Preparatory Methods for Kahuku Ground Water Site Characterization

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For

CEE 696

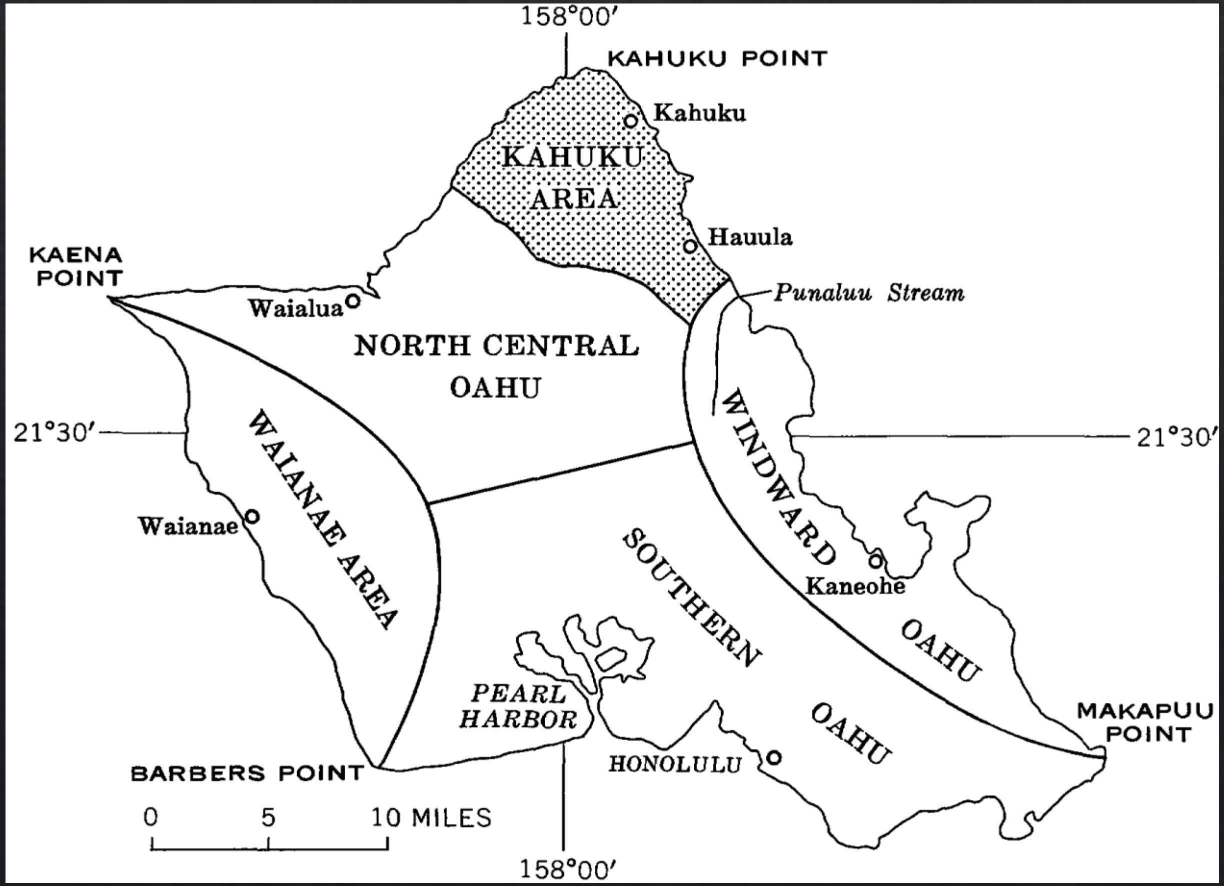
"Optimization in Groundwater Engineering"

