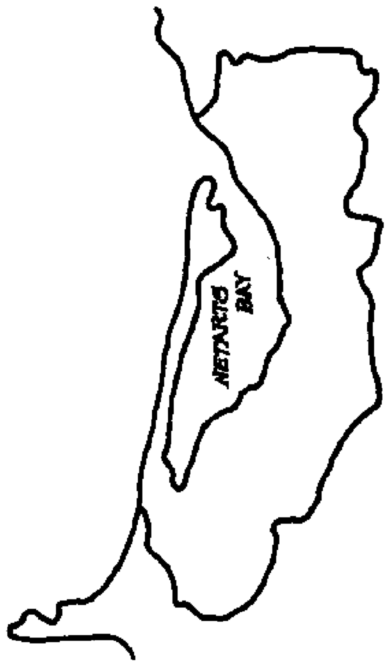
RELEVANT DATA
concerning proposed discharges of domestic wastes into
NETARTS BAY, OREGON

Scott L. Boley
and
Larry S. Slotta



OREGON STATE UNIVERSITY
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Bulletin no. 50

DECEMBER 1974

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ACKNOWLEDGEMENT

This report is in response to requests for information concerning Netarts Bay from the Environmental Protection Agency and other interested parties concerned with determining the best means of discharging domestic wastes collected from the communities of Netarts and Oceanside. Much of the data contained herein was collected during the summer of 1971, and has not been previously reported. The constituent transport analysis section of this report was performed by Charles Glanzman for an M.S. thesis (in preparation). Support for the collection of this data was granted by the Maude Hill Foundation, Minneapolis, Minnesota and the Sea Grant Project "Estuarine Hydraulics" at Oregon State University, sponsored by the National Oceanic and Atmospheric Administration.

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INTRODUCTION

Netarts Bay is a small tidal flat embayment located at the northern base of Cape Lookout, south of Tillamook Bay on the Oregon coast. At low tide the bay is a series of tortuous, braided channels, while at high tide the bay appears as a broad, shallow embayment. Figure 1 illustrates Netarts Bay and the surrounding area. The basic physical characteristics and dimensions of Netarts Bay are summarized in Table 1. More detailed information on tidal hydraulics, physical characteristics and water quality of Netarts Bay is contained in the report of Glanzman, Glenne and Burgess (1971).

The discharge of domestic wastes into Netarts Bay creates the possibility that the present nature of the bay might be altered. The effect of domestic wastes upon the pelagic and benthic life within the bay has not been determined, with the possibility that eutrophication of the bay system might be accelerated by the addition of nutrients to the system. In view of this, an analysis was performed to determine a schedule for discharging domestic wastes into Netarts Bay which would minimize the amount of nutrients added to the bay, and particularly to the shellfish production flats near the upper end of the bay. Such a discharge schedule would take advantage of the natural tidal flushing processes within Netarts Bay to help carry wastes into the open ocean.

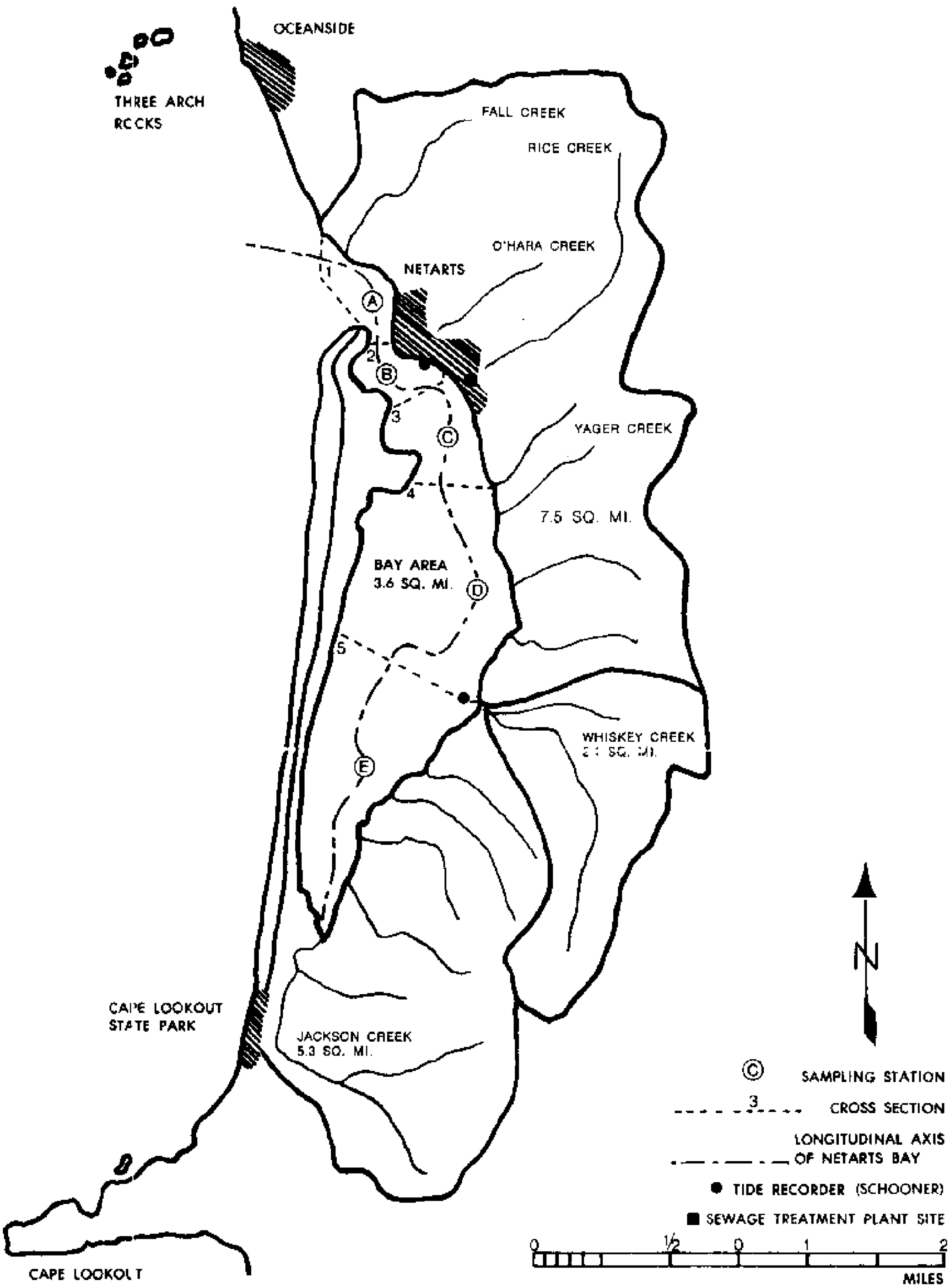

Figure 1.

Vicinity Map of Netarts Bay, Oregon,
Drainage Areas and Study Cross-Sections.

