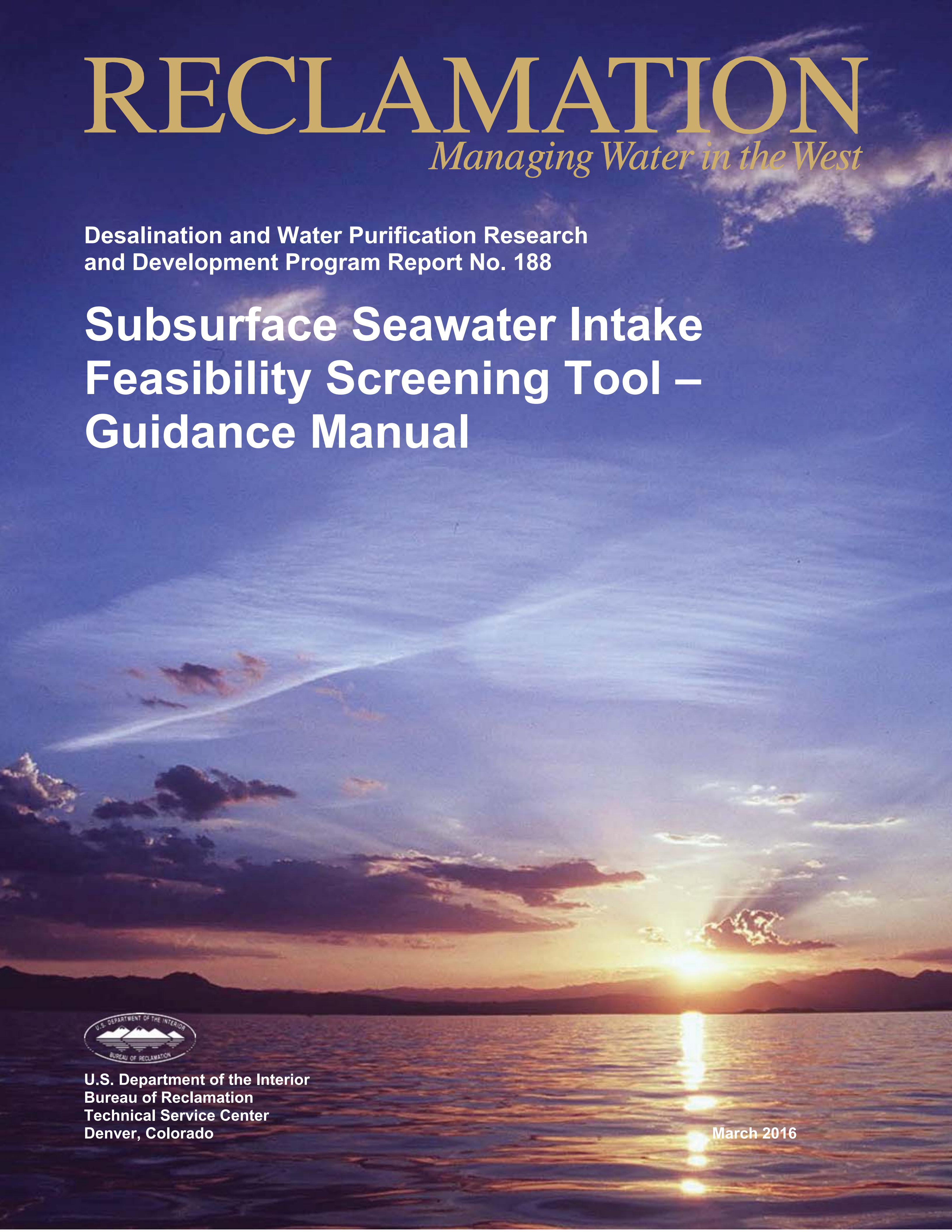

RECLAMATION

Managing Water in the West

Desalination and Water Purification Research and Development Program Report No. 188

Subsurface Seawater Intake Feasibility Screening Tool – Guidance Manual

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

March 2016

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14. ABSTRACT A computer-based general guidance tool was developed to evaluate the technical feasibility of subsurface seawater intakes (SSI) for desalination facilities. The screening tool includes evaluation of potential fatal flaws and potential challenges. For SSIs not eliminated by a technical fatal flaw, the tool provides a scoring system to quantify relative challenges for different SSI technologies. The evaluation is based on 18 criteria, grouped in five categories: construction of the SSI, operation of the SSI, operation of the treatment system, potential inland interference, and technical risk/uncertainty for project implementation. The tool also provides a list of potential tests and analyses that could be performed to obtain more data and improve understanding of site conditions for each of the evaluation criteria.					
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Desalination and Water Purification Research and Development Program Report No. 188

Subsurface Seawater Intake Feasibility Screening Tool – Guidance Manual

Prepared for Reclamation under Agreement No. 5-FC-81-1158

by

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Project Number: LA0324

for

West Basin Municipal Water District

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Denver, Colorado

March 2016

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ACRONYMS AND ABBREVIATIONS

AL	action level
BIG	Beach Infiltration Gallery
CEQA	California Environmental Quality Act
DDW	California Water Resource Control Board Division of Drinking Water
desal	desalination
Desal PMP	Ocean Water Desalination Program Master Plan
DIG	Deep Infiltration Gallery
EIR	Environmental Impact Report
ft^2	square feet
ft^2/MGD	square feet per million gallons per day
gpm	gallons per minute
gpd/ft	gallons per day per foot
HDD	Horizontal Directionally Drilled
IAP	Independent Advisory Panel
ISTAP	Independent Scientific Technical Advisory Panel
LARWQCB	Los Angeles Regional Water Quality Control Board
MCL	maximum contaminant level
MF	micro-filtration
MGD	million gallons per day
NOAA	National Oceanic and Atmospheric Administration
NRG Facility	NRG Generating Station site
NTU	Nephelometric Turbidity Unit
NWRI	National Water Research Institute
RO	Reverse Osmosis
SDI	Silt Density Index
SIG	Seabed Infiltration Gallery
SSI	Subsurface Seawater Intake
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
West Basin	West Basin Municipal Water District

1. BACKGROUND AND INTRODUCTION

1.1. Project background

West Basin Municipal Water District (West Basin) provides imported drinking water and recycled water to nearly one million people in the coastal Los Angeles area. To reduce dependency on imported water, and to reduce the vulnerability of its water supply to drought, West Basin is evaluating the feasibility of developing ocean water desalination (desal) as a component of its water supply portfolio.

For well over a decade, West Basin has conducted a step-wise investigation of desalination, which began with pilot testing from 2002 to 2009 at the NRG Generating Station site in El Segundo (NRG Facility). This pilot test involved operation of a 40 gallons per minute (gpm) facility that processed seawater through the use of micro-filtration (MF) and reverse osmosis (RO). Data and analytical results obtained from this pilot testing facility were used to develop a demonstration facility in Redondo Beach that was operated from 2010 to 2014 to research and test numerous methods and processes for all stages of operation of a desalination plant (intake, treatment, and discharge). The goal of the demonstration facility was to gather information that could be used for full-scale design simulations. This information included: optimizing operating parameters, evaluating water quality impacts on design parameters, assessing the design options for environmentally-protective source intake methodologies, consistent with the recent desalination amendment to the California Ocean Plan, approved on 6 May 2015 by the State Water Resources Control Board, and evaluating energy efficiency.

To identify the next steps for full scale development of ocean water desalination, West Basin completed an Ocean Water Desalination Program Master Plan (Desal PMP) (Malcolm Pirnie, 2013). This document identified an Environmental Impact Report (EIR) as the next step. One component of this EIR will be an evaluation of the feasibility of subsurface seawater intakes (SSI) in compliance with the California State Water Board's updated Ocean Plan (2015). Because open ocean intakes cause some impingement and entrainment of marine life, SSIs are needed instead of an open ocean intake to collect seawater when feasible. SSIs collect water from beneath the sea floor and coastal margin. However, if a site-specific evaluation determines that SSIs are not feasible, the affected Regional Water Board (e.g., for West Basin the Los Angeles Regional Water Quality Control Board [LARWQCB]) may approve open ocean intakes using best available technology to minimize entrainment and impingement. The feasibility definition in the context of the Ocean Plan (2015) is "*capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors*", which is also the feasibility definition in California Coastal Act of 1976 (California Coastal Commission, 2004).

West Basin initiated an "Ocean Water Desalination Subsurface Intake Study" to investigate SSI technologies and their potential viability for a full-scale desal facility.

A screening tool was developed as part of this study, in order to evaluate the feasibility of SSIs. This Guidance Manual serves as a user's guide for the screening tool and provides background on tool development and setup. The SSI Feasibility Screening Tool (Tool) will be available for download on the Bureau of Reclamation website (URL to be determined). This user guide is organized into five sections for easier navigation:

- Section 1 provides a summary of the purpose and need for the Tool.
- Section 2 briefly discusses SSI technologies to provide users with general technical information on the types of SSIs evaluated
- Section 3 provides a brief overview of the Tool and its main features.
- Section 4 provides a detailed "step-by-step" user guide
- Section 5 provides a description of Tool development and setup

1.2. Purpose of the screening tool

The Tool is a decision support process that provides a screening level methodology to assess the potential feasibility of seven different SSIs to provide the desired feed water to meet the design desalination production capacity at a particular location along the California coastline. "Feasibility" is defined by generally recognized factors as documented in the California Coastal Act of 1976 (California Coastal Commission, 2004). This Act provides the following definition:

> *"Feasible" means capable of being accomplished in a successful manner within a reasonable period of time, taking into account economic, environmental, social, and technological factors. (Section 30108 of the California Public Resources Code).*

This definition is consistent with the California Environmental Quality Act (CEQA) definition of "feasibility." However, while the CEQA definition considers technical, environmental, economic, and social feasibility, the scope of the Tool is limited to technical feasibility, defined as "*able to be built and operated using currently available methods*" (Independent Scientific Technical Advisory Panel [ISTAP], 2014). Additional analysis would have to be conducted to determine feasibility for the remaining three considerations.

Screening with the Tool is intended to be an iterative process, where additional, new information can be used to refine the evaluation and update the results. Additional information should include other considerations such as environmental, economic, and social feasibility, which are not included within the Tool framework, but can be used to inform the screening process between iterations. The flow diagram in Figure 1 provides an overview of the feasibility assessment process the Tool follows.

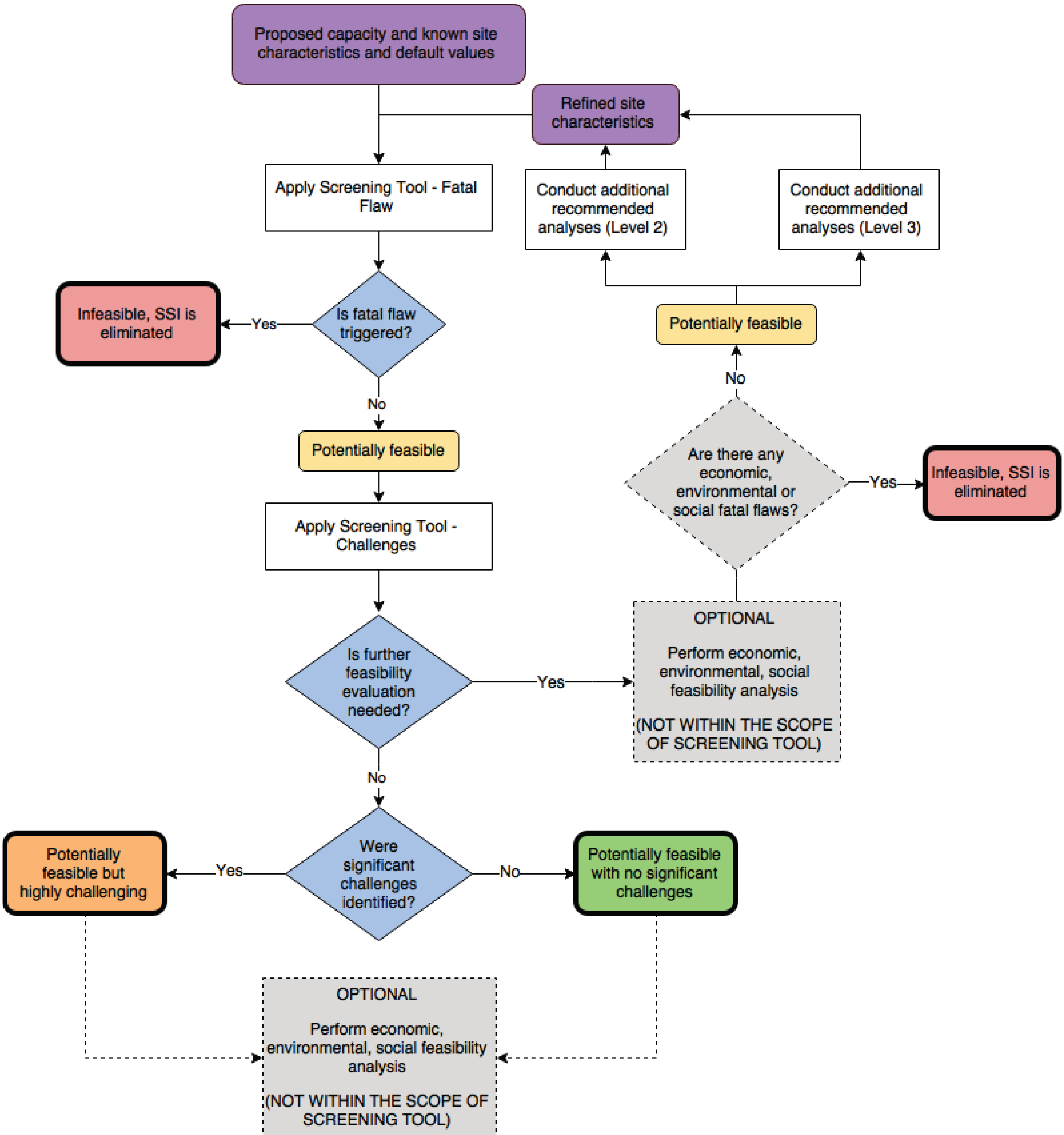


Figure 1.—Screening tool flow chart. The three possible end points after using the Tool are shown with thicker outlines.

