Overview of impacts of ocean intakes on the marine environment, mitigation strategies, and implications of the new California policy regarding ocean intakes

Peter Raimondi
Department of Ecology and Evolutionary Biology
UC Santa Cruz

with material from

John Steinbeck
Tenera Environmental

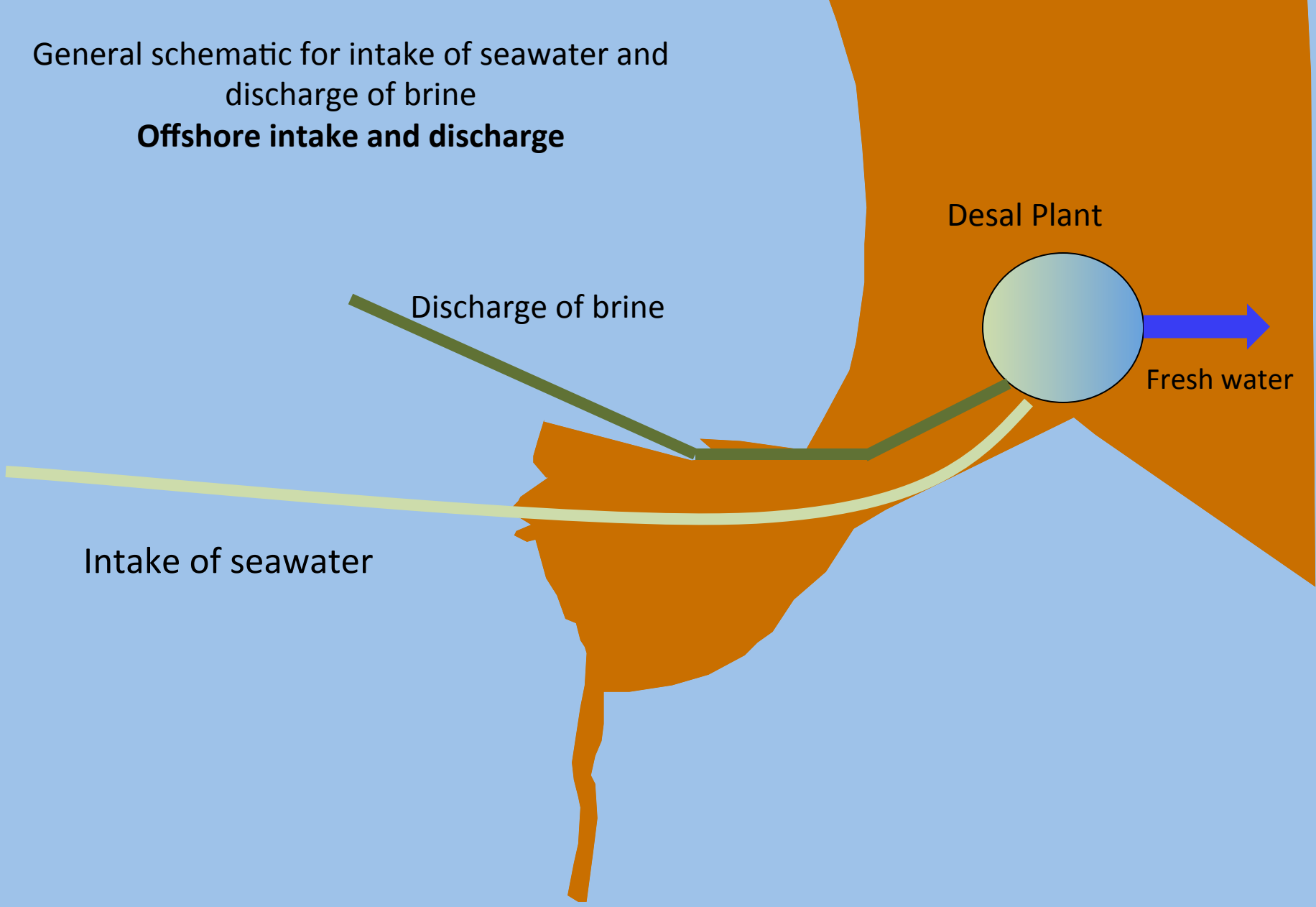
Topics

- Comparison of seawater intake approaches.
- Adequacy of existing data, studies, and other information for understanding impact of open water intakes
- Impacts and Mitigation
  - Experience in California with marine impacts of ocean water intakes, including desalination facilities and power plants.
- California policies and regulations, including compensatory mitigation frameworks and assessment of gaps.

First the big question – why not simply do open water intakes and discharges?

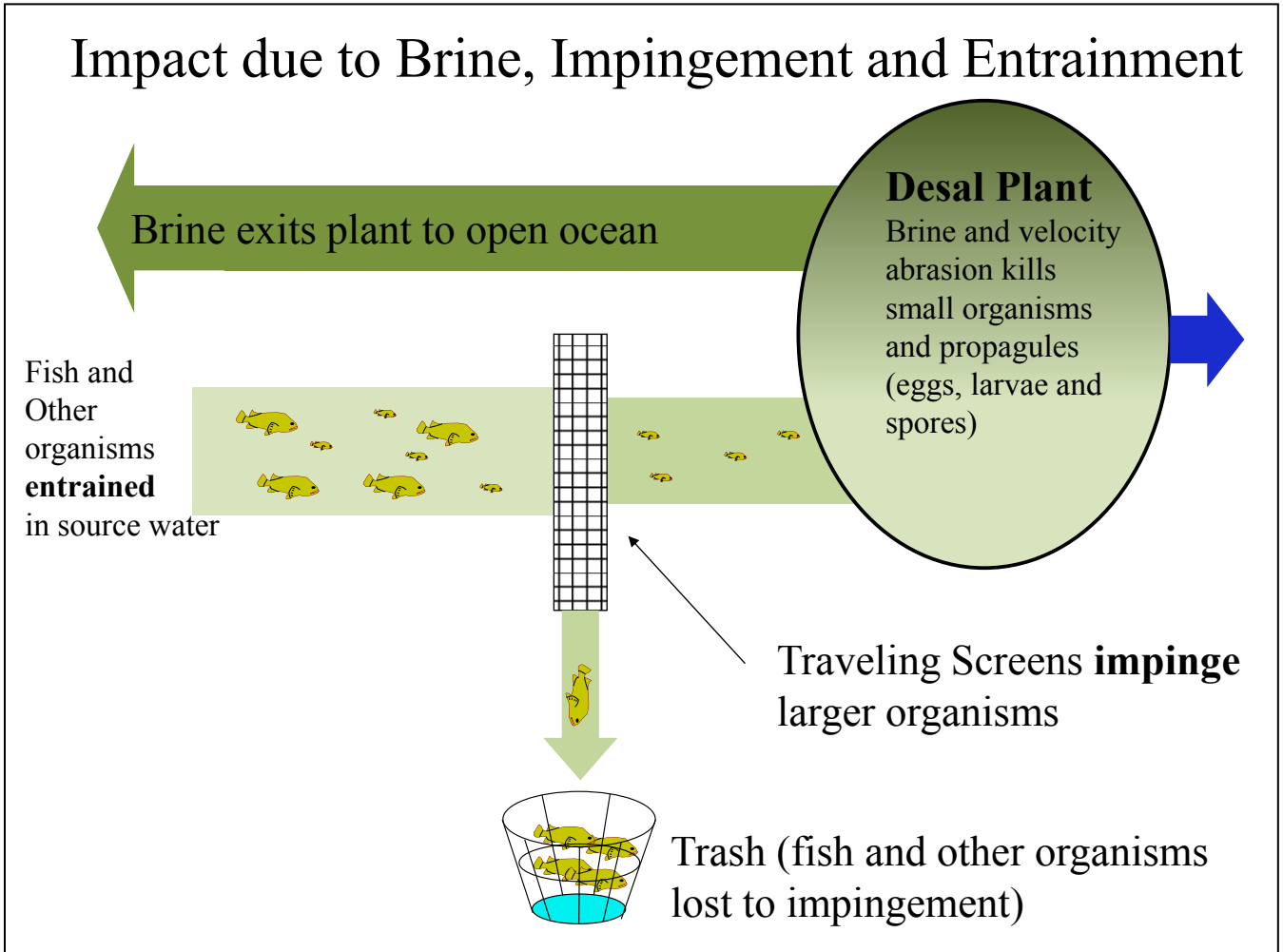
General schematic for intake of seawater and discharge of brine

Offshore intake and discharge



Entrainment is the most important marine concern (biological) with open water intakes