Table 1. Summary of Netarts Bay Physical Characteristics

Parameter	Entire Bay	Landward of Cross Section 3	Landward of Cross Section 5
Surface Area			
at MLW	$2.2 \times 10^7 ft^2$	$1.3 \times 10^7 ft^2$	$0.5 \times 10^7 ft^2$
at MTL	24.0×10^7	18.0×10^7	6.0×10^7
at MHW	108.0×10^7	94.5×10^7	39.5×10^7
Total Volume			
at MLW	$11.3 \times 10^7 ft^3$	$7.8 \times 10^7 ft^3$	$1.9 \times 10^7 ft^3$
at MTL	24.0×10^7	18.0×10^7	6.0×10^7
at MHW	44.5×10^7	36.0×10^7	12.9×10^7
Tidal Prism			
MHW to MLW	$33.2 \times 10^7 ft^3$	$28.2 \times 10^7 ft^3$	$11.0 \times 10^7 ft^3$
Cross-Section Area at MTL			
minimum	$4980 ft^2$		
maximum	$8250 ft^2$		
Tidal Data			
MHHW		7.66 ft	7.81 ft
MHW		6.59	6.50
MTL		3.78	4.09
MLW		0.97	1.67
MLLW		-0.25	--
Mean tidal range		5.62	4.83
Ebbing period		405 min.	410 min.
Flooding period		340	335

MLW - Mean Low Water
MTL - Mean Tide Level
MHW - Mean High Water
MHHW - Mean High High Water
MLLW - Mean Low Low Water

CONSTITUENT TRANSPORT IN NETARTS BAY

The following analysis was performed assuming that a sewage treatment facility would be built for the communities of Netarts and Oceanside and that the wastes would be discharged into Netarts Bay in the vicinity of Rice Creek (see Figure 1).

The transport and dispersion of soluble constituents in Netarts Bay should be considered such that an environmentally acceptable discharge schedule is included in the outfall design. The design problem is complicated by the unusual character of Netarts Bay. Numerous sand bars, tortuous diverging and reconverging channels complicate the tidal hydraulic situation. Because of the mixed semidiurnal tides observed on the Oregon coast and because the tidal prism for the bay is often greater than one-half the high water bay volume, presently available steady state predictive models of dispersive constituent transport would not be applicable. It is felt that a semi-empirical graphical approach illustrating tidal constituent transport in terms of tidal height versus time would be the most practical means of expressing an acceptable treatment plant effluent discharge schedule for Netarts Bay.

To assure the continuing present character of Netarts Bay water and sediments and to assure proper water quality for shell fisheries, two design guidelines were considered in the analysis:

1. No effluents shall be allowed to migrate directly to the head of Netarts Bay from the outfall.

2. Ninety five percent permanent removal of effluent waters from Netarts Bay is to be achieved by the effluent discharge schedule.

Several experiments were conducted in 1970 to give design information on dispersive transport phenomena in Netarts Bay. They included a drift drogue study, four dye studies and mathematical modeling of the tidal hydraulics. The dye studies are described in Appendix A of this report. The drift drogue study and the mathematical model are described in the report of Glanzman, Glenne and Burgess (1971). In the summer of 1971, additional dye studies and bottom drifter studies were conducted and are described later in this report.

Combining 1970 field data and tidal information, a safe discharge time projection was determined. This projection gives the time after high tide during which treated effluents may be discharged from the treatment plant site into the bay and which satisfies the above design guidelines for most tides.

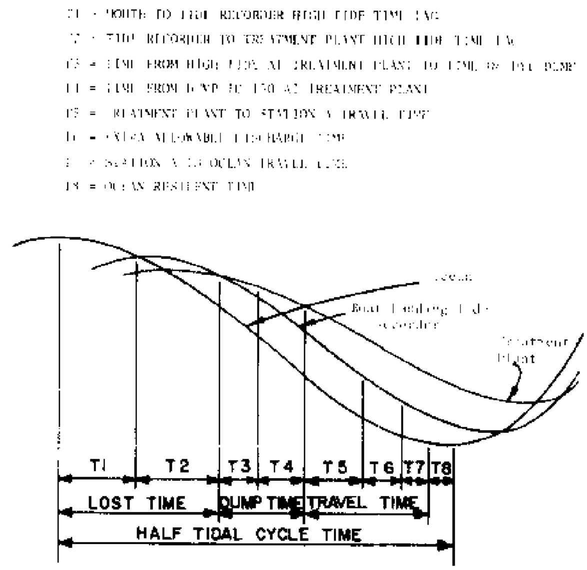

Figure 2. Definition Sketch for Safe Discharge Time

SAFE DISCHARGE TIME PROJECTION

The Netarts-Oceanside Sanitary District has proposed the construction of their sewage treatment plant at Rice Creek, on the Netarts Bay Front. This plant would discharge secondary treated sewage effluent into the main channel of Netarts Bay. In order to develope a safe discharge schedule, as is proposed, a knowledge of both the tidal dynamics of Netarts Bay and tidal transport phenomenon is required. Tidal dynamics can be determined through observing and recording tides at different points within the bay. Tidal transport can be better understood through dye studies, such as by placing of low toxicity Rhodamine WT dye at selected locations and subsequently measuring dispersion and travel times as the dye cloud moves through the bay.

Tidal hydraulics for the bay were analyzed by Glanzman, et. al. (1971), with percentage damping and time lags observed for typical tides during 1969 and 1970. Tidal data from this reference are listed in Appendix B. In Figure 2, three hypothetical, but representative tidal height vs. time curves are shown. Note the curves are for different points within the bay, illustrating frictional effects as the tide progresses into Netarts Bay.

The dye studies were conducted on the ebb tides of July 24 and August 30, 1970. On both days, dye was released in a line transverse the longitudinal axis of Netarts Bay near the proposed sewage treatment plant a short time after high tide. Measurements of travel time and dispersion were made at several points along the path of the dye clouds as they were carried by the outgoing tide.

For the analysis, the dye cloud is considered to represent the last effluent discharged from the sewage treatment plant on each ebbing tide. At several points along the path of the dye cloud, measurements were made to determine the percentage of the release which actually passed that point. A cumulative recovery curve, showing the amount of dye released, is shown in Figure 3 for August 30, 1970. Such curves show the effects of dispersion by the smoothness and slope of the curve.

From these dye studies, combined with tidal data, a method for determining suitable times for discharge of wastes was developed.

Time Increments Explained

Figure 2 shows the time increments that may be measured based upon tidal data and dye studies. Each time increment is defined and discussed in the following:

T_1 is the high tide time lag from the mouth of Netarts Bay or open ocean, to the tide recorder at the Netarts Bay Tillamook County boat landing. (This tide recorder was used during all dye studies.) T_1 may be found by subtracting eight minutes from the tidal time lag from Newport, Oregon to the Netarts Bay Tillamook County Boat Landing. The time lag from Newport to the Tillamook County Boat Landing is shown in Figure 4. Eight minutes corresponds to the time lag from Newport, Oregon to the mouth of Netarts Bay.

T_2 is the high tide lag time to the proposed sewage treatment plant from the boat landing and may be estimated by a proportioning of the lag time from the boat landing to Whiskey Creek. Though time lags differ for different tides, a value of T_2 = 15 minutes can be used with negligible error.

T_3 is the time elapsed from the time of high tide at the proposed plant to the time of the dye release. T_3 is known from the tide record of the day of the dye release and tidal information in Appendix B. In the use of a safe discharge schedule, T_3 does not need to be determined directly, as will be explained later.

