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THE HERBICIDE POLICY REVIEW

Military Assistance Command, Vietnam
APO San Francisco 96243

20 August 1968

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REPORT ON THE HERBICIDE POLICY REVIEW

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REPORT ON THE HERBICIDE POLICY REVIEW

This Report was prepared at the direction of the American Ambassador to Vietnam by a special Committee representing the Embassy, MACV (including CORDS), USAID and JUSPAO.

The Herbicide Policy Review was part of continuing efforts to assess the efficacy of herbicide programs in terms of military benefits to the Allied Forces—South Vietnamese and American as well as those of the other Free World nations—as compared to economic costs and possible ecological effects. Additionally, the Committee was charged with examining current procedures and techniques employed in implementing the programs with a view to possible recommendations for changes and improvements that would help maximize the benefits and minimize the costs and ecological effects.

The Committee conducted the review during the period March - May, 1968. Findings and recommendations were based upon information obtained from a wide range of documents, the testimony of many Mission military and civilian officers, and the specialized knowledge contributed by four consulting scientists, three of whom were especially brought from the United States to participate in the Committee's work.

The Commander, US Military Assistance Command, Vietnam, the Minister Counselor for Political Affairs, the Acting Director, USAID, and the Director, JUSPAO, concurred in the Report of the Committee.

The Report on the Herbicide Policy Review was reviewed by the Ambassador and approved by him on August 28, 1968.

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REPORT OF THE

HERBICIDE POLICY REVIEW COMMITTEE

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REPORT OF THE HERBICIDE POLICY REVIEW COMMITTEE

Principal Findings and Recommendations*

Overview

From a military point of view, the US/GVN herbicide program has been successful. Its military benefits, especially in defoliation operations, have been clearly demonstrated.

As with other military activities conducted jointly by the US and GVN in the prosecution of the war, however, the herbicide program carries within it the potential for causing serious adverse impacts in the economic, social, and psychological field. The program has therefore been conducted from its beginning in late 1962 under an elaborate system of policy and operational controls. As a result, these effects have not been permitted to develop into serious policy problems.

Nevertheless, the program has incurred substantial costs. Some of its economic costs, as is inevitable in war, are sizeable and involve permanent losses. It is within the capability of the US and the GVN, however, to reduce and even eliminate some of these cost by-products of the program. The psychological costs of the program have not been serious or unmanageable, however the public affairs efforts in support of the program could be considerably improved.

The management of a program as wide-ranging and requiring, as it does, the participation and specialized knowledge of so many people in different places, is bound to create problems of policy, administration, and communication. There have also been problems stemming from lack of detailed information in certain key aspects of the program.

In weighing the overall costs, problems, and unknowns of the herbicide program against the benefits, the Committee considers that, on balance, the latter clearly outweigh the former and that the program should be continued and refined in accordance with the findings and recommendations contained in this Report.

*All of the Committee's findings and recommendations are presented in detail in Sections A through G.

Principal Findings

1. Defoliation. The defoliation program has been instrumental, and at times decisive, in overcoming the difficulty of locating the enemy in heavily forested combat zones. It has thereby helped enable Allied forces to maximize their advantage of superior mobility and firepower. It has also enhanced the security of Allied lines of communication and facilities by helping to eliminate enemy ambush sites and by providing defensive fields of fire. Thus, both offensively and defensively, defoliation has reduced the number of men and the equipment required for combat missions, has protected war materiel, and most importantly, has helped to save many Allied lives.

2. Economic Costs. The defoliation program, however, has incurred some substantial costs for the United States as well as for the people and Government of the Republic of Vietnam.

(a) Large stands of merchantable timber in War Zones C and D have been damaged and many trees killed. The forests of Vietnam are one of its most important renewable natural resources and future sources of employment. Repeated application of defoliants in these Zones could seriously retard regeneration of these forests.

(b) Damage to crops in III CTZ has been attributed to defoliation operations. Further investigation indicates that these crop losses resulted from a combination of causes including plant diseases, lack of effective farmer care, herbicide drift, targeting and navigational errors, abortion of spray missions, and defective equipment on spray planes. It has not been possible to determine how much defoliation operations have been responsible for this damage.

(c) The alleged threat to the life of the rubber plantations in 1967 did not materialize.

3. Ecological Consequences. The ecological impact of herbicide operations to date does not appear to be serious. The herbicide program has no effect on precipitation, caused very minimal laterization of the soil, and apparently has had little or no effect on micro-organisms in the soil system. It has killed large stands of mangrove which will probably re-establish themselves

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in about 20 years. There has been no apparent effect on fish. It has probably caused some reduction in the number of birds and invertebrates living in the mangrove swamps. Semideciduous forests, especially in War Zones C and D, have been severely affected. The regeneration of these forests could be seriously retarded by repeated applications of herbicide. A few rare animal species may have been eliminated from War Zones C and D as a result of overall military operations.

4. Crop Destruction. Crop destruction operations constituted only approximately 15% of the herbicide effort in 1967. They destroyed an estimated 80,000 tons of paddy rice in 1967 - representing 1.75% of the total rice production of the country. However, crop destruction operations are directed against specific targets. As such, they are designed to affect the enemy food supply in localized situations, only. There is evidence that food shortages, for which crop destruction efforts were partly responsible, have at times created logistical problems for the enemy - especially in the Highlands and in mountainous parts of Binh Dinh, Phu Yen, and Quang Ngai provinces.

The main impact of crop destruction, however, falls upon the civilian population of the enemy-held or contested areas where the operations will take place. An estimated 90% of the crops destroyed in 1967 were grown, not by VC/NVA military personnel, but by the civilians living there. The Mission has very little systematic information about the economic and psychological effect of crop destruction operations upon the civilian populations, especially the Montagnards, who are most seriously affected.

Until the Mission has developed a comprehensive economic warfare program, the proper scale of crop destruction operations will remain untested. Except for units located deep in the Highlands, the enemy obtains most of his food through commercial channels, forced requisitions, taxation, and imports. Crop destruction should therefore be one of several interdependent factors in a comprehensive economic warfare effort designed, among other things, to deny food to the enemy.

5. Public Opinion. The herbicide program does not loom large as a public opinion issue in the US, South Vietnam, in Western Europe and elsewhere at the present time. It always carries with it a strong potential for trouble, however, because of its high emotional content. There is much confusion and ignorance about the herbicide program, and within RVN, especially in III CTZ. This is partly the result of Viet Cong propaganda exploitation. More importantly, it results from the fact that, from the outset, the psychological warfare support of the program has not been adequate.

6. Refugees. Herbicide operations have not generated a significant number of registered refugees.

7. Claims. US Advisors have not been sufficiently well informed about or active in the GVN claims program. It provides for solatium, not indemnification. The system of administration is unresponsive to the claimant and may be subject to administrative irregularities.

8. Management. The present system of herbicide program planning and procedures is not sufficiently responsive to management requirements. It takes much too long to process individual projects. New management procedures are needed which, without exceeding policy guidelines, will delegate sufficient authority to Corps commanders to prosecute certain important targets of opportunity in a practical and timely fashion. Province and Corps-level CORDS agricultural, refugee, and psychological warfare specialists have not been brought into the program sufficiently, and not enough attention has been paid on the local level to the economic, social, and political/psychological impact of projects. The present system has not provided enough of the right kind of information to enable Saigon-level officials to manage the program effectively or to monitor it from a policy point of view.

Principal Recommendations

1. Defoliation. Given the comparatively high concentration of effort in III CTZ to date, further defoliation operations there should be held to a minimum compatible with the overall requirements for the prosecution of the war.

2. Economic Costs.

(a) As soon as security conditions permit, the GVN, USAID, and MACV should cooperate to expand timber salvage operations to include all merchantable dead or damaged trees in War Zones C and D. USAID should also prepare plans for the reforestation of defoliated forest areas.

(b) MACV should obtain the full-time services of a qualified plant pathologist to assist in the investigation of claims for damage allegedly caused by defoliation operations. He would also orient program personnel in the field about the effects of defoliants upon plant life.

(c) MACV should ensure, in accordance with the proposed new program management procedures described in Section G, that CORDS agricultural, refugee and psywar advisers in the field are fully consulted in the preparation and post-audit of all herbicide projects.

(d) MACV and the "Ranch Hand" Squadron should maintain and continue to improve the review of all flight operational and navigational controls, spray delivery equipment, and methods of obtaining information about the atmospheric conditions over target areas, in order to ensure that everything possible is being done to minimize the chances of accidental damage to crops.

3. <u>Crop Destruction.</u> The Mission should develop a comprehensive economic warfare program designed, among other things, to deny food to the enemy. The proper scale of crop destruction operations should be determined on the basis of that program. In the meantime, the Mission should

(a) ensure that each crop destruction project is developed with a view to minimizing adverse effects upon the civilian population living in the target area to the extent possible,

(b) attempt to obtain more systematic information about the effect of crop destruction operations upon both the civil population, especially the Montagnards, as well as enemy forces,

(c) review the crop destruction program prior to December 31, 1968, on the basis of information provided by the new check list and post-audit system proposed in Section G in order to determine the most effective scale of the program.

4. <u>Ecological Consequences.</u>

(a) MACV should plan and execute any possible future area defoliation targets so as to ensure that strips of forest are left undefoliated which will serve as a seed source for regeneration and as habitat for wildlife.

(b) USAID, with the assistance of MACV, should maintain a continuing assessment of the impact of herbicide operations upon the forest and the watershed.

(c) With the end of hostilities, USAID should assist the GVN in the establishment of a comprehensive program of ecologic research designed to assist in the economic recovery of the country.

5. Psyops. Psyops support for the herbicide program has not been effective. A concerted effort should be undertaken by US and GVN psyops officials to correct shortcomings in planning and implementation of psyops programs to ensure that effective psyops support is provided. To this end, US and GVN resources should be utilized as required.

6. Claims.

(a) MACV should make a concerted effort to increase its advisors' knowledge, especially at province level, regarding the policies and procedures of MILCAP so that they can more effectively advise their counterparts about it.

(b) MACV, the Joint Economic Office, and JGS should undertake to simplify GVN Military Civil Assistance Program (MILCAP) procedures in order to permit up to SVN60,000 to be paid on a valid claim within one month of filing. This will expedite the payment of 80% of all herbicide claims.

7. JUSPAO Participation. JUSPAO should be represented along with the Embassy, MACV and USAID on the Saigon-level "203 Committee" which reviews all herbicide projects.

8. Management. MACV should adopt the following new methods and procedures in order to (a) make the program more responsive to the tactical requirements of major commanders, and (b) improve the quality of information about operations needed for maintaining Saigon-level policy review of the program:

(a) ensure that CORDS agricultural, psyops, and refugee specialists are fully consulted in the preparation and post-audit of all projects.

(b) require that checklists containing all relevant military, economic, psychological, and demographic information are completed in the field for all projects and forwarded to Saigon-level officials for use in the evaluation of projects.

(c) require that post-operations audits are conducted for projects on a regular basis as a means of strengthening program management and policy review.

(d) delegate authority to Corps commanders to carry out US helicopter defoliation operations in order to (1) maintain defensive fields of fire contiguous to Allied base camps, (2) re-treat Rome-plowed areas as required, and (3) uncover known small ambush sites along LOCs. These operations will be monitored by Headquarters MACV and carried out in accordance with the same policy guidelines and operational controls that apply to C-123 spray missions.

(e) continue area clearances for crop destruction operations according to which crop targets of opportunity may be executed within areas approved for such operations by the Ambassador. Such targets will be confined to low population density areas under enemy control. Approval will extend to 12 months or 2 growing seasons. MACV Headquarters will review specific targets to ensure that they are in accord with all policy and operational guidelines.

9. <u>Implementation</u>. MACV, in coordination with JUSPAO and USAID, should consult with appropriate GVN authorities in order to implement these recommendations as soon as possible.

SECTION A: THE DEFOLIATION PROGRAM

I. RECOMMENDATIONS

A. Given the comparatively high concentration of effort in III CTZ to date, future defoliation operations there should be held to the minimum compatible with military requirements.

B. As soon as security conditions permit, USAID and MACV should recommend expansion of the timber salvage program to include all valuable stands in War Zones C and D. USAID should also assist the GVN in the development of plans for the reforestation of defoliated forest areas.

C. MACV should obtain the full-time services of a qualified plant pathologist to assist in the investigation of defoliation damage claims. He would also raise the level of awareness on the part of program personnel in the field about the effects of defoliants upon plant life.

D. MACV should ensure, in accordance with the proposed new procedures described in Section G, that CORDS agricultural, refugee and psyops advisors in the field are fully consulted in the preparation and post-audit of all herbicide projects.

E. All spray systems used on aerial herbicide operations should be recalibrated.

F. MACV and the "Ranch Hand" Squadron should maintain and continue to develop an active review of all flight operational controls, spray delivery equipment, navigational techniques, and methods of obtaining information about the atmospheric conditions over target areas in order to ensure that everything possible is being done to minimize the chances of accidental damage to crops.

G. The improved psyops support program described in Section C should be implemented.

II. SUMMARY OF FINDINGS

A. Defoliation has been a successful military program in South Vietnam. Its objectives are twofold: (1) to help overcome the difficulty of locating the enemy in a heavily forested country, thereby enabling Allied forces to maximize their advantage of superior mobility and firepower, and (2) to enhance the security of Allied LOC's and facilities by providing defensive fields of fire. The defoliation program has achieved its foregoing objectives, and in so doing, has helped to save Allied lives.

B. The defoliation program has generated some adverse economic and psychological problems, primarily in III CTZ:

(a) War Zones C and D in III CTZ contain exploitable stands of timber that have been killed by defoliants. If logging operations are carried out within one to two years after defoliation, this timber can be salvaged. Such an operation is underway in secured parts of War Zone C.

(b) During 1966 and 1967 there were many claims of defoliant damage to cash food crops in III CTZ. Agricultural advisors in III CTZ discount between 80 and 90 percent of these claims. The difficulty of obtaining hard, timely data impedes successful investigation of claims.

(c) Many people, including even some Allied officials, are confused and poorly informed about the objectives of the defoliation program. Allied motives and actions have been the subject of successful VC propaganda attacks.

C. Drift is a difficult unresolved problem in the application of herbicides. This problem is not unique to military operations in Vietnam. Until scientists are able to provide definitive information about the range and effect of defoliants upon plant life, the policy maker will have to (1) continue to adopt an attitude of healthy respect for the various hazards which may result in unforeseen damage, and (2) devise whatever practical and prudent measures that given circumstances may require.

D. The foregoing problems are outweighed by the demonstrated military advantages of the program. They are significant program "costs," however. Although they cannot be eliminated, the adverse impact can be substantially reduced by the introduction of new and improved operational and program controls as well as improved economic and psychological support activities.

III. ANALYSIS OF THE DEFOLIATION PROGRAM

A. Development and Main Focus of Defoliation Operations

The defoliation program effectively began on December 4, 1961, when President Kennedy authorized the Secretary of Defense to test the military effectiveness of the defoliation of several lines of communication in South Vietnam. The Chart on the next page shows how the program has developed since then in terms of the number of square kilometers sprayed. The first four years of the program was a period of modest growth. 1966 and 1967, however, were years of very substantial expansion. Approximately five times more area was defoliated in 1966 than in 1965; approximately nine times more area was sprayed in 1967 than in 1965. The total area of South Vietnam is 173,000 square kilometers. By the end of 1967, approximately 5% of the country had been sprayed. The map on page five shows the pattern of defoliation operations in 1963-1967.

Buildup of III CTZ Operations. The bulk of the 1966/67 expansion of the program took place in III CTZ: 53% of the total area sprayed in 1966 was in III CTZ; this proportion had increased to 65% in 1967. III CTZ has accounted for approximately 60% of all the area sprayed in the country since the beginning of the program. Not surprisingly, it is also in III CTZ where the herbicide program has encountered most of the unfavorable economic and public opinion "fallout" that has been attributed to it.

The relative concentration of defoliation operations in III CTZ is a partial reflection of allied and enemy strategy. War Zone C (920 square km^2) was defoliated in 1966 as part of the successful campaign to destroy enemy forces located in this long-time enemy base area. Upwards of two US divisions were employed in this campaign. War Zone D (1,920 square km) was defoliated in 1967 as part of allied efforts to drive an anticipated large enemy force out of this major threat to Saigon. The defoliation of the Rung Sat Special Zone (460 km) was carried out in 1966 and 1967 as part of urgent US efforts to secure the main shipping channels leading to the Port of Saigon.

Estimated Plateau Level in 1968. If present plans eventuate, 1968 will be the first year in which the program will not have at least doubled in terms of area coverage. The 1968 coverage target of 7,700 km^2 is not substantially greater than the 6,016 km^2 sprayed in 1967. Only as the enemy's plan of battle unfolds will it be possible to estimate how much of 1968 operations will consist of retreatment of areas already sprayed. There are no present plans for the defoliation of any new large area targets such as War Zones C and D.

HERBICIDE OPERATIONS - AREA COVERAGE: KM^2

	DEFOLIATION						CROP DESTRUCTION				
	I CTZ	II CTZ	III CTZ	IV CTZ	SUB-TOT		I CTZ	II CTZ	III CTZ	SUB-TOT	TOTAL
1962	-	-	-	20	20	1962	-	-	3	3	23
1963	-	17	69	14	100	1963	1	-	-	1	101
1964	39	113	129	57	338	1964	6	17	19	42	380
1965	16	58	371	185	630	1965	22	63	182	267	897
1966	475	403	1,751	372	3,001	1966	247	106	68	421	3,422
1967	374	833	3,918	893	6,018	1967	250	531	115	896	6,914
TOT:	904	1,424	6,238	1,541	10,107	TOT:	526	717	387	1,630	11,737

DEFOLIATION: 1963 - 1967

TOTAL AREA SVN:

173,000 KM^2

I CORPS.

904 Square Kilometers

II CORPS:

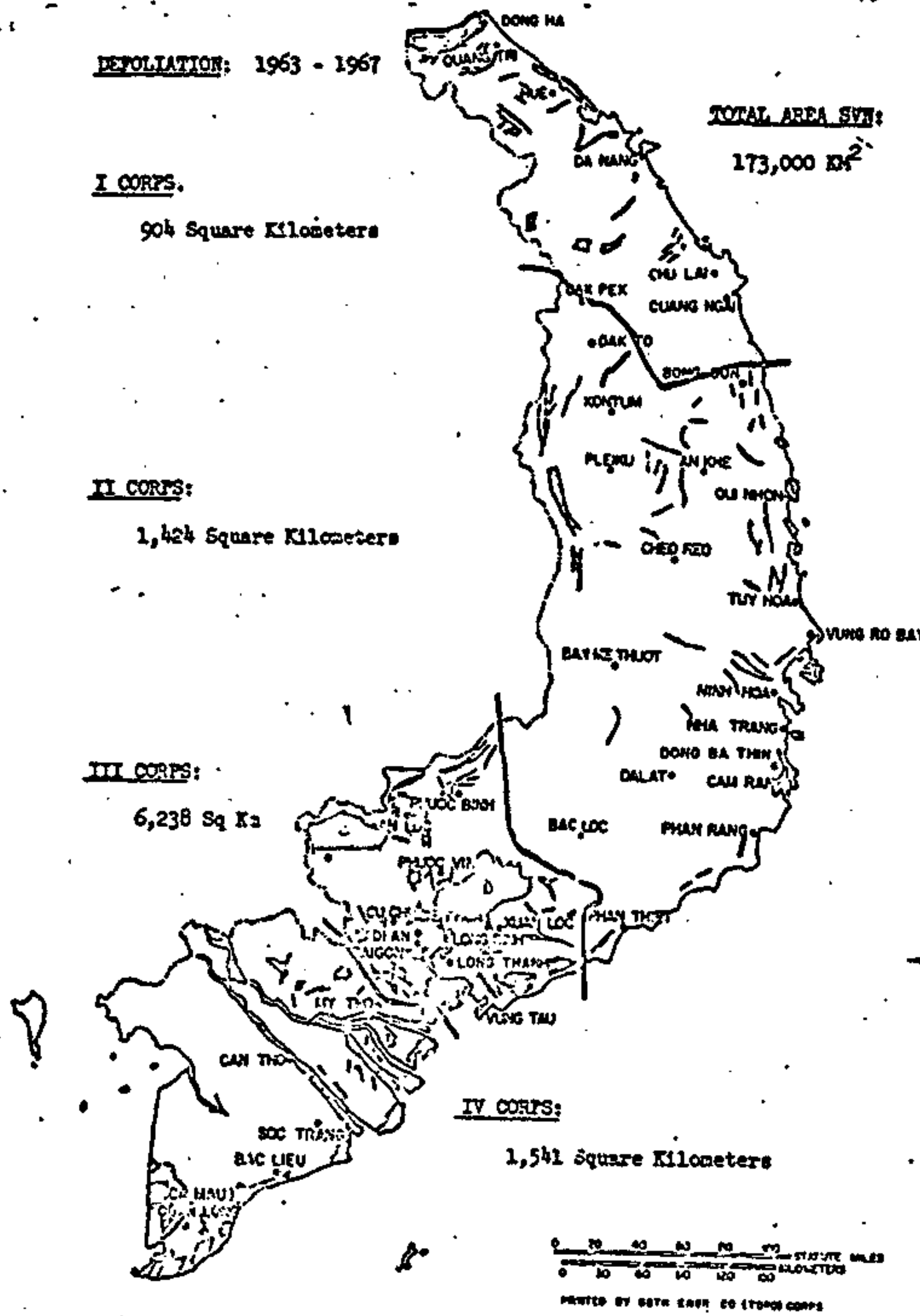
1,424 Square Kilometers

III CORPS:

6,238 Sq Km

IV CORPS:

1,541 Square Kilometers



AREA COVERAGE NOT TO SCALE

1968 Plans. Defoliation operations in support of the 1968 Combined Campaign Plan will concentrate upon:

(a) LOCs required by Allied forces for their operations and logistics.

(b) LOCs used by the enemy for his operations and logistics.

(c) Enemy base areas that are the object of specifically planned Allied military operations.

(d) The creation of 3-5 kilometer-wide buffer zone along South Vietnam's borders designed to help interdict enemy infiltration routes leading into the country.

Enemy operations will largely determine the extent to which the foregoing objectives can be pursued in 1968. Implementation of the plan would result in a substantial shift in defoliation operations from those carried out in portions of comparatively high population density areas to the more remote and less populated parts of the country along the Laotian and Cambodian borders. This shift in emphasis would have unquestionably beneficial effect in III CTZ.

B. Military Rationale of the Defoliation Program

A key element in Allied military strategy in the Vietnam war has been the utilization of the unprecedented firepower that modern science, industry and logistics have made possible. Allied forces are engaging the enemy with much higher rates of return fire than in any previous war. On the ground and from the air, commanders are substituting firepower for manpower. As a result, an undeterminable but large number of American and Allied lives have been saved.

Much of South Vietnam, however, is covered with dense forests, jungle and mangrove. Utilization of this natural concealment has afforded the enemy great tactical and logistical advantages vis-a-vis Allied forces. A paramount military problem from the outset, therefore, has been the difficulty of locating the enemy, his bases, and his LOCs. Without information about enemy dispositions, our forces cannot exploit their advantage of superior firepower.

Defoliation by chemical herbicides is the principal way by which

Allied forces obtain visual observation of enemy forces, facilities, ambush sites, infiltration routes and other enemy-used LOCs. It is also employed to enhance security around Allied base camps, airfields, ammunition dumps, ports, and along LOCs by providing defensive fields of fire. These fields of fire are also made by Rome Plow and chain saw operations conducted, sometimes jointly, with aerial and ground defoliation operations.

Improved Intelligence. Defoliation of large area targets such as War Zones C and D contribute importantly to improved military intelligence for plans and operations. Within a few weeks after the defoliation of the War Zones there was a dramatic improvement in vertical visibility. Just as the passenger in a plane flying 1000 feet over a deciduous American forest in winter-time can see brooks, paths, walls, and gullies which would be concealed by summertime leaf growth, so now can trenches, bunkers, structures, and trails formerly used by the enemy in War Zones C and D be seen clearly from observation planes.

Horizontal visibility can also be extended by defoliation from practically none in dense jungle to as much as 30-40 yards. One of the obvious, but sometimes overlooked, benefits of defoliation, further more, is the data which it provides for the correction of existing maps and the preparation of new ones. Accurate maps play an important role in ground and air operations.

Lower Casualty Rates. Experience in operations such as "Junction City" in War Zone C has shown that Allied troops meet significantly less enemy resistance in areas that have been defoliated. Exposure of his supply depots, base camps, and LOCs make the enemy much more vulnerable to Allied air strikes. The resultant damage, harrassment, and threat of impending attack by Allied airborne troops has frequently caused the enemy to move out.

It was originally estimated that more than two divisions would be required to clear the enemy out of War Zone D in 1967. The Zone was defoliated and, in the end, only one brigade was needed for the operation. It makes little difference whether defoliation caused the enemy to move out or whether it resulted in improved intelligence. Commanders used far fewer troops in the operation than they probably would have had to have used if the Zone had not been defoliated. Not only were there fewer casualties, but approximately two US divisions were freed for combat use elsewhere. For the most part, the enemy continues to avoid defoliated portions of War Zone D.

Defoliation of enemy secret zones reduces casualties among Allied infantry units engaged in seeking out the enemy. At the same time, however, it reduces the need for some ground search operations. After defoliation has helped in locating the enemy, tactical air strikes prepare the way for airborne troop landings. Thus, air mobility and firepower can be substituted for ground maneuver elements. This saves lives and permits more efficient use of manpower.