Impingement avoidance has been pretty well worked out



Intake option for collection of ocean water

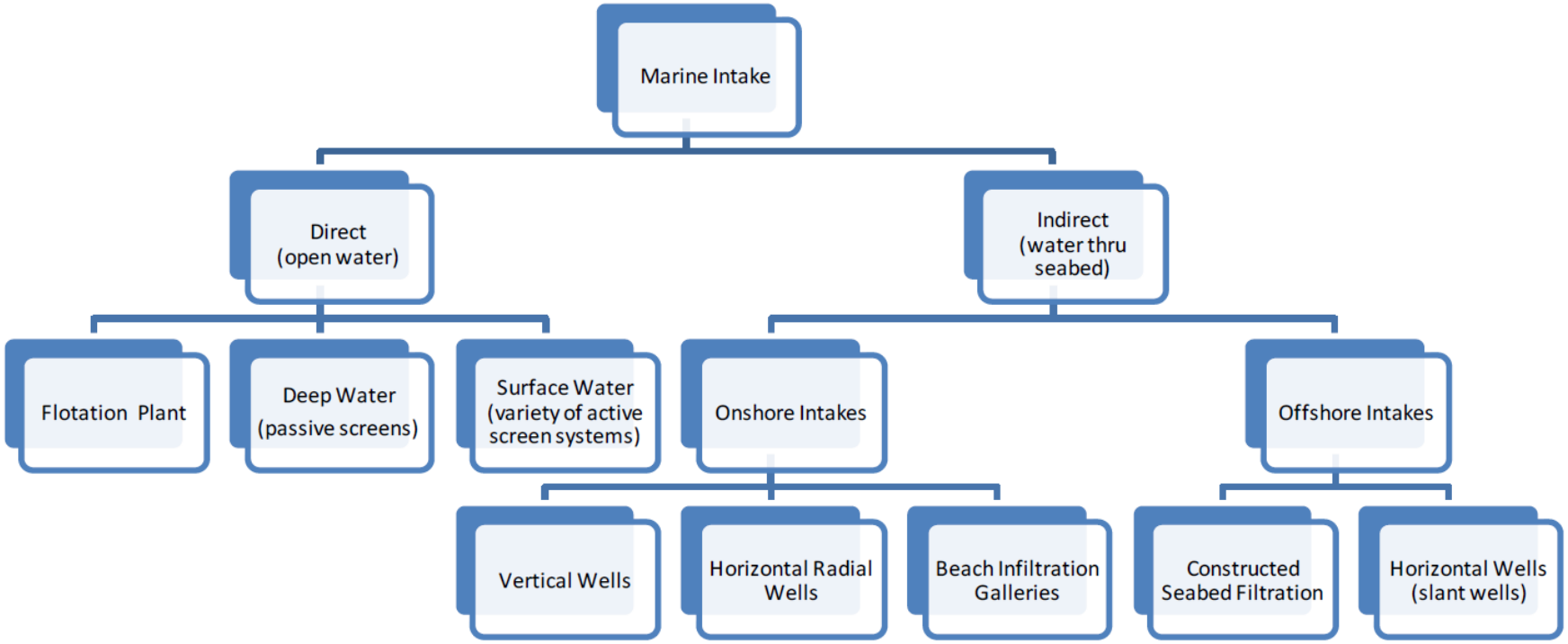
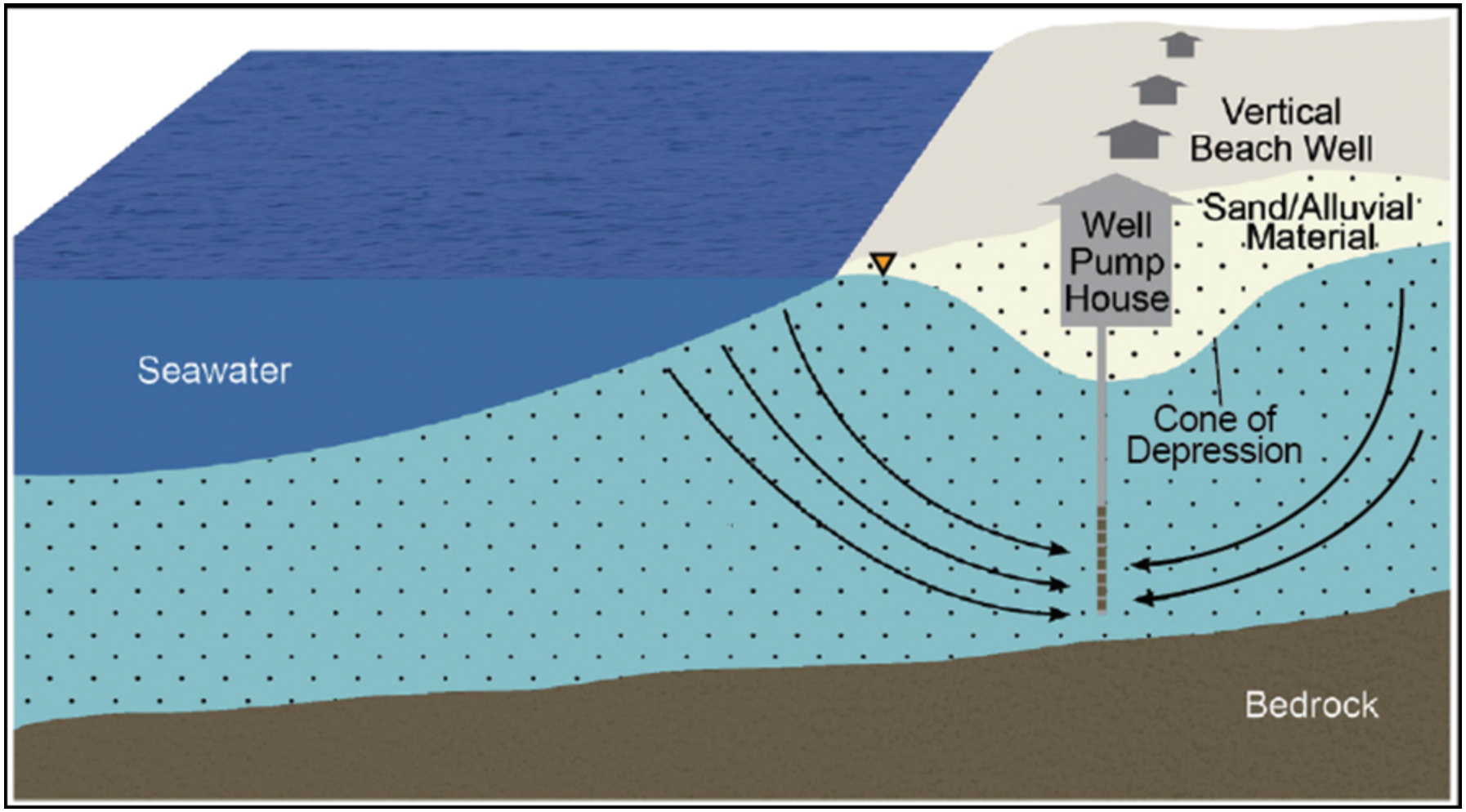


Figure 1. Flow chart showing various options for desalination plant ocean intakes. Adapted from presentation by Tom Pankratz, Global Overview of Seawater Desalination Intake Issues at Alden Desalination Intake Solutions Workshop, 16 October 2008.

Comparison of Desalinization plants

Type	Production	Total units or area (hypothetical 100 MGD plant)	Likely Marine Impact	Likely Terrestrial Impact	Best use
Vertical Beach Wells					
Horizontal Beach Wells					
Infiltration Galleries					
Seabed Filtration					
Slant Wells					
Open water intake					

