

## CHAPTER 3

### THE MILITARY USE OF TACTICAL HERBICIDES IN VIETNAM

The use of herbicides became a new technique in the arsenal for modern warfare when it was introduced into the armed conflict in Vietnam in 1962. "Tactical Herbicides" were used in a defensive role for defoliation. They were also used in offensive roles for crop denial and exposure of enemy weapons caches, transportation routes, and base camps. A large body of historical data exists on the use of tactical herbicides in Vietnam. The history of Operation RANCH HAND in Vietnam has been thoroughly documented in books by Buckingham in 1982 (*OPERATION RANCH HAND: The Air Force and Herbicides in Southeast Asia, 1961-1971*), and Cecil in 1986 (*Herbicide Warfare: The RANCH HAND Project in Vietnam*). Many of the primary historical records are now available online through the Special Collection Initiative of the National Agricultural Library, the Agricultural Research Service, United States Department of Agriculture, Beltsville, Maryland, <http://www.nal.usda.gov/speccoll/findaids/agentorange/index.htm>.

Almost a decade after the termination of tactical herbicide use in Vietnam, veterans of the Vietnam War expressed concern over the potential impact that the use of tactical herbicides many have had of their health. The unit histories of ground troops stationed in Vietnam from 1964 through 1971, the major period of tactical herbicide use, are housed in the National Archives and have been the subject of intense interest since 1979 when the first epidemiological studies of Vietnam veterans and Agent Orange were proposed. Epidemiologists must rely heavily upon historical records to construct exposure assessments. However, factors that were critical to the re-construction of such exposures were not documented in the combative and hostile environment of Vietnam. The procedures governing the use of tactical herbicides, and the supporting historical data, have only recently been recognized as important to the debate on whether ground troops were significantly exposed to tactical herbicides while serving in the Vietnam War. This chapter summarizes many of the issues that impact exposure determinations, including the environmental characteristics of South Vietnam, the rationale and procedures for the military use of tactical herbicides, the historical and operational concepts of Operation RANCH HAND and, the actual dissemination of tactical herbicides in the Vietnam War.

#### 3.1 Environmental Characteristics of South Vietnam

The environmental characteristics of the former Republic of Vietnam (RVN) had a major impact on all facets of American involvement in the war in Southeast Asia. The environmental setting exerted an influence on the local ground defense of hamlets, cities, and military bases as well as on the conduct of both air and ground offensive operations. The environmental setting's impact came chiefly from the configuration, topography, climate, and vegetation of the Republic of Vietnam [Fox 1979].

The Republic of Vietnam was a classic example of exposed territory. Its boundaries were

extremely lengthy in relation to its size. As a result, infiltration points accessible to enemy forces by land and sea were almost unlimited. The RVN extended more than 1,300 km from its northern border at the Demilitarized Zone (DMZ) to its southern border, while its width from east to west varied from 50 to 200 km. Saigon (now Ho Chi Minh City), the RVN's capital, was located less than 60 km from the Cambodian frontier to the west [Fox 1979].

Topography also favored the insurgency forces of the Viet Cong (VC) and the regular Armed Forces (NVA) of the Democratic Republic of Vietnam (hereafter referred to as North Vietnam). Nearly 60% of the RVN consisted of relatively high mountains and plateaus rising to elevations of 2,500 m. This mountain range, the Annamite Chain, extended southeastward from the border between North Vietnam and the People's Republic of China to form the border between the RVN and Laos, and further south, between the RVN and Cambodia. The mountains and plateaus making up the Annamite Chain terminated at a point in the Mekong Delta about 80 km north of Saigon. Numerous spurs extended to the east and provided broken and rugged terrain in close proximity to almost all of the major cities and allied military installations in the RVN [Cima 1989; Fox 1979]. Lowlands with little or no topographical relief comprised the remaining 40% of the country. The lowlands were located primarily in the Mekong Delta where the land seldom was more than 4 to 5 m above sea level. In addition, the Mekong Delta was intersected by numerous waterways. Consequently, almost the entire countryside of the RVN offered cover and concealment to enemy troops while presenting major obstacles to observation, penetration, and movement by friendly ground forces. For example, each of the 14 primary American bases was vulnerable to access by land and/or water by VC and NVA forces [Fox 1979].

Except in the mountains and plateaus of the Annamite Chain (e.g., Pleiku Air Base and the Central Highlands area), high temperatures typically prevailed throughout the year. The high temperatures accompanied by high humidity created a climate that physically stressed the military personnel and increased enormously the maintenance requirements for all equipment. The average rainfall was heavy in all regions of South Vietnam, ranging from less than 200 cm near Saigon in the south to more than 325 cm near Da Nang in the north. For most of South Vietnam, the rainy season occurred from the summer through fall (June to November), when an annual average of 10 typhoons off the South China Sea produced even more rainfall. In the Da Nang area, the wettest period lasted from December through January. The heavy rainy season, including periodic monsoons, crippled friendly and hostile military operations alike and marked the yearly low point in VC and NVA attacks [Fuller 1974; Hackworth 2002].

The abundant rainfall and the year-round high temperatures gave much of South Vietnam a 12-month growing season that resulted in luxuriant vegetation. More than 80% of the Republic of Vietnam had a natural cover of rain forests, monsoon forests, and savanna lands. Approximately 57% of the land area of South Vietnam was covered by a diversity of upland (inland) forests, 23% by grasslands or savannas (the Plain of Reeds vegetational type), 18 % agricultural and urban lands, and 2 % coastal mangrove forests [Westing 1976].

The upland forests were characterized by dense and diverse tree species that varied in height, usually forming two or three rather indistinct strata (storeys) of a multi-canopy jungle, dominated by the plant family Dipterocarpaceae, which was represented by at least 30 major species. The upper canopy usually attained a height of 20 to 40 m. **Figure 3.1** was a photograph of a typical double and triple canopy jungle that characterized more than 50% of South Vietnam. One scientist described the upland forests as:

*“...a confusing conglomeration of what appears to be primary forest interspersed with secondary forest in all stages. Moreover, the forests have been subjected over the years and centuries to varying intensities of exploitation for timber, firewood, and miscellaneous products. And of course, many years of war have left their mark as well, in a variety of obvious and subtle ways”*[Westing 1976].

