USE OF AGRICULTURAL CHEMICALS AND FACTORS CONTRIBUTING TO THEIR TRANSPORT TO ESTUARIES IN HAWAII

By

Donald H. Hall

Technical Memorandum Report No. 30
Working Paper No. 21

Water Resources Research Center
University of Hawaii
Honolulu, Hawaii

TABLE OF CONTENTS

Subject	Page
Objective	1
Scope of Service	1
Approach	1
Pineapple	3
Field's disposure to runoff or erosion	3
Agricultural chemicals applied; rates and timing	3
Discussion	6
Sugar Cane	7
Field's disposure to runoff or erosion	7
Agricultural chemicals applied; rates and timing	7
Discussion	9
Pest Control Operators and Homeowners	11
Disposure to runoff or erosion	11
Agricultural chemicals applied; rates and timing	11
Discussion	12
Information on Specific Estuaries	14
Waialua Bay	14
General description	14
Rainfall	14
Soils	14
Agriculture	15
Urban	15
Agricultural chemicals used	15

Subject	Page
Kahana Bay	
General description	17
Rainfall	17
Soils	17
Agricultural chemicals used	17
Maunalua Bay and Kuapa Pond	19
General description	19
Rainfall	19
Soils	19
Agriculture	20
Urban	20
Agricultural chemicals used	20
Kaiaka Bay	21
General description	21
Rainfall	21
Soils	21
Agriculture	22
Urban	22
Agricultural chemicals used	22
Pineapple	22
Sugar cane	25
Urban	25
Estuaries in the State of Hawaii: A Brief Survey of Agricultural Chemical Input into their Watersheds	26
Kauai	27
Waimea River	27

Subject		Page
	Hanapepe River, Hanapepe Bay and Port Allen	27
	Wahiawa Bay	27
	Lawai Stream and Bay	28
	Nawiliwili Bay	28
	Hanamaula Bay	29
	Wailua River and Bay	29
	Waiakea and Moikeha Canals	29
	Kapaa Stream	30
	Anahola Stream and Bay	30
	Molaa Bay	30
	Kilauea Stream and Bay	31
	Kalihiwai Stream and Bay	31
	Hanalei River, Waioli and Waipa Streams and Hanalei Bay	31
	Lumahai River	32
	Wainiha River	32
	Kauai (general comments)	32
Oahu		
	Pearl Harbor	32
	Kalihi Channel and Keehi Lagoon	33
	Honolulu Harbor	33
	Ala Wai Canal and Yacht Basin and Kewalo Basin	34
	Kuapa Pond	34
	Waimanalo Stream	34
	Kaelepulu Stream and Kawainui Canal	35

Subject	Page
Kaneohe Bay	35
Kahana Stream and Bay	36
Waimea River and Bay	36
Waialua Bay, Loko Ea and Anahulu River	36
Kalaka Bay and Paukauila and Kiikii Streams	37
Oahu (general comments)	37
Molokai	37
Halawa Stream and Bay	37
Pelekunu Bay	37
Fishponds of South Molokai	38
Maui	38
Estuaries of the Northeast Coast of East Maui	38
Maliko Bay	38
Kahului Harbor	39
Kahakuloa Bay	39
Honokohau Bay	39
Honolua Bay	40
Maui (general comments)	40
Hawaii	
Hilo Harbor and Wailuku and Wailoa Rivers	40
Waipio Stream	40
Polulu Stream	41
Hawaii (general comments)	41
Discussion and Summary	42
References	44

Objective:

To propose a "simplified" program of estuary sampling for specific "agricultural chemicals".

To support this proposal with facts and reasoning.

To aim the proposal toward delineating the origin of estuarian "agricultural chemical" containments.

The contractual scope of services asked of this contractee have been written as follows by the University of Hawaii, the contractor.

Scope of service:

Determine for watersheds contributing to specified important estuaries in the State of Hawaii the types and quantities of "agricultural chemicals (pesticides and fertilizers) applied; the timing of such applications and acreages involved. Relate the foregoing to cultural practices, terrain features, and rainfall characteristics with the objective of assessing the likelihood of chemical containments being transported from the site of application to estuarian waters by surface runoff and/or erosion.

Approach:

This proposal is being set forth in a sequential manner in the attempt to keep the sampling and analytical workload in reign.

Therefore it is initially proposed that only four estuaries be sampled and that these, all on Oahu, be Kaiaka Bay, Waialua Bay, Kahana Bay, and Kuapa Pond- Maunalua Bay.

After these four estuaries have been investigated to the extent that some understanding of the objectives is obtained consideration might be given to Nawiliwili, Pearl Harbor, Honolulu Harbor, Halawa Bay on Molokai, Kahului Harbor, and Hilo Bay.

Actually some analytical data already exist and more will be derived in studies concurrent to this "agricultural chemical" portion of the Sea Grant in those estuaries other than the initial four herein proposed.

The reasoning behind the suggestion to use only the four, aforementioned Oahu estuaries as the initial sampling sites is as follows.

(1) Expenses can be held down by limiting the site numbers and having them all on Oahu.

(2) Of the total Hawaii State population of 768,561 persons, including military, 629,176 or over 80% live on Oahu and if any pollution problems exist they are most certainly going to exist first in Oahu's estuaries (1).

(3) These four sites provide:

(a) a water shed including sugar cane, a sugar cane mill, pineapple, residential areas including sewage treatment plants and some diversified farming (i.e. Kaiaka Bay).

(b) a watershed including sugar cane, limited residential and limited diversified farming (i.e. Waialua Bay).

(c) a watershed of principally suburban housing (i.e. Kuapa Pond) and

(d) a relative control whose watershed is mostly "natural" forest (i.e. Kahana Bay).

(4) Hopefully, initially avoiding such complex estuaries as typified by Pearl Harbor and Kaneohe Bay will give data that can be more easily understood.

Pineapple

1. Field's Disposure to Runoff or Erosion

Depending upon whether a field is being put through a three or four year cycle only from 25 to 33% of the pineapple acreage of any plantation is vulnerable to runoff or erosion. The remaining acreage will be either under full crop canopy or knocked down lying fallow with a heavy cover of the preceding crop's plant residue.

Since most of the agricultural chemicals are applied in the first year beginning just before planting and since most of the plantings are made from August to December with the peak in October the most likely time for pineapple to contribute any agricultural chemicals into the watershed of which it's a part would be brought about by exceptionally heavy rainfall during the months from November through March.

2. Agricultural Chemicals Applied; Rates and Timing

Cultural practices involving agricultural chemicals differ both between and within pineapple companies so the following can be only taken as generalized information.

Where the anomala grub is found from soil sample surveys up to two pounds active Heptachlor per acre may be applied before field preparation so that it becomes well tilled into the plow zone. This practice gives ant control as well but is usually only followed where anomala grubs have been shown to be present. At one time DDT was used for both anomala and ant control but this is no longer true.