Vertical Beach Wells



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Horizontal Beach Wells

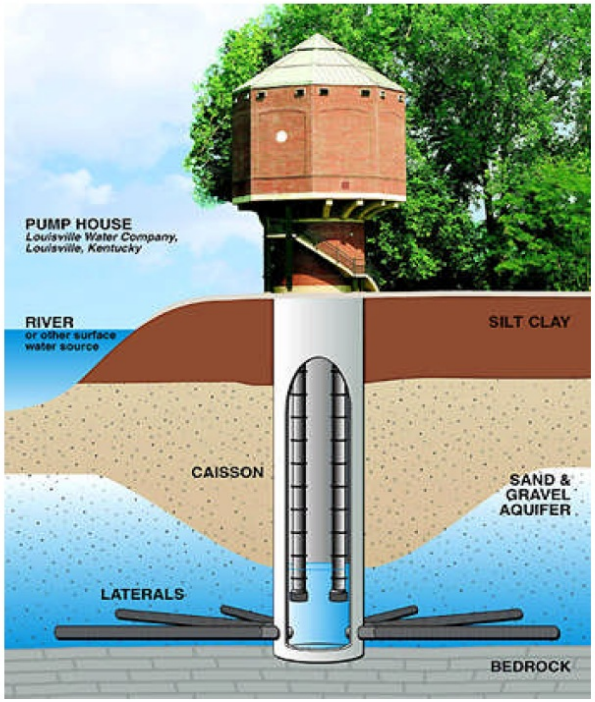


Figure 1 – Horizontal (Ranney) Beach Well

Figure 2 – 3.8 MGD Horizontal Seawater Intake Beach Well

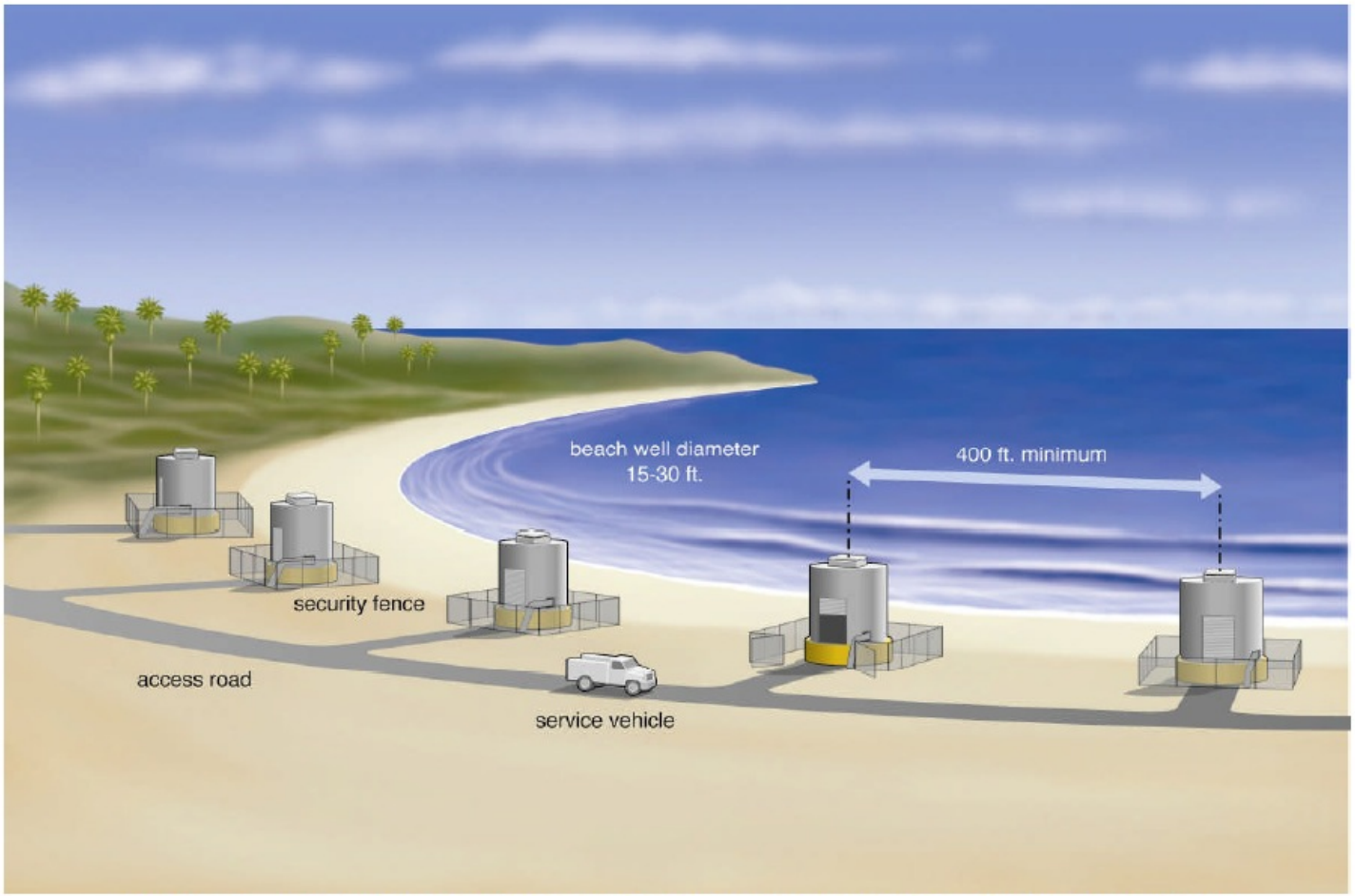
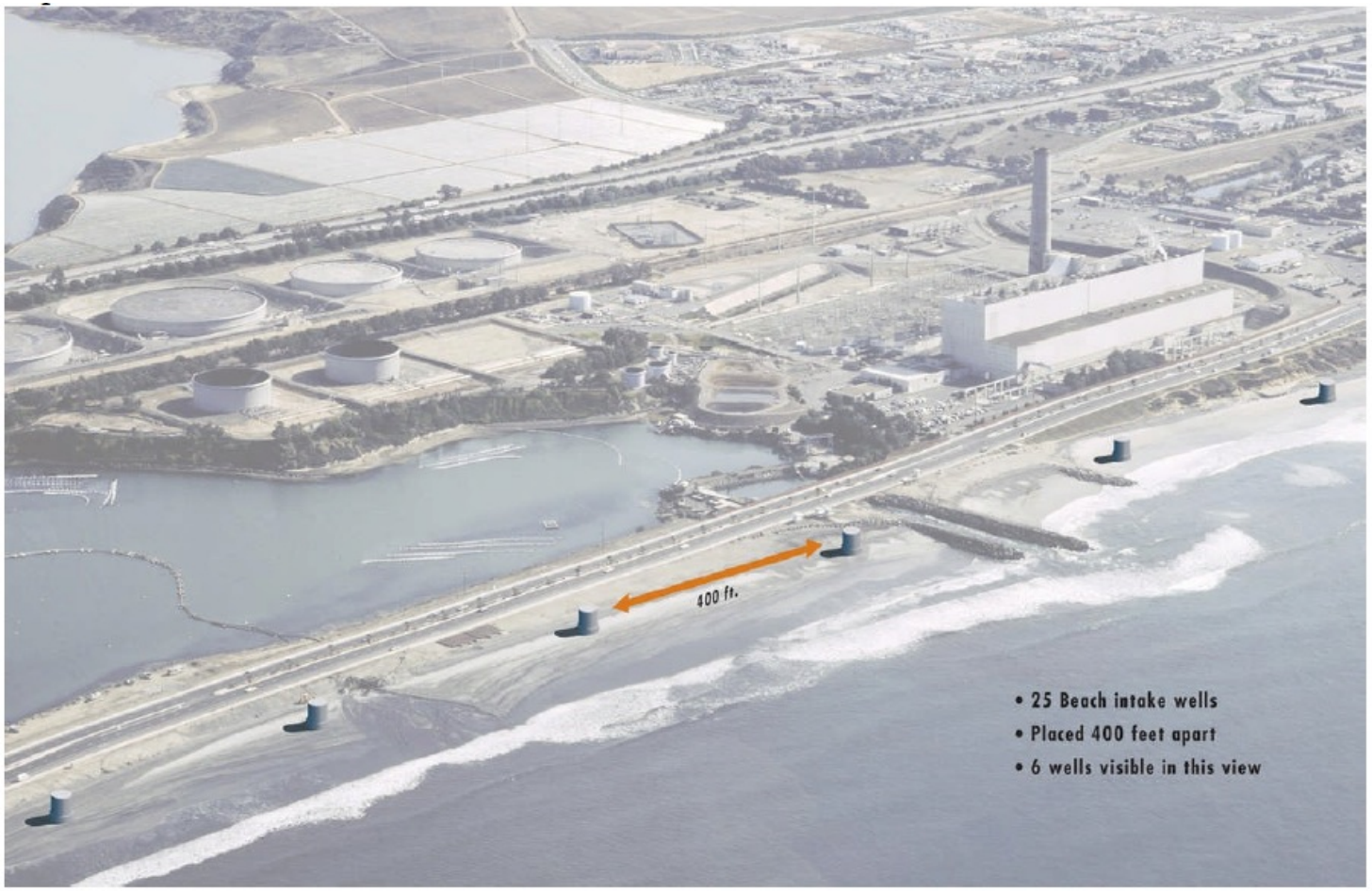


Figure 3 – A Horizontal Beach Well System for 10 MGD Desalination Plant

Potential plant (100 MGD) using beach wells (actual length would be 4 miles)



Potential (100 MGD) using infiltration galleries (actual length would be 4.7 miles)

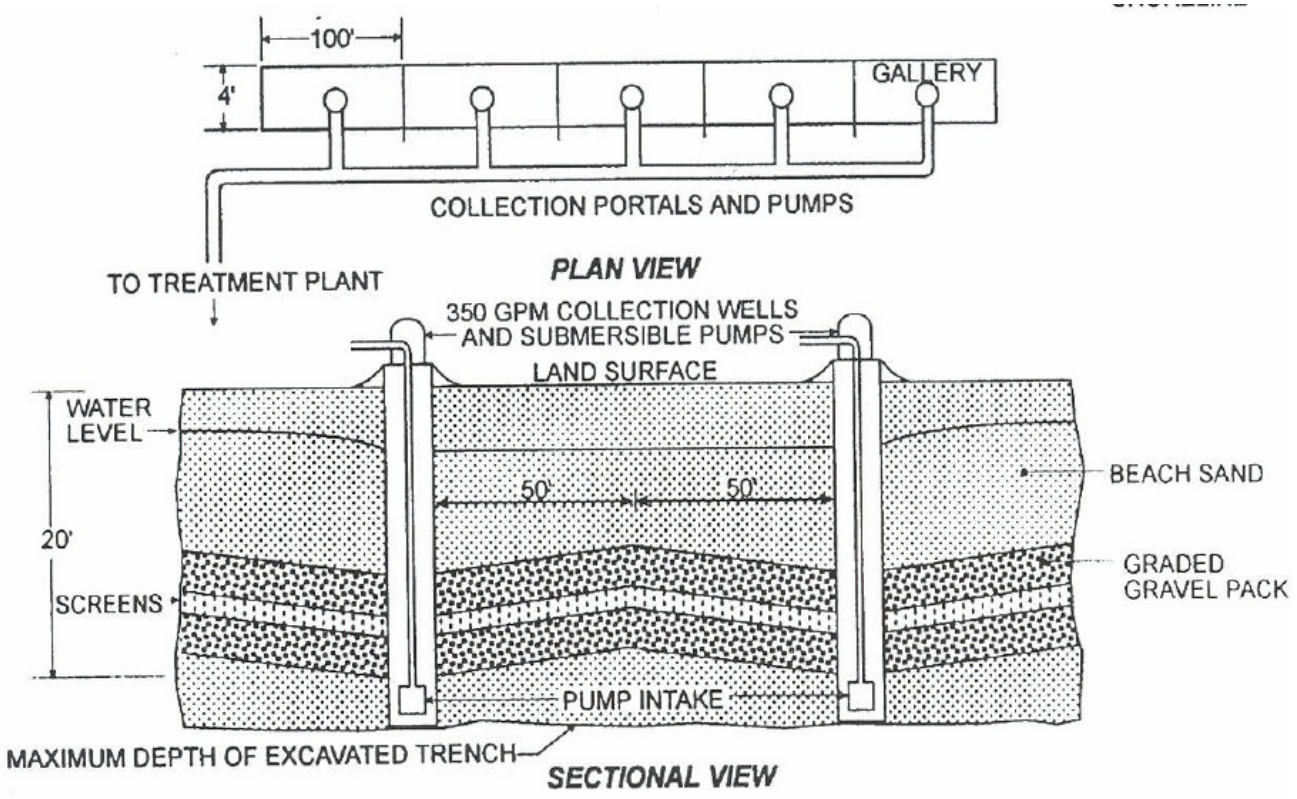


Figure 5 – Infiltration Gallery

Comparison of Desalinization plants

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Seabed Filtration					
Slant Wells					
Open water intake					

Potential plant (100 MGD) using seabed filtration system (actual area would be ~24 acres)

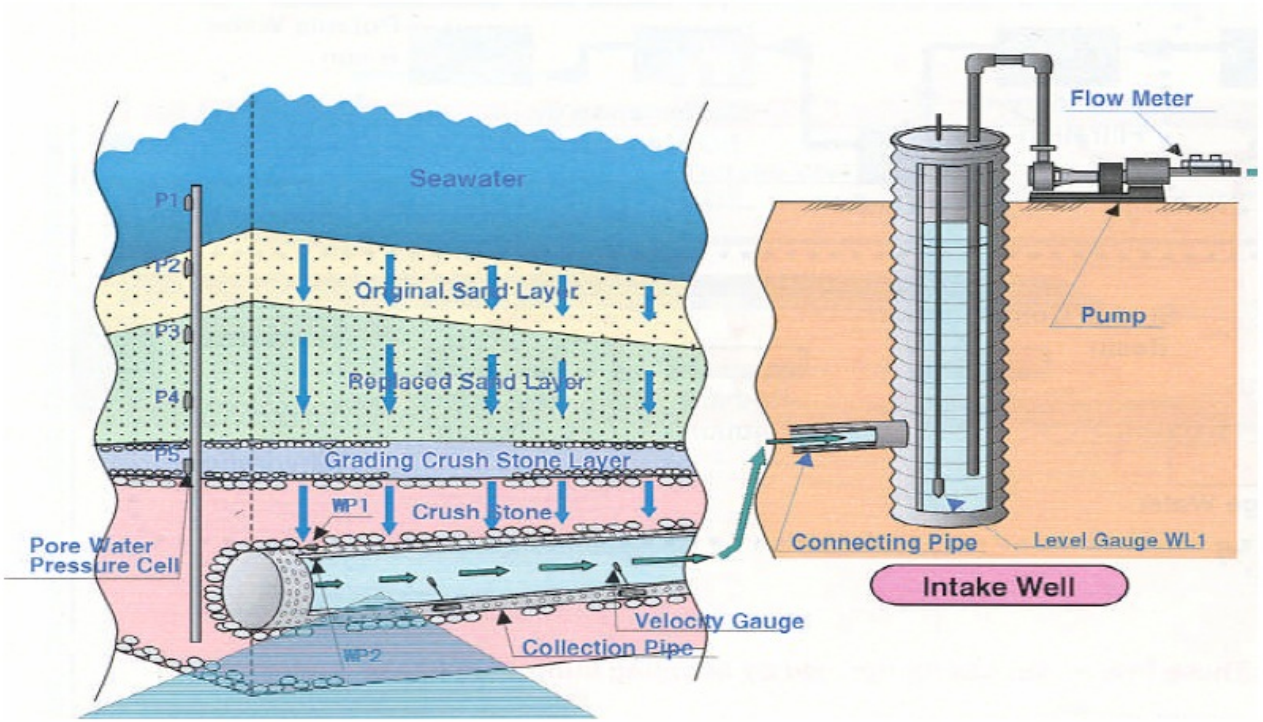


Figure 7 – A Cross-Section of a Seabed Intake System

Potential plant (100 MGD) using seabed filtration system (actual area would be ~24 acres)