Reed grasses and shrubs dominated the grasslands and savannas of Vietnam. Especially widespread was tranh grass (*Impertea cylindrical*) that reached a height of 1 to 2 m, while the brush yen-back (*Eupatorium odoratum*) grew densely and to a height of almost 2 m. Widespread was bamboo (*Bambusa arundinacea*), which frequently formed almost impenetrable stands of vegetation that ascended to 12 m [Westing 1976]. The height and density of the vegetation in South Vietnam afforded ideal concealment for ambush and infiltration. **Figure 3.2** was a photograph of Allied troops on maneuvers in dense savanna vegetation. **Figure 3.3** was a quotation from a Field Commander explaining the military significance of the dense and almost impenetrable vegetation where military operations frequently occurred.

### 3.2 The Rationale for Herbicide Use in South Vietnam

The extensive vegetation was a major barrier to effective base defense. Dense ground cover flourished around and within all 10 of the major Allied bases, **Table 3.1**. These ten bases housed the vast majority of aircraft, munitions, and fuels [Fox 1979]. They were the center of the US Air Force Logistics Command activities of delivering equipment, supplies and combat personnel to the war in Vietnam. They also housed the major commands for the Allied Forces as well as US Air Force, Army, and Marine units. The widespread vegetation hid the enemy, shut off friendly observation and fields of fire, neutralized fencing and other defense barriers, slowed the movement and response of security forces, and nullified detection by sentry dog teams [Fox 1979]. The need to control this noxious vegetation was evident. How to do so was the challenge confronting the American military and its South Vietnamese allies [Brown 1962].

**Table 3.1** Primary Republic of Vietnam Air Bases used by US and Allied Forces during the Vietnam War [Fox 1979)

Air Base	Urban Locations <sup>1</sup>	RANCH HAND Base <sup>2</sup>	FLYSWATTER Base <sup>3</sup>
Bien Hoa	X	1966—1970	1967—1971
Binh Thuy	X	—	—

Cam Ranh Bay	—	—	1967—1971
Da Nang	X	1964—1971	1967—1971
Nha Trang	X	1968—1969	—
Phan Rang	X	1970—1972	1970—1972
Phu Cat	—	1968—1970	—
Pleiku	X	—	—
Tan Son Nhut	X	1962—1966	—
Tuy Hoa	—	1971—1972	—

<sup>1</sup> Older bases dating from the French regime and that were located in or near population centers

<sup>2</sup> Bases used for servicing RANCH HAND C-123 aircraft and/or tactical herbicide storage

<sup>3</sup> Bases used for servicing RANCH HAND C-123 aircraft for Insecticide operations (Operation FLYSWATTER)

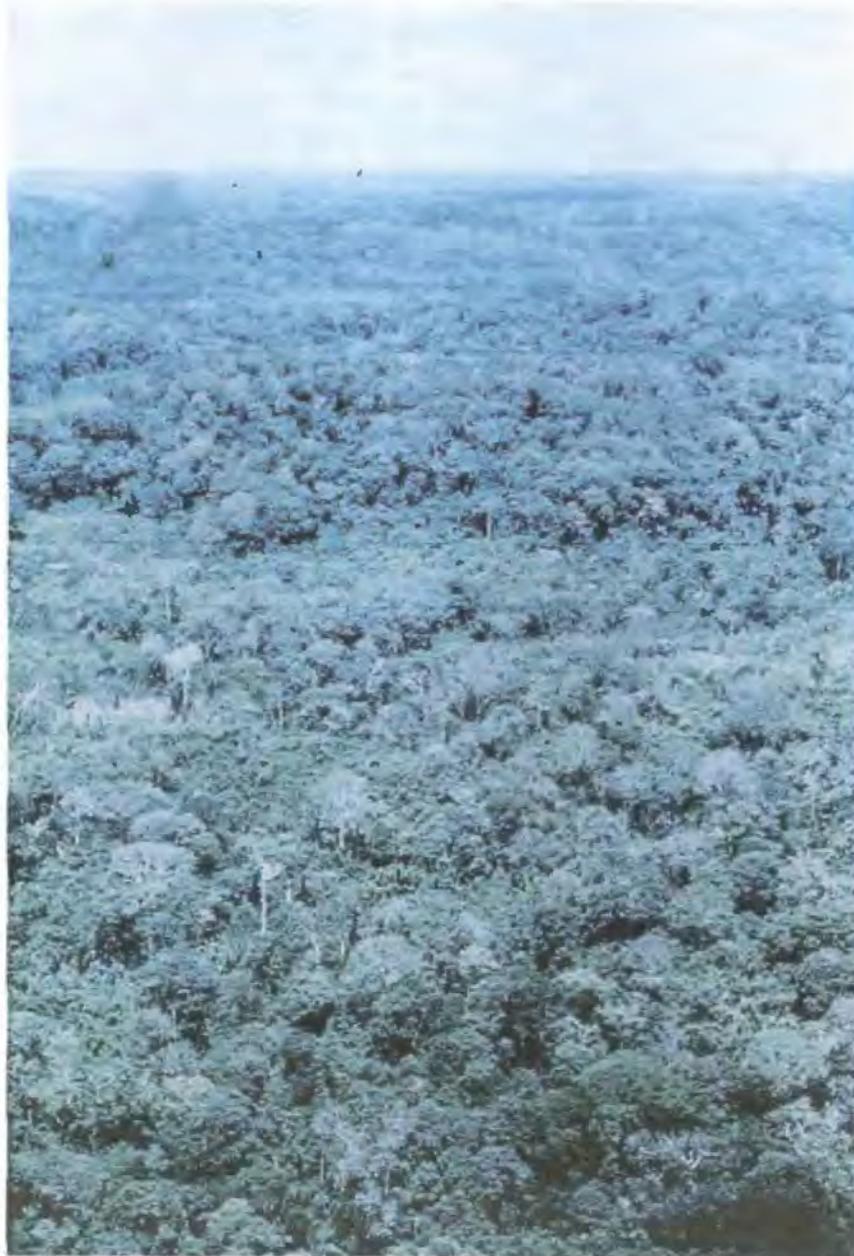
In late June 1961, the United States and South Vietnamese Government established a Joint United States/Vietnamese Combat Development and Test Center (CDTC) in Saigon, under the direction of the Defense Department's Advanced Research Projects Agency (ARPA). One of its first tasks was to evaluate the use of herbicides to destroy concealing vegetation and enemy food supplies (Project AGILE) [Cecil 1986]. As part of Project AGILE, a contract was negotiated in 1962 with the Institute for Defense Analyses, Washington DC to do an in-depth analysis of the available literature on "Chemicals for Control of Vegetation" [Coates and Sharpe 1963]. The Institute concluded that the selection of chemicals should be evaluated on the basis of plant physiology (how they physiologically affect the plant); on the basis of health and safety; and, on performance characteristics of commercially available herbicides/desiccants. The Institute identified five principal military applications for anti-vegetative agents:

- Roadside clearance to reduce ambush,
- Boundary demarcation,
- Vegetation control in depot areas,
- Area denudation to uncover selected targets and to reveal enemy hideouts, and
- Aquatic weed control [Coates and Sharpe 1963].