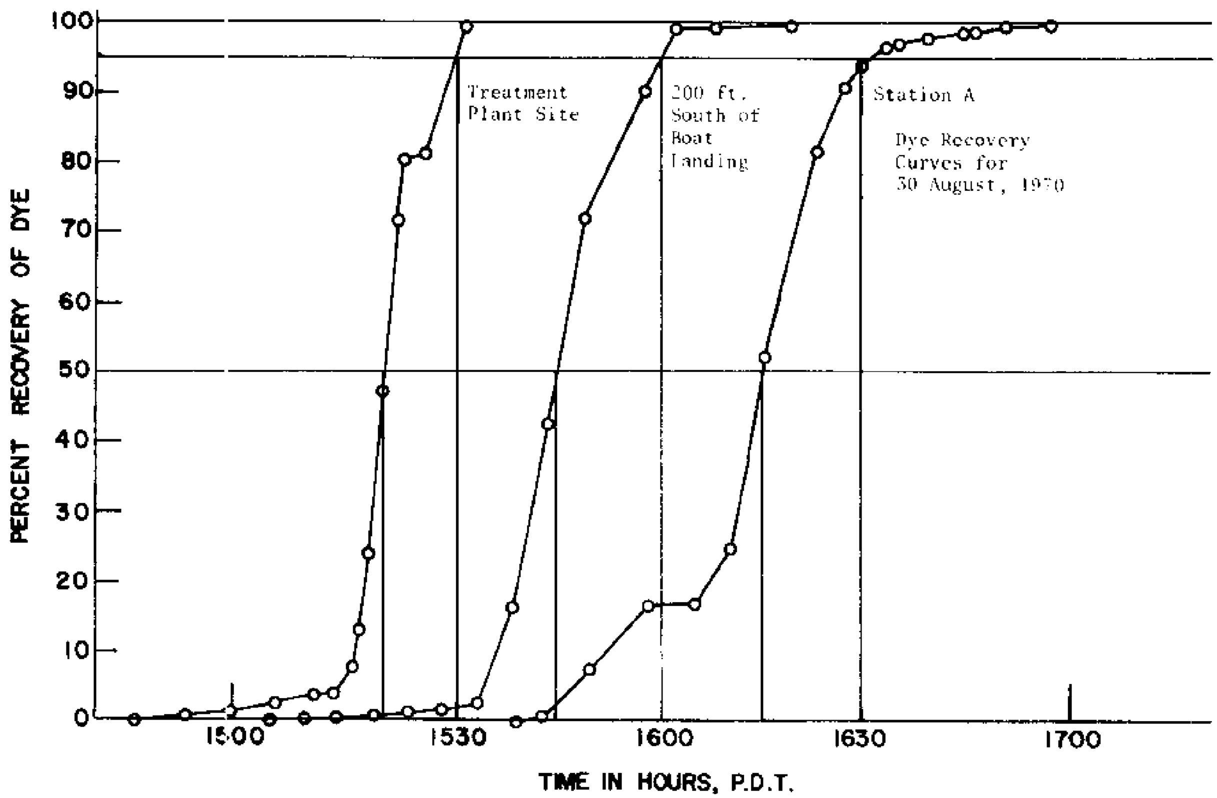

Figure 3. Cummulative Recovery Curve, August 30, 1970

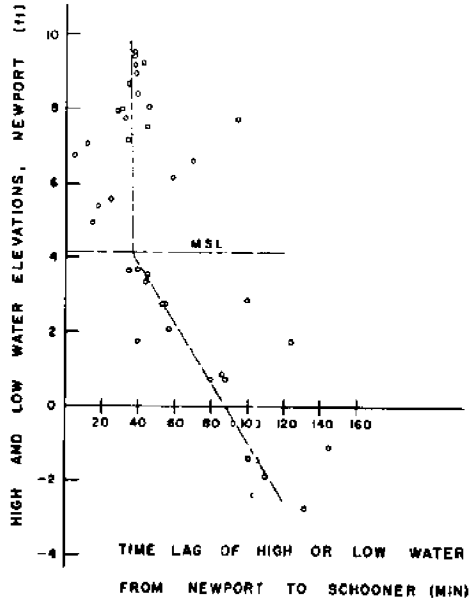

Figure 4. Tidal Time Lag from Newport to Netarts Bay Boat Landing (from Fig. 14, Glanzman et. al., 1971)

T_4 The August 30, 1970 dye release occured at a point upstream from the proposed treatment plant site. T_4 is the time from the dye release above the proposed plant to the time at which 50 percent of the recovered dye passed the treatment plant site (T_{50}). T_{50} is used as the median travel time since the dye cloud dispersed naturally while traveling past the plant site. The sum of T_3 and T_4 is the period after high tide during which effluent could be discharged. In the use of a safe discharge schedule, (T_3+T_4) is not determined directly, but is found by subtracting all undesireable discharge periods from the total time for the particular ebb tide of concern.

T_5 is the travel time of 95% of the effluent from the proposed plant to Station A at the mouth of Netarts Bay (see Figure 1).

T_6 is extra time needed to complete a half tidal cycle. T_6 could be added to T_3 and T_4 to give added discharge time (as in the sample calculations) or kept as a safety factor

T_7 is the travel time from Station A to the 40-foot ocean depth or "depth water", which is the hydrodynamic mouth of Netarts Bay and is presumed to be the bay-ocean interface.

T_8 is the required time of ocean residence seaward of the 40-foot contour before low tide at the mouth to provide approximately 95 percent permanent removal of effluent from the bay. For example, on September 22, 1970, discharging dye seaward of Station A at the end of an outgoing tide, and monitoring at the Station A during the incoming tide, indicated about 17 percent of soluble, conservative effluent constituents would return to the bay from the last half-hour of outgoing tide at the ocean-bay interface. It is felt if T_8 is set to one hour, nearly 95 percent permanent removal of conservative constituents from Netarts Bay could be expected resulting from dispersion of these constituents in the open ocean.

T_{95} or the time of 95 percent dye passage was chosen as a desirable measure of full effluent transmission. Thus, the T_{95} for each downstream sampling point is also a measure of the effluent travel time. This represents the second effluent discharge criteria as previously discussed.

Tidal Cycles and Their Effect

In review, half a tidal cycle is divided into three major segments: lost time, travel time, and safe discharge or release time (see Figure 2). *Lost time* is that part of the tidal cycle expended while the tidal wave moves from the mouth of Netarts Bay to the effluent discharge site. Due to tidal transport phenomenon, wastes should not be discharged during this time. *Travel time* is that part of the tidal cycle which must be allowed in order for natural tidal processes to carry the effluent from the discharge site to the open ocean. Once reaching the open ocean, the effluent would be allowed to remain in the ocean a period of time (e.g. one hour) in order to further reduce the return of effluent to Netarts Bay. Again wastes should not be discharged during the times designated as travel time or ocean residence time, since to do so would not allow the suspended constituents entrained in their waters to be carried out of the bay by tidal flows. The remaining part of the half tidal cycle [after excluding the lost time (T_1 + T_2), travel time (T_5 + T_7), and ocean residence time (T_8)] can then be used for discharge of wastes (T_3 + T_4 + T_6). It should be noted that the (T_3 + T_4 + T_6) interval would not be determined directly, but would be found by eliminating the times when it is not desirable to discharge effluent into Netarts Bay.

Following are sample computations for the ebb tide of July 24, 1970 giving the period of time during which effluent could have been discharged at Rice Creek. Discharge for a period of one hour and ten minutes following high tide would result in permanent removal of most of this effluent from Netarts Bay.

Sample Computations

July 24, 1970

Tidal Predictions - Newport

Tidal Height	5.4 feet
Time of High	4.42 AM

Low Tide Newport

Tidal Height	-1.0 feet
Time of Low	10:20 AM

LOST TIME ($T_1 + T_2$)

T_1 = high tide time lag from the mouth of the Tillamook County Boat Landing. From Figure 4, for a tidal height of 5.4 feet, T_1 = 38 minutes - 8 minutes: (8 minutes is the travel time of the tide in the open ocean from Newport to Netarts Bay mouth); or T_1 = 30 minutes.

T_2 = high tide time lag from the boat landing to the treatment plant site = 15 minutes.

Lost Time = ($T_1 + T_2$) = (30 min. + 15 min.) = 45 minutes.

TRAVEL TIME ($T_5 + T_7$)

T_5 = travel time from discharge point to Station A = 2 hours 45 minutes (determined by measurements of the travel time for a dye cloud).

T_7 = travel time from Station A into the open ocean = 1 hour (as estimated from observations).

Travel Time = ($T_5 + T_7$) = 3 hours 45 minutes.

OCEAN RESIDENCE TIME (T_8)

T_8 = Ocean Residence Time (time required for ocean waves and currents to disperse pollutant). T_8 is assumed to be 1 hour; T_8 = 1 hour.