While the Tool is based on CEQA definition of "feasibility," it can be used in places other than California However, the feasibility definition and regulatory requirements might be different in a different state or country, and these differences should be taken into account when using the Tool outside of California.

The Tool is to be used for evaluation of the technical feasibility of various types of SSIs based on site setting, conditions, and production requirements. The intended users of this Tool are primarily water industry professionals and regulators, although other stakeholders involved in the decision-making process for desal projects might also use the Tool for assessing the technical feasibility of SSIs.

This Tool is intended to facilitate the screening process, but it is not intended for design purposes. It is assumed that if the user were to pursue development of a SSI and desal facility after using this Tool, a detailed design process would be initiated before any final decisions were made.

The Tool was peer-reviewed by an Independent Advisory Panel (IAP) formed by the National Water Research Institute (NWRI). The IAP consisted of four panel members with expertise in the fields of intake and well design, hydrogeology, coastal processes, evaluation of structures and vessels in the marine and coastal environment, development and implementation of alternate water supply projects (such as seawater desalination) at public agencies, and other areas relevant to the study (NWRI, 2015a).

The peer review was coordinated and facilitated by the NWRI. Two public meetings were held at the Edward C. Little Water Recycling Facility in El Segundo, California on February 26 and April 14, 2015. After each meeting, the IAP issued a draft report summarizing IAP's review and comments on the Tool (NWRI, 2015a and 2015b) and the Tool was revised accordingly.

2. OVERVIEW OF SSI TECHNOLOGIES

The seven SSIs included in the Tool for screening analysis are listed below, along with short descriptions and a schematic illustration of each technology is provided in Figure 2:

1. **Vertical well**
   Vertical wells are identical to conventional groundwater production wells. Typically, a series of vertical wells are drilled along a beach location, and the number of wells is a function of the hydraulic conductivity of sediments or aquifer transmissivity (depending on the location of the screened interval) and the desired capacity of the desal unit.

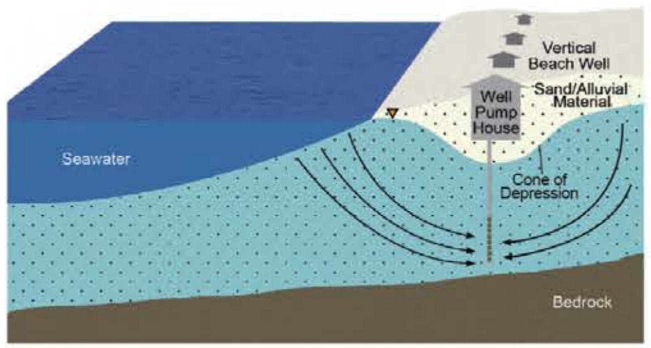
2. **Slant wells**
   Slant wells are wells drilled at an angle from the shore toward the sea, with the well screen beneath the sea floor. Several wells (typically two to four) can be drilled from a single location to create a cluster of wells.

3. **Radial (Ranney) collector wells**
   Radial collector wells (e.g. Ranney Wells^{TM}) include a central caisson that extends down into the sand, with a series of horizontal lateral wells fanning out from the caisson.

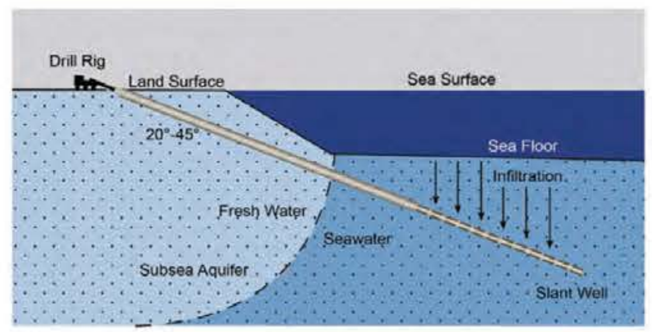
4. **Horizontal directional-drilled wells (sometimes called drains)**
   Horizontal directional-drilled (HDD) technologies can be used to install wells beneath the seafloor from the shoreline (or set back from the shoreline). The angle of the well can be adjusted gradually over the length of the well, allowing it to remain in the desired stratum and close to the sea floor. Similar to slant wells, groups of HDD wells (drains) can fan out from a common location inland of the beach.

5. **Seabed infiltration gallery**
   Water is pumped from the sea through seabed infiltration galleries (SIG) installed over a large surface area and consisting of engineered sand and gravel fill placed within an excavation of the seabed. They typically consist of a network of perforated pipes placed beneath a series of sand layers that increase in grain size with depth. Seawater percolates through the sand into the pipes, which feed a single pumped collector pipe (Missimer at al., 2013).

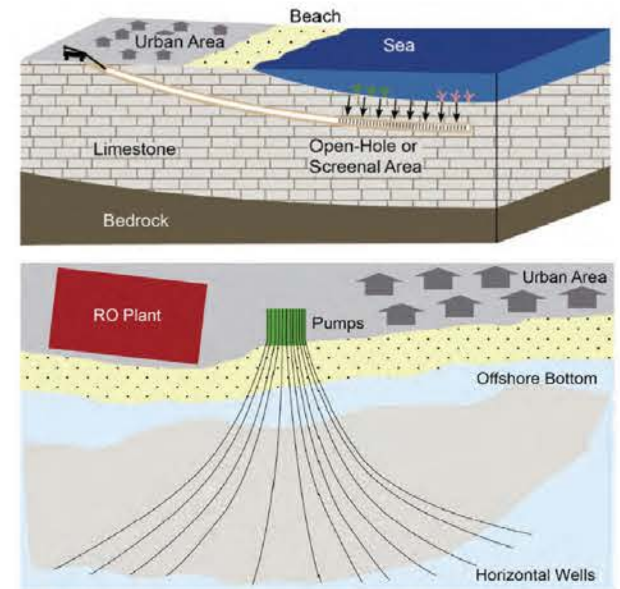
6. **Beach (surf zone) infiltration gallery**
   Beach infiltration galleries (BIG) are similar to SIGs, but are constructed in the surf zone, with the mechanical energy of the breaking waves used to continuously clean the face of the filter (Missimer et al., 2013).



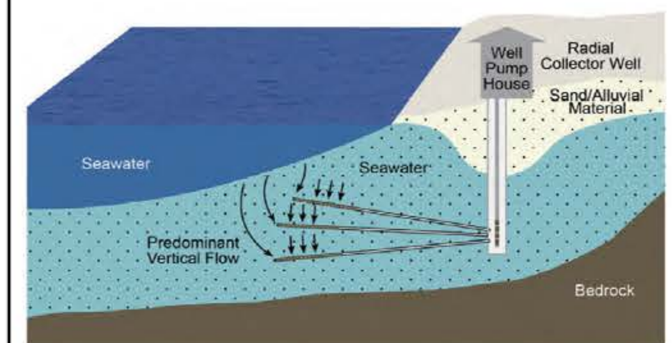
Schematic Representation of a Series of Vertical Wells Along a Beach. (Adapted from Missimer et al., 2013)



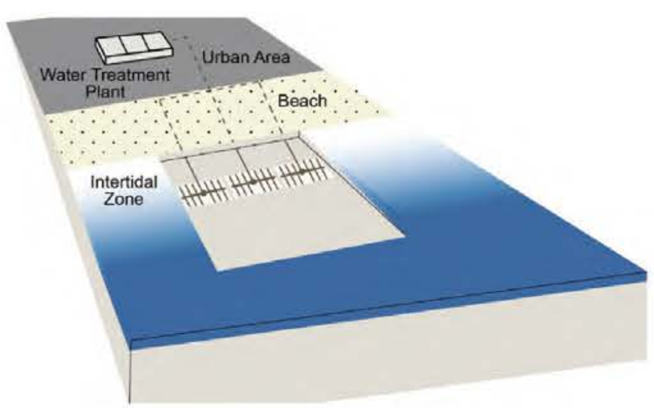
Schematic Representation of a Slant Well. (Adapted from Missimer et al., 2013)



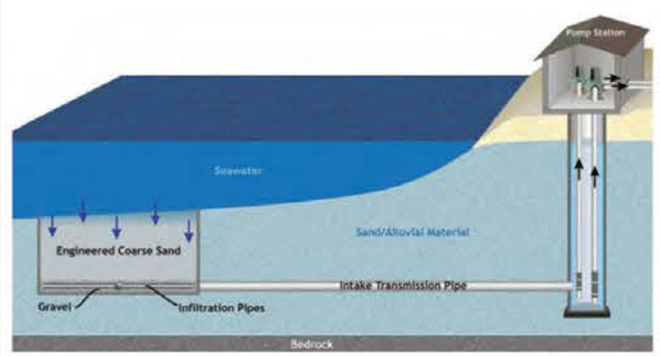
Schematic Representation of a Well Installation (Cross-Section) and a Cluster of HDD Wells. (Adapted from Missimer et al., 2013)



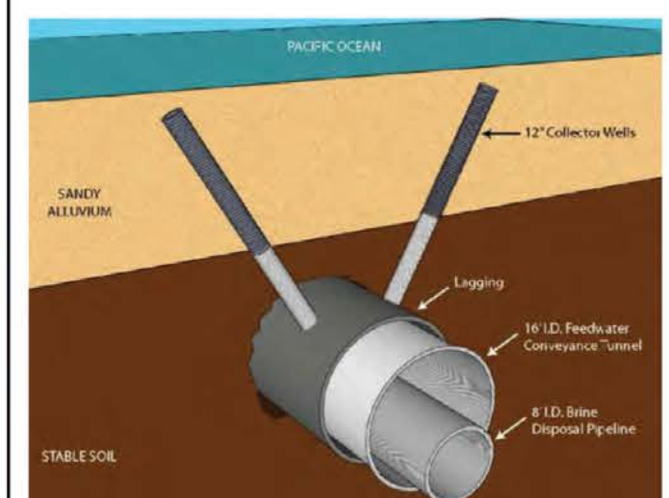
Schematic Representation of Radial Collector Wells. (Adapted from Missimer et al., 2013)



Schematic Representation of a Beach Infiltration Gallery. (Adapted from Missimer et al., 2013)



Schematic Representation of a Seabed Infiltration Gallery. (Adapted from Missimer et al., 2013)



Schematic Representation of a Deep Infiltration Gallery. (Adapted from ISTAP, 2014)

Figure 2.—Schematic illustrations of subsurface seawater intake technologies.

7. **Deep infiltration gallery (water tunnel)**
   A deep infiltration gallery (DIG) or water tunnel is a large pipe or tunnel beneath the sea floor that connects a series of vertical or radial collector wells to an onshore pump station.

An overview of SSI technologies, including a summary of case studies of existing and proposed SSIs and a review current regulatory requirements in California applicable to permitting of a desalination facility, is provided in the Technical Memorandum "Subsurface Seawater Intake Technology Overview" prepared by Geosyntec Consultants (Geosyntec, 2015), as part of the "Ocean Water Desalination Subsurface Intake Study".

3. TOOL OVERVIEW

The Tool is Excel-based, and consists of two steps:

1) Evaluation of potential fatal flaws to SSI implementation, and
2) Evaluation of potential challenges to SSI implementation.

The evaluation is conducted separately for all seven types of SSIs. First, all seven SSIs are subjected to independent fatal flaw analyses. Those SSIs not eliminated in the first step are then scored based on the technical features and potential challenges (second step). The score is intended to assess the technical feasibility of each SSI by ranking the degree of challenge associated with construction, operation, inland interference, and risk/uncertainty.

3.1. List of inputs

The data required to evaluate an SSI scenario are input into the Tool as answers to 31 questions, which define both the intake scenario and the project setting.

Project specific information is required for the first question (requesting the design intake rate), however for all other questions, default inputs may be used if the user does not have project specific inputs.

For each question, the user is required to assess the quality of the input data as low, medium or high.

3.2. Fatal flaws

Projects are evaluated first for fatal flaws. For this evaluation, a fatal flaw is defined as a factor that cannot be reasonably mitigated. Potential fatal flaws incorporated into the Tool include:

1. Land type makes construction of the SSI infeasible

2. Available beach front is insufficient to construct the SSI

3. The area of available land (offshore and/or onshore) is insufficient to construct the SSI

If the proposed project and site characteristics trigger an infeasibility ranking in any of the three fatal flaw criteria for a given SSI, then that SSI is considered infeasible, and no further analysis is required. If none of the fatal flaws are triggered for a given SSI, then that SSI would be considered potentially feasible, and assessment would continue using the Tool to address the significant challenges criteria.

It should be noted that although a given SSI may be considered feasible based on a screening assessment using this Tool, further analysis that is beyond the scope of this Tool may later determine the SSI to be infeasible.

3.3. Significant challenges

For SSIs that are determined to be potentially feasible, the degree of challenge associated with their implementation and operation is evaluated in the Significant Challenge component of the Tool. This component evaluates the Project for potential challenges associated with five general categories as follows:

- Construction of the SSI
- Operation of the SSI
- Operation of the treatment system
- Potential inland interference
- Risk/uncertainty for project implementation

Within each challenge category, a number of criteria are included to address the degree of challenge that might be faced. The tool encompasses a total of 18 criteria.

3.4. Results

The output of the Tool consists of a table indicating whether each SSI is potentially feasible/infeasible and identifying the fatal flaw if the Tool finds the SSI infeasible. In addition, a score is compiled for each potentially feasible SSI, indicating the degree of challenges, a score of 100 being the most feasible/least challenging.