They reasoned that three distinct phytochemical activities were required, namely the rapid reduction in foliage by desiccation; the systemic herbicidal activity to kill the plants; and residual herbicidal action in the soil to prohibit or retard growth. They concluded that no single herbicidal agent would bring about all three effects; it was essential to consider the use of mixed or formulated herbicides, applied together or successively [Coates and Sharpe 1963].

Prior to 1962, a large and useful amount of information about vegetation control, especially woody species control, existed in American agriculture [Bovey and Young 1980]. Thus, the use of herbicides in South Vietnam was recommended to support the military effort. As a result, the tentative choice of tactical herbicides for use in Vietnam was based upon proven performance in both military and commercial situations,

availability in large quantity, costs, and known or accepted safety in regard to their toxicity to humans and animals [Irish, Darrow, and Minarik 1969]. The phenoxy and arsenical herbicides were the chemicals of choice, having been tested and evaluated in numerous locations in the United States and Puerto Rico [Tschirley 1968; Young 2006].



**Figure 3.1** The dense inland forests of South Vietnam contained a vast diversity of species. The tree species varied in height, usually forming two and occasionally three rather indistinct strata (storeys). The upper canopy usually attained a height of 20 to 40 m (Photograph courtesy of J. Ray Frank, Frederick, Maryland)



**Figure 3.2** The grasslands and savannas of South Vietnam were characterized by grasses and shrubs that frequently formed almost impenetrable stands of vegetation and which afforded ideal concealment for ambush and infiltration (Photograph courtesy of J. Ray Frank, Frederick, Maryland)

“. . .THE KHE SANH PLATEAU, IDEAL TERRAIN FOR NORTH VIETNAMESE. THE RUGGED MOUNTAINOUS COUNTRYSIDE PROVIDED A NATURAL INFILTRATION ROUTE. MOST OF THE MOUNTAIN TRAILS WERE HIDDEN BY TREE CANOPIES OF JUNGLE UP TO 60 FEET HIGH, DENSE ELEPHANT GRASS, AND BAMBOO THICKETS. CONCEALMENT FROM RECONNAISSANCE AIRCRAFT WAS GOOD, AND THE HEAVY JUNGLE UNDERGROWTH LIMITED GROUND OBSERVATION TO FIVE METERS IN MOST PLACES.”

W. PEARSON, 1975.

**Figure 3.3** A Department of Defense briefing slide of a quotation from a Combat Field Commander who served in Vietnam during the Vietnam War (Courtesy of Air Force Logistics Command, Wright-Patterson AFB, Ohio)

In October 1961, the newly created Air Force Special Air Warfare Center at Eglin Air Force Base (AFB), Florida was tasked with assisting the Vietnamese Air Force (VNAF) by augmenting their capability through the deployment of three companies of Army H-21 helicopters, a squadron of Air Force C-123 transports, and the loan of 30 T-28 training aircraft. This deployment, under the overall code name FARM GATE, eventually also included the temporary assignment of six C-123 aircraft and four H-34 helicopters for a defoliant spraying program [Cecil 1986]. The six aircraft selected for the defoliation operations were quickly modified with the installations of a modular internal spray system, spray booms, and armor plating [Cecil 1986]. The six aircraft departed from Pope AFB, North Carolina on 28 November 1961, and a separate operations order using the code name RANCH HAND was not published until the unit's arrival in the Philippines [Cecil 1986].

### 3.3 Combat Tactical Zones

South Vietnam was divided into four Combat Tactical Zones (CTZ), also called Military Regions or Corps, and the Special Capital Zone (Saigon area) for purposes of RVN, U.S., and other Allied military operations. These four CTZs were identified as I, II, III, or IV Corps. Each Corps became administrative areas for RANCH HAND and other tactical operations. I Corps was located in the region nearest North Vietnam and hence, adjacent to the DMZ. II Corps encompassed the Central Highlands and III Corps surrounded the Saigon area. IV Corps was in the Mekong Delta region [Buckingham 1982]. **Figure 3.4** is a briefing slide of South Vietnam showing the division of the country into Combat Tactical Zones or Corps.

Although spraying occurred in most provinces of the RVN, certain areas of the country were subject to more intensive spraying. Most of the defoliation missions were conducted along transportation routes, in enemy-occupied areas around Saigon, on NVA infiltration routes along the Laotian and Cambodian borders and the DMZ, and on staging areas from which enemy attacks were likely [Cecil, 1986].

Primary target areas for crop destruction missions were in I Corps and along the upland and mountain valleys of II Corps. The areas within III Corps near Saigon afforded the enemy concealment along the main shipping routes providing access to the Port of Saigon. These areas were also the areas where the NVA infiltrations of troops and supplies terminated in base camps in South Vietnam. As a result, the Rung Sat Special Zone and War Zones C and D were areas that were sprayed repeatedly to reach all levels of the triple canopy forest and restrict re-growth. In IV Corps, the Ca Mau peninsula was a temporary staging area for infiltration into the Mekong Delta and hence, was the target of defoliation operations [Cecil 1986].

In order to effectively target defoliation or crop destruction missions in all four Combat Tactical Zones, RANCH HAND Squadrons established bases of operation in three of the four CTZs. A base of operations was not established in CTZ IV because IV Corps was readily accessible from Bien Hoa Air Base that was located in III Corps [Cecil 1986]. The Combat Tactical Zones and the RANCH HAND bases are also shown in **Figure 3.4**.



**Figure 3.4** A 1969 Department of Defense briefing slide showing the Combat Tactical Zones and the location of the major RANCH HAND bases in South Vietnam

3.3<sup>2</sup>  
3.3<sup>3</sup> **Historical Background on Early Spray Missions**

The mission of Operation RANCH HAND was unique. It required the development and use of aircraft capable of disseminating large quantities of herbicides at very low altitudes and slow speeds. It required herbicides that were effective against the vegetation encountered in South Vietnam. It also required tactics that had to be designed and implemented on a trial and error basis in order to provide maximum surprise and concealment when approaching targets to minimize hostile ground fire to aircraft and crew [Clary 1971].

