative, and are not directly related to the alternative. The comments in the DEIR are the focus here. |
| -192 | Re Non revenue water: "...Cal Am's annual reports to the CPUC of district water system operations for 2012 and 2013 (Cal Am 2014b, 2014c) show that non-revenue water represented 6 percent and 11 percent of system production, respectively." | This is a significant difference in only one year. Is this a trend? Was there an analysis of a trend line? This is noticeable enough that it deserves a comment on future. Projections or assumptions. Will it increase, or remain at about 11%. Or what? Will the FEIR address this? |
| "" | "Assuming for this analysis that additional system improvements could reduce non-revenue water losses by an additional 2 percent, such improvements would result in additional savings of about 265 afy based on the existing average annual demand of 13,291 afy. Further investigation would be needed before such savings could reliably be quantified and assumed as an offset of estimated demand." | What is the basis for assuming the losses will be reduced? What studies have been relied on? Will the FEIR demand further investigation? Will there be monitoring by the CPUC? Will the FEIR recommend such investigation? |
| -195 | "Rule 166 establishes a water use reduction goal of 35 to 49 percent in each user category (i.e., residential single-family and multi-family, commercial, industrial, public authority, golf course, other use, non-revenue metered uses, and reclaimed water users)." | Are there any backup references that non revenue water will be included in such restrictions? Will Cal Am get a free ride on its own losses, or will this loss be a target of attention? Will the FEIR contain a recommendation on this? |
| 7.11.2.1 Alternative 1, page 7-199 | Potrero Road subsurface intakes described to be inadequate. | Has some form of open ocean intake been considered here? It is an option. This DEIR focuses almost exclusively of subsurface intakes. SWRCB asks for a feasibility analysis of subsurface intakes. Every contingency plan of Cal Am calls for a subsurface option. Did ESA consider seriously an open ocean option, in the event subsurface options proved undesirable? ? Will the FEIR contain comments on this |

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| | | option? |
| No # | Peoples Desal at Moss Landing | Peoples Desal at Moss Landing just announced its schedule for an NOP, indicating it has officially begun. Will the FEIR contain new information on this project? Will it get the attention that Deep Water Desal got as an alternative in the DEIR? Will ESA explain why it is not analyzed if it chooses not to pursue these questions? |
| Appendix | **E1. Test Slant Well Groundwater Modeling and Analysis - CEMEX Active Mining Area** | Did Cal Am inform ESA or the Energy Division of CPUC that Williams had patents on slant wells? When, how and to whom? Will this be disclosed publicly? |
| | This entire section is the product of Dennis Williams, President of Geoscience. Recent research has revealed that previously undisclosed by any of the parties, nor Geoscience itself, that certain slant well patents are held personally be Dennis Williams. There has been a complete lack of transparency on this point by all parties, Mr Williams, Cal Am, ESA, CCC, staff of CPUC. Such secrecy suggests something to be kept from the public eye. Therefore some potential conflict of interest may be in the works. If it was not revealed to the many parties, then the suspicion is even greater. This must be investigated. . | Will this report be the subject of an internal or external review to determine if any bias is present in this report that supports slant wells? Was it common knowledge that such slant well patents were owned by Williams at the time he was retained to conduct modeling or other work in support of slant wells? Has it been reviewed with the point of view to look for a possible prejudice? What office will make such a review? |
| Appendix | **E2. Monterey Peninsula Water Supply Project Groundwater Modeling and Analysis** | Same questions from E.1. comments |

Attachment 2 to PCWN letter of 6/30/15 on DEIR

US008056629B2

ATTACHMENT 2 to PCWN comments on DEIR dated 6/30/15

(12) **United States Patent**
**Williams**

(10) **Patent No.: US 8,056,629 B2**
(45) **Date of Patent: Nov. 15, 2011**

(54) **SLANT WELL DESALINATION FEEDWATER SUPPLY SYSTEM AND METHOD FOR CONSTRUCTING SAME**

(75) Inventor: **Dennis E. Williams**, Altadena, CA (US)

(73) Assignee: **GEOSCIENCE Support Services, Inc.**, La Verne, CA (US)

( * ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **12/748,886**

(22) Filed: **Mar. 29, 2010**

(65) **Prior Publication Data**

US 2011/0162850 A1 Jul. 7, 2011

**Related U.S. Application Data**

(60) Provisional application No. 61/293,134, filed on Jan. 7, 2010.

(51) **Int. Cl.**

| | |
|---|---|
| *E21B 43/10* | (2006.01) |
| *E21B 43/04* | (2006.01) |
| *E02B 11/00* | (2006.01) |

(52) **U.S. Cl.** ......... **166/278**; 166/369; 166/51; 166/54.1; 166/105.1; 405/43; 405/47; 405/48; 405/50

(58) **Field of Classification Search** ................. 166/278, 166/369, 374, 51, 54.1, 74, 105.1; 405/43, 405/47, 48, 50
See application file for complete search history.

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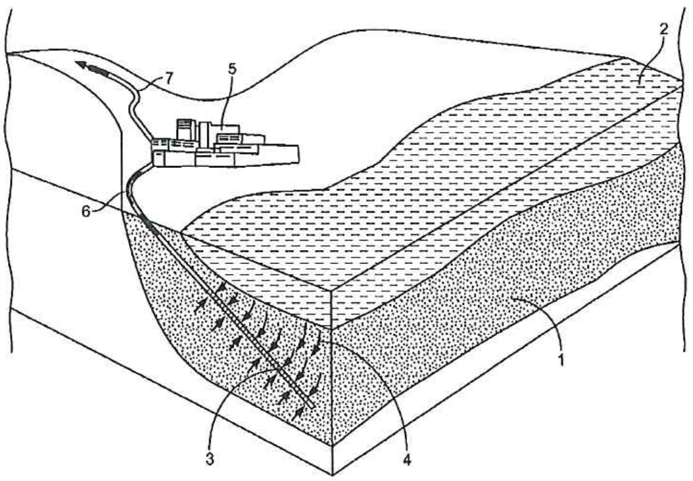
*Primary Examiner* — Jennifer H Gay
(74) *Attorney, Agent, or Firm* — Sheppard, Mullin, Richter & Hampton LLP

(57) **ABSTRACT**

A system is disclosed for supplying water to a desalination plant from a subsurface feedwater supply using one or more slant wells. A method is disclosed for constructing a slant well feedwater supply system for supplying water from a subsurface feedwater supply. A system of angled wells (slant wells) is constructed. The slant wells obtain a desalination feedwater supply from permeable aquifer systems near and/or beneath a saline water source (i.e., an ocean, sea, or salty inland lake). The slant wells induce recharge of the aquifer system through the floor of the ocean, sea, or inland lake due to the hydraulic head difference between the slant well pumping level and the level of the ocean, sea, or lake. As the supply source is relatively constant, the water supply to such a slant well system generally provides a long-term, sustainable water source for a desalination plant.

**46 Claims, 23 Drawing Sheets**



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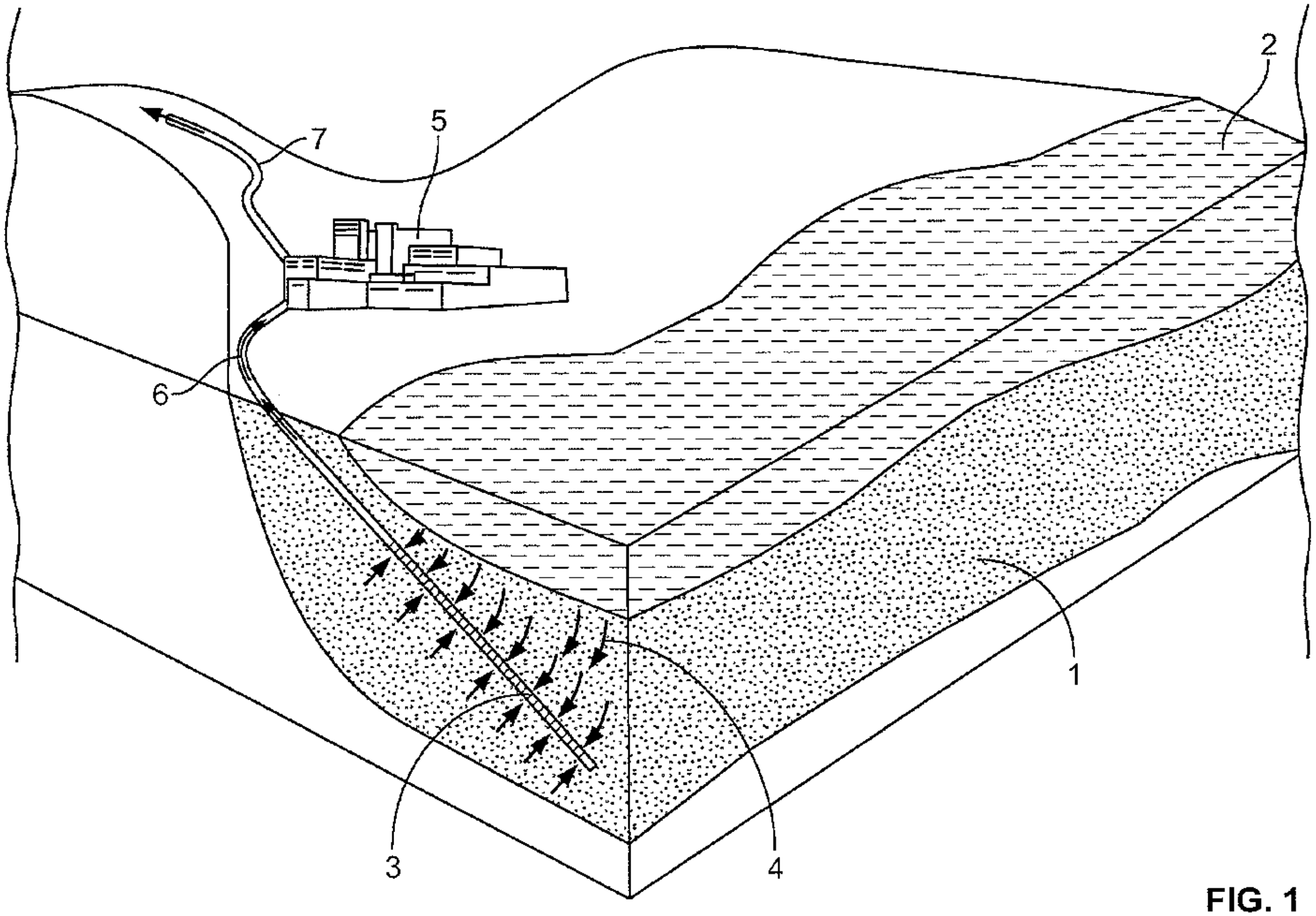