If an unexpected heavy rain were to follow the application of the Heptachlor before it was tilled in then runoff might occur but the frequency of this is remote because good field practice dictates that the tillage

follow as closely behind the Heptachlor spray as possible and this may range from a few hours to a day or two. Once tilled in only serious erosion would be able to take it into the estuary.

At the laying of the polyethylene mulch the nematocides, Lindane where Symphylid's are present, and the preplant fertilizers are applied.

Depending upon the species and seriousness of the nematode problem the rate and kind of fumigant is selected. Where the Reniform nematode is serious EDB (ethylene dibromide) alone or BBC (1,2-dibromo-3-chloropropane) in combination with DD or Telone (differing mixtures of 1,3-dichloropropenes and 1,2-dichloropropanes) are used. EDB may be used up to a maximum of twelve gallons per acre and the BBC - DD or Telone combination is usually 3 to 4 gallons of the first with 30 to 40 gallons of the second. Where Reniform is not present DD or Telone alone are usually used at rates of 40 to 60 gallons per acre. When Lindane is combined with the fumigant for Symphylid control it is usually applied at from 1.5 to 2 pounds active per acre. The fumigant, with or without Lindane, is injected into the soil beneath the polyethylene at depths of about 8 to 10 inches.

Because the fumigants are injected relatively deeply into the soil body, and because they break down fairly quickly it is unlikely that they would find their way into any coastal waters. Although Lindane is a "stable" chlorinated hydrocarbon its injection depth would protect it from surface runoff and only serious erosion from heavy storms would risk its movement into the watershed streams.

Pineapple plantings may receive up to six pounds per acre of 80% wettable powder Hyvar X and up to 16 pounds of 80% wettable powder Diuron during the cycle but because of the cost it would be a very rare situation indeed where these full USDA cleared amounts were used. Combinations of the

two are often applied immediately before and after planting at "ballpark" rates of from 1 to 4 pounds of Hyvar X with from 2 to four pounds of Diuron. Limited use is made of Atrazine and Ametryne.

As a generally true statement most pineapple soils have a very high adsorption capacity for the herbicides used, therefore it would probably require soil movement to take them out of the fields.

Pineapple plantings may get from 500 to 800 pounds of nitrogen during the cycle and 50 to 200 pounds of this may go on as aqua ammonia at the same time as the field is polyethylene mulched and fumigated. The aqua is injected into the soil beneath the polyethylene to a depth of five or six inches. All subsequent nitrogen goes on as postplant sprays of urea or ammonium nitrate at per application rates generally of from 5 to 20 pounds of nitrogen per acre.

In areas where soil and/or leaf tissue analysis indicate the need, phosphorus, potassium, and magnesium may be applied. Since these are not always used and since phosphorus particularly is used in such low amounts because it has been difficult to show economic returns, any nutrient sampling search in the estuaries which might be attributed to a pineapple origin should probably be limited to nitrogen.

For the control of mealybugs and scale plus as a general prophylactic insecticide Diazinon at per application rates of about 1/2 to 3/4 pounds active per acre are made. Malathion has and is being used for mealybugs, but its use is giving way to Diazinon. Occasionally these sprays will contain a pound or two of Heptachlor if ants are a threat. In the cycle it would be a very unusual situation where the total per acre active rates applied of either Diazinon or Heptachlor were to exceed four or five pounds.

Mirex, which is cleared for ant control in pineapple may come into use and has been used on some "expanded experimental" basis.

Captan is only used on a very limited scale for the treatment of localized rot areas caused by Phytophthora cinnamomi and P. parasitica.

3. Discussion

Since pineapple is not irrigated in the usually accepted meaning of the word there is no tail water which must be disposed of. All pineapple plantations are very thrifty in their use of agricultural chemicals for obvious economic reasons plus the fact that their management's are truly concerned about their maintaining a clean record and not contributing to a pollution problem.

Their only vulnerability would seem to be in those cases where unusually heavy rainfalls like those of some of the Kona storms occur in the fall and winter.

Where the Sea Grant workers are specifically looking for agricultural chemical indices that might have originated from pineapple in their sampling of estuaries whose watersheds are made up in part of pineapple lands, they should probably limit their search to Heptachlor, Diazinon, Hyvar X, Diuron and nitrogen. These should be sampled for both during "normal" weather and following a heavy winter storm.

Sugar Cane

1. Field's Disposure to Runoff or Erosion

Sugar cane is grown on a six year cycle which is made up of one plant crop and two ratoons. Each of these three crops of two years apiece means that about one sixth of the land area of a plantation is completely prepared each year and that one half is opened by harvesting.

When a field is ratooned there is much less done in the way of soil tillage so the plant crop installation is the more critical from the erosion risk viewpoint. The ratooning of a field following the harvest is to allow the residue cane to sprout, to reshape the contoured irrigation furrows around these sproutings and to replant seed cane pieces into those bare spots then showing.

Since the plant crop's field preparation requires the complete reinstallation of the field the difference can be appreciated.

Each two year growth period takes about six months to plant canopy close in.

Canefields are planted the year around so long as weather permits.

Nearly all of the agricultural chemicals applied are put on during the first year of the two year growth period.

2. Agricultural Chemicals Applied; Rates and Timing.

Herbicides account for nearly all of the pesticides used in sugar cane production in terms of absolute amounts.

Ametryne is the major sugar cane herbicide on Oahu. Generally, there will be an application of five pounds of 80% wettable powder just after planting and a second, or booster shot, of four more pounds about four or five weeks later. At present because of broadleaf weed problems the Waialua plantation is using a combination of ametryne and atrazine for their initial

application. The rate is three pounds plus three pounds.

After these two applications are made if weedy areas appear they are usually handled by spot spray applications of mixtures of Diuron-Dalapon-surfactant-and water. A typical such mix is made up of five pounds of 80% wettable powder Diuron, five pounds of Dalapon, 0.25% to 0.50% surfactant by volume and diluted to 100 gallons with water. The surfactant used is nearly all Union Carbide's biodegradable Tergitol 15-S-9 which is 100% nonionic. If broadleaf weeds are present in addition to grassy weeds about four pounds of 2,4-D may be added to this mixture. This combination is sprayed on weeds "to wet" (i.e. to the point where the entire weed surface is covered and dripoff just begins). A calculated prorating of this spot treatment usually shows that something like thirty gallons of the mixture is applied per acre of canefield. Once the field is closed in only borders and open ditch areas require weed control attention.

No insecticides nor nematocides are being used in sugar.

In the heavy rainfall areas where rat damage is a problem rat bait stations around the field edges containing anticoagulant rodenticides such as - Warfarin are employed. Warfarin is mixed into the oat bait at a 0.025% concentration. There is little liklihood of this material finding its way into an estuary.

The fungicidal treatment of the cane seed pieces to protect them from Thielaviopsis paradoxa is an economic necessity. PMA (phenyl mercuric acetate) has and is being used for this. The seed are given a hot water dip containing by volume one part PMA per 16,000 parts of water. Because of the desire to get away from the use of this mercuric poison there has been an active research program which has led to the now completed clearance of Benlate. Benlate can be expected to quickly replace the use of PMA since the latter's registration ends this year.