On 10 August 1961, as part of Project AGILE, Fort Detrick personnel initiated defoliation tests in South Vietnam [Brown 1962]. Stocks (10 drums – 1,900 liters) of the commercial herbicide “Dinoxol” had arrive on 17 July 1961. It was the first herbicide to be evaluated. It was aerielly sprayed using an H-34 helicopter equipped with the HIDAL (Helicopter Insecticide Dispersal Apparatus, Liquid) system. Dinoxol consisted of 20% 2,4-D as the butoxy ethanol ester, and 20% 2,4,5-T butoxy ethanol ester. On 4 September 1961, 2,025 liters of “Trinoxol” (40% 2,4,5-butoxy ethanol ester) arrived and was immediately evaluated [Brown 1962]. On 20 November 1961 Pink, Green, and a powdered formulation of Blue (Ansar) arrived. The first shipment of Purple arrived on 9 January 1962 [Brown 1962]. Between 10 August 1961 through 3 February 1962, 18 tests were conducted using the six different herbicide formulations [Brown 1962].

Three of the six United States Air Force (USAF) C-123 aircraft equipped with MC-1 spray tanks (3,785-liter capacity) landed at Tan Son Nhut Air Base, RVN on 7 January 1962 [Brown 1962]. The first RANCH HAND mission was flown on the morning of 10

January 1962. The target for this mission, and the subsequent missions during the first week of operations, was the vegetation on both sides of Route 15 between Bien Hoa and Vung Tau. These missions expended almost 30,000 liters of Purple and covered 28 square kilometers [Collins, 1967]. Tests conducted after 9 January involved the use of the modified C-123 aircraft. At the conclusion of the tests, the recommendation was that Purple, Pink, and Green should be used the tactical herbicides of choice for large scale use [Brown 1962].

On 21 –23 November 1962, the first crop destruction missions were flown in Phuoc Long Province. The operation, using H-34 helicopters and hand sprayers, destroyed an estimated 300 ha of crops consisting of rice, beans, and manioc. Subsequently, RANCH HAND aircraft completed additional crop destruction projects between November 1962 and March 1963 using Purple and Blue [Warren 1968].

The Pink and Green formulations of 2,4,5-T were received in limited quantities and evaluated during the first years of Operation RANCH HAND [Irish, Darrow, and Minarik 1969]. Pink was used extensively in early RANCH HAND operations as well as in the defoliation test program conducted during 1963 and 1964 in Thailand [Darrow et al 1966]. Green was a single component formulation and was used in limited quantities in the 1962 for broadleaf crop destruction, e.g., against manioc [Irish, Darrow, and Minarik 1969]. Cecil suggested that the limited amount of Green (365 drums) was generally mixed with Pink, and hence there were no records that specified “Green” only [Cecil 1986].

In March 1965, Herbicide Purple was replaced by “Herbicide Orange”, subsequently known as “Agent Orange”. Orange was a 50:50 mixture of the n-butyl esters of 2,4-D and 2,4,5-T. These esters were considered “less volatile” than the iso-butyl esters contained in Agent Purple, and hence, less likely to cause damage to non-target vegetation. Agent Orange replaced all uses of Purple, Pink, and Green, and eventually became the most widely used military herbicide in South Vietnam [Darrow, Irish, and Minarik 1969].

The final military herbicide added to the inventory was Herbicide White (Agent White). The records on herbicide use indicated that Agent White arrived in the RVN in limited quantities in December 1965 for evaluation. Small amounts of White also were tested in Thailand [Cecil 1986]. The first RANCH HAND missions using White actually occurred in early 1966.

### **3.5 Use Patterns of Individual Herbicides**

**Table 3.2** summarizes the military herbicides and their uses during the years 1961 to 1971 in South Vietnam. Each of the three major military herbicides (Orange, White, and Blue) used in the RVN had specific applications. About 90% of Agent White was applied in defoliation missions. It was an ideal herbicide for use in the inland forests in areas where immediate defoliation was not required, but where a longer more persistent

effect than spraying with “Orange” or “Blue” was desired.

**Table 3.2** The major tactical herbicides used by the United States Military in South Vietnam 1961–1971 [NRC 1974; Young and Andrews 2006]

Code Name (Herbicide)	Years Sprayed	Formulation	Purpose/Use
Dinoxol, Trinoxol	1961	2,4-D; 2,4,5-T	Defoliation tests
Purple	1962–1965	2,4-D; 2,4,5-T	General defoliation and destruction of broadleaf crops
Blue	1962; 1966–72	Cacodylic acid	Rapid defoliation, desiccation of grasses, and rice
Pink	1961–1964	2,4,5-T	Defoliation
Green	1962	2,4,5-T	Crop destruction
Orange	1965–1970	2,4-D; 2,4,5-T	Defoliation, crop destruction
Orange II	1968–1970	2,4-D; 2,4,5-T	Defoliation
White	1966–1972	2,4-D; Picloram	Defoliation

Blue was the herbicide of choice for crop-destruction missions involving cereal or grain crops. Approximately 50% of all Agent Blue applications involved crop-destruction missions in remote or enemy-controlled areas. The remainder was used as a contact herbicide (desiccant) for control of reed grasses and bamboo around base perimeters [Fox 1979]. The internal security concept called for by the US Military and Allied Forces at all major bases involved the preventive perimeter that traced the base boundary line as closely as possible [Fox 1979]. Being the first line of defense, it had to detect, report, and engage the enemy as far as feasible from the resources protected. On in the preventive perimeter area were “defoliant” (i.e., tactical herbicides) used. The Army Chemical Corps used helicopter and ground-based equipment, but as noted:

*“Defoliation needs of the 10 primary bases were specific, permanent, and known in advance. Still no ongoing long-term program to satisfy them was ever set up. Instead the job was done piecemeal, with each base handling defoliant requests. Despite the administrative and technical controls, chemical agents remained the single sure way to control vegetation in places where other means could not – notably in the critical perimeter complexes”* [Fox 1979].

