Underappreciated Effects of Sea-Level Rise (SLR) on Groundwater

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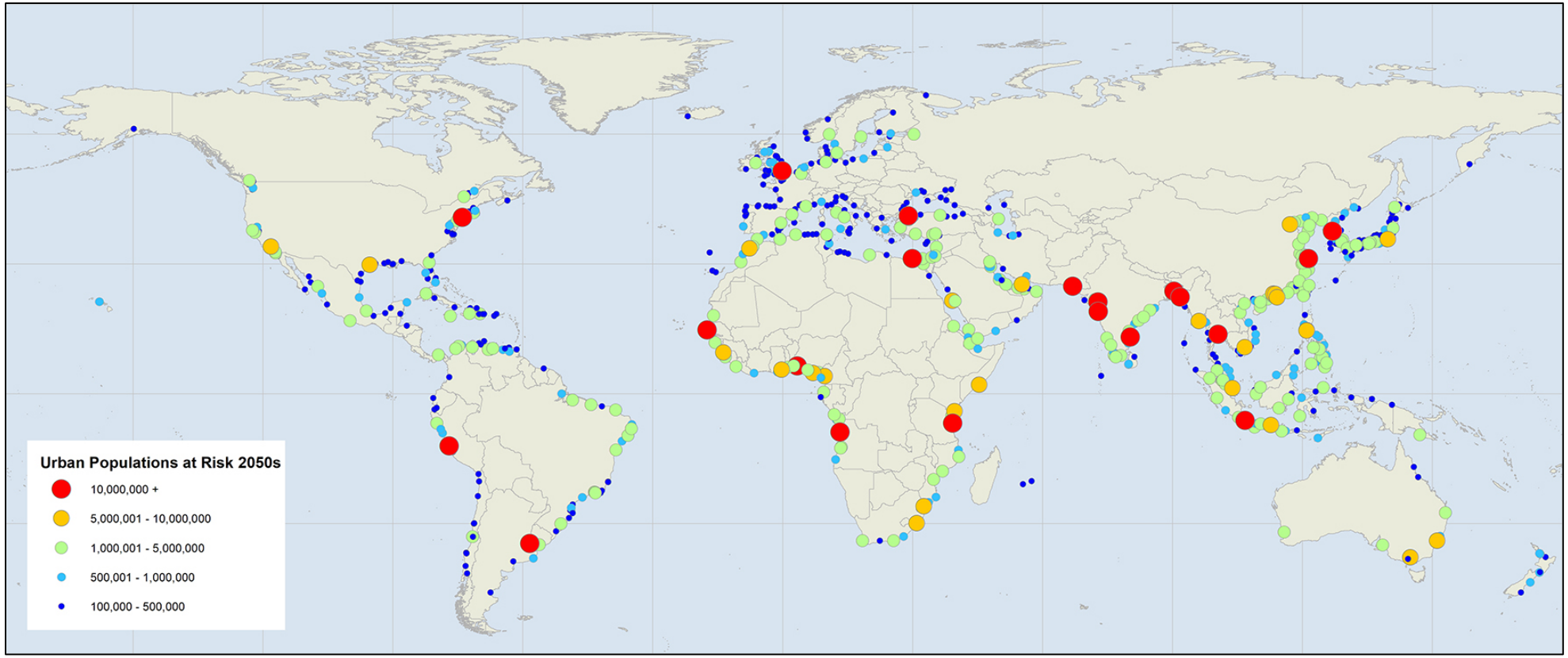
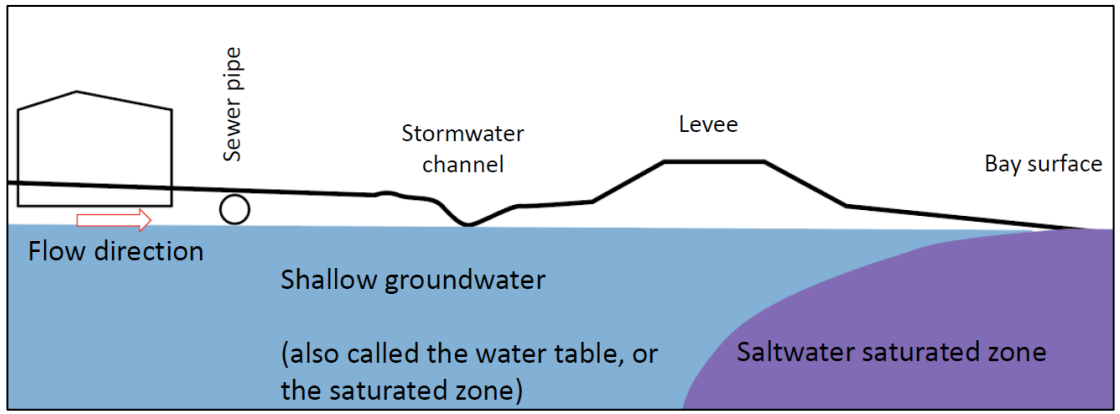
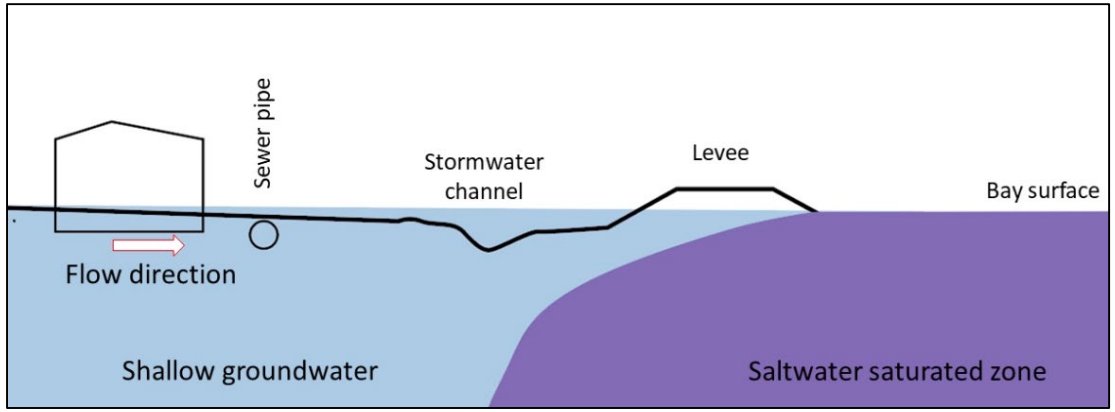
SLR – Ocean Margin Areas at Risk



Cities at risk by ~2050's under 0.5m SLR, under RCP8.5
(credit: Carbonbrief.org)

