EXCERPT FROM : Small Commercial Passenger Vessels Wastewater Discharge Impacts on the Marine Environment and Human Health. June 2003 *prepared for* Alaska Department of Environmental Conservation *Contract No. 18-5006-10 Work Order No. 18-5006-10-10B prepared by* Ecology and Environment, Inc. 840 K Street Anchorage, Alaska 99501

**Note: READ UNDERLINED AND BOLDED TEXT. IF SHORT ON TIME, READ ONLY #5.**

THIS STUDY WAS DONE ON SMALL SHIPS DISCHARGING AT ANCHOR IN KETCHIKAN, SKAGWAY, JUNEAU AND OTHER LOCATIONS. THE VOLUME OF EFFLUENT IS MUCH SMALLER THAN LARGE SHIPS. SMALL SHIPS HAVE <250 PASSENGERS. LARGE CRUISESHIPS HAVE UP TO 5,000.

THIS STUDY IS INFORMATIVE ABOUT THE SURPRISING FLOW OF EFFLUENT PLUMES INTO SENSITIVE AREAS, THE LARGE EXPANSE OF THE PLUMES, AND THE HOURS TO DAYS THAT PLUMES WITH ELEVATED LEVELS OF CONTAMINANTS LAST IN THE SITES STUDIED.

THIS STUDY WAS FUNDED AND REPORTED TO ADEC. IT IS INFORMATIVE WHEN DISCUSSING SHIP DISCHARGES, DILUTION RATES, DURATION AND MOVEMENT OF EFFLUENT PLUMES THAT CAN AFFECT SENSITIVE HABITATS, AND EXPOSE SPECIES IN THE WATER COLUMN FOR HOURS TO DAYS TO ELEVATED CONTAMINANTS.

WHY DIDN'T ADEC BRING THIS UP DURING DISCUSSIONS WITH LEGISLATORS ABOUT HB80 / SB29? WHY INSTEAD DID THEY ONLY REPEAT THE ALLEGED 'FINDINGS' TOLD TO THEM BY THE CRUISE SHIP APPOINTED PANELIST, WHO HAS REPEATED FOR 15 YEARS THAT EFFLUENT 'DILUTES IN SECONDS TO UNDETECTABLE LEVELS". MUCH AS WE WOULD ALL LIKE TO BELIEVE THAT, IT IS NOT ACCURATE, AND THE CONSEQUENCES OF REPEATING RHETORIC INSTEAD OF EXAMINING THE SCIENCE CAN BE SIGNIFICANT TO ALASKAN COASTAL WATERS AND SEAFOOD.

## 5.6 Summary of Observations on Pollutant Transport

Fate and transport of pollutants resulting from discharge of treated wastewater have been modeled by taking five (5) different geographic varieties of water bodies and the representative contaminants. The geometry of the water bodies includes that of a bay (Sitka), a strait (Ketchikan), a deep in-land estuary (Skagway), a coastal channel (Juneau), and a deep and wide estuary downstream of the confluence of two in-land estuaries (Haines). These water bodies represent the types of water systems present in the southeastern coastal zone of Alaska. The pollutants that were used in the model include; fecal coliform, degradable and non-degradable parts of COD, ammonia-nitrogen, CBOD, NBOD, phosphorous, free chlorine, and total suspended solids [due to analytical uncertainties, total nitrogen was not included in the model calculations]. Each of these are common pollutants found in treated wastewater. Furthermore, these pollutants cover the essential characteristics of all other pollutants. Therefore, the nature of migration of any other pollutant can be understood from the study of the nature of migration of the pollutants used in these models. In addition, copper, as the representative heavy metal pollutant, was also included in the models. The model calculations provide important insights into the fate and transport of pollutants discharged from treated wastewater in the southeastern coastal zone of Alaska from small passenger vessels (cruise ships).

The models show that:

1) Pollutant plumes are generated within the coastal waters of southeastern Alaska around the points of discharge of treated wastewater from the anchored cruise ships. Within a 24 h period, plume sizes can reach tens of square kilometers. The geometric shape of the plumes depends on the geographic type of the water bodies and hydrodynamics (velocity fields, tidal cycles etc.) of the water systems. In the case of a strait, the plume shape is long and elongated; within a bay the plumes are lobed to swirling branches; within an estuary, the plumes are oval to elliptical; and within a coastal water body having the geometry of a long open channel, the plumes are lenticular in shape. Thus, within an estuary the geographic extent of the plumes are smaller than those plumes within straits, bays, and channels. **The implication of these geometric shapes is that pollutants can migrate from the points of discharge to ecologically sensitive areas depending on the nature of the water bodies.**

2) **Owing to the dependence of plume shape and size on the geography and hydrodynamics of the water body, variation of concentration over time at a certain point is also highly variable depending on those factors**. Figure 32 (A-B) provides two examples. In the case of Sitka (Figure 32-A), where the plume geometry is not well defined, the pattern of variation of a pollutant concentration over time at different points are highly variable and erratic due to circulatory motion of the currents, ebbs and tides (Figure 32A). In the case of Skagway (Figure 32-B), where the pollutant plume has a well defined geometric shape, the variation of concentration near the source (point of discharge) is predictable. In this instance, the concentration increases, as discharge progresses and then declines as discharge stops and the plume migrates away with the flow of the water.