More Combat-available Manpower. Defoliation has permitted commanders to reduce the number of men committed to base security and convoy guard work. These men have then become available for offensive combat duty. This more efficient use of military manpower has resulted from the defoliation of broad defensive fields of fire around Allied base camps, and the defoliation of ambush sites and fields of fire along friendly LOCs. Improved fields of fire, wherever located, act as a deterrent to enemy attack, increase his casualties when he does attack, and correspondingly, help to reduce casualties among Allied troops.

Facilitates and Protects Movement of Supplies. The securing of LOCs as a result of defoliation, coupled with Rome Plow work, air observation, and road security patrolling, has played an important role in the movement of military supplies. An increasing number of South Vietnam's main highways, railroads, and main shipping channels have been cleared to as much as 100-200 meters on each side.

The priority defoliation in 1966 and 1967 of the main shipping channels leading to the Saigon Port through the Rung Sat Special Zone (RSSZ) was especially successful. For a long time, the enemy had regularly attacked Allied shipping from concealed small arms and mortars positions located in the dense mangrove swamps of the RSSZ. Since defoliation, such attacks have diminished substantially and they no longer pose a critical threat to this vital supply line. In addition to the preservation of ships, supplies, and crewman, fewer convoy guards and escort vessels have been required, thereby permitting their assignment to offensive combat missions. Herbicide operations in the RSSZ, for the most part, will henceforth be confined to the retreatment of mangrove swamps as required.

C. Problems in III CTZ

16% of the land area in III CTZ is under cultivation, a quarter of which is planted in rubber. In recent years, III CTZ has produced 70% of South Vietnam's timber. Production of vegetable and fruit crops increased an estimated 50% in the Corps during 1965- 1966. About 75% of the people living in III CTZ derive their income from agricultural work.

<u>The Rubber Plantation Episode</u>. Natural rubber has traditionally been Vietnam's most important export item. The rubber plantations provide jobs for an estimated 15,000 workers. In spite of current problems in the world rubber market, rubber is one of South Vietnam's long-term economic assets.

In late February 1967, the Embassy began to receive reports from plantation managers in III CTZ about unprecedented damage to the rubber plantations. They attributed the damage to drift emanating from defoliation operations being carried out against targets elsewhere in III CTZ. These allegations were supported by the Vietnam Rubber Institute.

As a consequence of these complaints, and in view of the economic importance of the plantations, the Mission Council established an <u>ad hoc</u> committee to examine the situation. Technical experts from MACV, USAID and CORDS, as well as a specialist on the effects of herbicides on plants from the US Army Plant Sciences Laboratories, Ft. Detrick, Maryland, participated in a special technical survey. The team examined representative areas where damage was alleged to have taken place. Security conditions in the field prevented access to all the plantations.

In a report to the Ambassador dated April 13, 1967, the team concluded that symptoms indicating damage by herbicide had been observed in 7 of 16 plantation sites examined. It stated that although most of the trees that had been accidentally sprayed would undoubtedly survive, it could not predict the extent of possible permanent damage. It recommended that the plantations should be carefully observed during the succeeding growing season. The team also observed, however, that disease and inadequate maintenance rather than defoliants were responsible for the poor health of many rubber trees. It also noted that some damage had been caused by operational and navigational errors.

<u>Buffer Zone Around Plantations Established</u>. As a result of the survey team's findings, a buffer zone was established around all active rubber plantations. No herbicide missions have since been flown over an inner 5 kilometer-wide zone around plantations, and only less volatile WHITE herbicide has been used over a second outer zone, also 5 km wide.

MACV and the 7th Air Force have scrupulously adhered to this policy. There have been no significant new claims of damage to the plantations by herbicide operations in 1967 or thus far in 1968. The Director-General of Terres Rouge Plantations verified this in a recent interview. The CORDS Agricultural Advisor in

Binh Long Province stated, furthermore, in a report dated December 22,1967, "The effects of defoliation have not been as disastrous as anticipated; refoliation has begun and blocks of trees marked off as lost will be able to be tapped again." Other preliminary evidence tends to substantiate further the view that herbicides may be less toxic to rubber trees than was previously thought.

Damage to Semi-deciduous Forests. SVN has a land area of 17,146,000 hectares of which 5,620,000, or 33% is classified as forest land. These forests contain many valuable species. The forest is one of the most important renewable natural resources in South Vietnam. The wood industry is one of the country's most important industries and is estimated to employ some 80,000 people. The present annual production of 243,000 M3 is only a fraction of the estimated peace-time potential production of 3,500,000 M3.

Salvage Program for War Zone C Initiated. Between 900,000 and 1,000,000 hectares of forest land, or approximately 20% of the total forested area have been treated by defoliants since 1961 (not all of this area contains merchantable timber). War Zones C and D in III Corps - defoliated in 1966 and 1967 - contain some of the country's most valuable hardwood timber. Forest reserves in War Zone C are estimated to contain some 2 million M3 of timber that is now dead, dying, or otherwise damaged. This timber is now being salvaged under a program supported by USAID and MACV. Salvage of this timber represents a value of 2 billion $SVN to the Government in timber taxes. War Zone D contains an estimated 25 million M3 of merchantable timber. Aerial observation indicates that much of this timber is also dead, dying or damaged by defoliants. Security limitations complicate salvage logging operation in this area at the present time.

Growth of Bamboo Observed. USAID foresters observe that there has been a marked increase in understory vegetation (low-growing trees and bushes) in the defoliated forests. In some areas, elimination of the overstory (upper canopy of high trees) has caused an increase in bamboo and shrubs to the point where they sometimes fully occupy the site. From a military standpoint, vertical and horizontal visibility is markedly reduced in such areas. Foresters, however, are primarily concerned about the effect of these less desirable competing species on the regeneration of the forest as a whole.

Tree Mortality Increases With Successive Herbicide Applications. A systematic examination of forest inventory sample areas was carried out during the period March 15-18, 1968 by USAID foresters and two consulting ecologists as a part of the Herbicide Policy Review. These areas were located at three places in Tay Ninh and Binh Long provinces. The foresters concluded that, despite the fact that ecological impact is minimal in such areas, light to moderate mortality occurs in forest stands following one application of herbicide. Two treatments in successive years, however, cause heavy mortality of saw timber, loss of reproduction sources, and hence introduce the possibility of adverse ecological impact. WHITE herbicide appears to cause heavier damage than ORANGE. After one year, all trees killed by defoliation remained sound and salvageable. Reseeding sources were found in adequate numbers. The foresters believe that bamboo site invasion will increase in areas where the normal forest trees have been killed by defoliants. They recommend that forests receiving two or more treatments of herbicides should be planned for reforestation. (An examination and related ecological consequences of the herbicide program is presented in Section F.)

Damage to Cash Food Crops. III Corps CORDS agricultural advisors believe that there has been substantial damage to cash food crops as a result of the defoliation program. They assert that there was heavy damage to crops in Tay Ninh Province during the defoliation of War Zone C in 1966. Many claims of herbicide damage were submitted in 1966. They attribute this damage to drift and to leaky valves on C-123 spray aircraft. (Revised maintenance and control procedures have significantly reduced damage from the latter.) They believe that damage caused by the latter was increased because C-123s were in the habit of making aerial rendezvous over Tay Ninh City and other cities in III CTZ prior to the start of spray missions.

The agriculture men in III CTZ have expressed the view that defoliants can drift some distance from the point of release from the aircraft. They believe that the 1965 papaya crop in Long Khanh Province was seriously damaged by drift. Papaya is extremely susceptible to defoliation. They also believe that more than half of the 1966 soy bean crop in Long Khanh Province was killed by drift. They recognize, however, that the soy bean plant is seriously affected by stem borers, and that it is difficult to distinguish between the two symptoms of damage.

The Committee is not prepared *ipso facto* to ascribe the plant mortality observed at significant distances from target areas to drift alone. Such plant mortality could also be ascribed to unidentified plant disease, volatilization of herbicide in unique combinations of meteorological conditions, abortions of missions, target error and faulty meteorological observations prior to the flying of the sortie. All of these conditions require further investigation.

Most Claims Believed Unjustified. The III CTZ CORDS Senior Agricultural Advisor has stated that he has seen no evidence of direct spraying of crops, whether caused intentionally or accidentally. He and his associates, however, believe that they have evidence of drift damage that has occurred in areas adjacent to and several kilometers away from defoliation targets. Although there have been many claims for damage submitted in III CTZ, they estimate that only 10-20% of the alleged damage has been caused by defoliants. In this connection, they consider that most of the allegations of drift damage made by rubber growers are not supportable. They also estimate that 10-15% of the actual drift damage has resulted from carelessly conducted ground spray operations.

Many Fewer Claims in 1968. The agriculture men also note that people in III CTZ fail to distinguish between herbicide aircraft and other aircraft engaged in insecticide operations. They also note that the farmer sometimes adopts a fatalistic attitude toward his crops. Seeing sick plants, he concludes that it is the result of herbicides. He then stops giving them proper care, and they fail. III CTZ agricultural specialists have noted a marked reduction in the number of claims submitted in III CTZ during the past 6 months. Whereas previously there were approximately 3-4 claims submitted every week, now only 3-4 per month are being received. (For an examination of public opinion reactions to the herbicide program in South Vietnam, the United States, and Western Europe, see Section C.)

D. The Drift Problem

Drift is a recognized phenomenon in aerial and ground herbicide spray operations. It is so recognized by the US Forest Service which has long carried out extensive but highly controlled herbicide operations, by companies that manufacture defoliants, by commercial herbicide spray operators, and by US military authorities. The present operational controls imposed upon the 7th AF "Ranch Hand" Squadron reflect a clear-cut recognition of the drift problem.

<u>Differing Views Over Range of Drift</u>. CORDS agricultural advisors in III CTZ do not agree with the analyses of drift and volatilization prepared by the consultants to the MACV representative on the Herbicide Policy Review Committee. The technical papers prepared by MACV consultants Minarik, Darrow and Blumenfeld have been included in the Appendix as expert information which the Committee took into consideration.

According to calculations made by Minarik and Darrow (see Appendix A), "the maximum distance at which drift hazard from 6 sortie missions with ORANGE would occur, was 1-2 kilometers under most unfavorable crosswind conditions of 9 miles per hour. Rice, sugar cane, corn and other grass-like crops can be located one kilometer or more from defoliation targets. Under the atmospheric conditions at which 12th Air Commando Squadron "Ranch Hand" operates, drift damage on broadleaf crops should not occur at distances greater than 2 kilometers. The theoretical analysis of drift prepared by Blumenfeld (see Appendix B) is consistent with these findings. Minarik and Darrow also assert that the possibility of crop damage from vaporized ORANGE herbicide is not significant "under current techniques of application" in South Vietnam.

<u>Difficulty of Isolating Damage by Herbicides</u>. The Committee observed that CORDS field investigations of damage to crops have not always had the benefit of hard, timely evidence and the technical-scientific expertise that is needed to make authoritative judgements as to the different possible causes of given plant sicknesses, e.g., defoliants, jet fuel, stem borers, or any of the many other plant diseases. The Committee considers that MACV should obtain the full-time services of a qualified plant pathologist to carry out this important work. This specialist would also engage in an educational effort designed to raise the overall awareness of all program personnel including Corps Chemical Officers and agricultural advisors, regarding the effects of herbicide on plant life. Agriculture men in the field, furthermore, have not had access (in all cases) to information about the specific times and places of herbicide flights in their areas of responsibility. The new procedures outlined in Section G, should remedy this shortcoming.

<u>Importance of Continuing Research and Operational Control System</u>. According to Minarik and Darrow, "the principle factors influencing drift from herbicide spray application are: droplet size, height of release and atmospheric conditions, principally horizontal air movement." In this connection, the Committee noted that the spray system currently being used by "Ranch Hand" has not been appropriately

calibrated for droplet size distribution. Given the importance of this information in the further development of the control system, it is imperative that the necessary tests should be carried out now.

The Committee also considered that MACV and "Ranch Hand" should maintain and continue to develop its active review of all flight operational controls, spray delivery equipment, navigational techniques, and especially its methods of obtaining information about atmospheric conditions over target areas to ensure that everything possible is being done to minimize the chances of accidental damage to crops. The Committee noted that MACV has requested that the required tests be carried out by the Department of the Air Force.

The Committee has not had the time or the independent expert resources to develop a position vis-a-vis the foregoing conflicting views. Debate as to the range and impact of herbicide drift is not, however, unique to the operations being carried out in South Vietnam. Research on this complex question is being conducted in both private and government laboratories. Until the scientist has provided more definitive information about the range of herbicide drift and its effect upon plant life, however, the policy-maker must adopt an attitude of healthy respect for it, and he must devise whatever practical and prudent measures that circumstances require.

E. Alternatives to the Use of Spray Defoliants

Rome Plows, bulldozers and teams of men using chain saws are now the most frequently employed alternatives to the use of herbicides in securing Allied LOCs. In situations where circumstances permit the use of defoliants, it is applied by C-123 aircraft, helicopters, or by ground systems in advance.

Where security conditions permit and appropriate supervision can be achieved, local workers have been used to cut down trees and bushes and remove the wood. This approach can be employed where many houses and gardens are located along the roadways. It offers the local people a stake in their security and in the protection of their own property. Plantation managers have similarly requested that their workers be permitted to do the clearing of LOCs that pass through plantations.

Military authorities are currently using and perfecting a number of specialized techniques designed to locate enemy forces and facilities. In time, these techniques may supplant some defoliation operations. Growth retardants are an additional alternative. They are chemical compounds which delay the regrowth of vegetation for periods of up to 18 months. Herbicides now being used may delay regrowth for 9-12 months. Retardants are described as non-corrosive, non-volatile, non-irritating and non-hazardous to people. Growth retardant has not been employed in South Vietnam.

SECTION B: THE CROP DESTRUCTION PROGRAM

I. RECOMMENDATIONS

A. Crop destruction should be considered an integral part of efforts to deny food to the VC/NVA.

B. A high proportion of civilians to enemy military in VC/NVA controlled territories were adversely affected by crop destruction missions in 1967, especially in several coastal provinces in I and II CTZ. The crop destruction program should be conducted in such a manner as to hold the number of sorties to the minimum compatible with the criteria set forth in the policy guidelines and the procedures proposed in Section G on Program Planning and Procedures.

C. Since crop destruction is only one aspect of a comprehensive food denial program, a greater effort should be made to coordinate crop destruction with other food denial activities. The Allies, therefore, should undertake a comprehensive review of how they can best coordinate food denial activities, preferably in the context of a general economic warfare policy review.

D. There is a need for flexibility and rapid response in crop destruction operations. Area clearances which will permit selection of targets of opportunity should therefore continue to be granted. They should continue to be strictly limited to sparsely populated, enemy-controlled areas in food deficit regions.

E. Priority should be given to missions flown in the vicinity of major VC/NVA base areas and to missions flown in conjunction with major allied military operations.

F. Every effort should be made to ensure that psycho-political disadvantages do not outweigh the military advantages. To facilitate this effort the crop destruction checklist (see Procedures, Section G) should be completed for both individual target and area requests.

G. A semi-annual evaluation (see Procedures, Section G) of the perceived costs and benefits of crop destruction missions flown should be submitted for each province. These post-audit reports would be used in planning future operations.

II. SUMMARY OF FINDINGS

A. Crop destruction operations have been successful, to an undetermined degree, in accomplishing the stated objectives of denying food to the VC/NVA and VC sympathizers, in diverting enemy manpower to food procurement, and in weakening enemy strength.

B. At the same time, the program has had significant but again undetermined adverse political, psychological, and economic impacts on civilians in VC controlled areas. Less than 10 percent of the crops destroyed were cultivated by personnel of VC/NVA units. More than 90 percent was grown, willingly or unwillingly, by civilians of varying allegiance to the GVN, all of whom are targets for pacification efforts.

C. Herbicide crop destruction is only one aspect of the efforts to deny foodstuffs to the VC/NVA. The enemy relies on commercial purchases, imports, taxation, requisition, and confiscation for some 90 percent of his food requirements. His greatest vulnerability in general, therefore, appears to be in his logistics system.

D. Consequently, if crops are destroyed while other avenues of food acquisition are left open, the program is militarily less effective. However, it will still incur most of the adverse political and psychological costs.

E. A comprehensive approach to food denial should be adopted. Past food control activities have not been sufficiently coordinated at the Saigon level and, therefore, have not realized their full potential.

F. Nonetheless, there are documented instances where VC/NVA units have suffered from serious food deprivation and herbicide crop destruction has contributed significantly to this situation.

G. However, the available evidence indicates that the civilian populations in VC controlled areas bears the brunt of food denial activities. This is not surprising, but it does imply that the relative costs of the program are high.

H. There has not been a systematic attempt to evaluate the relative costs and benefits of conducting alternative levels of herbicide crop destruction in the context of a coordinated food denial program. Such an analysis should be undertaken, but will require more and better information than is currently available.

III. ANALYSIS OF THE CROP DESTRUCTION PROGRAM

The objectives of the crop destruction program are to deny food (rice, cereals, and broad leaf crops) to the VC/NVA and their sympathizers, to divert VC/NVA manpower to crop production, to impose constraints on enemy logistical capacity, or otherwise weaken VC/NVA strength.

A. Scope of the Program. In 1966 and 1967 crop destruction constituted only 12-13 percent of the total number of herbicide missions by area covered. Thus crop destruction has been a relatively small part of the total herbicide effort. Nonetheless, the program has grown rapidly. In 1963 only one square kilometer of crop was sprayed; In 1964, 42 square kilometers were sprayed; in 1965, 257; in 1966, 421; and in 1967, 896 square kilometers of crop were destroyed. The map on the next page shows the pattern of crop destruction operations in 1963-1967.

In 1967 this amounted to the destruction of about 120,000 short tons of food, over 80,000 tons of which was paddy rice, the remainder being assorted broad leaf crops. This amounts to about 10 percent of the rice grown in the first three CTZ and less than 2 percent of the rice production in the entire country. Geographically crop destruction was concentrated in II CTZ where 71,154 tons were destroyed in 1967; 33,500 tons were destroyed in I CTZ, and only 15,410 tons in III CTZ. Crop destruction missions are not conducted in IV CTZ.

B. Herbicide Crop Destruction Has Met The Stated Objectives of the Program. It has contributed to food shortages, diverted manpower to crop production, and weakened enemy strength. This has been particularly true in the enemy's Military Region V (I CTZ and the top half of II CTZ) where most crop destruction has been concentrated. Food shortages in this area appear to have been largely caused by breakdown in normal VC/NVA logistics activities, but in some instances crop destruction has directly denied food and placed serious additional burdens on enemy supply activities. Crop destruction, therefore, plays and should continue to play, an important role in efforts to deny food and otherwise harass the enemy.

C. The Impact of the Program. The impact, however, by its nature has been largely on the civil population in VC/NVA controlled areas. To some extent this is due to the size of the program, but largely due to the great difficulty of distinguishing between crops grown by the VC/NVA and those grown by civilians in VC controlled areas.

CROP DESTRUCTION: 1963 - 1967

TOTAL AREA SVN:

173,000 KM^2

I CORPS:

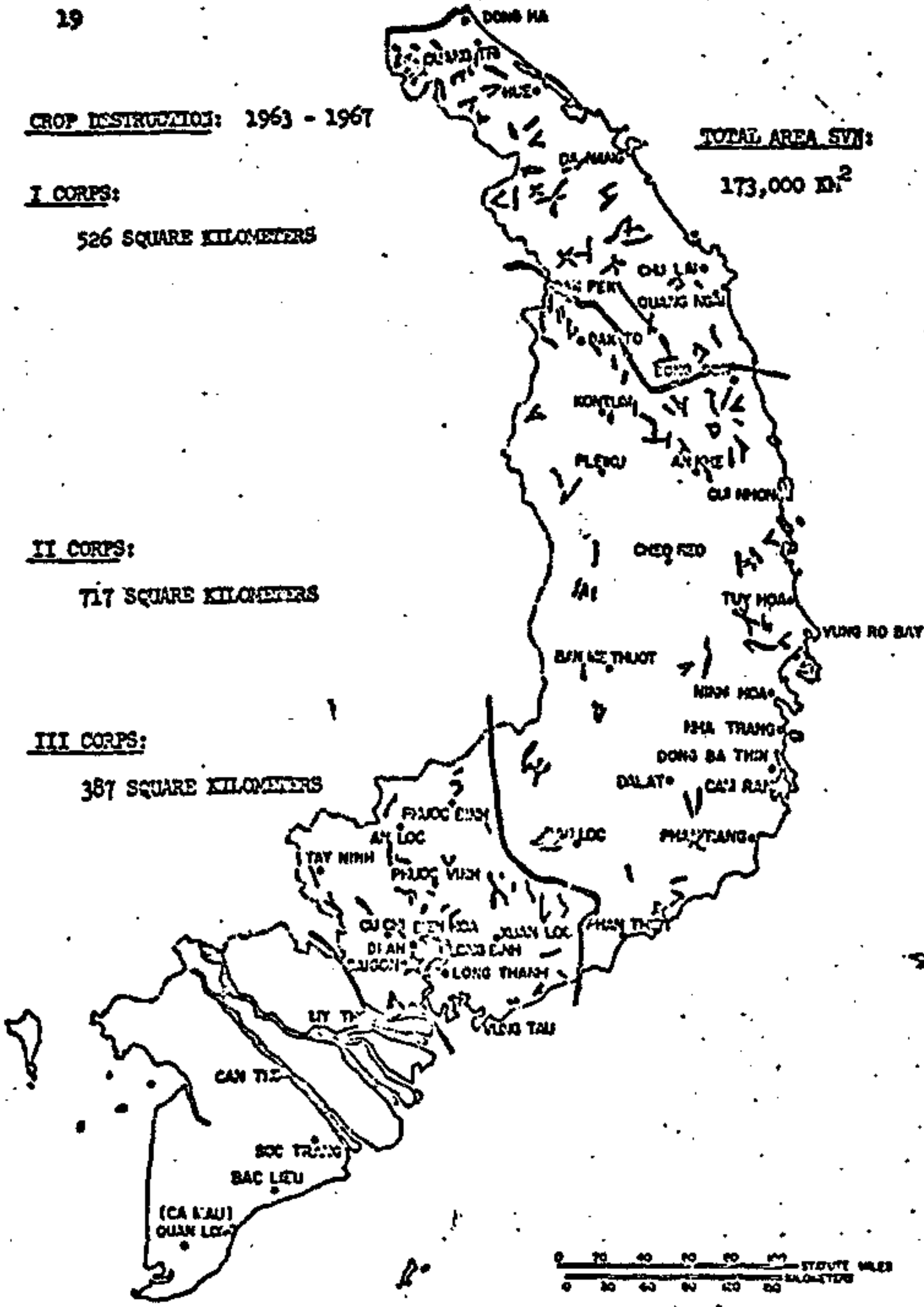
526 SQUARE KILOMETERS

II CORPS:

717 SQUARE KILOMETERS

III CORPS:

387 SQUARE KILOMETERS



AREA COVERAGE NOT TO SCALE

In the first three CTZ there were approximately 175,000 VC/NVA in 1967. If we make the assumption that each man consumes a higher than average ration of 500 pounds of rice per year (625 grams per day, which is high consumption for I, II & III CTZ), this implies a total enemy consumption of roughly 45,000 tons of rice per year. In comparison we destroyed about 48,000 tons of milled rice (i.e, based on a 40% milling loss from the 80,000 tons of paddy destroyed), or more than the total consumption of the VC/NVA in the area.

More importantly, the VC/NVA grow somewhat less than 10% of their requirements. On the average, therefore, we destroyed more than 10 times as much rice as the VC/NVA grew. Thus, less than 10 percent of the rice destroyed was cultivated by the personnel of VC/NVA units, the other more than 90 percent was grown, willingly or unwillingly, by civilian groups who may or may not have been VC sympathizers, but who are potential targets for pacification efforts.

D. Average Impacts are Less Important than Localized Impacts. The program aims at specific areas. It is therefore important to examine more localized areas, and while a province is still too large an area to be really meaningful, it is the only unit for which information is readily available. Of the various provinces, Binh Dinh is by far the most important in terms of the magnitude of crop destruction occurring in 1967, receiving one third of all crop destruction missions conducted in RVN in 1967. It had more than three times as much total crop destroyed as the next most heavily hit province (Quang Ngai) and about twice as much per capita.

Assuming that Binh Dinh had the same proportion of rice to broad leaf crops and the same productivity as other areas sprayed, some 27,000 tons of paddy (or 16,200 tons of milled rice) would have been destroyed and some 12,000 tons of other crops. If the recent CIC7 estimate (in ST 68-03) of 6400 VC/NVA in Binh Dinh is correct, their own production of rice was probably about 160 tons of rice. This would imply that only a little less than one percent of the rice destroyed was grown by personnel of VC/NVA units. About 99 percent was grown willingly or unwillingly by civilians of varying allegiance to the GVN.

E. Civilian Impact of the Program. Even if the foregoing statistics are wrong by a factor of as much as two or three, the civilian impact will still be very large. Binh Dinh Province is extreme, of course, since it received the most crop destruction. Yet, although it is atypical, it is also the most important. Furthermore, other provinces, while receiving less on the average, may have experienced similar impacts in more localized areas.

F. <u>The Costs and Benefits of This Program are Largely Unknown</u>. There is documented evidence that food shortages have caused serious problems for the enemy in Binh Dinh, as elsewhere. Yet it is not possible to separate the impact of herbicide crop destruction on food shortages from other causes, and there is evidence that these other causes are usually more important. For example, a compilation of 41 instances where reasons for food shortages were given broke down as follows:

Allied Movements	17
Poor Harvest & Planting	11
Inability of Cadre	8
Herbicide	5

The problem of assessment is further complicated by the fact that there is no accurate way of translating the effect of food shortages into the degradation of enemy fighting capability.

At the same time, there has been no satisfactory way of assessing the degree of political and psychological alienation of civilians whose crops were destroyed. Thus, attempts to measure either the costs or the benefits of the program are characterized by substantial uncertainty.