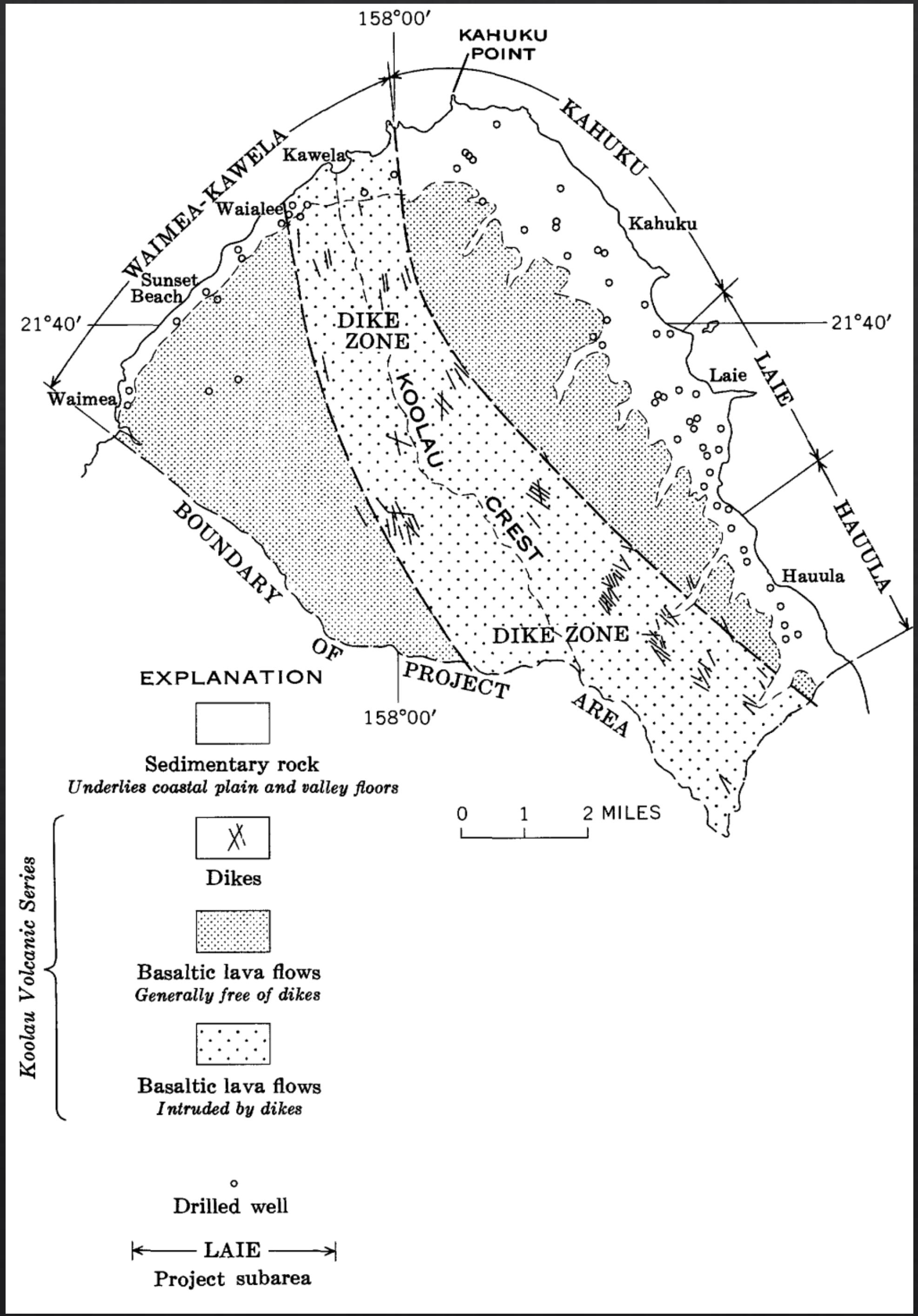
05/07/2018

Motivation:

Kahuku Basal Water

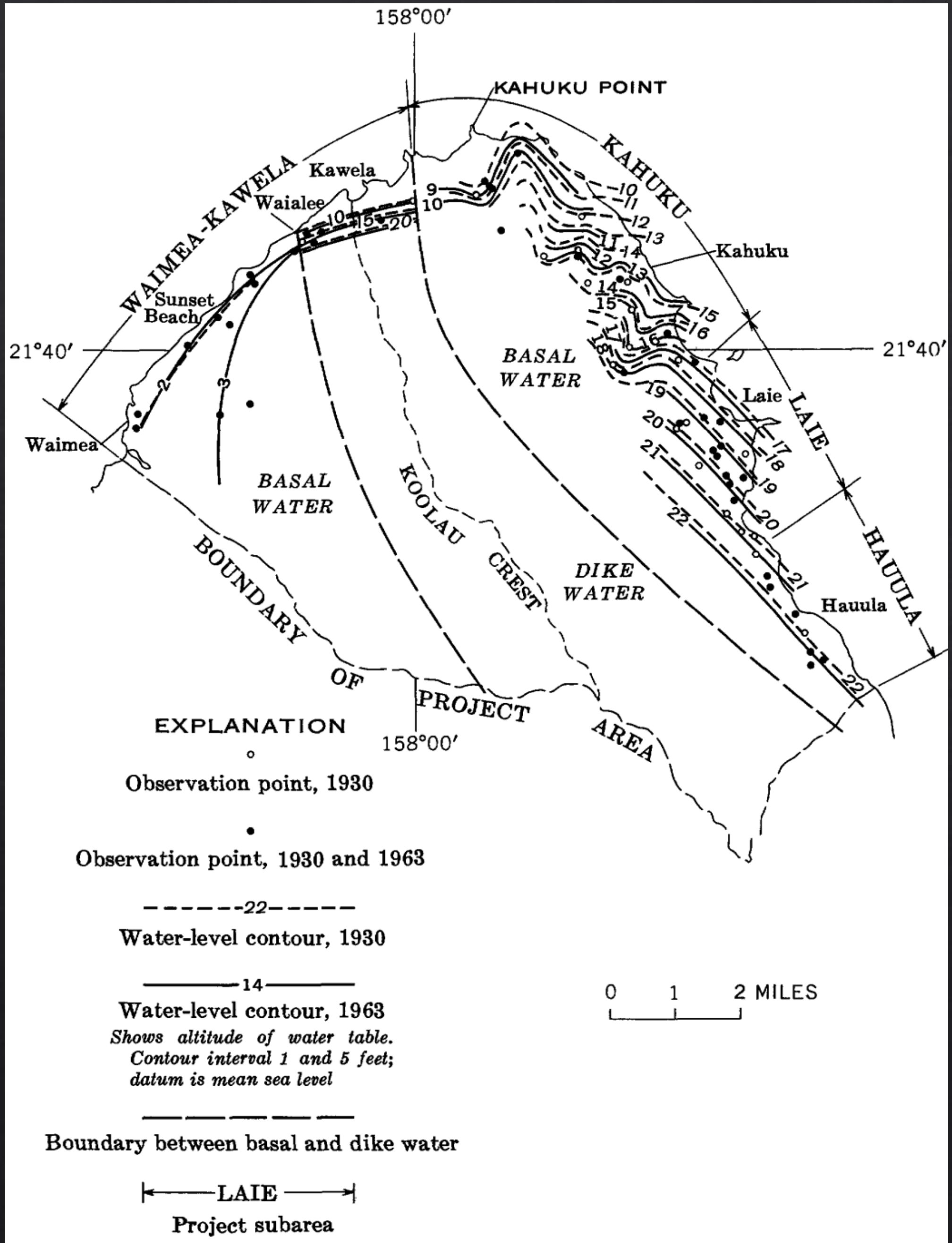
Kahuku, Oahu, Hawaii

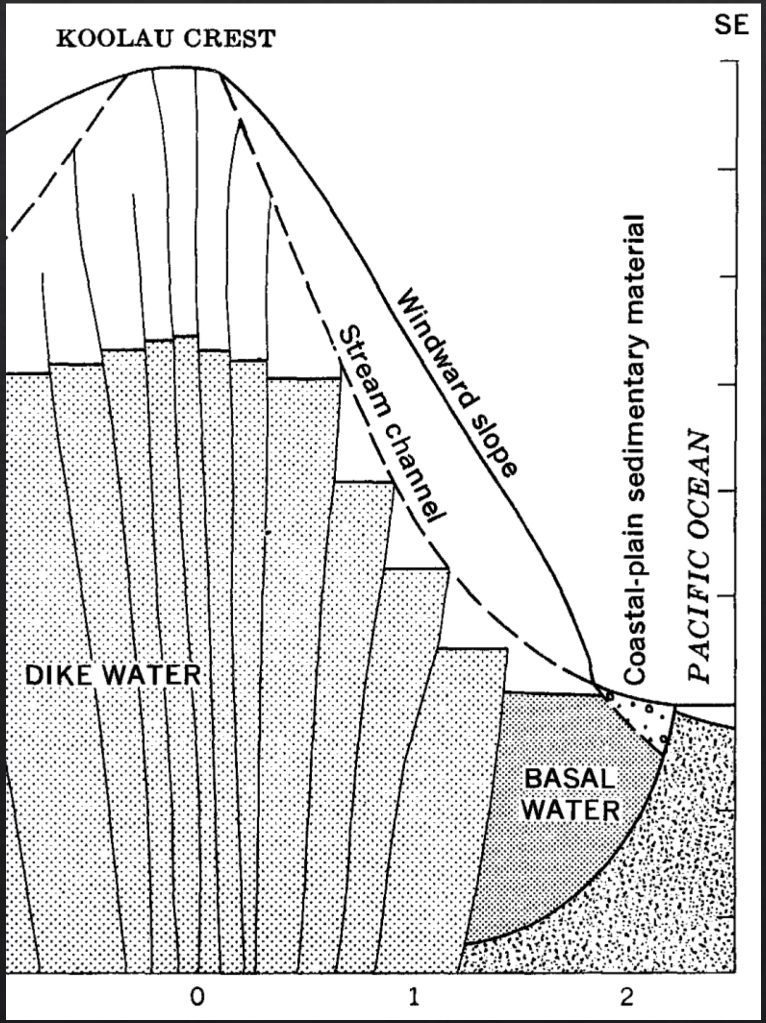




(Takasaki & Valenciano, 1969)

Basal Ground Water



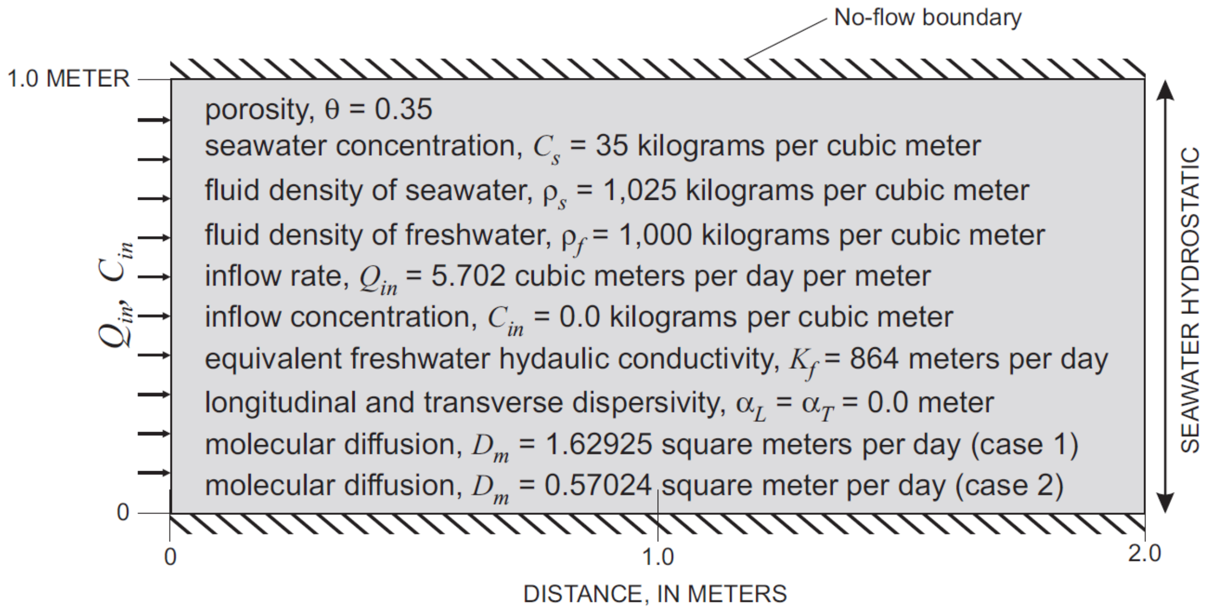


(Takasaki & Valenciano, 1969)

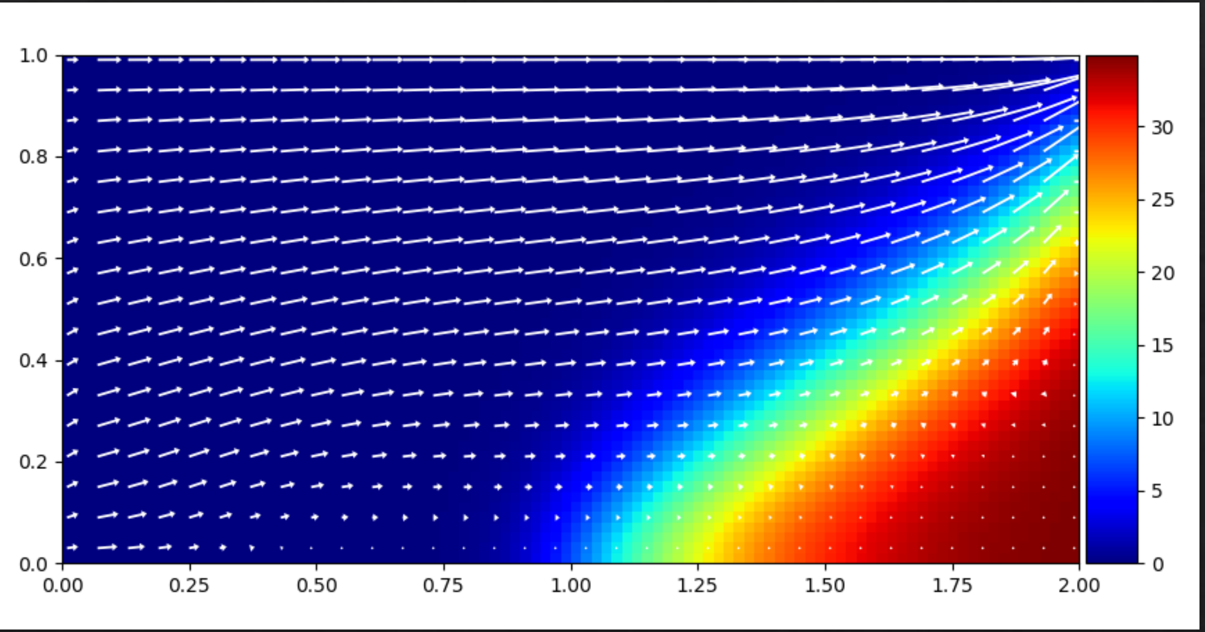
Groundwater Model:

Uncapped Basal Freshwater Lens

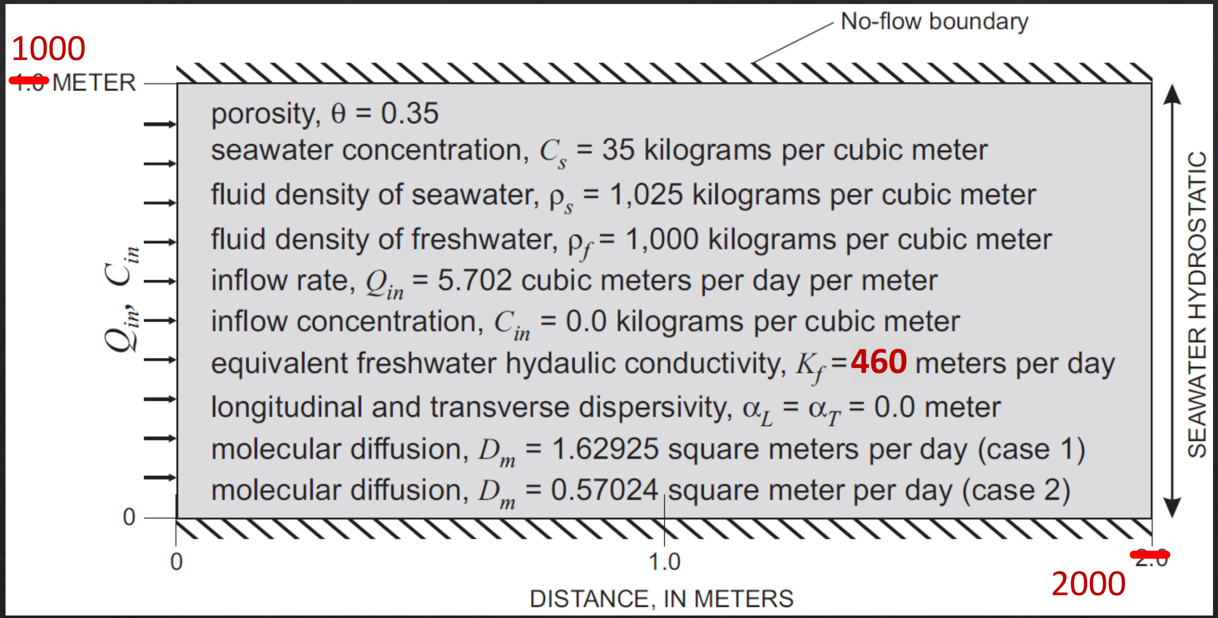
Salt-Water Interface: the “Henry Problem”



(Langevin, Thorne, Dausman, Sukop, & Guo, 2008)

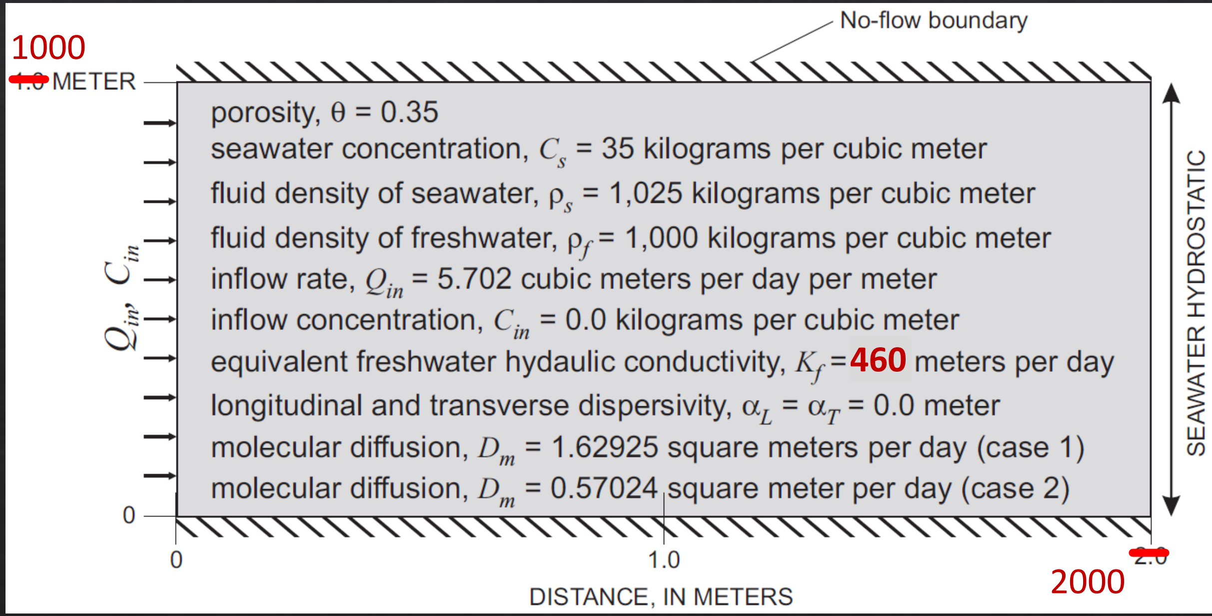


Basal Lens Model




```
# Assign name for modflow model objec
modelname = 'HiSeaWat'

# Input variables for the HiSeaWat Problem
Lx = 2000.
Lz = 1000.
nlay = 50
nrow = 1
ncol = 100
delr = Lx / ncol
delc = 1.0
delv = Lz / nlay
top = 1000.
botm = np.linspace(top - delv, 0., nlay)
hk = 460.  # m/day
```