Approximately 85% of all Agent Orange was used for forest defoliation, and it was especially effective in defoliating mangrove forests. Eight percent of Orange was used in the destruction of broadleaf crops (beans, peanuts, ramie, and root or tuber crops). The remaining 7% was used around base perimeters, cache sites, waterways and communication lines [Young 1988]. **Table 3.3** shows the number of hectares in South Vietnam, based on the major land cover classifications, that was sprayed with herbicides.

**Table 3.3** The number of hectares treated in South Vietnam, 1962 – 1971, with military herbicides within the three major land cover categories [NRC 1974]

<b>Land Cover Category</b>	<b>Hectares Treated*</b>
Inland forests	1,080,970
Mangrove forests	127,750
Cultivated Crops	105,260
Total	1,313,980

\* Areas receiving single or multiple applications.

### **3.6 Historical and Procedural Information on Operation RANCH HAND**

#### **3.6.1 Deployment of Aircraft**

Following World War II, the USAF assumed responsibility for the operations of the Special Aerial Spray Flight Unit, a military unit that provided control of insect pests through the use of aerial applications of insecticides [Cecil 1986]. By 1960, the Special Aerial Spray Flight Unit had conducted more than 1,200 missions in support of national and international control programs for mosquito, black fly, locust, and other pests of public health and economic importance [Cecil 1986].

In early 1960, the Special Aerial Spray Flight phased out the C-47 aircraft and selected the Fairchild-built C-123B “Provider” as its replacement. This high-wing, twin-engine assault transport had excellent low-speed maneuverability, and the high-mounted wings allowed convenient positioning of wing spray booms. More importantly, the large cargo compartment and load capacity were ideal to receive a large spray system for internal carriage. The initial spray system was the MC-1 Hourglass System, but beginning in July 1965, this spray system was replaced with A/A 45Y-1 Internal Defoliant Dispenser (**Figure 3.5**). This modular system consisted of a 3,785-liter tank, pump, and engine, which were all mounted on a frame pallet. An operator’s console was an integral part of the unit. Wing booms (3.8 cm in diameter, 6.7 m in length) extended from outboard engine nacelles toward the wing tips. A short tail boom (7.6 cm in diameter, 6.1 m in length) was positioned centrally near the aft cargo door [Irish, Darrow, and Minarik 1969].

Each C-123 aircraft had a crew of three men: the pilot, co-pilot, and flight mechanic (console operator) [Buckingham 1982]. The lead aircraft in a formation contained a fourth crewmember, a navigator. The pairing of equipment and aircraft appeared to be ideal. The UC-123 series aircraft became the “work horse” of Operation RANCH HAND. **Figure 3.6** was a photograph of the UC-123B RANCH HAND aircraft returning to Phu Cat from a defoliation mission in II Corps. During the peak activity of RANCH HAND operations (1968-1969), approximately thirty UC-123B or UC-123K (U designating spray aircraft and K, a jet booster modification) aircraft were employed [Cecil 1986].



**Figure 3.5** USAF Photograph of the A/A 45Y-1 Internal Defoliant Dispenser (Photo courtesy of the Air Force Armament Laboratory, Eglin AFB, Florida)



**Figure 3.6** The UC-123B "Provider" with its Modular Internal Spray System was the "workhorse" for RANCH HAND. This high-wing, twin-engine assault transport had excellent low speed maneuverability, and the high-mounted wings allowed convenient positioning of wing spray booms. Note the spray boom mounted aft of the cargo door and near the tail of the aircraft (Photograph courtesy of J. Ray Frank, Frederick, Maryland)

Four other squadrons of C-123 aircraft were routinely used throughout South Vietnam (as early as December 1961) in support of transport operations [Cecil, 1986]. In addition, starting in 1967, two of the UC-123 aircraft assigned to RANCH HAND were used for insecticide missions, Operation FLYSWATTER [Cecil and Young 2008]. These aircraft were used for spraying insecticide for the control of malaria-carrying mosquitoes. The UC-123 aircraft assigned to the insecticide program were not camouflaged. Instead, those aircraft were coated with a silver alodine treatment. The “silver bug birds” were considered “beneficial” by friendly and hostile forces alike and were seldom targets for VC or NVA weapons [Collins 1967; Cecil and Young 2008]. The insecticide program is described in more detail later in this chapter.

**Table 3.4** described the various military aircraft used in the dissemination of herbicides and insecticides in South Vietnam. Approximately 4-5 % of all herbicides used in South Vietnam were disseminated by helicopter or ground application equipment and was the responsibility of the US Army Chemical Corps [NRC 1974; Irish, Darrow, and Minarik 1969]. Generally, helicopter crews were not assigned to herbicide spray duties on a full-time basis and rotated the spraying duties with other mission requirements. The military H-19, H-34, and the UH-1 series of helicopters, deployed by the US Air Force, Army, and Navy units, generally sprayed the herbicides. The most common spray systems used were the HIDAL and AGRINAUTICS units. These units were installed in or removed from the aircraft in a matter of minutes because they were “tied down” to installed cargo shackles, and aircraft modifications were not required for their use [Young 1988]. Each unit consisted of a 760-liter tank and a collapsible 9.8-m spray boom. The unit was operated by manual controls to control the flow valve and a windmill brake. Generally, each helicopter had three crewmembers. **Figure 3.7** was a photograph of a helicopter readied for a base perimeter spraying with Agent Blue.

**Table 3.4** Military aircraft used in the dissemination of herbicides and insecticides in South Vietnam

<b>Fixed-wing Aircraft and Helicopters</b>	<b>Camouflaged</b>	<b>Chemical Disseminated</b>
UC-123B/UC-123K*	Yes	All Herbicides
UC-123B/UC-123K “Silver Bug Birds”	No	Malathion Insecticide
Air Force UH-1, Army H-34, UH-1B/UH-1D, Navy H-19	Yes	Orange, Blue

\* The “U” designation was for spray aircraft. The “B” model was used through early 1968 after which it was replaced by the “K” models, a jet modification. [Cecil 1986]



**Figure 3.7** The Military UH-34 series of helicopters generally sprayed the herbicides. The most common spray systems were the HIDAL and AGRINAUTICS units. They could be removed from the aircraft in a matter of minutes. Each unit consisted of a 760-liter tank and a collapsible 9.8-meter spray boom (Photograph courtesy of the US Army Chemical Corps)

### **3.6.2 Development, Test, and Evaluation of Aerial Spray Systems for Vietnam**

The challenges to obtain successful vegetation control in the military conflict in Vietnam required the application of modern science and technology backed by a cadre of professionally trained men dedicated to the successful completion of a military mission. The ground operations and oversight of the overall program were the responsibilities of the Army Chemical Corps. The aerial spray operations of Agent Orange and other tactical herbicides in Vietnam were conducted with highly trained RANCH HAND aircrews using aircraft and aerial spray equipment that had been specifically developed, thoroughly tested, and critically evaluated for their performance and dissemination characteristics. The USAF was responsible for the training of the aircrews, development of aerial tactics for herbicide missions, and development, testing and evaluation of the spray equipment with its associated aircraft. These programs were primarily conducted at Eglin AFB, Florida, and to a lesser degree at the Pran Buri Calibration Grid in Thailand [Darrow 1965]. The development and testing of the defoliant was the responsibility of the US Army at Fort Detrick, Maryland, with the cooperation of the US Department of Agriculture at research stations throughout the United States [Tschirley 1968; Young 2006].