The score is illustrated in two graphs with error bars indicating the uncertainty on the total score, based on the data quality assessment provided by the user.

3.5. Potential additional tests and analyses

Upon completion of an initial screening level assessment, the user may wish to obtain more accurate data and re-apply the Tool. The Tool provides a list of potential tests and analyses that could be performed to obtain more data and improve understanding of site conditions for each of the evaluation criteria.

4. USER GUIDE

This section walks the reader through each component of the Tool.

4.1. Step 1 - data input

4.1.1. "Project Description" tab

The "Project Description" tab of the Tool is shown in Figure 3. First (the "Project Description" tab of the Tool), the user is prompted to provide a description of the proposed project and the screening scenario with the following inputs:

- Project Name;
- Scenario Name;
- Scenario Description;
- Additional Information (optional);
- Prepared By; and
- Date.

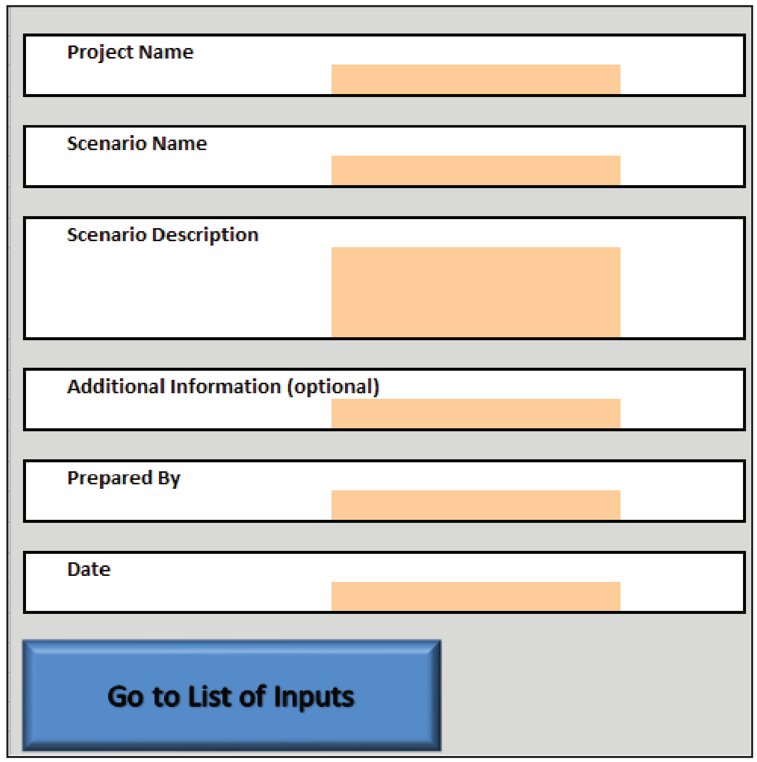


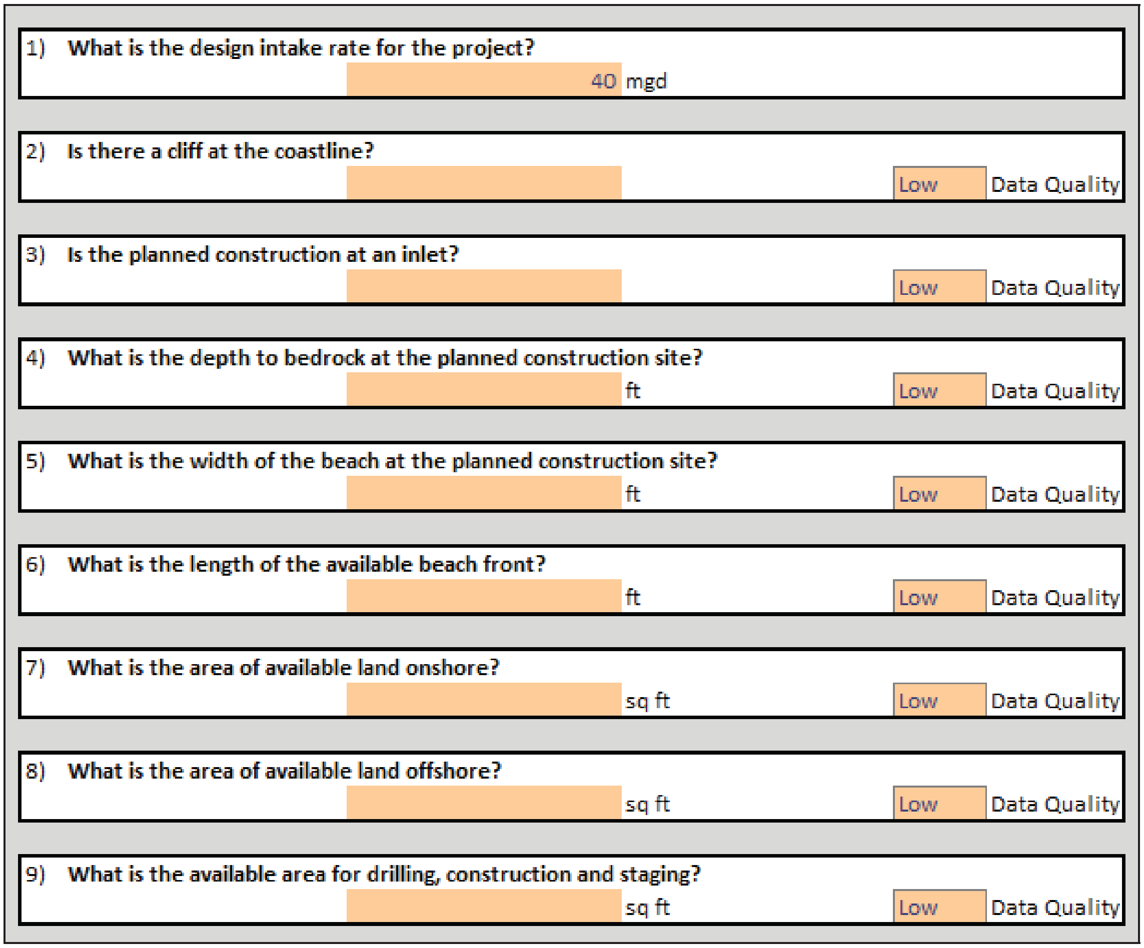
Figure 3.—"Project Description" tab.

If a given desal project is being considered at multiple locations, each location would be considered a different scenario and a complete set of inputs would be provided for each site. Similarly, a different scenario would be assessed for each design intake rate that is considered.

After entering the information, the user navigates to the next tab "List of Inputs" using the button shown below.

4.1.2. Input fields

There are 31 questions listed in the “List of Inputs” tab (Figure 4). Project-specific information is required for the first question (“What is the design intake rate for the project?”). However, default inputs may be used if the user does not have project specific inputs for all other questions.



Input fields are shown in orange

Figure 4.—"List of Inputs" tab.

To ensure that SSIs are not prematurely designated as infeasible or challenging based on a lack of data, the default values have been defined so that they result in the most favorable conditions for the given SSIs. The default value for each input is shown in the pop-up box that appears when the user clicks on the input field Figure 5 shows an example of the default value and explanation for Question 4.

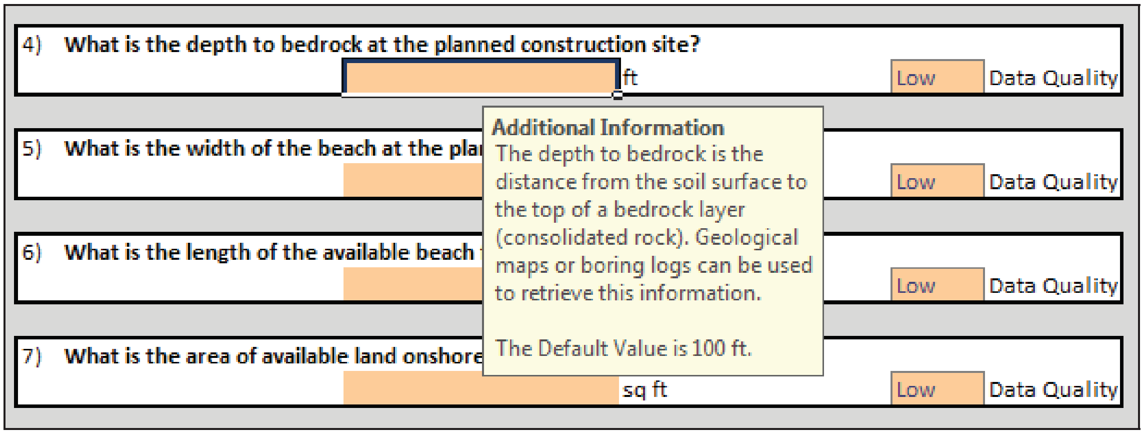


Figure 5.—Example of pop-up box providing additional information and the default value.

Additional information on the input is provided in the pop-up box to help the user. A full description of the additional information and default value is provided in the "Additional Information" tab in the tool that can be accessed from the "List of Input" tab by clicking on the "Go to Additional Info" button.

Specific input formats are expected for the different questions, e.g., a positive number should be entered for the depth to bedrock at the planned construction site (Question #4), and invalid entry in an input field generates a pop-up window, as shown in Figure 6 A full description of the expected format for each question is provided in the "Additional Information" tab in the Tool, that can be accessed from the "List of Inputs" tab by clicking on the "Go to Additional Info" button (Figure 7).

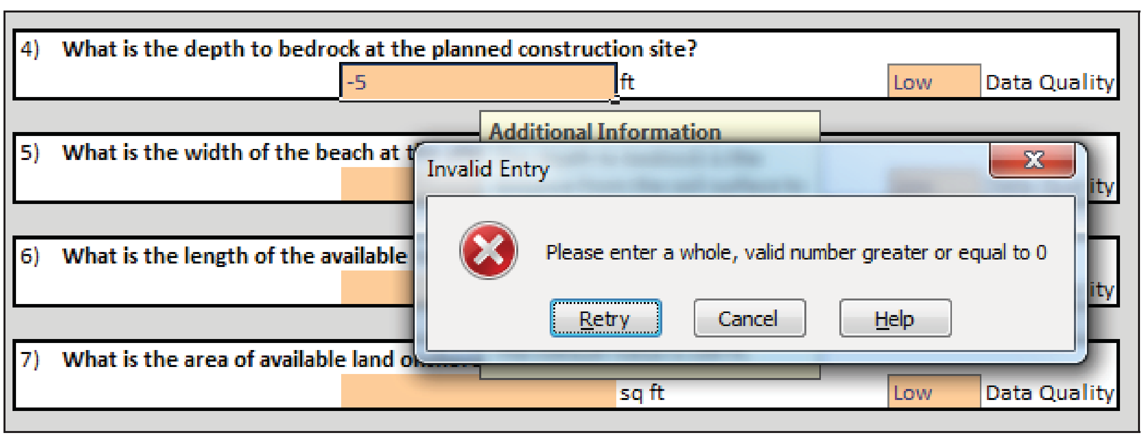


Figure 6.—Pop-up window indicating an invalid entry in the input field.

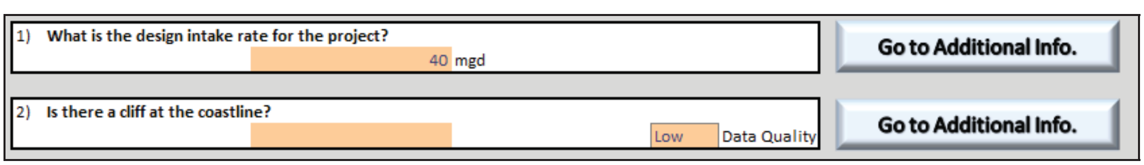


Figure 7.—"Go to Additional Info" button.

4.1.3. Data quality

For each question, the user is required to assess the quality of the input data as low, medium or high:

- **Low data** quality applies to input values derived from assumptions, anecdotal evidence, or unsupported sources. This also includes use of default values provided in the Tool;

- **Medium data** quality applies to input values derived from regional estimates, literature review or similar sites; and

- **High data** quality applies to input values derived from site-specific measurement or site-specific information.

The quality of the data is assigned using a drop-down menu as shown in Figure 8.

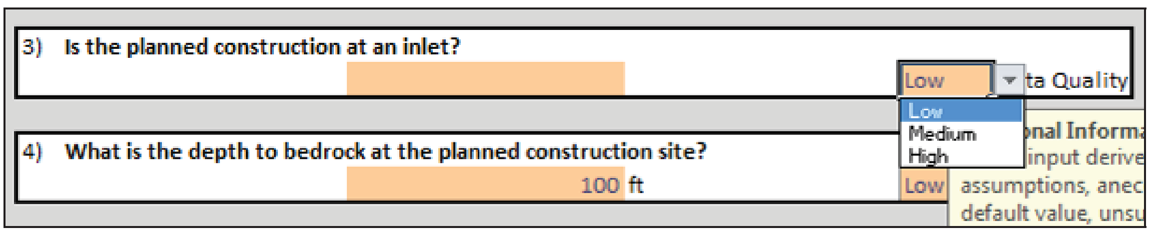


Figure 8.—Drop-down menu for entering data quality assessment.

4.1.4. Print data input

The "List of Inputs" tab can easily be printed for documentation by choosing File/Print.

4.1.5. Weighting system

A weighting system is applied to the criteria to account for the relative importance of each to the Project's success. The Tool incorporates a default weighting scheme which has been peer reviewed and is recommended for the screening process, however the user may change the defaults for Project-specific priorities. In this case, the user is prompted with a warning (as shown in Figure 9). The weighting system is further described in Section 5.3.