Consequently, any evaluation requires a subjective weighing of military benefits against psycho-political costs. Nonetheless, it does seem highly unlikely that destroying crops to the extent that more than 99 percent (or 95, or perhaps even 90 percent) are civilian grown is appropriate. This does not, however, answer the much more difficult question of how much should be destroyed. Attempts to answer this question must consider the strategies and tactics of the VC/NVA as well as the interaction with other food denial activities of Allied Forces.

G. <u>Crop Destruction Is Only One Aspect of Food Denial</u>. The program must be evaluated in the context of an overall food denial program. The VC have many alternative food supplies, and these must also be shut off if crop destruction is to be fully effective.

A major problem is that there may be large rice surpluses stored in food source areas. Binh Dinh is again an extreme example, but it illustrates the magnitude of the problem. Theoretically the province is a rice deficit area, producing only about 150,000 tons of rice per year. However, Binh Dinh imported 180,000 tons of US and GVN rice for local consumption and for export to surrounding provinces. Thus, in actuality the province had a surplus of over 100,000 tons of rice, but most of it was in commercial channels.

H. Corruption is an Obstacle to Effective Food Denial. This has made it possible for the VC to purchase through local commercial channels. The Binh Dinh Province Chief and several district chiefs were brought to trial in October 1967, one of the charges being their complicity in the sale of US/GVN rice to the enemy. Hopefully, behavior of this kind is rare. However where it exists it eases VC/NVA supply problems, and is also believed to contribute to general alienation of the population. Anticorruption measures are, therefore, important to an effective food denial program.

I. Other Sources of Food Must Also be Interdicted. In areas of high, and even medium, population density this will be very difficult, if not impossible. In areas of sparse population, however, the interdiction of other food sources becomes feasible and desirable.

There is a broad range of food denial activities which should be planned in conjunction with crop destruction. These include, but are probably not limited to, destruction of stockpiles, military cordoning activities (especially during harvest time), counter logistics missions (e.g., military patrols and PRU operations), removal of civilians and other population control measures, border control, and National Police Resources Control efforts. These activities have not received adequate coordination.

J. New Procedures Should Facilitate Operations and Program Evaluation. In the past, decisions as to program size and implementation had to be made without the benefit of all available information. The new procedures should increase the amount and quality of information available to the decision maker in planning and evaluating crop destruction activities. More information and analysis will presumably still be required, but the new procedures should offer substantial improvements in themselves.

Since crop destruction is only one of the means of denying food to the enemy, however, the appropriate size of the program will to some extent be a function of its relative effectiveness with respect to other food denial activities. This, however, can probably only be determined in the context of an overall review of the food denial effort.

SECTION C: PSYCHOLOGICAL WARFARE SUPPORT PLANNING

I. RECOMMENDATIONS

A. Effective psyops for the herbicide program has not been provided. MACV and JUSPAO should therefore make a concerted effort in cooperation with the GVN psyops officials to correct this shortcoming, utilizing our combined resources as required.

B. Psyops directives should be reviewed and brought into conformity with the policies and procedures proposed in this report.

C. There should be two psyops programs in support of herbicide operations: (1) a continuing low-key educational program, (2) the development and execution of psyops campaigns geared directly into specific herbicide projects.

D. Nation-wide campaigns should be avoided. Psyops should be concentrated on those areas where public disaffection is evident or potential. The population of enemy-controlled or contested areas should not, however, be neglected.

II. SUMMARY OF FINDINGS

A. The herbicide issue does not loom large at present. It carries with it, however, a strong potential for trouble due to its emotional content.

B. Although the psychological costs of the program have not been serious or unmanageable, the psyops support to the program has not been adequate. The primary problem appears to be the failure to execute the prepared psyops plans.

C. The present psyops policy guidelines require review.

D. Psyops personnel at the provincial level are often unaware of the herbicide program and its implications.

E. The VC are active in exploiting our vulnerability in this field; and the population in the affected areas is receptive to their distortions.

F. A responsive indemnification program would help minimize the psychological costs of the herbicide program.

III. ANALYSIS OF PSYCHOLOGICAL WARFARE SUPPORT PLANNING

In the context of the total war effort in the military, political, economic, social and psychological spheres, the present psywar/psyops problems in the herbicide program are of comparatively minor significance either in South Vietnam or abroad. (III Corps, where the majority of defoliation projects have been carried out, is an exception.) Nevertheless, the issues involved have high emotional content, and thus are potentially hazardous within specific audiences. Within South Vietnam, such audiences include those whose livelihood is affected, those susceptible to the natural misgivings of a rural community toward a deliberate program of destruction of living, productive plants and those susceptible to VC-inspired distortions of the side-effects of herbicide use. Abroad, and particularly in the United States, the audiences include scientists who are sincerely concerned about the long-term effects of defoliation upon the ecology of the country, laymen who are concerned about any destructive aspects of war, and those who welcome another club with which to belabor the US Government.

A. Problems by Area

South Vietnam

According to the 1967 Nationwide Hamlet Survey, in secure hamlets herbicide measures are far from uppermost among villager grievances. (Attitudes of people living in enemy-controlled or contested areas, however, are likely to be more critical.) Nationwide, the spraying of fruit trees and crops is mentioned by about one per cent of the rural population as being something that should not be done. However, objective data are rare and contradictory, and "informed" opinions range from minimization of the public impact to the view that the herbicide issue is of very high priority. In what is perhaps the middle ground, it is reported that many people are willing to accept herbicide losses as unavoidable in the war, and that they are open to persuasion that a reduction in VC activity has resulted.

Reports indicate that III CTZ is the area of greatest concern. Although the hamlet survey indicated that only 5% of the population included spraying as one of their grievances, other opinion surveys rank the issue of defoliation as very high in discontent. Some US officials gave top priority to the problem in III CTZ, although they also said that if timely indemnification payments were to be made, the problem would disappear. Significant in an assessment of the potential impact is the report that in the election campaign of 1967, 12 candidates in III CTZ are said to have included the herbicide question among their political issues, and several of these candidates won seats in the national legislature. The issue became a subject of scheduled joint hearings of the Upper House committees on agriculture and defense, focusing on compensation procedures and on criteria for conducting defoliation operations.

The VC have exploited the issue successfully in many places. It lends itself to rumor-mongering and other means used by Communist agit-prop teams. In addition to aggravating the dislike and distrust engendered by the herbicide operations themselves, the VC have embroidered the issue by attributing all manner of disease of man, plant or beast to the employment of chemicals.

The United States

Media and public have shown relatively little interest in herbicide operations. The press has confined itself to factual news items of protests by scientists, replies by government officials, and routine Department of Defense announcements, plus features generated from these items. Editorial comment has been rare, but is generally critical or questioning. Radio and television coverage has been infrequent.

The apathy of the public has been so far unaffected by the protests of some scientists. However, the linking of herbicide with chemical warfare, as has been done, reveals the inherently explosive nature of the attitudinal problem.

It would seem that the need in the United States is for a clear-cut delineation between herbicide and other chemical programs, coupled as much as possible with factual data on objectives, methods, and results of the former.

B. Present Psyops Support Activities

All herbicide projects must include a psyops plan according to present procedures. Approval of projects, however, is not contingent upon actual execution of previous plans. As far as can be determined, these plans generally have not been executed.

In addition there is a lack of background material on the herbicide program in general, which has led to false claims about its effect on vegetation as well human and animal life. Furthermore a less than fully responsive indemnification program has not properly served to minimize the psychological costs of the herbicide program.

C. Present Needs

In the execution of policy, psychological operations must be concentrated in those areas — both secure and non-secure — in which herbicide missions are carried out. A nationwide campaign would unduly advertise the herbicide program; but scanting our psyops action in affected areas unnecessarily leaves a vulnerability undefended. It should be emphasized that the population in the VC-controlled, or contested areas should not be ignored, in a spirit of defeatism. They constitute an important audience as pacification and nationwide political development advance.

The psyops support program must have two aspects, to be carried on as appropriate. The first is a low-key, ongoing campaign of education in those areas where the herbicide programs present a public opinion problem. This could be done under the supervision of the provincial psyops committee, using radio, press and other appropriate media. The second aspect must be geared directly into each defoliation or crop destruction project, following on the heels of a particular mission, or preceding it when feasible. In order to ensure its execution, this must be the responsibility of provincial officials who must have specific committments and sufficient assurance for psyops support before concurring in a project.

SECTION D: REFUGEE SUPPORT PLANNING

I. RECOMMENDATIONS

A. The new procedures outlined in Section G on Program Planning and Procedures should be instituted. They will involve refugee specialists in the preparation and post-audit of herbicide projects to a greater extent than before, help ensure better care of whatever refugees may be generated, and provide improved information for Saigon-level policy and program officials.

B. Preparation of refugee support plans will be required only in those instances where refugee generation is anticipated.

C. More information should be obtained about the conditions of life of highland residents and others who have been under enemy control for several years, stressing information about the effects of crop destruction and other food denial efforts upon them.

II. SUMMARY OF FINDINGS

A. Herbicide operations alone have not generated a significant number of registered refugees.

B. Although the highland residents have been adversely affected by crop destruction operations, with some exceptions their food supply has not been so seriously impaired as to cause many of them to come over to GVN control.

C. Refugee support contingency plans prepared for herbicide projects in the past have largely been a pro forma response to a standing program requirement.

D. Although the generation of refugees by herbicide has been minimal, there is a need for a continuing review of all projects from this standpoint. In a great many instances, province and Corps-level refugee officials have not been consulted sufficiently in the preparation of herbicide projects. Introduction of the new procedures outlined in Section G will eliminate this deficiency.

III. ANALYSIS OF REFUGEE SUPPORT PLANNING

A. Purpose of Refugee Support Plans

Present herbicide program guidelines require that a refugee support contingency plan must be prepared for each herbicide project. This plan is supposed to be based upon a Province-level assessment of whether the project will have a sufficiently serious effect upon the food supply of people in the target area that they could be expected to move out and apply to the GVN for food, shelter and general assistance.

The refugee support plan requirement is a feature of the herbicide program which probably reflects the early uncertainty on the part of policy makers as to whether the program would generate a significant number of refugees. The requirements were built into the program as a safeguard to ensure that refugees who might be generated would be cared for.

B. Preparation and Review of Plans

The care of refugees is a GVN responsibility. The program is carried out with the close collaboration and assistance of the Refugee Division of CORDS. Anticipation of refugees as a consequence of military operations and the preparation of contingency plans for their care is the responsibility of local GVN officials. The Province Chief is assisted in this work by a Refugee Chief from the GVN Ministry of Social Welfare and Refugees.

C. Do Herbicide Operations Generate Refugees?

According to the testimony of CORDS Refugee Division officials as well as the experience of other Mission officials who have had experience with the herbicide program, there is little evidence to indicate that herbicide operations have caused any significant refugee outflow during the war in South Vietnam. A few refugees, when questioned, have said that they left their homes because of herbicide operations. They represent only an extremely small portion of all refugees, however.

According to Refugee Division officials, it has been difficult to ascertain, in any definitive way, why people become refugees. Combinations of the following reasons, however, have been cited in interview surveys: (1) combat operations or the threat of them, (2) bombing, (3) VC pressures, e.g., taxes and recruitment, (4) marginal and uncertain economic conditions. People leave areas that have been significantly subjected to general military operations. Presumably, this would be true whether or not herbicide operations had taken place. Some refugees are reported to have left their homes upon seeing spray missions in the area. They considered this signified other impending military operations. The latter, rather than the herbicide missions, was the real source of their anxiety.

On the other hand, there have been military operations in which it was intended that the population in the area involved would be obliged to move out. Herbicide operations in these instances are but one aspect of the overall battle plan, however, and are not alone responsible for the refugee outflow.

D. The Special Problem of the Montagnards

We do not know very much about conditions of residents living in highland areas that have been under enemy control for several years. Similarly, we have only scanty information about the actual effects of crop destruction operations upon them. Yet most of the crop destruction missions are flown in these areas.

As pointed out in Section D (Crop Destruction), although crop destruction operations are specifically designed to weaken the military position of the enemy, they have a heavy impact upon the civilian population living in the area, i.e., in the present instance, primarily the Montagnards. The enemy can be assumed to exercise immediate or ultimate control over most food production in areas that it controls. The analysis in Section B concludes that approximately 90-95% of the crops destroyed in enemy-controlled areas is grown by the civil population. The Montagnard is in the unenviable position of possibly having some of his food crop destroyed by herbicide operations or perhaps having it seized by the VC/NVA. Other commercial sources of food are rarely available to him.

SECTION E: THE GVN CLAIMS PROGRAM

I. RECOMMENDATIONS

A. The Military Civil Assistance Program (MILCAP) procedures should be simplified in order to permit up to $VN60,000 to be paid on a valid claim within one month of filing. This will expedite the payment of 80% of all herbicide claims.

B. A concerted educational effort must be made to increase the advisors' knowledge, especially at province level, regarding the policies and procedures of MILCAP so that they can be implemented more effectively.

C. The full-time services of a qualified plant pathologist should be obtained to assist in the investigation of defoliation damage claims and to raise the level of awareness on the part of program personnel in the field about the biological effects of defoliants on plant life.

II. SUMMARY OF FINDINGS

A. <u>This Program is Operative Only in Secure and in Some Contested Areas.</u>

B. <u>Solatium Not Indemnification</u>. MILCAP provides only for solatium payments as opposed to full or reasonable indemnification for damages.

C. <u>Comparatively Small Amount Paid Out in 1967</u>. In 1967 $VN35,380,000 were paid to 5,853 claimants for herbicide damage as opposed to $VN381,004,000 paid to 16,013 claimants for other war damage.

D. <u>Administration is Not Efficient</u>. The administration of the claims program is complex and time-consuming. By way of example, each claim requires seven or more supporting documents which must be submitted in eight copies.

E. <u>Implementation is Not Uniform</u>. Application of policies and procedures varies widely from place to place largely because it is dependent on the personal interpretation of the province and district chiefs.

F. Knowledge of Herbicide Effects Is Spotty. Farmers and US and GVN officials do not know enough about the biological effects of herbicides.

G. Administrative Irregularities Exist. There is evidence that disbursement of MILCAP funds may be subject to administrative irregularities.

III. ANALYSIS OF THE GVN CLAIMS PROGRAM

A. The Financial Magnitude of the Program is Presently Small.

Calendar year 1967 was the first year in which herbicide damage claims have been separately identified in the GVN Defense Budget. In that year $35,380,000 were paid to 5,848 claimants as opposed to $VN381,004,000 paid to 16,013 claimants for other war damage. It should be noted that $VN14,000,000 of the $VN35,380,000 were paid out in the month of December and represent a clean-up of outstanding claims that were submitted under procedures in effect prior to 6 September 1967, the effective date of the current procedures.

Herbicide damage claims are handled by the RVNAF Political Warfare Department as a sub-category under general war damage claims. The change to a new procedure required the determination of a policy which would expeditiously dispose of outstanding claims from the older programs. The policy devised included the following action: rejection of all claims dating from 1964; settlement of 1965 claims (processed on or before March 1967) at 50% of the approved amount; settlement of the first half year of 1966 claims at 50% of the approved amount. Claims submitted for the second half year of 1966 and in 1967 before 6 September were to be settled in full under the former MILCAP criteria. If existing MILCAP procedures are streamlined as recommended above and the farmers become more aware of them, the financial magnitude of the program will increase.

B. Computation of Payment

Under the present system, payment is made on a solatium basis, that is, only a portion of assessed amount of damage is to be paid. As an example, province may approve claims assessed up to $VN100,000 but must compute the payment as follows: 100% of the first $VN20,000 and 50% of the difference between $VN20,000 and $VN100,000. Thus the claimant would receive only $VN60,000 of a claim assessed at $VN100,000. Over 80% of the farmers in Vietnam have under 4 hectares of land. The average productive value of a hectare under rice cultivation is $VN24,000, thus 80% or more of the farmers would be submitting claims of $VN100,000 or less.

C. Policies and Procedures Are Not Adequately Executed.

The Military Civil Assistance Program is also called the "Plan for the Promotion of Friendship between the People and the Army." Procedures contained in the plan were designed to reduce the opportunities for administrative irregularities, and to shorten the delays encountered in the pre-6 September 1967 system. These goals were to be accomplished by reducing the value of a claim that could be approved at province level, requiring payment of check instead of cash, and by setting limitations on the processing time at each level.

Some province and district chiefs have made arbitrary decisions as to who may or may not submit a claim. These decisions have reflected a lack of knowledge of the claim policies and procedures and may be viewed as lack of concern for the welfare of the people. Opportunities for administrative irregularities still exist which lead to charges of the sale of claims forms, the payment of bribes for processing and/or favorable consideration of claims, the charging of a fee to have the payment check cashed, and collusion as to the amount to be paid.

Interviews with US advisors in the field indicate that their knowledge of MILCAP procedures is spotty and insufficient for them to advise their counterparts in this area.

D. The System Is Not Sufficiently Responsive to the Claimant

The claimant must acquire many forms and supporting documents and prepare them in eight copies. He must have some of them verified at village level, some at district, and others at province level. The procedures allow for 172 days cumulative processing time through the various steps. There are indications that this time is being exceeded.

For the most part, the claims forms must be locally reproduced. Since whole hamlets, or possibly villages, are often affected at the same time, the process imposes an unmanageable burden on the limited administrative resources of the affected provinces and districts.

Administrative complexity, authorized processing times, and irregular practices make this system unresponsive to the needs of farmers who have sustained damage to their crops.

F. Assessment

An effective indemnification program is necessary whether on a reasonable compensation or solatium basis. It is a very tangible way by which the government's concern for the people can be demonstrated. It must be simple, however, and require a minimum of administrative effort on the part of the claimant. It must be rapid and responsive enough to allow him to replant his crops as quickly as possible without personal, out-of-pocket expense.

The principal objective of the claims program should be to promote good relations between the GVN and the people.

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Section F: AN ASSESSMENT OF ECOLOGICAL CONSEQUENCES OF THE DEFOLIATION PROGRAM IN SOUTH VIETNAM

NOTE: The following paper was prepared by Fred H. Tschirley, ecological consultant to the Herbicide Policy Review Committee. Mr. Tschirley is an ecologist with the US Department of Agriculture whose expert services were made available to the Committee, at its request, during the period of Mr. Tschirley's special field trip to South Vietnam from mid-March to mid-April 1968.

I. RECOMMENDATIONS

A. The desirability of ecologic research after the war ends cannot be over-emphasized. The research should be administered through an institution that will provide continuity and breadth for the research program. If the war ends soon, the opportunity of establishing ecologic research under the International Biological Program should be explored.

B. Continuing assessment of the defoliation program as it affects forestry and watershed values should be made by the Forestry Branch of USAID. Ground observations are most desirable, but aerial surveys during various seasons of the year will contribute much good information.

C. From an ecologic point of view, the concept of defoliating large area targets in strips or in a checkerboard pattern has great merit. Undefoliated areas would serve as a seed source for regeneration and as habitat for wildlife.

II. SUMMARY OF FINDINGS

A. No Effect on Precipitation

Defoliation has no measurable effect on atmospheric moisture. It would thus have no effect on precipitation.

B. Some Possible Laterization

Laterization of soil is a long-term process which is speeded up when soil is exposed to direct solar radiation and wind. Tschirley does not believe that laterization has been hastened in Vietnam because defoliation does not result in bare soil. Laterization could be speeded up, however, around Allied base camps where the soil is kept free of any vegetation.

C. Some Erosion Around Base Camps

Tschirley was not able to examine defoliated forests in mountainous terrain for evidence of accelerated erosion. He did not observe any such evidence, however, from the air. He did see gully and sheet erosion around Allied base camps where vegetation has been kept to a minimum.

D. Effect on Water Table Not Assessed

Due to lack of time and easy access to the countryside, Tschirley was not able to assess whether defoliation may have affected the level of the water table. This could take place, he believes.

E. Adverse Effect on the Soil System Unlikely

Micro-organisms are an essential feature in the soil system. Herbicides that kill the micro-organisms would have a severe effect on the soil ecology. Orange and white herbicides should not, however, have any detrimental effect on microbial populations in the soil.

F. Regeneration of Mangrove at Least 20 Years

Twenty years have been estimated as a normal time frame for the regeneration of mangrove. Tschirley believes this same time table would apply to areas in South Vietnam where mangrove trees have been killed by herbicides. He bases this opinion upon aerial observation of new mangrove growth extending into an area along the Ong Doc River that had been defoliated in 1962. Tschirley considers that 20 years is a conservative estimate of the time needed for the restoration of mangrove forests.

G. No Apparent Effect on Fish

Statistics show that there has been a steady increase in the fish catch between 1965 and 1967. Tschirley believes this indicates that herbicides have not seriously disturbed the aquatic food chain.

H. Some Reduction in Bird Life, in Mangrove Swamps

Tschirley believes there probably has been some reduction in the bird population of mangrove swamps that have been heavily treated with herbicides. There still remains, however, more untreated than treated mangrove.

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I. Some Effect on Invertebrates in Mangrove Swamps

The population of invertebrates surely has also been reduced in the mangrove forests, although it is unlikely that any have been reduced to the point of extinction. Again, there are still many areas of untreated mangrove forests.

J. Effect on Semideciduous Forests

The ecological consequences of defoliation would be expected to be most evident in War Zones C and D. Tschirley found it difficult to assess the ecological effects of the war on these Zones and on the semideciduous forests of South Vietnam, in general. There are approximately 50,150 km^2 of such forests of which 8,140 km^2 have been treated, i.e., 16.2% of the total semideciduous forests. Based upon extrapolations from other data and his own experiences in tropical forests elsewhere, Tschirley considers that the defoliation by herbicides of South Vietnam's semideciduous forests would be about the same as obtained elsewhere. The forests in South Vietnam, however, are sometimes treated two and three times. Tschirley infers that the ecological impact would become progressively greater with each succeeding treatment. Initial defoliation will kill some trees, but not a high percentage of them. Successive treatments will increase the percentage of kills.

K. Regeneration of Forests.

Data on regeneration of forests is scanty, and particularly so with respect of South Vietnam. The principal ecological damage imposed by repeated treatments is that saplings and poles present in the lower story, and the seedlings, may be killed. This will create problems for natural reseeding. The forests being defoliated in South Vietnam are secondary, not primary forests. Less time is needed for the establishment of a secondary forest.

L. Site Invasion by Bamboo Could Retard Regeneration

The greatest damage from repeated defoliation is that the affected areas will be invaded by bamboo. This will surely cause a retardation in the successional progression. It is difficult to eradicate bamboo once it has established itself. The time scale for succession in the semideciduous forests of South Vietnam is not known. Single treatment should not cause severe successional problems. Multiple treatments will probably cause site dominance by bamboo.

M. Effect on Animal Life Not Known

The effect on animal life in Vietnam is not known. According to Tschirley, the greater the number of treatments, the greater will be the damage to animal populations. Tschirley believes that it is clearly possible that such rare bovines as the kouprey, gaur and banteng have been eliminated from the defoliated areas in War Zones C and D. Other military activities, however, have probably had a far greater impact.

III. AN ASSESSMENT OF ECOLOGICAL CONSEQUENCES OF THE DEFOLIATION PROGRAM IN VIETNAM

Fred H. Tschirley
Saigon
April 12, 1968

INTRODUCTION

The science of ecology may be simply defined as a study of the inter-relationships among biological organisms and their influence on, or their reaction to the environment. Ecologic investigations may take the form of studying the response of a single species to the environment (autecology), or the interactions of a community of species (synecology). More recently the study of ecology has been approached on an ecosystem basis which involves the capture and storage of radiant energy by green plants and its subsequent transformation and reduction by the biological and environmental systems. For those who want a more detailed description of the interactions in an ecosystem, I would suggest Chapter IX of the NRI Report (House, et al, 1967) because it is locally available. It is important to remember that the ecosystem involves not only the biological organisms, but also all aspects of the physical environment in which those organisms live.

I have stressed the ecosystem approach to ecologic thought because it is a modern concept that has evolved in response to needs that were not being met by the more classical concepts. Despite the interpretive excellence of an ecosystem analysis, it will not be used in this report because the quantitative data needed for such an analysis are not available. But I would hope the reader is aware that an effect on one element of an ecosystem cannot be isolated. That effect will in turn be an influencing factor on one or several other aspects of the ecosystem. The possible effects on the defoliation program in Vietnam on biota, soils, and climate will be discussed separately. Synthesis of the various parts into a fully interpretable whole is not possible with the current state of knowledge. In addition, there are certain specific questions of importance about which a responsible judgement cannot be given simply because there are no data available on which to base a judgement.

The discussion of the possible ecologic consequences of the defoliation program in Vietnam will be based on published literature, prior experience in the ecology of the American tropics, many years of experience in the response of woody plants to herbicides, and aerial and ground surveys of selected areas in Vietnam.

The mangrove vegetational complex was viewed from a helicopter overflight of the Rung Sat Special Zone (RSSZ) on March 28, 1968. Defoliation of the mangrove in the RSSZ was started in 1966, but most of the defoliation flights were made after June, 1967. A mangrove area on the Cng Doc River that had been sprayed in 1962 was viewed from a C-123 overflight on April 7, 1968.

Semideciduous forest in War Zones C and D were surveyed from a C-123 on March 23, 1968. A more detailed aerial survey was made on March 27, 1968 from a high-wing Porter aircraft. Helicopter flights were also made over many of the same areas, and some new areas, in the course of being transported to and from specific areas that were surveyed on the ground.