SLR - Landside Flooding

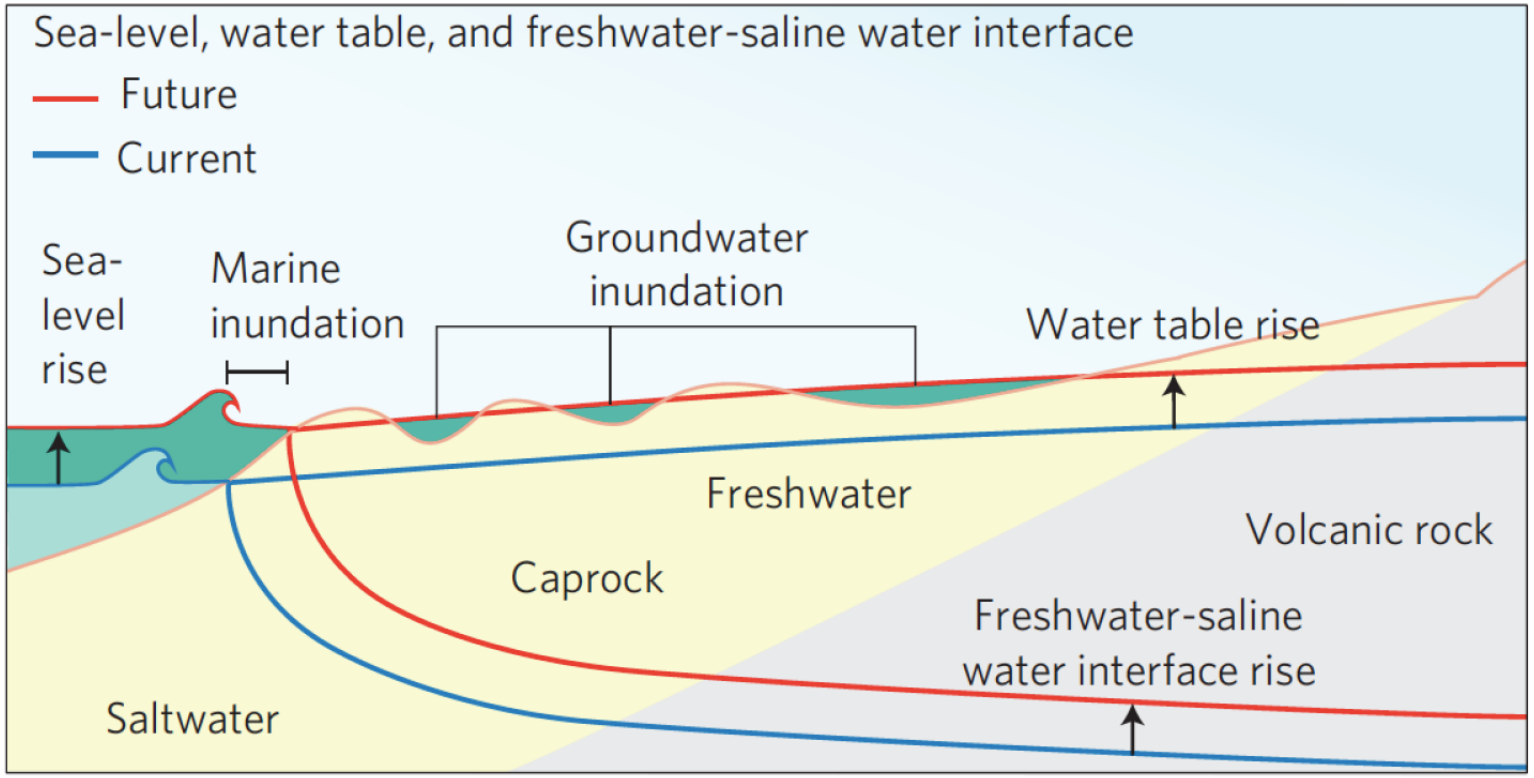




Credit: excerpted from presentation by Kristina Hill (2019)

SLR - Landside Flooding, Groundwater Rise

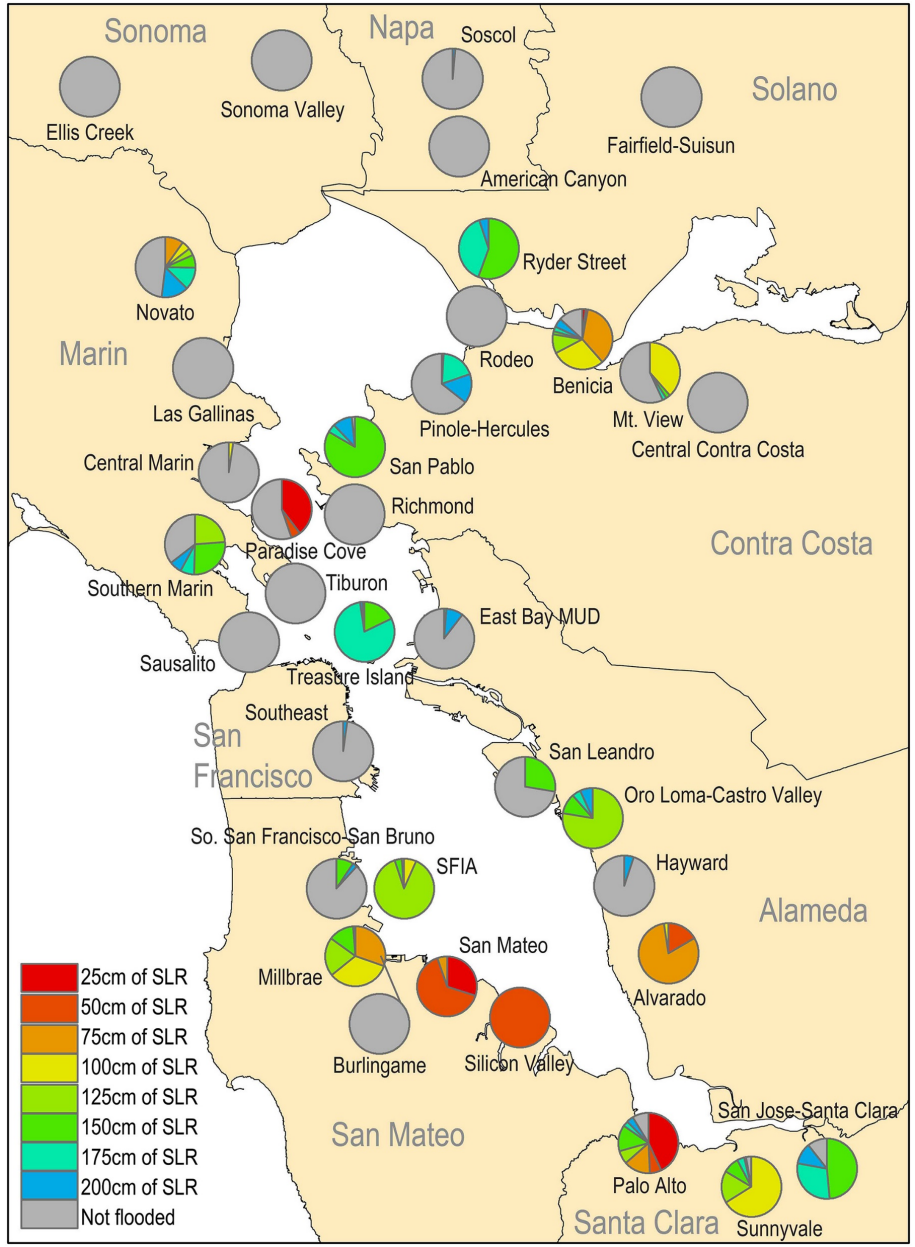
Rotzoll and Fletcher, 2012



Credit: excerpted from presentation by Kristina Hill (2019)