FIG. 1

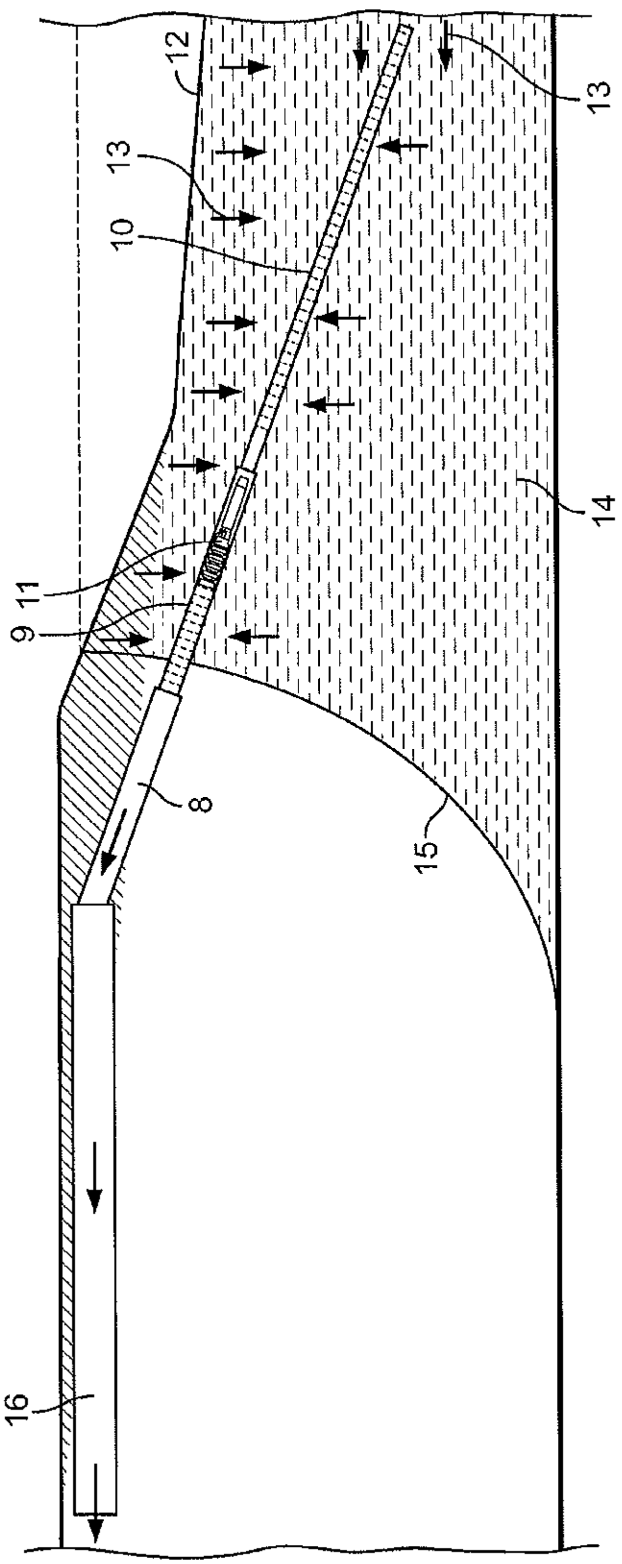

FIG. 2

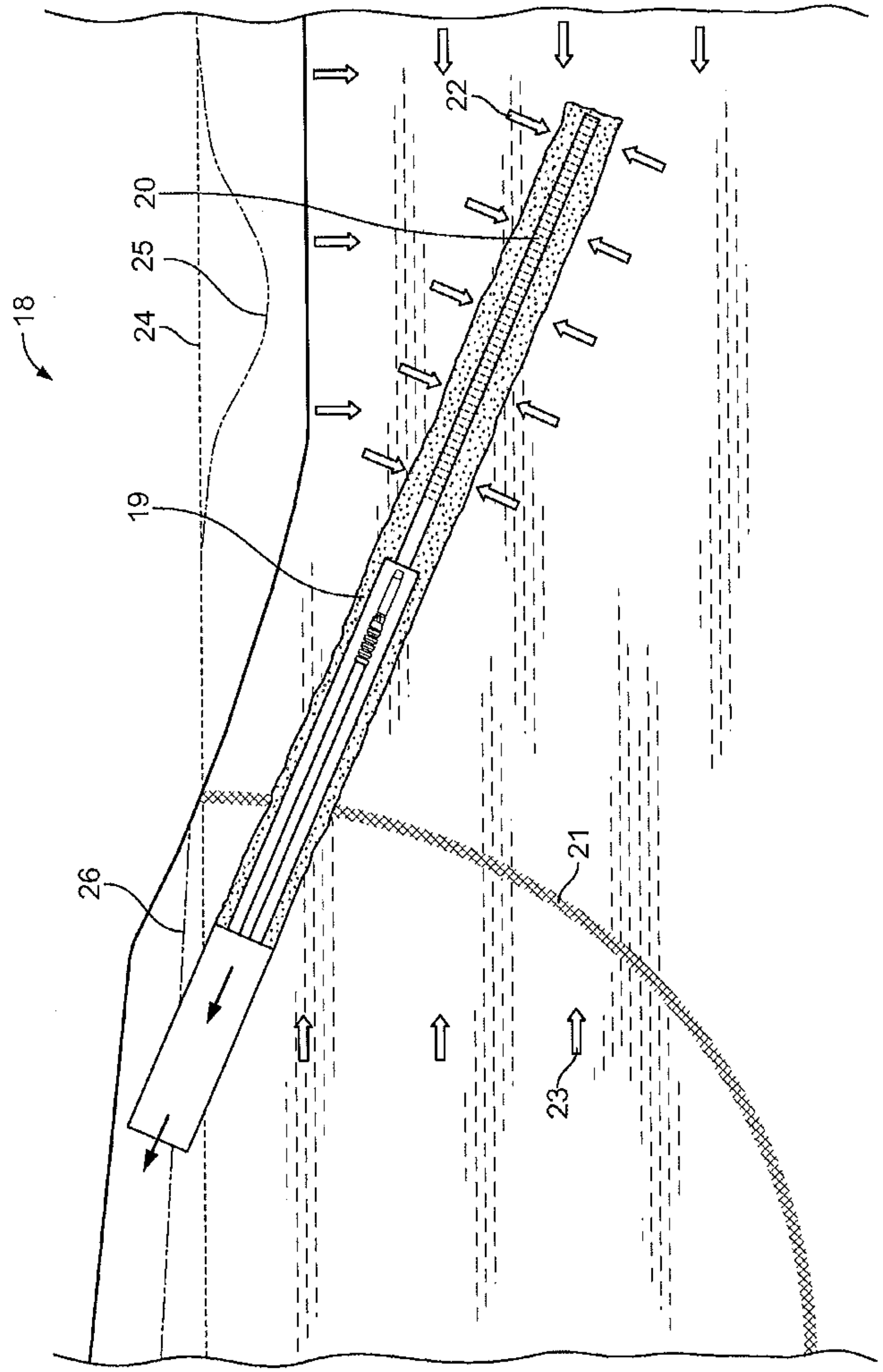

FIG. 3

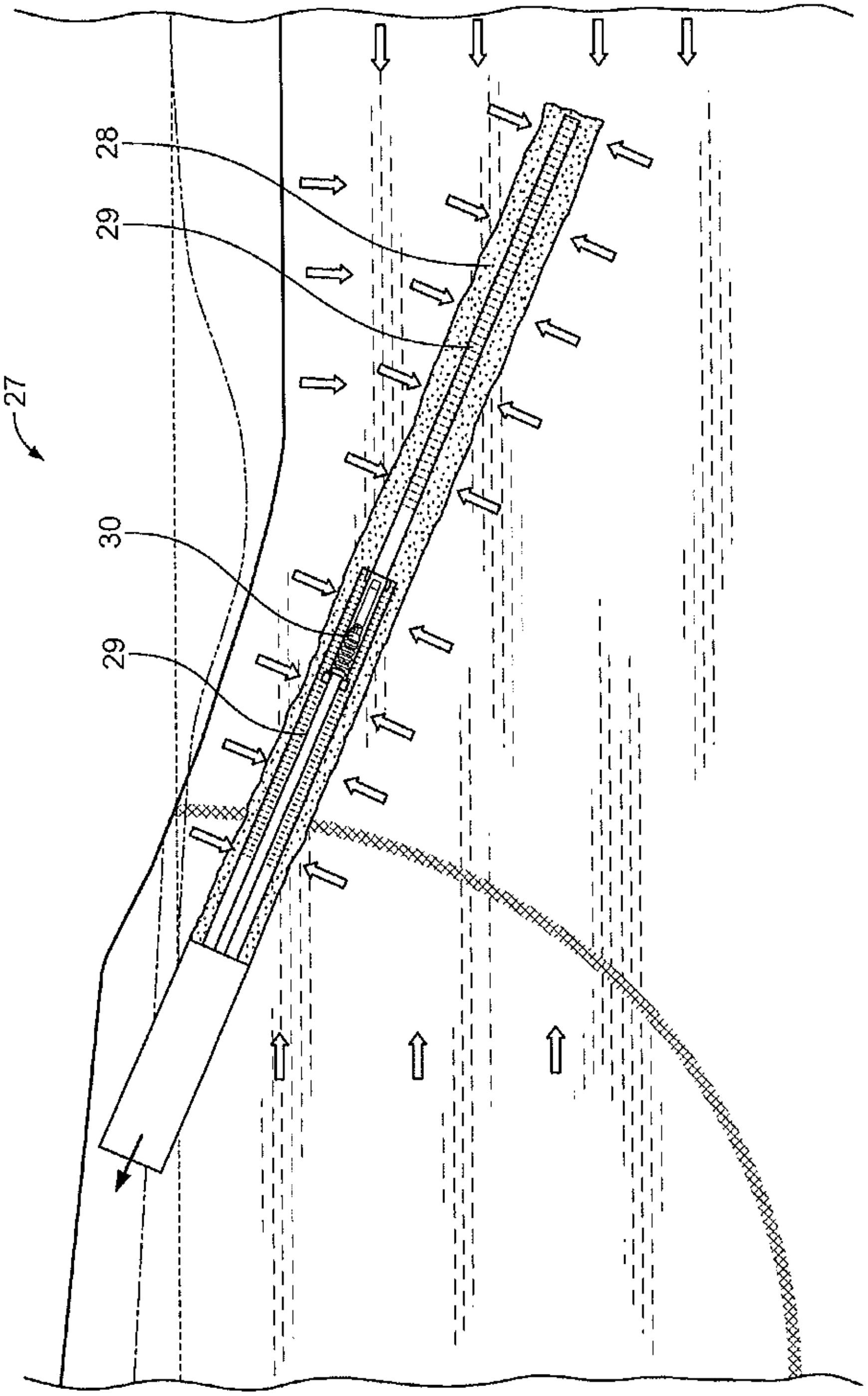

FIG. 4

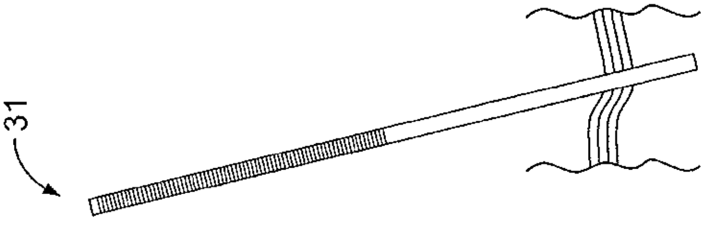

FIG. 5A

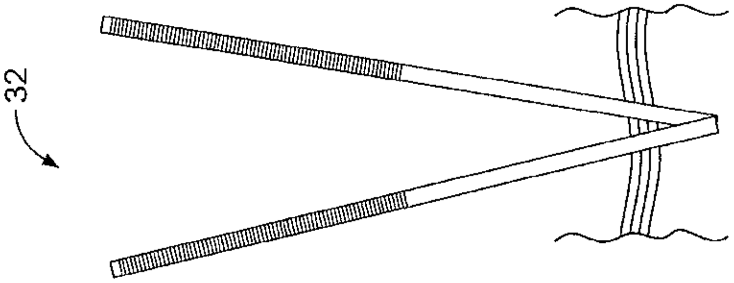

FIG. 5B

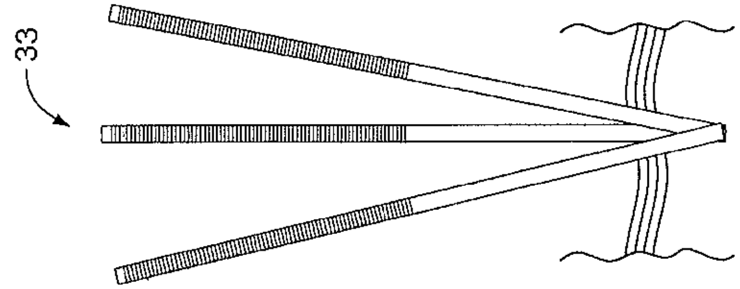

FIG. 5C

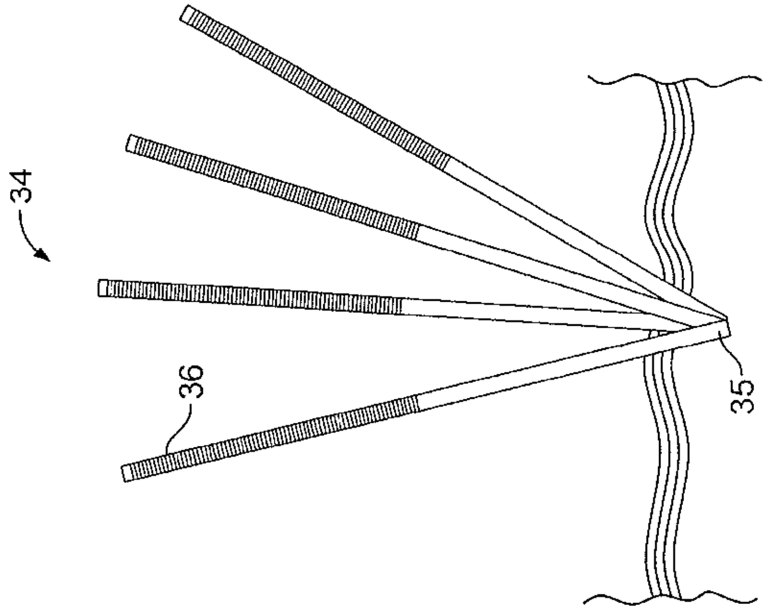

FIG. 5D

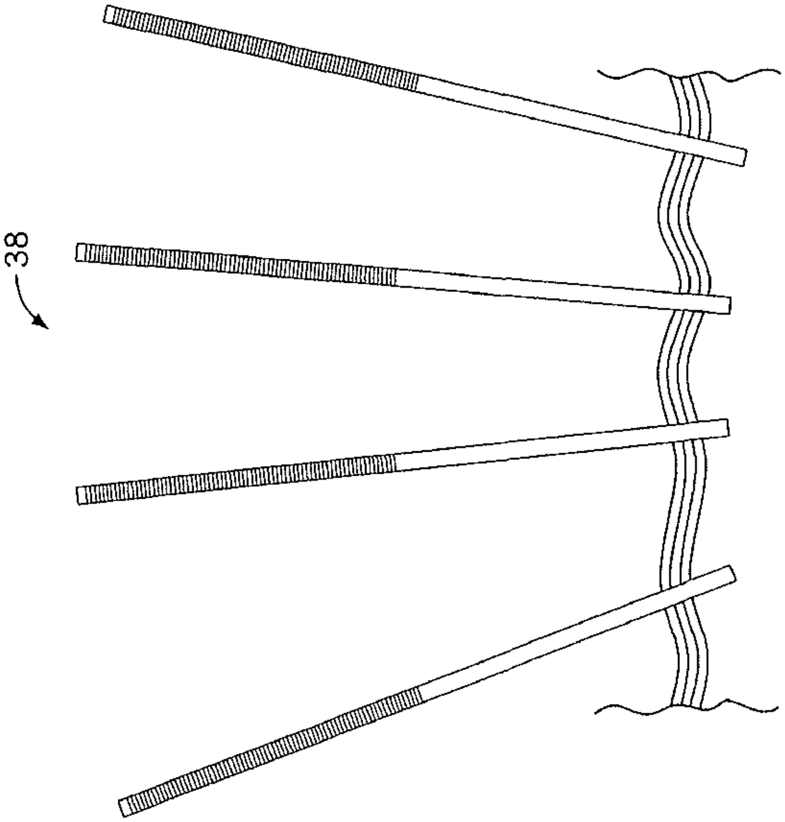

FIG. 6B

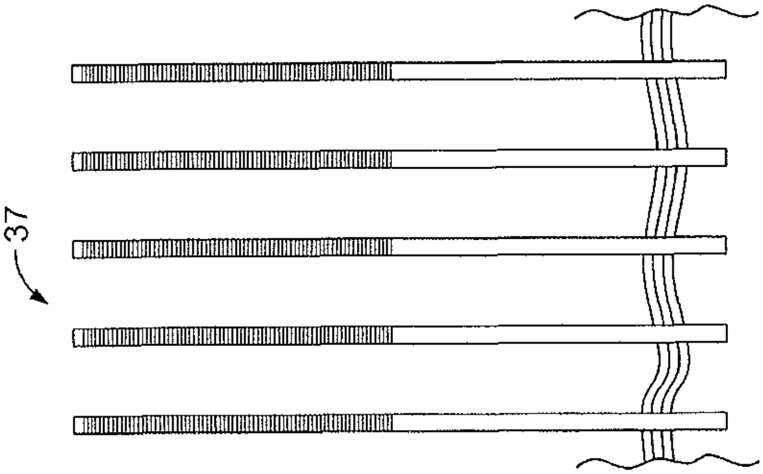

FIG. 6A

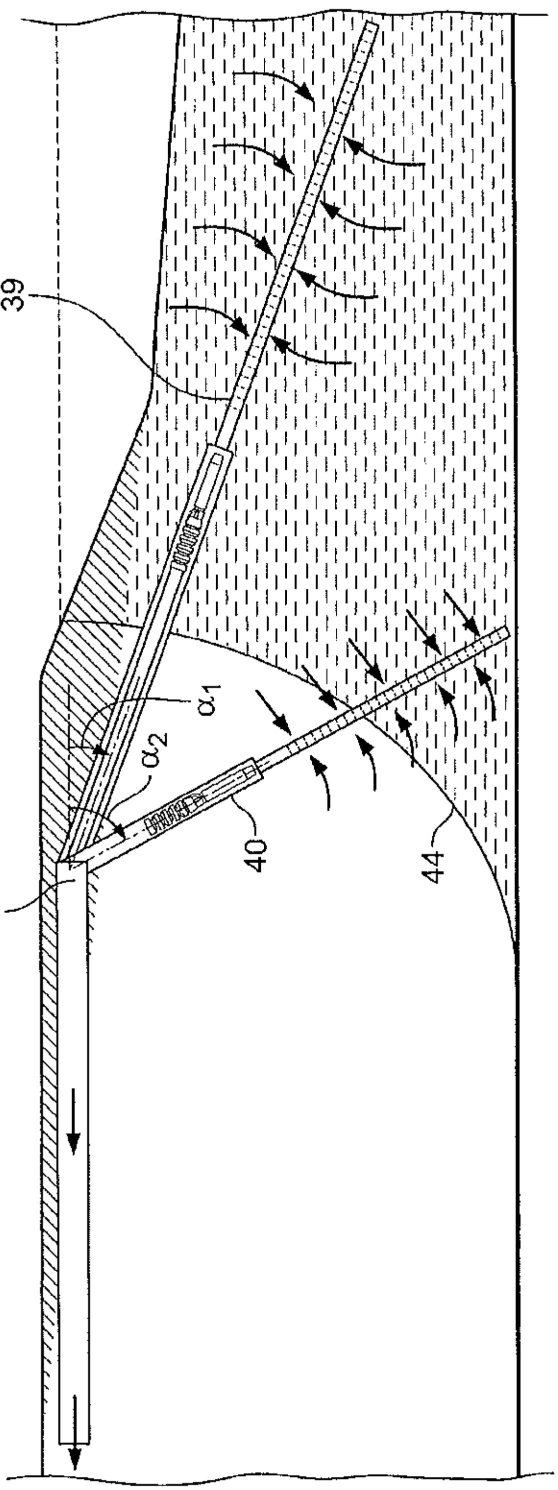

FIG. 7

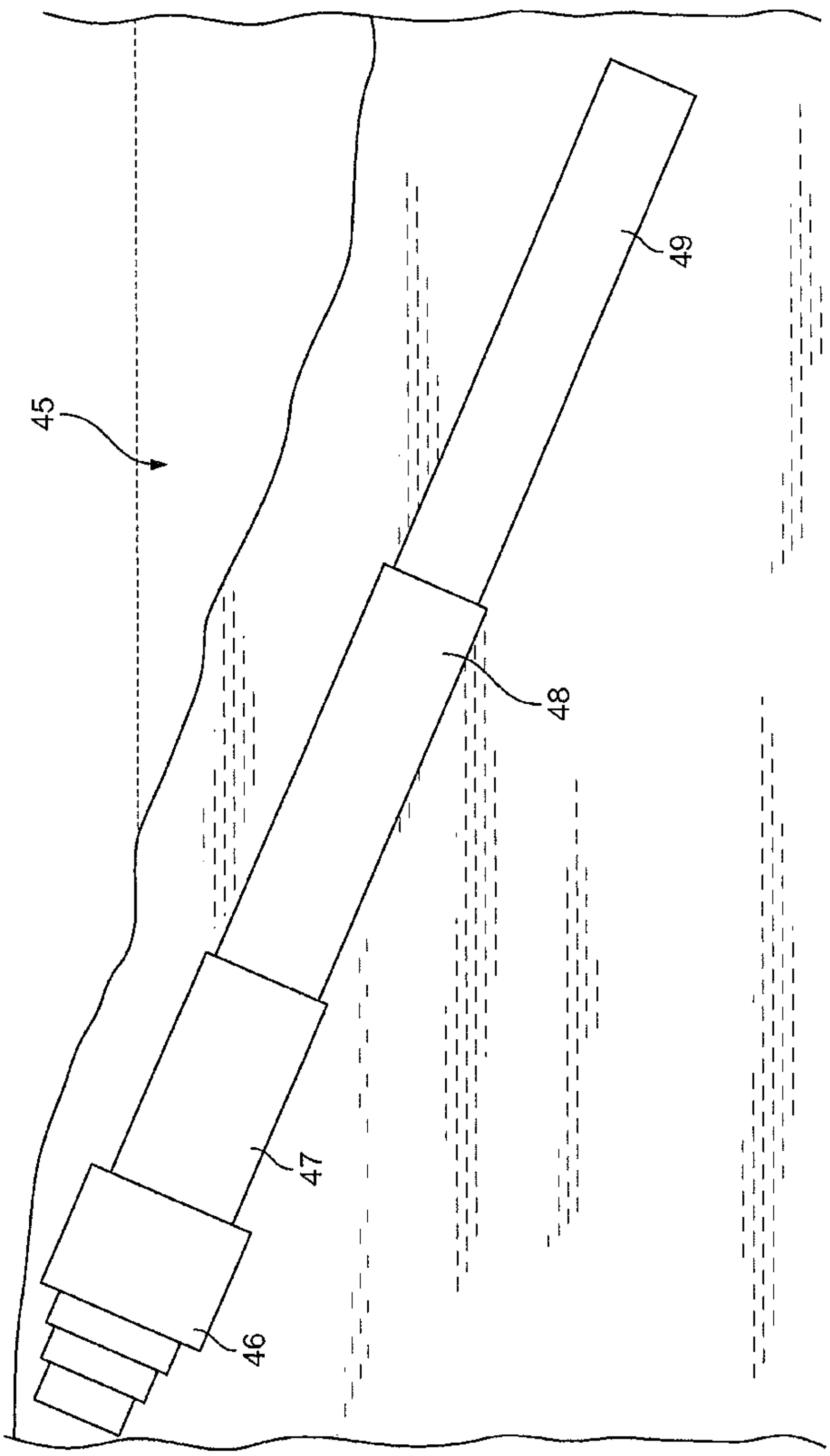

FIG. 8

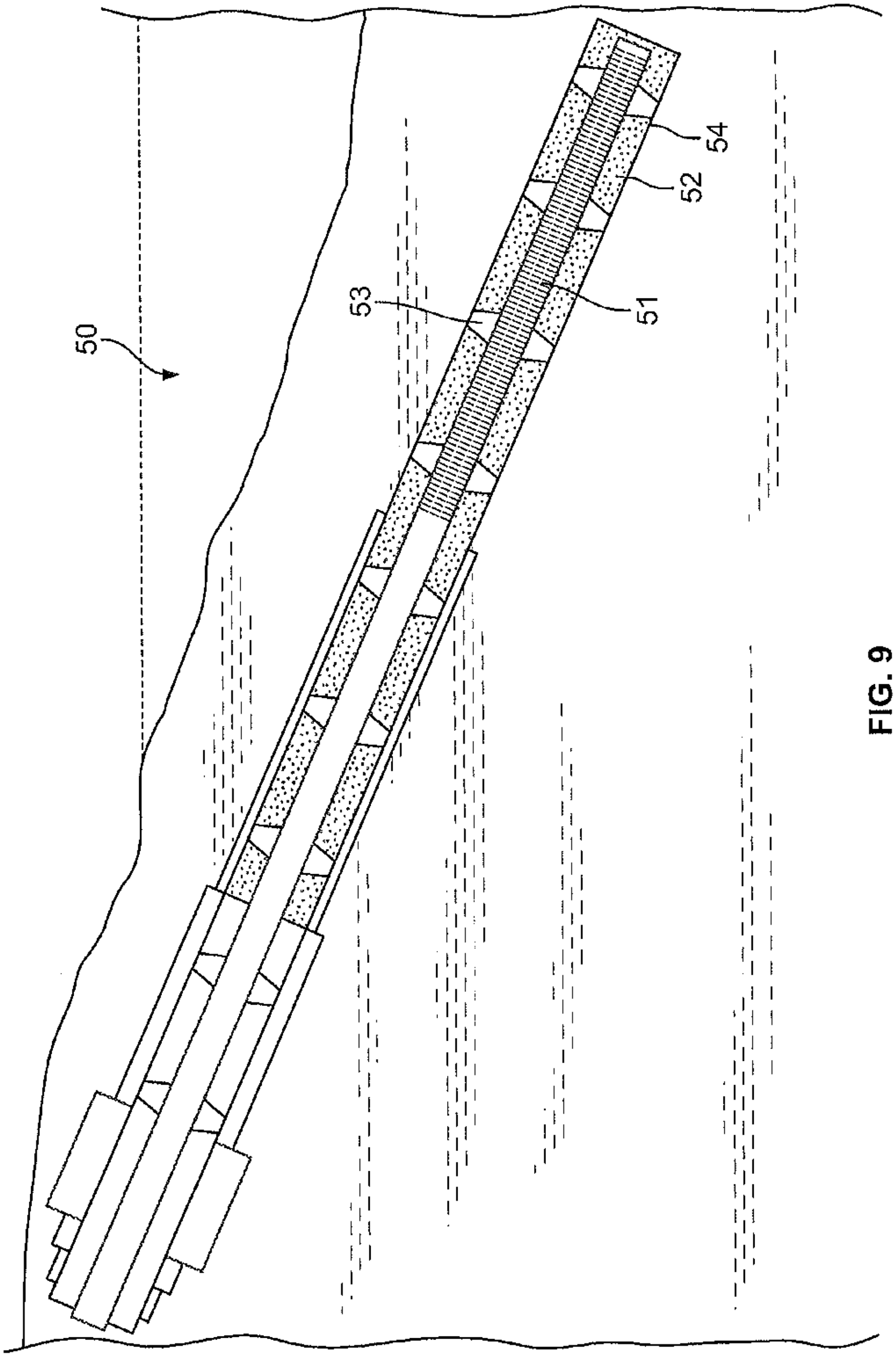

FIG. 9