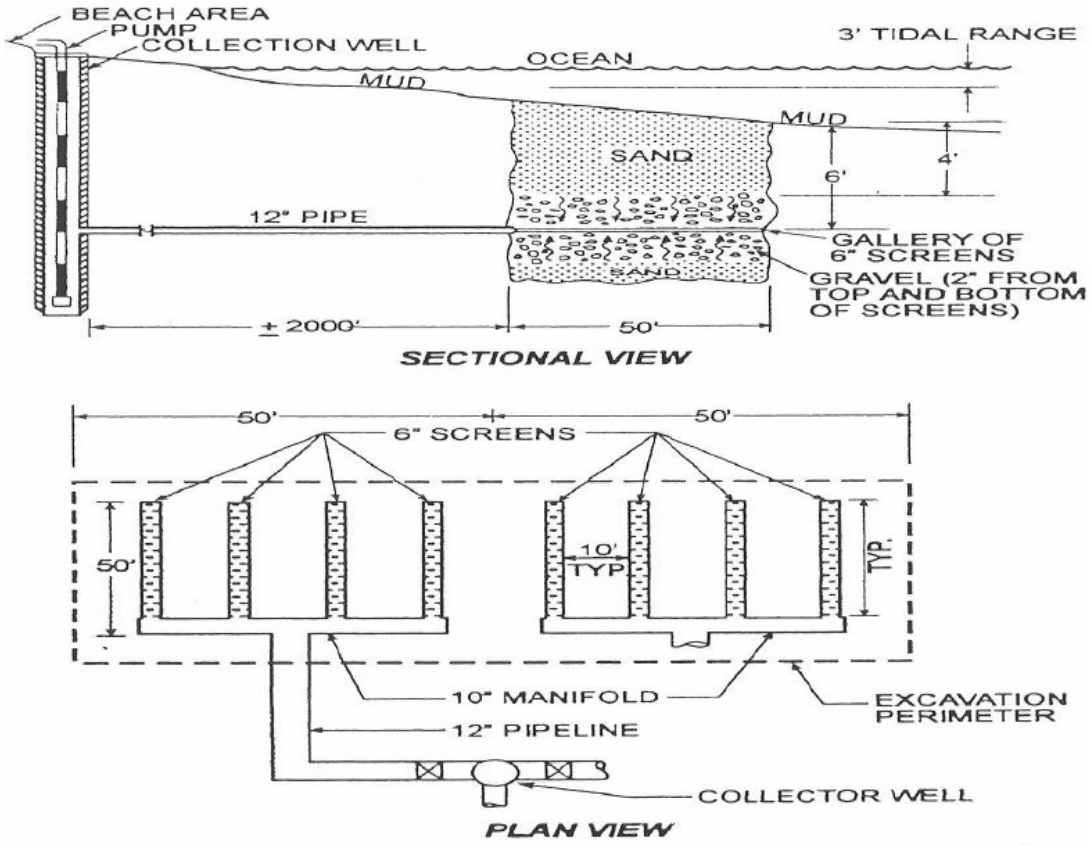
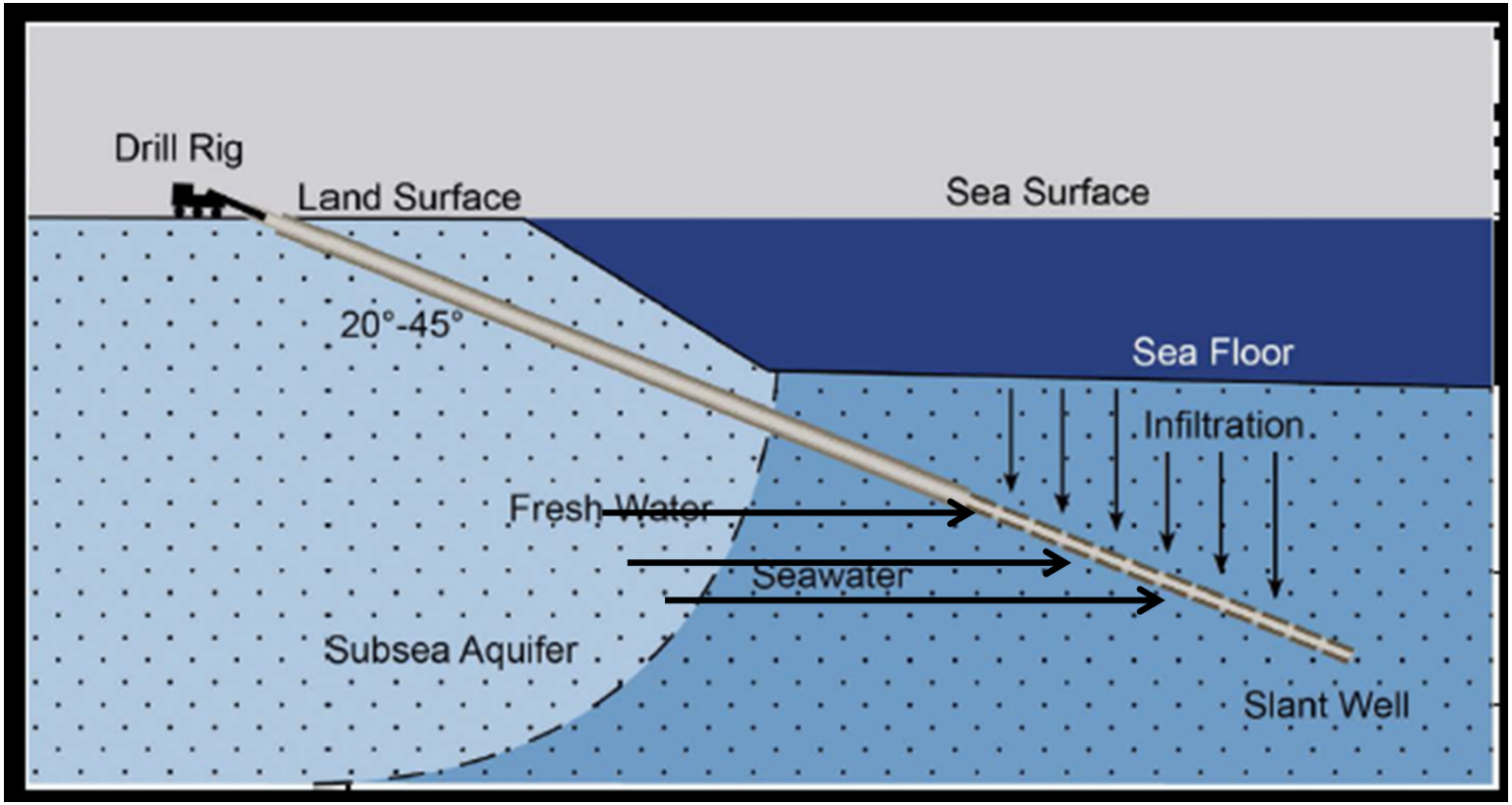


Figure 6 – Seabed Filtration System

Slant beach well system



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Entrainment is the most important marine concern (biological) with open water intakes