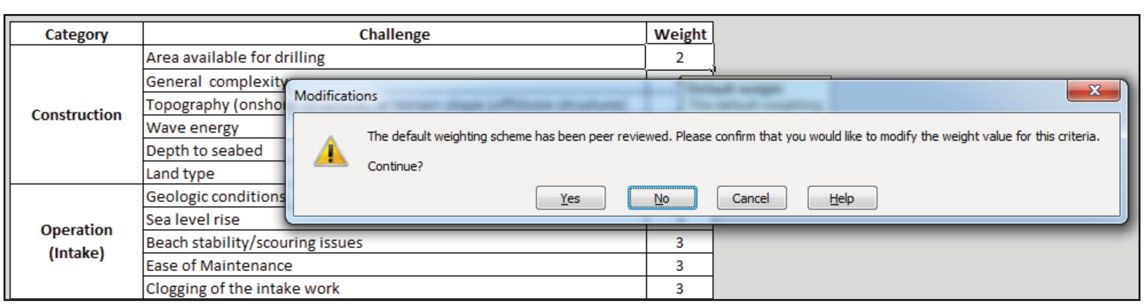


Figure 9.—Pop-up window warning about changing the default values of the weighting scheme.

4.2. Step 2: Result summary

Once the user has completed the "List of Inputs" tab, the screening results can be accessed by clicking on the "Result Summary" button. A summary table for all SSIs is provided at the top of the "Result Summary" tab. The table indicates whether each SSI is potentially feasible/infeasible and identifies the fatal flaw if the Tool finds the SSI infeasible. Figure 10 shows an example. For potentially feasible SSIs, a technical feasibility score is provided, a score of 100 being the most feasible. In the second part of the table, the contribution from the different categories to the technical feasibility score is provided for each potentially feasible SSI. A high percentage means that this category contributes significantly to the feasibility score and therefore does not present a significant challenge.

Normalized Challenge Score 0=most challenging 100=most feasible							
	Vertical Wells	Slant Wells	Radial Collectors (Ranney Wells)	Horizontal Wells	Beach Infiltration Gallery	Seabed Infiltration Gallery	Deep Infiltration Gallery
Totals (100 = most feasible)	**NOT FEASIBLE**	**NOT FEASIBLE**	**NOT FEASIBLE**	**54**	**71**	**60**	**26**
Fatal Flaw	**Land Type**	**Land Type**	**Land Type**	**No**	**No**	**No**	**No**
Contribution from the five categories to the normalized score (%)							
Construction				24%	44%	52%	13%
Operation (Intake)				49%	38%	29%	63%
Operation (Treatment)				10%	8%	10%	25%
Potential Inland Interference				N/A	N/A	N/A	N/A
Risk				17%	10%	10%	0%

SSIs that are eliminated due to a fatal flaw do not receive a challenge score because they are considered infeasible.
N/A = Not Applicable

Figure 10.—Example result summary table.

The "Result Summary" tab also includes two graphs illustrating the scores. Error bars on the graphs represent the uncertainty in the result scores, based on the data input quality provided by the user. The two graphs are shown in Figure 11 and Figure 12. The two graphs illustrate the same results, the graph shown in Figure 12 also illustrates the contribution from the different categories to the technical feasibility scores, based on the

The user may click on each SSI to navigate to the detailed result table (Figure 13 and Figure 14). The detailed results tables provide information on the fatal flaw and challenge analyses, including the scoring applied for each criteria.

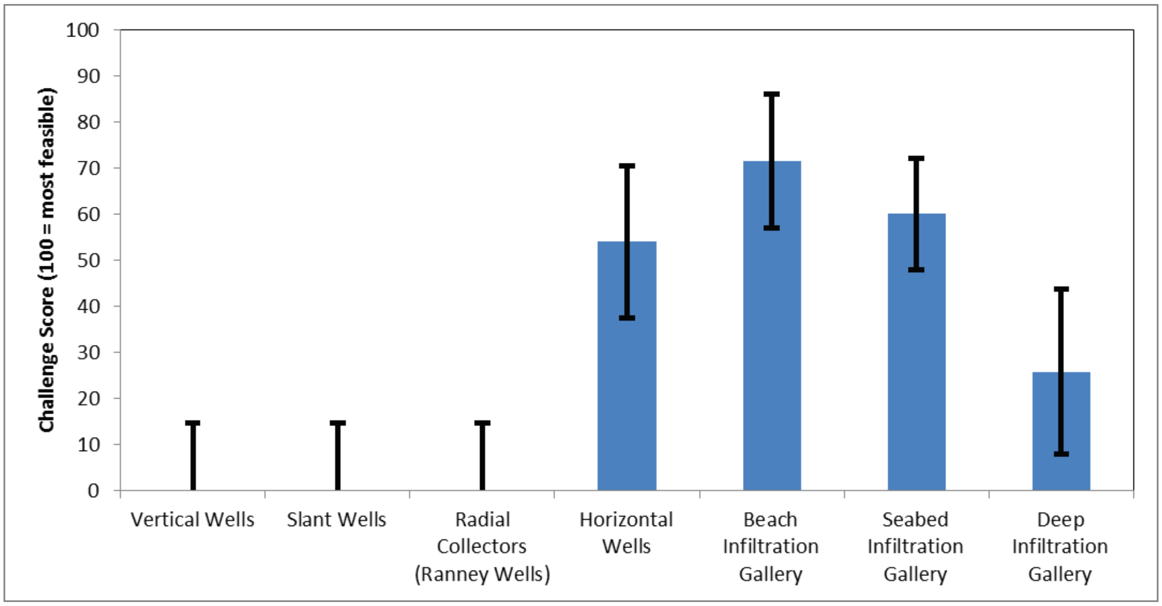


Figure 11.—Example of summary graph with error bars.

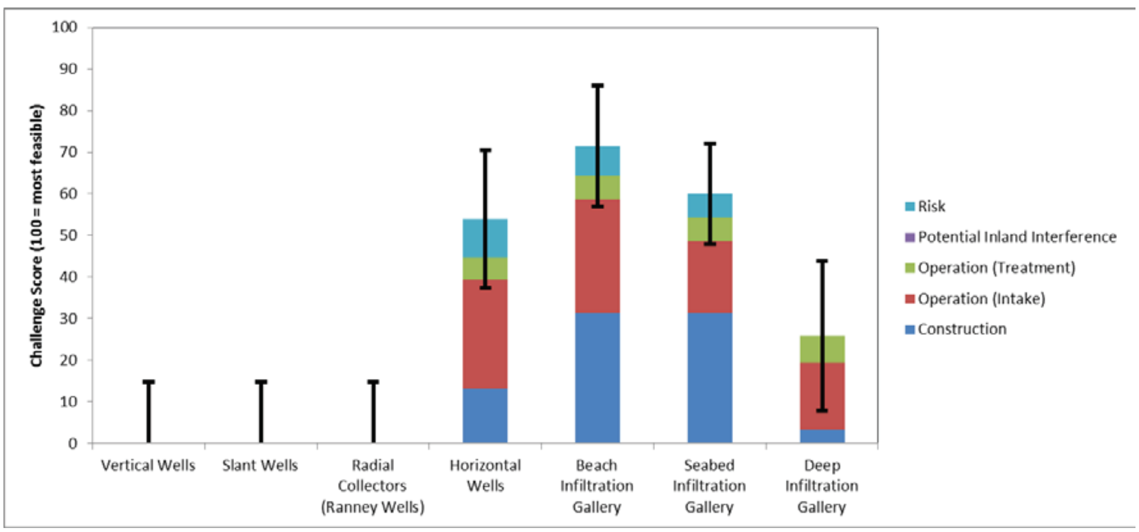


Figure 12.—Example of summary graph with error bars and category contribution.

Vertical Wells						
Fatal Flaw						
Fatal Flaw	**Feasibility**	**Criteria**	**Value**	**Threshold for infeasibility**	**Input**	**Data Quality**
Land type at construction site	Potentially feasible	Depth to bedrock (ft)	100	< 25 ft	4	Low
		Cliff and beach width (ft)	No Cliff and 500	Cliff and < 50 ft	2 and 5	Low and Low
		inlet	Inlet	No inlet	3	Low
Available Beach front	Potentially feasible	Length of beach front needed (ft)	5,250	< 4875 ft	1	N/A
					6	Low
					10	Low
					12	Low
Available area	Potentially feasible	Available area needed (Sq Ft)	100,000	< 12500 Sq Ft	1	N/A
					7	Low
					11	Low
					12	Low

Figure 13.—Example detailed results for fatal flaw analysis.

Signicant Challenges Scoring										
Challenge	Challenge Score	Weight	Criteria	Value	Threshold			Input	Data Quality	Comments
					Not Challenging	Moderately Challenging	Highly Challenging			
Construction Challenges										
Available area for construction equipment	Not Challenging	1	Available area (ft^2)	51,000	> 50,000	10,000 - 50,000	< 10,000	9	Low	
General complexity of construction	Not Challenging	4	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Topography at construction site	Not Challenging	2	Topography	flat	flat	moderately uneven	highly uneven	13	Low	
Wave energy at construction site	N/A		Significant wave height (ft)	N/A	N/A	N/A	N/A			
Depth to seabed	N/A		Depth to seabed (ft)	N/A	N/A	N/A	N/A			
Land type at construction site	Not Challenging	4	Presence of cliff Beach Width (ft) Depth to bedrock (ft)	No Cliff 500 100	No Cliff > 200 ft > 50 ft	N/A N/A N/A	Cliff < 200 ft < 50 ft	2 5 4	Low Low Low	
Operation (Intake) Challenges										
Geologic conditions	Not Challenging	5	Transmissivity (gpd/ft)	100,000	> 88,000	25,000 - 88,000	< 25,000	16	Low	
			Leakance (1/d)	0.12	> 0.1	0.01 - 0.1	< 0.01	17	Low	
Vulnerability to sea level rise	Not Challenging	2	Planned SSI infrastructure located within an area potentially impacted by sea level rise within 40 years	No	No	N/A	Yes	26	Low	
Beach stability	Not Challenging	3	Beach nourished in the last 10 years Mean sea lea level shoreline change (ft/year)	No 0	No < 15 ft	Yes OR > 15 ft	Yes > 15 ft	22 23	Low Low	
Maintenance	Not Challenging	3	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI
Clogging potential	Highly Challenging	3	Saturation Index Turbidity (NTU)		< 0 < 10	0 - 1 10 - 25	> 1 > 25	31 28	Low Low	default is highly challenging
Operation (Treatment) Challenges										
Fouling of treatment work	Not Challenging	1	SDI	2	< 2	2 - 5	> 5	29	Low	
Potential for poor feedwater quality	Not Challenging	1	Feedwater meets at least one of the criteria listed by DDW for extremely impaired source	No	No	N/A	Yes	30	Low	
Potential Inland Interference										
Potential to interfere with groundwater pumping or injection	Not Challenging	4	Inland groundwater level	below sea level	below sea level	N/A	above sea level	24	Low	
Potential to mobilize contaminanted groundwater	Not Challenging	3	Presence of contaminated groundwater in the vicinity	No	No	N/A	Yes	25	Low	
Risk/Uncertainty										
Demonstrated success with similar capacity	Not Challenging	3	% of design capacity for existing systems	105%	> 100%	50% - 100%	< 50%	1	N/A	
Demonstrated success with similar number of units	Moderately Challenging	1	% of number of units for existing systems	75%	> 100%	50% - 100%	< 50%	1 12	Low	
Pilot test implementation	Not Challenging	5	N/A	N/A	N/A	N/A	N/A	None		fixed for each SSI

Figure 14.—Example detailed results for challenge analysis.

4.3. Step 3: Result analysis

The detailed result table for each SSI can be used to further analyze the screening results and assess which criteria/inputs are driving the feasibility assessment and/or the challenge scoring. The detailed result table provides the challenge score for each criteria, and the weight applied to each criteria. It also provides the input number that is used to assess this criteria and the data quality assessment entered by the user. Using this table, the user may assess the scoring with regard to data quality and may decide to refine the analysis. In addition, the user can navigate to the input entry field by clicking on the input number.

4.4. Analysis refinements: Levels 2 and 3

Levels 2 and 3 analyses for each input are provided by clicking on the Level 2 Analysis (or Level 3 Analysis) buttons in the "List of Input" tab. The user should consider performing levels 2 and 3 analyses for the inputs for which the data quality is low or medium to improve the accuracy of the screening analysis.

Level 2 tests and analyses can generally be performed for \$50,000-\$200,000 and within a six month time frame and include the following:

- Characterization of subsurface hydrostratigraphy
    - Compilation and review of existing boring logs
    - Drilling borings
    - Geophysical surveys
- Characterization of seafloor geometry
    - Compilation and review of bathymetry data, such as data from U.S. Army Corps of Engineers (USACE) and National Oceanic and Atmospheric Administration (NOAA)
    - Geophysical bathymetric surveys
- Characterization of hydraulic properties
    - Grain-size analysis
    - Permeability testing
    - CPT pore pressure dissipation testing
    - Specific capacity testing
    - Aquifer testing

- Hydraulic assessment
    - Hydraulic calculations
    - Groundwater modeling
- Review of site-specific potential SSI construction requirements
- Characterization of topography
    - Review of topographic data
    - Preliminary design assessment
    - Compilation and review of Lidar data, such as data from U.S. Geological Survey (USGS) Center for Lidar Information Coordination and Knowledge
- Characterization of seabed slope
    - Preliminary design assessment
    - Compilation and review of bathymetry data, such as data from USACE and NOAA
    - Geophysical bathymetry survey
- Wave climate analysis
    - Compilation and review of wave climate data, such as data from USACE and NOAA
    - Site-specific wave climate analysis
- Beach profile analysis
    - Historical Aerial Photo Survey
    - Compilation and review of beach profile data, such as data from USACE and NOAA
- Coastal aquifer review
    - Compilation and review of groundwater contour maps
    - Compilation and review of water level data at nearby coastal wells
- Existing pumping/injection review
    - Review of existing groundwater pumping or injection in the same basin or aquifer system
- Contamination review
    - Compilation and review of groundwater contamination data. In California, information on many contaminated sites can be obtained from the State Water Board Geotracker site
    - Compilation and review of chemical data at nearby coastal wells

- Sedimentation analysis
    - Offshore borings
    - Dating of seabed sediment profile
    - Sediment transport analysis (sediment budget)
    - Coastal dynamics modeling
- Source water analysis
    - Sampling and analyzing of groundwater in coastal wells, beach and seabed
- Geochemical assessment
    - Groundwater samples and chemical analysis
    - Geochemical modeling

Level 3 are more in depth analyses that would typically require more time and money and include the following:

- Additional characterization of offshore geometry
    - Geophysical bathymetry surveys
- Additional characterization of hydraulic properties
    - Grain-size analysis
    - Permeability testing
    - CPT pore pressure dissipation testing
    - Specific capacity testing
    - Aquifer testing
- Additional characterization of subsurface hydrostratigraphy
    - Drilling borings
    - Offshore vibracore borings and samples
    - Onshore and offshore geophysical surveys
- Installation of test SSIs, pilot testing, and sampling
- Wave climate, beach profile, and sedimentation analysis
    - Coastal dynamics modeling
- Geochemical assessment
    - Advanced geochemical modeling

It is recommended that further study and testing be focused on SSIs that are determined to be potentially feasible by the Tool instead of on additional studies for SSIs that are determined to be infeasible by the Tool.