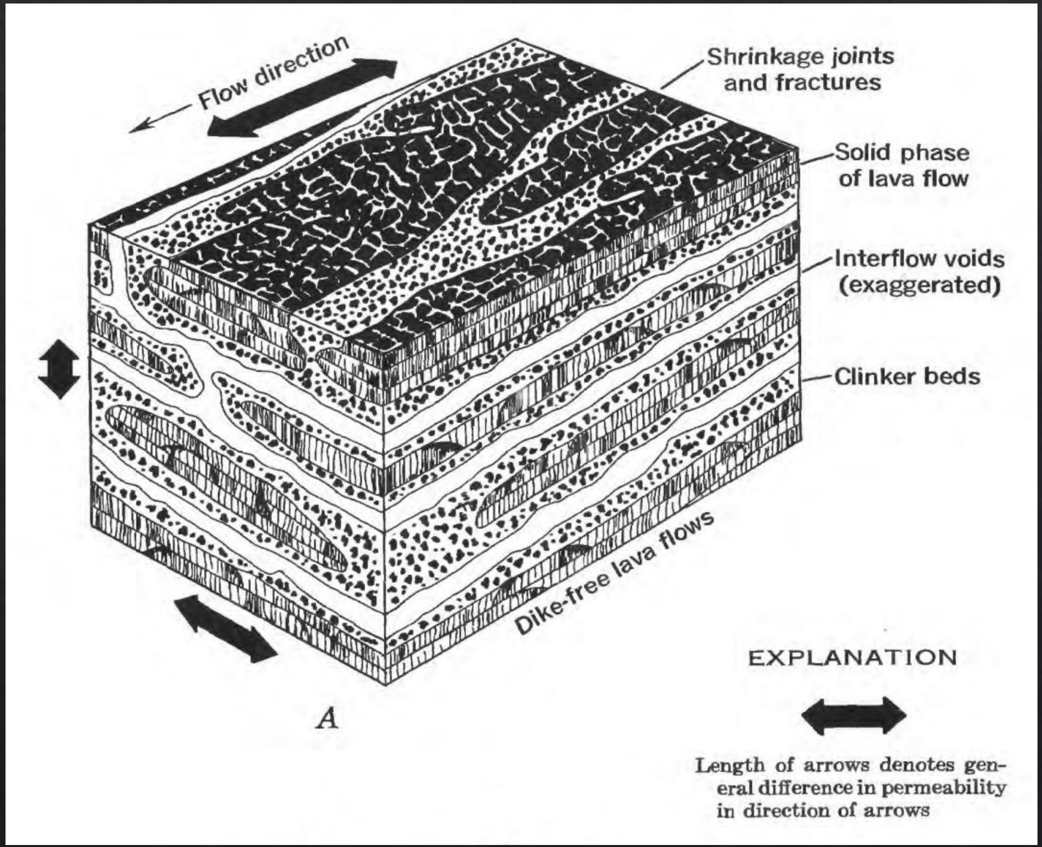
Basal Lens Model




```
# Create the basic MODFLOW model structure
self.mf = flopy.seawat.Seawat(modelname,
exe_name='./swt_v4.exe')
print(self.mf.namefile)

# Add DIS package to the MODFLOW model
dis = flopy.modflow.ModflowDis(self.mf, nlay,
nrow, ncol, nper=1, delr=delr, delc=delc,
laycbd=0, top=top, botm=botm, perlen=1.5,
nstp=15)

# Variables for the BAS package
ibound = np.ones((nlay, nrow, ncol),
dtype=np.int32)
ibound[:, :, -1] = -1

# Add BAS package
bas = flopy.modflow.ModflowBas(self.mf,
ibound, 0)
```

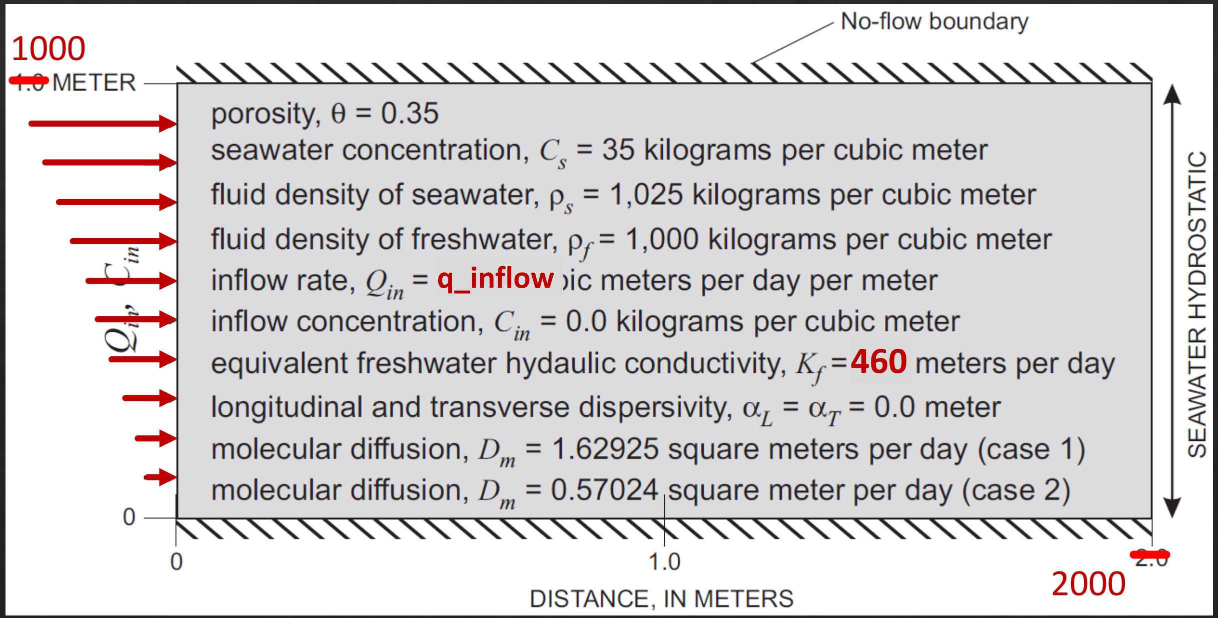
Basal Lens Model

```
# Add LPF package to the MODFLOW model
lpf = flopy.modflow.ModflowLpf(self.mf, hk=hk,
vka=hk/3., ipakcb=53)

# Add PCG Package to the MODFLOW model
pcg = flopy.modflow.ModflowPcg(self.mf, hclose=1.e-8)

# Add OC package to the MODFLOW model
oc = flopy.modflow.ModflowOc(self.mf,
                              stress_period_data={(0,
0): ['save head', 'save budget’]}, compact=True)
```