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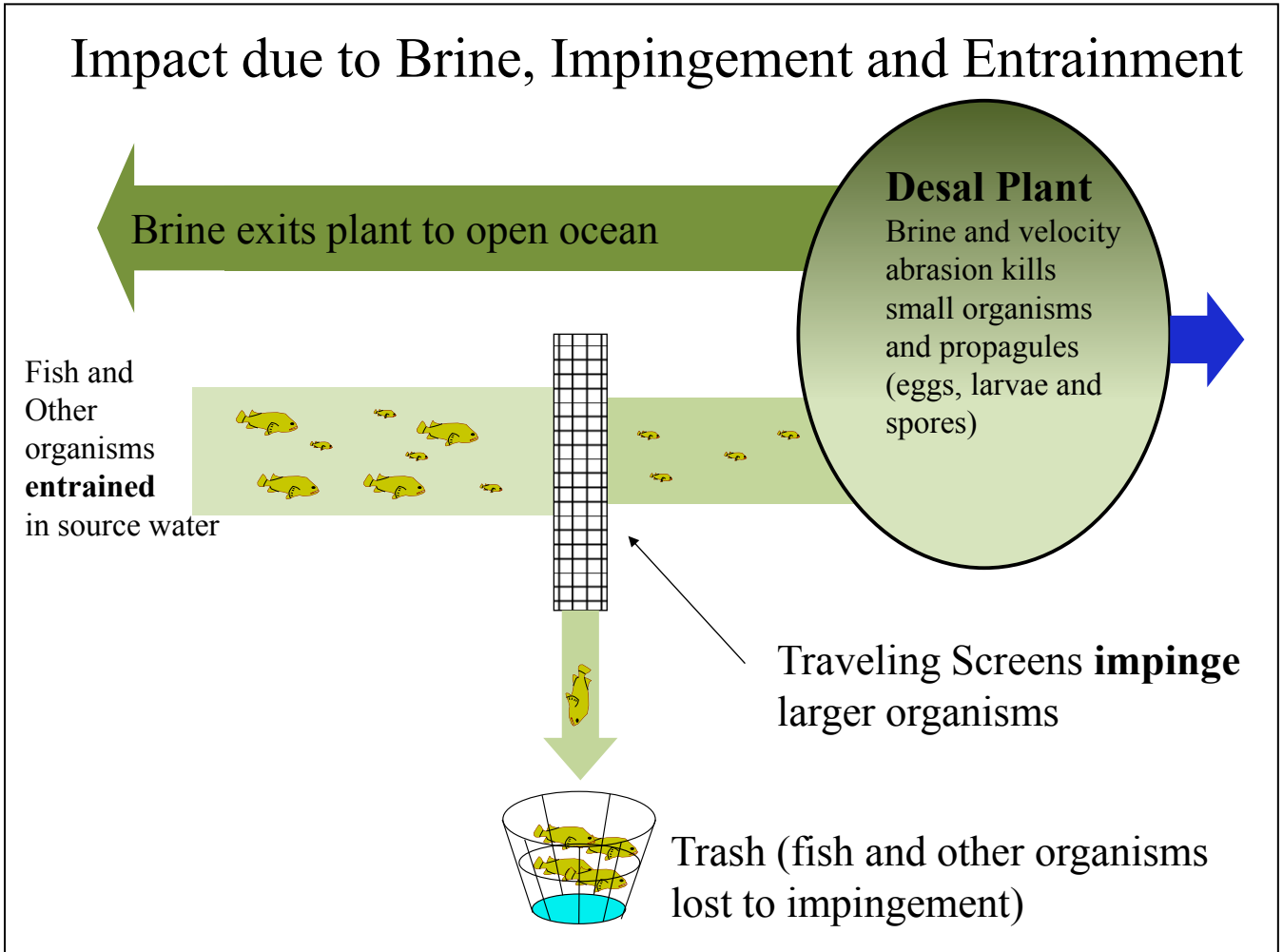
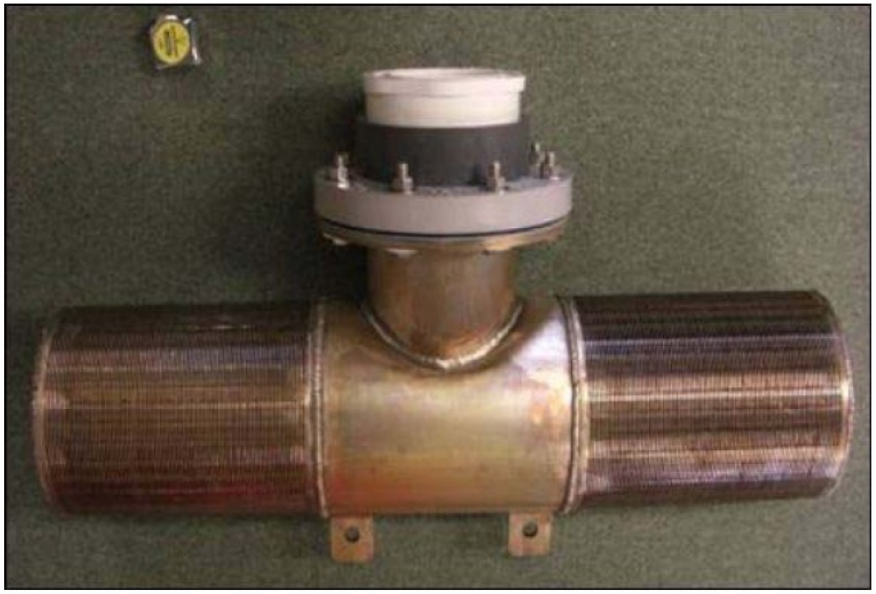


Avoidance of impingement entrainment in open water intakes

Type	Method	Technologies	Reduction or Avoidance Potential	
			Impingement	Entrainment
Physical Barriers	Reduction of velocity. Impeding Intake.	Wedgewire screens, Fine Mesh Screens, Barrier nets and Filter Barriers	Yes	In some cases
Collection and Return Systems	Collection from screens or diversions	Ristroph screens Fine Mesh Screens	Yes	In some cases
Diversion Systems	Diversion systems and collection	Fish elevators or sluice returns	Yes	No
Behavioral approaches	Direct individuals away from intake or in plant screens	Velocity caps Acoustic Barriers Strobe lights Bubble curtains	In some cases	In some cases and only for some species

Wedgewire Screens



Source: Tenera Environmental

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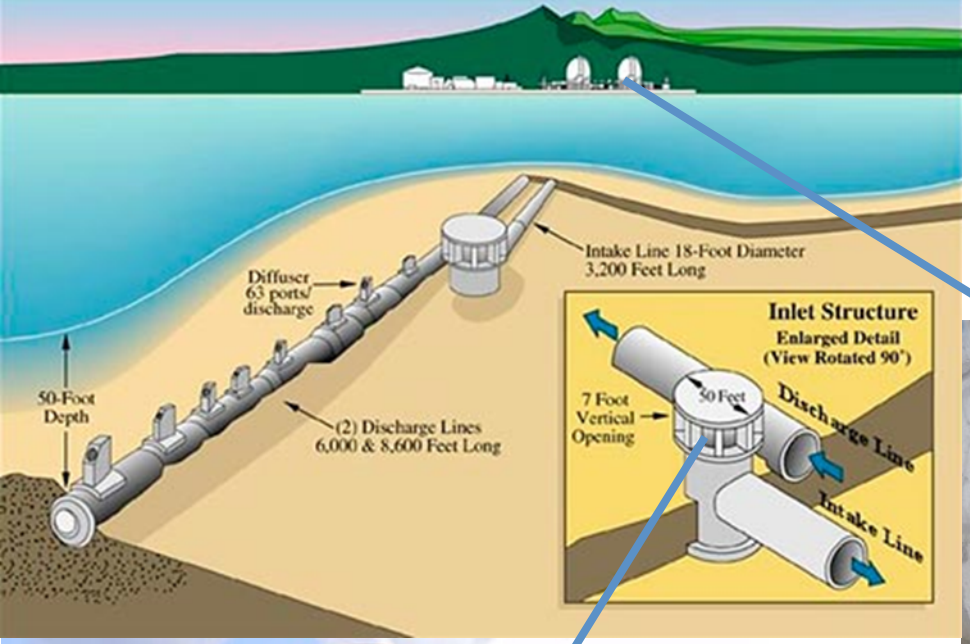
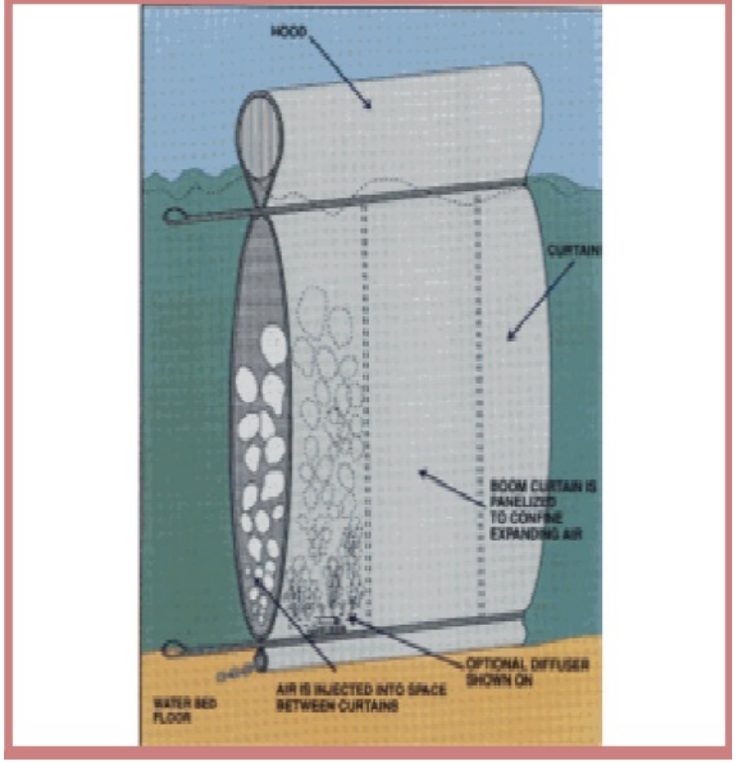
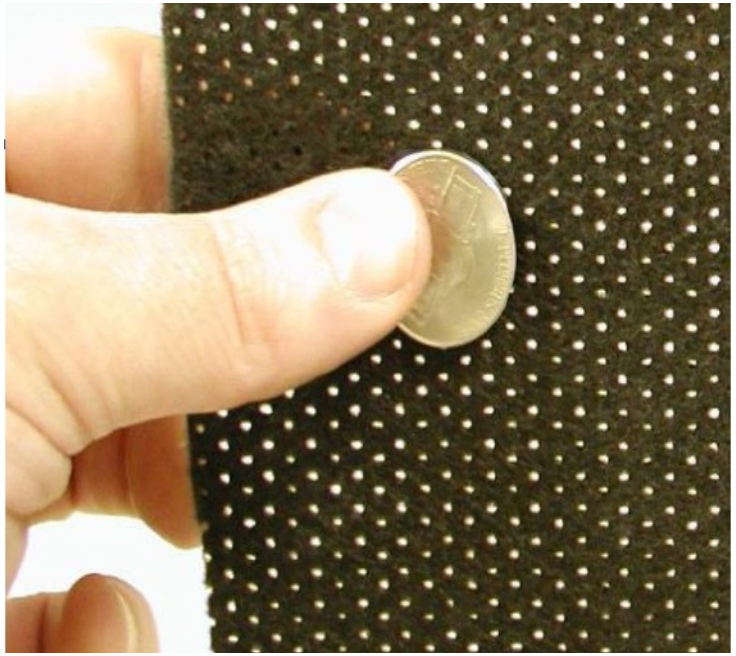
Figure 8 – Rockfish Sitting on Screen