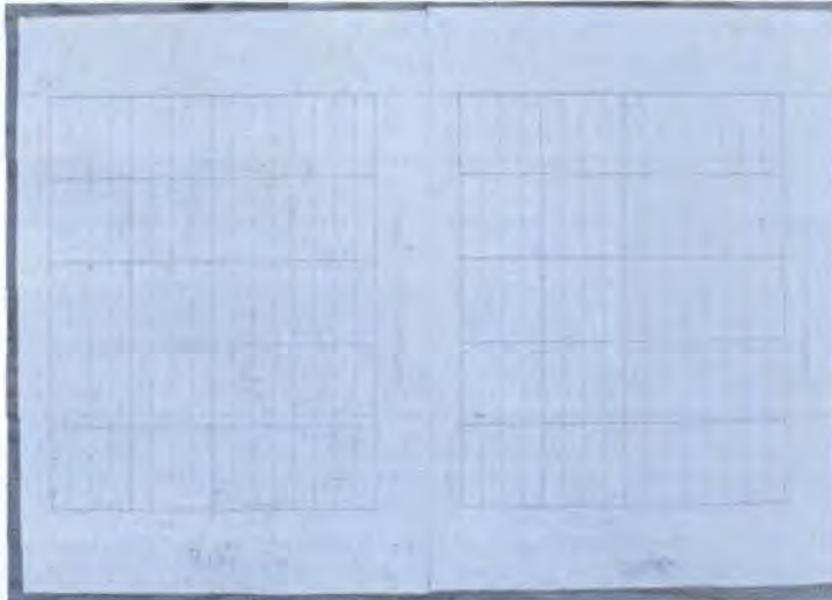
The Eglin AFB Reservation in Northwest Florida served various military uses during the 1960s and 1970s, including the development and testing of aerial spray equipment for disseminating the herbicides used in the Vietnam War. It was necessary for this

equipment to be tested under controlled conditions that were as near to those prevalent in South Vietnam as possible. For this purpose, a testing installation was established in 1962 on the Eglin AFB Reservation. Direct aerial application was restricted to an area approximately 2.6 km<sup>2</sup> within Test Area C-52A. The Test Area covered an area of approximately 8 km<sup>2</sup> and was a grassy plain surrounded by a forest stand that was dominated by pine and oak species [Young 1974]. Details of the programs instrumental in the development and testing of aerial spray equipment are provided in **Chapter 6**. All of the aerial spray equipment used in Vietnam was initially evaluated at the Eglin AFB testing facility, but the need for developing operational parameters and herbicidal effectiveness in a jungle environment prompted the Military Assistance Command, Vietnam (MACV) to develop a test site in Thailand [Darrow 1965; Darrow, Truchelut, and Bartlett 1966].

The test program conducted in Thailand during 1964 and 1965 was to determine the effectiveness of aerial applications of Purple, Orange, and other candidate chemical agents in defoliation of upland jungle vegetation representative of Southeast Asia [Warren 1968]. The Pran Buri Calibration Grid was located about 260 km southwest of Bangkok, Thailand. The test area or calibration grid was located in a broad valley bordered on the west and partially on the east by precipitous mountain ranges, which rise 90 to 450 m above the valley. The test area was about 1,600 m long and 5,000 m wide and included about 570 ha of forest. Tests were conducted on duplicate 4-ha plots [Darrow 1965]. The value of the Pran Buri Calibration Grid was two-fold. First, it provided a field site to evaluate the performance of the spray system as configured for defoliation missions in Southeast Asia. Second, it was used to evaluate the concentration of applied herbicides (i.e., effectiveness of nine versus twenty-eight liters per hectare) on jungle vegetation that was native to Southeast Asia. These evaluations could be done without the threat of hostile forces [Cecil 1986]. Both the hourglass and the AA-45Y-1 spray systems were evaluated successfully in Thailand [Darrow, Truchelut, and Bartlett 1966].

Development, testing, evaluation and calibration of the spray equipment were critical to successful vegetation control. Literally hundreds of such tests occurred between 1962 and 1970 for the UC-123 and helicopter spray systems [Young and Newton 2004]. Field tests of the herbicides established a minimum biologically effective ground deposition rate. The goal of the test programs was to match the herbicide, equipment, and aircraft with the operational parameters to obtain the ideal deposition rate. For Agent Orange, the optimum application parameters and spray characteristics of the UC-123 modular internal spray system were as follows: 130 KIAS (knots indicated air speed) at an altitude of 50 m AGL [above ground (or tree-top) level] producing a spray swath of 80 m (plus or minus 6 m) with a mean deposition of 28 liters/hectare and treating a total area/tank of 130 ha. These parameters allowed the aircraft to be on target for 3.5 to 4.0 minutes and resulted in a particle size where 98% were greater than 100 microns [Harrigan 1970]. Tests showed that 87% of the herbicide would have impacted the vegetation within one minute and within the swath width [Klein and Harrigan 1969; Harrigan 1970]. **Figure 3.8** illustrated the use of Kromekote cards for assessing particle size and distribution. The remaining 13% drifted or volatilized. Similar tests and evaluations provided the optimum

parameters for the other herbicides and the helicopter systems [Boyer and Brown 1964].