Ground surveys were made from Special Forces Camps located at Thien Ngon, Katum, Tong le Chon, and Bu Dop from March 29 to April 1, 1968, inclusive. Several hours were spent in the forest at each location to assess defoliation, refoliation, successional patterns, and to get a feel for the possible effects of the defoliation on wildlife. In addition to the personal observations, men at the camps were questioned regarding the effect of defoliation on their operation, their impressions about the relative difficulty of human movement in the forest (a rough measure of the density and composition of the ground story vegetation), and sightings they had made of wildlife.

Aerial and ground surveys were concentrated in War Zones C and D because large areas hade been sprayed with defoliant in those zones. Portions of C and D Zones have been sprayed 2 and 3 times. There are no other areas in Vietnam where such large blocks have been treated or that have been treated so intensively (an exception to that statement would be the DMZ) Thus, the ecological consequences of the defoliation program would be expected to be most evident and most easily defined in those areas. War Zones C and D were also accessible for aerial surveys and the location of Special Forces Camps afforded the opportunity of close observation from the ground.

A concluding introductory remark is necessary. This report can in no sense be considered a complete, authoritative assessment of the ecologic effects resulting from defoliation of forest canopy. The conclusions reached are judgements based on prior experience and the necessarily few observations that were possible in an area of war activity within the time frame demanded.

A. Effect of Defoliation on Climate

Not uncommonly one hears that large-scale modification of vegetation (forest to grassland, for example) or the vegetative denudation of an area will cause a change of climate, particularly the amount of rainfall. The theory behind this statement is that as forest is converted to grassland or the soil is bared of vegetation, the evapo-transpirational surface is reduced and thus there is less moisture released to the atmosphere for subsequent precipitation. The fallacy of the theory is readily apparent when one considers the vast scale of atmospheric air flow, with the moisture it contains, and the relatively insignificant reduction in moisture that might be caused by reduced evapo-transpiration. It is instructive to make some simple calculations that point out the fallacy of the theory more explicitly.

By applying the reasoning used for an arid area (McDonald, 1962), let us apply some simple calculations to a forested area that is 100 km on a side. If we assume, conservatively, that the total moisture in a vertical column of the atmosphere above our area has a depth of 3 cm and the air mass is moving over the area at a rate of 5 km per hr, then we can calculate that moisture is passing over our area at a rate of 4.17×10^9 gm per second. Now let us further assume that our hypothetical forest has been entirely denuded of vegetation and we reasoned that it may have been contributing 10 percent to the total atmospheric moisture. In other words, we expect a 10 percent decrease of rainfall. That would be 4.17×10^8 gm per second that would have been contributed by evapo-transpiration from our forest. In other words, our hypothetical forest would have to be contributing moisture to the atmosphere at a rate of 1.1×10^5 gallons per second. Clearly, such a figure is unreasonable. If we carry this calculation further and consider one tree with its branches in the upper or middle canopy for each 10 m^2, then evapo-transpiration from each 10 m^2 area would have to be 417 ml per second. That is far beyond the measurements that have been made of the most profligate water users, such as salt cedar (*Tamarix pentandra*).

Looking at the problem in another way, the work of Chmak and Pratt (1956) lends itself to this discussion. They made measurements of dew point over and downwind from a desert irrigation project covering some 100,000 acres near Yuma, Arizona (annual precipitation about 3 in). Despite application of annual totals of from 5 to 10 ft of irrigation water on this area extending some 20 miles parallel to prevailing winds for the summer months studied, all influence of the irrigated fields upon crop-level dew points became immeasurably small only 100 ft to the lee of the downwind edge of the entire area. And at 12 ft above the crop level, dew points were not measurably increased even at points inside the irrigated acreage. These measurements were made under midday conditions in July and August when monthly totals of irrigation varied between about 0.7 and 1.5 ft of applied water. These measurements show impressively the small effect that artificial measures have on atmospheric moisture content.

The conclusion must be that defoliation, or even denudation, has no measurable effect on atmospheric moisture and thus would have no effect on precipitation.

Another point that refutes the evapo-transpiration:precipitation theory is that water molecules are not motionless in the atmosphere. Sutcliffe (1956) estimated that the average time between a water molecule's evaporation into and its precipitation from the atmosphere to be about 10 days. Thus, from mean wind speed considerations, the average water molecule must drift many hundreds of miles before it is precipitated.

Extensive defoliation would be expected to change temperature patterns through a forest profile simply because there would be less shielding of direct solar radiation. In addition, the average wind speed would be greater in a defoliated than in an undefoliated forest. These two factors would probably not have a great effect on higher plants and animals, but might temporarily affect lower life forms that are more dependant on specific micro-climatic niches for growth and survival.

B. Effect of Defoliation on Soils

One of the principal fears about exposing soil in the tropics is the possibility of increased laterization. The term laterite generally refers to an indurated concretionary deposit, high in iron or aluminum oxide content, which has formed in place by the weathering of rocks. True laterite hardens irreversibly; it will not become soft upon wetting. Laterite has been found to be best developed when the following conditions exist:

1. The climate must have high rainfall and uniformly high temperatures.

2. The topography must have been fairly gentle, peneplain in nature.

3. A well drained soil must have been present. This is usually an alluvial soil, but soils high in iron content may be an exception.

4. There must have been a uniformly fluctuating water table which had a definite high level during the monsoon and a definite low level during the dry season.

5. Stable geological conditions must have existed for a long time.

Only about 30 percent of the soils of Vietnam have a potential for laterization (Tarenik and Cording, 1967). Many of the red soils of Vietnam, which are often confused with laterite, dry out and become hard, but soften again upon wetting. The soft doughy laterite, which hardens to a rock-like material upon exposure to alternate wetting and drying is not found in significant amounts in Vietnam.

Two kinds of laterite are found in Vietnam. Worm-hole laterite is generally consolidated and occurs as massive beds, commonly at the bottom of a 1 to 30 ft layer of well drained soil. In some cases it may be a hard crust right at the surface of the ground. It is red to brown in color, and has a slaggy appearance due to numerous holes that are often interconnecting and thus facilitate the passage of ground water. Worm-hole laterite has been called "ground water laterite" by earlier researchers and "Bien Hoa Stone" by the local people of Vietnam. Worm-hole laterite occurs throughout most of the Mekong Terrace region, in soils of both forested and cultivated areas.

Pellet laterite is unconsolidated and occurs as small pellet-like concretions in an iron- or aluminum-rich soil. The hard concretions are usually surrounded by fine grained material which is generally clayey when moist. The coarser particles in this fine grained material are commonly quartz sand which is iron stained. Pellet laterite occurs on the iron-rich basalt plateau soils of the Mekong Terrace, the basalt plateau of Ban Me Thuot, the extreme western edge of the high plateau west of Pleiku, and in a small area around Quang Ngai. Pellet laterite has been observed forming on the metamorphic rocks near Bong Son and on some of the rocks near Qui Nhon. It is likely that worm-hole laterite and pellet laterite could occur in the Northeastern Coastlands, but this has not been substantiated by field studies.

Under natural conditions laterization is a long term process. The process is speeded up when soil is exposed to direct solar radiation and wind. I do not find it reasonable that the defoliation program in Vietnam would hasten the laterization process significantly because bare soil does not result from defoliation. It is possible, however, that laterization will be speeded up around Base and Special Forces Camps where the soil is maintained free of vegetation.

A description of the major soils of Vietnam (including a map) in relation to their agricultural use was prepared by Moorman (1961).

Erosion as a consequence of defoliation must also be discussed briefly. The degree of erosion that will occur depends on soil type, topography, relative degree of vegetative cover, and rainfall intensity. In general erosion will be greatest on steep slopes of bare soil, decreasing as slope decreases and vegetation becomes more dense. But dense vegetation is not a guarantee that erosion will not occur. I have seen for example, a solid 3 to 4 inch sheet of water flowing down a slope under a dense tropical rain forest. It has not been possible to critically examine defoliated forest in mountainous terrain for evidence of accelerated erosion. I have failed to detect such evidence during aerial overflights of defoliated areas. Gully and sheet erosion have been noted around camps where there was little or no vegetation.

The possibility of flooding or of changes in the water table as a result of defoliation are subjects that need careful consideration. The replacement of woody vegetation with grass in the Southwestern U.S. has resulted in perennial flow of streams that were only intermittent before and also in the flow of springs that had been dry for many years. There are cases in the U.S. Lake States where the rise of an already high water table after logging created a marshy condition that was unsuitable for desireable timber species. I mention these points because they have occurred elsewhere and could conceivably occur in Vietnam. But I do not know the local situation well enough to make a reasonable assessment of the probability of their occurring here.

Micro-organisms are an essential feature in the soil system. A herbicide that killed the micro-organisms would have a severe effect on the soil ecology. What are the possibilities of Orange and White destroying the microbial population in the soil?

The constituents of Orange are 2,4-D (2,4-dichlorophenoxyacetic acid) and 2,4,5-T (2,4,5-trichlorophenoxyacetic acid). The constituents of White are 2,4-D and picloram (4-amino-3,5,6-trichloropicolinic acid). There seems to be no danger that any of the three chemicals will kill micro-organisms. Actually, numbers of soil micro-organisms capable of inactivating 2,4-D apparently increase when 2,4-D is present in the soil. Thus, repeat applications of 2,4-D were less persistent in soil than the initial application (Sheets and Danielson, 1960). I do not have similar information here for 2,4,5-T, but I remember no published literature suggesting that its effect on micro-organisms is significantly different from 2,4-D. Picloram did not destroy soil micro-organisms, but neither was the microbial population enriched as a result of picloram application. Thus, picloram cannot be considered a good energy source for micro-organisms. The decomposition of picloram was an incidental process in the breakdown of soil organic matter, requiring the loss of approximately 10,000 to 100,000 lbs of organic matter per lb of herbicide (Youngson, et al, 1967).

Orange and white should have no detrimental effect on microbial populations in soil.

C. Effect of Defoliation on Plant and Animal Populations

Not all plant species react similarly to herbicides. The differential susceptibility may be a function of time of treatment, nature of the leaf surface, variable capacity for absorption and translocation of the herbicide, biochemistry of the plant, or the nature of the herbicide itself. Thus, in any vegetative type, one would expect that some species would be killed easily; others with great difficulty. The mangrove association seems to be an exception to the general rule in that most, if not all, of the mangrove species are susceptible to the herbicides being used in Vietnam. For that reason, and because the mangrove association presents a different set of ecological considerations than does the semideciduous forest, each will be discussed separately.

1. Mangrove Forest

Botanical considerations - The mangrove association is relatively simple floristically. The principal species are listed below.

Species	Family	Local Name
Avicennia marina	Verbenaceae	Mam Den
Avicennia intermedia	"	Mam Trang
Rhizophora conjugata	Rhizophoraceae	Duoc
Bruguiera parviflora	"	Vet Tach
Bruguiera gymnorhiza	"	Vet Du
Ceriops divers	"	Da
Nipa fruticans	Palmae	(Water palm)
Phoenix spp.	"	(Date palm)
Lumnitzera coccinea	Combretaceae	Coc
Sonneratia acida	Punicaceae	Ban
Melaleuca leucadendron	Myrtaceae	Tram
Excoecaria agallocha	Euphorbiaceae	Gia
Carapa obovata	Meliaceae	Su
Achronychia laurifolia	Rutaceae	Bibai

Other plant species are represented in the mangrove type, but they are of lesser importance.

Susceptibility to herbicides - The mangrove species seem to be almost uniformly susceptible to Orange and White, the herbicides used for their control in Vietnam. One species in the RSSZ was not defoliated, but it did not constitute a higher percentage of the composition. Undefoliated trees were not observed in An Xuyen Province. An area on both sides of the Ong Doc River, which was sprayed in 1962, was of particular interest. The treated area was still plainly visible.

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Thus, one must assume that the trees were not simply defoliated, but were killed.

Successional aspects - The mangrove type in RVN occurs on about 2,800 km^2 (McKinley, 1957). According to McKinley, *Avicennia marina* is the pioneer species of the mangrove type, colonizing on the clay accretion areas at the sea face. At the 5th and 6th year *Rhizophora conjugata*, *Bruguiera parviflora*, and *Ceriops divers* will develop where there has been partial stabilization of the soil. About the 29th year *Rhizophora* and *Bruguiera* will dominate the site. From that point on, further succession depends on the degree of silting and the consequent decrease of water circulation. As organic matter accumulates, conditions are created for the advent of other species of the mangrove complex. The final stage in the mangrove type is the cajeput (*Melaleuca leucadendron*), found on the highest, most stable soil above high tide.

Seed production is annual and abundant to prolific, with seeds viviparous or otherwise, of high germinability and capable of remaining viable for long periods (Anonymous, 1958a). Germination and rooting are usually rapid and successful. In some locations, when the seeds are able to settle as a result of favorable water conditions, natural regeneration may become successfully established in less than a year. The movement of the water, however, may not only bring in seeds but may also carry them away before they can take root.

The most serious animal pest is the crab, which may entirely prevent regeneration by attacks on seedlings (Noakes, 1957). In Malaya 2 species of *Acrostichum* (a fern) may hinder the establishment of water-borne seedlings. The fern grows and spreads rapidly when the tree cover is removed. McKinley (1957) mentions two (Choai, a creeping form; [illegible], an erect form) as occurring in the climax mangrove, but does not comment on their possible interference with regeneration.

Ecologic considerations - According to the timetable discussed by McKinley, about [illegible] years are required for the establishment of a dominant *Rhizophora-Bruguiera* association. That timetable was established for a situation in which newly silted areas were colonized by *Avicennia* and then replaced by *Rhizophora-Bruguiera*. But it is not unreasonable to suspect that the same timetable would apply to areas in which the trees had been killed by herbicides. Dead trees do not hold soil as well as do living trees. The amount of soil removed would be dependant on the rapidity of tidal recession, which is unknown to me. The greater amount of soil removed, the greater will be the time required for regeneration of a mangrove stand similar to the original.

The 20 yr timetable for regeneration of mangrove is supported by aerial observations of the 1962 treatments along the Ong Doc River. And please remember that this interpretation is based only on an aerial survey from about 2000 ft. Regeneration of mangrove was apparent as fingers extending into the treated area, but in no case did I observe those fingers extending the entire breadth of the treated area. I assume that seedlings and juveniles were present in a front beyond the trees that were discernable, but I have no proof.

Six years have passed since treatment and trees of the colonizing species are not yet discernable from 2000 ft. on all the treated area. Thus, extrapolating the information provided by McKinley, 20 years is a conservative estimate of the time needed for this forest to return to its original condition.

Little information is available regarding the effect of killing mangrove on animal populations. In that regard, I have considered the food chain among aquatic organisms. Although it has not been possible to obtain information on the many links in the food chain, phytophagous and carnivorous fish would be at the top of the food chain. Disruption of lower links in the chain would be reflected in reduced fish populations.

Information on fish populations is based on fish catch statistics provided by the Fisheries Branch of USAID. The total catch, in metric tons, for the past three years is given below.

Year	Fresh water	Marine	Cuttlefish, molluscs, shrimp, crabs, etc.	Total
1965	57,000	289,000	29,000	375,000
1966	64,710	287,450	28,340	380,500
1967	54,300	324,700	31,700	379,700

In general there has been a steadily increasing fish catch. The drop for fresh water fish in 1967 was at first a cause for concern. But Mr. Thuong, Assistant Chief of Inland Fisheries, explained that the reduction was due to an absence of flooding in the Mekong Delta in 1967. When flooding does occur, fish are trapped in rice paddies and fishermen have no trouble catching them.

The fish catch statistics give a strong indication that the aquatic food chain has not been seriously disturbed.

Birds depending on the mangrove for nesting, food, and cover have, of course, been affected. They cannot survive when the environment has been altered so drastically. But there is still more untreated than treated mangrove. Unless the mangrove type was already saturated with a bird population, some of the birds would move to untreated areas. It is important to remember, however, that most bird species observe a strict territoriality. Individuals or family units will nest and search for food only within a specific area. An intruder will either be driven off or will supplant the present occupants; they will not both occupy the same area. Thus, it is reasonable to assume that there has been some reduction in bird populations. I suspect that, proportionately, the bird population reduction has been less than the area treated with herbicide.

Effects on other forms of animal life are unknown, but surely the population of invertebrates in particular has been reduced. With habitat destroyed, there could be no other conclusion. It is extremely unlikely, however, that any invertebrate species has been decimated to the point of extinction. There are still many mangrove areas in which the trees have not been killed.

The application of herbicide in strips or in a checkerboard pattern, rather than large-area treatment, would be a tremendous ecologic advantage. The trees remaining in untreated areas would provide a seed source for reforestation as well as habitat for animals and lower plant forms.

2. Semi-Deciduous Forest

RVN has a total area of 172,540 km^2, of which about 30 percent is forested (McKinley, 1957). The types of forest and their area of coverage were stated by McKinley to be:

Open forest	50,150 km^2
Flooded forest	
Mangrove	2,800
Other aquatic plants	2,000
Coniferous forest	
3-leaved pine	900
2-leaved pine	350
	56,200 km^2

Through 1967, 10,107 km^2 had been treated with defoliant (Moran, 1968). That figure does not represent the actual area because some sites have been treated two and three times, principally in War Zones C and D. Retreatment areas represent about 10 percent of the total, so the actual treated area is, in round numbers, 9,100 km^2, which represents about 16.2 percent of the total forested area in RVN.

The mangrove area treated in the RSSZ is 460 km^2 (Moran, 1968). Other treated mangrove in IV Corps probably represents about 500 km^2. Thus, approximately 960 km^2 of mangrove have been treated, leaving 8,140 km^2 for the treated area in the semideciduous forests of RVN. That represents 16.2 percent of what McKinley designates as "open forest" and I designate as semideciduous forest.

I have concentrated my efforts on War Zones C and D because large blocks have been treated and numerous areas within those blocks have received multiple treatments. Thus, the ecologic effect would be greater than in areas not treated so intensively. The area of treatment in War Zone C was 920 km^2 at the end of 1967; in War Zone D 1,920 km^2 (Moran, 1968). Another large treated area is the DMZ. But the law of "preservation of the species" took precedence over scientific curiosity and precluded a visit by me.

Botanical considerations - In keeping with my concentration on War Zones C and D, I will not attempt to characterize the forest vegetation of all RVN. There are different forest types, but, except for the pine forest, the differences are ones of degree rather than substance. My discussion of the forests in III Corps can be extrapolated to other semideciduous forests of RVN, but not to the pine forests, or to the small area of rain forest that probably exists (based on literature reviews and weather records) in a small area of NW RVN along the Laotian border.

The forests of War Zone C are, for the most part, what has been described as secondary forests with an admixture of bamboo, and semideciduous forest of *Lagerstroemia* and legumes (General Forest Map of RVN, Phan Thuong Tuu, '66). The forests of War Zone D are Moist Forest over most of the area, and semideciduous forest of *Lagerstroemia* and legumes over the remainder (ibid. above).

There are obvious differences among the three forest types to a trained botanist or ecologist. But the differences are taxonomic for the most part. Physiognomically, they are similar. In terms of ecologic considerations therefore, they will be discussed on the basis of similar successional patterns and similar time scale in which the successional patterns will occur.

The three forests are similarly characterized by having members of the family Dipterocarpaceae as dominant trees in the upper canopy. But this does not mean, necessarily, that Dipterocarps are numerically superior. Other families that are well represented include the Leguminosae, Meliaceae, Lythraceae, Guttiferae, and Sterculiaceae (personal observation; Tung, 1967; McKinley, 1957; Williams, 1965). Botanical composition, taxonomically and numerically, will vary from one location to another.

The difficulty of a botanic description of the forest may be appreciated with the knowledge that about 1500 woody species occur in RVN (McKinley, 1957). Moreover, I saw the forests at a time when identification was most difficult. Many species are normally deciduous at this time of the year; many that are normally evergreen have been defoliated by herbicides.

I must mention at this point, there could not have been a worse time to assess the ecologic impact of the defoliation program on the semideciduous forests of RVN. Impressions are most confusing. The combination of natural defoliation, defoliation by herbicides, and defoliation by the many, many fires (civilian and military caused) in War Zones C and D leave me with the helpless feeling that many factors have caused the present condition of the forests, but the relative importance of each factor cannot be properly assessed. Given enough time and accessibility to the forests for intensive study, the present confusion could be resolved. But to even attempt a careful delineation of the causative factors within a 1-month period would be presumptuous. An ecologic assessment during the middle or latter part of the rainy season would not have to contend with the confounding influences of natural defoliation and fire.

Susceptibility to herbicides - The relative susceptibility of specific species in the semideciduous forests of Vietnam is not known. In addition, the average susceptibility of the vegetative type is unknown. The best estimate I can obtain is an extrapolation of data developed in Thailand by Darrow, et al (1966) and in Puerto Rico by Tschirley, et al (1968).

Darrow's tests in Thailand were conducted in a semi-evergreen monsoon forest having an annual precipitation of about 40 inches. Two hundred twenty plant species were identified from two test sites totalling 3,400 acres, so species diversity was high. Darrow found that 2 or more gallons of purple caused effective defoliation (more than 60 to 65 percent) of the forest complex for a period of 6 to 8 or 9 months. Percentages of kill were not given, but they would have been considerably lower than for defoliation.

Tschirley, et al worked in a semi-evergreen forest in Puerto Rico having an annual precipitation of about 85 inches. Species diversity was high; 106 woody species were recorded on 2.4 acres in an area adjacent to the aerial test plots. Tschirley, et all also worked in a tropical rain forest in Puerto Rico having an annual precipitation of about 120 inches. About 88 woody species were recorded for the rain forest site. Defoliation in the semi-evergreen forest treated with 3 gallons of purple was 61 percent 6 months post treatment. In the rain forest, an equivalent rate of orange provided 66 percent defoliation 6 months post treatment and 55 percent 1 year post treatment.

Thus, the defoliation obtained in taxonomically distinct forests in opposite parts of the world was similar. It is justifiable, then, to expect that average defoliation in the semideciduous forests of Vietnam would be about the same. Actually, I would expect defoliation in Vietnam to be somewhat lower because applications are made from a greater height than was the case for the experimental work in Thailand and Puerto Rico.

Multiple treatments were not made in Thailand or Puerto Rico so the effects of 2 and 3 treatments in War Zones C and D can only be inferred instead of being extrapolated from actual research data. But the inference is necessary because the ecologic impact becomes progressively greater with each succeeding treatment.

A single treatment with 3 gallons of orange or white would not be expected to have a great or lasting effect on a semideciduous forest in Vietnam. Some trees would be killed and the canopy would be less dense. But within several years the canopy would again be closed and even a careful observer would be hard pressed to circumscribe an area that had been treated. But a second application, especially if made within 3 or 4 months after the first, would have a wholly different effect.

Research on a 2-storied oak-yaupon forest in Texas showed that the top canopy intercepted about 72 percent of the spray droplets and the understory intercepted an additional 22 percent. Only 6 percent of the droplets reached the ground (Tschirley, et al, 1968). Thus, one would expect that the principal effect from an initial treatment would be on trees of the top canopy. As the density of the top canopy is reduced, second and third treatments will kill more trees in the top canopy and have a far greater effect on the understory, regenerating vegetation.

The theoretical response to multiple herbicide applications developed in the previous paragraph was supported by observations on the ground. The area visited at Thien Ngon was sprayed with orange on 19 Dec 65, the area at Katum was treated with white on 9 Nov 66 and with orange on 28 Oct 67. Two areas were visited at Tong le Chon; one treated with orange on 23 Sept 67 and the other with white 7 Nov 65. There were more dead trees and a higher defoliation percentage at Katum than at any other site. Granting the inadequacy of the sample at each location, the difference between Katum and the other sites was obvious.

Successional aspects - I can think of no better introduction to this section of my report than a quotation from a recognized authority on tropical forests (Richards, 1964). "The process of natural regeneration in tropical forests is no doubt exceedingly complex, and, though its practical importance to the forester is obvious, surprisingly little is known about it. Much of what has been written about the so-called 'natural regeneration' of rain forest refers to the reproduction of a few economic species under conditions rendered more or less unnatural by the exploitation of timber. Before regeneration under these artificial conditions can be understood or controlled scientifically we need to know what happens under undisturbed conditions, and information about this is extremely scanty".

I must emphasize the last sentence of Richards. Data on regeneration of tropical forests is indeed scanty -- and particularly scanty for Vietnam.

There seems to be general agreement that the usual successional series in a terrestrial tropical forest is grass----> shrub----> secondary forest----> primary forest (Richard, 1964; Williams, 1965; Anonymous, 1958 b). But such a general statement is hardly comforting. It is born of desperation, matures through repetition, and dies only in some distant generation. The same successional series could be applied equally well to deciduous forests in temperate zones.

The theory is not really all that bad. If there were only a temporal determination that could be applied, the general statement could be made more specific.

Because of the absence of data about forest regeneration in Vietnam, perhaps an example in a different situation would be instructive. The island of Krakatau represents a classic example of ecologic succession. According to Richards, Krakatau is one of a group of small volcanic islands situated between Java and Sumatra. Early in 1883 it was about 9 km long and 5 km broad, rising to a peak 2728 ft (822 m) above sea level. At this date the whole island was covered with luxuriant vegetation. About the nature and composition of this vegetation next to nothing is known, but there is every reason for supposing that it was mostly tropical rain forest similar to that now existing in the neighboring parts of Sumatra. In May 1883 the volcano which had long been regarded as extinct, became active and the activity gradually increased till it reached a climax on 26 and 27 August. On those two days occurred the famous eruption, the sound of which was heard as far away as Ceylon and Australia. More than half the island sank beneath the sea, the peak being split in two, though its highest point still remained. The surviving parts of Krakatau were covered with pumice stone and ash to an average depth of about 30 m and a new marginal belt 4.6 km^2 in area was added to the southern coast. During the period of volcanic activity the bulk of the vegetation was certainly destroyed. The annual precipitation on Krakatau is over 100 inches -- considerably more than the 80 inch average for War Zones C and D. For a while the island remained without any vegetation. The only living thing a visitor saw in May, 1884 was one spider. In 1886 there was already a considerable amount of vegetation on the island and the succeeding seral stages have developed quite rapidly. A diagram of the succession is given on the next page.