5. TOOL DEVELOPMENT AND ADDITIONAL GUIDANCE

This section describes the development and setup of the Tool, and provides additional guidance on data input.

5.1. Definitions of fatal flaws and challenges

5.1.1. Fatal flaws

The Tool covers three criteria, which are considered fatal flaws:

1. **Land type at the construction site** makes construction of the SSI infeasible

2. **Available beach front** is insufficient to construct the SSI

3. **Area of available land** (offshore and/or onshore) is insufficient to construct the SSI

The fatal flaws are defined based on the definition of technical feasibility; "*able to be built and operated using currently available methods*" (ISTAP, 2014). The three criteria listed above were identified as conditions that could not be mitigated using available methods.

5.1.2 Significant challenges

Eighteen criteria for assessing challenges associated with construction and operation of SSIs are included in the Tool. The criteria are grouped in five categories:

- **Construction Challenges:**

    - *Available area for construction equipment:* A limited available area for conducting the construction of the SSI and/or staging the construction equipment may be challenging.

    - *General complexity of construction:* The general complexity of the construction that depends on the SSIs, independently of site-specific conditions; e.g., construction of slant wells is generally more challenging than construction of vertical wells.

    - *Topography and bathymetry at construction site:* An uneven topography or a significant slope may be challenging for staging construction equipment, designing the SSI, and/or conducting the construction.

- *Wave energy at the construction site:* High wave energy at the construction site may be challenging for construction staging and implementation for offshore construction projects. The wave energy is characterized by the typical significant wave height at the planned construction site. For BIG, the water depth at the seaward end of the gallery can be used to estimate the wave height at that location with the ratio 0.78*depth, as suggested by the IAP (NWRI, 2015b).

- *Depth to seabed at the construction site:* A deep seabed may be challenging and require non-standard equipment and methods for construction of seabed infiltration galleries.

- *Land type at construction site:* The presence of cliff, a limited beach width and/or shallow bedrock may be challenging for construction of the SSIs.

- **Operation of the SSI:**

  - *Geologic conditions:* Geologic conditions may limit the intake rate of the SSIs, and require construction and operation of a larger number of units. Geologic conditions are characterized by both the transmissivity of the sediments in which the SSI is constructed and the leakage of the sediments between the SSI and the ocean. The geologic conditions are not a challenge for the beach and seabed infiltration galleries as it is assumed that engineered fill will be used.

  - *Vulnerability to sea level rise:* Significant measures may be required to protect the SSI against sea level rise. The vulnerability to sea level rise is assessed based on whether the planned SSI infrastructure is in an area that potentially will be impacted within 40 years (from project initiation) by sea level rise. 40 years includes: 8 years for planning and permitting, 2 years for construction, and 30 years for operation, as suggested by the IAP (NWRI, 2015b). The vulnerability to sea level rise only applies to onshore infrastructure (vertical wells, slant wells, HDD wells, radial collector wells, and beach infiltration galleries) (ISTAP, 2014).

  - *Beach stability (onshore structures) or scouring (offshore structures):* Significant measures may be required to protect or restore intake works from beach instability or scour. Beach stability is assessed based on the beach re-nourishment cycle and/or annual changes in shoreline geometry relative to mean sea level. Potential for scouring is assessed based on the water depth and the distance from the shore at the depth of closure. The depth of closure is defined as the depth beyond which sediment transport or bottom changes are negligible.

- *Maintenance of the intake work:* The general complexity of maintaining the intake works for the SSIs, independently of site-specific conditions; e.g. maintenance of HDD wells is generally more challenging than maintenance of vertical wells.

- *Clogging of the intake work:* Frequent and significant clogging of SSI intakes may require additional maintenance due to the characteristics of source water and potential mixing of different water qualities. By default, the clogging potential is based on the SSI; e.g., vertical and HDD wells have a high clogging potential, while infiltration galleries have a low clogging potential. If information is available, the clogging potential is assessed based on source water turbidity and saturation index for precipitates in the source water.

- **Operation of the treatment system:**

  - *Fouling of treatment system:* Frequent and significant fouling of the treatment works may require additional maintenance due to the characteristics of the feed water. The potential for fouling of the treatment system is assessed based on the Silt Density Index (SDI) of the feed water.

  - *Potential for poor feed water quality:* Poor feed water quality may necessitate additional permitting requirements to use the feed water as a source water for drinking water. The potential for poor feed water quality requiring additional permitting and approval is assessed based on whether the feed water will be considered an extremely impaired source by the California Water Resource Control Board Division of Drinking Water (DDW). DDW considers feed water as an extremely impaired source if it meets one or more of the following criteria (California Department of Health Services, 1997):

    - Exceeds 10 times a maximum contaminant level (MCL) or action level (AL) based on chronic health effects
    - Exceeds 3 times an MCL or AL based on acute health effects
    - Is a surface water that requires more than 4 log *Giardia*/5 log virus reduction

- Is extremely threatened with contamination due to proximity to known contaminating activities
- Contains a mixture of contaminants of health concern
- Is designed to intercept known contaminants of health concern

Salinity is not a consideration since seawater is a major component of the source water.

Water quality standards and regulatory requirements may be different in a different state or country, and should be taken into account when using the Tool outside of California.

- **Potential inland interference:**

  - *Potential to interfere with groundwater pumping or injection:* Potential to disrupt existing and/or planned groundwater pumping or injection may make permitting and approval of the project challenging. The potential to interfere with groundwater pumping or injection is assessed based on the inland groundwater level relative to the sea water level.

  - *Potential to mobilize contaminated groundwater:* Potential to mobilize contaminated groundwater may make permitting and approval of the project challenging. The potential to mobilize contaminated groundwater is assessed based on the presence of contaminated groundwater in the vicinity of the planned construction site.

  Note that the potential for inland interference only applies to SSIs that draw inland groundwater—generally only vertical wells, slant wells and radial collector wells.

- **Risk/uncertainty for project implementation:**

  - *Demonstrated success with SSIs of similar capacity:* The lack of demonstrated success of SSIs with similar production capacity generally imposes significant risks and design challenges to the project (ISTAP, 2014). This is assessed by comparing the design capacity to the capacity of existing systems.

  - *Demonstrated success with similar number of units:* The lack of demonstrated success of SSIs with a similar number of units may impose significant risks and design challenges to the project. This is assessed by comparing the required number of units to the number of units of existing systems.

- *Pilot test implementation:* The general impracticability of performing a pilot test may impose significant risks and design challenges to the project (NWRI, 2015a).

5.2. Threshold values

5.2.1. Fatal flaws

The threshold values for evaluating the infeasibility of each SSIs were based on literature and professional judgment and have been reviewed by the NWRI panel. The threshold values are provided in Table 1 at the end of this section and the rationale for selection of threshold values is described below for each criterion that comprises the fatal flaw.

1. The following land types make construction of the SSI infeasible:

    - *Depth to bedrock* (shallow bedrock):
        - Below 25 feet for vertical wells
        - Below 100 feet for slant wells, as slant wells are drilled at an angle of approximately 20˚ (ISTAP, 2014)
        - Below 25 feet for radial collectors, as the caisson depth of the radial collector ranges typically from 30 to over 150 feet (Water Research Foundation, 2011)
        - Below 10 feet for HDD wells, as 10 feet is considered the minimum thickness to be able to drill and install a HDD well
        - Below 5 feet for beach and seabed infiltration galleries, as engineered fill is used for these galleries and 5 feet is considered the minimum thickness for installation and operation of the filter media (NWRI, 2015b)
        - Below 15 feet for DIG

    - *Cliff and beach width.* Presence of a cliff and narrow beach: for all SSIs, except SIG, the presence of a cliff with a beach narrower than 50 feet constitutes a fatal flaw, as there is not enough space available for construction of the SSIs (NWRI, 2015b).

    - *Inlet.* The presence of an inlet, which is a channel that connects the ocean to a bay of lagoon, constitutes a fatal flaw for all SSIs, except SIG and DIG, as it is a high energy feature that is unstable due to currents and sediment deposition changes (NWRI, 2015b).

2. **Available beach front**. If the amount of available beach front is less than 80% of the required length, then the construction of the SSI infeasible. A value of 80% of the required length is used to account for redundancy and safety factor (ISTAP, 2014).

3. **Area of available land**. If the amount of available land (offshore and/or onshore) is less than 80% of the required area, then the construction of the SSI infeasible. Similarly to the amount of beach front needed, a value of 80% of the required area is used to account for redundancy and safety factor (ISTAP, 2014).

5.2.2. Significant challenges

Similarly, the threshold values for developing the challenge/feasibility scoring are provided in Table 2 and the rationale for selection of threshold values is described below.

- **Construction of the SSI:**
  - *Available area f*or construction equipment is classified as follows, based on professional judgement and typical size of drilling equipment:
    - Above 50,000 square feet (ft^2) (1.2 acres) is not considered challenging;
    - Between 10,000 and 50,000 ft^2 is considered moderately challenging; and
    - Below 10,000 ft^2 is considered highly challenging.
  - *General complexity* of construction is defined for each SSI as follows:
    - Vertical wells are not considered challenging, because they are the same as common conventional groundwater production wells (Missimer et al., 2013);
    - Slant wells are considered moderately challenging, as construction of angle wells is more complex compared to conventional vertical wells and requires the use of specialized equipment (Missimer, et al., 2013 and Kennedy/Jenks Consultants, 2011)
    - Radial collector wells are considered moderately challenging, because construction is more complex compared to conventional vertical wells, but radial collector wells have been used previously for drinking

water supply along rivers (Kennedy/Jenks Consultants, 2011)

- HDD wells are considered moderately challenges, because their construction requires specialized drilling technology, but have been used extensively in the petroleum and power industries (Water Research Foundation, 2011)
- BIGs are considered moderately challenging, because of the high-energy breaking wave conditions in the surf zone and the lack of precedent (ISTAP, 2014 and Missimer et al., 2013)
- SIGs are considered highly challenging, because of the off-shore construction, that requires specialized equipment (ISTAP, 2015 and Missimer et al., 2013)
- DIGs are considered highly challenging, because ground freezing or other advanced technologies may be required to stabilize the sea floor during construction of the tunnel (ISTAP, 2014).

- *Topography and slope* at construction site. Staging construction equipment, designing the SSI, and/or conducting the construction has challenge levels commensurate with topography and slope:
  - A highly uneven topography onshore or a high slope offshore (for BIG and SIG) is highly challenging
  - A moderately uneven topography onshore or a high slope offshore (for BIG and SIG) is moderately challenging
  - A flat topography onshore or a high slope offshore (for BIG and SIG) is not challenging, respectively, for
- *Wave energy at the planned construction site* is characterized by the typical significant wave height at the planned construction site, and classified as follows based on input from the IAP (NWRI, 2015a):
  - Above 3 feet is considered highly challenging
  - Below 3 feet is considered not challenging
- *Depth to seabed* at the construction site is classified as:
  - Above 50 feet is considered highly challenging, as 45 feet is a limit for SIG construction using the trestle approach (Bittner, 2015)
  - Between 15 and 50 feet is considered moderately challenging

        - Below 15 feet is considered not challenging.

  - *Land type at construction site* is classified as:
    - The *presence of a cliff* or a *beach width* narrower than 200 feet are considered highly challenging for all SSIs except for SIG, because of the complexity associated with limited space for equipment staging and operation
    - *Depth to bedrock :*A shallow bedrock is considered highly challenging under these conditions:
      - Below 50 feet for vertical wells
      - Below 200 feet for slant wells
      - Below 50 feet for radial collectors
      - Below 25 feet for HDD wells
      - Below 15 feet for BIG and SIG
      - Below 25 feet for DIG

- **Operation of the SSI:**
  - *Geologic conditions* are characterized by both the transmissivity and the leakance. The most challenging score (based on transmissivity or leakance values) is applied to the criteria. Geological condition challenges do not apply to SIG or BIG, under the assumption that engineered fill will be used for these SSIs.
    - Transmissivity above 88,000 gallons per day per foot (gpd/ft) is considered not challenging, as transmissivity values above 88,000 gpd/ft are recommended for SSIs to be practical (Water Research Foundation, 2011)
    - Transmissivity between 25,000 and 88,000 gpd/ft is considered moderately challenging
    - Transmissivity below 25,000 gpd/ft is considered highly challenging.
    - Leakance above 0.1 1/d is considered not challenging, as it corresponds to a vertical hydraulic conductivity of 10 1/d for a thickness of 100 feet (or 1 1/d for a thickness of 10 feet);
    - Leakance between 0.01 and 0.1 1/d is considered moderately challenging; and
    - Leakance below 0.01 1/d is considered highly challenging.
  - *Vulnerability to sea level rise* is considered highly challenging if the planned SSI infrastructure is in an area that potentially will be

impacted by sea level rise within 40 years (from project initiation) and not challenging otherwise. The vulnerability to sea level rise only applies to onshore infrastructure (vertical wells, slant wells, HDD wells, radial collector wells, and BIGs) (ISTAP, 2014).