3) Due to strong control of the hydrodynamics on the plume shape and size, ebbs and tides affect both extension and restriction of a plume within a water system. In general, within the 24 h modeling period, plumes do not leave the boundary of a water system. However, the extent of the plume also depends upon the duration of the discharge. In the models, the duration of discharge from each of the cruise ships is a discrete time period less than 24 h. If discharge continues for a longer period, the possibility exists for plumes to migrate beyond the boundaries of the model domains used in the present study.

4) **A pollutant plume generated through discharge of a conservative (non-degradable) substance can migrate to great distances from the initial point of discharge and affect various areas.** An example is provided in Figure 33. Figure 33A shows the locations of the point of discharge and the pollutant plume 5 hours later after discharge from the vessel *Spirit of 98* [Ketchikan] has ceased. Note that the plume has propagated about 10 km to the southeast through the eastern passage around the Pennok Island. Its length has increased about 2 times. The details of the isopleths within this plume at this hour are captured in Figure 33B. The concentration-time history at the point of discharge shown in Figure 33A, has been recorded in Figure 33C. **Note that at the point of discharge, the concentration of the pollutant drops to an almost undetected levels after discharge ceased. But this does not imply that the pollutant plume has vanished from the water. It has simply been advected at another place.**

5) As illustrated above, **pollutant plumes can migrate several kilometers from the source and can persist in the water for a long period of time after the discharge ceases. This indicates that mixing zones of varying dimensions and concentrations exist within many portions of coastal southeast Alaskan waters due to discharge of treated wastewater from small passenger vessels. Dilution of these mixing zones takes a long time and can be inhibited by further or continued discharge.**

6) In general, a pollutant plume exhibits relatively concentrated portions (shown in red and maroon), surrounded by very dilute portions (shown in green, blue, and black). A combination of factors such as the treated nature of the discharged wastewater, great volumes of the receiving water bodies, strong currents, etc., exert considerable influence on the dilution of the pollutants within the receiving waters. The models presented show that concentration levels for all the pollutants used are extremely low, even within the relatively more concentrated portions of the plumes. As modeled in this study, none of the calculated concentrations appear to pose a serious threat to receptors found within the aquatic environment.

7) A single plume can be divided into two or more parts due to the action of tidal actions and counter currents. This causes further spread and migration of the plume, a result of the complex function of the hydrodynamics of the water systems.

8) The present model calculations show that, in general, the concentration of the

pollutants, even in the concentrated parts of the plumes, are very low. However, before interpreting these dilute concentrations as a confirmation that no resources are at stake from the nature of the pollutant plumes, the numerous sources of uncertainties in the model results should also be considered. Most, if not all, of these uncertainties stem from the lack of site-specific chemical, water quality, and hydraulic data (see section 5.5). For example, for all pollutants except for TSS, the settling velocity is considered to be zero. As a result, for all these pollutants the depth-averaged values are obtained in the model. But as shown with the TSS model (see section 5.4.5), even a pollutant that is considered to be sinking, the concentrated parts remain mostly near the water surface. Thus, depth-averaging reduces the concentrations that are actually present near the surface layers. **In other words, in realty, the concentrations of pollutants in various parts of the plumes should be considered higher than those calculated in the models.**

9) From the discussions presented above it can be concluded that the general patterns of migration of the pollutants (transport of contaminants) predicted by the model calculations are valid. However, the magnitude of pollution (fate of the contaminants) predicted by the models has considerable uncertainties and should not be used as an absolute indication of the level of contamination that can result from discharge of treated wastewater from the numerous cruise ships found at many locations for substantially longer durations than those addressed by the model calculations.

10) Accurate estimation of model parameters is necessary for better interpretation of the model results. To illustrate the importance of these factors such as the decay coefficient, settling velocity, etc., Figure 34 (A-E) shows the fecal coliform model with decay coefficient 0 $day^{-1}$ and settling velocity 0 cm/day. In this case, the maximum fecal coliform concentration is calculated as 0.21 $MPN/m^3$ after 2 h of discharge from *Malaspina*. This is in contrast to the models previously presented (see Fig. 24) where a large decay coefficient (37 $day^{-1}$) was used. In that case, the maximum fecal concentration was calculated as $0.99 \times 10^{-2}$ $MPN/m^3$. This example also shows that if a pollutant behaves as a conservative substance then not only is its concentration increased in the water body, but its persistence is also increased around the point(s) of discharge.