ACCEPTABLE DISCHARGE TIME ($T_3 + T_4 + T_6$)

This is determined by finding the duration of the ebb tidal cycle, then subtracting lost time, travel time, and ocean residence time. The time left over is thus acceptable discharge time.

DURATION OF EBB TIDAL CYCLE

From Figure 4, high tide at the Netarts Bay Tillamook County Boat Landing would occur at 5:20 AM. (High tide at Newport is 4:42 AM + 40 minutes (from Figure 4) = 5:20 AM.)

Low tide at the Netarts Bay Tillamook County Boat Landing will occur at 12:00 noon. (Low tide at Newport is 10:20 AM + 100 minutes (from Figure 4.) = 12:00 noon).

Duration of ebb tidal cycle = 12:00 noon - 5:20 AM = 6 hours 40 minutes.

Now, since (lost time + travel time + ocean residence time) = (45 min. + 3 hour + 45 min. + 1 hour) = 5 hours 30 minutes, the length of time *acceptable for discharge* = (6 hours 40 min.) - (5 hours 30 min.) = 1 hour 10 minutes. This time will begin 15 minutes (T_2) after high tide at the Netarts Bay Tillamook County Boat Landing, e. g. 5:20 AM + 15 min. = 5:35 AM.

Acceptable discharge time is thus from 5:35 AM to 6:45 AM, for July 24, 1974 morning ebb tide.

The field data on which this analysis is based was collected within Netarts Bay the summer of 1970. The following summer, 1971, additional studies of the entrance region of Netarts Bay were conducted with pertinent data being reported next.

BOTTOM DRIFTER STUDIES

Bottom currents and the bay-ocean exchange of water were studied at Netarts Bay in the summer of 1971. To study bottom currents a total of one hundred and fifty Woodhead-type bottom drifters were released, fifty within the bay and one hundred outside the entrance. A photograph illustrating release of these bottom drifters is shown in Figure 5.

Figure 5.
Releasing Woodhead Bottom Drifters

The 50 bottom drifters released within the bay were placed just within the entrance at high tide on midnight of August 17, 1971. The object of this release was to determine where these drifters would go, and whether or not they would be washed back into the bay on subsequent tidal cycles. Of the 50 bottom drifters released, 27 were subsequently recovered. The distance traveled by these bottom drifters varied, with the maximum excursion being to the north a distance of several miles. Twenty-two drifters were found on the beach north of the entrance to Netarts Bay, three drifters were found south of the entrance, and two drifters were found within the bay near Happy Camp. This would indicate a return of approximately eight percent of the bottom drifters to the bay.

At 8:30 a.m. on August 18, 1971, 100 bottom drifters were released outside the entrance to Netarts Bay on a flooding tide. Four bundles of 25 drifters each were released at the positions shown in Figure 6. Of these, 59 were subsequently recovered. Five drifters were recovered south of the entrance, 42 drifters were recovered north of the entrance, and eight drifters were recovered within the bay. This indicates that approximately fourteen percent of the drifters were carried into the bay from this release. The predominant direction of travel in both cases was to the north, with some drifters being carried beyond Cape Mears and recovered on the Tillamook Spit.

On November 24, 1971, 20 bottom drifters were again released in the vicinity of Netarts Bay, this time 1/2 mile south of the entrance and 3/4 mile offshore. Of these 20 bottom drifters, one was recovered.

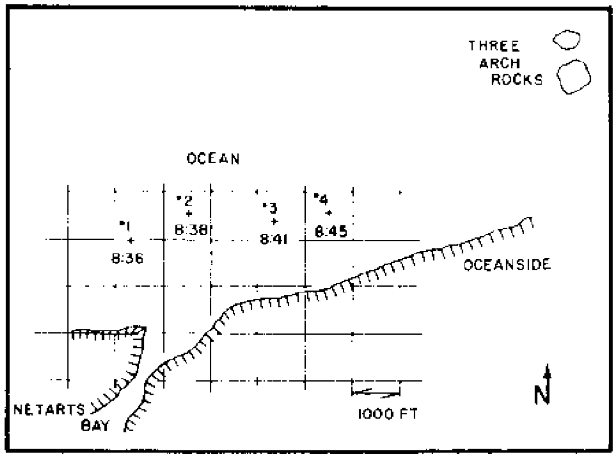

Figure 6. Release Positions of Bottom Drifters, August 18, 1971.

This drifter was recovered by Oceanside, indicating nearshore currents to the north for the period. This flow direction is consistent with the results obtained from bottom drifter studies along other sections of the coast conducted at the same time.

Although few measurements have been made of littoral currents near Netarts Bay, the net littoral transport of sand is probably to the north as inferred from the geomorphology of the area betweeen Cape Lookout and Cape Mears. One measurement of littoral current was made on October 17, 1971, 1/2 mile south of the entrance to Netarts Bay. On this occasion the direction of current was to the north with a velocity of greater than one foot per second. This measurement should not be considered as typical of the area, since the direction of littoral current and the velocity will change on a day-to-day basis.

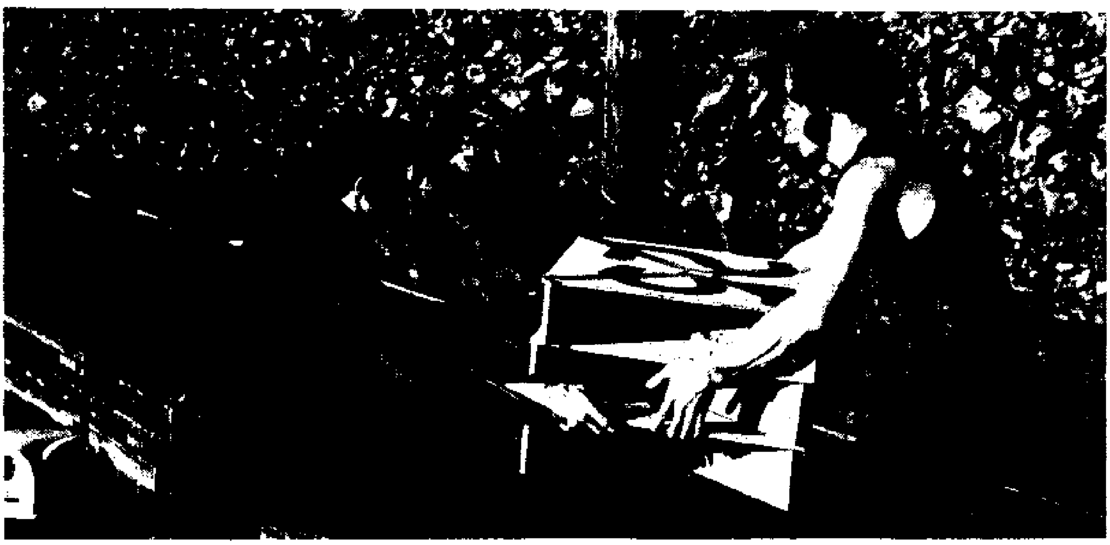

Figure 7. Loading Shallow Water Surface Floats

BAY-OCEAN EXCHANGE OF WATER

On August 18, 1971, studies were made of currents near the entrance to Netarts Bay. The motive behind these studies was to increase our general knowledge of estuarine processes, and specifically to ascertain the magnitude and direction of currents seaward of the estuary entrance occurring during a flood tide. To determine these currents, both Rhodamine WT dye and large surface floats were released and were subsequently photographed aerially. These aerial photographs were analyzed with photogrammetric plotters and the aid of a computer to give both magnitude and direction of surface currents. A more thorough description of the methods of analysis can be found in James (1971) and Weise (1973). The dye releases were made by releasing dye packets from an airplane and from a 16 ft. open aluminum boat. Surface floats, shown in Figure 7, to determine direction and velocities of surface currents were released and recovered manually using the 16 ft. aluminum boat.