- *Beach stability* (onshore structures) is assessed based on the beach re-nourishment cycle and/or annual changes in shoreline geometry relative to mean sea level, as suggested by the IAP (NWRI, 2015b):
  - Beaches that exhibit peak annual mean sea level shoreline changes greater than 15 feet/year, and have not been re-nourished in the last 10 years are considered highly unstable (highly challenging);
  - Beaches that exhibit peak annual mean sea level shoreline changes greater than 15 feet/year, or have been re-nourished in the last 10 years are considered moderately unstable (moderately challenging);
  - Beaches that have been re-nourished in the last 10 years and with seasonal beach profile changes below 15 feet/year are considered stable (not challenging).
- *Sea floor scouring* (offshore structures) is assessed based on the water depth and the distance from the shore at the depth of closure, as suggested by the IAP (NWRI, 2015b):
  - Water depth greater than 20 feet, or distance further than 2,000 feet from the shore is considered highly challenging;
  - Water depth between 10 and 20 feet, or distance between 1,000 and 2,000 feet from the shore is considered moderately challenging; and
  - Water depth of less than 10 feet, and distance less than 1,000 feet from the shore is considered not challenging.
- *Maintenance of the intake work* is defined for each SSI as follows:
  - Not challenging for vertical wells, as it follows industry standards (Missimier et al., 2013 and Water Research Foundation, 2011);
  - Highly challenging for slant wells, as it may require specialized maintenance techniques in order to access and rehabilitate the full length of the screened interval effectively (Water Research Foundation, 2011);
  - Not challenging for radial collector wells, as it follows industry standards (Water Research Foundation, 2011);

        - Highly challenging for HDD wells, because of the complexity of the maintenance due to the length of the screen and the risks of damaging the screen (Missimer at al., 2013; Water Research Foundation, 2011);
        - Moderately challenging for BIGs, as minimum maintenance is expected because of the self-cleaning aspect of the design (Missimer et al., 2013), but maintenance, when needed, will be complicated by the high-energy breaking wave conditions in the surf zone (ISTAP, 2014);
        - Highly challenging for SIGs, as although potential maintenance is technically simple (e.g., scraping the seabed surface), it can be highly challenging to perform offshore (ISTAP, 2014);
        - Highly challenging for DIGs (ISTAP, 2014).

    - *Clogging potential* of the intake work is based by default on the SSI , if information is available, it is assessed based on source water turbidity and saturation indices for precipitates in the source water for vertical wells, slant wells, radial collector wells, and DIG, based on source water turbidity, saturation index for precipitates in the source water and sedimentation rate for HDD wells and on source water turbidity, and sedimentation rate for BIG and SIG. The most challenging score (based on water turbidity or saturation index or sedimentation rate) is applied to the criteria. The threshold values for turbidity were based on the Manual of Design for Slow Sand Filter (AWWA Research Foundation, 1991), as suggested by the IAP (NWRI, 2015a).
        - Turbidity above 25 Nephelometric Turbidity Unit (NTU) is considered highly challenging, as turbidity above 25 NTU necessitates pre-treatment for slow sand filtration processes (AWWA Research Foundation, 1991)
        - Turbidity between 10 and 25 NTU is considered moderately challenging
        - Turbidity below 10 NTU is considered not challenging, as slow sand filtration is considered appropriate for these values (AWWA Research Foundation, 1991)
        - Saturation index for manganese oxides, ferric oxides or calcium carbonate above 1 is considered highly challenging, as it indicates high potential for precipitation of minerals
        - Saturation index between 0 and 1 is considered moderately challenging

    - Saturation index below 0 is considered not challenging, as it indicates dissolution of minerals
    - Sedimentation rate above 5 mm/year is considered highly challenging
    - Sedimentation rate between 1 and 5 mm/year is considered moderately challenging
    - Sedimentation rate below 1 mm/year is considered not challenging.

- **Operation of the treatment system:**
  - *Potential for fouling of the treatment system* is assessed based on silt density index (SDI) of the feed water, as SDI is the parameter used by membrane manufacturers and consultants to determine the potential for membrane fouling (ISTAP, 2014; Voutchkov, 2013).
    - SDI above 5 is considered highly challenging, as membrane manufacturers usually require that the SDI of the source water fed to the RO membranes be less than 5 (Bartak et al., 2012; Voutchkov, 2013)
    - SDI between 2 and 5 is considered moderately challenging (Bartak et al., 2012; Voutchkov, 2013)
    - SDI below 2 is considered not challenging, as it is considered to have a very low fouling potential and to be of good quality (Voutchkov, 2013)
  - *Potential for poor feed water quality* is considered highly challenging if the feed water might be considered an extremely impaired source by DDW (California Department of Health Services, 1997) and not challenging otherwise.
- **Potential inland interference:**
  - *Potential to interfere with groundwater pumping or injection* is considered highly challenging if the inland groundwater level is above sea water level and not challenging otherwise.
  - *Potential to mobilize contaminated groundwater* is considered highly challenging if there is contaminated groundwater less than 5,000 feet from the planned construction site, and not challenging otherwise.

- **Risk/uncertainty for project implementation:**
  - Demonstrated success with SSIs of *similar capacity* is assessed by comparing the proposed capacity to the capacity of existing systems and classified as:
    - Existing system with less than 50% of the proposed capacity is considered highly challenging
    - Existing system with between 50 and 100% of the proposed capacity is considered moderately challenging
    - Existing system with more than 100% of the proposed capacity is considered not challenging

    The proposed capacity (Input #1) is compared to the characteristics of existing systems. Therefore, no specific inputs are needed to assess these criteria.

  - Demonstrated success with a *similar number of units* is assessed by comparing the required number of units to the number of units of existing systems as:
    - Existing system with less than 50% of the required number of units is considered highly challenging;
    - Existing system with between 50 and 100% of the required number of units is considered moderately challenging; and
    - Existing system with more than 100% of the required number of units is considered not challenging.

    The required number of units is calculated in the Tool based on the proposed capacity and the expected capacity per unit, and is compared to the characteristics of existing systems. Therefore, no specific inputs are needed to assess these criteria.

  - *Pilot test implementation* is defined for each SSI as follows and suggested by the IAP (NWRI, 2015a):
    - Not challenging for vertical wells, as a pilot test vertical well can be installed and tested relatively easily
    - Moderately challenging for slant wells, as drilling of pilot test slant well requires specialized equipment, but it has been done previously at Dana Point, California (Geoscience, 2009)
    - Moderately challenging for radial collector wells
    - Moderately challenging for HDD wells, as drilling of pilot test HDD well requires specialized equipment
    - Moderately challenging for BIG

- Highly challenging for SIG
- Highly challenging for DIG

Table 1.—Threshold values for fatal flaws

Fatal Flaw	Criteria	Threshold for infeasibility
Land type at construction site	**Depth to bedrock (ft)**	
	Vertical wells	< 25
	Slant wells	< 100
	Radial collectors	< 25
	HDD wells	< 10
	BIG	< 5
	SIG	< 5
	DIG	< 15
	Cliff and beach width (ft)	
	Vertical wells	Cliff and < 50
	Slant wells	Cliff and < 50
	Radial collectors	Cliff and < 50
	HDD wells	Cliff and < 50
	BIG	Cliff and < 50
	SIG	N/A
	DIG	Cliff and < 50
	Inlet	
	Vertical wells	Inlet
	Slant wells	Inlet
	Radial collectors	Inlet
	HDD wells	Inlet
	BIG	Inlet
	SIG	N/A
	DIG	N/A
Available beach front	**Length of beach front needed**	
	Vertical wells	> 80% of available beach front
	Slant wells	> 80% of available beach front
	Radial collectors	> 80% of available beach front
	HDD wells	> 80% of available beach front
	BIG	> 80% of available beach front
	SIG	N/A
	DIG	N/A
Area of available land	Available area needed	> 80% of available area

Table 2.—Threshold values for challenge scoring

Challenge	Criteria	Threshold		
		Not Challenging	**Moderately Challenging**	**Highly Challenging**
Construction of the SSI Challenges				
Available area for construction equipment	**Available area (ft^2)**	> 50,000	10,000 - 50,000	< 10,000
General complexity of construction	N/A	N/A	N/A	N/A
Topography/ slope at construction site	**Topography**			
	Vertical wells	flat	moderately uneven	highly uneven
	Slant wells	flat	moderately uneven	highly uneven
	Radial collectors	flat	moderately uneven	highly uneven
	HDD wells	flat	moderately uneven	highly uneven
	BIG	N/A	N/A	N/A
	SIG	N/A	N/A	N/A
	DIG	N/A	N/A	N/A
	Slope			
	Vertical wells	N/A	N/A	N/A
	Slant wells	N/A	N/A	N/A
	Radial collectors	N/A	N/A	N/A
	HDD wells	N/A	N/A	N/A
	BIG	low	moderate	high
	SIG	low	moderate	high
	DIG	N/A	N/A	N/A
Wave energy at the planned construction site	**Typical significant wave height (ft)**			
	Vertical wells	N/A	N/A	N/A
	Slant wells	N/A	N/A	N/A
	Radial collectors	N/A	N/A	N/A
	HDD wells	N/A	N/A	N/A
	BIG	< = 3	N/A	> 3
	SIG	< = 3	N/A	> 3
	DIG	N/A	N/A	N/A

Table 2 (continued).—Threshold values for challenge scoring

Depth to seabed	**Depth to seabed (ft)**			
	Vertical wells	N/A	N/A	N/A
	Slant wells	N/A	N/A	N/A
	Radial collectors	N/A	N/A	N/A
	HDD wells	N/A	N/A	N/A
	BIG	N/A	N/A	N/A
	SIG	< 15	15 - 50	> 50
	DIG	N/A	N/A	N/A
Land type at construction site	**Presence of cliff**			
	Vertical wells	No Cliff	N/A	Cliff
	Slant wells	No Cliff	N/A	Cliff
	Radial collectors	No Cliff	N/A	Cliff
	HDD wells	No Cliff	N/A	Cliff
	BIG	No Cliff	N/A	Cliff
	SIG	N/A	N/A	N/A
	DIG	No Cliff	N/A	Cliff
	Beach Width (ft)			
	Vertical wells	> 200 ft	N/A	< 200 ft
	Slant wells	> 200 ft	N/A	< 200 ft
	Radial collectors	> = 200 ft	N/A	< 200 ft
	HDD wells	> = 200 ft	N/A	< 200 ft
	BIG	> = 200 ft	N/A	< 200 ft
	SIG	N/A	N/A	N/A
	DIG	> = 200 ft	N/A	< 200 ft
	Depth to bedrock (ft)			
	Vertical wells	> 50 ft	N/A	< 50 ft
	Slant wells	> = 200 ft	N/A	< 200 ft
	Radial collectors	> = 50 ft	N/A	< 50 ft
	HDD wells	> = 25 ft	N/A	< 25 ft
	BIG	> = 15 ft	N/A	< 15 ft
	SIG	> = 15 ft	N/A	< 15 ft
	DIG	> = 25 ft	N/A	< 25 ft

Table 2 (continued).—Threshold values for challenge scoring

Operation (Intake) Challenges				
Geologic conditions	**Transmissivity (gpd/ft)**			
	Vertical wells	> 88,000	25,000 - 88,000	< 25,000
	Slant wells	> 88,000	25,000 - 88,000	< 25,000
	Radial collectors	> 88,000	25,000 - 88,000	< 25,000
	HDD wells	> 88,000	25,000 - 88,000	< 25,000
	BIG	N/A	N/A	N/A
	SIG	N/A	N/A	N/A
	DIG	> 88,000	25,000 - 88,000	< 25,000
	Leakance (1/d)			
	Vertical wells	> 0.1	0.01 - 0.1	< 0.01
	Slant wells	> 0.1	0.01 - 0.1	< 0.01
	Radial collectors	> 0.1	0.01 - 0.1	< 0.01
	HDD wells	> 0.1	0.01 - 0.1	< 0.01
	BIG	N/A	N/A	N/A
	SIG	N/A	N/A	N/A
	DIG	> 0.1	0.01 - 0.1	< 0.01
Vulnerability to sea level rise	**Planned infrastructure located within the area potentially impacted area by sea level rise within 40 years**			
	Vertical wells	No	N/A	Yes
	Slant wells	No	N/A	Yes
	Radial collectors	No	N/A	Yes
	HDD wells	No	N/A	Yes
	BIG	No	N/A	Yes
	SIG	N/A	N/A	N/A
	DIG	N/A	N/A	N/A
Beach stability	**Beach nourished in the last 10 years and Mean sea lea level shoreline change (ft/year)**			
	Vertical wells	No and < 15	Yes or > 15	Yes and > = 15
	Slant wells	No and < 15	Yes or > 15	Yes and > = 15
	Radial collectors	No and < 15	Yes or > = 15	Yes and > = 15
	HDD wells	No and < 15	Yes or > = 15	Yes and > = 15
	BIG	No and < 15	Yes or > = 15	Yes and > = 15
	SIG	N/A	N/A	N/A
	DIG	N/A	N/A	N/A