Ceresan L is no longer used as a sugar cane fungicide.

Diquat, though it is registered for the control of tasselling or flowering, is still only being used in localized experimental fields.

Cane receives from 300 to 400 pounds of nitrogen per acre during its two year growth period and nearly all of this is applied during the first year. About 100 pounds of this nitrogen is injected below the seed piece as urea or diammonium phosphate.

Sugar cane requires considerable phosphorus and potassium and these are applied where they are either not available from the soil or the irrigation water. Some waters are high in these as for example where the mill water is used which usually contains substantial amounts of phosphorus and potassium as well as other nutrients. On Maui at H.C. and S. there is the situation where some of their non-mill irrigation water runs so high in potassium that they occasionally have the problem of potassium chloride crystallizing out in their molasses. When phosphorus is applied about 200 pounds per acre is put on at planting either as diammonium phosphate or, less frequently, as treble superphosphate. Potassium may be used at rates of from 300 to 400 pounds per acre with maybe 100 pounds of this going on at the time of planting. These rates refer to the oxides P_2O_5 and K_2O.

3. Discussion

About fifty percent of the sugar cane area in the state is irrigated. The intent of each plantation's irrigation program is to have no tail water left upon completion of an irrigation round. The general aim is to get on a two acre-inch application every two weeks and to uniformly do this across a field may require as much as a four acre-inch application.

Many plantations make use of their mill water which is desirable for a number of reasons. These include:

1. Avoiding the disposal of the mill water over a seafall or into a watershed.
2. The use of water which has a high plant nutrient content. and
3. The economics of utilizing something they already have.

In the sugar industry of Hawaii the general statement can be made that they either are or shortly will be making use of all their water including mill water in such a manner that they will be "self contained" units. The accomplishment of this will of course reduce the risk of moving any of their agricultural chemicals into estuaries.

Sugar industry management is well aware of the importance of their attaining and maintaining an "in fact" record of being as ecologically clean as possible with respect to the Island's estuaries, and their selection of practices are aimed in this direction. A great deal of effort is expended on contour shaping of fields to minimize runoff and erosion and to maximize irrigation efficiency.

The hazard that exists is that of the unexpected erosion which follows the occurance of a storm of exceptionally heavy rainfall. When this happens it can be expected that some agricultural chemicals will find their way into the estuaries.

Sea Grant researchers looking for indices of agricultural chemical pollutants that might have come from sugar cane should check for Ametryne, Atrazine, Diuron, Dalapon, 2,4-D, nitrogen and phosphorus.

Samples should be taken before and after a heavy rainfall.

1. Disposure to Runoff or Erosion

Most urban areas are adjacent to ocean frontages including estuarian waters. Thus runoff or erosion movement of agricultural chemicals used in urban sites generally would not have to move long distances to reach any estuary in question. Some compensation for this would result from the fact that once an urban area is established it is well stabilized with buildings, lawns, walkways, various retaining walls, plantings, etc. This factor should reduce erosion (and perhaps runoff) risks as compared to the agricultural situation of a newly plowed field. This consideration would be less applicable in a new housing development where in the beginning there were no plantings.

Because of the extremely high rates of pesticides used any heavy runoff or erosion from an urban area could be expected to move some of these chemicals into the coastal waters.

2. Agricultural Chemicals Applied; Rates and Timing

Pest Control Operators and Homeowners are presently using nearly a quarter of a million pounds of active pesticides per year in Hawaii. Pest control usage in urban areas accounts for the lion's share of the chlorinated hydrocarbons applied in Hawaii and the main reason is the ground termite problem.

Per unit area the rates employed for urban termite control are orders of magnitude greater than anything ever done in agriculture.

The following table gives these rates (2)

	Pounds Active Per Acre	
	Post Slab and Foundation (4 gals./10 sq. ft.)	Pre Slab (1 gal./10 sq. ft.)
Chlordane	1,512	378

cont.	Post Slab and Foundation (4 gals./10 sq. ft.)	Pre Slab (1 gal./10 sq. ft.)
Heptachlor	1,512	378
Lindane	1,208	302
Aldrin	752	188
Dieldrin	452	113

These treatments are generally made at the volume application of about 1000 gallons per acre. They are supposed to be applied out to the drip line of the dwelling giving a three foot border around the slab. Not all dwellings are on slabs, however. Some are stilt type therefore more predisposed to runoff and erosion and these receive similar treatment rates.

At the present time relative price structures are resulting in Aldrin's being the most extensively used chlorinated hydrocarbon for ground termite control.

Diazinon and Baygon both organophosphates with similar modes of action are used extensively in urban areas as general insecticides. They are often used inside buildings for such things as cockroach control.

In the case of plant nutrients it is impossible to say much about rates and application timing. It would probably not be unreasonable to assume that where they are used they are probably put on at per acre rates far in excess of those used in agriculture.

3. Discussion

Since there are more than 80,000 acres of urban area in the state and since more than 80% of the population dwells on Oahu it is not out of order to conclude that the urban use of agricultural chemicals make up the most serious risk of estuarian pesticide input on Oahu, particularly with respect to the chlorinated hydrocarbons.

Another very real risk factor that must be taken into consideration in this segment of pesticide usage is the large number of persons involved. Kimura and Hurov stated that there were forty-four Pest Control Operators on Oahu in December 1969. This is a business that is constantly fluctuating and it involves a number of part time members. At present there are between forty to fifty doing business on Oahu (estimate of Mr. Miles Honda of Ultramar). In the case of the home dwellers thenselves it is almost anyone's guess as to just how, how much and what they are using in the way of agricultural chemicals. Viewed from this standpoint we are given an unfavorable comparison as against the relatively strict controls employed in sugar cane and pineapple.

When sampling waters for agricultural chemicals that might have originated from urban applications researchers should consider looking for Chlordane, Heptachlor, Lindane, Aldrin, Dieldrin, Diazinon, Baygon, nitrogen phosphorus, and potassium. Samples should be selected both before and after heavy rains.

Information on Specific Estuaries

Waialua Bay

General Description

This distinct estuary on the north shore of Oahu drains a watershed of 8,384 acres (3).

A portion of this estuary is used as a small boat marina and a substantial number of semicommercial fishing and pleasure craft make good use of the harbor.

The main and final tributary of the bay is the Anahulu River. Upstream it is fed by the Kawailoa Stream which further up itself is made up from the Kawainui and Kawaiiki Streams.

Described by drainage pattern the bay traces its entire origin to a northern section of the Koolau Mountain Range.

Rainfall

The annual rainfall at the crest of the watershed is 300 inches and at the bay the nearest isohyet is given as 30 inches. The agricultural lands in this watershed are encompassed pretty well between 30 and 75 inches per year.