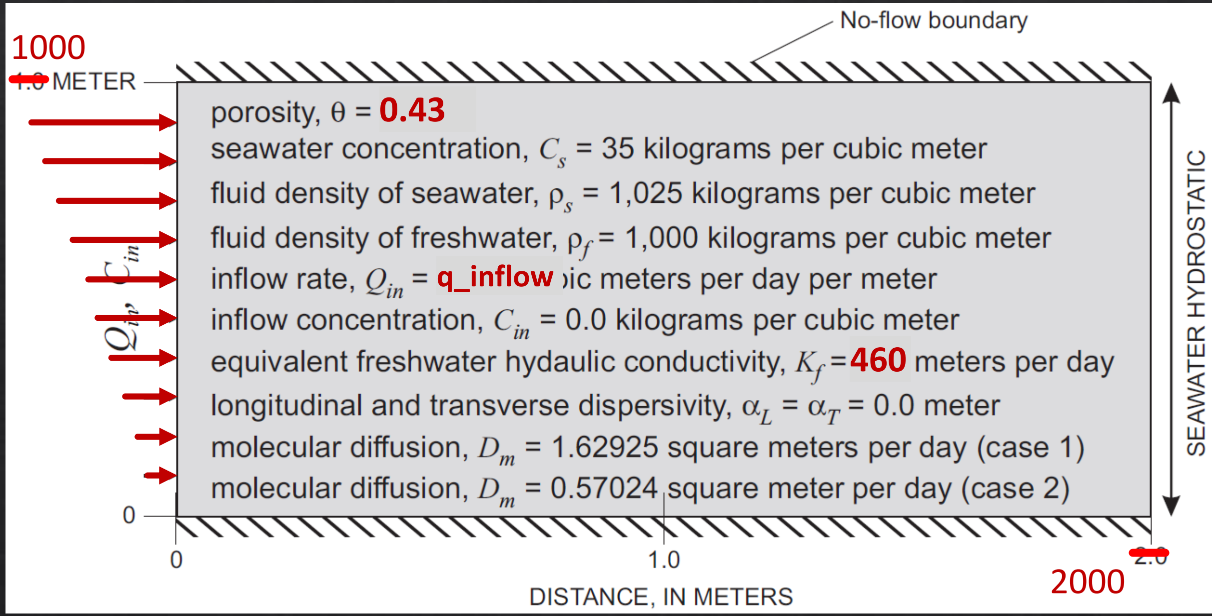
(Takasaki & Valenciano, 1969)

Basal Lens Model




```
def run(self, q_inflow):

    # Create WEL and SSM data
    itype = flopy.mt3d.Mt3dSsm.itype_dict()
    wel_data = {}
    ssm_data = {}
    wel_sp1 = []
    ssm_sp1 = []

    b = q_inflow / 25.
    for k in range(self.nlay):
        q = (b - (b/50.)*k)
        wel_sp1.append([k, 0, 0, q])
        ssm_sp1.append([k, 0, 0, 0.,
                        itype['WEL']])
        ssm_sp1.append([k, 0, self.ncol - 1,
                        35., itype['BAS6']])
    wel_data[0] = wel_sp1
    ssm_data[0] = ssm_sp1
    wel = flopy.modflow.ModflowWel(self.mf,
        stress_period_data=wel_data, ipakcb=53)
```

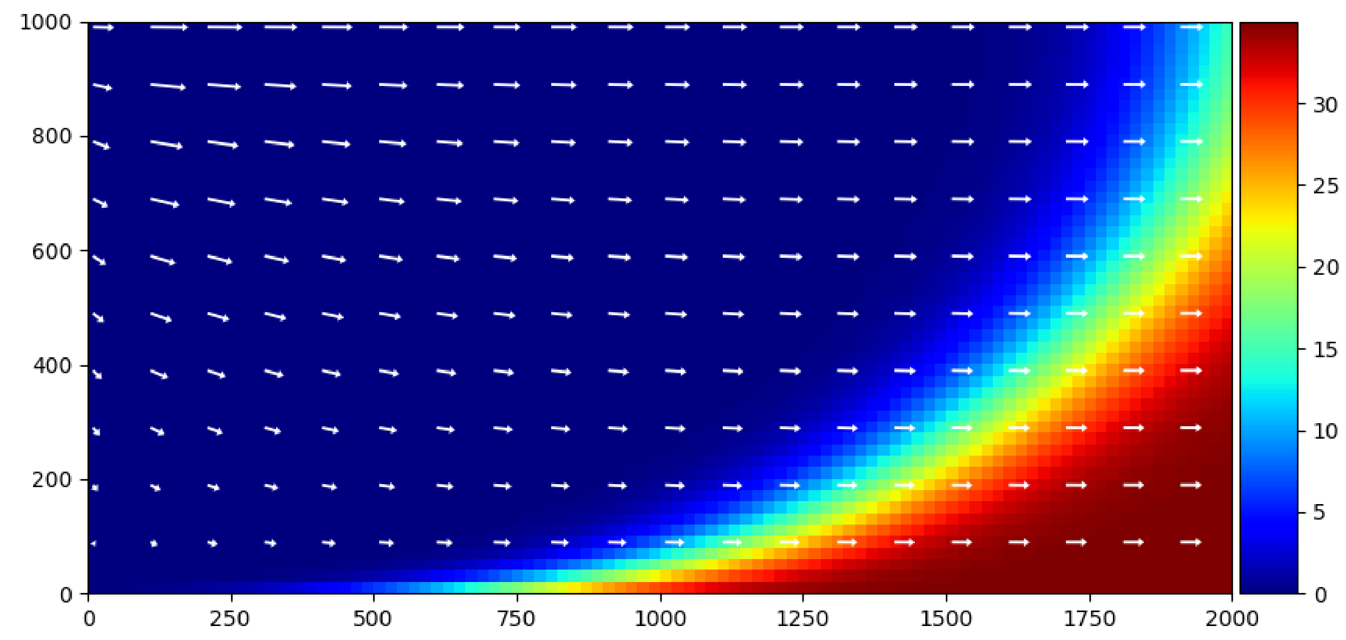
Basal Lens Model




```
# Create the basic MT3DMS model structure
btn = flopy.mt3d.Mt3dBtn(self.mf, nprs=-5, prsity=0.43, sconc=35., ifmtcn=0,
                         chkmas=False, nprobs=10, nprmas=10, dt0=0.001)
adv = flopy.mt3d.Mt3dAdv(self.mf, mixelm=0)
dsp = flopy.mt3d.Mt3dDsp(self.mf, al=0., trpt=1., trpv=1., dmcoef=self.dmcoef)
gcg = flopy.mt3d.Mt3dGcg(self.mf, iter1=500, mxiter=1, isolve=1, cclose=1e-7)
ssm = flopy.mt3d.Mt3dSsm(self.mf, stress_period_data=ssm_data)
```