**Figure 3.8** In the test and evaluation of the UC-123K Modular Internal Spray System at Eglin AFB, Florida. Kromekote cards were employed for physical collection of test material in droplet form. These two cards, each 15 x 20 cm, showed the distribution of particle size and deposition rate when the aircraft was flown in wind at 150 KIAS and 50 m AGL. The Kromekote cards confirmed a deposition rate of 28 liters/hectare with approximately 98% of the particles greater than 100 microns intersecting the cards (Photograph courtesy of A. L. Young)

### 3.6.3 RANCH HAND Support Activities and Concepts

This section describes the background and mechanics of a “typical” herbicide mission in order to provide some perspective in terms of how Agent Orange was transported, stored, handled and disseminated in the RVN. The following summary of “standard operating procedures” was compiled from the literature and interviews with RANCH HAND aircrews and ground personnel [Craig 1975; Young et al 1978; Buckingham 1982; Cecil 1986; Young 1988; Young 2006]

1. Each of the 11 different companies that manufactured military herbicides packed them in new ICC 17C 208-liter, 18 gauge-steel drums for shipment to the RVN. Until 1967, lined drums were used only for shipment of Blue. Because of the results of compatibility tests, lined drums were also used to ship White beginning in 1967.
2. Each herbicide drum was marked with a 7.6-cm color-coded band around the center to identify the specific military herbicide. The marking was initially a 30-cm band, but was changed to 7.6 cm in March 1965, with the introduction of

Agent Orange into the RVN.

3. The various companies shipped the herbicide by rail to Mobile, Alabama. At the port, the drums were loaded aboard cargo transport ships. Shipping time from the arrival of the herbicide at the Port of Mobile until it arrived in South Vietnam varied from 47 to 52 days. **Figure 3.9** were photograph taken of the arrival of Agent Orange by train, and the subsequent transfer of the drums to a ship at the Port of Mobile.



**Figure 3.9** (Top) The companies that produced Agent Orange shipped the herbicide in railroad cars to the port at Mobile, Alabama; (Bottom) The 208-liter drums of herbicide were transferred from rail to a cargo vessel at the port of Mobile for shipment to Vietnam. Transport time varied from 47 to 52 days (Photographs courtesy of Air Force Logistic Command, Kelly AFB, Texas)

4. About 10 out of every 10,000 drums shipped were received in a damaged or

defective state. This represented a damage rate of 0.1%. About 50% of these damaged drums leaked as a result of punctures or split seams. The damages to the drums were caused by improper loading or because some of the drums were initially defective. Forklifts operated by stevedores also caused punctures. **Figure 3.10** was a photograph of a defective drum that was leaking after shipment to Vietnam.

5. About 65% of the herbicide was shipped to the 20th ARVN Ordnance Storage Depot, Saigon, and 35% was shipped to the 511th ARVN Ordnance Storage Depot, Da Nang. Under normal handling procedures, drums were unloaded at Saigon and Da Nang from the cargo vessel directly into semi-trailers and were placed in an upright position (See **Figure 3.11**). The trailers were driven to the various units of the 12th Air Commando Squadron/12<sup>th</sup> Special Operation Squadron (i.e., RANCH HAND) at the air bases of Tan Son Nhut, Da Nang, Phu Cat, Nha Trang, or Bien Hoa for disposition.



**Figure 3.10** Out of every 10,000 drums of herbicide shipped to Vietnam, about 10 of them (0.1%) were received in a damaged or defective state. Leakage from these drums contaminated the docks and the semi-trailers used to haul them to the RANCH HAND bases (Photograph courtesy of Air Force Logistics Command, Kelly AFB, Texas)

6. Normally the contents of the drums were transferred into blocked F-6 trailer tanks through a suction tube without removing the full drums from the semi-trailers. Each F-6 trailer tank held 16,300 liters or about 78 drums of herbicide. Blocked F-6 trailers were tied to plumbing and pumps so that the herbicide could be delivered to the aircraft without moving the trailers. If blocked F-6 trailers could not accommodate the total inventory, the drums were stacked in pyramidal style until needed. During the peak activity of the RANCH HAND operations

(1968–1969), it became necessary to construct large above ground holding tanks for the herbicides. These large color-coded tanks held almost 30,000 gallons (113,550 liters) of herbicide. **Figure 3.12** was a photograph of semi-trailer loaded with 48 drums of Agent Orange at Bien Hoa Air Base. **Figure 3.13** was a photograph of F-6 trailers “blocked” near the RANCH HAND flightline at Bien Hoa. **Figure 3.14** was a photograph of drums of Agent Orange stacked in “pyramidal style” at Bien Hoa Air Base. **Figure 3.15** were photographs taken of the 113,550-liter tanks at Bien Hoa Air Base for Agents Orange, White, and Blue, respectively.



**Figure 3.11** When the Agent Orange was received in South Vietnam the drums were off-loaded directly from the cargo vessel into a semi-trailer. The 48 drums were placed upright and transported to the RANCH HAND units at Tan Son Nhut (1962-1966), Bien Hoa (1966-1970), Da Nang (1964-1971), Phu Cat (1968-1970) or Nha Trang (1968-1969) (Photograph courtesy of J. Ray Frank, Frederick, Maryland)



**Figure 3.12** (Top) A “blocked” F-6 trailer served as a temporary tank for Agent Orange prior to its off-Blocked F-6 trailers are circled in red on the far side of the tarmac loading into the RANCH HAND UC-123 aircraft. The F-6 trailer held 78 drums (29,000 liters) of herbicide (stacked on semi-trailers circled in red). Photograph of the flight line at Bien Hoa Air Base showing support facilities and aircraft for the RANCH HAND operation. (Photograph courtesy of J. Ray Frank, Frederick, Maryland)



**Figure 3.13** The “pyramidal style” of stacking Agent Orange drums in temporary storage at Bien Hoa Air Base, 1968 (Photograph courtesy of J. Ray Frank, Frederick, Maryland)



**Figure 3.14** Photographs of the 30,000-gallon (113,550-liter) above ground tanks constructed at Bien Hoa Air Base in December 1969 for the temporary storage of Agents Orange, White, and Blue, respectively. Each tank was color-coded to prevent mixing of the herbicides (Photographs courtesy of J. Ray Frank, Frederick, Maryland)

7. As previously noted, Orange was insoluble in water, while Blue and White were not. When Orange was mixed with either Blue or White, a gummy substance was formed. The F-6 trailers, other holding tanks, and even the RANCH HAND aircraft were color-coded to correspond to the drum color-codes and used exclusively for the herbicide to which the code applied.

8. The aircraft spray tanks (positioned in the center of the airplane) and the spray systems were purged before the type of herbicide carried was changed. Particular attention had to be given to sequences involving Agents Blue and White. A mixture of these two herbicides resulted in the formation of a precipitate consisting of the sodium salt of 2,4-D.