One Example - Loss of "Fall" - Wastewater Treatment Plant Effects

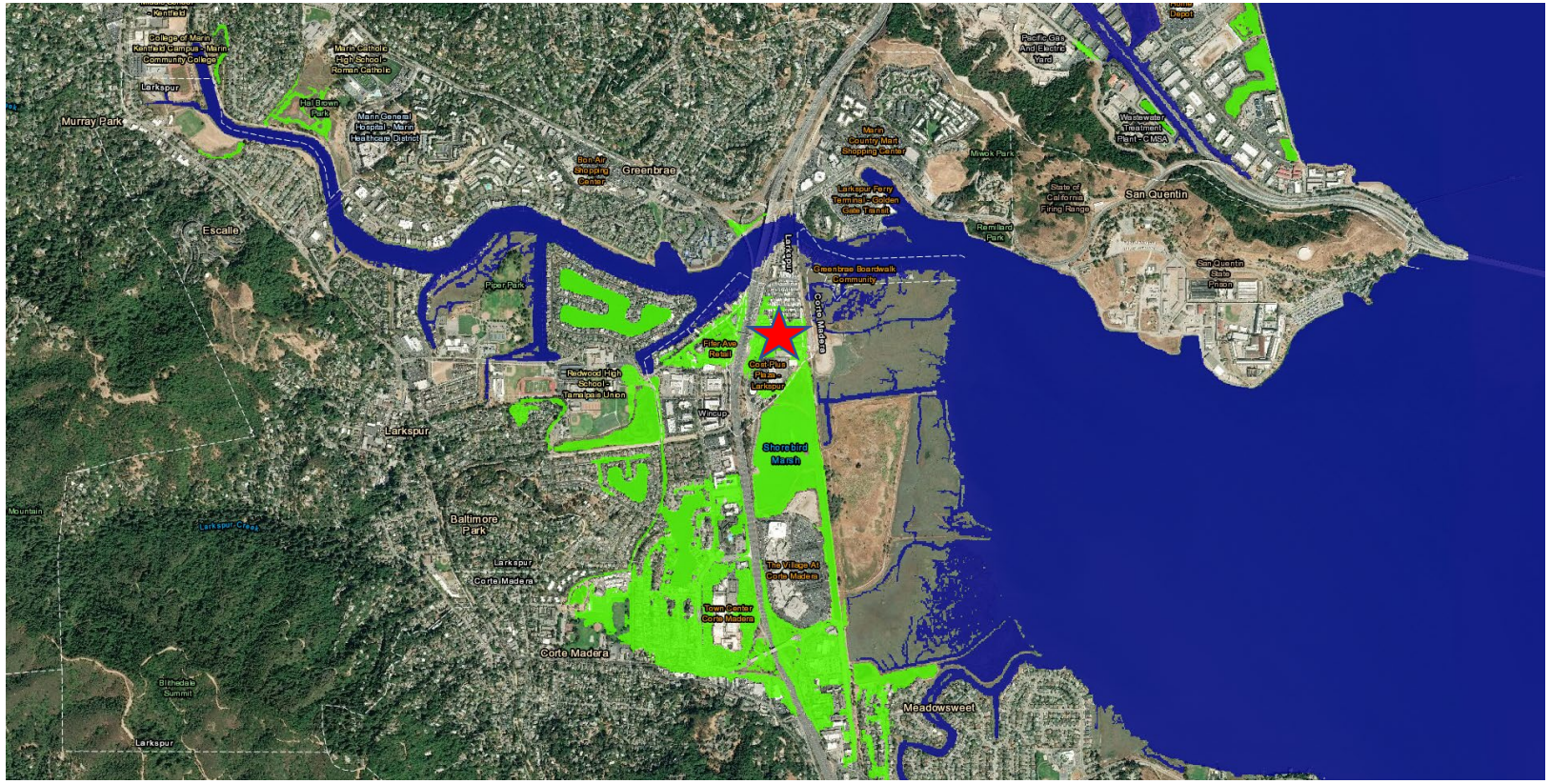
Incremental flooding at WWTP's, for SLR increments