Basal Lens Model

```
# Create the SEAWAT model structure
vdf = flopy.seawat.SeawatVdf(self.mf,
iwtable=0, densemin=0, densemax=0,
denseref=1000., denseslp=0.7143,
firstdt=1e-3)

self.mf.write_input()

# Run the MODFLOW model
success, v = self.mf.run_model(report=True)
for idx in range(-3, 0):
    print(v[1][idx])
```

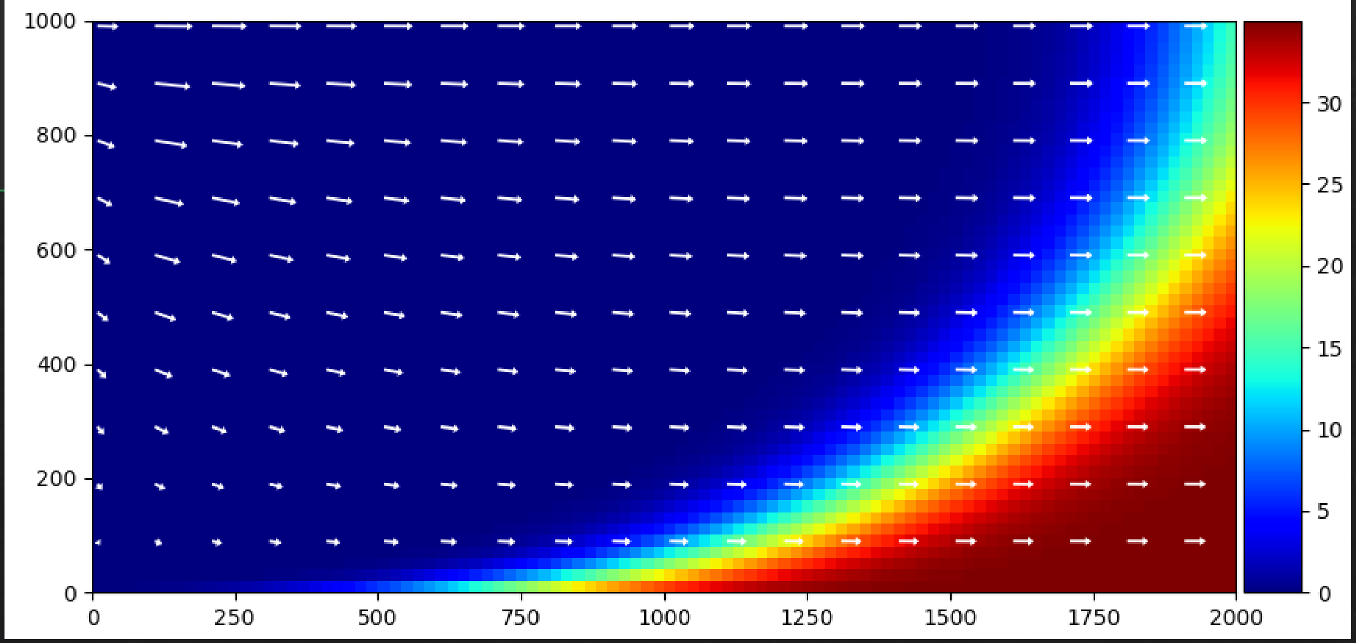


Preparatory Optimization:

Methods for Site Characterization

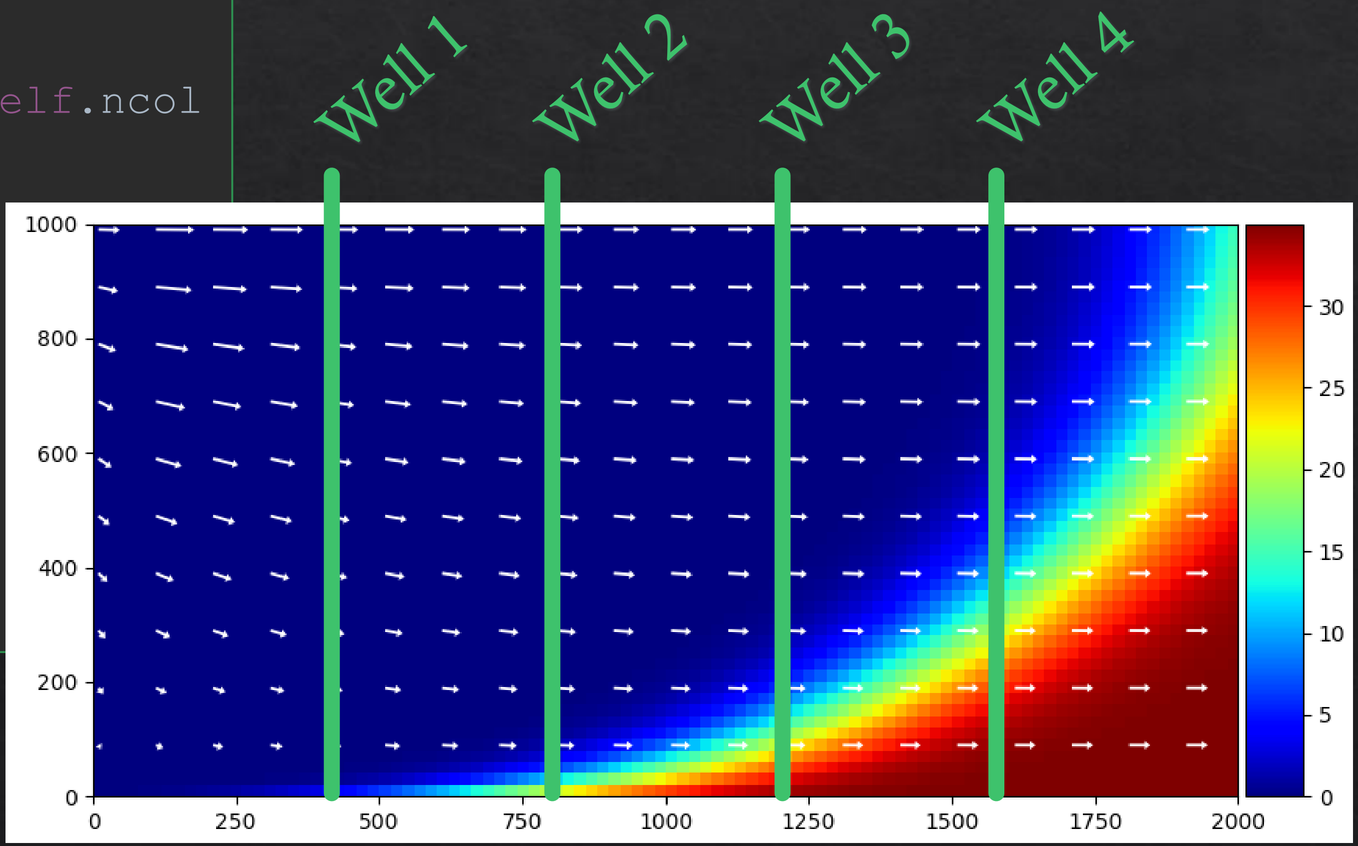
Monitoring Well Data: sampling the prototype model

```
from HiSeaWat import mymf
import numpy as np
from scipy.optimize import differential_evolution

dmcoef = 0.57024# m2/day  Could also try 1.62925/0.57024

#Kahuku Aquifer Model
model = mymf(dmcoef=dmcoef)
qinflow = 472500
model.run(q_inflow=qinflow)
welobs_real, welloc = model.observation()
model.plot()
```