Low tide at the Tillamook County Boat Landing for Netarts Bay for August 18, 1971 was predicted to occur at 7:10 a.m. with high tide measured as occuring at 1:40 p.m. Within Netarts Bay, slack water will occur 40 to 60 minutes after low tide (Glanzman, Glenne, Burgess, 1971). Flooding currents were thus starting at approximately 8 a.m. A graph of flow rate versus time for August 18, 1972, at Station A, was formulated as based upon the mathematical model results reported in Glanzman, Glenne and Burgess (1971) and shown in Figure 8.

A comparison of predicted velocities with measured velocities for the Netarts Bay entrance region would confirm the present understanding of the physical phenomenon affecting currents in the entrance region. From the information in Figure 8 and the hydrography of the entrance region an attempt was made to predict water velocities in the entrance region. Based upon a 1957 hydrographic chart (the most recent available for the area), two cross-sections perpendicular to the flow were determined: these cross sections being located 500 yards and 1000 yards from the entrance, as shown in Figure 9. These cross-sections are identified as section a-a and section b-b, and are shown in Figures 10 and 11. Dividing the tidal flow rate at any one time by the cross-sectional area of a section yields the average velocity through this section for that time. Necessarily, the actual velocity at any specific point on the section may differ considerably from this average velocity due to differing water depths, frictional effects, and perhaps surf action, all of which change on a day-to-day basis. However, the average velocity for a section should provide an order of magnitude of the expected velocity for various distances from the mouth.

Figure 12 shows the predicted average velocities for sections a-a and b-b at four times during the flood tide on August 18, 1971. (Tidal range for this day was predicted to be 7.3 feet.) Three of these times were chosen to correspond to periods when measurements of velocity in the entrance region were made, with the fourth time, 12:30 p.m., corresponding to the time of maximum flow rate as given in Figure 8. As indicated, the average velocity for section b-b is only one-fourth to one-fifth as great as the velocity for section a-a. Section a-a is within the shallow region of the offshore bar for Netarts Bay, while section b-b is beyond this bar.

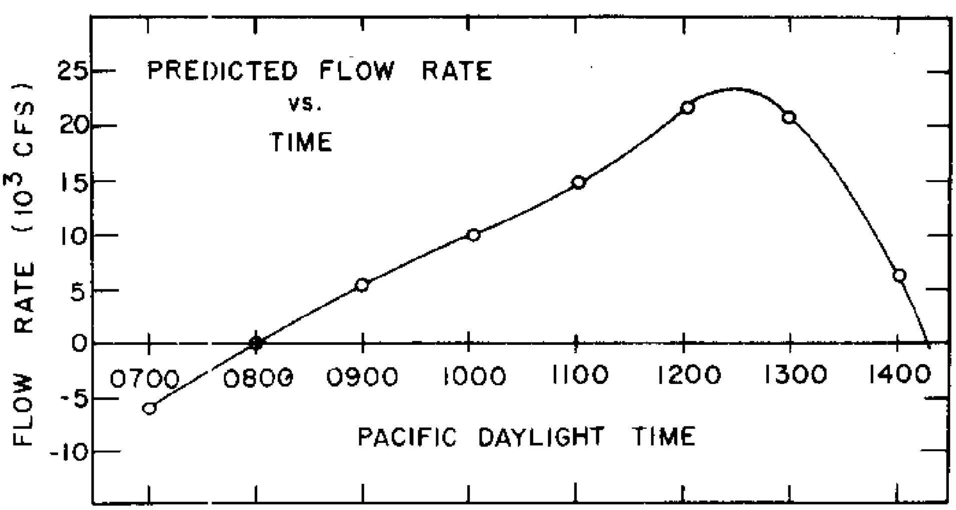

Figure 8. Predicted Tidal Flow Rate vs. Time, Flood Tide August 18, 1971

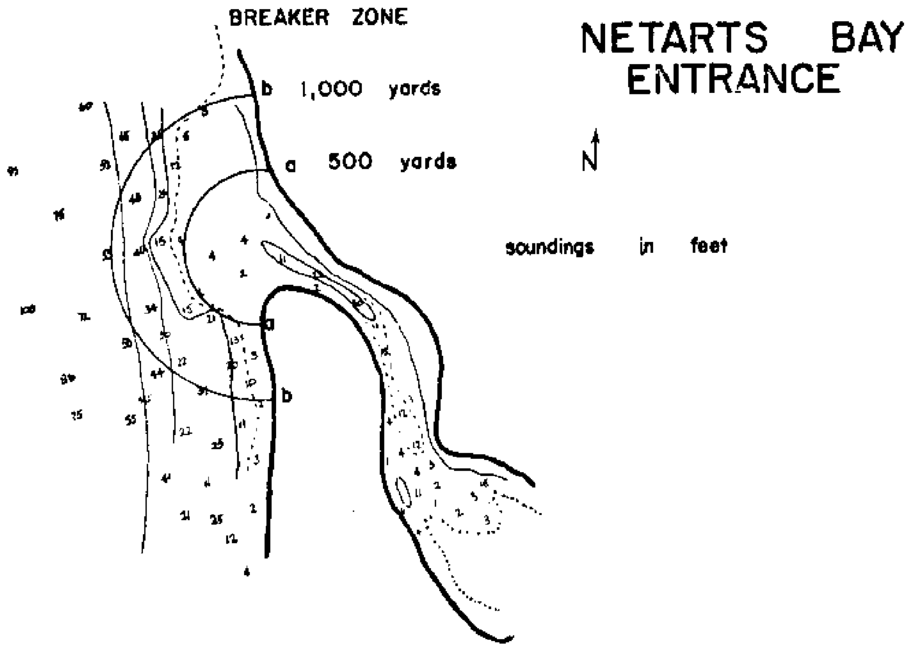

Figure 9. Entrance Region of Netarts Bay
(from 1957 USC&GS Chart 8372)