Credit: Hummel and others, 2018

Example Bay margin commercial – San Rafael, CA

Current conditions

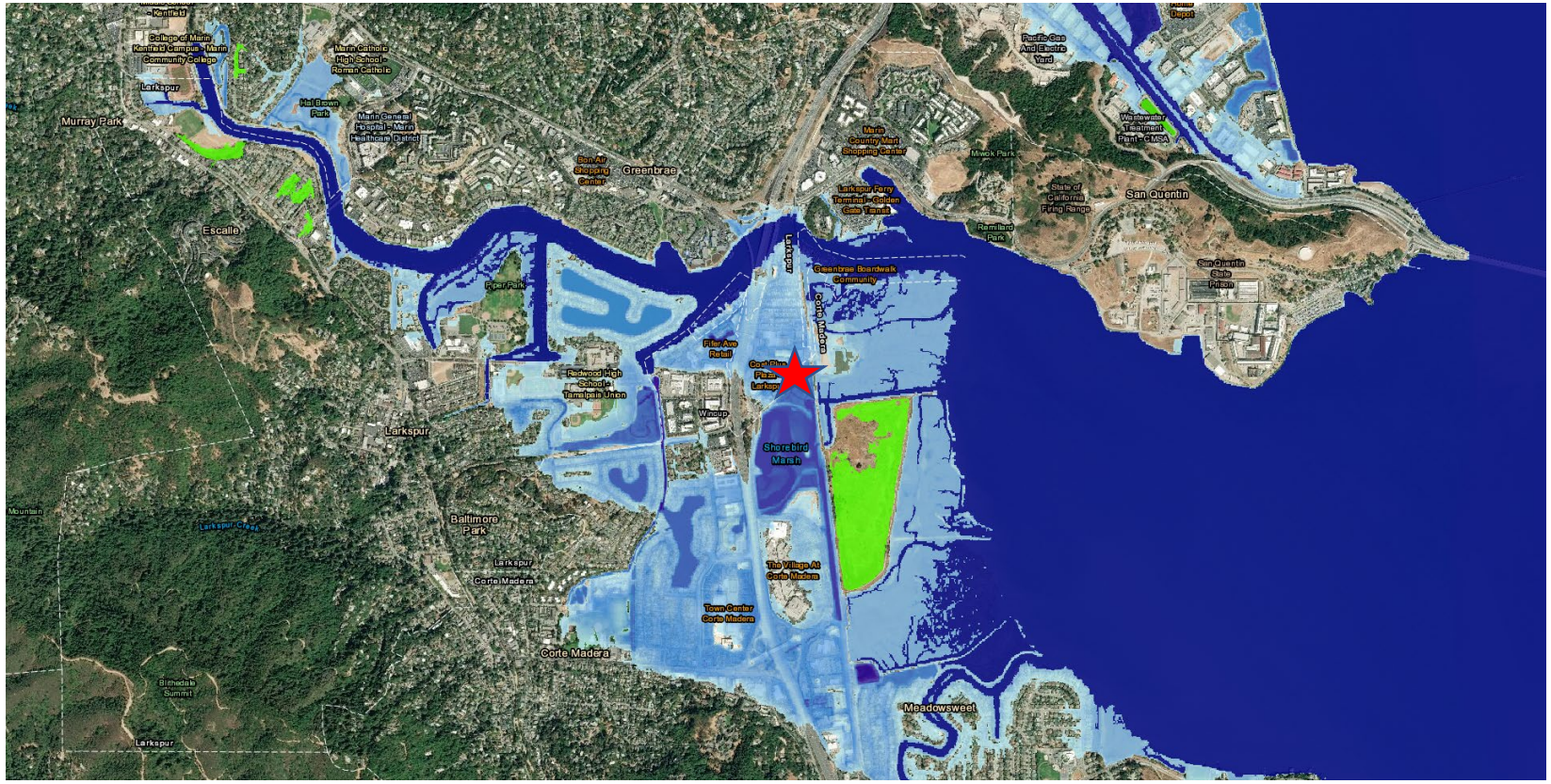


Credit: NOAA Coastal Sealevel Rise Viewer

Example Bay margin commercial – San Rafael, CA

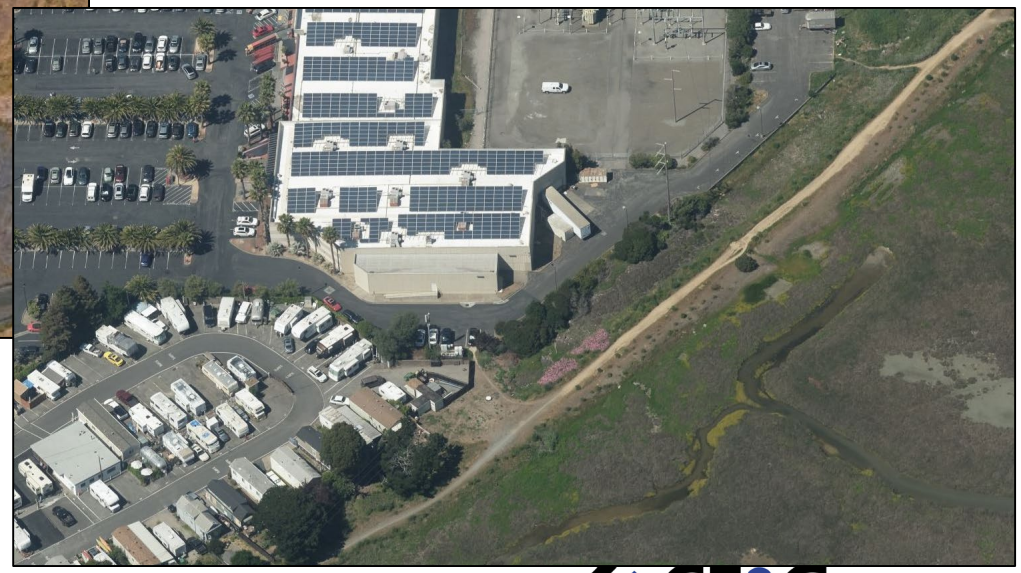
SLR = 3ft; blue areas flooded;

- Let's zoom to area at ★

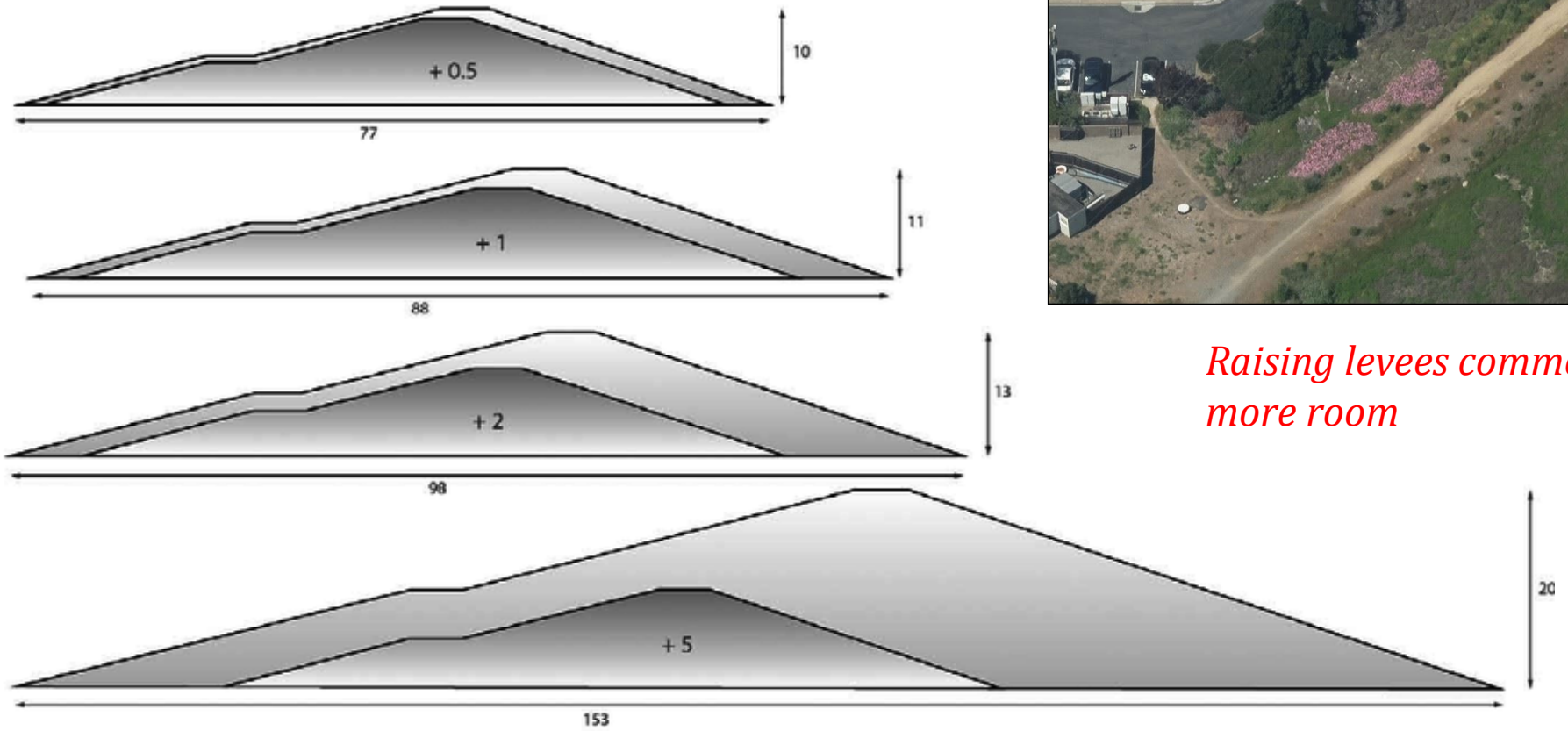


Credit: NOAA Coastal Sealevel Rise Viewer


Corte Madera Creek
Redwood Hwy
Marin RV Park
Navsky Imports
Private Mortgage Advisors - Marin
450B
Redwood Pet Clinic
Barcelino Continental Corporation
Star Smog Check
Rich St
Mellow Motors, Inc.
450A
Larkspur Econogas
Robin's Auto Service, Inc
Lucky Dr
Big 5 Sporting Goods
Shineology - Lucky I
Industrial Way
FITNESS SF - Marin
Nellen Ave
Fifer Ave
JOANN Fabrics and Crafts
The Vitamin Shoppe
Trader Joe's
Tamal Vista
Cost Plus World Market
Marin Municipal Water District
BevMo!
450A