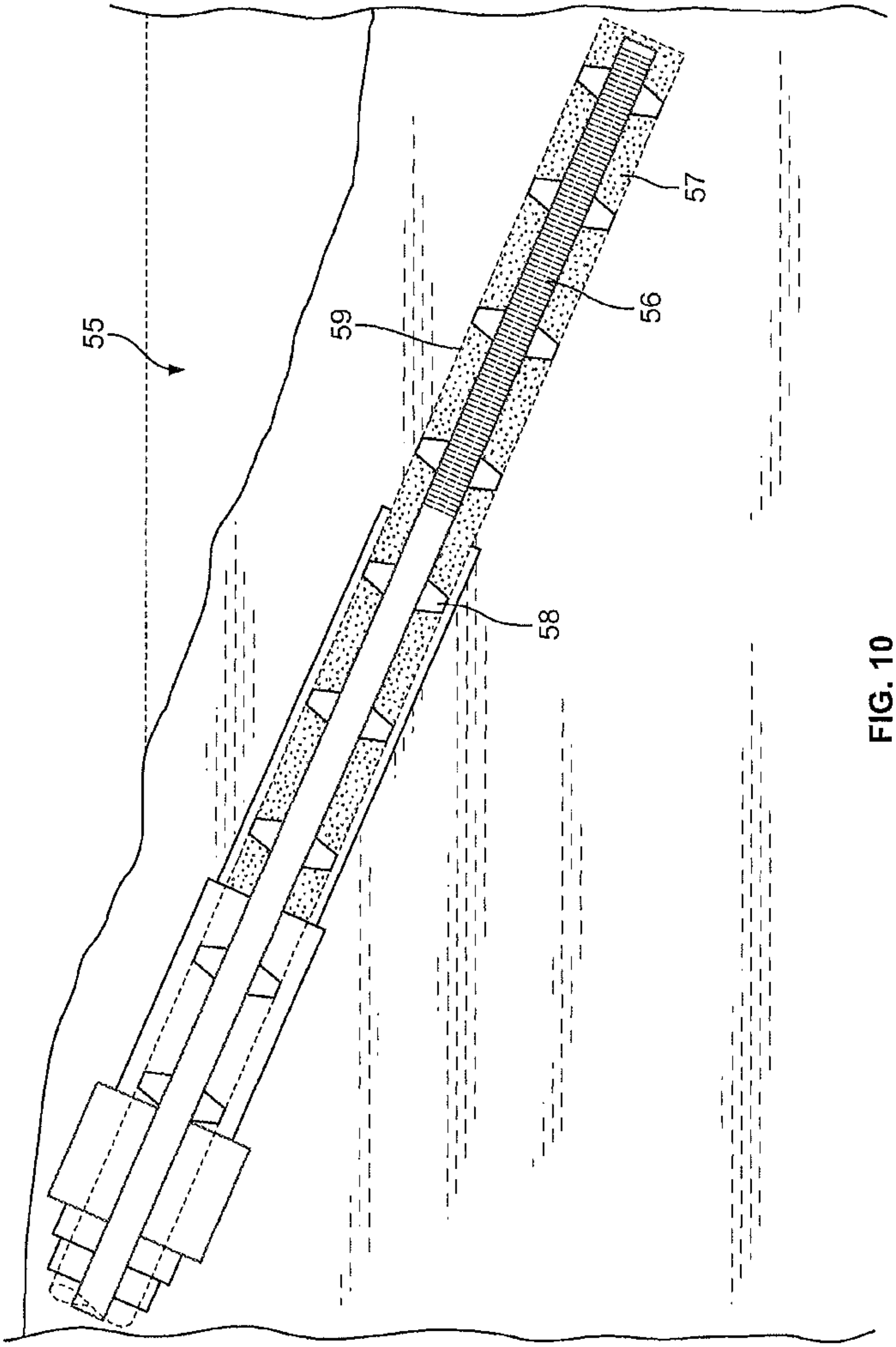

FIG. 10

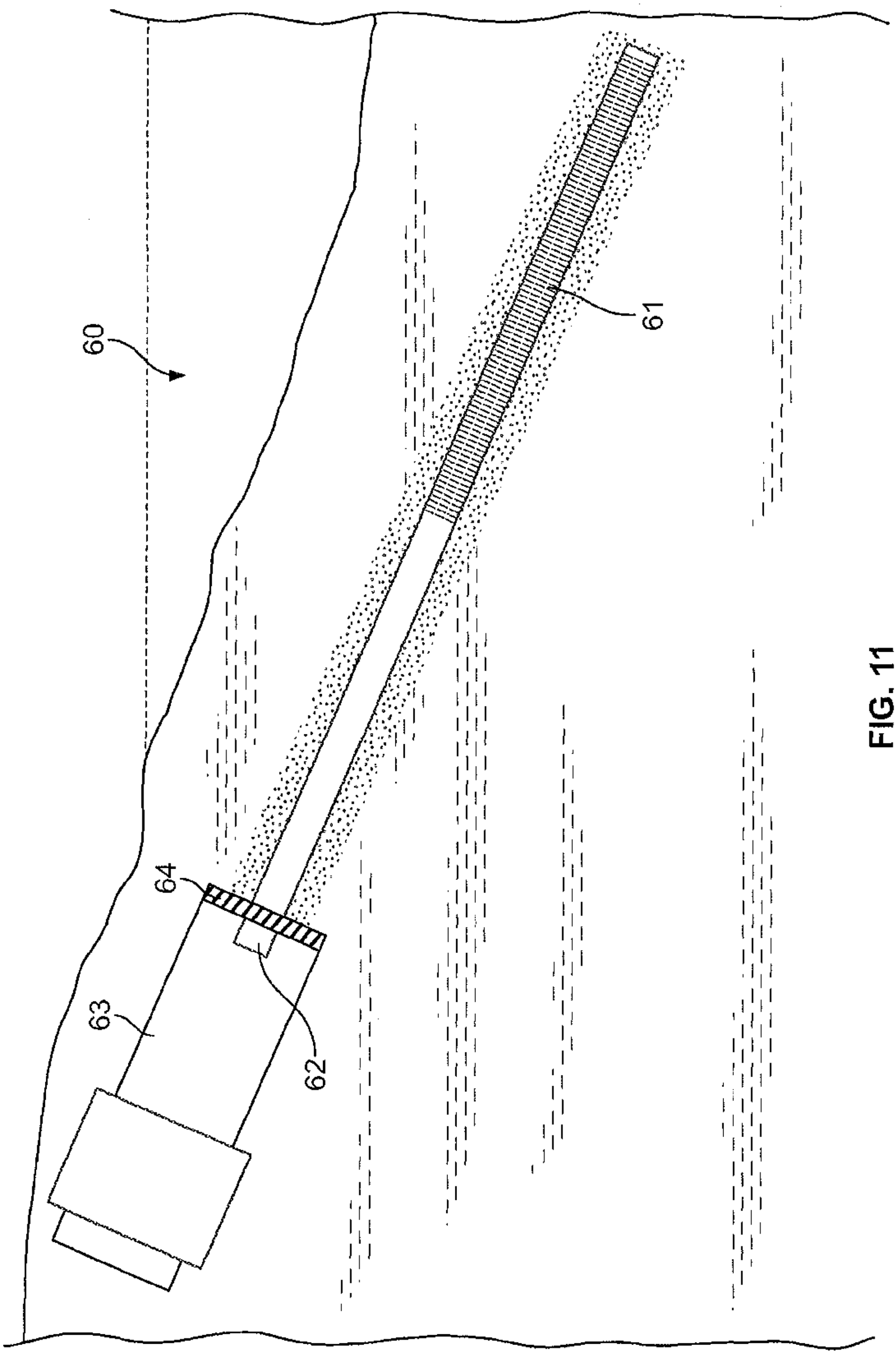

FIG. 11

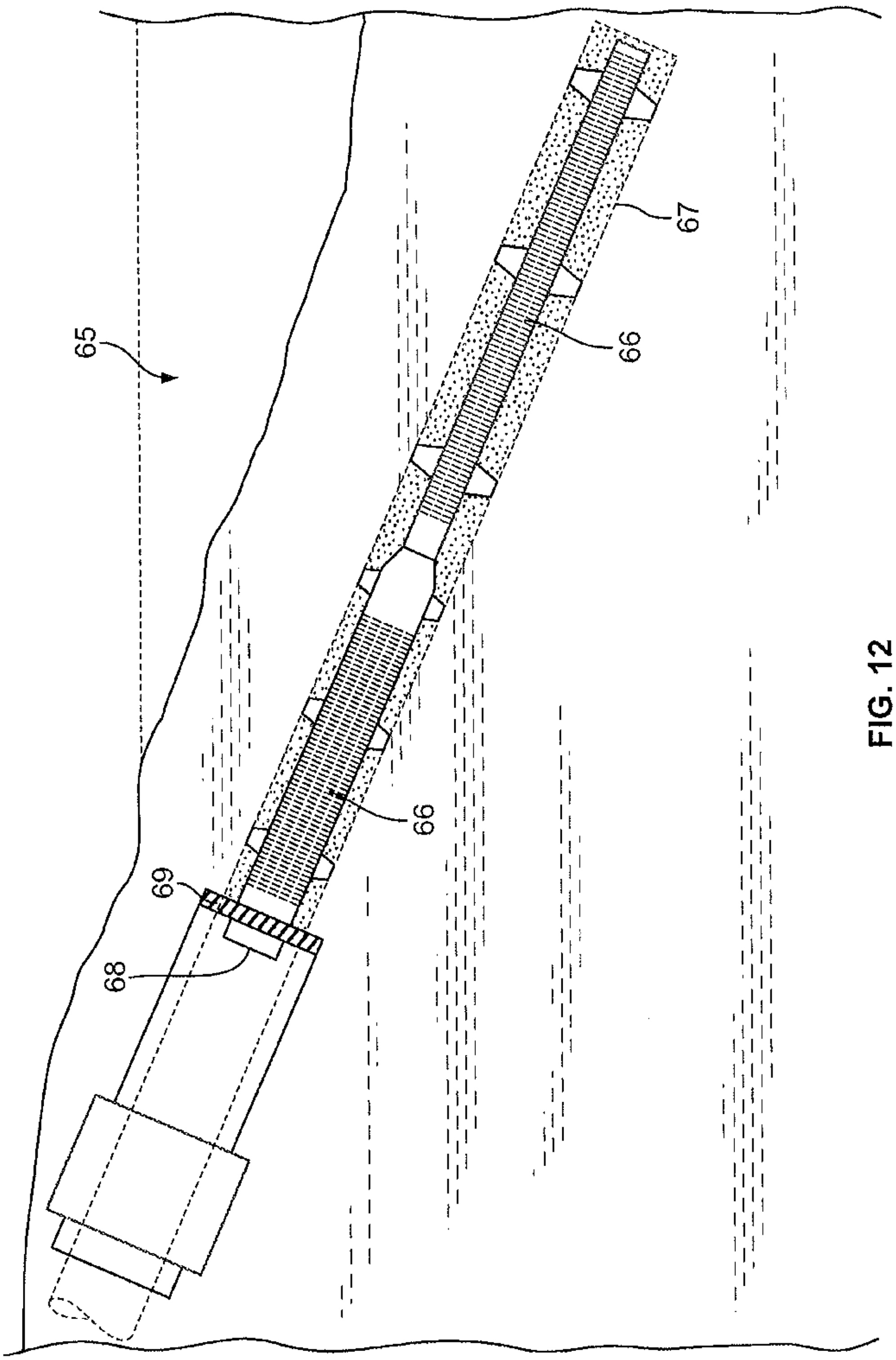

FIG. 12
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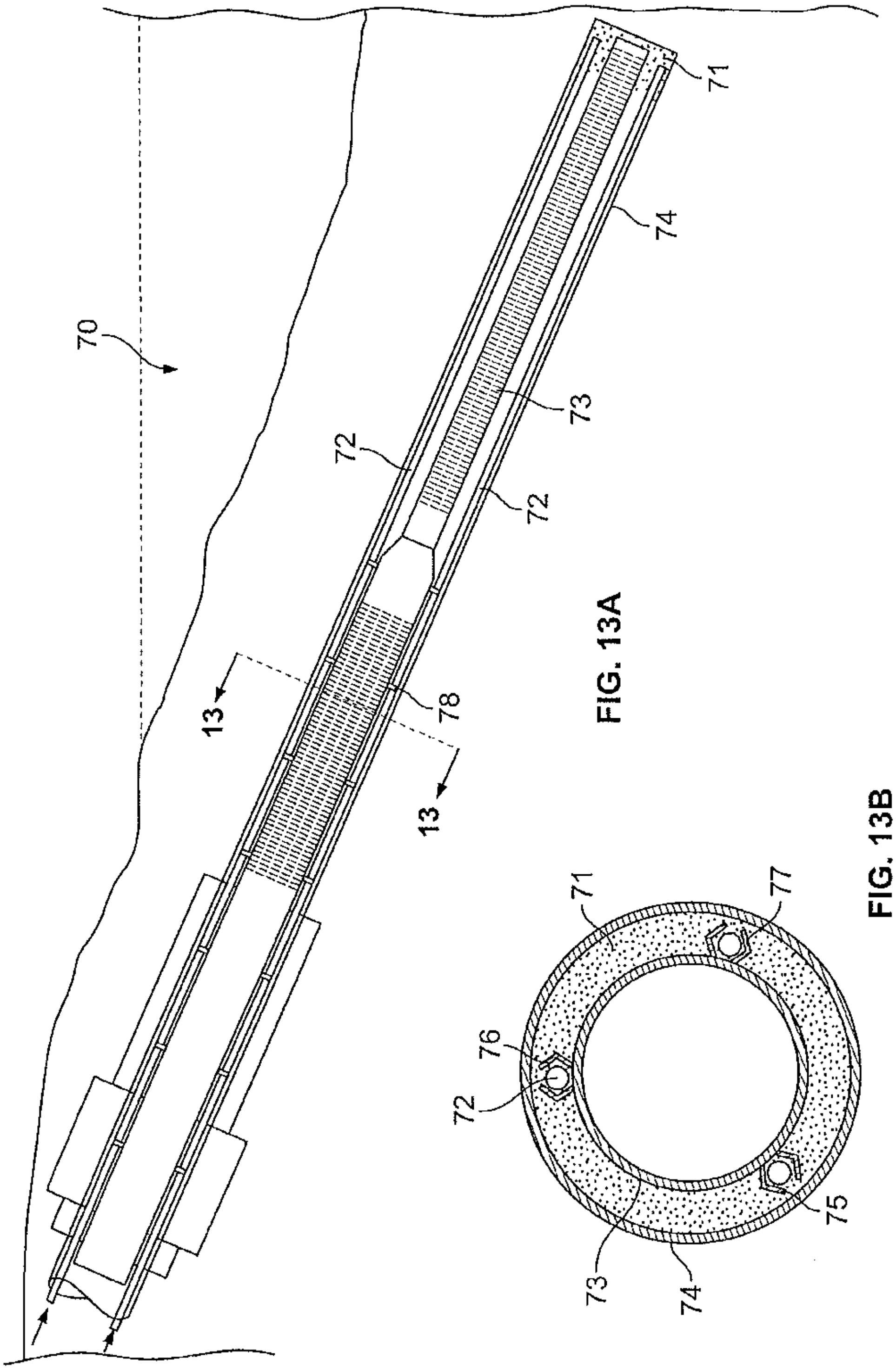

FIG. 13A

FIG. 13B

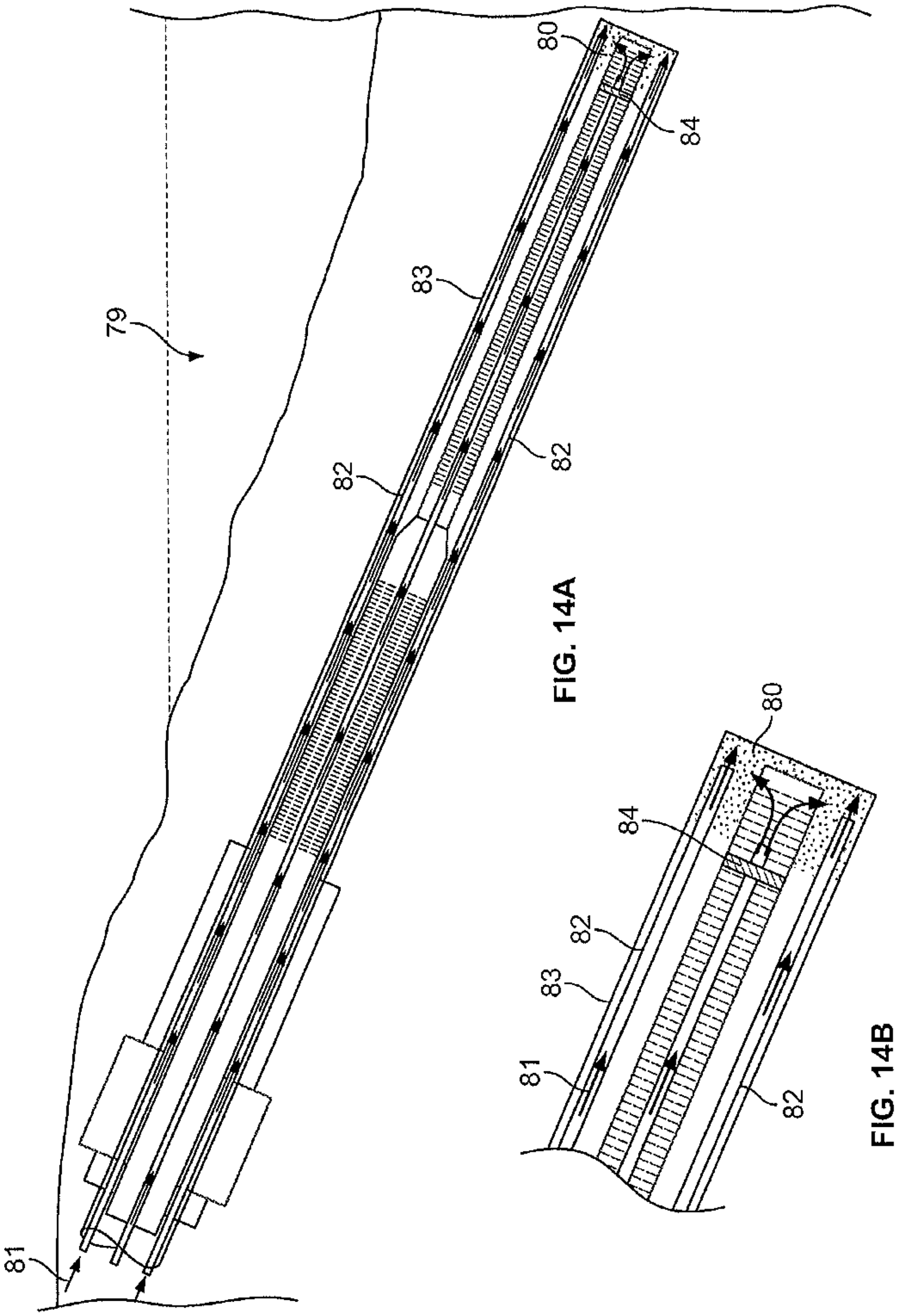

FIG. 14A

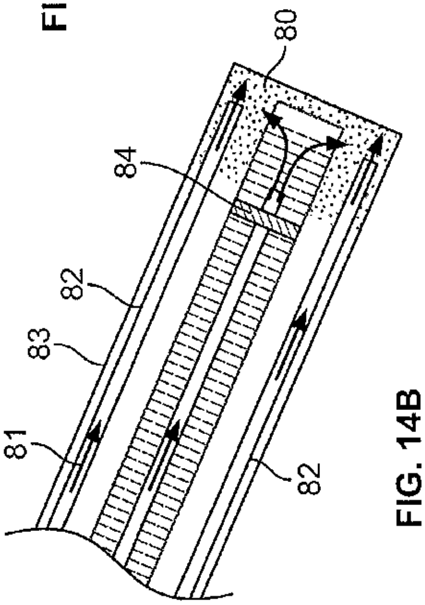

FIG. 14B

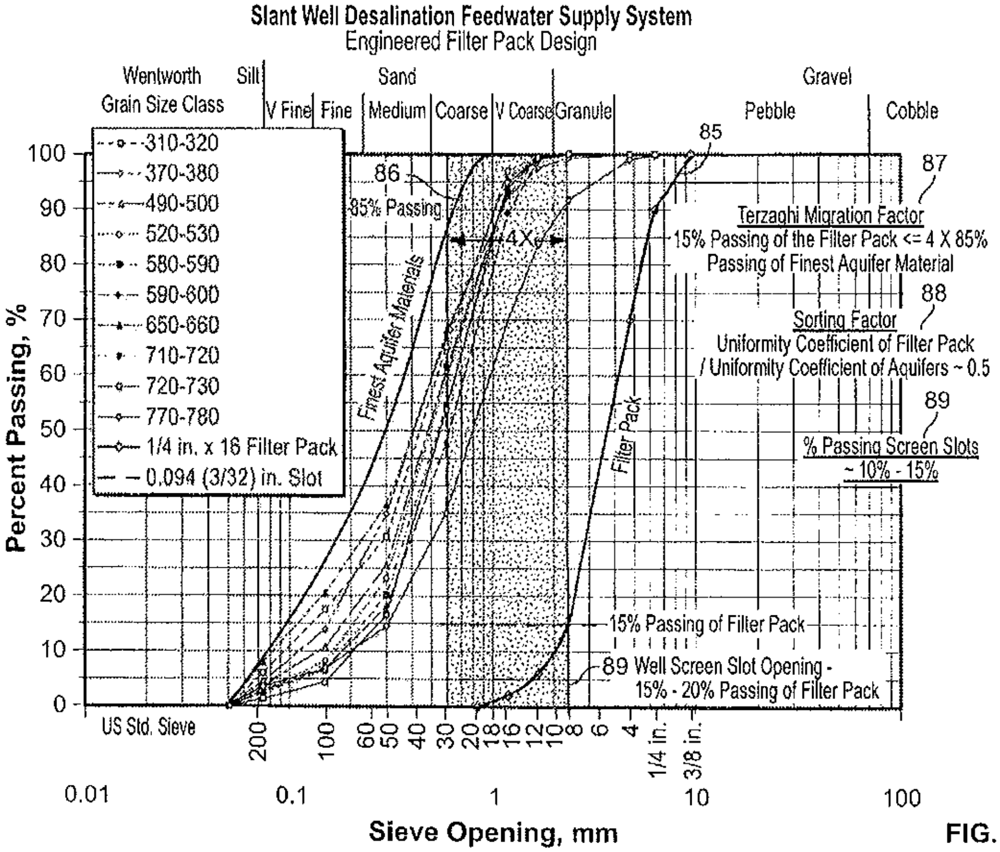
Slant Well Desalination Feedwater Supply System
Engineered Filter Pack Design
Wentworth
Grain Size Class
Silt
Sand
V Fine
Fine
Medium
Coarse
V Coarse
Granule
Gravel
Pebble
Cobble
310-320
370-380
490-500
520-530
580-590
590-600
650-660
710-720
720-730
770-780
1/4 in. x 16 Filter Pack
0.094 (3/32) in. Slot
86
85% Passing
Finest Aquifer Materials
4X
85
87
Terzaghi Migration Factor
15% Passing of the Filter Pack <= 4 X 85%
Passing of Finest Aquifer Material
88
Sorting Factor
Uniformity Coefficient of Filter Pack
/ Uniformity Coefficient of Aquifers ~ 0.5
89
% Passing Screen Slots
~ 10% - 15%
Filter Pack
15% Passing of Filter Pack
89 Well Screen Slot Opening -
15% - 20% Passing of Filter Pack
Percent Passing, %
100
90
80
70
60
50
40
30
20
10
0
US Std. Sieve
200
100
60
50
40
30
20
18
16
12
10
8
6
4
1/4 in.
3/8 in.
0.01
0.1
1
10
100
Sieve Opening, mm