Soils

The largest portion of the agricultural soils in this watershed are the low humic latosols of the Lahaina and the Wahiawa families. At the higher elevations there are some fields of Humic Latosols of the Honolua family. There is a limited area of Hydrol Humic Latosols classed as the Koolau family, undifferentiated. Near the bay there is an alluvial fan of the Kawaihapai family, a small area of Hauula paddy soil and then the upstream balance of the

watershed is classed as a Lithosol. The latter defined as "Rough broken land, residual material" is nonagricultural and nonurban.

Agriculture

In this watershed there are 2,700 acres of sugar cane. Actually 280 of these acres are still in pineapple but will become sugar at the end of this cycle. The pineapple planting is now one year old.

Below Kawailoa Camp along the upper portion of the Anahulu River there are some small patches of hasu and even smaller patches of taro. However, no pesticides are used in their culture (5).

Urban

There are about 550 acres classed as Urban lands which could drain into this bay (4). Except for Kawailoa Camp these urban areas are limited to those portions of Haleiwa near the Bay itself.

The census gives the 1970 population of Haleiwa as 2,626 (1). A conservative estimate on the high side should put no more than 1500 of these persons residing in the Waialua Bay watershed.

Agricultural Chemicals Used

Using the 2,700 acres of sugar cane as the base and following the cultural practices of the Waialua Agricultural Company that involve agricultural chemicals we can rough out the following as estimates of the totals applied in the watershed during a year's period.

(a) $\frac{2700 \text{ acres}}{} \times \frac{1}{2}$ acres planted per year $\times$ 7 pounds of ametryne equals 9.450 pounds of ametryne 80% w.p.

(b) $\frac{2700}{2} \times 3 = 4{,}050$ pounds of atrazine 80% w.p.

(c) $\frac{2700}{2}$ x $\frac{30}{100}$ gals. per acre of 100 gal. mix x 5 pounds of Diuron

equals 2,025 pounds of Diuron 80% w.P.

(d) same calculation as (c) gives 2,025 pounds of Dalapon

(e) 4/5 ths of (c) or (d) gives 1,620 pounds of 2,4D

(f) $\frac{2700}{2}$ x 400 pounds of N = 540,000 pounds of nitrogen

(g) up to 270,000 pounds of P_2O_5

and

(h) up to 540,000 pounds of K_2O

Making any reasonable approximation of the amount of agricultural chemicals used in the urban portion of this watershed can get pretty wild. A very crude guess might be:

250,000 pounds of active chlorinated hydrocarbons used in the state by PCO's and home dwellers x $\frac{1500}{768,561}$

where the 1500 over 768,561 is the population factor.

This gives us about 490 pounds of active chlorinated hydrocarbons used in the watershed. This figure is probably in error on the low side of what is actually used.

Kahana Bay

General Description

This site is intended as the reference control for the other three estuaries.

Located on the windward coast of Oahu, Kahana drains a watershed of 5,312 acres (3).

The main tributary is the Kahana Stream which is joined about a mile inland by the Kawa Stream.

All of the drainage of this bay originates in the north-central area of the Koolau Range.

Rainfall

Rainfall at the top of the watershed is 250 inches per year and at the Bay itself just under 75 inches.

Soils

Starting at the bay and working inland the soils encountered in sequence are a Regosol of the Haleakala family, undifferentiated; an Alluvial soil of the Hanalei family, normal phase; a Lithosol described as "Rough broken land, alluvial material; and a Lithosol described as Rough broken land, residual material. Going up the sides of the watershed from the bay you first encounter the Gray Hydromorphic soils of the Kalihi family, normal phase; and then the Lithosols described as Rockland, with very thin weathered lava.

Agricultural Chemicals Used

There is no longer any farming in the Kahana Valley. There are about thirty-five families living in a scattering on the valley floor but none of them are presently doing any small scale farming. Conversations with a few

of these residents indicate that little or no agriculture chemicals are used even around the household.

Kahana Bay looks like a pretty well qualified control estuary.

Maunalua Bay and Kuapa Pond

General Description

This estuary is located between Diamond Head and Koko Head. Considering the whole bay there is a watershed of 13,824 acres (3). However, when we consider the Hawaii Kai-Portlock Road urban area alone, there is a watershed of 4,608 acres (3). This smaller watershed includes everything that would drain between the ridge immediately east of Kuliouou and Kawaihoa Point (i.e. the point of Koko Head). This includes Kuapa Pond. It is this pond estuary that is being proposed for study.

Rainfall

All of this watershed has an annual rainfall of less than forty inches with most of it being less than thirty inches.

Soils

The largest section of soils in this watershed is the Red Desert Soil of the Kawaihae family, normal phase which runs all along the western slope of Koko Head. There is a relatively small area of a Regosol, Haleakala family, undifferentiated which lies roughly in the triangle formed by Kalanianaole Highway-Portlock Road-and Lunalilo Home Road.

Rimming Kuapa Pond is a Gray Hydromorphic Soil, Kaloko family, normal phase. North of Kuapa Pond there is another Gray Hydromorphic, the Kalihi family, normal phase and on the northeast side of the pond there is a relatively small section of Dark Magnesium Clay, Lualualei family, undifferentiated. The remaining soils up the slopes are all Lithosols either described as Rough broken land, alluvial material or Rockland with very thin weathered lava.

Agriculture

Situated along the western slope of Koko Head there are three small growers of Manoa lettuce together using no more than ten acres (5). This is the only agriculture in the watershed.

Urban

Using the 1968 figures and estimating the residential growth since there are about 20,000 persons living in this watershed described in area as 4,608 acres.

Agricultural Chemicals Used

The small growers of Manoa lettuce are using the systemic insecticide Cygon and the herbicide Vegedex.

Using the same method of calculation as was done for Walalua Bay to guess at the urban use of chlorinated hydrocarbons we have:

$$250{,}000 \times \frac{20{,}000}{768{,}561} = 6{,}600 \text{ pounds active}$$

Kaiaka Bay

General Description

This bay is on the north shore of Oahu near the town of Waialua. Its watershed is very large, 54,080 acres, and very complex relative to the three others described in this proposal.

The immediate tributaries of Kaiaka are Kiiki and Paukauila Streams. Moving inland these names change and the four main tributaries are Kaukanahua, Poamoho, Helemano, and Opaeula Streams. Thus this includes drainage from both the Waianae and Koolau Mountain Ranges and the watershed includes Wahiawa, with its reservoir, Wilson Lake; portions of Schofield Barracks; Wahiawa Naval Communications Station; Helemano Army Radio Station; Poamoho Village; and most of Waialua.

Rainfall

In the crest of the Koolaus at the headwaters the annual rainfall isohyet reads 300 inches and just inland from the bay it is given as 30 inches. Most agricultural and urban areas are between 100 and 30 inches.