Levees

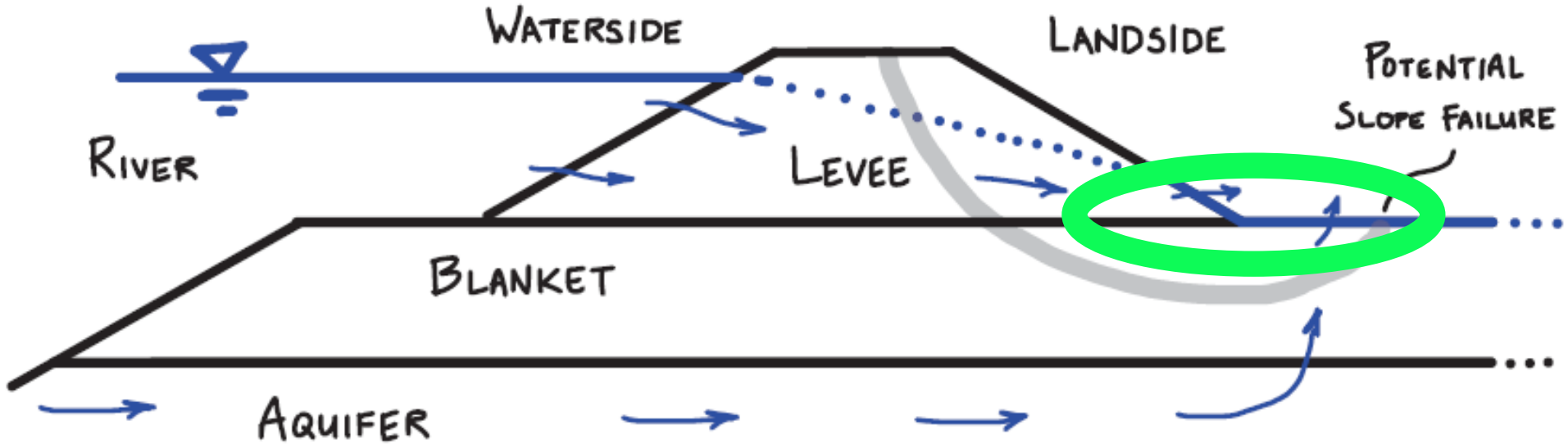


Raising levees commonly requires more room

Credit: Jonkman and others (2013)

Levee Detail – SLR and higher groundwater

SLR will affect improvements on landside, not just levee stability



Credit: Modified from Lanzafame and Sitar (2018)