"The development of vegetation on Krakatau has not yet reached a stable climax stage, but the general course of future changes can be predicted with some confidence, at least for the middle and upper regions of the island. In the former it may be expected that the Macaranga-Ficus woodland will develop by a series of changes into stable climax rain forest to some extent similar to the mixed primary rain forest of the neighboring parts of Sumatra and Java. How long this development will take is difficult to guess, but the study of secondary successions suggest that it will be much longer than from the great eruption to the present day (Richards, 1964)."

The example of Krakatau cannot, of course, be directly applied to the semideciduous forests of Vietnam. But Krakatau is an excellent example of the relative time that is needed for the development of a mature forest when it must start from nothing.

There are a few published records of tree ages in tropical forests that give an indication of the time required for regeneration of a mature forest. Brown (1919) showed that an average individual of Parashorea malaanonan in the Philippine Dipterocarp forest reaches a diameter of 80 cm in 197 years. Watson (1937) established the average maximum age of Shorea leprosula in Malaya at 250 years. Both are primary forest species. The fast-growing trees characteristic of young secondary forest have a shorter life than do primary forest species (Richards, 1964).

The principal ecologic danger imposed by repeated treatments with herbicide is that saplings and poles present in the lower story, and then seedlings, may be killed. If that happens in large areas, natural reseeding will be a problem. Dipterocarp seeds are wind-disseminated and thus would be expected among the first three species to repopulate an area. Seeds of other species, dependent on dissemination by small mammals and rodents and by birds, would probably not spread as rapidly. Seeds of some species would undoubtedly remain

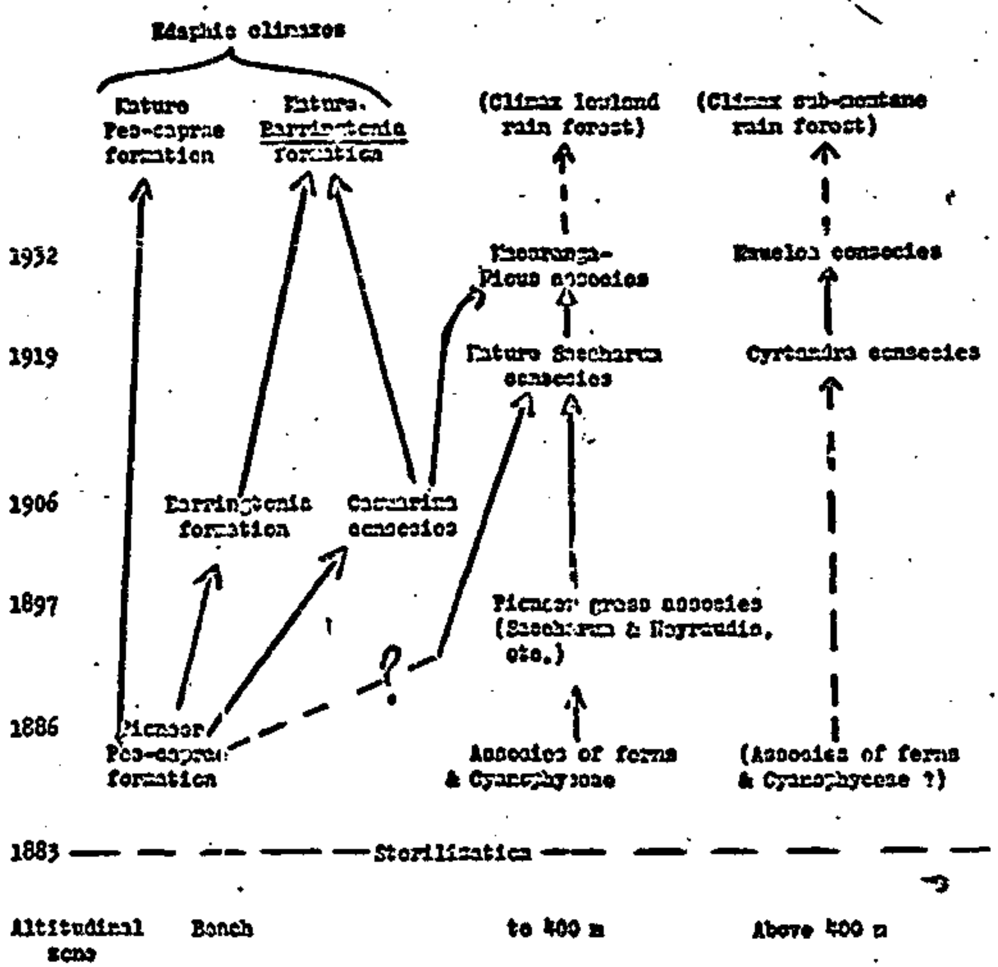

Diagram of successions on Krakatau since the eruption of 1883 (Richards, 1964) viable in the soil ' ' would germinate after the last in a series of multiple treatments. Many species in the family Leguminosae have that capability. Less is known about seed characteristics in other families. I have found no information about the longevity of seeds in tropical soils. Turrill (1957) reported it has been proved at Rothamstead that seeds of arable weeds remained viable in soil under pasture after 300 years in one area and 30 to 40 years in others.

"Little is known of the time scale of secondary successions in the tropics. Chevalier (1948) states that the forest on the site of the ancient town of Angkor Vat in Cambodia, destroyed probably some five or six centuries ago, now resembles the virgin tropical forest of the district, but still shows certain differences. In general it seems clear that the longer the period between the destruction of the primary forest and the onset of the secondary succession and the greater the modification of the soil and the environment in general during this period, the longer the time needed for the re-establishment of the climax (Richards, 1964)".

The paragraph quoted does not apply to the forests being defoliated in Vietnam because the Vietnamese forests were not primary, but secondary at the time of treatment. The time required for the establishment of a secondary forest is much less than for a primary forest.

The greatest danger resulting from repeated defoliation treatments in Vietnam is that such areas will be invaded by bamboo. The presence of bamboo is the most constant feature of the forests I have seen. Species of large bamboo (the most common being Dendrocalamus strictus and Bambusa arundinacea according to a local VN forester) are particularly apparent in areas where the "rai" (slash and burn) system of agriculture has been practiced. But bamboo is not limited to areas that were previously cleared of trees. A small-stemmed bamboo is present as an understory in many forested areas and can be seen frequently where trees have been defoliated. In addition, the small bamboo (Schizostachyum zollingeri), 10 to 15 ft high, was present in the forest at all of the camps visited. The presence of bamboo in Asian forests is well documented (Richards, 1964; Williams, 1965 and 1967; Ahmat, 1957; Anonymous, 1958 c; Anonymous, 1961).

Bamboo in RVN cannot be considered gallery vegetation, as it is in Puerto Rico, because it occurs commonly throughout the forest. But aerial observations suggest that it first invades new areas along routes of more favorable moisture supply. From there it can spread throughout the forest.

While making ground observations at the 4 camps, we attempted to evaluate the relative density of seedling and sapling tree species in bamboo-infested and bamboo-free sites. Although I have no quantitative data, Mr. Plumm and I agreed that seedlings were rare in dense bamboo, but frequent to numerous where there was no bamboo. Probably of more importance is the fact that saplings were extremely rare in dense bamboo.

The length of time that bamboo might retard the usual successional progression is unknown, but I am certain it would cause a retardation. The statement of Ahmed (1957) which follows is probably an exaggeration, but nonetheless cause for concern. "A bamboo will be the first member to colonize on a new site in a seed year and will be the last to leave it. Once established on a soil it is difficult to eradicate it".

The life history of different bamboo species varies, but usually culms die after flowering. The germination to flowering cycle may be from 30 to 50 years (Richards, 1964; McClure, 1966). Flowering is gregarious (whole populations flowering in one year) in some species and sporadic in others. Most bamboo species have very efficient vegetative reproduction from buds on creeping rhizomes.

Seedling mortality of tree species is naturally high in tropical forests. A study of Euterpe globosa, a palm found in the American tropics, showed that the mortality of seedlings was 95 percent, of established seedlings 12 percent, and of shrubs 64 percent. Thus, only 1.6 percent of the seedlings survived to the tree stage (J. F. McCormick in Odum, 1965). Another study (R. F. Smith in Odum, 1965) showed the average half life of all seedlings in test plots to be 6 months.

If it were not for the probable invasion by bamboo of severely defoliated areas in the forests of Vietnam, I am resonably certain that the successional progression to a secondary forest of trees would proceed without undue retardation. A reason for feeling so is based on data from plots in Puerto Rico that were treated with 3,9, and 27 lb/acre rates of picloram, bromacil, dicamba, diuron, fenac, and prometone applied to the soil. The plots were examined 2 years after treatment for seedling presence. Many of the secondary forest species and several primary forest species were present as seedlings. In addition, there was no apparent differential effect of the 6 herbicides. (Tschirley, unpublished data).

In conclusion, the time scale for succession in a semideciduous forest in RVN is unknown. Single treatments with defoliants should not cause severe successional problems, but multiple treatments probably will because of site dominance by bamboo. For what it is worth in estimating the successional time scale, the average annual diameter increment of <u>Parashorea malaanonan</u>, (a Phillipine Dipterocarp) growing in the open was 0.42, 0.55, and 0.73 cm, respectively, for diameter classes of 0 - 5, 5 - 10, and 10 - 15 cm.

<u>Ecologic considerations</u> - The ecologic considerations as they apply to plant populations were discussed in the previous section of this report. The effect of defoliation on animal populations is truly unknown. However, the degree of effect on animals would parallel that for plant populations -- the greater the number of herbicidal treatments, the greater the harm to animal populations.

Men stationed at Special Forces Camps have told us of seeing deer (2 reports), birds (many reports), tiger (1 sighting, several sound identifications), elephant (2 reports), monkey (numerous reports), cold blooded vertebrates (numerous reports). We saw a tiger track in the road at Katum. There were no reports of bovines. It is surely possible that such rare bovines as the kouprey, gaur, and banteng have been eliminated from the defoliated areas in War Zones C and D. But I suspect that bombing, artillery, fire, human presence, and hunting have had a far greater effect than defoliation.

D. Toxicity of Herbicides

A discussion of ecologic effects would hardly be complete without mentioning the relative toxicity of the herbicides being used for defoliation and crop destruction. All the herbicides used here are only moderately toxic to warm blooded animals. None deserves a lengthy discussion except for agent Blue, which contains arsenic. Inorganic arsenicals such as arsenic trioxide, sodium arsenite, lead arsenate, calcium arsenate, and Paris Green are extremely toxic. Organic arsenicals, such as Blue, have a low mammalian toxicity. Two series of organic arsenicals are used as herbicides. The arsonic acid series is formed by a single organic group combined directly to arsenic; the arsinic acid series has two organic groups. By varying the organic group in either series, a wide range of phytotoxicities can be obtained in products with a relatively low level of mammalian toxicity. The chart on the next page gives the LD_{50} (mg/kg of body weight needed to kill 50 percent of rat test animals) for the herbicides used in RVN and for several other chemical compounds.

LD$_{50}$ for some common pesticides compared with aspirin. Values for each chemical are milligrams per kilogram body weight.

25	Sodium arsenite
25	Methyl parathion
50	Endrin
75	Dieldrin
125	DDT
175	Paraquat
300	2,4,5-T
400	2,4-D
525	Chlordane
1775	Asprin
2600	Phytar 560 (Agent Blue)
8200	Picloram

Reference: Herbicide Handbook of the Weed Society of America. M. M. Hull, Ed.

E. Conclusions

If my assignment here had been simply to determine if the defoliation program had an ecologic effect, the answer would have been a simple "yes", and a trip to the country would not have been necessary. But to assess the magnitude of the ecologic effect is an entirely different matter.

One must realize that biologic populations, even those remote from man, are dynamic. Seasonal changes, violent weather events, fire, birth, maturation, senescence, and death cause a continuing ecologic flux. Normally, the ecologic flux operates within narrow limits in a climax community. It is only catastrophic events that cause an extreme ecologic shift and reduce the community to a lower seral stage.

That defoliation has caused an ecologic change is undeniable. I do not feel the change is irreversible, but recovery may take a long time.

The mangrove type is killed with a single treatment. Regeneration of the mangrove forest to its original condition is estimated to require about 20 years.

A single treatment on semideciduous forest would cause an inconsequential ecologic change. Repeated treatments will result in domination of many sites by bamboo. Presence of dense bamboo will then retard regeneration of the forest. The time scale for regeneration of semideciduous forest is unknown. Available information is so scanty that a prediction would have no validity and certainly no real meaning. The time required for regeneration to its original condition would certainly be longer than was estimated for mangrove.

The effect of defoliation on animals does not appear to have been extreme. But I hasten to add that I know far less about animals than about plants. The fish catch has been increasing at about the same rate as number of fishermen, which surprised and pleased me. Actual data were not available for population trends of other forms of animal life. Large mammals have been seen recently in War Zones C and D, the areas of greatest defoliation activity. Included were tiger, monkey, elephant, and deer.

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SECTION G: PROGRAM PLANNING AND PROCEDURES

Contents

I. RECOMMENDATIONS

A. That revised project approval procedures contained in paragraph III B be approved.

B. That proposed project request checklists at paragraph III C be approved and included with all future project files.

C. That exceptions to revised procedures noted in paragraph III D be approved.

D. That post-project evaluation checklists outlined in paragraph III E be approved and used during reviews of herbicide operations.

E. That the above changes in, and additions, to current procedures be included in revised directives.

F. That the 203 Committee be expanded to include a representative from JUSPAO.

II. SUMMARY OF FINDINGS

A. Strengths and Weaknesses of Current Procedures. The current system for approval of projects (paragraph III A) has assured that the military aspects of defoliation and crop destruction are given full consideration. Additionally, the current system requires that recommended projects be developed at Province level and may not be approved or executed over the objections of local GVN officials. This has assured that the interests of Province officials are given paramount consideration. On the other hand, current approval procedures tend to be both unwieldy and time consuming. In some areas, there is excessive coordination while in other cases there is a lack of sufficient control. In some instances, inadequate attention is given to herbicide requests during the project formulation at sector level. Psywar and civil affairs annexes often appear to be developed on a pro forma basis. Indications are that participation by local CORDS personnel is limited. Finally, once the herbicide project has been approved and executed, post-project evaluation has been limited to an assessment of the purely military benefits gained from the operation. Insufficient attention has been given to the economic and political/psychological impact.

B. Revised U.S. Procedures. To strengthen the current system for approving herbicide requests, the procedures outlined in paragraph III B, below, were developed. These procedures reinstitute periodic meetings of the 203 Committee in order to reduce project coordination and review time at the Saigon level. This committee should be expanded to include a member from JUSPAO. The 203 Committee, comprised of representatives from MACV (MACCOC7, MACCORDS, MACPD), USAID, JUSPAO and AMEMB, performs a coordination and review function in the processing of requests for herbicide operations. This committee, chaired by the MACV Staff Chemical Officer, also conducts reviews of post-project evaluations (see paragraph II E, below). In no instance will this committee function in a program management capacity. Additionally, the revised procedures limit project execution periods to six months with requests for extensions beyond that time subject to review by the 203 Committee. Revised procedures which are intended to reduce project processing time below Saigon level are included. Finally, the revised procedures require that the economic and political/psychological aspects be given additional emphasis during project formulation.

C. Checklists. Checklists noted in paragraph III C, below, were devised to assure that all necessary factors are considered during formulation of a herbicide spray request and that sufficient information is available to the 203 Committee on which to base recommendations to the Ambassador and COMUSMACV. It is intended that these checklists be filled out in detail and accompany the project file.

D. Exceptions to Revised Procedures. To permit a more timely response to herbicide spray operations requirements of the local tactical commander, certain exceptions can be made to the revised procedures without any substantial loss of control at the Saigon level. Modified procedures in approval of certain types of crop destruction and helicopter defoliation targets are suggested in paragraph III D, below.

E. Post-Project Evaluation. The post-project evaluation of herbicide operations is an instrument of program management and review designed (1) to help ensure that herbicide operations are carried out in accordance with MACV Directive 525-1 and State/Defense policy guidelines, and (2) to help assess the results of these operations in terms of their military, economic and political/psychological impact. The evaluations of individual herbicide projects will be used by the MACV elements charged with responsibility for managing herbicide operations as a tool of command, administrative and quality control. These same evaluations can be used also as a source of relevant information by those US Mission component organizations responsible for assisting in the overall program review of herbicide operations. Areas to be considered in post-project evaluation are contained in paragraph III E, below.

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III. ANALYSIS OF PROGRAM PLANNING AND PROCEDURES

A. Current Procedures. The use of herbicides for defoliation and crop destruction is a Republic of Vietnam program which is supported by the United States. The RVNAF responsibilities are exercised through a committee composed of representatives from the Joint General Staff J3 Section, J4 Section, VNAF, J2 Section, J5 Section and RVNAF/CDEC, the organization which has operational responsibility for supply of herbicide. This committee, called the 202 Committee, is not a standing committee and only meets when considering requests or writing directives for herbicide operations. In addition, each Corps has a similar committee responsible for reviewing herbicide requests at that level.

The US Defense and State Department establish policy for US support of the herbicide program. State/Defense have delegated the approval authority for conducting herbicide operations to the Ambassador and COMUSMACV jointly. To exercise control over the program, the Chemical Operations Division, Combat Operations Center, MACV has been assigned the supervisory responsibility to accomplish the necessary coordination.

A committee, designated as the 203 Committee, has been established to review all requests. This committee is composed of representatives of the J3, Psyops Directorate, CORDS, J2, USAID and Embassy.

All herbicide requests under current directives are required to be submitted through territorial command channels, therefore all GVN requests must originate at district or province level. After formulation of the herbicide plan, which must include as a minimum the area requested to be treated with herbicide, psyops, civil affairs and intelligence annexes, along with a statement by the Province Chief that he will indemnify just and legal claims for any accidental damage to friendly crops, the request is submitted to ARVN Corps headquarters through the ARVN division. Since ARVN Corps Commanders and Corps Senior Advisors have authority to approve ground based spray defoliation, only requests for aerial spray and all crop destruction requests are forwarded to the Joint General Staff. The request is reviewed by the JGS 202 Committee and approved by the Chief of the Joint General Staff. Once approved, the request is forwarded to COMUSMACV for approval.

Concurrently, on the US side at each comparable level (e.g., province senior advisor), a US position on the request is recommended to higher authority. This US position is developed as the result of coordination with CORDS, USAID, military and political representatives at each level where they exist.

Upon arrival at MACV of the GVN request and the US position recommended by the Corps US Senior Advisor, the project case is prepared within the Chemical Operations Division. Proposed areas are defined by those coordinates on which both the GVN and US agree. In many cases, the US position on target area will differ from the GVN request because of varying opinions on military advantages to be gained. An aerial reconnaissance is conducted to ensure that all populated areas and friendly crops are deleted from the target area. Having determined that the project is a valid herbicide target from the aerial reconnaissance and an analysis of the military worth of the request, the project case is submitted to the members of the MACV 203 Committee individually for review. All members of the MACV 203 Committee must concur in the proposed project in order for it to be approved. Frequently, during processing, target parameters are changed and operational restrictions are added in order to get unanimous agreement in the proposed project. After consideration by the MACV 203 Committee, the project is forwarded to the Ambassador and COMUSMACV for approval.

Minimum processing time has been 8 weeks after arrival at the Saigon level, while the average processing time has been 4-5 months. Projects often take 3-4 months after initiation by the Province Chief to reach Saigon level.

Prior to initiation of herbicide operations against a specific target, a coordination meeting is held with provincial officials at which final details or any changes in previous requests are ironed out. At this time the Province Chief has the option of altering the approved target because of changes in the local situation since initiation of the original request. The military worth of the target, psyops and civil affairs are reviewed and intelligence is updated. Special conditions required during spray operations are established (e.g., wind direction, areas in which prestrike or return fire-for-fire tactics may be employed, no-spray zones) and expiration date for the project is agreed upon.

After conclusion of the coordination meeting, the Joint General Staff publishes an operations order for execution of the target which is distributed to concerned parties in the GVN down to Province level. Concurrently, 7th Air Force is ordered to execute the mission with C-123 spray aircraft. Coordination details are furnished to RANCH

HAND by memorandum which spell out specific target coordinates, herbicide to be used, weather condition requirements and any other unusual considerations developed during the staffing and coordination of the project.

As a final control measure, each spray run over the target must be approved by both the US and RVNAF. The Province Chief must clear individual spray runs 24 to 48 hours prior to the mission.

B. Revised Procedures. The procedures outlined below apply to the processing of those herbicide spray requests which must come to the Saigon level for approval.

SAIGON LEVEL

1. Project file will be prepared by MACV (COC7) based upon input from JGS and the Corps Senior Advisor.

2. Documentation in the project file will be responsive to the areas of interest outlined in the checklists. The dated signature of the Province Chief recommending the project will be included in the project file.

3. Copies of the project file will be provided simultaneously to each member of the 203 Committee for review. Individual 203 Committee members will coordinate with their counterparts in the GVN on significant aspects of the proposed project as necessary.

4. The 203 Committee will meet monthly to review and coordinate on each project case. More frequent meetings may be called if workload so dictates or to process projects of urgent military necessity. COC7 action officers will participate in order to brief the project and to respond to questions, if any. At the meeting, members of the 203 Committee will be prepared to state their agency's position on the proposal. The coordination sheet accompanying the project case will be signed by individual 203 Committee members (less AMEMB) at the conclusion of the meeting. Nonconcurrences will be explained in writing and will be made a part of the case.

5. Immediately upon completion of the 203 Committee meeting, the AMEMB member will present each project file to the Ambassador for consideration.

6. After the approval of the Ambassador has been received, COC7 will forward the project case to the Chief of Staff, MACV for COMUSMACV approval, signature and dispatch of the letter to Chief of JGS announcing US concurrence in the GVN request. The letter will

indicate that execution of the project will be limited to a six (6) month maximum period from the date of the first sortie flown.

7. A final coordination meeting will be held at Province level after US concurrence in the GVN request. Alterations in target area as the result of this meeting will be submitted to AMEMB by memorandum for final consideration.

8. Requests for extension of project execution periods will be submitted to the 203 Committee for review and concurrence.

BELOW SAIGON LEVEL

1. Corps Senior Advisors will be responsible for establishing procedures to ensure expeditious processing within the Corps Tactical Zone of the proposed US position on each GVN request. Procedures should require that advisor recommendations be forwarded to higher levels concurrently with, but separate from the GVN request. Province advisory staffs will retain translated copies of all documents submitted by the Province Chief in his request for herbicide operations.

2. In establishing the US position to be proposed to the Saigon level, the Corps Senior Advisor will assure that the views of the following members of his staff and at lower levels (where they exist) are considered:

- Regional RD Operations Officer
- New Life Development Officer
- Agricultural Advisor
- Regional Economic Advisor
- Political Reporting Officer
- CORDS Refugee Coordinator
- Asst DEPCORDS for PsyOps

A statement to the effect that these views were considered will be included in the project recommendations forwarded to MACV.

3. In addition to those responsibilities outlined in paragraph 4a (2) of MACV Directive 525-1, Corps Senior Advisor's recommendations will include a comment reflecting the DEPCORDS position

in the project. In the case of I CTZ, POLAD concurrence will be included. Additionally, a brief narrative of the major advantages and possible disadvantages of undertaking the proposed herbicide operation will be included.

4. Documentation to be included in project recommendations (over and above that already required in paragraph 5a of MACV Directive 525-1) will be responsive to the areas of interest outlined in the checklist. This checklist will be prepared on basis of input provided by qualified specialists at appropriate levels as required.

5. To ensure proper development and execution of the psyops support program on individual projects, the Corps Senior Advisor must have specific commitments and sufficient assurance for psyops support before recommending the project.

6. An information copy of the initial request for herbicide operations will be furnished to MACV (COC7). This information copy will be used to follow processing of the request through intervening headquarters to MACV. When the project request reaches the Corps Senior Advisor level, members of the 203 Committee will be alerted in order that preliminary staff work can be accomplished.

7. In order to be responsive, the JGS project request and the Corps Senior Advisor's recommendation should arrive at HQ, MACV within 45 days from the date of the origination of the request.

C. Checklists.

DEFOLIATION CHECKLIST
(Below Saigon Level)

GENERAL:

1. What is the objective and the military worth of the proposed defoliation operation?

2. How urgent is the proposed project?

3. Have the DEPCORDS and PSA concurred in the proposed project? In the case of nonconcurrences, have the reasons been stated?

4. Have Provincial CORDS and Regional CORDS specialists taken part and had opportunity to express their views in the approval process at their level?

TARGET DESCRIPTION:

1. What are the UTM grid coordinates:

2. Have overlays been included in project recommendations?

3. What type of vegetation is located in the target area (e.g., canopy, species)?

MILITARY SITUATION:

1. What is the military purpose of defoliating the proposed target area?

2. What is the enemy situation in the proposed target area?

   a. Disposition (i.e., strength, location, activity)?

   b. Nature and pattern of enemy LOC's?

   c. Location of enemy base camps?

   d. Air defense capability?

SENSITIVE AREAS:

1. Are active rubber plantations, orchards and cultivated areas located in the vicinity of the target? If so, how far are these areas from the target limits? In the case of cultivated areas, when is the harvest period?

PSYOPS ASPECTS:

1. Who and how many inhabitants are located in and near the target area?

2. What is the predicted psychological impact within the area of operation?

3. What psyop media is to be used?

4. What will be the thematic content of the media?

5. Is any additional support required?

6. Does the psyop plan include provisions for operations directed toward population living in the area contiguous to the target?