Course and finer barriers

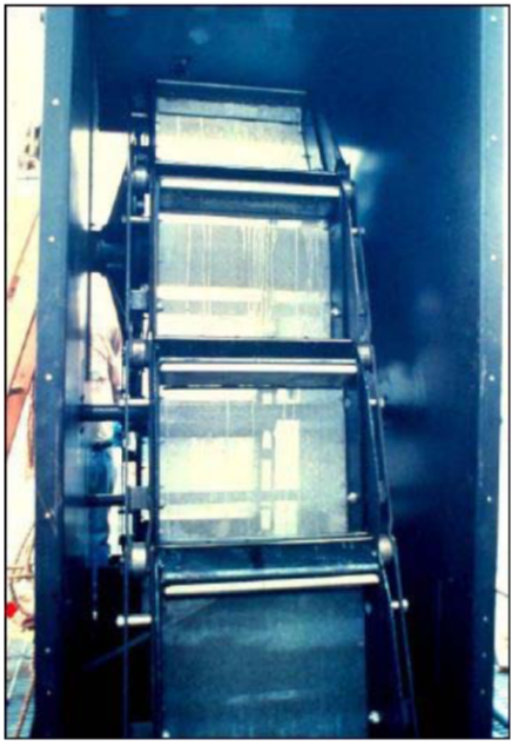


Gunderboom Nets





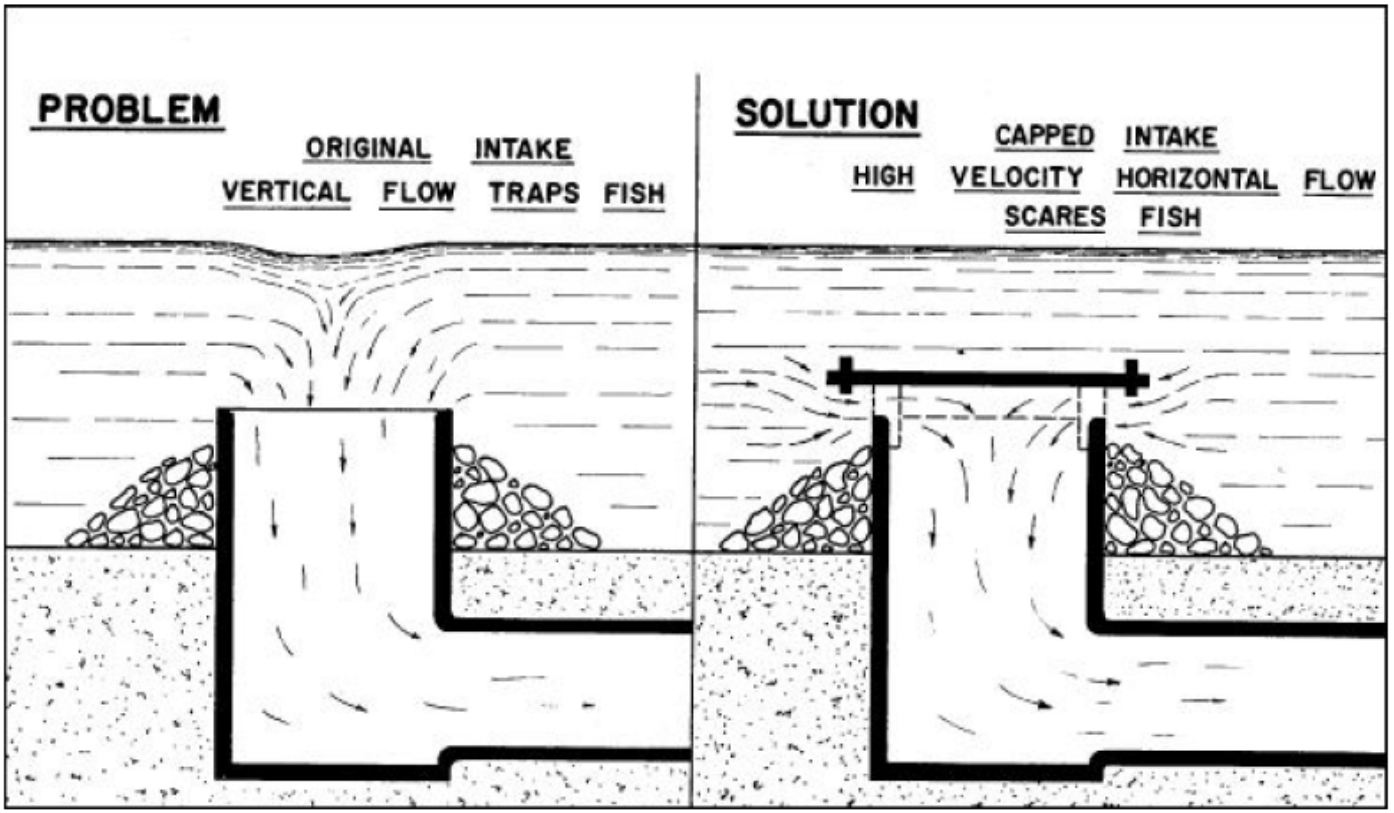
Traveling screens



Source: Water Globe Consulting

Figure 13 – 0.5 mm Fine Mesh Screens of the Tampa Bay Power Plant Intake

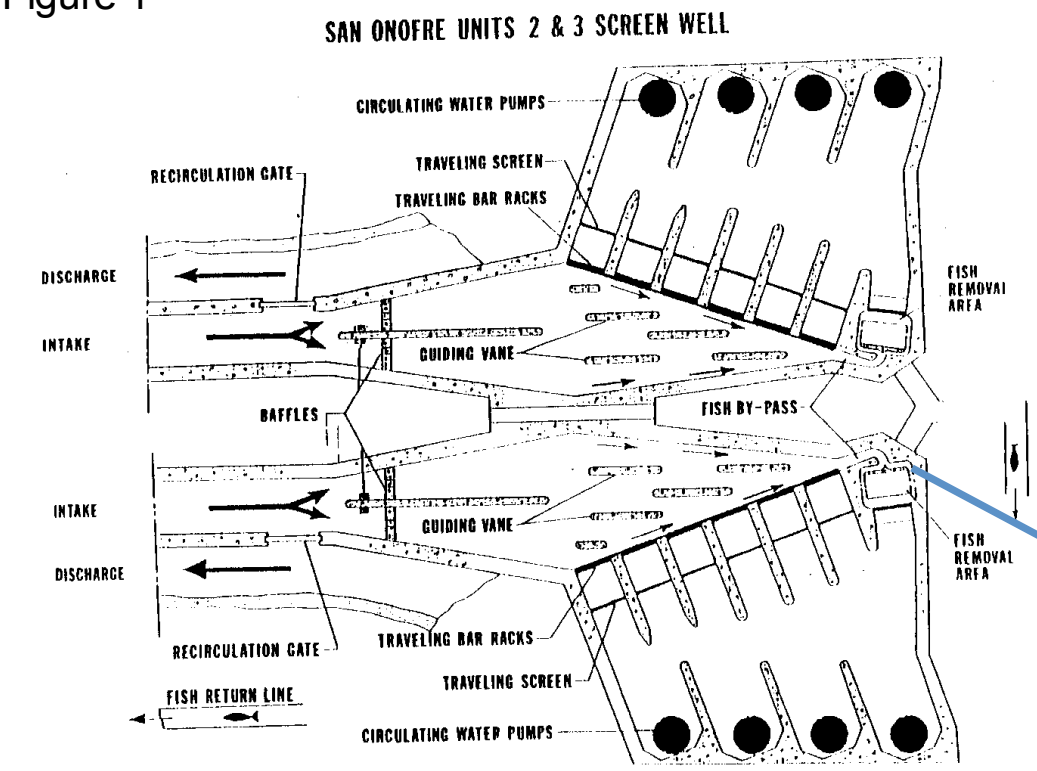
Velocity Caps (can also be configured to reduce flow)

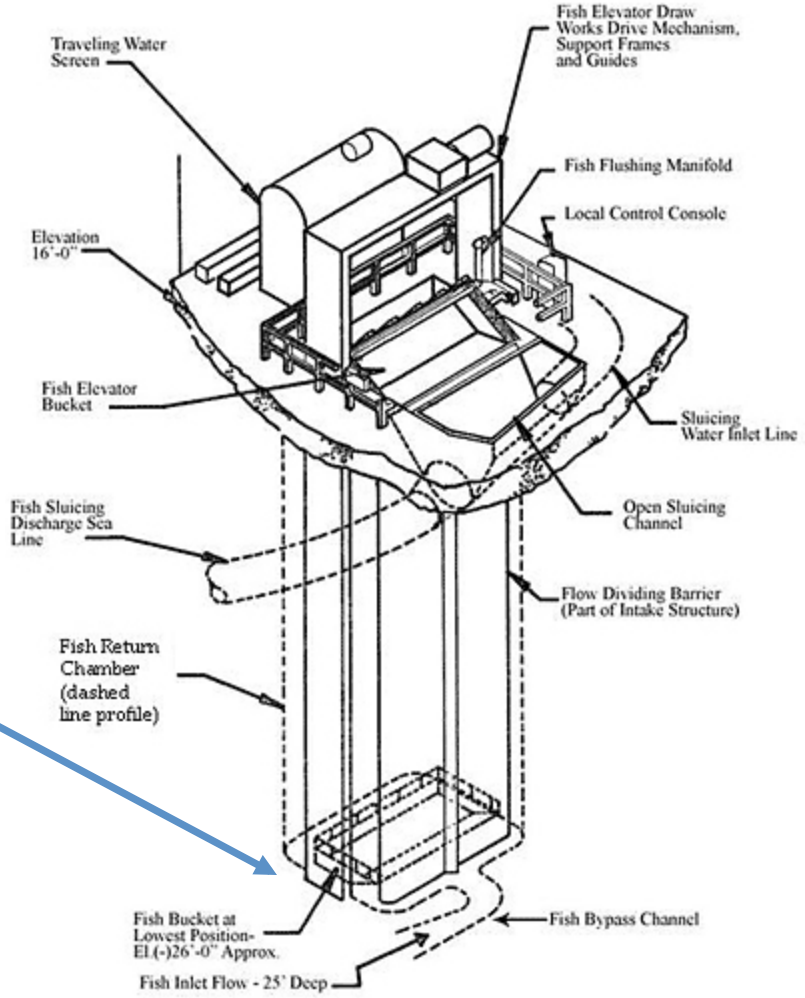


Source: US EPA

Fish return system

Figure 1





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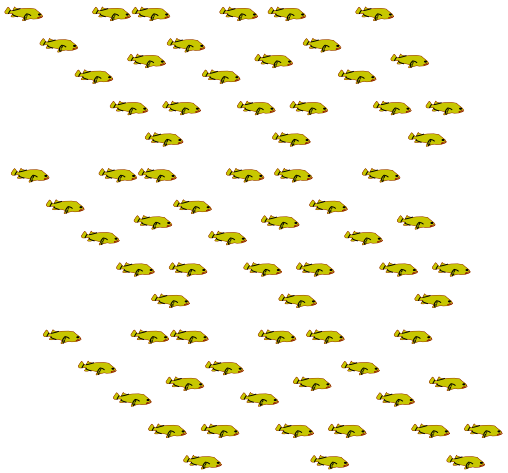
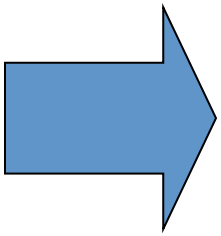
Slant Wells					Small plant, local distribution of fresh water
Open water intake	Can be very large		Potentially high	Low depending on location of plant	Large plant, broad distribution of fresh water