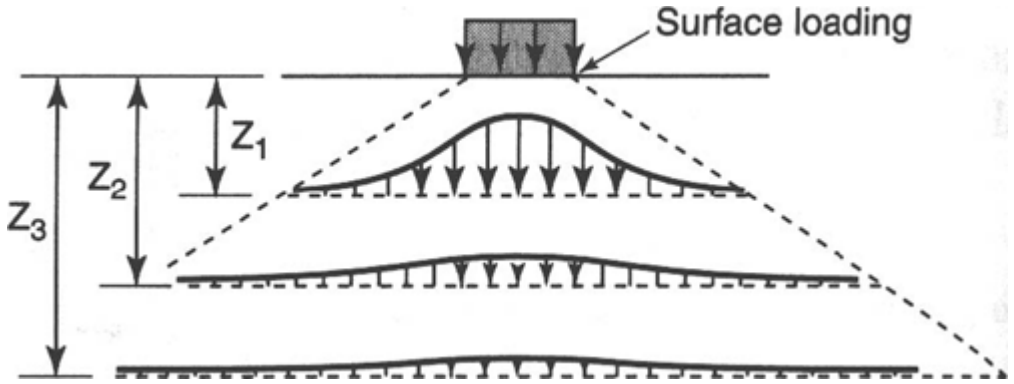
Roadways and Pavements

Credit: GoogleEarth Streetview

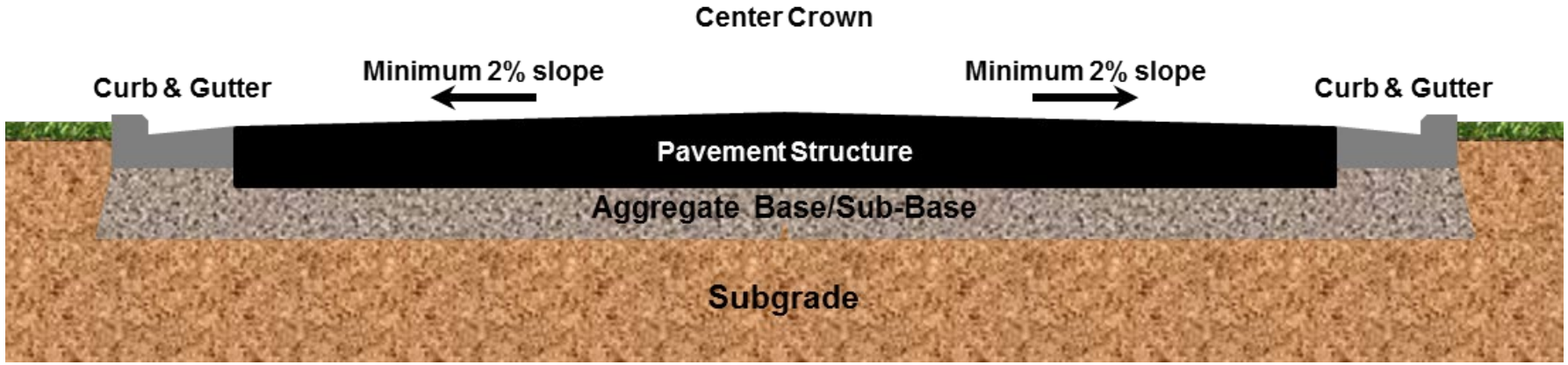
Credit: FHWA.dot.gov

Credit: NOAA SeaGrant Program

Pavement Loading

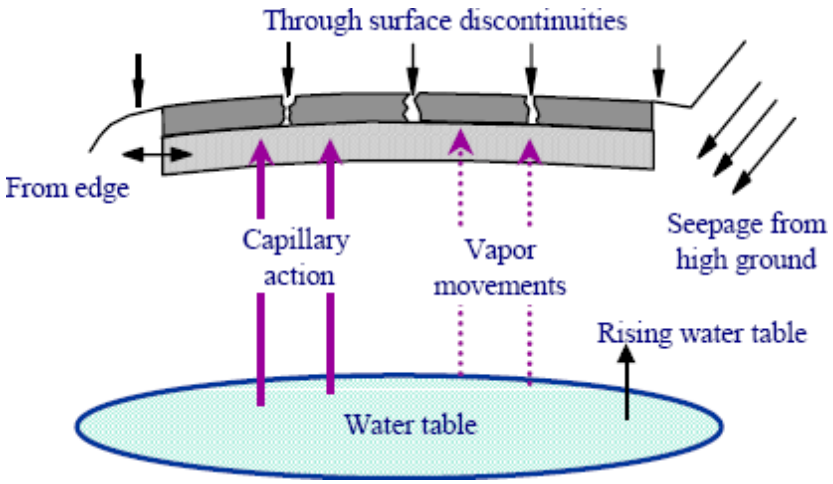


Credit: FHWA.dot.gov



Credit: VAAshpalt.org

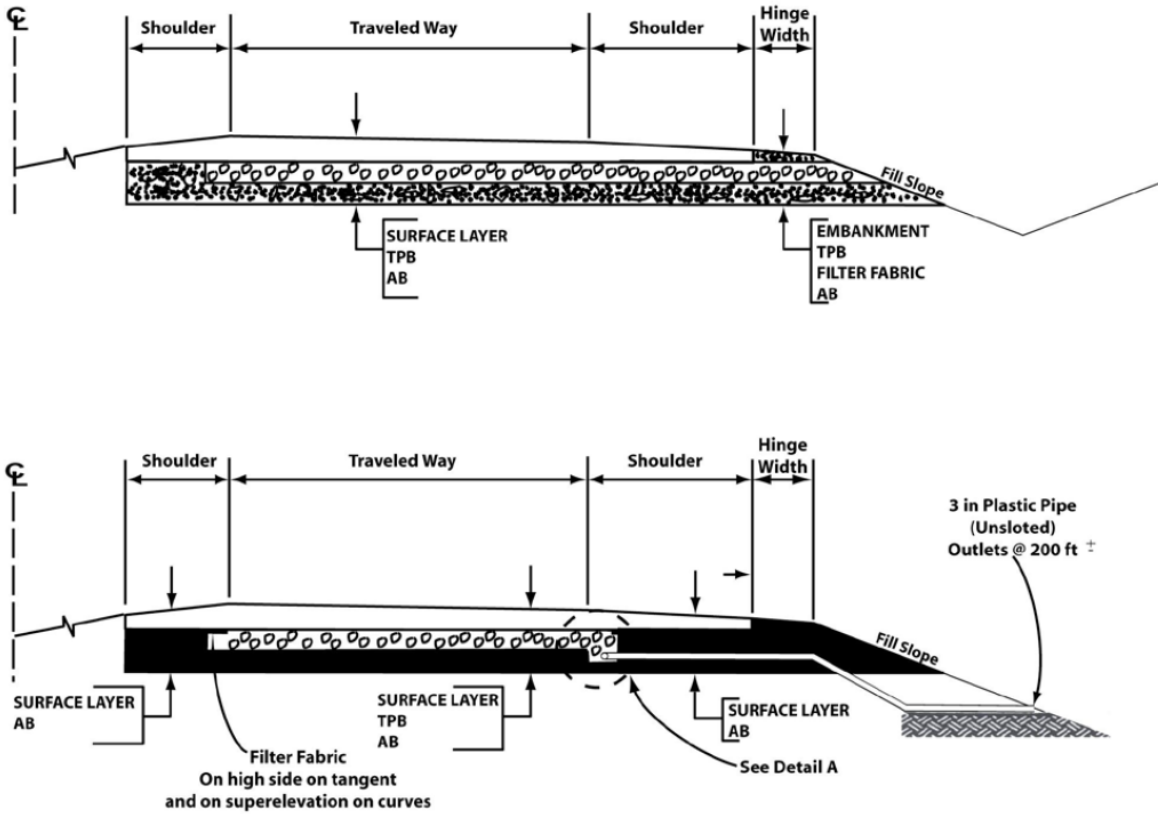
Subgrade Moisture Is Critical for Pavements



Credit: FHWA.dot.gov

Every attempt is made to hold down the water table, provide dry subgrade

Figure 651.2A
Typical Section with Treated Permeable Base Drainage Layer



Credit: Caltrans HDM

Subgrade Moisture Is Critical for Pavements

US 101 in Marin County – in many areas existing highway is only a couple of feet above Bay (and groundwater) even without any future SLR.

Credit: GoogleEarth Streetview

Take away #1 - Even with surface flood protection (i.e. levee or floodwall) SLR will induce GW rise that necessitates raising of pavement surface.

Take away #2 – Intermittent flooding is not nearly as economically damaging as permanent rise in GW due to SLR.

Overpasses/Overhead Clearance

Raising pavement grade affects overhead clearance –
Increasing overhead clearance is extremely costly for bridges and overhead utilities

Credit: FHWA.dot.gov

Below-Grade Structures

- Elevator Pits
- Buried Tanks
- Pipelines
- Utility Vaults
- Basements

Buried concrete tanks are susceptible to structural failure when being drained and subjected to a high groundwater table.

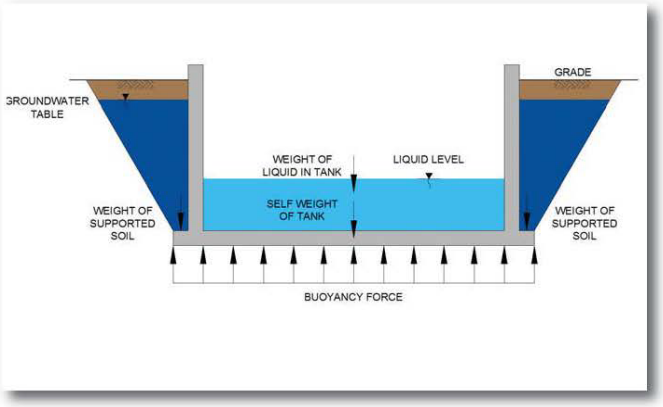
Storage Tanks Containment & Spills

Beware of buried tank buoyancy

By Mark Bruder

Concrete tanks are commonly used in water and wastewater treatment plants and reservoirs. Depending on process requirements and site considerations, they may be fully or partially buried, covered or uncovered, and frequently have both full and empty liquid levels throughout operation. An individual tank can be used for storage, aeration, filtration, clarification, digestion, sludge holding, or one of many other treatment stages.

Buried concrete tanks can be damaged by groundwater-generated buoyancy force. Buoyancy is an upward force exerted by a fluid that acts on an immersed object. Over two millennia ago, Archimedes of Syracuse developed the Archimedes Principle,



Two common failure mechanisms for buried tanks due to groundwater-generated buoyancy:

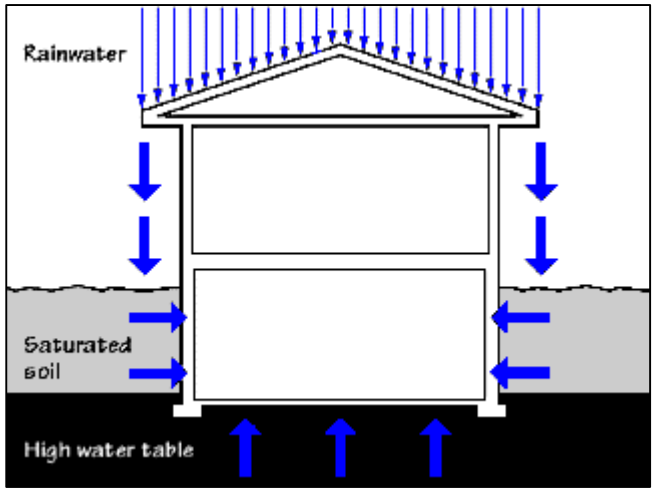
- structural failure of the base slab
- complete tank flotation.