FIG. 15

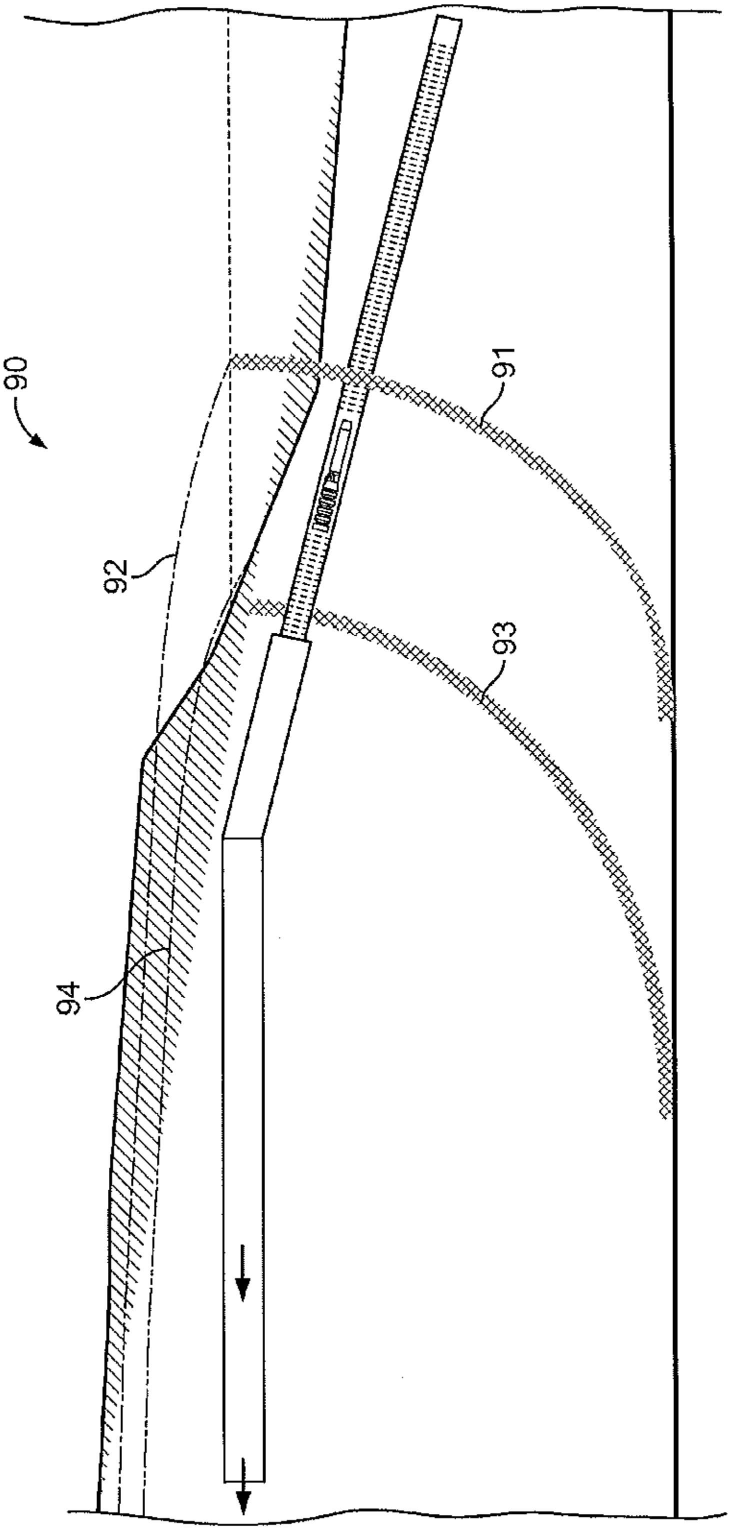

FIG. 16

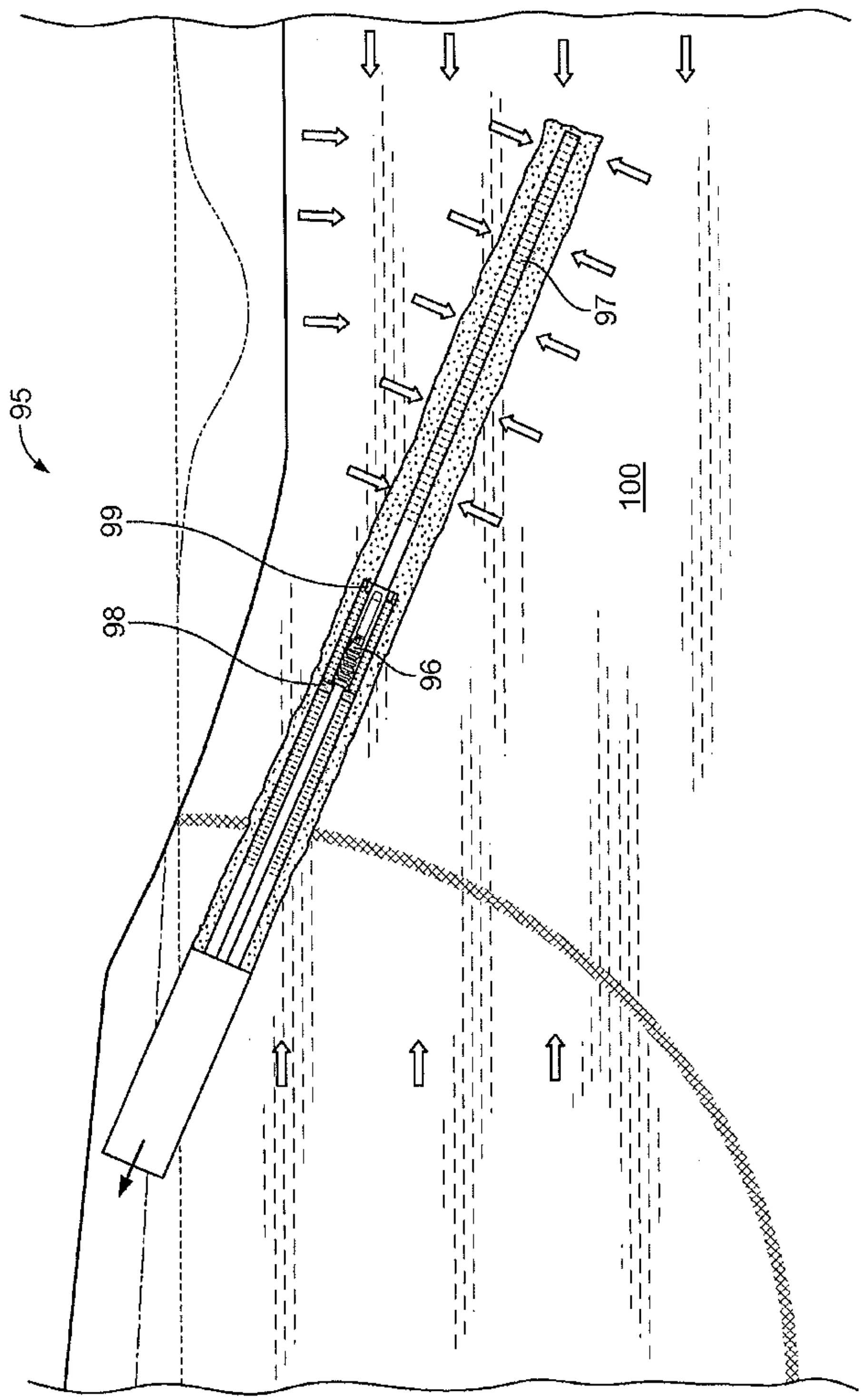

FIG. 17

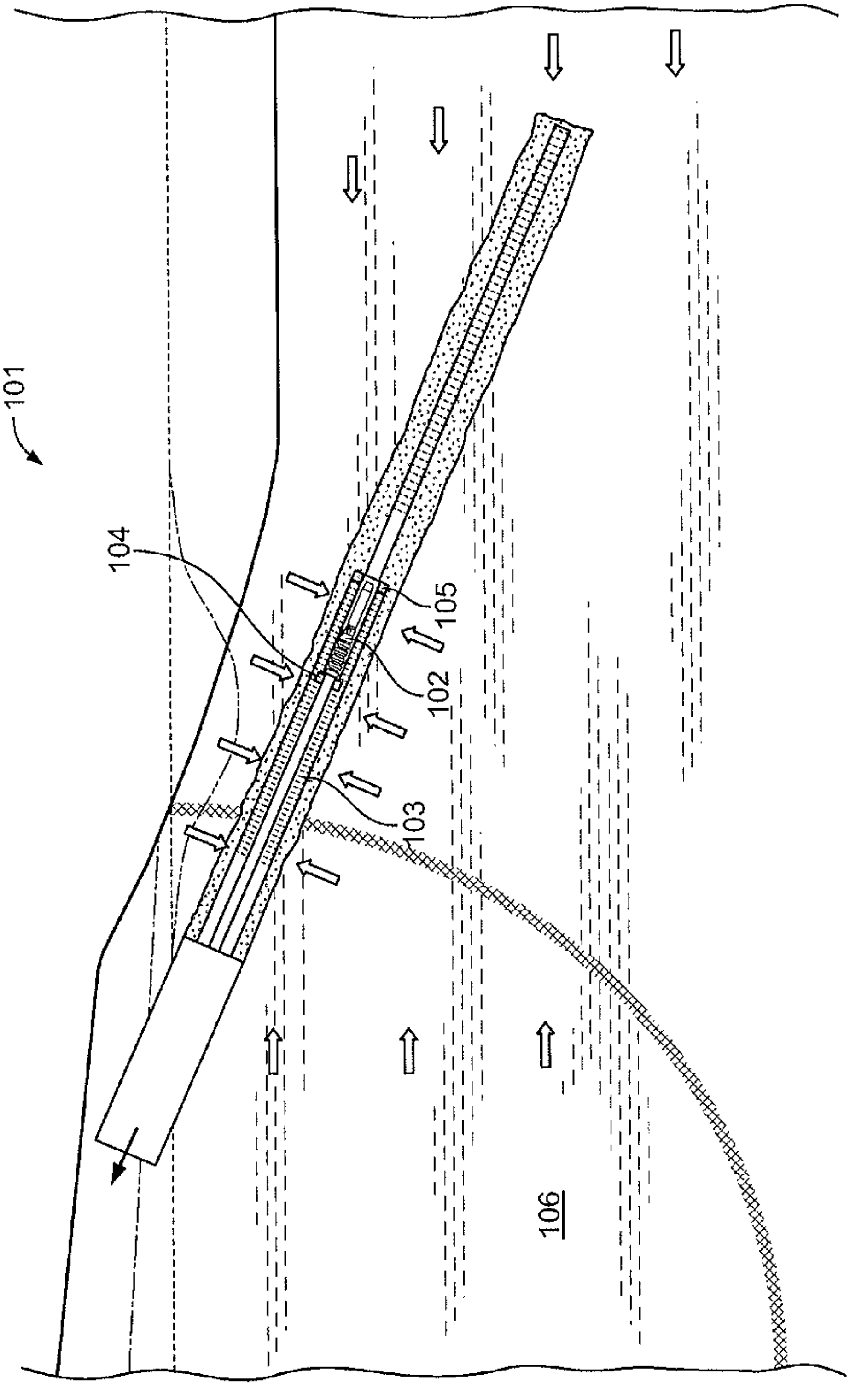

FIG. 18

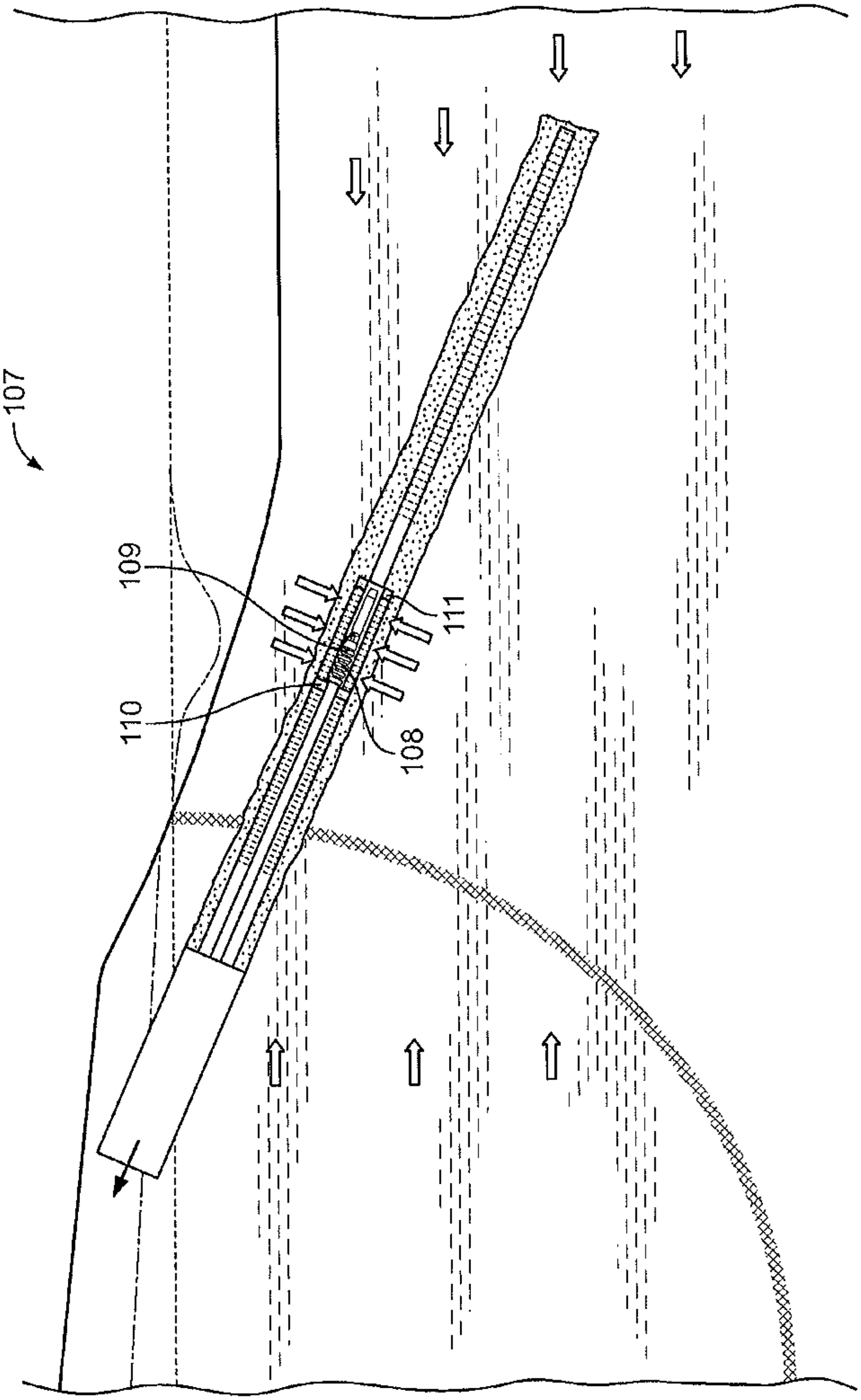

FIG. 19

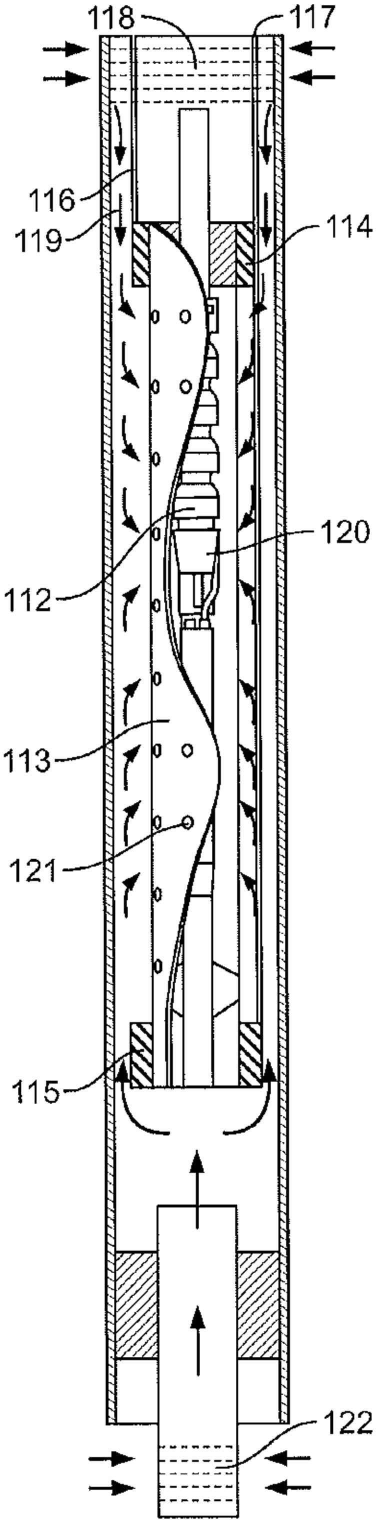

FIG. 20

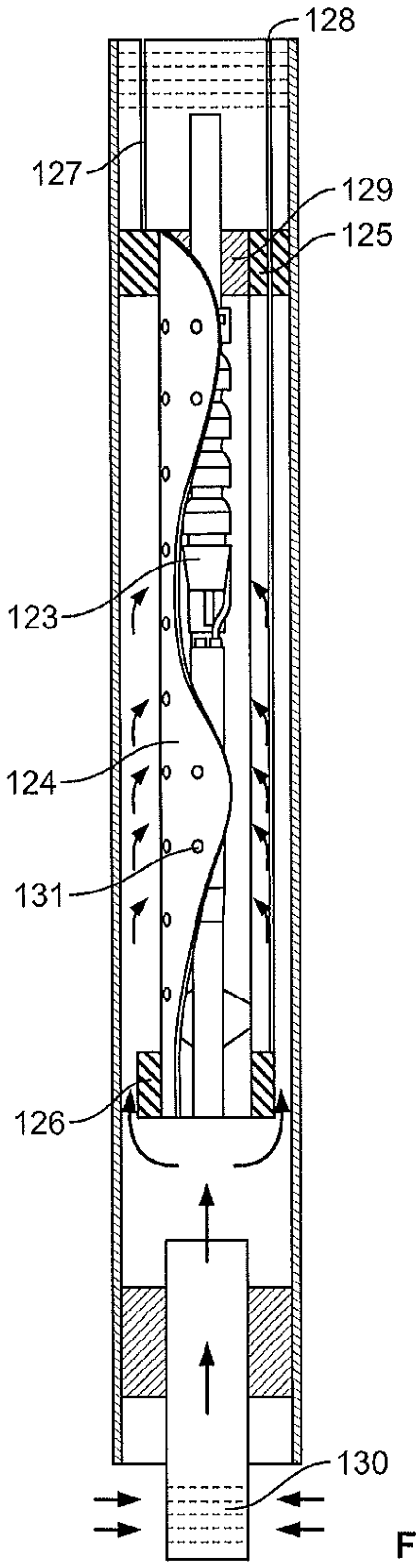

FIG. 21

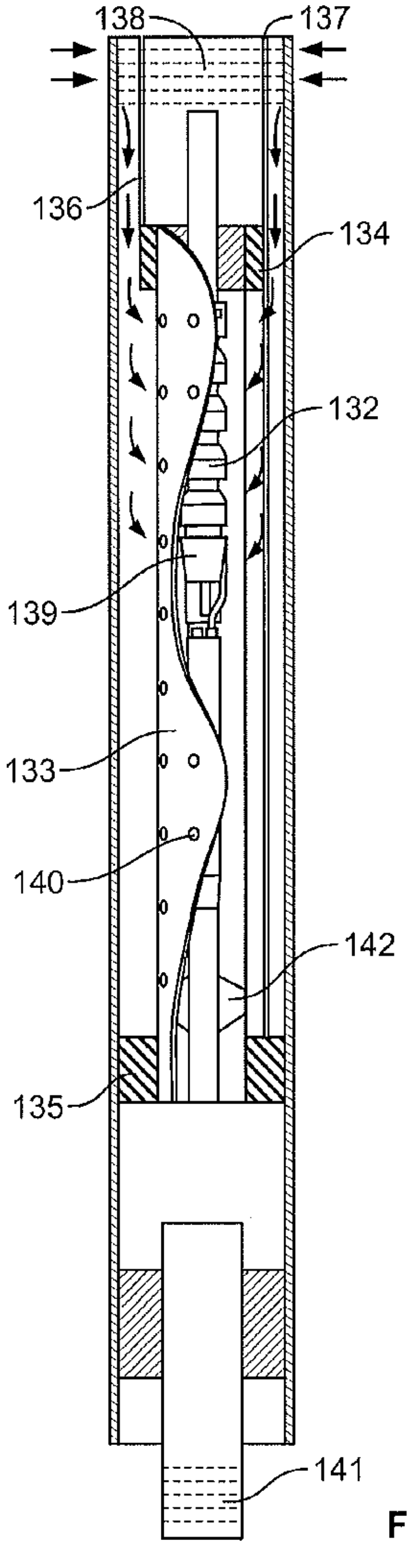

FIG. 22

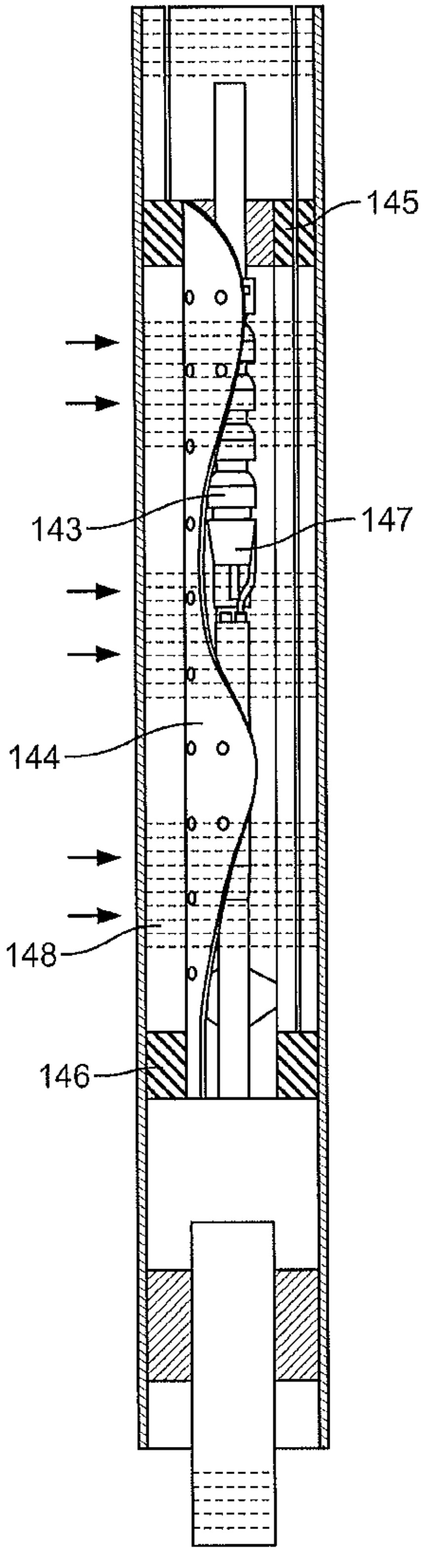

FIG. 23

# SLANT WELL DESALINATION FEEDWATER SUPPLY SYSTEM AND METHOD FOR CONSTRUCTING SAME

## CROSS-REFERENCE TO RELATED APPLICATION

Priority is claimed under 35 U.S.C. §1.19(e) to U.S. Provisional Application No. 61/293,134, filed by Dennis E. Williams on Jan. 7, 2010 and entitled "Slant Well Desalination Feedwater Supply System." This application is incorporated by reference herein.