Table 2 (continued).—Threshold values for challenge scoring

Sea floor scouring	**Water depth (ft) and distance from shore (ft) at depth of closure**			
	Vertical wells	N/A	N/A	N/A
	Slant wells	N/A	N/A	N/A
	Radial collectors	N/A	N/A	N/A
	HDD wells	N/A	N/A	N/A
	BIG	N/A	N/A	N/A
	SIG	<10 and <1,000	10-20 or 1,000-2,000	> 20 or > 2,000
	DIG	N/A	N/A	N/A
Maintenance of the intake work	N/A	N/A	N/A	N/A
Clogging potential	**Saturation Index**			
	Vertical wells	< 0	0 - 1	> 1
	Slant wells	< 0	0 - 1	> 1
	Radial collectors	< 0	0 - 1	> 1
	HDD wells	< 0	0 - 1	> 1
	BIG	N/A	N/A	N/A
	SIG	N/A	N/A	N/A
	DIG	< 0	0 - 1	> 1
	Turbidity (NTU)	< 10	10 - 25	> 25
	Sedimentation Rate (mm/year)			
	Vertical wells	N/A	N/A	N/A
	Slant wells	N/A	N/A	N/A
	Radial collectors	N/A	N/A	N/A
	HDD wells	< 1	1 - 5	> 5
	BIG	< 1	1 - 5	> 5
	SIG	< 1	1 - 5	> 5
	DIG	N/A	N/A	N/A
Operation (Treatment) Challenges				
Potential for fouling of the treatment system	**SDI**	< 2	2 - 5	> 5
Potential for poor feed water quality	**Feed water meets at least one of the criteria listed by DDW for extremely impaired source**	No	N/A	Yes

Table 2 (continued).—Threshold values for challenge scoring

Potential Inland Interference				
Potential to interfere with groundwater pumping or injection	**Inland groundwater level above sea level**			
	Vertical wells	No	N/A	Yes
	Slant wells	No	N/A	Yes
	Radial collectors	No	N/A	Yes
	HDD wells	N/A	N/A	N/A
	BIG	N/A	N/A	N/A
	SIG	N/A	N/A	N/A
	DIG	N/A	N/A	N/A
Potential to mobilize contaminated groundwater	**Presence of contaminant groundwater in the vicinity (less than 5,000 feet from the planned construction site)**			
	Vertical wells	No	N/A	Yes
	Slant wells	No	N/A	Yes
	Radial collectors	No	N/A	Yes
	HDD wells	N/A	N/A	N/A
	BIG	N/A	N/A	N/A
	SIG	N/A	N/A	N/A
	DIG	N/A	N/A	N/A
Risk/Uncertainty				
Demonstrated success with similar capacity	**% of design capacity for existing systems**	> 100%	50% - 100%	< 50%
Demonstrated success with similar number of units	**% of number of units for existing systems**	> 100%	50% - 100%	< 50%
Pilot test implementation	N/A	N/A	N/A	N/A

6. WEIGHTING SYSTEM FOR CHALLENGES

The Tool includes a weighting scheme to account for the relative importance of each of the criteria. More weight is given to challenges that are more difficult to mitigate, such as challenging geological conditions. The weights incorporated in the Tool, which are listed in Table 3 below, have been peer reviewed and are recommended for the screening process.

Table 3.—Weighting system included in the tool

Category	Challenge	Weight[1]
Construction	Area available for drilling	1
	General complexity	4
	Topography or terrain slope	2
	Wave energy	2
	Depth to seabed	2
	Land type	4
Operation (Intake)	Geologic conditions	5
	Sea level rise	2
	Beach stability/scouring issues	3
	Ease of Maintenance	3
	Clogging of the intake work	3
Operation (Treatment)	Fouling of treatment works	1
	Potential for poor feed water quality	1
Potential Inland Interference	Potential to interfere with groundwater pumping or injection	4
	Potential to mobilize contaminated groundwater	3
Risk (Uncertainty)	Demonstrated examples (similar design capacity)	3
	Demonstrated examples (similar number of units)	1
	Pilot test implementation	5

[1]Higher weight means that the challenge is more difficult to mitigate.

6.1. Calculations of technical feasibility scores

The technical feasibility scores presented in the "Result Summary" tab are calculated based on the score for each criteria and the weight assigned to each criteria.

The score applied for each criteria is:

- 0 for highly challenging conditions
- 1 for moderately challenging conditions
- 2 for not challenging conditions

The raw score for each SSI (S_R) is obtained by multiplying the score for each criteria (S_i) with the corresponding weight (W_i) and summing the scores for each SSI is shown in Equation 1:

$$S_R = \sum_i W_i \times S_i$$

Equation 1

Normalized scores are calculated to allow for clear comparison across SSIs. The normalized scores, corresponding to the scores provided in the "Result Summary" tab, are calculated by dividing the raw score for each SSI by the maximum possible score for each SSI and multiplying by 100. For example, the maximum possible score for vertical wells is 90, therefore a raw score of 45 corresponds to a normalized rating of 50.

6.2. Estimation of uncertainty

For each potentially feasible SSI, the Tool provides a score calculated based on the user inputs. The Tool also provides an estimate of the uncertainty of the result scores, calculated based on the data input quality provided by the user. The uncertainty is illustrated with error bars on the graphs presented in the "Result Summary" tab and calculated as described below.

Based on professional judgment and evaluation of the Tool uncertainty results under different data quality assumptions, the error on the score of each criteria were assigned to be:

- 0.25 for inputs for which the data quality is high
- 0.50 for inputs for which the data quality is medium
- 1 for inputs for which the data quality is low

For criteria based on multiple inputs, e.g., wave energy based on depth of closure and water depth, the error on the score of the criteria is equal to the square root of the sum of squares of each error, under the assumption that the errors are independent.

The error for each criteria (E_i) is multiplied by the corresponding weight (W_i) (Section 5.3), and the total error (E) on the score of each SSI is equal to the square root of the sum of squares in Equation 2:

$$E = \sqrt{\sum_i (W_i \times E_i)^2}$$

Equation 2

The uncertainty on the result scores provided in the Result Summary tab is +/- the total error E and is illustrated with the error bars on the graphs. The error bars can be used to assess whether the scores of the SSIs are significantly different.

6.3. Default input values

Project specific information is required for the first question (requesting the design intake rate), however for all other questions, default inputs may be used if the user does not have project specific inputs.

Where inputs are not known with reasonable certainty, the most favorable conditions are assumed as a default score. In other words the Tool is designed to determine that SSIs are potentially feasible unless data supports they are not. The default value for each input is provided in Table 4 at the end of this section and the rationale for selection of default values is described below.

1. What is the design intake rate for the project?

   The design intake rate is the source water rate to the intake works. This value is typically double the design treated water rate (Voutchkov, 2013). The design intake rate is the only input without a default value.

2. Is there a cliff?

   The default value is "No," as it ensures all SSIs are potentially feasible by default (Section 5.2).

3. Is the planned construction an Inlet?

   The default value is "No", as it ensures all SSIs are potentially feasible by default (Section 5.2).

4. What is the depth to bedrock at the planned construction site?

   The default value is 200 feet, as it ensures all SSIs are potentially feasible and not challenging by default (Section 5.2).

5. What is the width of the beach at the planned construction site?

   The default value is 500 feet, as it ensures all SSIs are potentially feasible by default (Section 5.2).

6. What is the length of the available beach front?

   The required available beach front is calculated in the Tool, based on the design intake rate, the expected capacity per unit and the linear beach front required per unit. The default value used in the Tool is higher than the required value.

7. What is the area of available land onshore?

   The required area is calculated in the Tool, based on the design intake rate, the expected capacity per unit and the area required per unit. The default value used in the Tool is higher than the required value.

8. What is the area of available land offshore?

   The required area is calculated in the Tool, based on the design intake rate, the expected capacity per unit and the area required per unit. The default value used in the Tool is higher than the required value.

9. What is the available area for drilling, construction and staging?

   The default value is 100,000 ft^2, as it represents the most favorable conditions (Section5.2).

10. What is the linear beach front required per unit?

    a. The default value for vertical wells is 100 feet per well (ISTAP, 2014 and Water Globe Consulting, 2011).
    b. The default va`lue for slant wells is 600 feet per cluster of three wells (ISTAP, 2014 and Water Globe Consulting, 2011).
    c. The default value for radial collector wells is 350 feet per group of collectors (ISTAP, 2014 and Water Globe Consulting, 2011).
    d. The default value for HDD wells is 1,400 feet per fan of 10 wells (drains). This corresponds to a distance of 140 feet between wells at the offshore extremity. If 10 or fewer wells are required, then the linear beach front required for HDD wells is 100 feet.
    e. The default value for BIG is 0.0033 feet per square feet, based on 150 feet width by 300 feet length cells (ISTAP, 2014).

11. What is the area required per unit?

    a. The default value for vertical wells is 250 ft^2 of onshore area per well (ISTAP, 2014).
    b. The default value for slant wells is 5,000 ft^2 of onshore area per cluster of three wells (ISTAP, 2014).
    c. The default value for radial collector wells is 5,000 ft^2 of onshore area per group of collectors, assuming similar to cluster of slant wells.
    d. The default value for HDD wells is 100,000 ft^2 of offshore area per well (drain), assuming 1,000 feet long screen and average spacing of 100 feet.
    e. The default value for BIG is 6,950 square feet per million gallons per day (ft^2/MGD), corresponding to a flow rate of 0.1 gpm/ft^2, which is a typical value for slow sand filtration (Water Globe Consulting, 2011; WateReuse, 2011).
    f. The default value for SIG is 6,950 ft^2/MGD, corresponding to a flow rate of 0.1 gpm/ft^2, which is a typical value for slow sand filtration (Water Globe Consulting, 2011; WateReuse, 2011).

12. What is the expected capacity per unit?

    a. The default value for vertical wells is 1 MGD (Pankratz, 2006 and Water Research Foundation, 2011) per well (ISTAP, 2014).
    b. The default value for slant wells is 5 MGD per cluster of three wells, as slant wells generally have about 1.5 times the yield of a vertical well (ISTAP, 2014 and Water Research Foundation, 2011).
    c. The default value for radial collector wells is 5 MGD per group of collectors (ISTAP, 2014 and Water Research Foundation, 2011).
    d. The default value for HDD wells is 3 MGD per wells (drains), assuming 1,000 feet long screen, corresponding to 2 gpm/ft (ISTAP, 2014).
    e. The default value for BIG and SIG is 0.1 gpm/ft^2, which is a typical value for slow sand filtration (Water Globe Consulting, 2011 and WateReuse, 2011).
    f. The default value for DIG is 1.8 gallons per minute per foot (gpm/foot), corresponding to the average rate of the operating system at Alicante, Spain (ISTAP, 2014).

13. What is the topography in the vicinity of the planned construction site?

    The default value is "flat," as it represents the most favorable conditions (Section 5.2).

14. What is the seabed slope at the planned construction site?

    The default value is "low slope," as it represents the most favorable conditions (Section 5.2)

15. What is the depth to seabed at the planned construction site?

    The default value is 10 feet, below the 15-foot threshold value, to represent the most favorable conditions (Section 5.2).

16. What is the transmissivity of the sediments underlying the planned construction site?

    The default value for all SSIs is 100,000 gallons per day per foot (gpd/ft) (13,000 square feet per day (ft^2/d)), above the 88,000 gpd/ft threshold value, to represent the most favorable conditions (Section 5.2).

17. What is the leakance of the sediment overlying the planned SSI site?

    The default value for all SSIs is 0.2 1/d, above the 0.1 1/d threshold value, to represent the most favorable conditions (Section 5.2).

18. What is the typical significant wave height at the planned construction site?

    The default value is 2 feet, below the 3 feet threshold value, to represent the most favorable conditions (Section 5.2).

19. What is the water depth at the seaward end of the gallery?

    The default value is 3 feet, which corresponds to a wave height of 2.34 feet (using the ratio 0.78*depth [NWRI, 2015a]), below the 3 feet threshold value, to represent the most favorable conditions (Section 5.2).

20. What is the water depth at the depth of closure?

    The default value is 5 feet, below the 10 feet threshold value, to represent the most favorable conditions (Section 5.2).

21. What is the distance of the depth of closure from the shore?

    The default value is 500 feet, below the 1,000 feet threshold value, to represent the most favorable conditions (Section 5.2).

22. Has the beach been re-nourished in the last 10 years?

    The default value is "No", as it represents the most favorable conditions (Section 5.2).

23. What is the beach peak annual mean sea level shoreline change?

    The default value is 0 feet, below the 15 feet threshold value, to represent the most favorable conditions (Section 5.2).

24. Is the inland groundwater level of the coastal aquifer above sea water level?

    The default value is "No", as it represents the most favorable conditions (Section 5.2).

25. Is there existing contaminated groundwater in the vicinity (less than 5,000 feet from the planned construction site)?

    The default value is "No", as it represents the most favorable conditions (Section 5.2).

26. Is the planned SSI infrastructure located within an area potentially impacted by sea level rise within 40 years (from project initiation)?

    The default value is "No", as it represents the most favorable conditions (Section 5.2).

27. What is the sedimentation rate at the planned construction site?

    There is no default value for sedimentation rate. The sedimentation rate is used to assess the potential clogging for HDD wells, BIG and SIG. The default value for the potential for clogging is defined by SSIs as follows, as suggested by the IAP (NWRI, 2015b):

    a. The potential for clogging is high for HDD wells, because of their long screen that may pass through zones of varying oxidation conditions (Missimer et al., 2013).
    b. The potential for clogging is low for BIG and SIG, because they produce water mainly by vertical infiltration (ISTAP, 2014).

28. What is the source water turbidity?

    There is no default value for source water turbidity. The source water turbidity is used to assess the potential clogging. The default value for the potential for clogging is defined by SSIs as follows, as suggested by the IAP (NWRI, 2015b):

    a. The potential for clogging is high for vertical well, because of the high likelihood of mixing of seawater and freshwater (Missimer et al., 2013).
    b. The potential for clogging is moderate for slant well
    c. The potential for clogging is moderate for radial collector wells
    d. The potential for clogging is high for HDD wells, because of their long screen that may pass through zones of varying oxidation conditions (Missimer et al., 2013).
    e. The potential for clogging is low for BIG, SIG and DIG, because they produce water mainly by vertical infiltration (ISTAP, 2014).