Soils

The major agricultural and urban areas are on Low Humic Latosols the most expansive of which is the Wahiawa family, normal phases. Next are the Kahana family, normal phases; the Lahaina family, normal phases and the Waialua family, normal phases. Fairly large areas of Humic Latosols of the Honolua family, normal phase are found on the Koolau side above the Low Humics and on both the Waianae and Koolau sides of the watershed there are some relatively small area higher elevation pieces of Humic Ferruginous Latosols of the Manana and Naiwa families. Around the bay itself is an alluvial soil Kawaihapai

family, normal phase and up in both the mountain ranges are large areas of Lithosols of various description.

Agriculture

In this watershed there are 7,800 acres of pineapple, 5,288 acres of sugar cane, nearly forty acres of miscellaneous vegetable crops and just under ten acres of commercial flowers.

Urban

Approximately 5,350 acres of urban land drains into Kaiaka (4). Roughly 36,000 people live in the watershed. The need to hedge here is that portions of Schofield drain to Pearl Harbor down the Waikele Gulch so that only about 9,000 of its actual present population of 13,516 is credited as being on the Kaiaka side.

One feature of these urban areas that may be of particular importance to the study is that there are three sewage treatment plants that empty into the watershed. These are located at Wahiawa, Wahiawa Naval Station, and Helemano Army Station. The Schofield sewage plant drains to Pearl Harbor via Waikele Gulch and the other urban areas make use of cesspools. Probably the most important estuary containment to check for due to these treatment plants is phosphate from household detergents.

Agricultural Chemicals Used

Pineapple

For this estimate it is assumed that one third of the 7,800 acres of pineapple are planted each year. This will cause the final figures to be conservative on the high side since not all of the pineapple fields are on a strict three year cycle. A limited acreage is fallowed or "carried over" each year.

Another factor which will cause an overestimate is that not all areas are treated for Anomala nor Symphylid although the latter is more widespread than the former.

Calculations

Heptachlor (active)

$\frac{7800}{3}$ x 4 pounds/cycle = 10,400 pounds

Lindane (technical)

$\frac{7800}{3}$ x 2 pounds/cycle = 5,200 pounds

EDB

$\frac{1800*}{3}$ x 12 gals/cycle = 7,200 gallons

* Used by Del Monte not Dole therefore only 1800 acres of the watershed treated.

BBC or DBCP

$\frac{6000}{3}$ x 4 gals = 8,000 gallons

DD

$\frac{6000}{3}$ x 40 gals. = 80,000 gallons

Hyvar X (80% w.p.)

$\frac{7800}{3}$ x 3 pounds = 7,800 pounds

Diuron (80% w.p.)

$\frac{7800}{3}$ x 6 pounds = 15,600 pounds

Nitrogen

$\frac{7800}{3}$ x 600 pounds = 1,560,000 pounds

Potassium (K_2O)

$\frac{7800}{3}$ x 300 pounds = 78,000 pounds

Sugar Cane

For the following it is assumed that one half of the 5,288 acres of cane are planted or ratooned each year.

Ametryhe (80% w.p.)

$\frac{5,288}{2}$ x 7 pounds = 18,508 pounds

Atrazine (80%)

$\frac{5,288}{2}$ x 3 pounds = 7,332 pounds

Diuron (80%)

$\frac{5,288}{2} \times \frac{30^*}{100} \times 5$ pounds = 3,966 pounds

Dalapon (technical)

$\frac{5,288}{2} \times \frac{30^*}{100} \times 5$ pounds = 3,966 pounds

2,4D (active)

$\frac{5,288}{2} \times \frac{30^*}{100} \times 4$ pounds = 3,173

*the gallonage conversion factor for spot spray weeding, refer to discussion under sugar cane cultural practices.

Nitrogen

$\frac{5,288}{2}$ x 400 pounds = 1,057,600 pounds

Phosphorus (P_2O_5)

$\frac{5,288}{2}$ x 200 pounds = 528,800 pounds

Potassium (K_2O)

$\frac{5,288}{2}$ x 400 pounds = 1,057,600

Urban

For the estimate of the urban usage of chlorinated hydrocarbons the population factor of 36,000 is used.

$250,000^{*} \times \frac{36,000}{768,561^{**}}$ = 11,740 pounds active

* State usage of chlorinated hydrocarbons, approx.
** State population

In the miscellaneous crops small amounts in terms of totals include Cygon, Thiodan, Gardona, Sevin, Malathion, Zineb, Maneb, Suten, Lasso, Dacthol, and Dimed.

Amino Triozole is used occasionally along the highways.

Estuaries in the State of Hawaii: A brief Survey of Agricultural Chemical Input into their Watersheds.

Technical Report Number 31 of the Water Resources Research Center, University of Hawaii, titled "Estuarine Pollution in the State of Hawaii; Volume One" by Doak C. Cox and Lawrence C. Gordon, Jr., March 1970 was used as the framework for that which follows.

The intent justifying this segment is to provide a reference of the water bodies in the state which qualify as estuaries and to evaluate them very briefly in terms of potential pollution by agricultural chemicals.

KAUAI

Waimea River

The tributaires of this estuary of southeastern Kauai are the Waimea and Makaweli Rivers. The headwaters of both of these rivers are in state park and forest reserve lands. The lower lands of the watershed include cattle ranch use, sugar-cane fields and the urban area of the town of Waimea. The major potential source of pollution would probably be from the urban use of agricultural chemicals principally the chlorinated hydrocarbons, nitrogen and detergent phosphates. The town of Waimea uses cesspools. A sewage treatment plant is planned and the treated effluent is to be discharged at least 1,000 feet offshore.

Hanapepe River, Hanapepe Bay and Port Allen

The headwaters of the Hanapepe are in forest reserve. The lower elevation areas of the watershed include cattle pasture lands, sugar cane fields and the urban towns of Hanapepe and Port Allen. The town of Eleele on the highlands east of Hanapepe Valley is served by a sewer system from which raw sewage is discharged about fifty feet offshore into the ocean. Hanapepe and Port Allen use cesspools.

The leading pollution possibility is probably from the urban areas. Chlorinated hydrocarbons, nitrogen and detergent phosphates are to be considered.

Wahiawa Bay

This estuary is one mile east of Hanapepe. Wahiawa Bay is considered to be within the plume of the water discharged from the McBryde mill cane washer. The mill is about a mile east of the bay.

Forest lands, cattle pastures, and sugar cane fields are included in the watershed. This should be a pretty clean estuary. Erosion and runoff from heavy rains could bring soil adsorbed herbicides and plant nutrients into the bay.

Lawai Stream and Bay

This estuary is about four and three quarters miles east of Wahiawa Bay. All of the comments made about Wahiawa would apply to Lawai.