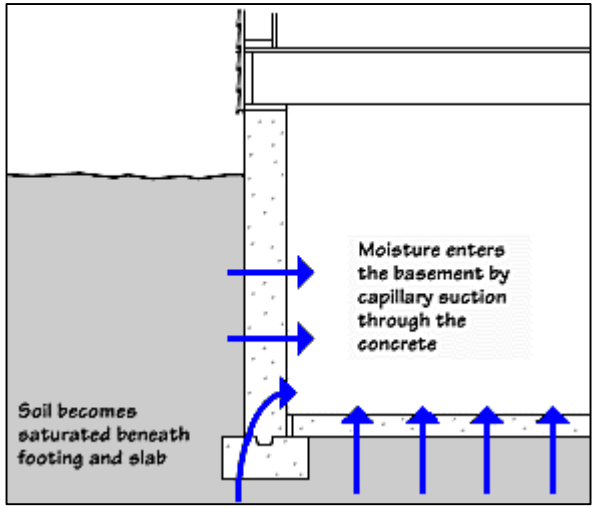
Take away – significant modification to buried tanks will be needed to address GW rise due to SLR

Credit: Bruder (2013)

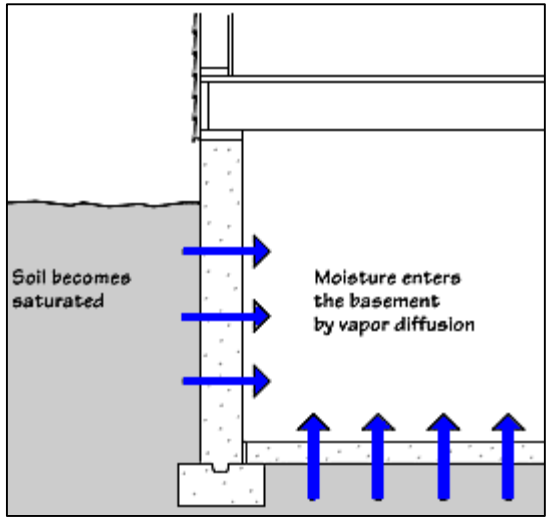
Slab-On-Grade vs. Water

High water table, saturated soils





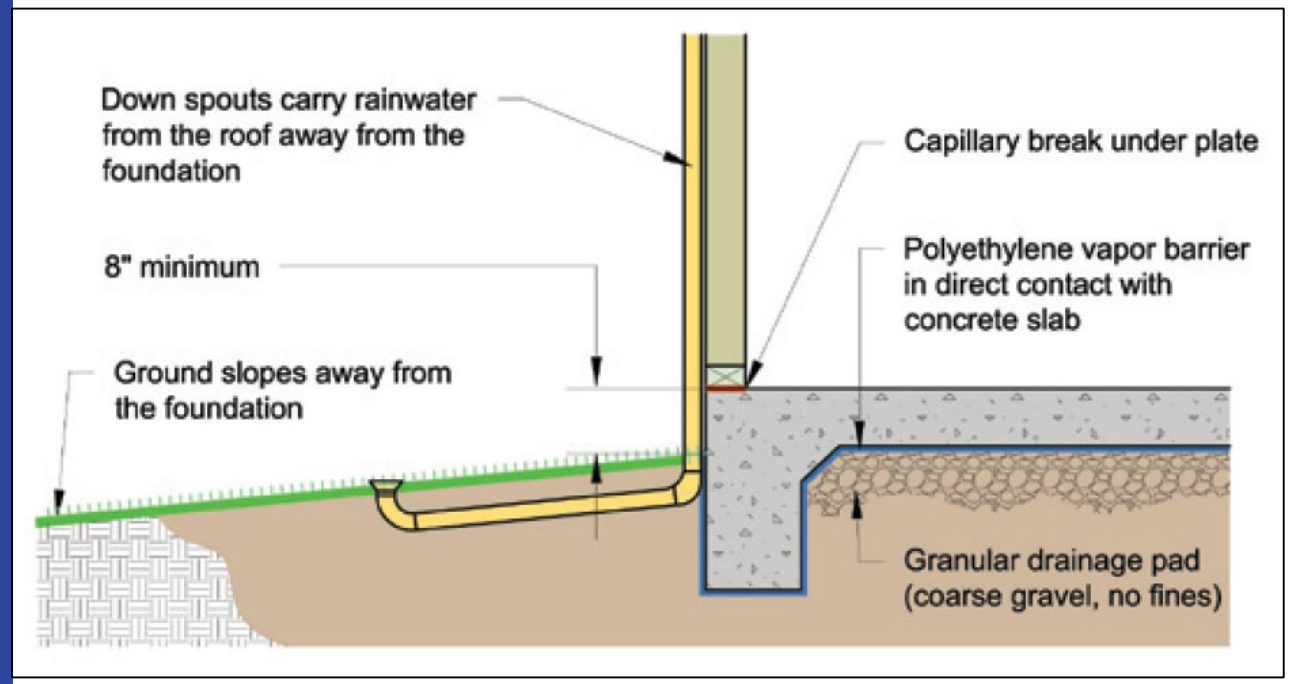
Capillary suction, vapor diffusion (even if not saturated)

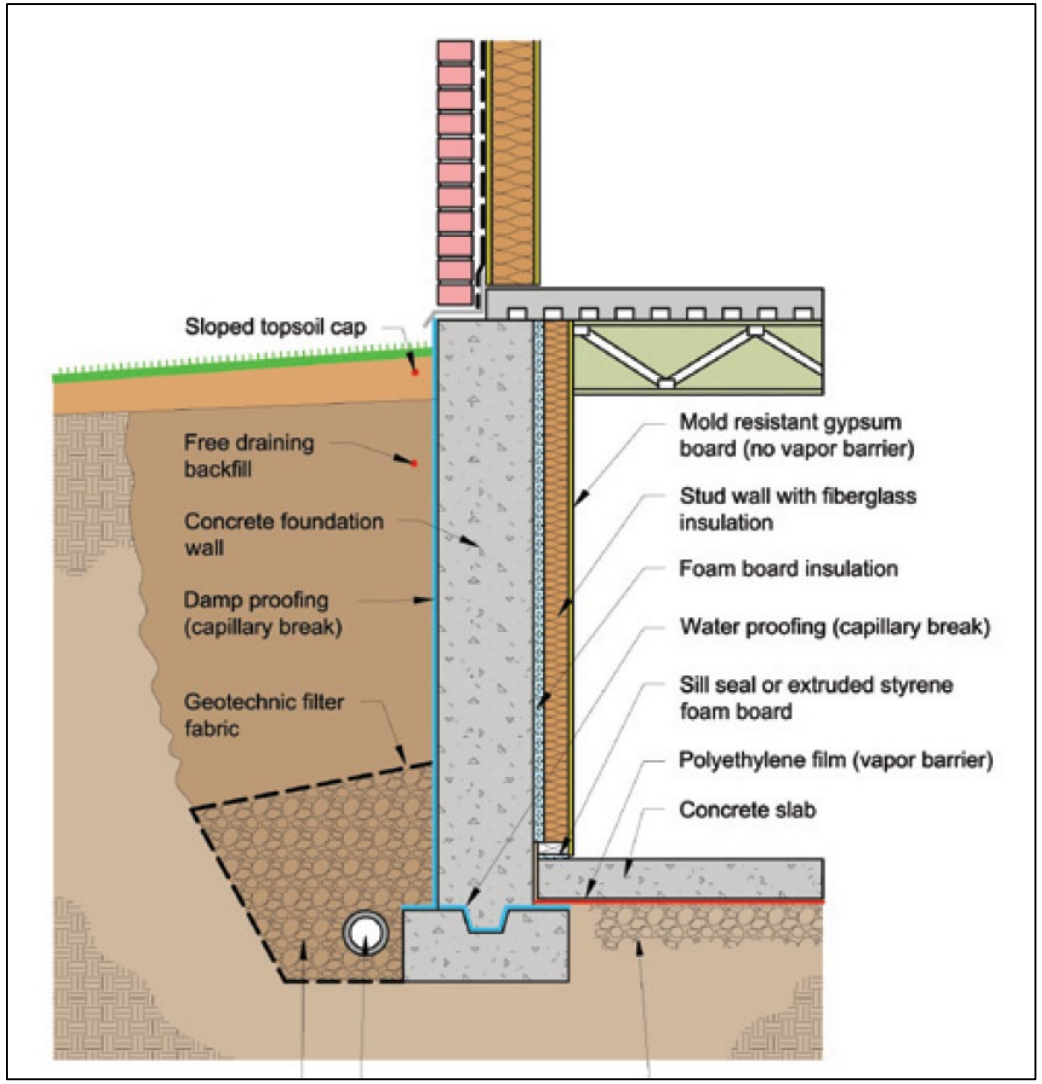


Credit: Univ MN

Slab-On-Grade

Design relies heavily on gravity drainage mechanisms
-- what if water table rises long-term?