7. What, if any, problems have been encountered in the execution of psyops plans prepared for previous herbicide projects?

8. Are there procedures to notify the psychological operations personnel to execute the psyops plan before the mission is initiated?

CIVIL AFFAIRS ASPECTS:

1. Is there any likelihood that execution of the project will create problems or conflict with RD programs in the area?

2. How many refugees could be produced by the operation which this project supports?

3. Are Provincial facilities adequate to handle generated refugees?

4. If there is a refugee problem, has an adequate support plan been prepared?

5. Are procedures and funds available to satisfy damages which might be included under the claims program?

DEFOLIATION CHECKLIST
(Saigon Level)

Responsible Agency:	GENERAL:
MACCOC7	1. Has the Province Chief signed the basic request?
	TARGET DESCRIPTION:
MACCOC7	1. What are the target boundary coordinates on which both the JGS and Corps Senior Advisor agree?
MACCOC7	2. What is the size of the target area?
MACCOC7	3. How many sorties will be required to achieve target objectives?
	SENSITIVE AREAS:
MACCOC7	1. In the case of targets in the vicinity of international boundaries, what is the distance from target edge to the international border or Military Operational Boundary? For targets in the southern

portion of the DMZ, what distance is the southern edge of the target from the PMDL?

USAID 2. Have other sensitive areas been identified, i.e., forest nurseries, plantings for erosion control, research plots, forest species adaptation plots, agricultural pilot test plots, critical watershed areas?

USAID 3. Have provisions for salvage of dead and dying timber been considered, i.e., industrial capacity available, security considerations, transportation?

CROP DESTRUCTION CHECKLIST

(Below Saigon Level)

GENERAL:

1. What is the objective and the military worth of the proposed herbicide crop destruction operation?

2. How urgent is the proposed project?

3. Have the DEPCORDS and PSA concurred in the proposed project? In the case of nonconcurrences, have the reasons been stated?

4. Have Provincial CORDS and Regional CORDS specialists taken part and had opportunity to express their views in the approval process at their level?

TARGET DESCRIPTION:

1. What are the UTM grid coordinates?

2. Have overlays been included in project recommendations?

3. What type of crop is in the target area and what is its growing season?

MILITARY SITUATION:

1. What is the enemy situation in the proposed target area?

   a. Disposition (i.e., strength, location, activity)?

   b. Location of major VC/NVA base areas?

   c. Air defense capability?

RESOURCES DENIAL ASPECTS:

1. What are the characteristics and vulnerabilities of VC/NVA food production efforts in the area?

   a. To what extent is the enemy in the area reliant on local production for food requirements?

   b. Whatare alternative sources of food for VC/NVA in the area?

   c. How far is the target area from the nearest commercial center or major agricultural area?

   d. Is there evidence that enemy units currently are suffering food shortages?

2. What measures besides herbicide crop destruction are being made to control food in the area?

3. What efforts are being made to eliminate the enemy's logistics infrastructure in the area?

4. Is there effective resources control to prevent the importation of food from nearby commercial sources into the target area?

PSYOPS ASPECTS:

1. What is the approximate population density in the area?

2. Are there any special characteristics of the population in the area (i.e., ethnic, religious, vocational, political, degree of literacy)?

3. Will psychological operations be conducted in advance of the crop destruction mission?

4. What is the predicted psychological impact within the area of operation?

5. What psyop media is to be used?

6. What will be the thematic content of the media?

7. What, if any, problems have been encounted in the execution of psyops plans prepared for previous herbicide projects?

CIVIL AFFAIRS ASPECTS:

1. Is there any likelihood that execution of the project will create problems or conflict with RD programs in the area?

2. If there is a refugee problem, has an adequate support plan been prepared by Province officials?

3. How many refugees could be produced by this operation?

4. Are Provincial facilities adequate to handle generated refugees?

5. Are procedures and funds available to satisfy damages which might be included under the claims program?

CROP DESTRUCTION CHECKLIST
(Saigon Level)

Responsible Agency:	GENERAL:
MACCOC7	1. Has the Province Chief signed the basic request?
	TARGET DESCRIPTION:
MACCOC7	1. What are the target boundary coordinates on which both the JGS and Corps Senior Advisor agree?
MACCOC7	2. What is the size of the target area?

D. Exceptions to Revised Procedures.

1. Helicopter Defoliation. The requirements for herbicide operations have increased so rapidly that available C-123 spray aircraft cannot attack all approved targets within the desired time frame. Many targets are small and located in areas where they can be sprayed more effectively by helicopter spray systems.

It would be beneficial to delegate authority to major field commanders for approval of helicopter defoliation operations in support of local base defense, maintenance of defoliated areas, and the uncovering of known small ambush sites along lines of communication. This will permit a more timely response to defoliation requirements of the local tactical commander.

Because helicopter spray operations can be conducted at low altitudes and slower speeds than C-123 spray aircraft, risk of damage to crops outside of approved target areas will be minimized. In addition to normal restrictions outlined in existing Directives, the major field commanders would have to observe the following additional requirements: (a) a buffer distance of at least two (2) kilometers from active rubber plantations must be maintained; (b) helicopter spray operations will not be conducted when ground temperatures are greater than 85° Fahrenheit and wind speed in excess of 10 m.p.h.; (c) a monthly report will be submitted by major field commanders which will specify areas defoliated by helicopter, agent used and evaluation of results.

2. Area Clearance for Crop Destruction. Flexibility and rapid response for crop destruction is required because most target areas are small, widely dispersed and difficult to locate. At the same time, it is necessary to maintain adequate safeguards to assure that the advantages of the mission will outweigh the disadvantages.

All crop destruction projects must adhere to policy which requires that operations be conducted in food scarce areas and at locations far removed from population centers.

At the initiation of the Province Chief and the US Senior Province Advisor, a request for area clearance is processed in the same manner as other herbicide requests. In order to facilitate the area clearance request, areas of low population density and under VC control or uninhabited will be considered, prima facie, as possible targets for crop destruction. As an operational guideline, low population density can be defined as less than approximately 20 inhabitants per square mile. When approved, the period of execution for the area project would extend for 12 months to allow attack of targets over two growing cycles.

Specific target coordinates will be relayed directly to MACV (COC7) for approval prior to attack. MACV will assure that specific targets meet original criteria. Questionable targets will be coordinated with members of the 203 Committee. Upon approval, MACV will direct appropriate agencies to fly the mission.

E. Post-Project Evaluation.

DEFOLIATION

Principal Elements of Evaluation:

1. Dates defoliation missions were flown and type of aircraft used.

2. Brief restatement of military justification of project, including description of enemy use of target area.

3. Extent of defoliation of single, double and triple canopy jungle, bushes, grasses and other cover. Use the following scale to indicate vertical and horizontal (where applicable) visibility of enemy facilities, LOC's and personnel: I - slightly increased visibility; II - moderately increased visibility; III - markedly increased visibility.

4. Observed changes in the utilization and location of enemy facilities and LOC's as well as the movement of enemy personnel.

5. Description of targeting or operational errors to include exceptions to established meteorological standards during spray operations.

6. Solatium Requests. (a) number and description of requests submitted to claims authorities as an alleged consequence of the project; (b) evaluation of the effectivness of the claims procedures.

7. Civil Affairs Plans. Evaluation of population dislocation resulting from the herbicide project. Comments should not be confined to registered refugees alone.

8. Psyops Support Plans. (a) number and sample of leaflets and other printed media used in support of the project; (b) number of loudspeaker plane sorties flown; (c) description of other psyops support activities carried out; (d) description of local attitudes toward the project or toward defoliation operations in general; (e) existence and extent of local enemy propaganda activities directed against the project or the program as a whole.

9. Over-All Evaluation. Assessment by Province Senior Advisor of the results of the project in terms of its military, economic and political/psychological impact.

Evaluation Procedures:

1. Number of Evaluations Per Project. All defoliation projects will be evaluated within 3 months of inception and each 3 month interval thereafter until completion. Reports will be submitted within 30 days after the end of the reporting period.

2. Saigon Distribution. Copies of the evaluation will be distributed to the 203 Committee by MACV (COC7).

CROP DESTRUCTION OPERATIONS

Principal Elements of Evaluation:

1. Dates crop destruction missions were flown and type of aircraft used.

2. Brief restatement of military justification of project, including description of enemy use of target area.

3. Extent of herbicide crop destruction in the province by type of crop, by percentage of estimated VC/NVA requirements, and by percentage of VC/NVA self-production.

4. The current enemy food situation, and any changes in food situation over the last six months.

5. Do food shortages (if any) appear to have caused the enemy to have changed his area of operations or tactics? Have there been identifiable strains placed on his logistics capacity?

6. What other efforts have been made to control food supplies (e.g., military operations, attacks against infrastructure, border control, National Police resources control)?

7. How have these activities been coordinated and have they been effective?

8. Civil Affairs Plan. Evaluation of population dislocation resulting from herbicide projects. Comments should not be confined to registered refugees alone.

9. Psyops Support Plan. (a) number and sample of leaflets dropped and other printed media used in support of the project; (b) number of loudspeaker plane sorties flown; (c) description of other psywar support activities carried out; (d) description of local attitudes toward crop destruction operations in general; (e) existence and extent of local enemy propaganda activities directed against the project or the program as a whole.

10. Over-All Assessment. Assessment by the Province Senior Advisor of the results of the project in terms of its military, economic and political/psychological impact.

Evaluation Procedures.

1. The Province Senior Advisor will submit a semi-annual report (1 May and 1 November) on crop destruction in each province where crop destruction missions were flown within that six month period.

2. Evaluation will be processed so as to arrive at the Saigon level no later than 30 days after the date of completion of the report.

3. Copies of the report will be distributed to all members of the 203 Committee by MACV (COC7).

APPENDIX

NOTE: The following technical papers were prepared by consultants to the MACV representative on the Herbicide Policy Review Committee. They contain expert information and analysis which the Committee took into consideration in its deliberations.

A - Herbicide Spray Drift

B - Theoretical Analysis of Downwind Drift of Herbicide Sprayed from an Aircraft

C - Toxicity of Herbicides in Use in RVN

D - Persistence of Herbicides in Soil and Water

E - Potential Hazards of Herbicide Vapors

APPENDIX A

HERBICIDE SPRAY DRIFT

by

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2-A

SUMMARY

An assessment of potential drift hazards to crops is presented for the military application of defoliant herbicides conducted in RVN with C-123 aircraft. Principal factors influencing drift from herbicide spray applications are: droplet size, height of release and atmospheric conditions, principally horizontal air movement.

The spectrum of mass deposition with droplet size is not available for the current operational C-123 system. Droplet data for an equivalent system with D8/45 nozzles with mass deposit of 350 microns MMD were used in calculation of herbicide drift potential from a flight altitude of 150 feet under maximum crosswind velocities of 9 mph.

It was concluded that the maximum distance at which drift hazard from 6 sortie missions with C-123 would occur was 1 to 2 kilometers under most unfavorable crosswind conditions of 9 mph. Rice, sugarcane, corn and other grass-like crops can be located 1 kilometer or more from defoliation targets. Under the atmospheric conditions in which 12th Air Commando Squadron operates, drift damage on broadleaf crops should not occur at distances greater than 2 kilometers.

To further minimize drift hazard, it is recommended that flight targets be oriented in an in-wind direction as far as possible.

HERBICIDE SPRAY DRIFT

The use of herbicides to defoliate vegetation in areas of military interest is a new military weapon which has proven its effectiveness in operations in RVN. The improvement of air-to-ground and ground-to-ground visibility has uncovered enemy positions, permitted observation of his movements and has been a primary factor in reducing the incidence of ambushes with a resultant saving of lives of Allied military personnel. The military worth of defoliation is not being addressed in this study.

Occasionally "damage" to desirable crops outside the target area is reported subsequent to defoliant spray operations. In many cases, investigation of the alleged damage claims has disclosed conditions totally unrelated to herbicides. Minarik (1) has reported alleged rubber damage to be unfounded in 9 cases out of 16 investigated. The "damaged" trees were severely infested by insect pests and plant pathogenic fungi. Gross neglect of other plantations was responsible for deterioration of the rubber trees. Viruses and nematodes produced symptoms resembling herbicide responses, and it is the view of Dr. Nader Vakili (2) and the authors that in many cases observed, crop damage is due to these causal agents.

Other damage has been determined to be the result of misuse of herbicides by the grower himself while navigational error by 12th Air Commando Squadron has also caused damage to some crops. Leaking equipment is another potential source of unwanted damage.

It is not the intent of this study to disclaim the existence of spray drift or to infer that all crop damage claims outside target areas are due to causes other than herbicide drift. The objective of this study is to place in proper perspective the amount of drift that can occur and its potential hazard. In RVN drift becomes a potential problem only when desirable crops are in close proximity to the target. In large area targets and along isolated lines of communication, drift is of little significance.

A number of factors influence drift of spray droplets when a liquid is released from an aircraft in flight. These factors include:

(1) Droplet size
(2) Specific gravity
(3) Evaporation rate
(4) Height of release
(5) Horizontal air movement
(6) Vertical Air movement

(7) Temperature
(8) Humidity
(9) Aerodynamic forces caused by the aircraft

Particle size, height of release and air movement are the principal factors in this complex interaction.

When one considers the large volumes of herbicides being disseminated over such vast areas of RVN under combat conditions, the amount of drift damage that has occurred is truly small. It is a tribute to the expertise of the personnel of the 12th Air Commando Squadron that more drift damage has not occurred.

The C-123B/A/A45Y-1 spray system, currently being employed in herbicide operations in RVN, is usually functioned at approximately 150 feet above the vegetation while the plane is traveling at 130-135 knots (150 mph) indicated airspeed. The liquid herbicide is forced through check valves or nozzle-bodies having an internal diameter of 3/8 inch. The orifice plate, strainers and whirl plates having been removed, the liquid leaves the nozzle as virtually a solid stream and is broken into discrete particles by shear forces as it enters the turbulent airstream. The drops thus produced have a range of sizes with the mass median diameter (MMD) estimated at approximately 350 microns. This means that 50% of the mass of the liquid sprayed is in particles whose size is larger than 350 microns and 50% in sizes smaller than 350 microns.

Although the C-123/A/A45Y-1 system has never been calibrated for drop size distribution, its predecessor, the C-123/MC-1, has been calibrated (3), and an MMD of approximately 350 microns was found. The MMD was determined by the D-max method of Maksymiuk as reported by J. W. Brown and D. W. Whitten (4). It is assumed that the MMD for both systems is essentially the same.

The D-max method is a short cut for determining MMD without going through the laborious process of measuring the diameters of large numbers of droplets, thus unfortunately the droplet size spectrum for neither the MC-1 nor A/A45Y-1 is available.

However, Coutts and Yates (5) have published typical spectra for spraying systems D6/46 hollow cone nozzle at 40 psi releasing the liquid into an airstream having a 100 mph velocity. Data taken from the curves of spectra with MMD's of 450, 350 and 300 microns show the cumulative percentage of volume (or mass) for each drop size and are presented in Table 1. The droplet spectrum with an MMD of 350 microns has been selected as representative of that obtained with the current C-123 dissemination equipment. The 3/8 inch check valves used in the C-123 system produce coarser droplets than the D6/46 nozzles for which droplet spectra are available for MMD's of 350, 300 and 450. Thus, the

TABLE 1

Droplet Diameter and Cumulative Percentage of Volume at MMD of 300, 350 and 450 microns for D6/46 nozzle, 40 psi, 100 mph Airspeed, 2.8% Oil in Emulsion.*

DROPLET SIZE (microns)	CUMULATIVE PERCENT OF VOLUME 300 μ	350 μ	450 μ
50	0.05	0.01	0.01
70	0.4	0.1	0.02
100	2.	0.8	0.2
200	20.	10.	7.
300	58.	35.	20.
400	80.	66.	40.
500	98.	80.	60.
580		98.	80.
700			98.

* Adapted from Coutts and Yates (5)

proportion of droplets below 100 microns from the C-123 system is less than the 0.8 to 2.0 percent cited for the D6/46 system in Table 1. The table shows that for the MMD of 350 microns, only 0.01% of the spray mass or volume is in a size range of 50 microns or smaller, and that only 0.1% consists of 70 micron droplets or smaller.

Dorrell (6), using Stokes' law, has calculated the nominal fall velocities of droplets of herbicide ORANGE. From Dorrell's data, the distance downwind that ORANGE droplets will be carried by 3, 6 and 9 mph winds while falling 150 feet are given in Table 2.

Using the droplet spectrum for application at 350 micron MMD from Table 1, the relative areas and deposition rates from downwind drift of various droplet sizes of ORANGE are shown in Figure 1 under crosswind conditions of 9 mph. The areas of deposition for droplets of different sizes were computed based on a 1 minute flight at 150 mph (13,200 ft) with dissemination at 250 gal/minute and horizontal distances traveled downwind from release at 150 feet elevation. For example, droplets ranging in size from 500 to 580 microns fall within a distance of 63 feet of the flight path for an area of 19 acres. At a flow rate of 250 gal/minute, 18% of the total spray volume or 45 gallons is in the 500μ-580μ droplet class. The deposition rate is thus 45 gallons on an area of 19 acres for approximately 2.25 gal/acre. Under the stated conditions, approximately 89% of the spray volume (200 microns or larger) falls within 411 feet of the aircraft flight path giving a ground deposit ranging from 1.4 to 3 gallons per acre.

Droplets smaller than 200 microns are more subject to drift. Particles between 100 and 200 microns fall in the area of 366 acres up to 1,584 feet from the release line with a deposit rate of approximately 0.6 gal/acre. Droplets ranging from 70 to 100 microns will be deposited within an adjacent strip 1,809 feet in width with an application rate of 0.032 gal/acre up to a total distance of 3,303 feet or 1.0 kilometers from the flight line. This distance represents the maximum distance at which the rate of deposit of herbicide from a single sortie would affect crop plants.

Droplets ranging in size from 50 to 70 microns constitutes only 0.09% of the total volume, and, inspite of the greater distance travelled (total of 6,597 feet or 2.0 kilometers), the rate of deposition from a single sortie is negligible - 0.0002 gal/acre. In the usual operations of the 12th ACS, six sorties are flown on a given target. The superimposed drift of 50-70 micron particles from six adjoining sorties would represent a maximum deposit of .0012 gal/acre.

Since ORANGE contains 8.6 lb/gallon of 2,4-D and 2,4,5-T expressed as acid equivalent, the dosage rate of 50-70 micron droplets from six sorties would be only 0.01 lb/acre. This rate of application would not deleteriously affect the productivity of most crop plants. Maximum

TABLE 2

Rate of fall and downwind drift of herbicide ORANGE from 150 foot altitude in 3, 6 and 9 mph wind.

DROPLET SIZE (microns)	RATE OF FALL (ft/min)	TIME TO FALL 150' (minutes)	DRIFT DISTANCE WHILE FALLING 150' IN CROSSWINDS OF DIFFERENT SPEEDS		
			3 MPH (ft)	6 MPH (ft)	9 MPH (ft)
50	18	8.33	2199	4398	6597
70	36	4.17	1101	2202	3303
100	73	2.0	538	1056	1594
150	164	0.91	240	480	720
200	291	0.52	137	274	411
250	456	0.33	87	174	261
300	657	0.23	61	122	183
400	1162	0.13	34	68	102
500	1812	0.08	21	42	63

FIGURE 1

WIND DIR 9 MPH ↓

AIRCRAFT FLIGHT PATH (13,200 Ft) →

% OF VOL.	DROPLET SIZE	Acres	Gals	Rate	SWATH WIDTH	CUMULATIVE SWATH WIDTH
18	580µ – 500µ	19 Acres	45 Gals	2.25 Gal/A	63'	63'
14	500µ – 400µ	12 Acres	35 Gals	3 Gal/A	39'	102'
31	400µ – 300µ	25 Acres	77.5 Gals	3 Gal/A	81'	183'
25	300µ – 200µ	70 Acres	100 Gals	1.4 Gal/A	220'	411'
9.2	200µ – 100µ	366 Acres	23 Gals	0.6 Gal/A (5.0 lbs/A)	1183'	1584'
0.7	100µ – 70µ	548 Acres	1.75 Gals	0.032 Gal/A (0.275 lbs/A)	1809'	3303'
.09	70µ – 50µ	972 Acres	0.22 Gals	0.0002 Gal/A (0.002 lbs/A)	3294'	6597'

FIGURE 1. Drift patter for droplet spectrum with 350µ MMD in 9 mph crosswind. Data represents areas and volumes of deposition from one minute flight with flow rate of 250 gal/min, at 150 mph (13,200 ft/min) based on Tables 1 and 2. Rates of application for droplets of 50 to 200 microns are expressed in lbs/acre of acid equivalent in ORANGE.

response to ORANGE at this rate would consist of malformation of the leaves of sensitive broadleaf plants such as tomatoes and soybeans, with no reduction in crop yield. There would be absolutely no harm to rice, corn, sugarcane or other grass-like plants.

The above discussion has assumed a droplet spectrum with 0.09% of the total volume in droplets less than 70 microns in diameter. Even if the droplet spectrum included a 10x greater volume of droplets under 70 microns, the maximum rate of drift deposition would be only 0.12 lb/acre for a 6 sortie mission. Again only the most sensitive crops would exhibit leaf malformation or reduced yield at this rate of deposition from a 6 sortie mission.

Thus, under the most unfavorable conditions of a 9 mph crosswind, a multiple sortie mission with dissemination at 350 micron MMD should give no drift damage to broadleaf crops at distances greater than 1 to 2 kilometers at a maximum. Rice and other grass-like crops will not be affected by drift from ORANGE at distances greater than 1 kilometer.

It should be emphasized that the crosswind conditions at right angles to the flight path used in this example are the most extreme under which defoliation flights are made. For true inwind flights, the spray drift will fall within the normal swath pattern and with partial crosswind the zone of spray drift will be proportionately reduced in area and distance from the flight path.

The preceding discussion pertains to releases under neutral conditions where atmospheric turbulence is at a minimum. If the releases are made under strong lapse conditions or extreme turbulence, the small (under 50 microns droplets could be carried upward and possibly be deposited some distance from the release line. However, any herbicide carried upward in convection currents would become diluted in the air and if the herbicide cloud should touch down to earth, its concentration would undoubtedly be in a sub-lethal range.

Dorrell (6) has reported that lapse conditions develop slowly over the jungle and generally are weak in character. He states: "...the influence of temperature gradient on the diffusion of particles would be negligible if the particles were in the 300 micron range (or even down to 50 microns). Ballistic trajectories (gravitational velocity influenced by wind vector) of particles would prevail and temperatures would be of little concern unless a volatile material was being used." It must be borne in mind that the drift shown in Figure 1 was based on the most unfavorable conditions as far as wind speed is concerned. Generally 12th ACS aborts missions if the wind speed exceeds 10 mph and ground temperatures exceed 85° F.

Thus, drift of the magnitude shown would not be the usual case since most missions are flown early in the morning when winds are relatively calm and inversion conditions obtain.

Air temperature and humidity also have an effect on drift, but these generally relate to the physical and chemical properties of the spray. Low humidity causes evaporation of water from droplets of aqueous solutions, which results in a reduction in droplet size, thus increasing the number of small drops available for drift. High temperatures accelerate evaporation of water spray droplets and are responsible for reduction in droplet size of non-aqueous drops of volatile liquids. ORANGE, however, with its low vapor pressure is not significantly affected by the temperatures that may be encountered during spray operations in RVN. Although ORANGE is regarded as a volatile herbicide in the weed control field, it is considered essentially non-volatile by the physical chemist.

Table 3 shows the comparative volatility of butyl 2,4-D and other common liquids. The volatility of butyl 2,4-D, a component of ORANGE, is assumed to be approximately the same as that of ORANGE. Values in Table 3 are the temperatures at which the vapor pressure of the material equals 1 mm of mercury; a high value such as that of butyl 2,4-D thus represents low volatility.

Drops of ORANGE as released from the aircraft would not change in size due to volatility to a degree that would affect drift.

Evaporation rates of WHITE and BLUE, which are aqueous formulations, are not available for consideration in this study, although some decrease in droplet size due to evaporation would be expected to occur during the dry season. During the rainy season, because of the high humidity during the early morning hours when spray missions are conducted, evaporation would be minimal.

The aerodynamic characteristic of the aircraft that exerts the greatest influence on drift is the turbulence at the wing tips. The vortex created in this area sends the spray drops into a high spiral above the aircraft. Drops in this spiral remain aloft for longer periods of time and drift farther downwind than the bulk of the spray mass. The present configuration of the C-123/A/A45Y-1 spray system does not have nozzles within approximately 15 feet of the wing tips, thus reducing the vortex effect. In a similar manner, the nozzles on the tail boom are positioned to avoid the area where the slip stream would cause the spray to be carried upward.

TABLE 3

Relative Volatility of Common Chemicals: Temperature at which vapor pressure equals 1 mm of mercury.*

SUBSTANCE	TEMPERATURE °C
Water	-17
Butyl Alcohol	- 1
Ethylene Glycol (permanent anti-freeze)	53
Napthalene (solid moth balls)	53
Hexachlorobenzene	114
Kerosene	120
No. 1 Fuel Oil	120
Glycerine	125
Butyl 2,4-D	147
No. 2 Fuel Oil	(153)

* Data from Handbook of Chemistry and Physics

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APPENDIX B

A THEORETICAL ANALYSIS OF DOWNWIND DRIFT OF HERBICIDE SPRAYED FROM AN AIRCRAFT

by

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SUMMARY

The problem of drift of herbicide released from an aircraft is treated theoretically herein. The parameters of release are an altitude of 50 m (162.5 ft), a windspeed of 10 knots (11.5 mph), and neutral temperature gradient. Two hypothetical distributions of particle size are postulated, both statistically normal and centering on a median size of 300 microns. In the first case, the major fraction of the particles are distributed over a fairly narrow size range: 68% of all the particles fall within 300 ± 100 microns. In the second case, the particles are distributed more widely: 68% of the particles fall between 300 ± 200 microns, only 38% within 300 ± 100 microns.