Nawiliwili Bay

This is the most complex estuary on the Island of Kauai in terms of watershed description. Located on the southern side of the island this bay is fed by three tributaries. These are the Huleia, Puali and Nawiliwili Streams. Quoting directly from Cox and Gordon "Large areas in the drainage basins of all three streams are in sugar cane fields of comparatively low relief and there is a large cattle ranch in the drainage basin of the Huleia Stream. The headwaters of the Nawiliwili and Puali Streams are in the flat-sloped post-erosional lava dome of Kilohana. The headwaters of the Huleia are in the extremely rugged Waialeale-Kawaikini mass of central Kauai. Irrigation water is diverted from all three streams." A sizable portion of the town of Lihue is in the Nawiliwili Stream basin. The Lihue Plantation sugar mill is also in this same valley. The urban areas of Lihue town, Nawiliwili Village and Niumalu Village all make use of cesspools. Kalapaki Beach which is at the head of the northern arm of the bay is the site of the large Kauai Surf Hotel. The hotel has a sewage plant and after treatment the effluent is discharged into the bay.

Heading the list of potential "agricultural chemical" pollutants would be urban used chlorinated hydrocarbons and detergent phosphates. Next on the list but of lower risk would be the sugar cane herbicides and nutrients.

Hanamaulu Bay

This bay is just north of the Lihue Airport. Hanamaulu Stream is the main tributary. The valley head is in forest lands on the slopes of the Kilohana cone. Sugar cane fields cover most of the valley's length. The villages of Kapaia and Hanamaulu which are in the bay's watershed both use cesspools.

Urban and sugar cane agricultural chemicals are the ones that could find their way into this estuary.

Wailua River and Bay

This estuary is on the east coast of Kauai. Its tributaries are the Wailua River and Opaikaa Stream. For irrigation use water comes into the north fork of the Wailua from the Hanalei River, from the North Fork to the South Fork and from the South Fork to an area further south. Headwaters are in forest reserve lands. The South Fork runs through sugar cane fields and these fields extend northward to the southern edge of the valley of the North Fork. The northern edge of the valley of the North Fork is in homesteads. A number of miscellaneous vegetable crops are grown in this watershed. The valley of Opaika Stream is planted to rice. The large resort hotel, the Coco Palms, on the north edge of the mouth of the Wailua River uses a sewage treatment plant.

Agricultural chemicals reaching this estuary could derive from sugar cane, vegetable crops, cattle ranching and/or urban usage.

Waiakea and Moikeha Canals

These two estuaries are located south and north of the town of Kapaa respectively. The town uses cesspools. Their drainage has been poor due to clay soils and a high water table. Sugar cane fields, pineapple,

miscellaneous vegetable crops, the urban area of Kapaa plus many scattered homesites in the Kapaa Homesteads and the pineapple processing Hawaiian Fruit Cannery can all be considered as potential sources of agricultural chemical wastes. The cannery is recorded as disposing of 300,000 gallons of waste water per day when operating. Cattle ranching operations are included in this watershed.

Kapaa Stream

This stream reaches the ocean on the east coast of Kauai at Kealia. The headwaters are in forest lands and the watershed includes sugar cane, pineapple fields, cattle ranching, small independent growers of varied crops, scattered homesites in the Kapaa Homesteads, and the urban area of the town of Kealia which is served by cesspools. Water from this stream is used for irrigation.

Agricultural chemicals could derive from any of the aforementioned. Chlorinated hydrocarbons, nitrates, and phosphates should be considered.

Anahola Stream and Bay

This stream originates in forest lands. Sugar cane fields, cattle ranching, and scattered homesites with very small areas of varied crops are within the watershed. The homes use cesspools. The stream is diverted for irrigation. Nitrates and phosphates are probably to be considered.

Molaa Bay

The headwaters are in forest lands and the lower valley in sugar cane. Cattle ranching is included in the watershed. The few houses at Molaa use cesspools. This is probably a pretty clean estuary. Perhaps some nitrates and soil-adsorbed herbicides from the canefields reach it after heavy rains.

Kilauea Stream and Bay

Kilauea Stream begins in forest lands and passes through cattle ranch areas and sugar cane fields enroute to the bay. Its waters are used for irrigation. The Kilauea Plantation is scheduled to end its sugar cane operations in another year. Homes in the town of Kilauea use cesspools. Nitrates and soil adsorbed herbicides might reach the bay on occasion.

Kalihiwai Stream and Bay

The stream is diverted at low flow for irrigation. The valley includes cattle ranch lands and sugar cane fields. The few homes in the lower valley use cesspools. As noted above, the Kilauea Plantation plans to end its sugar operations in the near future. Seed corn is being grown and may be expanded. Present plans call for the planting of sorghum in the spring of 1971.

Pesticides used in corn include the insecticides Sevin and Gardona, the fungicide Zineb, and the herbicides Atrazine, Suten and Lasso.

Hanalei River, Waioli and Waipa Streams and Hanalei Bay

The river and both streams enter Hanalei Bay. This river is the largest one on the north coast of Kaual. Forest reserve, cattle pastures, and wet land taro paddies make up most of the watershed. No pesticides are used for Taro.

A few scattered homesites and the town of Hanalei use cesspools. The resort hotel Hanalei Plantation is served by septic tanks discharging to leaching wells near the shoreline.

Nitrates would probably be the most likely "agricultural chemical" to get into the estuary.

Lumahai River

The headwaters are in the forest lands deep in the central rainy portion of the island. The flood plain is used mainly as a ranch. There are very few homesites in the valley and these make use of cesspools.

This is probably a pretty clean estuary.

Wainiha River

Forest lands, cattle ranching and wet land taro culture agriculturally describes this watershed.

The village of Wainiha uses cesspools.

This estuary is probably pretty clean. Nitrates might be considered.

Kauai

Sugar cane is by far the principle agricultural crop of the island and the major user of agricultural chemicals. There are 51,389 acres of cane on the island.

The windard plantations make extensive use of Atrazine-Diuron, or Atrazine-Ametryne 3 pounds plus 3 pounds initial with ametryne boosters and the southern side uses more ametryne initially with Diuron boosters. All plantations use 2,4D and Dalapon.

OAHU

Pearl Harbor

Viewed ecologically and morphogenically Kaneohe Bay is probably the most complex estuary in the state but viewed in terms of the agricultural chemical usage in the watershed and evaluated as to the likelihood of these chemicals reaching the estuary this is the most complex inshore waterbody-watershed system in the state.

There are eight tributary streams entering the harbor. These are the Honouliuli, Waikele, Waiawa, Waiau, Waimalu, Kalauao, Aiea and Halawa Streams. In addition there are five large springs. These are the Waikele, Waiawa, Waimano, Waiau, and Kalauao Springs.

Sugar cane, pineapple, cattle ranching, headwater forest lands, dairy farming, watercress, taro paddies, bananas, and miscellaneous small patches of vegetable, fruit, and flower farming agriculturally describes the watershed in qualitative terms. In addition there are highly urbanized areas close to the harbor and the Waipahu area is one of the most rapidly growing population centers in the state.

In spite of the vast agricultural enterprises in the watershed their "agricultural chemical" input is probably slight compared to urban and industrial sewage and erosion from new housing developments.

Analysis for chlorinated hydrocarbons, dalapon, Hyvar X, nitrates and phosphates should provide an insight respecting any agricultural contamination of Pearl Harbor.