## FIELD OF THE INVENTION

The invention relates generally to the field of supplying water from subsurface intake systems to desalination plants. More specifically, the invention relates to the construction of slant well systems to supply water from near-shore or subsea aquifers to desalination plants.

## BACKGROUND OF THE INVENTION

Water developers in California and other coastal communities throughout the world are increasingly considering seawater desalination as a potential source of water for municipal and industrial supply. Limited ground water supplies in the coastal areas, poor inland ground water quality, and decreasing reliability of imported water have made seawater desalination a viable consideration. Seawater desalination has been made even more viable through more cost-effective and efficient subsurface intake systems and water treatment technologies.

Slant well drilling is included in the practice of drilling non-vertical wells. Non-vertical wells are typically used in the petroleum industry and are also known as horizontally directionally drilled wells (HDD wells). Slant wells are also used in other applications, such as drilling beneath roadways or rivers in order to provide conduits for facilities. Slant well desalination subsurface intake systems present significant advantages over traditional open water desalination plant intakes. These advantages include avoidance of entrainment and impingement impacts to marine life, reduction or elimination of costly reverse osmosis pretreatment, and reduction or elimination of permanent visual impacts. Slant well systems are buried systems (i.e, there are little or no visual impacts on the surface), as the wells and connecting pipelines are typically completed below the land surface.

In the past, slant well technology has not been successfully applied to subsea construction of desalination feedwater supplies, as the well screen slots have become clogged during pumping. Once the well screen slot openings are clogged, it becomes difficult or impossible to continue to pump water. Accordingly, there is a need for a reliable slant well system that is able to supply water from near-shore or subsea aquifers to a desalination plant without becoming clogged with fine-grained materials (e.g., fine sands and silts) over time. There is also a need for a method of constructing such a system—especially at low angles below horizontal in order to minimize impacts to inland fresh water sources. The present invention satisfies these needs and provides further related advantages, especially with regard to regulation of feedwater salinity.

## SUMMARY OF THE INVENTION

The present invention is embodied in a system for supplying water to a desalination plant from a subsurface feedwater supply using one or more slant wells. The present invention is also embodied in a method for constructing a slant well feedwater supply system for supplying water from a subsurface feedwater supply. A system of angled wells (slant wells) is constructed. In one embodiment, the slant wells obtain a desalination feedwater supply from permeable aquifer systems near and/or beneath a saline water source (i.e., an ocean, sea, or salty inland lake). The slant wells induce recharge of the aquifer system through the floor of the ocean, sea, or inland lake due to the hydraulic head difference between the slant well pumping level and the level of the ocean, sea, or lake. As the supply source is relatively constant, the water supply to such a slant well system generally provides a long-term, sustainable water source for a desalination plant. The slant wells may be constructed at angles that vary from zero to ninety degrees below horizontal.

In one embodiment, the systems and methods discussed here are different from other non-vertical well applications in that they include an engineered, artificially filter-packed, angled well designed specifically to produce a high-capacity, low-turbidity desalination plant feedwater supply source from near-shore and offshore subsurface aquifer systems.

In one embodiment of the invention, the slant wells include a unique telescoping set of casings and screens. This design allows for a larger pump house casing near the land surface, with successively smaller casing and screen diameters as the well extends downward. The telescoping casings and screens facilitate extending the well to lineal lengths of 1,000 feet or greater beneath the floor of the saline water body, with angles below horizontal ranging from zero to ninety degrees.

In other, more detailed features of the invention, the slant well feedwater supply system may comprise a single slant well, an array of two or more slant wells, or multiple arrays of two or more slant wells, the location, spacing, and geometric layout of which may vary among feedwater intake sites depending upon the geohydrologic extent (horizontal and vertical) and characteristics of the subsurface aquifer materials, as well as upon the subsurface aquifer system salinity variation.

In another embodiment of the invention, an engineered artificial filter pack is placed around the well screen portions of the slant wells through a multi-step process that includes:

a. Placing the artificial filter pack in the annular space between the well screen and a temporary casing by pumping the filter pack material under pressure through one or more movable tremie pipes;

Placing a movable packer assembly within the bore of the well screen section near the portion of the well where the artificial filter pack is being placed;

c. Pumping water through the center of the well-screen packer assembly so that the water exits the well screen below the packer assembly and travels out of the well screen into the filter pack (water injection through the well-screen packer assembly helps to settle the filter pack, as well as ensure that the filter pack completely surrounds the well screen in the annular space between the well screen and the temporary casing);

d. Slowly withdrawing the tremie pipes and well-screen packer assembly up the screened portion of the well so that the artificial filter pack is placed along the length of the screened portion; and

e. Simultaneously withdrawing the temporary casing surrounding the well screen and filter pack by pulling, rocking and/or vibrating the casing.

Placement of the engineered artificial filter pack around the screened portions of the slant well helps stabilize the subsea aquifer materials and prevent migration of fine sand and silt materials (from subsea aquifers) into the well. This both inhibits the screen portions from becoming clogged and results in a desalination feedwater water quality, as measured by turbidity and silt density indices (a measure of fouling in reverse osmosis desalination systems), that eliminates or minimizes the need for pre-treatment of the water prior to desalination.

In one embodiment, the well screens are centered inside the temporary casings through a system of centralizers or screen centering guides.

The present invention is also embodied in a method of minimizing variations in feedwater salinity, the method comprising providing a plurality of slant wells, each having a different angle below horizontal. Shallower-angled wells tend to produce water having greater salinity, whereas steeper-angled wells tend to produce water having lesser salinity. By varying the amounts of water pumped from shallower-angled wells versus steeper-angled wells, variations in feedwater salinity that occur due to natural variations in the hydrologic cycle can be minimized. Natural variations in the hydrologic cycle (such as wet and dry hydrologic periods) can impact the location of the freshwater-saltwater interface due to variations in fresh water flowing from the land to the ocean, sea, or inland lake.

On one embodiment, multiple well screens are placed in a single slant well to minimize variations in feedwater salinity in that well that occur due to natural variations in the hydrologic cycle. The slant well can be equipped with a submersible pumping system fitted with a dual-packer shroud assembly. Using the dual-packer shroud assembly, the slant well can selectively pump from upper or lower portions of the subsea aquifer, thereby varying feedwater salinity as required to help minimize variations in feedwater salinity due to hydrologic cycles. The dual-packer shroud assembly (DPSA) allows selective production from well screens both above and below the packers (maximum production), well screens above the upper packer only (lower salinity), well screens below the lower packer only salinity), or well screens between the packers (focused salinity).

Embodiments of the present invention include a telescoping slant well feedwater supply system for supplying water from an aquifer. The system comprises a primary well screen for admitting water from the aquifer (the primary well screen oriented along an axis angled below horizontal and having a substantially uniform cross-sectional area); a filter pack substantially surrounding the primary well screen; a pump house casing oriented along the axis, upward of the primary well screen, and having a substantially uniform cross-sectional area; and a submersible pump contained within the pump house casing for pumping water admitted through the primary well screen. The cross-sectional area of the pump house casing is greater than the cross-sectional area of the primary well screen.

In another embodiment, the axis is straight. The system may further comprise a secondary well screen for admitting water from the aquifer, the secondary well screen oriented along the same axis but having a substantially uniform cross-sectional area greater than the cross-sectional area of the primary well screen. The system may additionally comprise a dual-valve assembly contained within the pump house casing. The dual-valve assembly may comprise a first valve for regulating the flow of water from the primary well screen to the submersible pump, and a second valve for regulating the flow of water from the secondary well screen to the submersible pump. In one embodiment, the first valve is a first pneumatic packer, and the second valve is a second pneumatic packer. The system may further comprise a first air line configured to extend from an air pump to the first pneumatic packer for inflating and deflating the first pneumatic packer, and a second air line configured to extend from an air pump to the second pneumatic packer for inflating and deflating the second pneumatic packer. The system may additionally comprise a tertiary well screen for admitting water from the aquifer, the tertiary well screen oriented along the axis between the first valve and the second valve. The dual-valve assembly may further comprise a shroud substantially surrounding the submersible pump. The shroud may have a plurality of holes through which water from the primary or secondary well screens can flow to the submersible pump. The dual-valve assembly may further comprise centering guides attached to the shroud for centering the submersible pump within the shroud.

Embodiments of the present invention also include a method of constructing a slant well feedwater supply system for supplying water from an aquifer. The method comprises the steps of placing a telescoping plurality of casings below a land surface so that the telescoping plurality of casings extends along an axis angled below horizontal to beneath a water body, wherein the telescoping plurality of casings comprises one or more temporary casings; placing a well screen along the axis within the one or more temporary casings so that a space is formed between the well screen and the one or more temporary casings; and placing a filter pack in the space between the well screen and the one or more temporary casings.

In one embodiment, the method further comprises the step of withdrawing the one or more temporary casings. The step of placing the well screen may comprise the step of centering the well screen within the one or more temporary casings using centering guides. In the step of placing a telescoping plurality of casings, the telescoping plurality of casings may comprise a pump house casing. In one embodiment, the pump house casing has an upward end and a downward end, and the step of placing the well screen comprises placing the well screen so that the well screen extends upwardly through the downward end of the pump house casing along the axis. The method may further comprise the step of fitting the downward end of the pump house casing with a seal, the well screen extending upwardly through the seal.

In another embodiment, the step of placing the filter pack comprises the steps of extending one or more tremie pipes to the space between the well screen and the one or more temporary casings, and pumping filter pack material under pressure through the one or more tremie pipes into the space between the well screen and the one or more temporary casings. The step of extending the one or more tremie pipes may comprise the step of positioning the one or more tremie pipes within the one or more temporary casings using tremie pipe guides. In one embodiment, the one or more tremie pipes consist of three tremie pipes, and the step of positioning the tremie pipes comprises spacing the tremie pipes uniformly about the well screen. The step of placing the filter pack may further comprise the steps of placing a packer assembly within the well screen, the packer assembly comprising a packer and a water pipe extending through a hole in the packer, and pumping water through the water pipe to settle the filter pack material. The method may further comprise the step of withdrawing the packer assembly and the one or more tremie pipes. The steps of withdrawing the one or more temporary casings and withdrawing the packer assembly and the one or more tremie pipes lay be gradually performed as the steps of pumping and settling filter pack material are performed, so that the filter pack is placed and settled along the length of the well screen.

Embodiments of the present invention also include a method for reducing salinity variation in feedwater supplied from a slant well system comprising an upper well screen and a lower well screen for admitting water from an aquifer, a submersible pump for pumping water admitted through the upper or lower well screens, an upper valve for regulating water flow from the upper well screen to the submersible pump, and a lower valve for regulating water flow from the lower well screen to the submersible pump. The method comprises the steps of controlling the upper valve to inhibit water flow from the upper well screen to the submersible pump if the salinity of the feedwater decreases below a first predetermined threshold, and controlling the lower valve to inhibit water flow from the lower well screen to the submersible pump if the salinity of the feedwater increases above a second predetermined threshold. In one embodiment, the upper valve, in the step of controlling the upper valve, is a first pneumatic packer, and the lower valve, in the step of controlling the lower valve, is a second pneumatic packer.

Other features of the invention should become more apparent from the following description of the preferred embodiments taken in conjunction with the accompanying drawings, which illustrate, by way of example, the principles of the invention.

## BRIEF DESCRIPTION OF THE DRAWINGS

Various embodiments of the present invention will now be described, by way of example only, with reference to the following drawings.

FIG. **1** is an isometric diagram illustrating a slant well feedwater supply system for producing water from a subsurface aquifer system below an ocean floor and pumping the feedwater to an inland desalination plant, in accordance with an embodiment of the present invention.

FIG. **2** is a side elevation view of a telescoped slant well having upper and lower well screens and showing water infiltration from the ocean and the freshwater-saltwater interface, in accordance with an embodiment of the present invention, with the aquifers shown in cross-section and the pump house casing cut away to show a submersible pump inside the pump house casing.

FIG. **3** is a side elevation view of a telescoped slant well having a single well screen interval and showing primary and secondary sources of water recharge to the slant well, in accordance with an embodiment of the present invention, with the aquifers and artificial filter pack surrounding the well screen shown in cross-section, and the pump house casing cut away to show a submersible pump inside the pump house casing.

FIG. **4** is a side elevation view of a telescoped slant well having multiple screened intervals, in accordance with an embodiment of the present invention, with the aquifers and artificial filter pack surrounding the well screens shown in cross-section, and the pump house casing cut away to show a submersible pump inside the pump house casing fitted with a dual-packer shroud assembly having both packers deflated for maximum well production.

FIGS. **5A-5D** are top plan views of four slant well configurations, each having a common well head area for the slant wells in the configuration, the configurations including a single well configuration, a two-well array, a three-well array, and a four-well array, in accordance with embodiments of the present invention.

FIGS. **6A** and **6B** are top plan views of two slant well configurations, each having separate well head areas for the slant wells in the configuration, in accordance with embodiments of the present invention.

FIG. **7** is a side elevation view showing two telescoped slant wells extending from a common well head but at different angles below horizontal to produce water having different salinities (higher salinity production from the shallower-angle slant well and lower salinity production from the steeper-angle slant well), in accordance with an embodiment of the present invention, with the aquifers shown in cross-section and the pump house casings cut away to show submersible pumps inside the pump house casing.

FIG. **8** is a side elevation view of a telescoped slant well having successively reduced casing diameters, the well extending to a lineal length of approximately 1,000 feet, in accordance with an embodiment of the present invention.

FIG. **9** is a side elevation view of a telescoped slant well showing the placement of a single screened section centered within a temporary casing using centering guides and surrounded by an artificial filter pack, in accordance with an embodiment of the present invention, with the casings, centering guides, and filter pack cut away to show the well screen.

FIG. **10** is a side elevation view of a telescoped slant well illustrating the removal of the 20-inch diameter temporary casing surrounding the well screen and filter pack, in accordance with an embodiment of the present invention, with the casings, centering guides, and filter pack cut away to show the well screen.

FIG. **11** is a side elevation view of a telescoped slant well having a single screened section with the 20-inch and 22-inch temporary casings removed and a seal placed at the bottom of the 24-inch pump house casing, in accordance with an embodiment of the present invention, with the filter pack cut away to show the well screen.

FIG. **12** is a side elevation view of a telescoped slant well having dual screened intervals with the 20-inch and 22-inch temporary casings removed and a seal placed at the bottom of the 24-inch pump house casing, in accordance with an embodiment of the present invention, with the centering guides and filter pack cut away to show the well screen.

FIG. **13A** is a side elevation view of a telescoped slant well showing the placement of an artificial filter pack through a system of multiple tremie pipes in the annular space between the lower well screen and the temporary casing, in accordance with an embodiment of the present invention, with the casings, centering guides, and filter pack cut away to show the tremie pipies and upper and lower well screens. FIG. **13B** is a cross-section view of the telescoped slant well of FIG. **13** A, taken along the line **13-13** in FIG. **13A**, showing the temporary casing, upper well screen, filter pack, tremie pipes, and tremie pipe guides.

