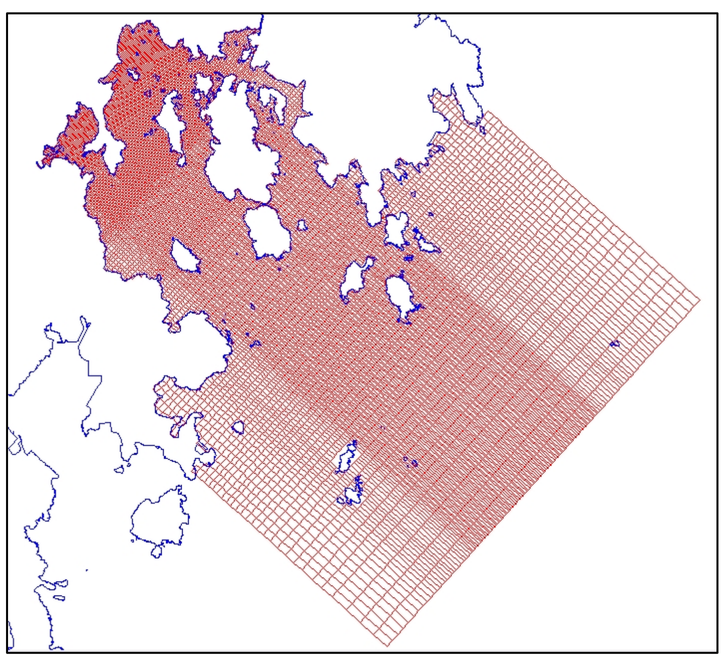
Tutorial 6 - Environmental Impact Assessment for Sai Kung Sewage Treatment Works (SKSTW) Outfall

In many densely populated cities in Asia, such as Hong Kong, jet groups discharged from an outfall is usually located not far away from water sensitive receivers (beaches or fish farms). While relying on the near-field model alone can give one a quick impression of the outfall performance close to the source, a complete computation from near to far field is necessary when conducting the environmental impact assessment.

The purpose of this example is to evaluate the potential environmental impact of the operation of the Sai Kung Sewage Treatment Works (SKSTW) under the design capacity of 22,000 m3/day. The SKSTW dry-weather influent flow pattern observed in mid-December 2001 was adopted to derive the 24-hour effluent flow pattern. The outfall for SKSTW is assumed to be a 90 m long diffuser with 18 vertical jets of diameter 0.1 m. Pollution loads from 12 storm outfalls and Sai Kung Typhoon Shelter are also included. The effluent discharge flow is taken to be fresh water with zero salinity.



The far field model uses a 153 x 153 x 8 curvilinear grid and has 100192 active cells. The tidal forcing at the open boundary consists of the five main tidal constituents (M2, S2, O1, P1 and K1) and 15-day spring-neap cycle is simulated. With DESA, the impact of the effluent discharge from the SKSTW outfall in both the near and far field is simulated.

The files for this tutorial are “PS06_scan07b9.vjx”, “PS06_scan02b9.vjx” and PS07w_nh301.vjx”.

Problem definition

Example sensitive receivers near the Sai Kung Sewage Treatment Works include :

Kiu Tsui beach (1.6 km from SKSTW)
Trio beach (1.9 km from SKSTW)
Ma Nam Wat (1.8 km from SKSTW)

You are asked to investigate whether the pollutant concentration (e.g. *E. coli* and un-ionized ammonia) will exceed the water quality objective at the above sensitive receivers, under the following land-based sewage treatment scenarios:

(a) No sewage treatment before discharge
(b) Only primary treatment

Water Quality Objectives for Port Shelter Water Control Zone (WCZ)

Parameters	Objectives	Sub-zone
E. coli	Not to exceed 610 counts/100 ml, calculated as the geometric mean of all samples collected in one calendar year	Secondary Contact Recreation Subzone and Fish Culture Subzones
	Not to exceed 180 counts/100 ml, calculated as the geometric mean of all samples collected in one calendar year	Bathing Beach Subzones
Ammonia	Annual mean not to exceed 0.021 mg/L as unionized form	Whole zone

General Notes:

1. To study the GIS application.
   (i) Load "PS06_scan07b9_set". This scenario simulates the case of no sewage treatment and the effluent *E. coli* concentration is 10^7 counts / 100 mL.
   (ii) Zoom in to Sai Kung District until names of beaches and marine water quality monitoring stations can be seen.
   (iii) Left click a marine water quality monitoring station (e.g. PM3). Past data of water quality will be displayed. Water quality data at surface, middle and bottom layer are available at a monthly/bi-monthly interval.
   (iv) Left click Trio Beach. Water quality data, including water temperature, DO, DO saturation, salinity, pH, turbidity and *E. coli* concentration, are available. Click the '+' button next to the parameter to display the data time series from 1986 to 2007. Data interval ranges from 3 to 14 days.
   (v) By looking at the time series of *E. coli* concentration, you can observe significant *E. coli* reduction since 2000. The high bacteria concentration in 90's is possibly caused by the contribution of polluted fresh water source from the Ho Chung River (west of Trio beach) and Sai Kung.
   (vi) Relationship between *E. coli* concentration and environmental parameters can also be observed. Left click and drag on the *E. coli* time series from 1992 to 1993, the selected area will be enlarged. Observe the sudden increase in *E. coli* concentration with the corresponding salinity reduction. The immediate surge in *E. coli* due to salinity change suggests the impact from fresh water source (i.e. Ho Chung River and stormwater outfalls).
   (vii) Left click Kiu Tsui Beach. Observe the time series of *E. coli* concentration, and note the difference between Trio and Kiu Tsui. Although the two beaches are close to each other, Kiu Tsui is facing more open oceanic water without major freshwater source. The consistently lower *E. coli* concentration at Kiu Tsui indicates the importance of beach orientation, existence of a nearby freshwater source etc., towards beach water quality.

2. To display the model output (non-conservative pollutants, *E. coli*)
   (i) Press space bar to begin the modeling output display.

(ii) Click ‘View’ and select ‘Current Flow’. Arrows with length and direction representing current speed and current direction respectively will be displayed.

(iii) Left click any point in the map to display the time series of *E. coli* concentration, tide level and current speed.

(iv) Observe if the current speed in Port Shelter lies between 0 to 0.05 m/s.

(v) Click ‘View’ and select ‘Jets’. Sewage outfall with 18 jets will be displayed at grid [846523.9 825846.5].

(vi) These 18 jets are computed from the Lagrangian model JETLAG, and dynamically coupled with the 3D far field circulation model through the distributed entrainment sink approach (DESA) at grid cell level.

(vii) At each time step, ambient information from the 3D circulation model is fed back into the near field model. Using the updated ambient data, the near field jet characteristics are then re-computed using JETLAG. The updated jet trajectories and the action of the jet entrainment on the far field are then computed for the next time step. This process is repeated for every time step. When close up the jet trajectories can be seen to move back and fro with the tidal current direction; in this case the action of the jets on the ambient current is small since the current speed is small (see (iv)).

(viii) Observe how the current changes with the tide again. The current is relatively constant over a time scale in the order of an hour. Since the jet mixing process has a time scale of minutes, it is justified to assume a quasi-steady flow for computing near field jet mixing (this is not relevant to the present simulation but is expressed as a point of note).

(ix) This dynamic coupling of the near and far field is necessary in Hong Kong as it can be seen sensitive receivers are not far away from the source. This is also the uniqueness of the VISJET 3 system.

(x) The modeling result shows that Kiu Tsui beach is the only sensitive receiver that may be affected by the sewage outfall. Right click Kiu Tsui beach and observe the time series of *E. coli* concentration. The *E. coli* concentration is below 24 count / 100 mL most of the time, reflecting an effective dilution and bacterial decay that reduces the impact to the beach.

(xi) Click ‘View’ and select ‘clip plane’ to observe the vertical profile of *E. coli* concentration.

(xii) Other sensitive receivers, Trio and Ma Nam Wat, are not directly influenced by the SKSTW and thus are not heavily polluted in this scenario.

(xiii) Besides the main source contributed by the sewage outfall, locate the 12 storm outfalls distributed along the shoreline of Sai Kung. Investigate their area of influence.

(xiv) Load "PS06_scan02b9". This scenario models the sewage outfall with primary treatment and the effluent *E. coli* concentration is 1500 counts/ 100 mL. A clear improvement can be observed in this scenario when compared to scenario "PS06_scan07b9". The impact from the sewage outfall nearly fades out before reaching Kiu Tsui beach.

3. To display the modeling output (conservative pollutants, un-ionized ammonia)

    (i) Load "PS07w_nh301". This scenario simulates the case when a conservative pollutant, un-ionized ammonia, is considered. It represents the operation of SKSTW under the design capacity of 22,000 m^3/day, and the effluent un-ionized ammonia concentration is 0.9 mg/L.

    (ii) Observe the difference between non-conservative and conservative pollutants.

    (iii) Due to the conservative nature of un-ionized ammonia, the region affected by the discharge increases with time. However, the concentration at most locations is below the 0.0046 mg/L threshold.

    (iv) Given that the source concentration of the nutrient is 0.9 mg/L, ambient current near the outfall can be observed to be about 0.04 m/s – 0.05 m/s, outfall depth is 11.5 m, and linear ambient stratification can be assumed with salinity varies from 33.5 ppt on the top to 34 ppt at the bottom. With the given information try run VISJET 2. What is the initial dilution for this case? How does it compare with the VISJET 3 output?

    (v) The near field average dilution for this case is computed to be about S=200–300 at the water surface with a near field model. The VISJET 3 results show that the **minimum dilution** at the surface near the outfall is about 200 (~0.05 mg/L). It can be seen that the two models given comparable results; with some additional mixing in the intermediate field (average dilution is typically 1.7-2 times minimum dilution).