The goal of the analysis is the determination of the percentage of released agent which drifts various distances downwind of the release line. This is done in stepwise fashion, starting from an analysis of the distribution of particle size by percentage within 50-micron categories for each postulated distribution. The rate of fall of particles in each of the categories is calculated, and from these data, downwind drift is determined. Next, the percentage of total output mass falling in each size range is developed, and this leads directly to the desired information on the percentage of agent output which drifts varying distances downwind. These data, developed for the general case, can easily be employed to ascertain the ground concentration of agent at any point downwind for any initial concentration of agent sprayed from the aircraft. For example, in the specific case of an initial concentration of agent of 3 gal/acre, it may be seen that a dose of 0.03 gal/acre will be produced some 262 m (852 ft) downwind, and a dose of 0.003 gal/acre some 348 m (1131 ft) downwind. Smaller amounts of agent will drift even further and, due to eddies and thermals, "hot spots", concentrations of agent greater than that over the surrounding area are also likely to be formed.

In conclusion, it must be pointed out that a theoretical analysis can only provide orientation as to the overall magnitude of the problem of drift. It can not be substituted for real testing of the equipment actually in use under the conditions in which the actual operational missions are flown. Only such tests can reasonably assure verity in the final evaluation of this problem.

A THEORETICAL ANALYSIS OF DOWNWIND DRIFT OF HERBICIDE SPRAYED FROM AN AIRCRAFT

The problem of drift is here treated in its theoretical aspects. Two possible normal distributions of particle size output by the spray rig are postulated. Both employ a distributional median diameter of 300 microns; the first postulates a standard deviation of 100 microns, the second a standard deviation of 200 microns. Thus, in the first case, approximately 68% of the effluent particles will fall in the size range of 200-400 microns, and 95% in the range 100-500 microns. In the second case ($\sigma = 200\mu$), 68% of the particles will lie between 100-500 microns; 16% of the particles will be smaller than 100 microns and the remaining 16% may be expected to be larger than 500 microns. Tables 1 and 2 show the percentage of total particles which lie in the stipulated size categories for each of the two postulated distributions.

The goal of the analysis is to determine the percentage of total output mass of agent which moves downwind various distances from the line of release. The assumptions, besides those pertaining to particle size distribution, are a release altitude of 50 m (162.5 ft) and a 10-knot (11.5 mph) wind normal to the release line. Also implicit in the analysis is the assumption that the wind is constant in both speed and direction from the 50 m level down to the ground, and that the temperature gradient is neutral (i.e., neither inversion nor lapse conditions prevail). No account is taken of the possible effects of eddy currents since the numerical and positional occurence of these, and the possibilities of their being summative or self-neutralizing in their ultimate effects, is virtually imponderable.

Equations governing the rate of fall through the air of small particles are given in Mark's Standard Handbook for Mechanical Engineers (7^{o} ed.). In the region between 1000 microns and approximately 100 microns, the following approximation for terminal velocity holds:

$$v_t = (0.51)ks^{2/3}d,$$

where v_t is terminal velocity in cm/sec

$k = 0.81$ (for a sphere)

s = specific gravity of the particles (taken to be 1.25 gm/cc)*

d = diameter of the particle in microns

---

* 1.25 g/cc is the approximate density of herbicide ORANGE. WHITE has a density of 1.15, BLUE a density of 1.32. The use of either of these would change the outcome of the analysis by six or seven percent.

TABLE 1

Distribution of Particles by Size for $\mu = 300$, $\sigma = 100$.

SIZE CATEGORY		PERCENTAGE
0-25 microns		0.04%
25-75	"	0.92%
75-125	"	2.79%
125-175	"	6.56%
175-225	"	12.10%
225-275	"	17.97%
275-325	"	19.74%
325-375	"	17.97%
375-425	"	12.10%
425-475	"	6.56%
475-525	"	2.79%
525-575	"	0.92%
>575	"	0.04%

TABLE 2

Distribution of Particles by Size for $\mu = 300$, $\sigma = 200$

SIZE CATEGORY		PERCENTAGE
0-25 microns		8.44%
25-75	"	4.58%
75-125	"	6.05%
125-175	"	7.52%
175-225	"	8.78%
225-275	"	9.64%
275-325	"	9.95%
325-375	"	9.64%
375-425	"	8.78%
425-475	"	7.52%
475-525	"	6.05%
525-575	"	4.58%
> 575	"	8.47%

In the region between approximately 100 microns and 10 microns, the more familiar Stokes' Law governs the settling rate of the particles:

$$v_t = (0.51)ksd^2$$

where v_t is terminal velocity in cm/sec

$k = 5.9 \times 10^{-3}$ for spherical particles

s = specific gravity (1.25 g/cc)*

d = diameter of particle in microns

Both curves are shown in figure 1. It may be seen that the two curves cross at the point d = 125. A composite curve, constructed of the appropriate segment of each curve, was employed to yield the terminal velocity of particles throughout the size range of interest.

The downwind travel of a particle of a given size is directly proportional to the altitude of release and the ratio of its terminal velocity to the velocity of the wind, i.e., $S = h \frac{v_w}{v_t}$. In the specific case of a particle at an altitude of 50 m in a 10-knot wind, the horizontal distance S from the line of release to touchdown is given by $S = 5000 \frac{508}{v_t} \times 10^{-3}$, for S in meters. Figure 2 shows the downwind drift of particles in the size range of interest in this paper.

The next step in the analysis is a determination of the relative amounts of the total mass of released agent which fall into each size range for each distribution. This quantity is calculated from the relative number of particles in each size range and the relative mass of a particle in each size range, thusly:

$$P_i = \frac{100 n_i V_i}{\sum_{1}^{N} n_i V_i}$$

where P_i is the percentage of the total output mass in the i^{th} size range

* See footnote, page 3-B

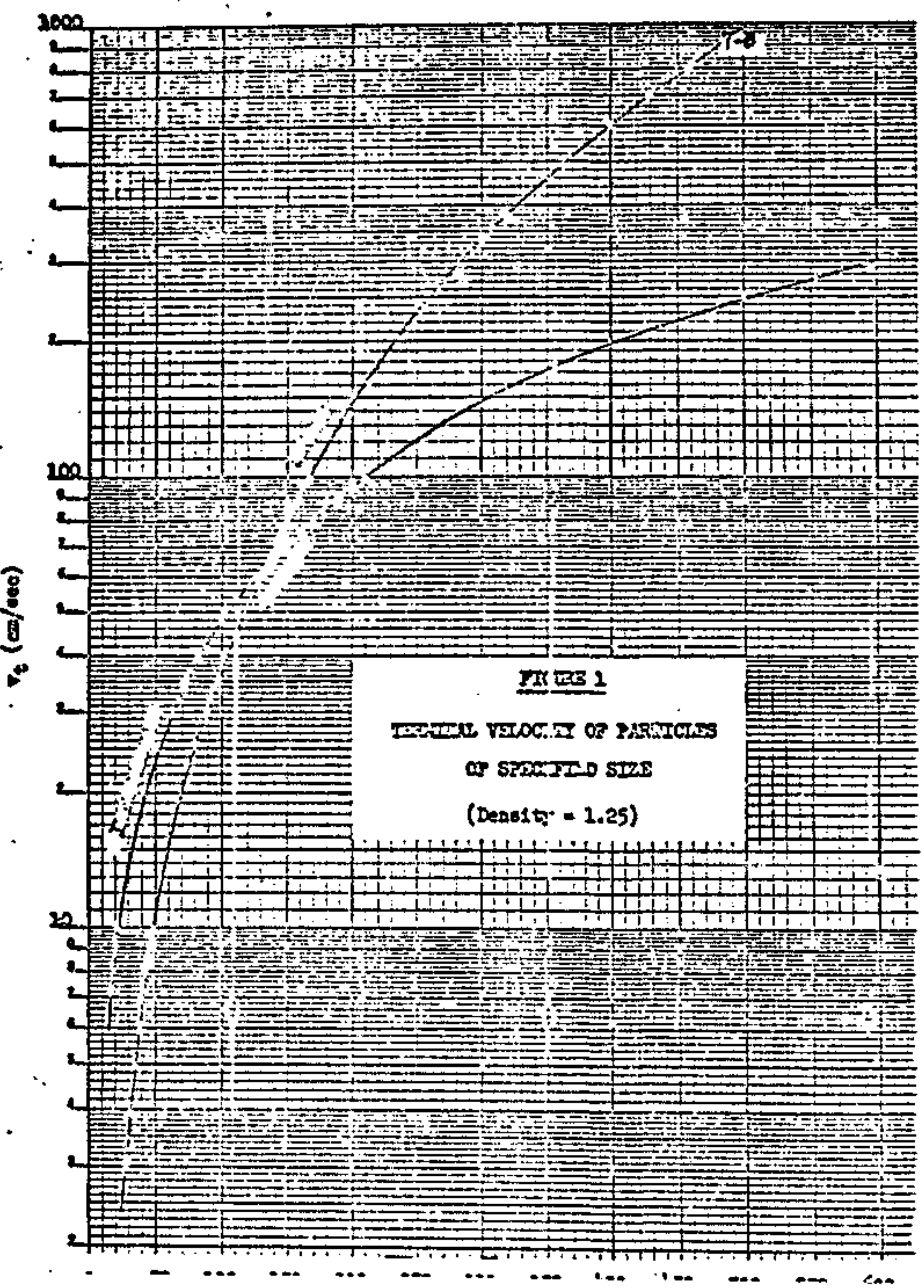

FIGURE 1

TERMINAL VELOCITY OF PARTICLES OF SPECIFIED SIZE

(Density = 1.25)

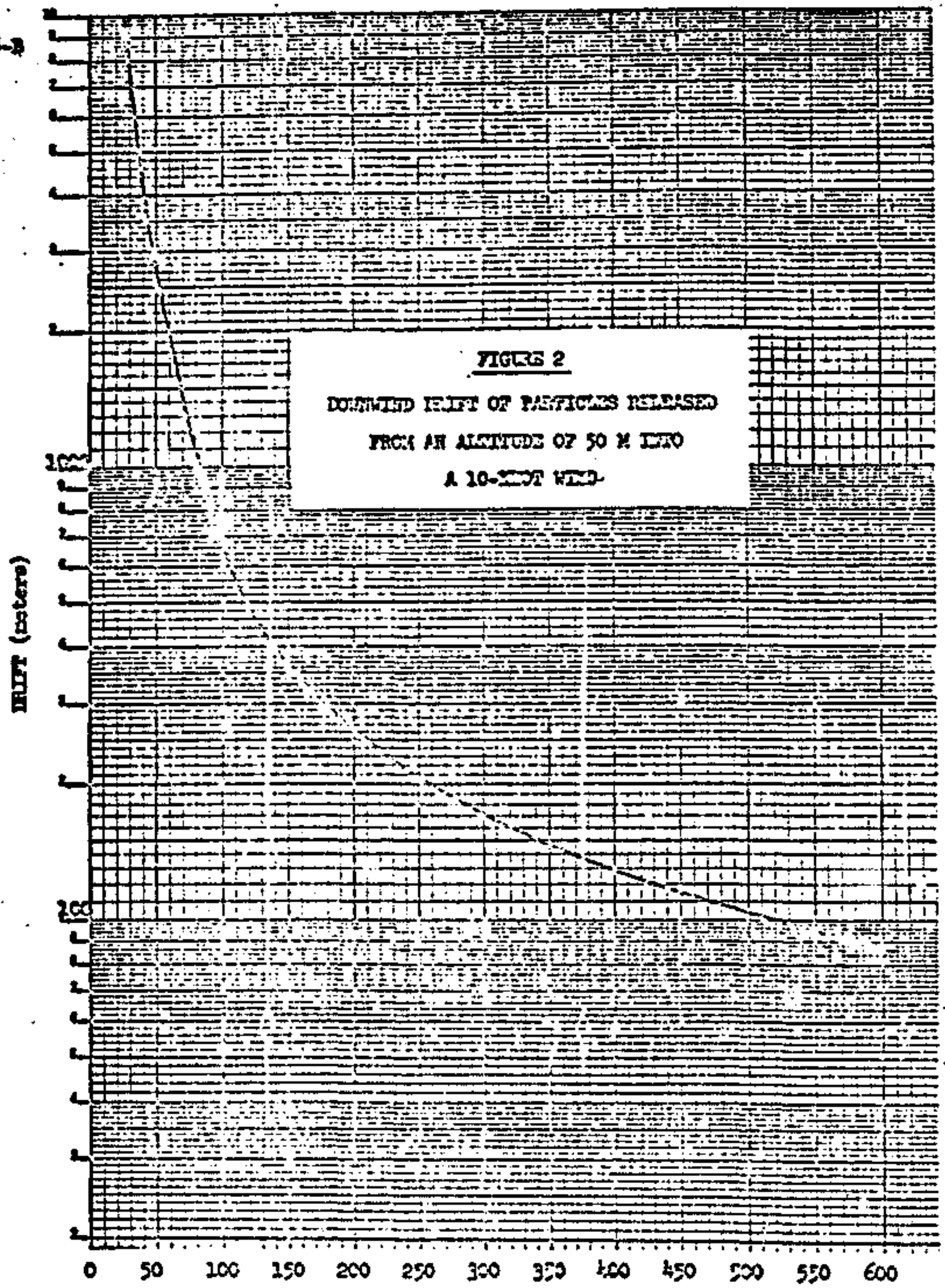

FIGURE 2

DOWNWIND DRIFT OF PARTICLES RELEASED FROM AN ALTITUDE OF 50 M INTO A 10-KNOT WIND.

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n_i is the percentage of all output particles falling in the i^{th} size range

V_i is the volume of a sphere in the i^{th} size range

$\sum_{1}^{N}$ is the sum of all the products of n_iV_i

Table 3 shows the results of these calculations for each of the two hypothetical particle size distributions in terms of the percentage of total output mass which falls into each size category.

By combining table 3 and figure 2, we may determine the percentage of the total output mass of agent which drifts various distances downwind. These data are shown in table 4. Table 5 shows the cumulative percentage of the total mass of output agent which falls out by various distances downwind. An examination of table 5 indicates that, under the conditions stipulated (i.e., 50 m release altitude, 10-knot wind), 99% of the agent released by the aircraft reaches the ground by 262 meters (852 ft) downwind of the aircraft line of flight, and 99.9% by 348 m (1131 ft) downwind. Thus, for an aircraft calibrated to produce an agent concentration of 3 gal/acre more or less directly under the plane, under the assumptions made here, one may also expect to produce ground concentrations of 0.03 gal/acre approximately 262 m downwind, and less than 0.003 gal/acre beyond 348 m downwind. It should be pointed out however that tangible, though very small, amounts of the herbicide will drift as far downwind as 2 km.

As mentioned earlier, certain factors have been neglected in this theoretical analysis of the drift of herbicide particles off the target area. For one thing, the drift distance is directly proportional to the altitude of release. Employing a release altitude of 50 m (162.5 ft) means that fairly small absolute changes in the aircraft's altitude will have relatively large proportionate effect on the distance of drift. Also, in rolling terrain, as the aircraft attempts to fly the contours of the terrain, at certain points in the flight silhouette an upward vector will be imparted to the effluent, and it will tend to rise a little higher than the aircraft. Similarly, if the terrain elevation is falling in the downwind direction, the effluent will take longer to reach the ground and will be carried further downwind. Conversely, if the terrain rises, the particles will be intercepted earlier.

Another factor which is very difficult to fit into an analysis is the effect of turbulence around the aircraft and spray boom as the spray is injected from the nozzles into the slipstream. The vortices created near the wingtips and ends of the boom would tend, if they catch part of the effluent, to throw the particles in circles for a short time, so

TABLE 3

PERCENTAGE OF PARTICLES AND PERCENTAGE OF

TOTAL OUTPUT MASS BY SIZE RANGE

	$\sigma = 100\ \mu$		$\sigma = 200\ \mu$	
SIZE RANGE	% IN RANGE	% OF TOTAL MASS	% IN RANGE	% OF TOTAL MASS
0-25	0.04	< 0.01	8.44	< 0.01
25-75	0.92	< 0.01	4.58	0.01
75-125	2.79	0.08	6.05	0.11
125-175	6.56	0.62	7.52	0.61
175-225	12.10	2.70	8.78	1.27
225-275	17.97	7.82	9.64	2.72
275-325	19.74	14.84	9.95	4.85
325-375	17.97	21.46	9.64	7.47
375-425	12.10	21.61	8.78	10.18
425-475	6.56	16.65	7.52	12.36
475-525	2.79	9.73	6.05	13.69
525-575	0.92	4.26	4.58	13.75
> 575	0.04	0.24	8.47	33.12

TABLE 4

DOWNWIND DRIFT BY PERCENT OF TOTAL MASS OUTPUT

DOWNWIND DRIFT, M	PERCENTAGE OF TOTAL MASS OUTPUT $\sigma = 100$	$\sigma = 200$
5.08×10^4	<0.01	<0.01
2.70×10^3	<0.01	0.01
6.68×10^2	0.08	0.11
3.48×10^2	0.62	0.61
2.62×10^2	2.70	1.27
2.08×10^2	7.82	2.72
1.74×10^2	14.84	4.85
1.49×10^2	21.46	7.47
1.30×10^2	21.61	10.18
1.16×10^2	16.65	12.36
1.03×10^2	9.76	13.69
9.43×10^1	4.26	13.75
8.70×10^1	0.24	33.12

TABLE 5

CUMULATIVE PERCENTAGE OF TOTAL OUTPUT MASS FALLING OUT BY VARIOUS DISTANCES DOWNWIND

DISTANCE (meters)	PERCENTAGE $\sigma = 100$	PERCENTAGE $\sigma = 200$
8.70×10^1	0.24	33.12
9.48×10^1	4.50	46.87
1.05×10^2	14.26	60.56
1.16×10^2	30.91	72.92
1.30×10^2	52.52	83.10
1.49×10^2	73.98	90.57
1.74×10^2	88.82	95.42
2.08×10^2	96.64	98.14
2.62×10^2	99.34	99.41
3.48×10^2	99.96	>99.99
6.68×10^2	>99.99	*
2.70×10^3	*	*
5.08×10^4	*	*

that rather than beginning to drop immediately, they could maintain altitude for a few seconds and be carried downwind somewhat further than they otherwise would be. This effect is minimized somewhat in practice by not extending the spray booms all the way out to the wingtips.

Evaporation from the particles while in flight is another consideration. As a particle moves through the air, evaporation takes place and it becomes smaller and lighter, the effect of which is to permit it to be carried further downwind. However, since one of the factors governing rate of evaporation is exposed surface, this process moves in the direction of self-limitation. (Of course, it does not reach zero until the surface and mass reach zero). Also, since mass is directly proportional to volume (mass = density x volume), we may compare the equation which governs the volume of a sphere with the laws which govern its terminal velocity (which in turn leads directly to its downwind travel) to see how they behave as the particle grows smaller.

$$V_{sphere} = \frac{4}{3} \pi r^3$$

$$S = h \left(\frac{v_w}{2k_1 s^{2/3} r} \right) \quad \text{or}$$

$$S = h \left(\frac{4v_w}{k_2 s r^2} \right)$$

where S is downwind travel. It may be seen that, while the increase in downwind travel of a particle is proportionate either directly to the decrease of its radius or to the square of its radius, a reduction in radius produces a cubic decrease in its mass. In short, while evaporation may cause particles to float further downwind, it also acts, and in much more pronounced manner, to reduce the actual amount of agent which is finally deposited on the ground.

In conclusion, it should be pointed out that the foregoing theoretical analysis of the problem of drift of herbicide is not an adequate substitute for good operational testing of the spray equipment as it exists and is employed in Vietnam. Such an analysis at best yields only an idea of the magnitude of the problem. It tells us only that, under the altitude, windspeed, and atmospheric conditions which are employed as operational constraints in-country, and assuming that the equipment functions within reasonable reach of its design characteristics, then we should not expect to find significant fractions of the agent output moving great distances downwind.

APPENDIX C

TOXICITY OF HERBICIDES IN USE IN RVN

by

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2-C

SUMMARY

The toxicity of the three herbicides in large scale use as defoliants in RVN has been reviewed. With respect to the toxicity of ORANGE, the authors quote the conclusions presented in the Midwest Research Institute Report which states "...that the risk of human and animal toxicity from the use of 2,4-D and its various esters and salts is very, very low. Its possible effects on fish and fish foods may be a problem under certain conditions...2,4,5-T resembles 2,4-D in its toxicity to animals and fish but is a little more toxic ... no synergestic toxicities were noted in animals as a result of using these mixtures."

Data are presented on fish toxicity that was not available at the time the Midwest Research Institute Report was written, and the study concludes that there is very little fish toxicity hazard from the dosage of ORANGE being used. They also point out that during the time that ORANGE has been in use in RVN, there have been no reports of fish kill resulting from the use of this herbicide.

Toxicity data for BLUE (cacodylic acid) and WHITE (picloram and 2,4-D) are presented, and it is concluded that they also do not present safety hazards to using personnel or personnel who are sprayed. Food that has been sprayed can also be safely consumed since quantities of herbicide deposited per unit area do not constitute a hazardous dose.

TOXICITY OF HERBICIDES IN USE IN RVN

ORANGE

Herbicide ORANGE, the principal defoliant being used in RVN, is composed of the butyl esters of 2,4-D and 2,4,5-T, two of the most widely used herbicides in agricultural and industrial vegetation control. Until 1965 there had been no substantial case of death to man or animals due to these two herbicides in the more than 20 years that they have been in large scale use.

In 1965, Di Palma* reported that a man committed suicide by consuming about 6.5 grams of 2,4-D. Millions of gallons of ORANGE have been handled by ARVN and US personnel during the past 5 years without any reports of illness even though ARVN personnel frequently work in clothing soaked with herbicide. Personnel involved in manufacturing these herbicides have also been singularly free from ill effects attributable to these herbicides even though they were exposed to them for long periods of time on a daily basis. It must therefore be concluded that even prolonged exposure to ORANGE is not harmful to humans except in those rare instances where an individual may have a specific allergy to this substance.

A detailed review of herbicide toxicological data is contained in "Assessment of Ecological Effects of Extensive or Repeated Use of Herbicides" prepared by Midwest Research Institute in 1967. The authors concluded "...that the risk of human and animal toxicity from the use of 2,4-D and its various esters and salts is very, very low. Its possible effects on fish and or fish foods may be a problem under certain conditions." With respect to 2,4,5-T they state "In summary, 2,4,5-T resembles 2,4-D in its toxicity to animals and fish but is a little more toxic ... no synergistic toxicities were noted in animals as a result of using these mixtures."

The toxicity to fish varies with the species, the salt or ester of 2,4-D or 2,4,5-T employed and the duration of exposure. For example the LD_{50} in 48 hours for the dimethylamine salt of 2,4-D for bluegill sunfish is 166-458 ppm while in 9[illegible] hours for fathead minnow it is 10 ppm.

A 2,4-D alkanolamine salt has an LD_{50} of 435-840 ppm for bluegills while the propylene glycolbutyl ether, butoxyethyl, ethyl, butyl and isopropyl esters have LD_{50}'s ranging from 1.1 to 2 ppm.

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* Di Palma, J. R. (Ed.), p. 1003 from Drill's Pharmacology in Medicine, McGraw-Hill Book Co., New York (1965).

One ppm is the equivalent of 2.72 lbs of herbicide per acre-foot of water. If 3 gallons of ORANGE were sprayed on an acre of water one foot deep, the concentration would be approximately 11 ppm. This would be a toxic dose for bluegills if the exposure to this concentration were 48 hours or longer. In bodies of water deeper than one foot, the concentration would be proportionately decreased. If the herbicide fell on a stream with even a slow current, the herbicide would move down stream and might not expose the fish to the lethal dose for more than a few hours. It should be noted that in the past few years with the large volumes of herbicide being disseminated in Vietnam, there have been no reports of fish kill attributed to herbicides.

BLUE

The active ingredient of BLUE or Phytar 560G is cacodylic acid as its sodium salt. Cacodylic acid is dimethyl arsenic acid in which the arsenic is in the innocuous pentavalent state rather than the toxic trivalent state. Cacodylic acid has been used medicinally for years, being administered either orally as pills or by hypodermic injection in doses varying from 0.025 to 0.15 grams/day. Human toxicity information is not available, but personnel involved in the manufacturing process who have been exposed to this herbicide over long periods of time feel that the toxicity must be relatively low.

Acute oral toxicity (LD_{50}) of cacodylic acid in rats is 1400 mg/kg for males and 1200 mg/kg for females. Skin tests on albino rabbits with cacodylic acid itself and a commercial formulation of cacodylic acid were found to be essentially non-irritating to the skin. Cows fed 24.5 mg/kg of cacodylic acid daily in a 60 day feeding test showed no arsenic in the milk, but arsenic was excreted, principally in the urine. After 30 days, the amount ingested was balanced by the amount excreted. The cows were sacrificed after 60 days and ten tissue components and bone were analyzed for arsenic. No tissues stored arsenic compounds on a cumulative basis even though fractional parts per million of arsenic were detected in the liver, spleen and pancreas.

Fish are able to withstand concentrations of cacodylic acid of at least 100 ppm for 72 hours. The LD_{50} for Gambusia and Notrophis was reported to be about 631 ppm for 72 hours.

Pink shrimp, eastern oysters and longnose killifish were able to tolerate 40 ppm for 48 hours with no effects.