FIG. **14A** is a side elevation view of a telescoped slant well showing the placement and settlement of an engineered artificial filter pack through a multi-step process of placing the filter pack by pumping filter pack material through tremie pipes under pressure, simultaneously removing the temporary casing surrounding the tremie pipes, settling the filter pack using an in-screen packer assembly, and gradually withdrawing the in-screen packer assembly, in accordance with an embodiment of the present invention, with the casings and well screens cut away to show the in-screen packer assembly. FIG. **14B** is a detail view of the telescoped slant well of FIG. **14A**, showing the filter pack placement.

FIG. **15** is a chart of sieve opening versus percent of filter material passing the well screen slots for designing an engineered filter pack from site-specific samples of aquifer materials.

FIG. **16** is a side elevation view of a multiple-screened, telescoped slant well showing how the slant well can pump water with higher or lower salinity because of variations in the freshwater-saltwater interface due to natural variations in the hydrologic cycle, in accordance with an embodiment of the present invention, with the pump house casing cut away to show a submersible pump inside the pump house casing.

FIG. **17** is a side elevation view of a multi-screened, telescoped slant well equipped with a submersible pump fitted with a dual packer shroud assembly and pumping from the lowermost screen only (upper packer inflated, lower packer deflated), in accordance with an embodiment of the present invention, with the aquifers and artificial filter pack surrounding the well screens shown in cross-section, and the pump house casing cut away to show the submersible pump and dual-packer shroud assembly.

FIG. **18** is a side elevation view of a multi-screened, telescoped slant well equipped with a submersible pump fitted with a dual packer shroud assembly and pumping from the uppermost screen only (upper packer deflated, lower packer inflated), in accordance with an embodiment of the present invention, with the aquifers and artificial filter pack surrounding the well screens shown in cross-section, and the pump house casing cut away to show the submersible pump and dual-packer shroud assembly.

FIG. **19** is a side elevation view of a multi-screened, telescoped slant well equipped with a submersible pump fitted with a dual packer shroud assembly and pumping from the well screen portion between the dual packers (upper and lower packers inflated), in accordance with an embodiment of the present invention, with the aquifers and artificial filter pack surrounding the well screens shown in cross-section, and the pump house casing cut away to show the submersible pump and dual-packer shroud assembly.

FIG. **20** is a detailed side elevation view of a portion of a well having a submersible pump fitted with a dual packer shroud assembly configured for maximum production (both upper and lower packers deflated), in accordance with an embodiment of the present invention, with portions of the well cut away to show the submersible pump.

FIG. **21** is a detailed side elevation view of a portion of a well having a submersible pump fitted with a dual packer shroud assembly configured for production from below the lower packer (upper packer inflated and lower packer deflated), in accordance with an embodiment of the present invention, with portions of the well cut away to show the submersible pump.

FIG. **22** is a detailed side elevation view of a portion of a well having a submersible pump fitted with a dual packer shroud assembly configured for production from above the upper packer (upper packer deflated and lower packer inflated), in accordance with an embodiment of the present invention, with portions of the well cut away to show the submersible pump.

FIG. **23** is a detailed side elevation view of a portion of a well having a submersible pump fitted with a dual packer shroud assembly configured for production from between the dual packers (both upper and lower packers inflated), in accordance with an embodiment of the present invention, with portions of the well cut away to show the submersible pump.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The invention is generally embodied in a slant well or system of slant wells that produces water from permeable deposits near or beneath saline water bodies (e.g., oceans, seas, or inland lakes). The invention can provide a long-term, sustainable feedwater supply for a desalination plant with virtually unlimited recharge potential.

With reference now to the illustrative drawings, and particularly to FIG. **1**, there is shown an isometric diagram illustrating a slant well feedwater supply system for producing water from a subsurface aquifer system below an ocean floor and pumping the feedwater to a desalination plant, in accordance with an embodiment of the present invention. Permeable materials comprising the subsea aquifer **1** are recharged from the overlying ocean **2**. The slant well **3** receives recharge from induced infiltration of ocean water **4** and pumps this feedwater to a desalination plant **5** through a pipeline **6**. The desalination plant **5** pumps out freshwater through a freshwater pipeline **7** to meet inland water supply demands.

With reference now to FIG. **2**, there is shown a telescoped slant well **8** configured for use in a feedwater supply system **17**, in accordance with an embodiment of the present invention. In one embodiment, the slant well is drilled at a low angle below horizontal using a dual rotary drilling rig or other suitable device to a total lineal length of approximately 1,000 feet or more. In one particular embodiment, the slant well is drilled at an angle of approximately 23 degrees below horizontal. The telescoped slant well has an upper well screen **9** and a lower well screen **10** for admitting water from a saltwater aquifer **14**. A submersible pump **11** pumps water out of the slant well to a desalination plant. The slant well is recharged from induced infiltration of water **13** that flows from the ocean floor **12** and lateral offshore sources through the saltwater aquifer **14**. The saltwater aquifer meets the freshwater aquifer beneath the land surface at a freshwater-saltwater interface **15**. Saline water is pumped from the slant well **8** to the desalination plant via an underground pipeline **16** connected to the buried slant well head. In one embodiment, the buried slant well head is connected to the pipeline **16** via a caisson (not shown) sunk into the land surface.

The slant well **8** is part of a feedwater supply system **17** that comprises the slant well and the pipeline **16**. Because the slant well is buried beneath the land surface and ocean floor, the feedwater supply system avoids entrainment and impingement impacts to marine life. Additionally, the filtration process performed by the subsurface aquifer **14** reduces or eliminates costly reverse osmosis pretreatment that would otherwise need to be performed at a desalination plant. Furthermore, because the slant well is completed eland and ocean surface, aesthetic impacts are minimized or eliminated.

Various configurations of a slant well for use in a feedwater supply system will now be described in more detail. With reference to FIG. **3**, there is shown a telescoped slant well **18** having an artificial filter pack **19** and a single well screen interval **20** in accordance with an embodiment of the present invention. The slant well extends through the freshwater-saltwater interface **21**. A primary recharge flow **22** and secondary recharge flow **23** provide recharge to the slant well. Sustained recharge to the slant well is largely provided by induced recharge from the ocean through the primary recharge flow **22** due to the hydraulic head difference between the ocean level **24** and the slant well pumping level **25**. The location of the freshwater-saltwater interface **21** is governed by the height of the freshwater elevation **26**.

A slant well in accordance with the present invention can have multiple screened intervals for providing greater flexibility in feedwater production. With reference to FIG. **4**, there is shown a telescoped slant well **27** having an artificial filter pack **28**, multiple screened intervals **29** (upper and lower), and a submersible pump **30** fitted with a dual-packer shroud assembly, in accordance with an embodiment of the present invention. In the configuration shown in FIG. **4**, both of the dual packers are deflated so that water is drawn into the well through both the upper and lower screened intervals. This configuration is for maximum feedwater production. In other configurations, one or both of the dual packers can be inflated so that water is drawn into the well through less than the full length of the screened intervals. These other configurations are described in greater detail below with respect to FIGS. **17-23**.

A feedwater supply system in accordance with the present invention can comprise a plurality of slant wells. With reference to FIGS. **5A-5D**, there are shown four slant well configurations, each having a common well head area for the slant wells in the configuration, the configurations including a single well configuration **31**, a two-well array **32**, a three-well array **33**, and a four-well array **34**, in accordance with embodiments of the present invention. In each configuration, the slant wells all begin in the same vicinity of each other, i.e., they have common well head area **35**. As shown in FIGS. **5A-5D**, the well head area is located above the high tide line to maximize the undersea screened portion **36** of the slant wells.

With reference now to FIGS. **6A** and **6B**, there are shown a parallel slant well configuration **37** and a nonparallel slant well configuration **38**, in accordance with embodiments of the present invention. Each of these slant well configurations has a separate well head area for the slant wells in the configuration.

With reference now to FIG. **7**, there are shown a shallower-angle slant well **39** and a steeper-angle slant well **40**, the slant wells extending from a common wellhead area **41** but at different angles $\alpha_1$ and $\alpha_2$ below horizontal to produce water having different salinities, in accordance with an embodiment of the present invention. The freshwater-saltwater interface **44** is also shown to illustrate higher salinity production from the shallower-angle slant well **39** and lower salinity production from the steeper-angle slant well **40**.

Construction of a stank well for use in a feedwater supply system will now be described in more detail. In one embodiment, the initial construction of the slant well involves placing a telescoping plurality of casings beneath the land surface and ocean floor. With reference to FIG. **8**, there is shown an initial step in the construction of a telescoped slant well **45** having successively reduced casing diameters, the well extending to a lineal length of approximately 1,000 feet, in accordance with an embodiment of the present invention. The slant well comprises a 26-inch permanent casing **46** for the sanitary seal, a 24-inch permanent pump house casing **47**, a 22-inch temporary casing **48**, and a 20-inch temporary casing **49**.

With reference now to FIG. **9**, there is shown a second step in the construction of a telescoped slant well **50** having a single 12-inch-diameter well screen section **51**, in accordance with an embodiment of the present invention. An artificial filter pack **52** has been placed around the well screen section. The well screen section has been centered within a 20-inch temporary casing **54** using centering guides **53**.

Before operating a slant well in accordance with the present invention, the temporary casings surrounding the artificial filter pack and well screen section need to be withdrawn. FIGS. **10** and **11** illustrate the process of removing a 20-inch and 22-inch temporary casings from a telescoped slant well having a single well screen section. FIG. **10** shows a telescoped slant well **55** having a single well screen section **56** surrounded by an artificial filter pack **57** and centered using centering guides **58**. Dashed line **59** shows the extent of the 20-inch temporary casing prior to the start of the removal process. FIG. **11** shows a telescoped slant well **60** having a single well screen section **61** with both the 20-inch and 22-inch temporary casings removed. The top of the well screen **62** is cut off within the 24-inch pump house casing **63**, which is fitted with a seal **64** at the bottom of the pump house casing.

With reference now to FIG. **12**, there is shown a telescoped slant well **65** having dual screened intervals **66** and the temporary casings removed, in accordance with an embodiment of the present invention. Dashed line **67** shows the extent of the 20-inch temporary casing prior to the start of the removal process. The top of the well screen **68** is cut off within the 24-inch pump house casing, which is fitted with a seal **69** at the bottom of the pump house casing.

Before completing construction of a slant well in accordance with the present invention, the artificial filter pack needs to be placed and settled around the well screen sections. With reference to FIGS. **13A** and **13B**, there is shown a telescoped slant well **70** with an artificial filter pack **71** being placed through a system of multiple tremie pipes **72** in the annular space between the lower well screen **73** and the temporary casing **74**, in accordance with an embodiment of the present invention. The tremie pipes **72** are positioned using tremie pipe guides **75**, **76**, **77** and **78**.

FIGS. **14A** and **14B** further illustrate the process of placing and settling the artificial filter pack. These figures show a telescoped slant well **79** with an artificial filter pack **80** being placed and settled through a multi-step process. The filter pack is placed by pumping filter pack material **81** through the multiple tremie pipes **82** under pressure. Simultaneously, the temporary casing **83** surrounding the tremie pipes is removed and the filter pack **80** is settled using an in-screen packer assembly **84**. The in-screen packer assembly is configured to be slid inside a well screen. A water pipe extends from a water pump (not shown) through a hole in the in-screen packer. The water pump may be a standard water pump known to persons of ordinary skill in the art, with sufficient flow and pressure to cause water at the depth below the packer to flow outward through the well screen portion below the packer, thereby settling the filter pack in the vicinity of the packer. The in-screen packer assembly and tremie pipes are gradually withdrawn so that the artificial filter pack is placed and settled along the entire length of the well-screen portion of the slant well.

An engineered filter pack is designed to stabilize the subsea aquifer materials and, after proper development, prevent migration of fine sand and silt materials from the subsea aquifer into the well. With reference to FIG. **15**, there is shown an example chart of sieve opening versus percent of titter material passing the well screen slots for designing an engineered filter pack (line **85**) from site-specific samples of aquifer materials (line **86**) using the Terzaghi Migration Factor **87** as well as the filter pack sorting factor **88** and percentage of filter material passing the well screen slots **89**. This figure illustrates the principles behind the design of the artificial filter pack. A key purpose of the filter pack is to stabilize the aquifer. A key purpose of the well screen is to stabilize the filter pack.

To design the engineered filter pack, site-specific samples of aquifer materials are taken. It is next determined what sieve opening would pass 85 percent of the aquifer materials in the finest zone. In the example shown in FIG. **15**, it is determined that a sieve opening of approximately 0.6 millimeters would pass 85 percent of the finest aquifer materials within the screened interval of the well. The grain sizes of the filter pack are then chosen such that the 15-percent-passing filter pack size is no more than four times greater than the 85-percent-passing size of the finest aquifer materials within the screened section of the well. In the example of FIG. **15**, the 15-percent-passing filter pack size is 2.4 mm. The well screen slot openings are then sized such that 15 to 20 percent of the filter pack material will theoretically pass through the well screen slots. In the example shown in FIG. **15**, a well screen having approximately 0.094-inch (3/32-inch or 2.4-millimeter) slots is chosen. The uniformity coefficient (60 percent passing/10 percent passing) of the filter pack is typically about half the uniformity coefficient of the aquifer. This ratio is known as the Sorting Factor.

As indicated above a slant well in accordance with the present invention can have multiple screened intervals and a dual-packer shroud assembly for providing greater flexibility in feedwater production. This flexibility can become important because of variations in the freshwater-saltwater interface due to national variations in the hydrologic cycle and a need to provide water of uniform salinity to a desalination plant. With reference to FIG. **16**, there is shown a multiple-screened, telescoped slant well **90** having multiple well screens, in accordance with an embodiment of the present invention. FIG. **16** illustrates how, without a means to vary the intake locations, a slant well can pump water with higher or lower salinity because of variations in the freshwater-saltwater interface due to natural variations in the hydrologic cycle. During wet hydrologic cycles, the freshwater-saltwater interface (line **91**) is farther from the shore due to the higher freshwater hydraulic head (line **92**). During dry hydrologic periods, the freshwater-saltwater interface (line **93**) is closer to the shore due to a lower freshwater hydraulic head (line **94**). The movement of the freshwater-saltwater interface is generally governed by the Ghyben-Herzberg principle, i.e., the depth to the interface (below sea level) is forty times the height of the freshwater head above sea level.

As will flow be described, multiple screened intervals and a dual-packer shroud assembly can provide greater flexibility in feedwater production and lessen the effects of variations in the hydrologic cycle. With reference to FIG. **17**, there is shown a multi-screened, telescoped slant well **95** equipped with a submersible pump **96** fitted with a dual-packer shroud assembly and pumping from the lowermost screen **97** only (upper packer **98** inflated, lower packer **99** deflated), in accordance with an embodiment of the present invention. This configuration allows for greater production from the more saline portion **100** of the aquifer.

With reference now to FIG. **8**, there is shown a multi-screened, telescoped slant well **101** equipped with a submersible pump **102** fitted with a dual-packer shroud assembly and pumping from the uppermost screen **103** only (upper packer **104** deflated, lower packer **105** inflated), in accordance with an embodiment of the present invention. This configuration allows for greater production from the less saline portion **106** of the aquifer.

With reference now to FIG. **19**, there is shown a multi-screened, telescoped slant well **107** equipped with a submersible pump **108** fitted with a dual-packer shroud assembly and pumping from the well screen portion **109** between the dual packers (upper packer **110** and lower packer **111** inflated), in accordance with an embodiment of the present invention. This configuration allows for focused production from the portion of the aquifer proximate the well screen portion **109**.

The various configurations of the dual packer shroud assembly will now be described in greater detail with reference to FIGS. **20-23**. FIG. **20** shows a portion of a well having a submersible pump **112** fitted with a dual-packer shroud assembly **113**, in accordance with an embodiment of the present invention. The shroud assembly comprises two pneumatic packers: an upper packer **114** and a lower packer **115**. In FIG. **20**, the dual-packer shroud assembly is configured for maximum production (both upper packer **114** and lower packer **115** deflated). The upper packer is inflated and deflated using an upper packer air line **116**. The lower packer is inflated and deflated using a lower packer air line **117**. When both packers **114** and **115** are deflated, water enters the upper screen **118** from the aquifer and travels downward toward the pump in the annular space **119** between the upper screen and the pump discharge pipe. This upper water passes by the upper packer **114**, which is deflated, and enters the pump intake **120** through holes **121** in the shroud assembly. Water entering through the lower screen **122** from the aquifer travels upward toward the pump and passes by the lower packer **115**, which is deflated, and enters the pump intake through the holes **121** in the shroud assembly.