Kalihi Channel and Keehi Lagoon

Moanalua and Kalihi Streams the tributaries of this estuary head in the forest reserve areas in the high rainfall belt along the summit of the Koolau Range. The heavy urban density of the watershed and the industrial areas along the coast would dominate the determination of pollutant input.

Chlorinated hydrocarbons, nitrates and phosphates originating from urban and industrial use should be checked for.

Honolulu Harbor

The main tributaries are the Nuuanu and Pauoa Streams and the Kapalama Canal. Nuuanu Stream begins in forest reserve lands at the crest of the Koolaus.

Comments on Kalihi Channel and Keehi Lagoon apply equally to the "agricultural chemical" situation of Honolulu Harbor.

Cox comments that the harbor waters are generally oily. It might be interesting to draw a set of samples from this surface oil slick and analyze for chlorinated hydrocarbons and compare the results to a set of deeper drawn samples.

Ala Wai Canal and Yacht Basin and Kewalo Basin

The Manoa and Palolo Streams can be considered as tributaries. Springs, intermittent tributaries and storm sewers add to the canal. As Cox points out "although the heads of Manoa and Palolo Valleys and the upper parts of the ridges in the tributary areas are in forest reserve, most of the drainage area tributary to the canal is in urban residential or business use." Therefore the character of chemical pollutants is determined by urban origins.

Chlorinated hydrocarbons, nitrates and phosphates are probably there.

Kuapa Pond

This estuary has been treated in greater detail earlier in this paper.

Waimanalo Stream

Headwaters of this stream reach the famous Pali. The watershed is rural for the most part and includes ranching, miscellaneous vegetable crops and a few fruit and ornamental plantings. The University's Waimanalo field station is within the drainage area. Beginning in forest reserve lands the stream reaches the coast through the U.S. Air Force Base at Bellows Field.

This is probably a pretty clean estuary but because so many agricultural odds and ends are in the watershed it might be well to check for such things as arsenic (perhaps from the herbicide MSMA) and mercury (of fungicidal origin).

Kaelepula Stream and Kawainui Canal

These two estuaries pretty well bracket the south and north edge of both Kailua Town and Kailua Bay respectively. Enchanted Lake drains to Kaelepula and Maunawili Stream is a tributary of Kawainui. The watershed heads in the forest reserve lands of the Koolaus and then moving to the shore includes ranch lands, golf courses, small plots of vegetables, ornamentals, and orchards and a heavily urbanized area which is rapidly expanding. Both sewers and cesspools serve the area. The urban population would be expected to dominate the chemical character of the estuary effluents. Chlorinated hydrocarbons, nitrates and phosphates should be considered.

Kaneohe Bay

This is the largest estuary in the state. Volume II of Technical Report No. 31 is being devoted entirely to this bay. It is unique in that it is both an estuary and a lagoon. Nine perennial streams are tributaries. These are Kawa, Kaneohe, Keaahala, Heeia, Kahaluu, Kaaleea, Waiahole, Waikane and Hakipu Streams. Intermittent streams, ground water and sewage add to the perennial stream's discharge into the bay. There are two sewage outfalls, one for Kaneohe Town and the other for the Kaneohe Marine Corps Air Station.

Urban development is rapidly expanding in the drainage area although diversified farming remains extensive. Forest lands, ranching, bananas, taro, pepayas, vegetable crops and ornamentals are all grown in the drainage area. In spite of this agricultural variety it is rational to expect that the urban development and established urban segments dominate the "agricultural chemical" input. Due to the complexity of the watershed a clean cut diagnostic evaluation of chemical pollutants would probably be pretty frustrating. Knowledgeable agricultural interpretation of data derived by others in the Sea Grant program would seem to have more possibilities.

Chlorinated hydrocarbons, nitrates and phosphates and perhaps arsenic and mercury might be considered.

Kahana Stream and Bay

This estuary has been discussed earlier in this paper.

Waimea River and Bay

Elehaha, Kamananui, and Kaiwikoele Streams are tributaries of Waimea River. Forest lands, cattle ranching and sugar cane fields plus scattered homesites with cesspools are all watershed components.

This should be a pretty clean estuary.

Nitrates, soil adsorbed herbicides and dalapon could be checked for. 2,4D is possible.

Waialua Bay, Loko Ea and Anahulu River

This estuary system was described earlier in this presentation.

Kalaka Bay and Paukauila and Kiikii Streams

This estuary, of relatively complex origin, was treated in some detail in a preceeding portion of this discourse.

Oahu

In terms of area sugar cane is the most extensive crop on the island. There are 37,409 acres of canefields. Pineapple occupies about 20,000 acres. Piggeries, cattle pastures and ranges, cattle pen feed lots, whole milk dairies and a variety of small scale producers of fruit, vegetables and ornamentals serve the large population.

In spite of this extensive and diverse agriculture there is little doubt that it is the urban, not the agricultural facet, that dominates the character and amount of "agricultural chemical" estuary input.

MOLOKAI

Halawa Stream and Bay

Moaula and Nawaihulili Streams are tributaries of Halawa Stream. This estuary is on the north coast near the eastern end of the island. Headwaters are in high rainfall forest lands. The lower portion of the valley is a part of the Pohakuloa Ranch and is grazed lightly by cattle. There are a few homesites in the lower valley and these use cesspools.

This is a very large "unimproved" watershed and would probably make a good control sampling site for statewide studies.

Pelekunu Bay

Kaliiili, Pilipililau, Kapuki, Kawainui, and Pelekunu Streams are all tributaries in the watershed of this bay. The valley is uninhabited and

cannot be reached by roadway. No "agricultural chemicals" are used in the drainage area.

Fishponds of South Molokai

Cox states that there are at least forty fish ponds along the south coast of Molokai that qualify as estuarine waters. With this number there is no doubt a considerable variety with respect to "agricultural chemical" content.

MAUI

Estuaries of the Northeast Coast of East Maui

Wailua Bay fed by Wailuanui and Wailuaiki Streams and Valleys; Nuaailua Bay fed by the Punaau and Nuaailua Streams; Honomanu Bay with the tributary of Honomanu Stream; Makaiwa Bay from Oopuola Stream; Waiplo Bay from Waipio Stream; Hoolawa Bay from Hoolawa Stream; Pilale Bay from Kapiki Stream and Kuiaha Bay from Kuiaha Stream are listed by Cox as the true estuaries of this coastline. Watershed agriculture includes cattle ranching for all of them plus pineapple for Kuiaha. They all have their headwaters in forest lands.

In addition to the above mention is made of two stream-mouth estuaries. These are Kopiliula Stream southeast of Wailuoiki Bay and Waialohe Pond at the mouth of Piinaau Stream. The village of Keanae using cesspools is on the northshore of Waialohe Pond which might cause some nitrates and perhaps phosphates to get into the pond.

Maliko Bay

Maliko Stream and Gulch begin in forest lands, pass through ranch lands and then through sugar and pineapple fields.