A review of data on the relationship between arsenicals and cancer has shown no greater incidence of systemic cancer in humans for those individuals who were exposed to arsenic trioxide over long periods of time than for those who were not. However, there is one report that indicates that cacodylic acid, when injected into mice, produced "profound disturbances of cell division" and stimulated mitosis in cells of the crypts of Lieberkuehn and of transplanted tumors.

Exposure to tadpoles to 100 ppm of cacodylic acid (equivalent to 270 lb/acre foot of water) produced abnormalties during embryonic development.

Since cacodylic acid is currently being employed at a rate no higher than 9.3 lb per acre, it is safe to assume that there will be no harm to man or animals at these use rates. The high tolerance of rats, other laboratory animals and fish to this herbicide place it in a safer category than herbicide ORANGE.

WHITE

TORDON 101 mixture which is composed of 2,4-D and picloram as the tri-isopropanalamine salt is the most recently introduced herbicide in Vietnam.

The toxicity of 2,4-D has been discussed under ORANGE and will not be repeated here. However, since WHITE includes surfectants and other adjuvants, toxicological data on the actual agent has been determined as well as on picloram alone.

Picloram has an oral LD_{50} for rats of 8200 mg/kg; for mouse 2000; guinea pig 3000; rabbit 1670 - 2000; sheep > 650; cattle > 488.

For TORDON 101, oral LD_{50} for rat has been reported as 3080 mg/kg; for sheep 2000; for cattle > 3163.

In a feeding test with a cow, 97.7 of the administered picloram was recovered unchanged in the urine. No picloram was detected in the milk.

The median tolerance limits of TORDON 101 to fish are as follows: fathead minnow, 64 ppm; brook trout, 240 ppm; brown trout, 230 ppm; rainbow trout, 150 ppm; green sunfish, 150 ppm.

Thus, it is apparent that neither picloram nor WHITE is to be considered toxic or hazardous to humans, animals or fish at the use rates being employed in Vietnam.

APPENDIX D

PERSISTENCE OF HERBICIDES IN SOIL AND WATER

by

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6 April 1968

SUMMARY

The persistence in soils and water of the three principal herbicides, ORANGE, WHITE and BLUE, used in RVN defoliation operations has been evaluated.

2,4-D and 2,4,5-T butyl esters in agent ORANGE are not persistent in soil. Microbial decomposition takes place rapidly and the chemicals disappear in one to three months at the rates of application used in RVN. Germination tests of Black Valentine beans in soils from areas in Bien Hoa and Binh Long Provinces which had been defoliated with ORANGE in 1966 showed no residual effects of chemical.

Agent WHITE, containing a mixture of picloram and 2,4-D amines, shows greater persistence than ORANGE due to its lower rate of microbial degradation. In Puerto Rico tests, the amount of chemical remaining 6 to 12 months after direct application to the soil of picloram in amounts 4 to 6 times greater than that used in RVN defoliation operations was insufficient to cause injury to planted crop seedlings of all but the most sensitive crop, soybeans. As confirmed in bean seedling tests on soils from two RVN provinces taken from 1966 and 1967 defoliation targets, no persistence of herbicide was found 11 to 17 months after single and double applications of WHITE. It is concluded that despite the greater persistence of WHITE in soils than ORANGE, the residual amounts are not detrimental to crop growth in sprayed areas in the crop season following defoliation.

Agent BLUE or cacodylic acid is rapidly absorbed and inactivated in soils. Field tests have shown that susceptible crops can be planted directly in soils within a few days after application of cacodylic acid at rates greater than the 3 gallons per acre used in RVN.

No direct evidence has been found of persistence of toxic residues in surface drainage and streamflow following applications of defoliants in RVN. Streamflow analysis in Oregon and other US locations has shown a rapid dissipation of 2,4-D and 2,4,5-T in drainage waters from aerial spray applications on forested areas. No detrimental effects on fish and other aquatic organisms were noted in streams on sprayed areas. Applications of 2,4-D and related herbicides are made directly into streams and reservoirs for aquatic weed control in temperate climates at rates considerably higher than those used for defoliation of RVN vegetation without detrimental effects on fish and other aquatic organisms or impairment of water quality.

In view of the minimal quantities of herbicide available for surface runoff into watershed drainages and streamflows from defoliated areas due to removal by vegetational interception, soil adsorption and the rapid chemical and photochemical decomposition and microbial degradation in soils, it appears extremely unlikely that toxic amounts of chemical will occur in drainage waters from defoliated areas.

PERSISTENCE OF HERBICIDES IN SOIL AND WATER

The persistence and degradation of herbicides are important aspects in an understanding of the ecological consequences of defoliation. The heavy rates of herbicide application used in defoliation in RVN have caused concern as to the persistence and subsequent effects of herbicides in soils and drainage water.

The herbicide reaching the soil surface following foliage applications are subject to:

(1) Leaching or transport in water downflow in the soil.
(2) Surface runoff into drainage channels and streams.
(3) Degradation by photo-decomposition, chemical breakdown and microbial degradation.

The rate of leaching is influenced by:

(1) Solubility of the herbicide.
(2) Effect of adsorption of the herbicide in the soil as related to soil type.
(3) Climatic conditions, particularly rainfall and temperature.

Herbicides in soils are further subject to loss by decomposition or degradation by chemical hydrolysis and by microbiological activity. The net amount of herbicide remaining in soils or other substances after herbicide application is thus subject to a complex array of variables.

Objective of the present discussion is to evaluate the available information on persistence of the three major herbicides used in RVN, ORANGE, WHITE and BLUE, in soils and water.

Persistence in Soils.

ORANGE

The butyl esters of 2,4-D and 2,4,5-T, comprising herbicide ORANGE, are relatively insoluble in water and resist washing from plant foliage. The amount of ORANGE reaching the soil during spray applications is influenced by the density of vegetation cover and the amount of washing of the herbicide from foliage by precipitation following spray application. ORANGE retained on either foliage or soil surface is subject to decomposition by sunlight.

Data available on persistence of 2,4-D and 2,4,5-T esters in soils from Sheets and Harris (1) indicate that residual phytotoxicity from 2,4-D at applications up to 40 lb/acre persisted about one month in greenhouse tests. In field tests, a 5 pound application of 2,4-D lasted one month while similar rates of 2,4,5-T ester persisted for three months. Low moisture conditions and low temperature may extend the period of persistence.

Bovey, Miller and Diaz-Colon (2) in studies conducted in Puerto Rico of crop seedling growth in soils following spray applications of 3 gal/acre of ORANGE on Guava found that the herbicide persisted for only one to two months in soils after herbicide application.

Numerous investigations have shown that the 2,4-D and 2,4,5-T esters in ORANGE are readily decomposed by microbiological activity. Audus (3) states that 2,4-D is the least persistent of a large number of herbicides investigated, and detoxification due to microorganisms was found to occur in 16 to 94 days depending upon soil type. Brown and Mitchell (4) in 1948 pointed out that the disappearance of 2,4-D in soils was favored by high temperature and by high moisture and organic contents; sterilization of the soil led to greatly reduced rates of detoxification. 2,4,5-T esters react in a similar manner.

As a part of the current investigation in RVN, the residual effects of ORANGE and WHITE were studied on soils from Bien Hoa and Binh Long Provinces by evaluation of Black Valentine bean seedlings grown in soil samples from defoliated and untreated areas with similar soil and vegetation. Bean seedlings were grown for a period of 9 days in soil samples from 0-3", 3-6" and 6-12" depths. No residual effects of ORANGE herbicide were found in soils from areas treated in single applications in September 1966 and with two applications in November 1966. Attempts to secure soil samples from areas defoliated in 1967 were unsuccessful due to lack of security in potential sites.

It is concluded that under tropical conditions in RVN, vegetated areas treated with ORANGE at 3 or 6 gallons per acre show no residual effects of herbicide in soil after a period of several months, although the limited data on soil persistence were taken on areas treated more than 12 months previous. The relatively rapid recovery of understory vegetation and establishment of vines and new plants on defoliated areas points to the rapid disappearance of ORANGE from soils of defoliated areas.

WHITE

Agent WHITE consists of a mixture of 0.54 lb/gal of picloram and 2.0 lb/gal of 2,4-D as tri-isopropanolamine salts in a water solution. As previously noted, 2,4-D formulated as ester or amine is readily decomposed in soil due to microbiological and chemical breakdown. Picloram or TORDON (4-amino-3,5,6-trichloropicolinic acid), the other phyto-toxic component of agent WHITE, is characterized by high solubility in water but is relatively presistent to microbial decomposition as compared to 2,4-D and 2,4,5-T. In the acid form, picloram has a solubility to 430 ppm in water at 25° C; the triisopropanolamine salt of picloram is highly soluble (5).

As a consequence of its high solubility in water, agent WHITE is readily leached downward in soils and herbicide remaining on foliage after application may be washed off and become incorporated into the soil. The amount of herbicide which reaches the ground surface for incorporation into the soil is strongly influenced by the density of vegetation cover. Merkle, Bovey and Hall (6) reported that only 10% of TORDON applied to a dense vegetation cover of live oak in Texas actually reached the soil. Under multiple canopy vegetation in RVN, the amount of active WHITE reaching the soil during aerial application or in subsequent washoff from the foliage is undoubtedly of a low order of magnitude.

Picloram or TORDON is absorbed rapidly by foliage, and translocation into the remaining parts of the plant takes place rapidly even though defoliation symptoms develop slowly (5).

Picloram exposed to sunlight and ultraviolet light undergoes degradation and loss of phytotoxicity, further reducing the amount of residual herbicide in soils (5). Tschirley (7) reported that 60% of picloram exposed in thin layers to ultraviolet light was degraded after 48 hours whereas 35% was degraded by sunlight; after seven days, more than 90% was degraded by ultraviolet light and 65% by sunlight.

WHITE or picloram is leached most rapidly in sandy or medium textured soils. In laterites, clays and soils high in organic matter, adsorption of the chemical results in reduced rates of leaching. Penetration to depths of 2 to 4 feet are reported in most soils although in clay soils with high organic matter, the chemical tends to stay in the upper 6 inches. Tschirley (7) reported on vegetation responses and soil residues following picloram applications in Puerto Rico at rates of 3, 9 and 27 pounds/acre on three clay and clay loam soils. At 12 months after application of picloram at 9 lb/acre under yearly rainfall of 85 to 126 inches, residues less than .005 parts per million (ppm) were found throughout the 4 foot soil profile. Of the crops grown in RVN only soybeans would be affected by this residual amount of picloram. The dosage rate of picloram (9 lb/acre) in the Puerto Rico tests was six times heavier than that in RVN defoliation using agent WHITE.

In other tests in Puerto Rico, Bovey, Miller and Diaz-Colon (2) grew seedlings of five crop species in surface soils following foliage application of picloram on Guava at 6 lbs/acre. All crop species, including soybeans, could be safely planted six months after picloram treatment without adversely affecting growth. Soybeans are one of the most susceptible plants to picloram with 90% kill in treatments at 0.006 ppm prior to seedling emergence. By contrast, germinating rice is killed by 0.75 ppm picloram in soils, an amount 125 times as great as for soybeans. In these Puerto Rico tests, 23 inches of precipitation completely removed phytotoxic amounts of picloram from the soil.

Similar evaluations of residual phytotoxicity from WHITE were made in March 1968 from two locations in RVN on sites treated with single applications of WHITE in November 1966 and April 1967, and of double treatments in August 1966 and January 1967, and in January and April 1967 representing rates of 1.5 and 3.0 lb/acre of picloram, respectively. No phytotoxic effects were obtained on 9-day-old Black Valentine bean plants from residual amounts of picloram in soils 11 to 17 months after defoliation treatment.

As indicated in the discussion of ORANGE persistence, no recent soil samples of areas treated with WHITE were available for evaluation. Calibration tests of Black Valentine beans at Fort Detrick show that 0.025 ppm of residual picloram is lethal, and reduced growth may occur at rates of 0.005 ppm as in soybeans. From the limited data available, areas treated with WHITE show no toxicity to the most sensitive crops 12 months after defoliant application.

BLUE

Cacodylic acid or agent BLUE is rapidly de-activated in contact with soils and causes no residual toxicity problem from applications at rates used in RVN.

In tests reported by Ehman (8), alfalfa and rye grass planted within three days after application of cacodylic acid at 5 lb/acre showed no inhibition of growth or residue of arsenic in crop yields. No arsenic residues were found in grapefruit after application of 10 lb/acre of cacodylic acid. In similar tests with the closely related compound, disodium methane arsenate (DSMA), at 9.5, 31.5 and 63 lb/acre, cotton, soybeans and sorghum planted on the day of treatment all developed normally.

Cacodylic acid is strongly adsorbed and inactivated by a wide range of soil types. In leaching tests with 60 inches of water following application of 15 lb/acre of cacodylic acid, only 9% leaching occurred in sand and 6% in sandy loam soils. This low rate points to the high rate of adsorption and inactivation of cacodylic acid in most soils. The extent and rate of inactivation is related to the amount applied, soil moisture content, rainfall after application (which hastens the rate of inactivation) and soil type. At usual rates of application, inactivation is practically complete in about one week in most soils. Because of this inactivation, cacodylic acid shows negligible herbicide response on subsequent planted crops.

TABLE 1

Persistence of Herbicide in Soil Horizons of Defoliated and Untreated Areas

In Bien Hoa and Binh Long Provinces

Bioassay with Black Valentine Bean Seedlings

BIEN HOA PROVINCE a/

	HERBICIDE	DATE	DEFOLIATION EFFECT	SOIL TYPE	HERBICIDE RESPONSE IN SOIL HORIZON 0-3"	3-6"	6-12"
1.	ORANGE	Sep 66	Canopy dead. Some undergrowth.	Grey brown sandy loam	NONE	NONE	NONE
2.	NONE	-	-	Yellow brown sandy loam	*	*	*
3.	WHITE	Apr 67	Top canopy bare. Regrowth in lower Canopy. Dense undergrowth.	Yellow brown sandy loam	*	*	*
4.	NONE	-	-	Black-brown silt loam	*	*	*
5.	WHITE	Jan 67 & Apr 67	Not noted.	Yellow brown sandy loam	*	*	*
6.	WHITE	Aug 66 & Jan 67	Canopy bare. Vine regrowth. Brush & grass undergrowth.	Yellow brown sandy loam	*	*	*
7.	NONE	-	-	Light brown sandy loam	*	*	*

BINH LONG PROVINCE b/

	HERBICIDE	DATE	DEFOLIATION EFFECT	SOIL TYPE	HERBICIDE RESPONSE IN SOIL HORIZON 0-3"	3-6"	6-12"
1.	WHITE	Nov 66	Canopy 90% defoliated. Undergrowth dense.	Grey brown sand	NONE	NONE	NONE
2.	ORANGE	2 Nov 66 & 15 Nov 66	Canopy 90% defoliated. Undergrowth dense.	Grey brown sand	"	"	"
3.	NONE	-	-	Grey brown sand to sandy loam	"	"	"
4.	ORANGE	Sep 66	Area Rome-Plowed and burned one year after spray. Small shrubby regrowth.	Grey brown sand	"	"	no germination

a/ Bien Hoa Province, 5-8 kilometers east of Long Binh.

b/ Binh Long Province, 20 kilometers south of An Loc on Highway 13.

Persistence in Water.

ORANGE

The accumulations of defoliant herbicides in surface drainages and their possible persistence in streams, lakes and reservoirs have been presented as a potential outcome of large-scale defoliation treatments.

Limited data are available on the amount of herbicide in streams and watershed drainages following herbicide applications of forested lands and from direct application of herbicides in streams and reservoirs.

Tarrant and Norris (9) reported only a light and short-lived contamination of stream water in Oregon as a result of aerial spraying with 2,4-D and 2,4,5-T at 2 lb/acre. The amount of chemical in stream water immediately after aerial application ranged from 0.2 to 70 parts per billion (ppb) but dropped to 0.2 ppb within a few days. No effect of herbicide was noted from these concentrations on salmon fry or stream bottom organisms. In other evaluations of herbicide content of stream drainage reported by House, et al (10) following aerial spraying and basal stem treatment with 2,4-D and 2,4,5-T at 3 lb/acre, no traces of herbicides were found in streamflow, and only traces in soils at 8 days after treatment.

Extensive use of 2,4-D and related phenoxy herbicides has been made for control of aquatic weeds in direct applications to streams and lakes without harmful effects on fish and aquatic organisms. Smith and Isom (11) have reported no adverse effects on aquatic organisms or water quality from applications of heavy rates of 2,4-D (44 to 100 lb/acre) made directly in the water of TVA reservoirs. These rates greatly exceed the 25 lb/acre acid equivalent of 2,4-D and 2,4,5-T used in RVN defoliation application. Recommended practices for aquatic weed control in temperate regions include 2,4-D at 4 to 6 lb/acre and the related phenoxy compound, 2,4,5-TP or SILVEX at 8 lb/acre which represent safe dosage limits in terms of effects on aquatic organisms, fish and water quality. With dilution from normal rainfall and watershed drainage following defoliation operations with ORANGE in RVN, the dosage levels in drainages would be substantially below toxic levels for fish and aquatic organisms.

There have been no reported instances of fish kill or reduction in fish catch in inland and coastal waters in South Vietnam as reported by the RVN Department of Fisheries. Although direct evidence of herbicide residues in streams and waterways of RVN is not available, indirect evidence points strongly to the conclusion that no harmful ecological consequences have resulted from the use of ORANGE and other defoliants on forest vegetation in RVN.

WHITE

Little information is available on the persistence of WHITE or picloram residues in a water environment.

Degradation of picloram in water by sunlight is reported by House, et al (10) to amount to 0.04 of 0.5 lb of picloram/acre/day at solution depths of 12 feet to 0.1 inch. At low concentrations, the rate of decomposition appears to increase with increased depth of water. Further, in deep water, rate of decomposition is more rapid when the water is circulating than when calm.

With the high degree of solubility of agent WHITE in water, surface washing into streams and drainage channels would normally lead to rapid diffusion and dissipation below limits which could affect water quality and toxicity to fish and aquatic organisms. Thus the combination of high solubility and rapid degradation of picloram in water solution by sunlight would tend to cause rapid disappearance of WHITE in water and lack of lethal residues.

BLUE

Cacodylic acid or agent BLUE contains 3.1 lb/gallon of sodium cacodylate and cacodylic acid in a water solution. Because of its high solubility, cacodylic acid is readily diffused in a water environment and should rapidly dissipate in normal stream flow.

Following the use of BLUE in foliage spray application for destruction of rice crops, the residual cacodylic acid will be rapidly adsorbed by soil as indicated in the earlier discussion. Although some varieties of rice are killed with cacodylic acid at rates of 0.5 to 1.0 lb/acre in foliage spray application, tests at Fort Detrick have shown that rates of 16 lb/acre and higher are required for kill of paddy rice when the herbicide is applied in water under field conditions.

Leaching and transport of toxic residues of BLUE would appear to present no hazard to adjacent crops or deleterious effects on water quality in streamflow or irrigation water from treated areas.

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APPENDIX E

POTENTIAL HAZARDS OF HERBICIDE VAPORS

by

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SUMMARY

Two of the three herbicides currently in large-scale use in Vietnam, agents BLUE and WHITE, are aqueous solutions of water soluble solids. The active ingredients are non-volatile, and therefore there is no vapor hazard associated with their use.

Although ORANGE is classified as a volatile herbicide by plant physiologists, the physical chemist regards it as essentially non-volatile. Damage arising from its vapor in defoliation operations in Vietnam are not significant. These hazards are adequately controlled under current techniques of application.

POTENTIAL HAZARDS OF HERBICIDE VAPORS

Two of the three herbicides currently in large-scale use in Vietnam, agents BLUE and WHITE, are aqueous solutions of water soluble solids. The active ingredients are non-volatile, and therefore there is no vapor hazard associated with their use.

In the field of vegetation control, ORANGE is regarded as a volatile herbicide. However, the physical chemist would regard it as essentially non-volatile.

Table 1 shows the comparative volatility of butyl 2,4-D and other common chemicals. The volatility of ORANGE is assumed to be essentially the same as that of butyl 2,4-D, a component of ORANGE. Values in the table are the temperatures at which the vapor pressure of the material equals 1 mm of mercury. A high value, such as that of butyl 2,4-D, thus represents low volatility.

Severity of plant responses is a function of vapor concentration and time of exposure. Vapors can arise from the spray drops regardless of their location. The fate of vapors arising in the following situations are considered in this study: (a) during drop fall from the aircraft under lapse and inversion conditions; (b) from herbicide deposited on the upper canopy; (c) from herbicide deposited below the upper canopy.

Since the vapor pressure of ORANGE is so low, and since approximately 97% of the spray volume is deposited on the ground or vegetation in less than one minute following release from the aircraft, it is concluded that the quantity of vapor released during droplet descent represents an extremely small percentage of the entire mass of herbicide sprayed.

Since evaporation is a function of surface area, most of the vapors that arise during a spray operation will come from the small drops which present the largest surface area; however, the percent of the total mass of herbicide that consists of drops 100 microns or smaller is less than 1%. Therefore, the vapors arising from this source during droplet descent would be an extremely small fraction of the total mass of herbicide released.

The vapors, being gaseous, behave in accordance with the laws of gaseous diffusion and under inversion conditions tend to fill the entire space between the bottom of the inversion layer and the ground. This diffusion results in dilution of the vapors, thus reducing herbicide vapor hazard. The rate of downwind movement of vapors, and

TABLE 1

Relative Volatility of Common Chemicals*

Temperature at which vapor pressure equals 1 mm of mercury:

SUBSTANCE	TEMPERATURE °C
Water	-17
Butyl Alcohol	- 1
Ethyl Glycol (permanent anti-freeze)	53
Naphthalene (solid moth balls)	53
Hexachlorobenzene	114
Kerosene	120
No. 1 Fuel Oil	120
Glycerine	125
Butyl 2,4-D	147
No. 2 Fuel Oil	(153)

* Data from Handbook of Chemistry and Physics

therefore the duration of exposure of plants to the vapors, is dependent upon wind speed in the first few minutes subsequent to spray release. While no quantitative data are available, it is our considered judgement, based on the above reasoning, that vapors arising during the actual spray operation, as usually carried out, can be dismissed as a source of herbicide for crop damage outside target areas.

If lapse conditions exist during the spray operation, vapors produced at that time will rise above the vegetation in convection currents, become diluted in the atmosphere and thus be removed as a potential crop hazard.

Under neutral conditions, when there is no vertical air movement due to temperature differences, vapors of ORANGE will be affected in the same manner as under inversion conditions except for the upper limit of diffusion. Since there is no inversion cap under neutral conditions, the vapors will be unrestricted in their upward movement, but downward movement toward the earth will also occur.

Since there is no vertical air movement under neutral conditions, the diffusion rate will be much slower than under strong lapse or inversion. The vapors will fill a large volume of air and thus become more diluted, but a longer period of time will be required for this to occur.

If there is wind during this period, the vapor cloud will move with it. However, there generally is a calm period during neutral conditions when the change-over from inversion to lapse occurs. This generally lasts for about an hour. During this period the vapor cloud will remain stationary or nearly so within or above the sprayed area. If there should be a slight breeze (2-3 mph), the cloud would move out of the sprayed area and could affect plants 2-3 miles immediately downwind of the target. Plant damage might occur under these circumstances if the concentration of the vapor and the exposure time were sufficiently great.

Frequently after the change-over to lapse, wind speed increases, thus reducing time of exposure to crops.

The greatest hazard of vapor damage occurs under neutral conditions and near-calm winds. However, only crops within 2-3 miles of the target will be exposed for a sufficiently long period of time to be affected. For this reason it is strongly recommended that spray missions be carried out only under inversion conditions insofar as the tactical situation permits.

Vapors from the herbicide deposited upon the upper layer of the canopy might also be considered a possible hazard to sensitive crops outside the sprayed area. However, absorption of herbicide ORANGE commences almost immediately upon being deposited on a leaf surface, and a lethal dose can be absorbed within a matter of minutes by small actively growing broadleaf plants. Absorption of the drops falling on the upper canopy removes some of the herbicide from the leaf surface, but the unabsorbed portion is subject to evaporation, yielding unknown quantities of vapors. However, under inversion conditions, vapors will filter down to the ground within the jungle, and under lapse conditions they will rise above the canopy and be dissipated.

The drops that filter down into the jungle and are intercepted at intermediate and lower levels release vapors, but these are entrapped "in situ" since there is very little, if any, horizontal air movement within the jungle.

Vapors that are released within the jungle continue to be absorbed by the plants in the sprayed area, thus supplementing the effects of the herbicide that was absorbed from the liquid drops.

Several days after spray applications have been made, it is possible to detect the odor of herbicide within the sprayed area but not outside it. It has been observed that broadleaf plants in adjacent unsprayed areas have not shown herbicide responses, indicating absence of significant lateral movement of herbicide vapors within and out of the jungle.

One of the authors has photographed rubber trees that were sprayed with ORANGE. The swath is quite distinct with a sharp line between the sprayed and unsprayed areas. If volatility were a serious hazard, one would expect to see a gradation of effects between the sprayed and unsprayed areas as vapors released from the sprayed area drifted toward the unsprayed area. Since rubber is sensitive to ORANGE, one can conclude that there was no lateral vapor movement or that the vapor concentration was insufficient to induce plant responses.

The crop damage that is attributed to herbicide vapors in the US occurs under different conditions. Generally the vegetation that is sprayed is not as tall or dense as the Vietnamese jungle. In some cases the sprayed area might be another crop such as rice. Movement of vapors from vegetation patterns of this type can occur more readily than from dense jungle. Moreover, much of the damage that has been reported has been to cotton, which is injured at dosage rates as low as 0.1 lb/A of 2,4-D when in early stages of development. Frequently with lower doses or at later stages of development, cotton will show severe leaf malformations, but yield of seed cotton will not be affected.

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