FIG. **21** shows a portion of a well having a submersible pump **123** fitted with a dual-packer shroud assembly **124**, in accordance with an embodiment of the present invention. The shourd assembly comprises two pneumatic packers: an upper packer **125** and a lower packer **126**. In FIG. **21**, the dual-packer shroud assembly is configured for production from below the lower packer (upper packer **125** inflated and lower packer **126** deflated). The upper packer is inflated and deflated using an upper packer air line **127**. The lower packer is inflated and deflated using a lower packer air line **128**. Water entering through the upper well screen is prevented from entering the pump intake by means of a permanent packer **129** and the inflated upper packer **125**. Water entering through the lower screen **130** from the aquifer travels upward toward the pump and passes by the lower packer **126**, which is deflated, and enters the pump intake through the holes **131** in the shroud assembly.

FIG. **22** shows a portion of a well having a submersible pump **132** fitted with a dual-packer shroud assembly **133**, in accordance with an embodiment of the present invention. The shroud assembly comprises two pneumatic packers: an upper packer **134** and a lower packer **135**. In FIG. **22**, the dual-packer shroud assembly is configured for production from above the upper packer (upper packer deflated **134** and lower packer inflated **135**). The upper packer is inflated and deflated using an upper packer air line **136** extending from an air pump (not shown) to the upper packer. The lower packer is inflated and deflated using a lower packer air line **137** extending from an air pump (not shown) to the upper packer. The air pump may be a standard air pump known to persons of ordinary skill in the art, sufficient to displace a volume of gas by physical or mechanical action to inflate and deflate the upper and lower packers. Water entering through the upper screen **138** from the aquifer travels downward toward the pump intake **139** and passes by the upper packer **134**, which is deflated, and enters the pump intake **139** through the holes **140** in the shroud assembly. Water entering through the lower well screen **141** is prevented from entering the pump intake by means of the inflated lower packer **135**. Guides **142** center the pump within the dual-packer shroud assembly.

FIG. **23** shows a portion of a well having a submersible pump **143** fitted with a dual-packer shroud assembly **144**, in accordance with an embodiment of the present invention. The shroud assembly comprises two pneumatic packers: an upper packer **145** and a lower packer **146**. In FIG. **23**, the dual-packer shroud assembly is configured for production from between the dual packers (both upper packer **145** and lower packer **146** inflated). The upper packer is inflated and deflated using an upper packer air line. The lower packer is inflated and deflated using a lower packer air line. Water enters the pump intake **147** from the screened section **148** between the packers. Water entering through the upper or lower well screens is prevented from entering the pump intake by means of the inflated upper packer **145** and lower packer **146**.

A slant well feedwater supply system in accordance with the present invention can be constructed near and/or beneath any saline water source, but more preferably is constructed where a river delta deposit meets the ocean, where a major drainage (such as a creek, stream or river) discharges into the ocean, or where an aquifer system under a land surface extends offshore. An initial field investigation is preferably conducted to determine the potential of a site to yield water for a desalination plant. This exploratory work may involve drilling boreholes and test wells to an appropriate depth both onshore and offshore to properly characterize the subsurface aquifer system, which may typically be sand and gravels but may also include secondary porosity features in consolidated rock aquifers (e.g. carbonate aquifers). In one embodiment, the boreholes and test wells are drilled 50 to 200 feet deep. The lithologic characterization of the aquifers may also indicate the quality of the water that might be supplied for a well drilled at that site (e.g., in terms of total dissolved solids (TDS), chlorides and other chemical constituents of concern in a desalination feedwater supply and how those constituents vary with depth).

In one embodiment, the slant well feedwater supply system extends at approximately a 23-degree angle below horizontal to a total length of approximately 350 feet and is capable of providing 2,000-gpm feedwater supply having an average silt density index of approximately 0.58 and an NTU between approximately 0.15 and 0.33. Of the total length, the first approximately 130 feet can comprise a blank casing, followed by approximately 220 feet of a well screen. The well screen can comprise a plurality of Roscoe Moss Full-Flo louver well screens having 3/32-inch slots, the plurality welded together end-to-end to form the complete well screen. The well screen and blank casing can have an inner diameter of 12⅛ inches and a wall thickness of 5/16-inches. In one embodiment, the well screen and blank casing comprise 316L stainless steel. The artificial filter pack can comprise Colorado Silica ¼×16 packed approximately 5 inches thick around the well screen. In one particular embodiment, the full scale system comprises a plurality of seven 1,000-foot slant wells, with each well supplying a feedwater supply of approximately 3,000 gpm for a total supply of approximately 30 mgd.

The foregoing detailed description of the present invention is provided for purposes of illustration, and it is not intended to be exhaustive or to limit the invention to the particular embodiments disclosed. The embodiments may provide different capabilities and benefits, depending on the configuration used to implement the key features of the invention. Accordingly, the scope of the invention is defined only by the following claims.

What is claimed is:

**1**. A telescoping slant well feedwater supply system for supplying water from a subsurface aquifer system, the feedwater supply system comprising:

a primary well screen for initially admitting water from the aquifer system, the primary well screen oriented along an axis angled less than ninety degrees below horizontal and having a substantially uniform cross-sectional area;

a filter pack substantially surrounding and adjacent to the primary well screen;

a pump house casing oriented along the axis, upward of the primary well screen, and having a substantially uniform cross-sectional area; and

a submersible pump contained within the pump house casing for pumping water admitted through the primary well screen;

wherein the cross-sectional area of the pump house casing is greater than the cross-sectional area of the primary well screen.

**2**. The system of claim **1**, wherein the axis is straight.

**3**. The system of claim **1**, further comprising a secondary well screen for admitting water from the aquifer system, the secondary well screen oriented along the axis and having a substantially uniform cross-sectional area greater than the cross-sectional area of the primary well screen.

**4**. The system of claim **3**, further comprising a dual-packer assembly contained within the pump house casing, the dual-packer assembly comprising:

a first packer for regulating the flow of water from the primary well screen to the submersible pump; and

a second packer for regulating the flow of water from the secondary well screen to the submersible pump.

**5**. The system of claim **4**, wherein:

the first packer is a first pneumatic packer; and

the second packer is a second pneumatic packer.

**6**. The system of claim **5**, further comprising:

a first air line configured to extend from an air pump to the first pneumatic packer for inflating and deflating the first pneumatic packer; and

a second air line configured to extend from an air pump to the second pneumatic packer for inflating and deflating the second pneumatic packer.

**7**. The system of claim **4**, further comprising a tertiary well screen for admitting water from the aquifer system, the tertiary well screen oriented along the axis between the first packer and the second packer.

**8**. The system of claim **4**, wherein:

the dual-packer assembly further comprises a shroud substantially surrounding the submersible pump; and

the shroud has a plurality of holes through which water from the primary or secondary well screens can flow to the submersible pump.

**9**. The system of claim **8**, wherein the dual-packer assembly further comprises centering guides attached to the shroud for centering the submersible pump within the shroud.

**10**. A method of constructing a slant well feedwater supply system for supplying water from an aquifer, the method comprising the steps of:

placing a telescoping plurality of casings below a land surface so that the telescoping plurality of casings extends along an axis angled below horizontal to beneath a water body, wherein the telescoping plurality of casings comprises one or more temporary casings;

placing a well screen along the axis within the one or more temporary casings so that a space is formed between the well screen and the one or more temporary casings, the well screen comprising a first portion having a substantially uniform cross-sectional area and a second portion having a substantially uniform cross-sectional area greater than the cross-sectional area of the first portion; and

placing a filter pack in the space between the well screen and the one or more temporary casings.

**11**. The method of claim **10**, further comprising the step of withdrawing the one or more temporary casings.

**12**. The method of claim **10**, wherein the step of placing the well screen comprises the step of centering the well screen within the one or more temporary casings using centering guides.

**13**. The method of claim **10**, wherein, in the step of placing a telescoping plurality of casings, the telescoping plurality of casings further comprises a pump house casing.

**14**. The method of claim **13**, wherein:

the pump house casing has an upward end and a downward end; and

the step of placing the well screen comprises placing the well screen so that the well screen extends upwardly through the downward end of the pump house casing along the axis.

**15**. The method of claim **14**, further comprising the step of fitting the downward end of the pump house casing with a seal, the well screen extending upwardly through the seal.

**16**. The method of claim **10**, wherein the step of placing the filter pack comprises the steps of:

extending one or more tremie pipes to the space between the well screen and the one or more temporary casings; and

pumping filter pack material under pressure through the one or more tremie pipes into the space between the well screen and the one or more temporary casings.

**17**. The method of claim **16**, wherein the step of extending the one or more tremie pipes comprises the step of positioning the one or more tremie pipes within the one or more temporary casings using tremie pipe guides.

**18**. The method of claim **17**, wherein:

the one or more tremie pipes consist of three tremie pipes; and

the step of positioning the tremie pipes comprises spacing the tremie pipes uniformly about the well screen.

**19**. The method of claim **16**, wherein the step of placing the filter pack further comprises the steps of:

placing a packer assembly within the well screen, the packer assembly comprising a packer and a water pipe extending through a hole in the packer; and

pumping water through the water pipe to settle the filter pack material.

**20**. The method of claim **19**, further comprising the step of withdrawing the packer assembly and the one or more tremie pipes.

**21**. The method of claim **20**, further comprising the step of withdrawing the one or more temporary casings;

wherein the steps of withdrawing the one or more temporary casings and withdrawing the packer assembly and the one or more tremie pipes are gradually performed as the steps of pumping and settling filter pack material are performed, so that the filter pack is placed and settled along the length of the well screen.

**22**. A method for reducing salinity variation in feedwater supplied from a slant well system comprising an upper well screen and a lower well screen for admitting water from an aquifer, a submersible pump for pumping water admitted through the upper or lower well screens, an upper packer for regulating water flow from the upper well screen to the submersible pump, and a lower packer for regulating water flow from the lower well screen to the submersible pump, the method comprising the steps of:

controlling the upper packer to inhibit water flow from the upper well screen to the submersible pump if the salinity of the feedwater decreases below a first predetermined threshold; and

controlling the lower packer to inhibit water flow from the lower well screen to the submersible pump if the salinity of the feedwater increases above a second predetermined threshold.

**23**. The system of claim **22**, wherein:

the upper packer, in the step of controlling the upper packer, is a first pneumatic packer; and

the lower packer, in the step of controlling the lower packer, is a second pneumatic packer.

**24**. A method of constructing a slant well feedwater supply system for supplying water from an aquifer, the method comprising the steps of:

placing a telescoping plurality of casings below a land surface so that the telescoping plurality of casings extends along an axis angled below horizontal to beneath a water body, wherein the telescoping plurality of casings comprises one or more temporary casings and a pump house casing, the pump house casing having an upward end and a downward end;

placing a well screen along the axis within the one or more temporary casings so that a space is formed between the well screen and the one or more temporary casings and so that the well screen extends upwardly through the downward end of the pump house casing along the axis; and

placing a filter pack in the space between the well screen and the one or more temporary casings.

**25**. The method of claim **24**, further comprising the step of withdrawing the one or more temporary casings.

**26**. The method of claim **24**, wherein the step of placing the well screen comprises the step of centering the well screen within the one or more temporary casings using centering guides.

**27**. The method of claim **24**, further comprising the step of fitting the downward end of the pump house casing with a seal, the well screen extending upwardly through the seal.

**28**. The method of claim **24**, wherein the step of placing the filter pack comprises the steps of:

extending one or more tremie pipes to the space between the well screen and the one or more temporary casings; and

pumping filter pack material under pressure through the one or more tremie pipes into the space between the well screen and the one or more temporary casings.

**29**. The method of claim **28**, wherein the step of extending the one or more tremie pipes comprises the step of positioning the one or more tremie pipes within the one or more temporary casings using tremie pipe guides.

**30**. The method of claim **29**, wherein:

the one or more tremie pipes consist of three tremie pipes; and

the step of positioning the tremie pipes comprises spacing the tremie pipes uniformly about the well screen.

**31**. The method of claim **28**, wherein the step of placing the filter pack further comprises the steps of:

placing a packer assembly within the well screen, the packer assembly comprising a packer and a water pipe extending through a hole in the packer; and

pumping water through the water pipe to settle the filter pack material.

**32**. The method of claim **31**, further comprising the step of withdrawing the packer assembly and the one or more tremie pipes.

**33**. The method of claim **32**, further comprising the step of withdrawing the one or more temporary casings;

wherein the steps of withdrawing the one or more temporary casings and withdrawing the packer assembly and the one or more tremie pipes are gradually performed as the steps of pumping and settling filter pack material are performed, so that the filter pack is placed and settled along the length of the well screen.

34. A method of constructing a slant well feedwater supply system for supplying water from an aquifer, the method comprising the steps of:

placing a telescoping plurality of casings below a land surface so that the telescoping plurality of casings extends along an axis angled below horizontal to beneath a water body, wherein the telescoping plurality of casings comprises one or more temporary casings;

placing a well screen along the axis within the one or more temporary casings so that a space is formed between the well screen and the one or more temporary casings;

placing a filter pack in the space between the well screen and the one or more temporary casings; and

withdrawing the one or more temporary casings;

wherein the step of placing the filter pack comprises the steps of

extending one or more tremie pipes to the space between the well screen and the one or more temporary casings,

pumping filter pack material under pressure through the one or more tremie pipes into the space between the well screen and the one or more temporary casings,

placing a packer assembly within the well screen, the packer assembly comprising a packer and a water pipe extending through a hole in the packer,

pumping water through the water pipe to settle the filter pack material, and

withdrawing the packer assembly and the one or more tremie pipes;

wherein the steps of withdrawing the one or more temporary casings and withdrawing the packer assembly and the one or more tremie pipes are gradually performed as the steps of pumping and settling filter pack material are performed, so that the filter pack is placed and settled along the length of the well screen.

35. The method of claim 34, wherein the step of placing the well screen comprises the step of centering the well screen within the one or more temporary casings using centering guides.

36. The method of claim 34, wherein, in the step of placing a telescoping plurality of casings, the telescoping plurality of casings further comprises a pump house casing.

37. The method of claim 36, wherein:

the pump house casing has an upward end and a downward end; and

the step of placing the well screen comprises placing the well screen so that the well screen extends upwardly through the downward end of the pump house casing along the axis.

38. The method of claim 37, further comprising the step of fitting the downward end of the pump house casing with a seal, the well screen extending upwardly through the seal.

39. The method of claim 34, wherein the step of extending the one or more tremie pipes comprises the step of positioning the one or more tremie pipes within the one or more temporary casings using tremie pipe guides.

40. The method of claim 39, wherein:

the one or more tremie pipes consist of three tremie pipes; and

the step of positioning the tremie pipes comprises spacing the tremie pipes uniformly about the well screen.

41. A telescoping slant well feedwater supply system for supplying water from a subsurface aquifer system, the feedwater supply system comprising:

a primary well screen for admitting water from the aquifer system, the primary well screen oriented along an axis angled less than ninety degrees below horizontal and having a substantially uniform cross-sectional area;

a filter pack substantially surrounding and adjacent to the primary well screen;

a pump house casing oriented along the axis, upward of the primary well screen, and having a substantially uniform cross-sectional area;

a submersible pump contained within the pump house casing for pumping water admitted through the primary well screen;

wherein the cross-sectional area of the pump house casing is greater than the cross-sectional area of the primary well screen; and

a dual-packer assembly contained within the pump house casing, the dual-packer assembly comprising:

a first packer for regulating the flow of water from the primary well screen to the submersible pump; and

a second packer for regulating the flow of water from the secondary well screen to the submersible pump.

42. The system of claim 41, wherein:

the first packer is a first pneumatic packer; and

the second packer is a second pneumatic packer.

43. The system of claim 42, further comprising:

a first air line configured to extend from an air pump to the first pneumatic packer for inflating and deflating the first pneumatic packer; and

a second air line configured to extend from an air pump to the second pneumatic packer for inflating and deflating the second pneumatic packer.

44. The system of claim 41, further comprising a tertiary well screen for admitting water from the aquifer system, the tertiary well screen oriented along the axis between the first packer and the second packer.

45. The system of claim 41, wherein:

the dual-packer assembly further comprises a shroud substantially surrounding the submersible pump; and

the shroud has a plurality of holes through which water from the primary or secondary well screens can flow to the submersible pump.

46. The system of claim 45, wherein the dual-packer assembly further comprises centering guides attached to the shroud for centering the submersible pump within the shroud.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION

PATENT NO. : 8,056,629 B2
APPLICATION NO. : 12/748886
DATED : November 15, 2011
INVENTOR(S) : Dennis E. Williams

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

At column 2, line 47, “Placing” should be -- b. Placing --.

At column 2, line 65, “titter” should be -- filter --.

At column 3, line 38, after “only” insert -- (higher --.

At column 4, line 64, “lay” should be -- may --.

At column 7, line 6, “easing” should be -- casing --.

At column 8, line 46, “eland” should be -- below the land --.

At column 9, line 39, “stank” should be -- slant --.

At column 11, line 36, “flow” should be -- now --.

At column 11, line 47, “8” should be -- 18 --.

Signed and Sealed this
Tenth Day of July, 2012

David J. Kappos

David J. Kappos
*Director of the United States Patent and Trademark Office*