Hyvar X and Dalapon might be worth checking for at sometime in the future.

Kahului Harbor

This is not a true estuary. Since it is the main harbor of the island and because it has some pollution problems in common with the true estuaries, Cox included it in Technical Report No. 31.

There are no fresh water stream tributaries. Storm drains go into the harbor but treated sewage reaches the bay through two outfalls outside of the harbor. Iao Stream discharges into the bay three quarters of a mile west of the harbor. Kanaha Pond a bird refuge is one half mile east.

Sugar cane, pineapple, a pineapple cannery, cattle ranching, dairy farming, and urban areas of the towns of Kahului and Wailuku can be said to be in the watershed of the bay and following a heavy storm some of the runoff from these would probably get into the harbor. Urban activities would be expected to dominate.

Hyvar X, dalapon, 2,4D, chlorinated hydrocarbons, nitrates and phosphates might be suspected and checked for.

Kahakuloa Bay

Kahakuloa Stream is the main tributary for this estuary. The stream heads in the rainy central mountains of West Maui. Forest lands account for most of the valley. Taro is grown in the lower portion. The village of Kahakuloa uses cesspools.

Water quality here is considered to be very good. Perhaps some nitrates reach the bay.

Honokohau Bay

This bay on the north point of West Maui is fed by Honokohau Stream. Headwaters of the stream reach way back up into the rainy mountainous center of West Maui.

Forest lands, pineapple fields, and a few homesteads in the lower valley

describes the watershed. Hyvar X and nitrates might be worth checking for someday.

Honolua Bay

All comments on Honokohau would apply to Honolua. More pineapple field drainage can be expected to take place into Honolua.

Maui

44,836 acres of sugar cane and about 9,000 acres of pineapple are the main crops. Cattle ranching, dairy farming, vegetable crops and some fruit crops are grown.

It is to be expected that "agricultural chemical" threats to estuary water quality are much less serious than on Oahu.

HAWAII

Hilo Harbor and Wailuku and Wailoa Rivers

Like Kahului Harbor on Maui, Hilo Harbor is not a true estuary.

The Wailuku and Wailoa Rivers are tributaries and fresh water also goes into the harbor from extensive springs at Keaukaha.

Forest lands, sugar cane fields and urban areas of Hilo are in the watershed. The city of Hilo is served partly by cesspools and partly by a sewer system. The treated sewage is put into the open ocean about a half mile east of the breakwater.

Dalapon, 2,4-D, chlorinated hydrocarbons, nitrates, and possibly phosphates might be worth checking for.

Waipio Stream

This estuary on the north coast of the island has in its watershed forest lands, sugar cane fields, taro paddies and a few scattered homes

using cesspools.

Dalapon, 2,4-D, and nitrates are possible candidates to search for. Following heavy rainfall erosion the soil adsorbed herbicides Ametryne, Atrazine and Diuron probably come down into the bay.

Polulu Stream

Although Cox states that the valley is unoccupied and uncultivated with a few cattle on the flood plain he does list sugar cane as an agricultural development in Table 15 on page 117 of Technical Report No. 31. Before any consideration is given to likely "agricultural chemical" containments in the estuary this possible discrepancy should be checked out.

Hawaii

Having a land mass greater than all the other islands put together the agricultural enterprises are of more diversity. Its lack of true estuaries due to its relative geomorphic youth places it low on the list when consideration of estuarine pollution problems is the subject.

Extensive development of the diverse vegetable crop farmlots at Lalamilo in the South Kohala District near Waimea makes it interesting to find out about Kawaihae Harbor. Although this is not a true estuary there could be a great variety, though relatively low volume, of "agricultural chemicals" used in the upper watershed.

Discussion and Summary

The primary intent of this discourse has been to provide a rational proposal upon which an estuary sampling program can be based that will provide an understanding of the "agricultural chemicals" found relative to their origin. Thus the four Oahu estuaries; Kalaka Bay, Waialua Bay, Kahana Bay and Kuapa Pond are intended to be diagnostic in nature. For example, a chemical known to be used in pineapple might be claimed to contribute to an estuary by the concentration of this chemical found in Kalaka Bay minus the concentrations found in the other three estuaries. This is an obvious oversimplification, but it remains the basis of reasoning for the proposal.

The chemicals mentioned as being presently actively used by the three major "agricultural" segments were:

Pineapple;

Heptachlor, Lindane, EDB, BBC, DD, Hyvar X, Diuron, Atrazine, Ametryne, Diazinon, Malathion, Mirex, Captan, Nitrogen, Phosphorus, Potassium, and Magnesium

Sugar Cane;

Ametryne, Atrazine, Diuron, Dalapon, 2,4-D, Warfarin, Benlate, Diquat, Nitrogen, Phosphorus and Potassium

Pest Control Operators and Homeowners

Chlordane, Heptachlor, Lindane, Aldrin, Dieldrin, Diazinon, Baygon, Nitrogen, Phosphorus and Potassium

Other agricultural chemicals mentioned during the treatment of miscellaneous agricultural segments other than the major three including the highway

department were; Cygon, Thiodan, Gardona, Sevin, Malathion, Vegadex, Suten, Lasso, Amino Triozole, MSMA, Dacthol, Dimed, Zineb, and Maneb.

Dr. Donald Crosby, Chairman of the Department of Environmental Toxicology, University of California at Davis led a Sea Grant Workshop during which this proposal was discussed and Dr. Crosby's evaluation received. The key issue then under consideration was the likelihood of a chemical's appearance in an estuary when it is known to be used in that estuary's watershed.

As the result of that workshop and because it is diagnostically necessary to cross index it is proposed that the four Oahu estuaries be sampled for chlorinated hydrocarbons, Diazinon, Hyvar X, Dalapon, 2,4-D, arsenic, mercury, nitrogen and phosphorus.

It is important that this sampling program be done over a time span resulting in samplings before and after heavy rainstorms. Careful, accurate notations of the soil erosion effects of these storms must be obtained.

Once the sampling program of these four estuaries is either completed or well enough on its way that insights have developed then other Hawaiian estuaries might be considered.

REFERENCES

(1) 1970 Census, report. Obtained from the State Statistician's Office of the Hawaii State Planning and Economic Development Department.

(2) Evaluation of Pesticide Problems in Hawaii, 1969, H. S. Kimura and H. R. Hurov.

(3) United States Soil Conservation Service. All gross watershed acreage figures were given by Stratford Whiting of the Honolulu office of the SCS. Room 440, Alexander Young Building, Phone 546-5792.

(4) United States Forest Service. The urban area acreages for Kaiaka and Waialua Bay estuaries were given by Bob Nelson of the United States Forest Service Institute, Pacific Islands Forestry, Phone 546-5644.

(5) University of Hawaii, College of Tropical Agriculture Extension Service, Wahiawa Office, Yukio Kitagawa.

(6) Estuarine Pollution in the State of Hawaii. Volume One by Doak C. Cox and Lawrence C. Gordon, Jr. March 1970.