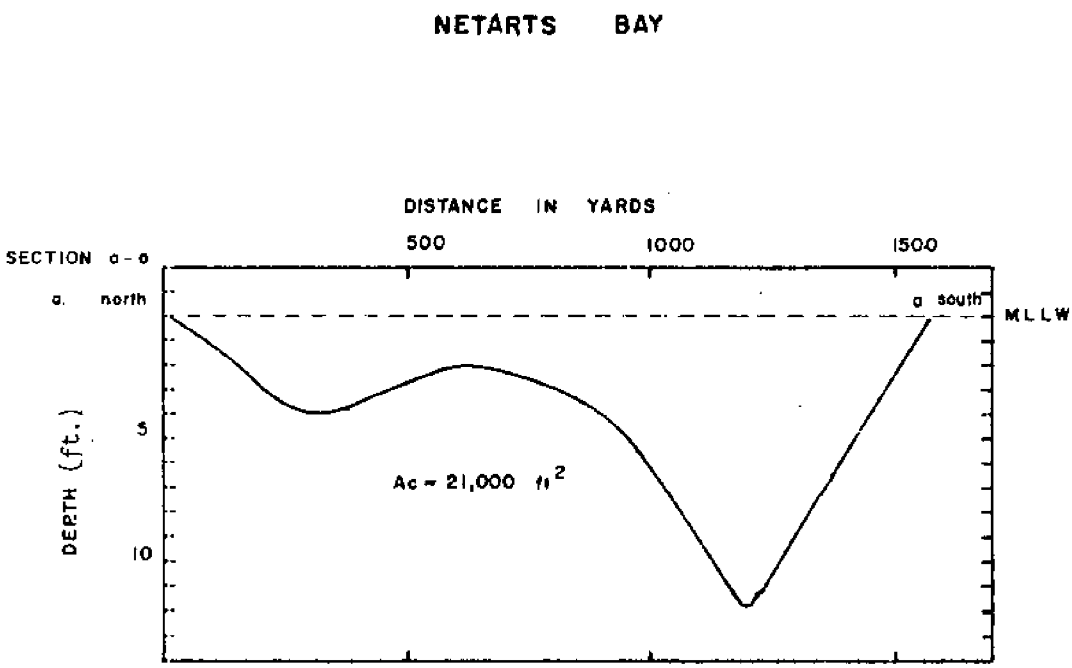

Figure 10. Cross-Section a-a, Netarts Bay Entrance, 1957

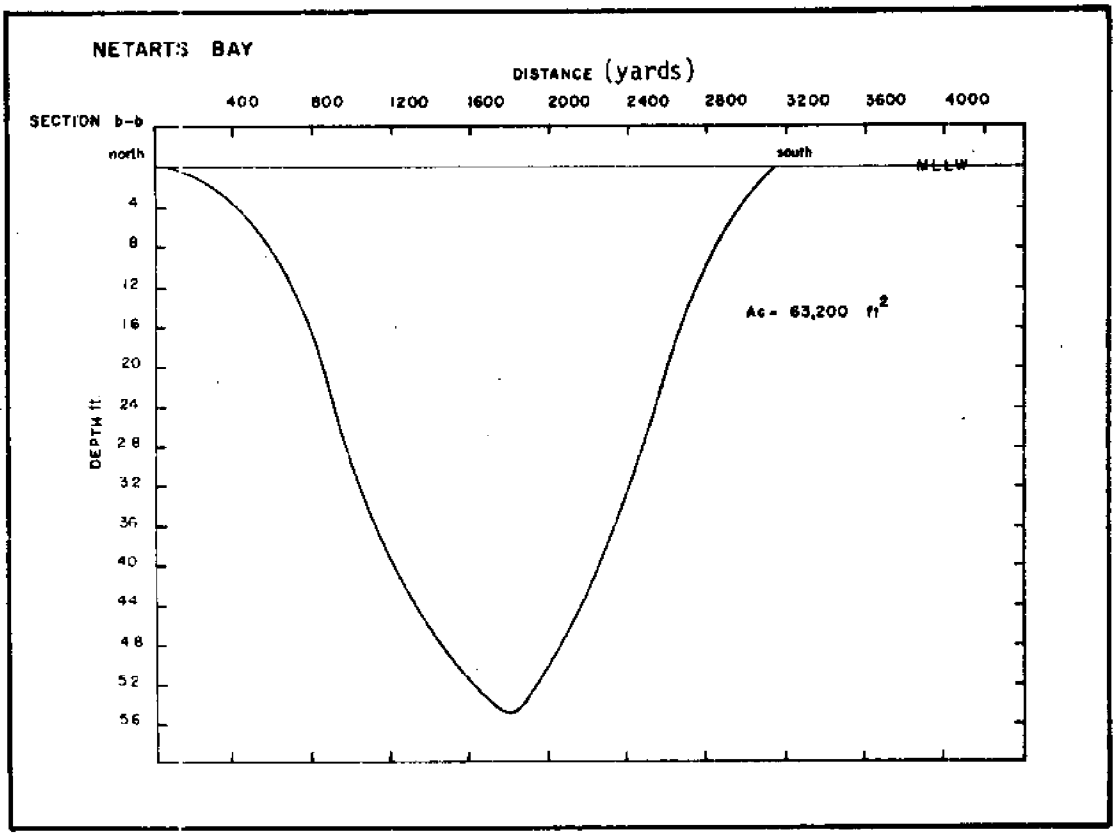

Figure 11. Cross Section b-b, Netarts Bay Entrance, 1957

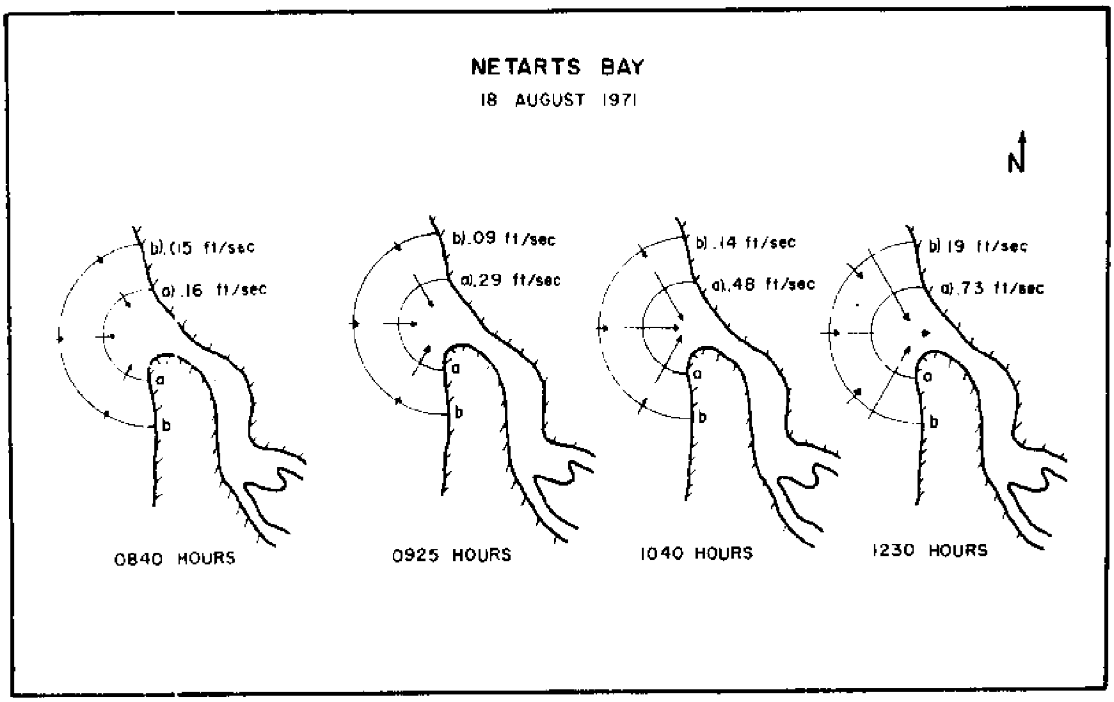

Figure 12. Predicted Average Velocities for Entrance Region, Netarts Bay 8-18-71

Seaward of the offshore bar depths increase rapidly, with a corresponding decrease in the average velocity.

Figures 13 and 14 show velocities determined on the basis of dye releases used to measure velocities in the entrance region. Generally, the measured velocities compare favorably with the predicted velocities, especially when one considers the many assumptions used in the predictions.

If a dye release is made in the surf zone the dye will be rapidly transported by the surf, yielding abnormally high velocity measurements. This occurred in the releases made at 8:36 a.m. to 8:41 a.m.

On the basis of these field measurements, and the confidence gained in the comparison of measured velocities with predicted velocities, it is felt that ocean water 1000 to 1500 yards beyond the entrance will not be carried into the bay during a tidal cycle. Waters carried near the entrance by longshore currents in the surf zone would be an exception. The effluent of an ocean outfall located more than 4500 feet from the Netarts Bay entrance would not be expected to be carried directly into Netarts Bay. Thus, an outfall located at Oceanside (such as proposed in the sewage treatment study by CH_2M, 1971) would not pose any danger of contaminating Netarts Bay.