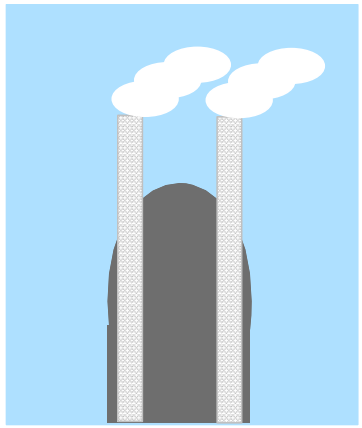
Estimation of Ecological Effects due to Entrainment

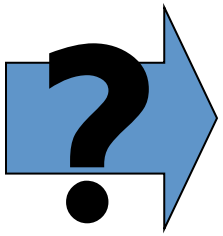
- Life history of most entrained organisms
- Methods of Estimation
  - **Fecundity Hindcast (FH)**
    - **Need estimate of average fecundity per female**
    - **Need estimate of mortality between reproduction and entrainment –**
  - **Adult Equivalent Loss (AEL)**
    - **Need estimate of mortality between entrainment and maturity for most species –**
  - **Proportional Mortality (ETM / PM)**
    - Area of Production Foregone (APF)
    - Mitigation estimation using ETM/APF

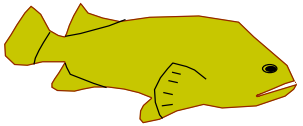
Importance of larval losses due to entrainment









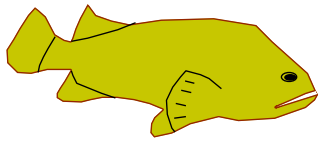


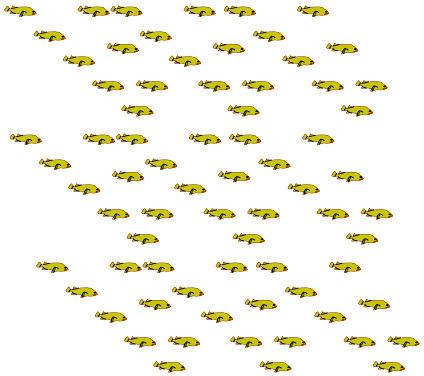
Larvae

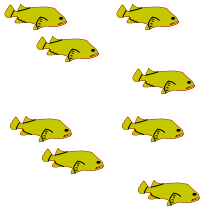
Loss of ????Adult fish

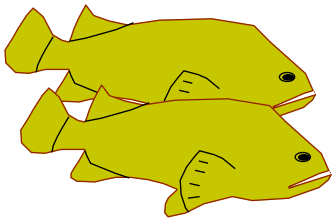
Question: How to estimate losses to adult populations?

Typical reproduction and survivorship for larval producing organisms







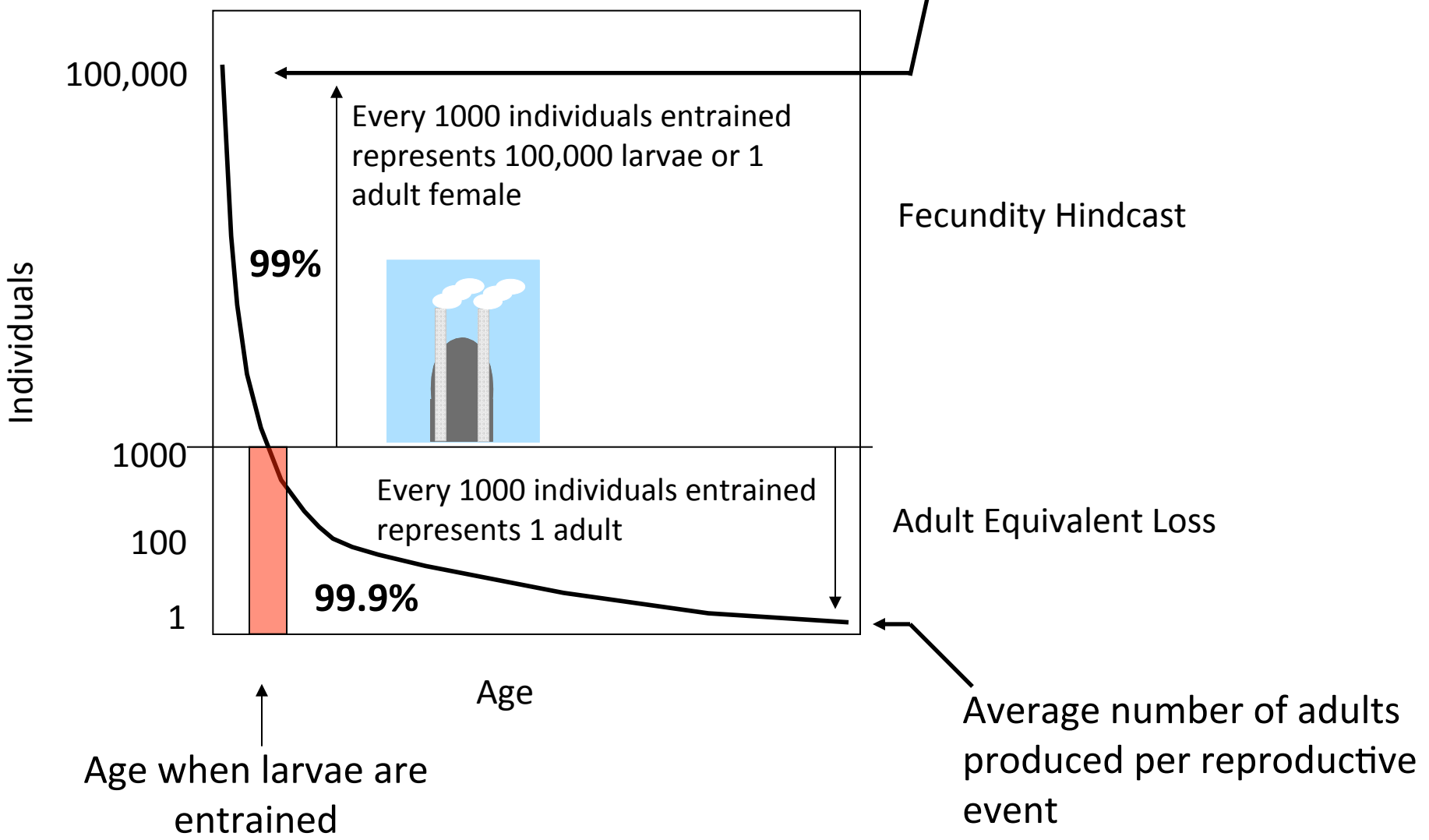


1 female → 100,000 larvae → 100 juveniles → 2 adults

99.9% 98%

Mortality Rate

Estimation of Adult Losses



Estimation of Ecological Effects due to Entrainment

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- Methods of Estimation
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  - **Adult Equivalent Loss (AEL)**
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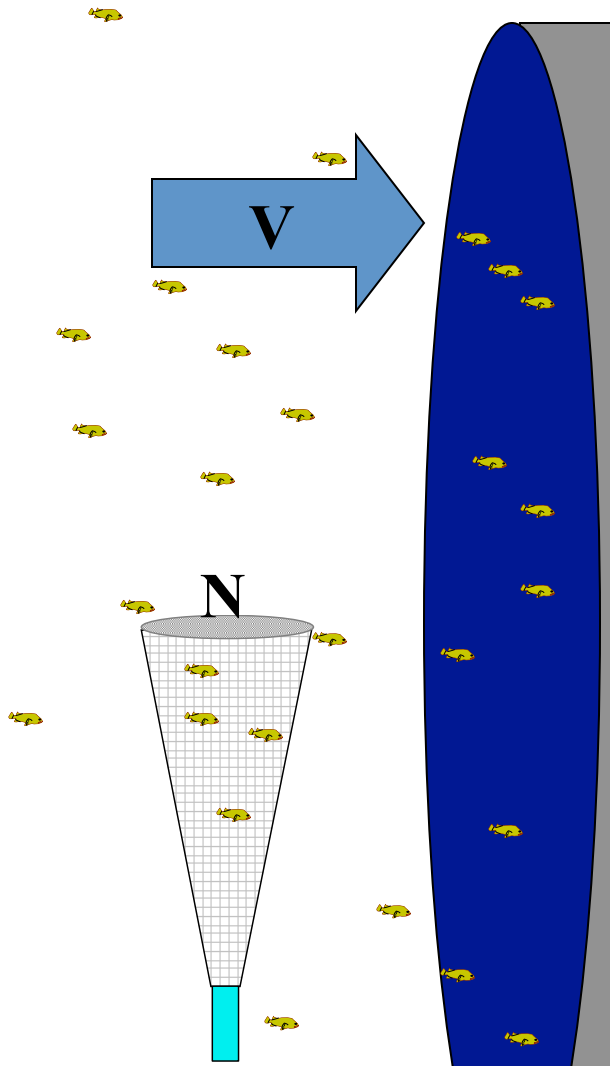
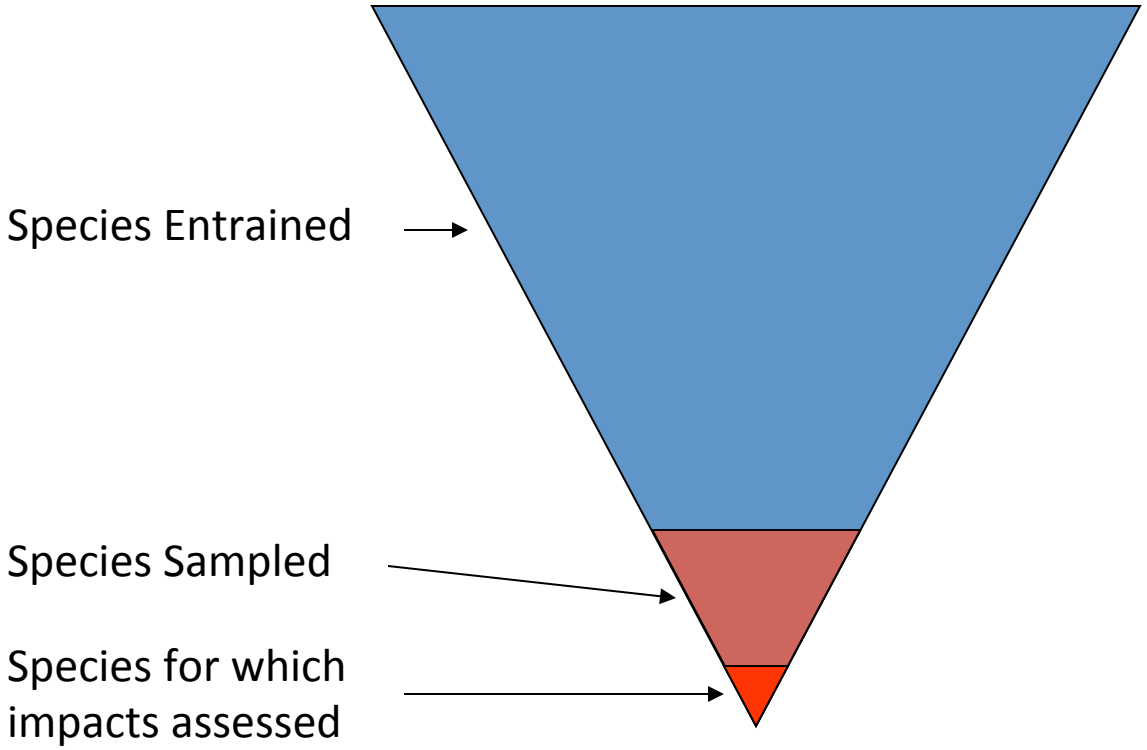
  - **Proportional Mortality (Empirical Transport Model - ETM / leading to Proportional Mortality - PM)**
    - Area of Production Foregone (APF)
    - Mitigation estimation using ETM/APF