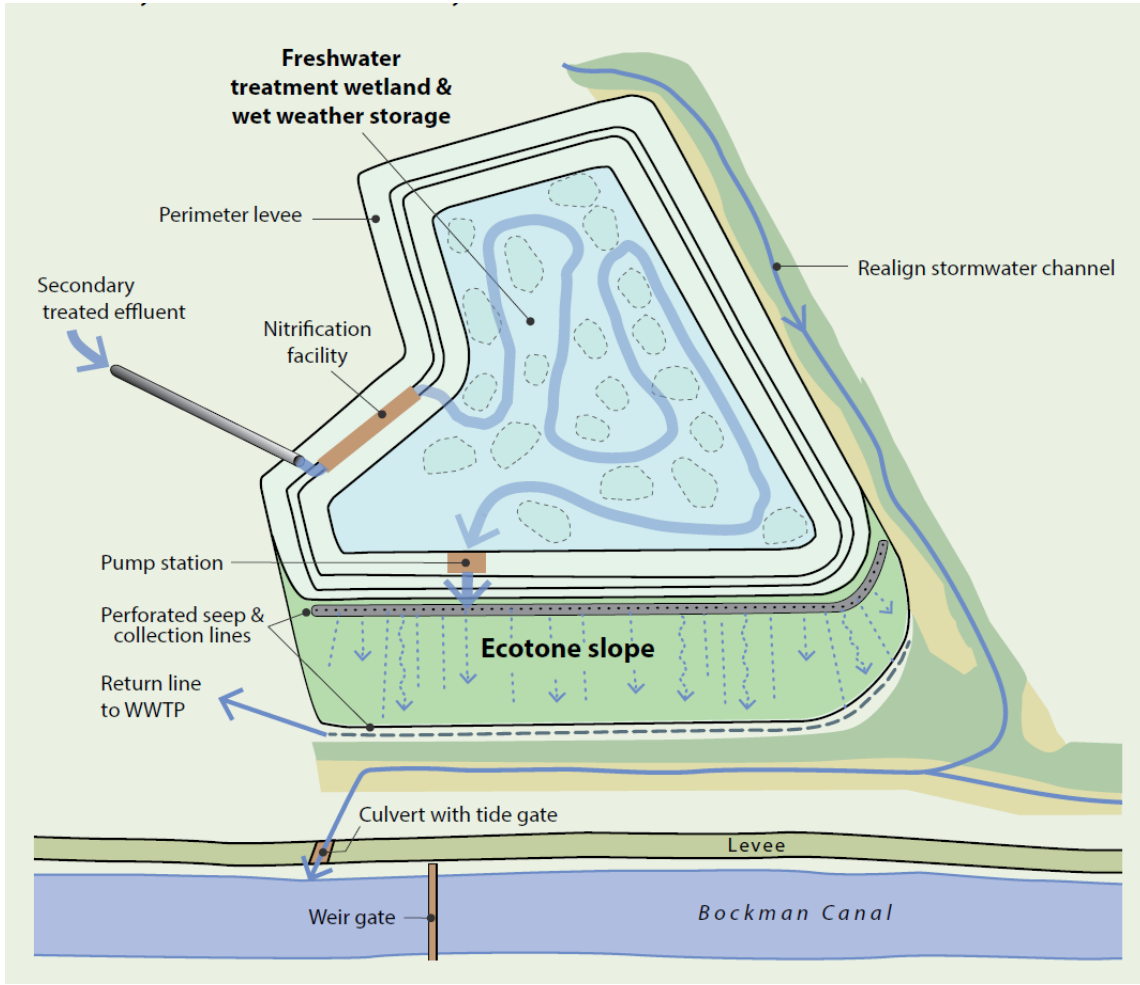


Credit: Univ MN

Storm Runoff Networks

Even improved approaches rely on available "fall", and an assumed base level

Credit: SFEI



Credit: ESA

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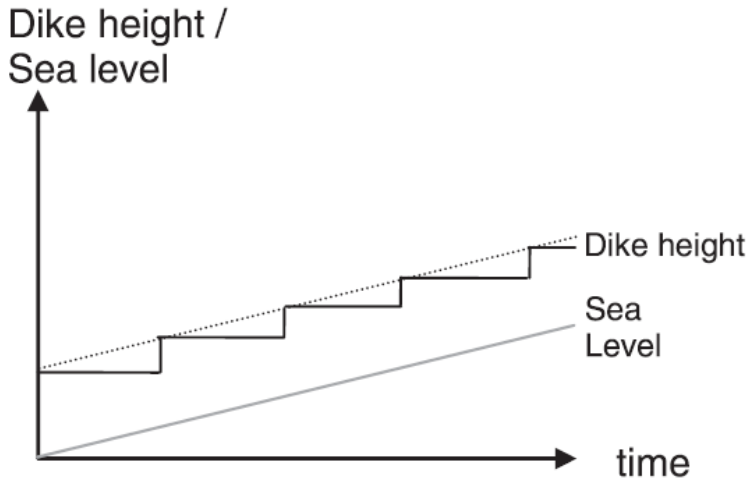
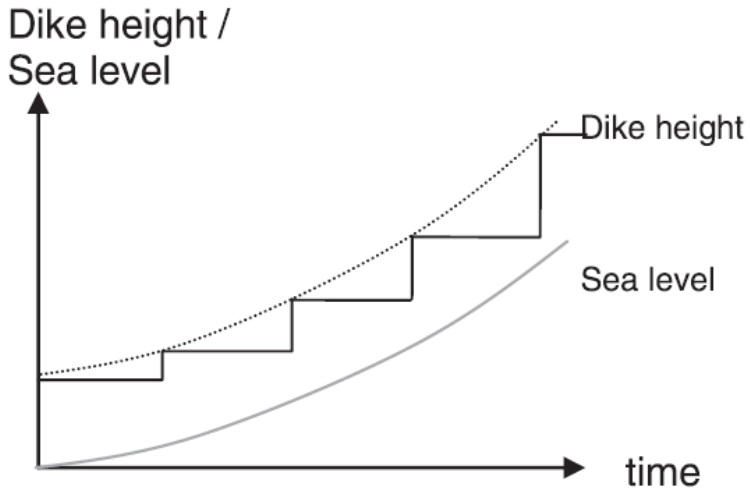
How Do We Adapt the Planning/Design Process for Continued SLR?





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Credit: Jonkman and others (2013)

Questions?