RECOMMENDATIONS

Based upon the data taken at Netarts Bay during 1970 and 1971, and the constituent transport analysis of Mr. Glanzman, the following is recommended concerning domestic waste discharge for the communities of Netarts and Oceanside:

1. The most acceptable location for a sewage outfall to discharge treated domestic wastes would be in the open ocean west of Oceanside. This would insure thorough mixing of the effluent with ocean waters, minimize the amount of effluent carried into Netarts Bay, and preclude any danger of ecological damage to the bay. This offshore location would negate the need for any sort of discharge schedule, such as would be required if wastes were discharged within the bay. An offshore outfall would also be aesthetically preferable to discharging wastes within Netarts Bay, since the effluent plume would not interfere with recreational activities, such as

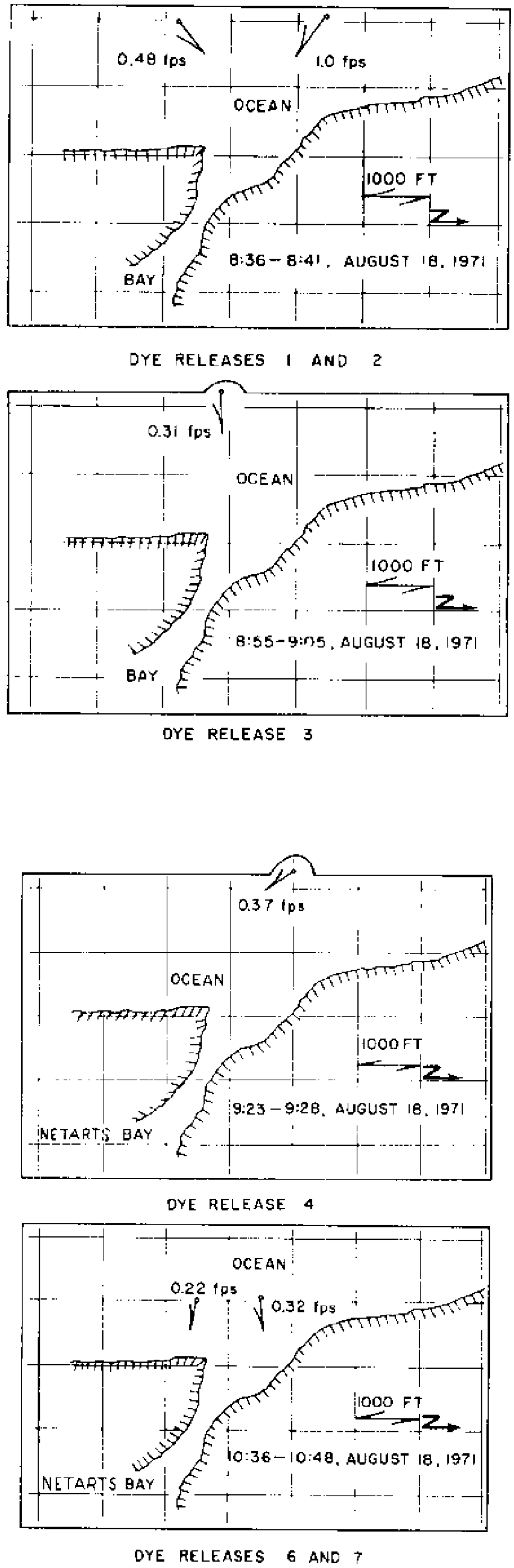

Figure 13. Measured Velocities for Entrance Region, Netarts Bay, August 18, 1971

clam digging, near the entrance to Netarts Bay.

2. The discharge of treated domestic wastes into Netarts Bay in the vicinity of Rice Creek would be acceptable only if a rigorous discharge schedule is strictly followed. Briefly, this schedule should allow the release of treated wastes into the main channel of the bay *through a diffuser* for a period of only one to two hours following high tide. Analyses indicate such a schedule would result in 95 percent removal of the effluent from Netarts Bay.

   A site giving greater removal of wastes than discharging near Rice Creek would be to place the outfall closer to the entrance to Netarts Bay, such as at Happy Camp. At this location more complete removal of the effluent from Netarts Bay would be insured than if wastes were discharged at Rice Creek. Also, the discharge of effluent would be allowed for a longer period of time, since the travel time of effluent from Rice Creek to the entrance would not have to be considered; however, a discharge release schedule would still have to be followed. By releasing the treated effluent at Happy Camp, advantage would be taken of natural tidal processes in carrying the effluent out of the bay and thoroughly mixing it with ocean waters. Disadvantages of locating an ocean outfall at Happy Camp would be that the effluent plume from the outfall would pose a hazard to clam digging in the area. Also, considerable sand movement in the entrance region has been witnessed with the channel subject to rapid changes, and engineering of an ocean outfall in this region would be difficult. However, the advantages of siting the outfall close to the entrance would seem to make this a possibility worth investigating.

3. If it is decided to release treated domestic wastes within the bay according to a discharge schedule, as proposed in this report, several additional dye and drift drogue studies should be conducted during neap tide situations to determine the acceptability of the discharge schedule for small tidal ranges.

   Whatever site is selected for the discharge of wastes from the communities of Netarts and Oceanside, it should be remembered that Netarts Bay has irreplaceable resources that should not be damaged by thoughtless or unwise actions.

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APPENDIX A

DYE STUDY RESULTS

(From Glanzman, Glenne, and Burgess, 1971)

Four dye studies of water mass movements have been conducted at Netarts Bay. Since the methods were refined with successive dye studies, each study will be considered in its entirety.

July 24, 1970

Description:

Dye dumped . . . 1.085 liters Rhodamine WT (20%) at 5% concentration. Time of dump - 6:30 a.m. Dumped at proposed sewage treatment plant site.

Sampling stations . . . Water quality station B, sampling points across channel - 3, recovery = 84.6%. Water quality station A, sampling points across channel - 2, recovery = 102%.

The dye was spread across the cross section perpendicular to the bay's longitudinal axis by discharging dye slowly through a boat propeller as the boat traversed the cross section. This achieves vertical distribution of the dye. A drift card placed at the west end of the patch moved due west, rather than down the channel with the main body of dye and other drift cards.

Three points at station B were sampled at both top and bottom. Top and bottom samples show fair consistency of concentration and time of peak concentration. However, each sampling point had different dye concentrations and remarkably different times of peak concentration. This is probably due to lateral differences in velocities of water rounding the two severe bends at Schooner.

Two points were sampled at station A. Sampling may have been discontinued accidentally before all dye had passed or perhaps an eddy current at the mouth recirculated the dye. Times of peak concentration varied, due to the vastly different velocities between the north and south points, as evidenced by drift card passage.

Samples were collected in well-cleaned bottles, thermally stablized and stored out of the light until processed. A fluorometer was used to measure dye conentration in each sample. No more than two hours storage time was allowed because of the surface adsorptive properties of Rhodamine WT dye.

Recovery was calculated using

$$\Delta V = \Sigma \Delta P_t \left(\frac{\bar{A}_c}{A_{CT}}\right) \bar{C}$$

where ΔV is the increment of dye passing on sampling interval Δt, ΔP_t is the incremental tidal prism passing during Δt, A_c is the portion of the total channel allocated to the sampling point midway in Δt, A_{CT} is the total cross section area and $\bar{C}$ is the average of the average of top and bottom concentrations during Δt.

$$\text{Recovery} = \frac{\Sigma_o^t \; (\Delta V)}{\text{volume of dye dumped}} \; (100\%)$$

As the dye cloud passes through the bay, it disperses longitudinally. The time of peak concentrations gives an indication of the modal time of travel of a dye particle. The times of 50% and 95% dye travel past the point are given as a statistical measure of particle residence times. Since recovered dye volume will deviate somewhat from the actual dumped volume, 50% and 95% passage times are reported based on recovered dye volume, as the elapsed times from the time of dump. The results are shown in Table A1.