Estimation of larval losses due to entrainment



1. Calculate volume of water entering the plant per year (V)
2. Measure concentration of larvae (number per volume) that are entrained (N)
3. ***Assume no survival of larvae through the plant*** – then
4. NV = the annual loss of larvae due to entrainment

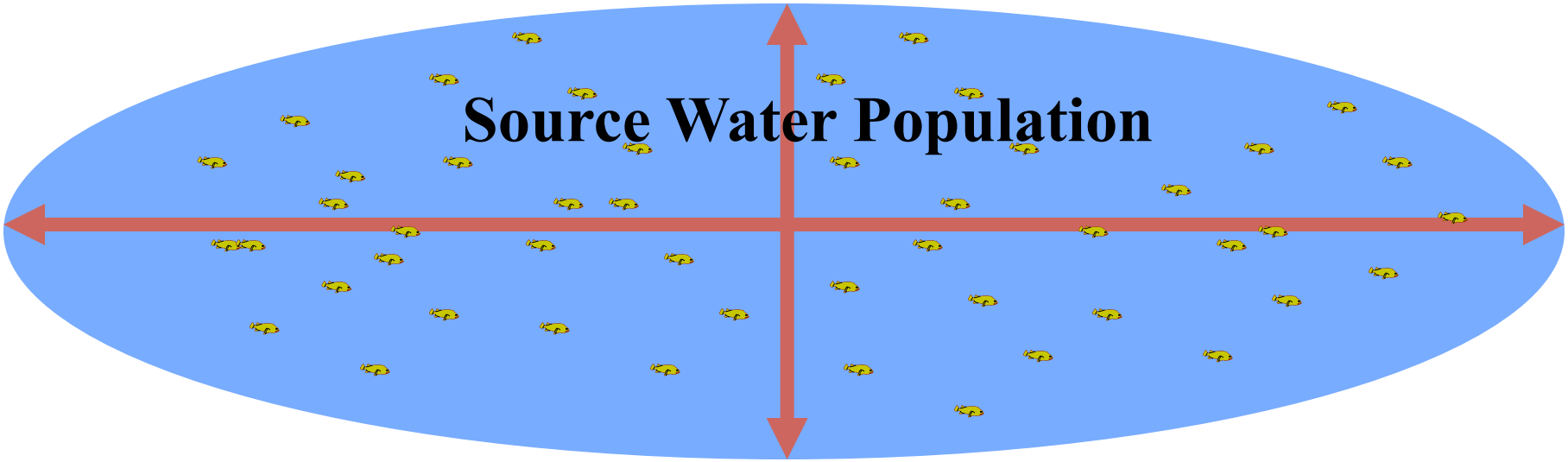
The inverse triangle of entrainment assessment



The goal is to use information from species for which impacts were assessed to estimate the overall impact of entrainment and ***to estimate mitigation that would be compensatory***

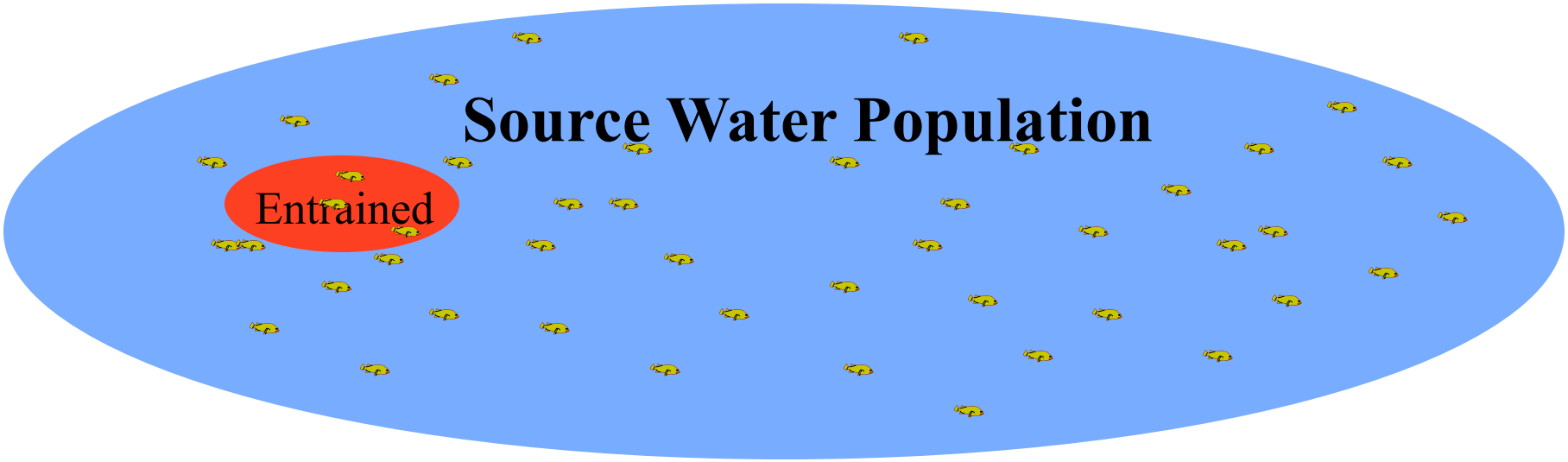
Empirical Transport Model: Understanding "Source Water Population" (SWP) and "Proportional Mortality" (P_m)

The SWP is that spatial area that contains the larvae at risk of entrainment.



Understanding "Source Water Population" (SWP) and "Proportional Mortality" (P_m)

P_m is the percentage of the larvae at risk that are entrained and killed (e.g. 2%).



Each species (for open coast intakes) will have a different Source Water Population
Example: Queenfish (50.9 miles along coast)

Based on:

- Period of vulnerability to entrainment
- Distance larvae could have come from during the period of vulnerability

The source water population resides in the Source Water Body (SWB), which is an area. This can be used in the calculation of Area of Production Foregone (APF).

Area of Production Foregone – a way to interpret loss

- Simple method allows for conversion of organismal loss to habitat

$$\mathbf{P_m \times SWB}$$

ETM Results

Taxon	Estimated Annual Entrainment	2·*FH*	*AEL*	P_M (SWB)
CIQ goby complex	113,166,834	202,538	147,493	1.0% (60.9 km)
northern anchovy	54,349,017	53,490	304,125	1.2% (72.0 km)
spotfin croaker	69,701,589	NA	NA	0.3% (16.9 km)
queenfish	17,809,864	NA	NA	0.6% (84.9 km)
white croaker	17,625,263	NA	NA	0.7% (47.8 km)
black croaker	7,128,127	NA	NA	0.1% (19.4 km)
salema	11,696,960	NA	NA	NA
blennies	7,165,513	6,466	NA	0.8% (12.8 km)
diamond turbot	5,443,118	NA	NA	0.6% (16.9 km)
California halibut	5,021,168	NA	NA	0.3% (30.9 km)

1) Assume that target species represent other species that were not targets

2) **These values represents the estimated rate of mortality for all species having a larval phase whose PM's were not directly determined**

Entrainment Study – ETM Model results

Taxon	Estimated Annual Entrainment	P_m Alongshore Extrapolation (Mean)	Length of Source Water Population (Miles)	Area (mi^2) of Production Foregone (Mean)
spotfin croaker	69,701,589	0.30%	10.1	0.085
Queenfish	17,809,864	0.60%	50.9	0.911
white croaker	17,625,263	0.70%	28.7	0.583
black croaker	7,128,127	0.10%	11.6	0.039
Salema	11,696,960	NA**		
Blennies	7,165,513	0.80%	7.7	0.170
diamond turbot	5,443,118	0.60%	10.1	0.170
California halibut	5,021,168	0.30%	18.5	0.131
rock crab	6,411,171	1.10%	15.9	0.486
AVERAGE (sq. miles)				0.325
AVERAGE (acres)				**208**

Area of Production Foregone – a way to interpret loss

- Simple method allows for conversion of organismal loss to habitat
- Works for species with very limited life history information
- Converts loss to habitat necessary to compensate for loss
- Covers both direct and indirect effects resulting from entrainment
- Currency is habitat, which can be monetized

Summary

- Entrainment is the major issue with open water intakes
- Most options that do not use open water intake are likely to be problematic for large capacity Desal plants
- There are potential engineering options to reduce entrainment
- The current model for assessing the impact of remaining entrainment is ETM/APF
- Results of APF can and have been used to guide compensatory mitigation
- SWB is considering using a fee (assessing a cost for use of seawater) approach based on previous ETM/APF assessments