Monitoring Well Data: sampling the prototype model

```
def observation(self):

    heads = self.head()
    concs = self.conc()

    welljs =
       np.rint(np.array([0.2,0.4,0.6,0.8])*self.ncol
              ).astype(int)
    self.welloc = welljs

    obsheads = heads[:,0,welljs]
    obsconcs = concs[:,0,welljs]

    obs = np.vstack([obsheads,obsconcs])
    obs = obs.reshape(-1)

    return obs, self.welloc
```



Single Variable Site Characterization

```
def f(Q):
    model = mymf(dmcoef=dmcoef)
    qinflow = Q
    model.run(q_inflow=qinflow)
    welobs_mod = model.observation()

    diff = np.subtract(welobs_real, welobs_mod)
    objval = (float(sum(diff))**2)

    if Q < 0.0:
        objval = objval*10000

    return objval

ret  = differential_evolution(f, bounds=[(0,1000000)], popsize=20, maxiter=30, disp=True)

print(ret)
```

Single Variable Site Characterization

```
 Run end date and time (yyyy/mm/dd hh:mm:ss): 2018/05/05 21:54:32
 Elapsed run time: 30.508 Seconds

 Normal termination of SEAWAT
n

4
     fun: 0.0
 message: 'Optimization terminated successfully.'
    nfev: 502
     nit: 24
 success: True
       x: array([ 472500.01055207])
```

```
#Kahuku Aquifer Model
model = mymf(dmcoef=dmcoef)
qinflow = 472500
model.run(q_inflow=qinflow)
```

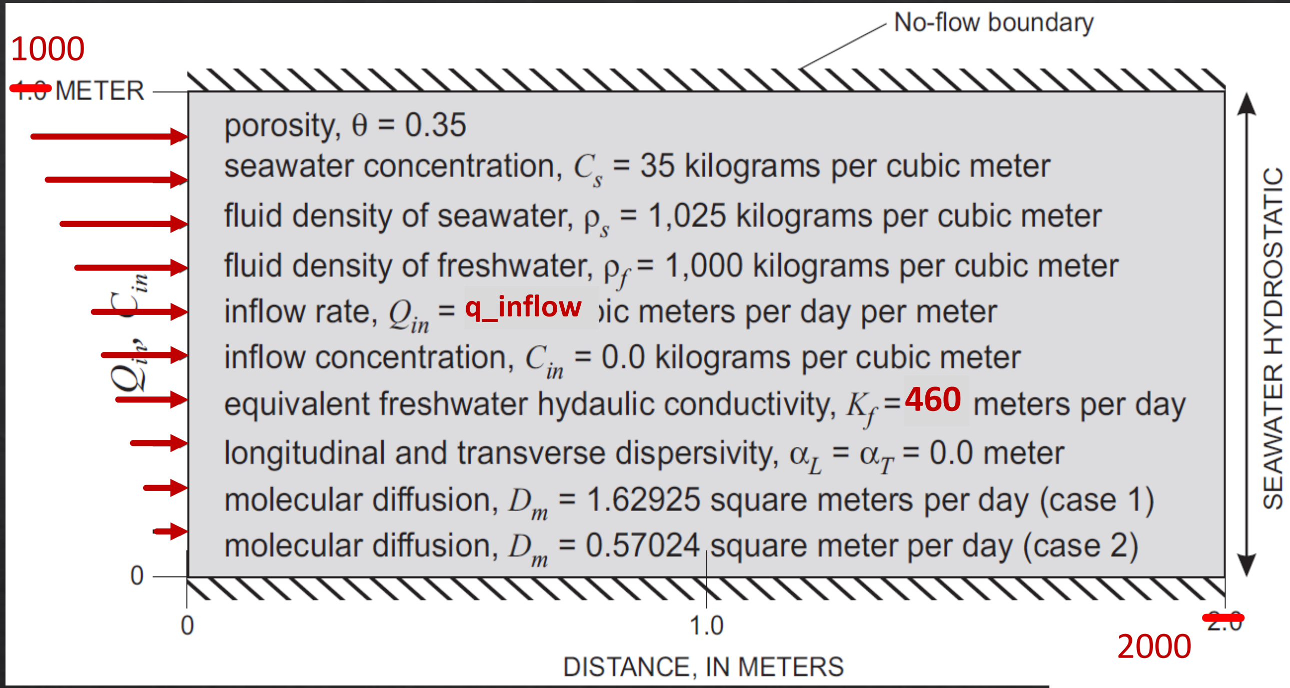
Method Development

- Monitoring Well Data
  - Collect all monitoring well data in the Kahuku Area
    - Focus on wells < 1000 meters from the beach
- Ground Water Model
  - Utilize monitoring well data to constrain conductivity at depth
    - 2D conductivity
- Site Characterization
  - Expand independent variables to include conductivity

References

- Langevin, C. D., Thorne, D. T., Dausman, A. M., Sukop, M. C., & Guo, W. (2008). *SEAWAT Version 4: A Computer Program for Simulation of Multi-Species Solute and Heat Transport.* Geological Survey (U.S.).

- Takasaki, K., & Valenciano, S. (1969). *Water in the Kahuku area, Oahu, Hawaii.* U.S. Govt. Print. Off.,.



Thank You

Questions?