For a 4.79 foot tidal range (at Schooner), with discharge of dye 45 minutes after high tide at the sewage treatment plant site, 95% of the recovered dye passed station A in 2 hours and 45 minutes. Drift cards which were released with the dye, reached the hypothetical mouth of Netarts Bay about one hour after the main dye body passed station A. If no waters would return to Netarts Bay, these data would suggest a safe discharge time (95% pollutant removal) of 2 hours 2 minutes. However, the suggested correction based on the dye study of September 22 yields a safe discharge time of 1 hour and 2 minutes for this day and tide.

August 22, 1970

Description:

Dye dumped . . . 3 liters Rhodamine WT (20%) at 4% concentration. Time of dump - 12:05 p.m. Dumped at mouth, cross section 0.

Sampling stations . . . Water quality station A, recovery = 24%.
Station 300 ft. South of boat landing, recovery = 158%.
Whiskey Creek west channel, recovery = 94% of total dump.
Whiskey Creek east channel, recovery = 127% of total dump.

This dye dump was performed on an incoming tide to gather data for a mathematical model of constituent transport in Netarts Bay. The dump was only partially successful due to large eddy current at the mouth, at the time of dumping. Because of this eddy current, a long, narrow patch, clearly not one dimensional, was formed. This eddy phenomenon is important because, while the tide level had begun to rise at the mouth, the momentum current outgoing on the north side of the channel still existed. Bay waters are often caught in a low-slack water eddy at the mouth and channeled partially back into Netarts Bay on the next flooding tide.

The two Whiskey Creek stations were located on an east-west line from the creek. Peak concentrations were 15 minutes apart and T_{95} times were 29 minutes apart, displaying the effects of channelization in Netarts Bay. The east channel carried most of the dye.

August 30, 1970

Description:

Dye dumped . . . 3 liters Rhodamine WT (20%) were dumped about 3,500 ft. south of the proposed sewage treatment plant site, at 2:15 p.m.

Sampling stations . . . Sewage treatment plant site, in channel, recovery = 195%.
Station 200 ft. south of boat landing, recovery = 66.5%.
Water quality station A, recovery = 126%.

This was another outgoing tide dye dump designed to eliminate some of the difficulties of the July 24 dye dump. A one-dimensional Gaussian distribution of dye concentration was observed at all three stations.

Considering the T_{50} at the sewage treatment plant site as a base time, the time of residence in Netarts Bay for this tide would be 2 hours 9 minutes, and the safe discharge time would be 2 hours and 20 minutes.

Comparing this safe discharge time with that of July 24, 1970, one notes that safe discharge time is a function of high tide level and tide range. At higher tides, bay volumes increase dramatically, as do tidal velocities.

As the safe discharge times for the July 24 and August 30 dye studies differed significantly for nearly similar tides, it is pertinent to question the reliability of the safe discharge time analyses. The investigators feel that the July 24 dye study results are more accurate. The multiple sampling points at each station more adequately describe the motion of a dispersing waste water mass than one point at each station. Remarkable different velocities and times of passage are observed at most of the cross sections of Netarts Bay.

For most tides, one may conclude that discharging for one hour immediately after high slack water at the proposed sewage treatment plant site would approach 95% permanent removal of sewage effluent from Netarts Bay.

September 22, 1970

Description:

Dye dumped . . . 2 liters Rhodamine WT (20%) at 8% at water quality station A, at 11:10.

Sampling station A occupied as tide returned.

This dye dump was at station A almost one hour before low slack. The dye was observed to pass out the mouth completely. Throughout the subsequent flood tide, dye was observed to re-enter Netarts Bay. The total calculated recovery was 16.8%. One may assume that from 10% to 25% of any constituent leaving Netarts Bay in the last hour of an outgoing tide will return, based on experimental accuracies.

To approach 95% pollutant removal from Netarts Bay, at least one hour should be subtracted from the safe discharge times inferred from other dye studies.

Table A1. Results of 1970 Dye Studies

Date	Tides (ft)			Type of Tide	Station	Distance from Dump (ft)	T_{50} (hrs: min)	T_{95} (hrs: min)	Safe Discharge Time (hrs: min)
	High	Low	Range						
July 24, 1970	4.49	-0.30	4.79	outgoing	Sewage Treatment Plant	0	0	0	
					Water Quality Station B.	4,507	1:27	2:25	
					Water Quality Station A.	7,301	1:50	2:45	1:02
August 22, 1970	7.63	0.76	6.87	incoming	Mouth	0	0	0	
					Water Quality Station A.	5,105	0:30	0:37	
					300 ft south of boat landing	11,000	1:36	2:03	
					Whiskey Creek West	28,500	3:23	3:55	
					Whiskey Creek East	28,012	3:33	4:24	
August 30, 1970	5.12	1.20	3.92	outgoing	King Realty	0	0	0	
					Sewage Treatment Plant	3,524	1:06	1:16	
					200 ft south of boat landing	4,168	1:31	1:46	
					Water Quality Station A.	10,895	2:01	2:15	2:20

APPENDIX B.

TIDAL OBSERVATIONS, NETARTS BAY 1970

Date	Time	Schooner Elev.	Range	Whiskey Creek Time	Whiskey Creek Elev.	Range	Time Lag (min.)	Choking coeff.
16 July	1050	-0.42						
	1525	5.50	5.92					
	2150	2.66	2.84					
17 July	0345	6.70	4.04					
22 July	1225	1.39						
	1915	6.59	5.20	1952	6.74		37	
23 July	0245	0.90	5.69	-	-		-	
	0800	4.23	3.33	0917	4.05		77	
	1310	2.46	1.77	1355	2.26	1.79	45	100%
	-	-	-	-	-		-	
24 July	-	-	-	-	-		-	
	0938	4.37	-	1045	4.27		67	
	1410	2.40	1.57	1520	3.05	1.22	70	83%
	2050	7.26	4.36	2105	7.54	4.49	15	99%
25 July	0512	0.36	7.62	-	-		-	
	1105	4.80	5.16	1205	4.49		60	
	1520	3.42	1.38	1625	3.42	1.07	65	78%
	2145	8.07	4.65	2158	7.93	4.51	13	98%
26 July	0523	-0.26	8.33	-	-		-	
	1205	5.13	5.39	1317	4.99		72	
	1558	3.29	1.84	1748	3.34	1.65	50	90%
	2250	8.26	4.97	2300	8.31	5.00	10	100%
27 July	-	-	-	-	-		-	
	1255	5.56	-	1405	5.19		90	
	1302	2.96	2.60	1845	3.26	1.93	43	74%
	2350	8.69	5.73	0015	8.31	5.05	25	88%
28 July	0320	-0.53	9.22	-	-		-	
	1335	6.01	6.54	1503	5.28		92	
	1905	2.74	3.27	2022	2.97	2.31	77	70%
29 July	-	8.64	5.90	0155	8.00	5.03	25	85%
	-	-	-	-	-		-	
	-	-	-	-	-		-	
	2010	2.42	-	2102	2.99		52	
30 July	0150	8.57	6.15	0210	7.75	4.76	20	77%
	0955	-0.48	9.05	-	-		-	
	1515	6.74	7.22	1558	6.61		43	
	2110	2.04	4.70	2205	2.62	3.99	55	87%
31 July	0245	8.03	5.99	0300	7.89	5.27	15	88%
	-	-	-	-	-		-	
	1515	6.72	-	1630	6.67		41	
	-	-	-					
1 August	-	-	-					
	1103	-0.18	-					
	1640	7.04	7.22					
	2320	1.42	5.62					
2 August	0428	6.34	4.92					ave. 86%
	1120	-0.22	6.56					
	1705	6.79	7.01					
3 August	0010	0.94	5.83					
	0505	5.39	4.43					

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