29. What is the Silt Density Index (SDI_{15}) value of the feed water?

    The default value is 1, below the 2 threshold value, to represent the most favorable conditions.

30. Will the source water be considered extremely impaired source by DDW?

    The default value is “No”, as it represents the most favorable conditions (Section 5.2).

31. What is the Saturation Index of selected precipitates in the source water?

    There is no default value for Saturation Index. The Saturation Index is used to assess the potential clogging. The default value for the potential for clogging is defined by SSIs as follows, as suggested by the IAP (NWRI, 2015b):

    a. The potential for clogging is high for vertical well, because of the high likelihood of mixing of seawater and freshwater (Missimer at al., 2013).
    b. The potential for clogging is moderate for slant well.
    c. The potential for clogging is moderate for radial collector wells.

d. The potential for clogging is high for HDD wells, because of their long screen that may pass through zones of varying oxidation conditions (Missimer et al., 2013).

e. The potential for clogging is low for DIG, because they produce water mainly by vertical infiltration (ISTAP, 2014).

Table 4.—Summary of default input values (in default values and units)

1)	**What is the design intake rate for the project?**		
		N/A	MGD
2)	**Is there a cliff?**		
		No	
3)	**Is the planned construction at an inlet (less than 2,000 feet)?**		
		No	
4)	**What is the depth to bedrock at the planned construction site?**		
		200	ft
5)	**What is the width of the beach at the planned construction site?**		
		500	Ft
6)	**What is the length of the available beach front?**		
		higher than required	ft
7)	**What is the area of available land onshore?**		
		higher than required	sq ft
8)	**What is the area of available land offshore?**		
		higher than required	sq ft
9)	**What is the available area for drilling, construction and staging?**		
		100,000	sq ft
10)	**What is the linear beach front required per unit?**		
	Vertical Wells	100	ft/well
	Slant Wells	600	ft/cluster of 3 wells
	Radial Collectors	350	ft/group of collectors
	HDD Wells	1,400	ft/fan of 10 wells
	BIG	0.0033	ft/sq ft
11)	**What is the area required per unit?**		
	Vertical Wells	250	sq ft
	Slant Wells	5000	sq ft/cluster of 3 wells
	Radial Collectors	5,000	sq ft/group of collector
	HDD Wells	100,000	sq ft/well
	BIG	6,950	sq ft/mgd
	SIG	6,950	sq ft/mgd

Table 4 (continued).—Summary of default input values

12)	**What is the expected capacity per unit?**		
	Vertical Wells	1	mgd/unit
	Slant Wells	5	mgd/cluster of 3
	Radial Collectors	5	mgd/group of collectors
	HDD Wells	3	mgd/well
	BIG	0.1	gpm/sq ft
	SIG	0.1	gpm/sq ft
	DIG	1.8	gpm/ft
13)	**What is the topography in the vicinity of the planned construction site?**		
		flat	
14)	**What is the seabed slope at the planned construction site?**		
		low slope	
15)	**What is the depth to seabed at the planned construction site?**		
		10	ft
16)	**What is the transmissivity of the sediments underlying the planned construction site?**		
	Vertical Wells	100,000	gpd/ft
	Slant Wells	100,000	gpd/ft
	Radial Collectors	100,000	gpd/ft
	HDD Wells	100,000	gpd/ft
	DIG	100,000	gpd/ft
17)	**What is the leakance of the sediment overlying the planned SSI site?**		
	Vertical Wells	0.2	1/d
	Slant Wells	0.2	1/d
	Radial Collectors	0.2	1/d
	HDD Wells	0.2	1/d
	DIG	0.2	1/d
18)	**What is the typical significant wave height at the planned construction site?**		
	BIG	2	ft
	SIG	2	ft
	DIG	2	ft
19)	**What is the water depth at the seaward end of the gallery?**		
	BIG	3	ft

Table 4 (continued).—Summary of default input values

20)	**What is the water depth at the depth of closure?**		
	SIG	5	ft
21)	**What is the distance of the depth of closure from the shore?**		
	SIG	500	ft
22)	**Has the beach been re-nourished in the last 10 years?**		
		No	
23)	**What is the beach peak annual mean sea level (MSL) shoreline change?**		
		0	ft
24)	**Is the inland groundwater level of the coastal aquifer above sea water level?**		
		No	
25)	**Is there existing contaminated groundwater in the vicinity (less than 5,000 ft from the planned construction site)?**		
		No	
26)	**Is the planned SSI infrastructure located within an area potentially impacted by sea level rise within 40 years (from project initiation)?**		
		No	
27)	**What is the sedimentation rate at the planned construction site?**		
	HDD Wells	Potential for clogging is high	mm/yr
	BIG	Potential for clogging is low	mm/yr
	SIG	Potential for clogging is low	mm/yr
28)	**What is the source water turbidity?**		
	Vertical Wells	Potential for clogging is high	NTU
	Slant Wells	Potential for clogging is moderate	NTU
	Radial Collectors	Potential for clogging is moderate	NTU
	Horizontal Wells	Potential for clogging is high	NTU
	HDD Wells	Potential for clogging is low	NTU
	BIG	Potential for clogging is low	NTU
	SIG	Potential for clogging is low	NTU
	DIG	Potential for clogging is low	NTU

Table 4 (continued).—Summary of default input values

29)	**What is the Silt Density Index (SDI_{15}) value of the feed water?**	
	Vertical Wells	1
	Slant Wells	1
	Radial Collectors	1
	HDD Wells	1
	BIG	1
	SIG	1
	DIG	1
30)	**Will the source water be considered extremely impaired source by DDW?**	
		No
31)	**What is the Saturation Index of selected precipitates in the source water?**	
	Vertical Wells	Potential for clogging is high
	Slant Wells	Potential for clogging is moderate
	Radial Collectors	Potential for clogging is moderate
	HDD Wells	Potential for clogging is high
	DIG	Potential for clogging is low

6.4. Additional guidance on data input

1. What is the design intake rate for the project?

   The design intake rate is the source water rate to the intake works. This value is typically double the design treated water rate (Voutchkov, 2013).

2. Is there a cliff?

   The presence of a cliff can be assessed by using aerial photos or maps.

3. Is the planned construction an Inlet (less than 2,000 feet)?

   The presence of an inlet can be assessed by using aerial photos or maps.

4. What is the depth to bedrock at the planned construction site?

   Geological maps or boring logs can be used to retrieve this information. If the depth to bedrock varies at the considered site, it is recommended to use the average value. Using the lowest value would result in potentially overestimating challenges or infeasibility of an SSI, while using the highest value would result in underestimating challenges or infeasibility.

5. What is the width of the beach at the planned construction site?

   The width of the beach can be assessed by using aerial photos or maps. It is recommended to use aerial photos from multiple time periods to assess the width of the beach to better take into account the tidal effect. If the width of the beach varies temporarily at the considered site, it is recommended to use the lowest value. If the width of the beach varies spatially along the coastline, it is recommended to use the average value.

6. What is the length of the available beach front?

   The length of the available beach front can be assessed by using aerial photos or maps.

7. What is the area of available land onshore?

   The available land onshore can be assessed by using aerial photos or maps.

8. What is the area of available land offshore?

   The available land offshore can be assessed by using ocean floor maps and maps of offshore outlets. Ocean floor maps are available on the National Centers for Environmental Information from NOAA (http://www.ngdc.noaa.gov). A link to this website is provided in the "Additional Info" tab in the Tool.

9. What is the available area for drilling, construction and staging?

   The available area can be assessed by using aerial photos or maps.

10. What is the linear beach front required per unit?

    The linear beach front required per unit depends mainly on the spacing required between two units for well-based SSIs. The spacing needed between two units can be assessed based on expected capacity per unit and characterization of the subsurface hydrogeology.

11. What is the area required per unit?

    The area required per unit depends mainly on the spacing required between two units for well-based SSIs. The user should ensure that the values entered in Inputs #11 and #12 are consistent and realistic, as the area is the required length multiplied by the required width.

12. What is the expected capacity per unit?

    The expected capacity per unit can be assessed based on characterization of the subsurface hydrogeology. The values entered in this field should be consistent with the values entered for transmissivity (Input #16) and leakance (Input #17), i.e., if transmissivity and leakance are low, the expected capacity per unit should also be lower than the default value.

13. What is the topography in the vicinity of the planned construction site?

    The topography can be assessed by using aerial photos, maps, or digital elevation model from USGS' National Elevation Dataset (http://nationalmap.gov/elevation.html).

14. What is the seabed slope at the planned construction site?

    The available land offshore can be assessed by using ocean floor maps. Ocean floor maps are available on NOAA's National Centers for Environmental Information (http://www.ngdc.noaa.gov). A link to this website is provided in the "Additional Info" tab in the Tool. A slope of 5 degrees or less is considered "low", a slope between 5 and 10 degrees is considered "moderate" and a slope above 10 degrees is considered "high".

15. What is the depth to seabed at the planned construction site?

    The available land offshore can be assessed by using ocean floor maps. If the depth to seabed varies at the considered site, it is recommended to use the average value. Using the lowest value would result in potentially overestimating challenges of an SSI, while using the highest value would result in underestimating challenges.

16. What is the transmissivity of the sediments underlying the planned construction site?

    The transmissivity can be estimated from geological description, grain size analysis, pumping tests, regional estimates. A different value for different SSIs can be entered to account for the fact that SSIs may not be constructed in the same formation. If the transmissivity varies at the considered site, it is recommended to use the average value. The transmissivity of the sediments underlying the planned construction site controls the expected capacity for each SSI, therefore the value for transmissivity should be consistent with the value entered for the anticipated capacity per unit (Input # 12). Specifically, if a value different than the default value is used for the transmissivity, the user should consider updating the anticipated capacity per unit.

17. What is the leakance of the sediment overlying the planned SSI site?

    The leakance can be estimated from geological description, grain size analysis, pumping tests, regional estimates. A different value for different SSIs can be entered to account for the fact that SSIs may not be constructed in the same formation. If the leakance varies at the considered site, it is recommended to use the average value. The leakance of the sediments overlying the SSI controls the expected capacity of the SSI, therefore the value for leakance should be consistent with the value entered for the anticipated capacity per unit (Input #12). Specifically, if a value different than the default value is used for the leakance, the user should consider updating the anticipated capacity per unit. The user should ensure that the values entered in Inputs #16 and #17 are consistent.

18. What is the typical significant wave height at the planned construction site?

    The significant wave height is the average of the highest one third of wave heights for 30 year record. Wave information can be obtained from the USACE's Wave Information Studies website (http://wis.usace.army.mil/).A link to this website is provided in the "Additional Info" tab.

19. What is the water depth at the seaward end of the gallery?

    This input is only used to estimate the significant wave height for the BIG, if a value is not provided in Input #18. The water depth can be assessed based on ocean maps.

20. What is the water depth at the depth of closure?

    The depth of closure can be assessed by conducting a wave climate analysis.

21. What is the distance of the depth of closure from the shore?

    The depth of closure can be assessed by conducting a wave climate analysis.

22. Has the beach been re-nourished in the last 10 years?

    Historical aerial photos can be used to assess whether the beach has been re-nourished.

23. What is the beach peak annual mean sea level shoreline change?

    The beach peak annual mean sea level shoreline change can be assessed based on historical aerial phots.

24. Is the inland groundwater level of the coastal aquifer above sea water level?

    The inland groundwater level can be assessed using water level contour maps of coastal aquifer or water level at wells screened in the coastal aquifers. In California, water levels are available from the California Department of Water Resources' website (http://www.water.ca.gov/groundwater/casgem). A link to this website is provided in the "Additional Info" tab.

25. Is there existing contaminated groundwater in the vicinity (less than 5,000 feet from the planned construction site)?

    The presence of contaminated groundwater in the vicinity can be assessed based on public databases. In California, Geotracker website from the State Water Board provides information on cleanup sites (http://geotracker.waterboards.ca.gov/). A link to this website is provided in the "Additional Info" tab.

26. Is the planned SSI infrastructure located within an area potentially impacted by sea level rise within 40 years (from project initiation)?

    The USACE's Climate Change Adaptation website (http://www.corpsclimate.us/cca.cfm) provides a tool to perform screening-level assessments of the vulnerability of projects to the effects of changing sea levels.

27. What is the sedimentation rate at the planned construction site?

    If site-specific data are not available for sedimentation rate, it can be assessed qualitatively. For example, sedimentation rate is generally high in the vicinity of the wastewater outfalls (Farnsworth and Warrick, 2007).

28. What is the source water turbidity?

    If site-specific data are not available for source water turbidity, it can be assessed qualitatively. For example, source water turbidity is generally high in areas significant fine-grained sediments.

29. What is the Silt Density Index (SDI_{15}) value of the feed water?

    Typical seawater SDI values are generally greater than 10 (Missimer et al., 2013), and SDI of the feed water is expected to be below SDI of seawater, because of the filtration of the sediments.

30. Will the source water be considered extremely impaired source by DDW?

    The presence of contaminated groundwater in the vicinity of the planned construction site would indicate the source water may be considered extremely impaired source. Therefore the user should ensure that values for Inputs #25 and 30 are consistent. Other criteria can be used to assess the potential of the source water to be considered extremely impaired, such as contaminated sediments on the sea floor, presence of wastewater outfalls in the vicinity.

31. What is the Saturation Index of selected precipitates in the source water?

    Concentrations of manganese, iron, oxygen, calcium, and bicarbonate can be used to assess the saturation index of manganese oxides, iron oxides or calcium carbonate.

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