9. The transfer of the herbicides from the 208-liter steel drums to storage tanks or aircraft tanks required some precautionary measures. Personnel charged with the supervisory responsibilities of handling the herbicides were indoctrinated in appropriate safety precautions including the use of gloves and face shields as needed. Personnel handling the chemicals were encouraged to take normal sanitary precautions and to maintain personal cleanliness and to avoid skin and eye contact with the material. Contaminated clothing was to be washed before re-use. Spillage on the skin or in the eyes was to be rinsed copiously with clean water.

10. When the herbicide was pumped from the drums into the F-6 trailers, about 2 to 5 liters remained in the drum. Hence the drums were placed on drain racks and the "drippings" were collected from many drums in a pan-type receptacle, re-drummed, and used for spraying base perimeter areas. **Figure 3.15** was a photograph of a trailer-mounted drain rack frequently used by the Chemical Corps to collect the "dregs" from herbicide drums and subsequently use for spraying base perimeters.



**Figure 3.15** At each of the RANCH HAND Bases (Tan Son Nhut, Bien Hoa, Nha Trang, Phu Cat and Da Nang) trailer mounted drain racks were used to recover the remaining "dregs" of herbicide from the 208-liter drums. These dregs were available for perimeter vegetation control (Photograph courtesy of J. Ray Frank, Frederick, Maryland)

11. Empty drums were generally given to the South Vietnamese or Free World Military Assistance Forces (primarily Australian or South Korean) for use as barriers in defensive positions. The drums were filled with sand, rock, or concrete and used in the construction of bunkers, protective barriers for buildings and check-points, and in foundations for runways and barbed wire perimeters.
12. Surface areas contaminated by spilled herbicides were flushed with diesel fuel or water with diversion of the drainage into settling basins or pits for incorporation into the soil
13. Within the aircraft, it was not uncommon to have herbicide leakage from around the numerous hose connections joining the spray tank and pumps with the wing and aft spray booms. In hot weather, the odor of herbicide within the aircraft was decidedly noticeable (a frequent term used by the aircrew was "overwhelming"). Periodically, the spray and console were removed (especially with the portable A/A 45Y-1 system) and the interior flushed with surfactant or soap and with water. Because of the corrosive nature of the herbicides (especially Agent Blue), it was also necessary for the aircraft to be painted periodically.
14. Most of the personnel involved in the actual handling of the herbicide were Vietnamese. However, a USAF flight mechanic or crew chief was responsible for insuring that the aircraft was properly loaded and the spray system functional. The flight mechanic was also the console operator for the spray unit. The pilot and co-pilot were USAF officers. The flight mechanic, crew chiefs and other ground support personnel were USAF enlisted men. Frequently a Vietnamese "observer" would accompany RANCH HAND aircraft.
15. For record keeping purposes, one tactical herbicide "mission" consisted of several to many aircraft. When referring to a single aircraft, the term sortie was used. All missions within a Target Area formed a Project. For example, Project 4-20-1-66, consisted of dozens of "sorties" supporting multiple missions on various "targets" within the Mekong Delta (the Project Target Area) of IV Corps. The concept of "targets" is often confusing, since RANCH HAND operations referred to target areas for individual missions, while also referring to support of a Project "Target" area. Frequently Projects were labeled with code names, e.g., Project Pink Rose and Project Swamp Fox.
16. Aircraft normally took off before sunrise. From a tactical point of view, the arrival of the aircraft at the target area just prior to sunrise permitted the aircraft to approach the target from the direction of the rising sun. This afforded some degree of protection from enemy ground fire. From the standpoint of herbicidal action, application by aerial spray was most effective if accomplished prior to 0800 hours while inversion conditions existed, in the absence of precipitation, and while the wind was calm, or not exceeding a velocity of 8 knots. This insured the proper settling of the spray on the target area.

17. From 1966 through 1968, more than one sortie per day was often common for every available RANCH HAND aircraft. For example, during the first 6 months of 1968, the twenty-four UC-123B aircraft assigned to RANCH HAND averaged approximately 39 sorties per day.

### 3.6.4 Accidental Spills

As seen in many of the Figures, spills of herbicides were a consequence of handling large volumes of materials, frequency of missions, and the inexperience of the indigenous personnel assigned to load and unload the drums, F-6 trailers and the UC-123 RANCH HAND aircraft. It was a common practice for Vietnamese military personnel to be assigned the duties of loading and unloading drums of herbicide [Cecil 1986].

In addition, on multiple occasions, failure of equipment resulted in large spills. An unsigned US Army Memo dated 15 January 1970 and obtained from the US Armed Services Center for Research of Unit Records, Springfield, Virginia cited two spills involving less than 2,000 liters of Orange and White [Young and Andrews 2006]. The first spill occurred in December 1969 approximately two weeks after the large 113,550-liter tanks were installed for tactical herbicide storage at Bien Hoa Air Base. The memo noted that a leakage was observed in the underground piping system associated with the Agent White tank. The system was shut down and Civil Engineering was notified. After digging up the area, it was discovered that a coupling was broken on the pipe that drained the tank. No surface run-off of White occurred, and *"all spillage was absorbed in the soil in the immediate vicinity of the break."* The Memo also mentioned a spill of less than 2,000 liters that occurred during the first week in February 1970 from the same Agent Orange tank noted above. No other information was provided [Young and Andrews 2006].

On 1 March 1970, in a unsigned US Army Chemical Corps Memo dated 31 March 1970, another underground leak occurred at Bien Hoa Air Base in the 113,550-liter Agent Orange Storage Tank [Young and Andrews 2006]. The memo indicated that approximately 7,500 gallons (28,000 liters) had drained into the soil. A dirt dike was immediately constructed to contain the surface runoff (estimated at approximately 400 liters). On 7 March, an earthwork dam was constructed downstream of the underground piping system to contain any residue. On 22 March, the following notation was made:

*"The local dam has contained all the water and residue. No flow of liquid down the drainage system has occurred. However, the damaged area is now full of water and will not work during the monsoon season. Limited quantities of the water have been flushed over the dam for absorption into the sandy soil in the drainage ditch."*

Also on 22 March 1970, the Squadron Flight Surgeon referred the problem to the Bien Hoa Public Health Section. The Bien Hoa Public Health Section determined that the nearest USAF facility capable of testing for 2,4-D and 2,4,5-T was at McCellan AFB,

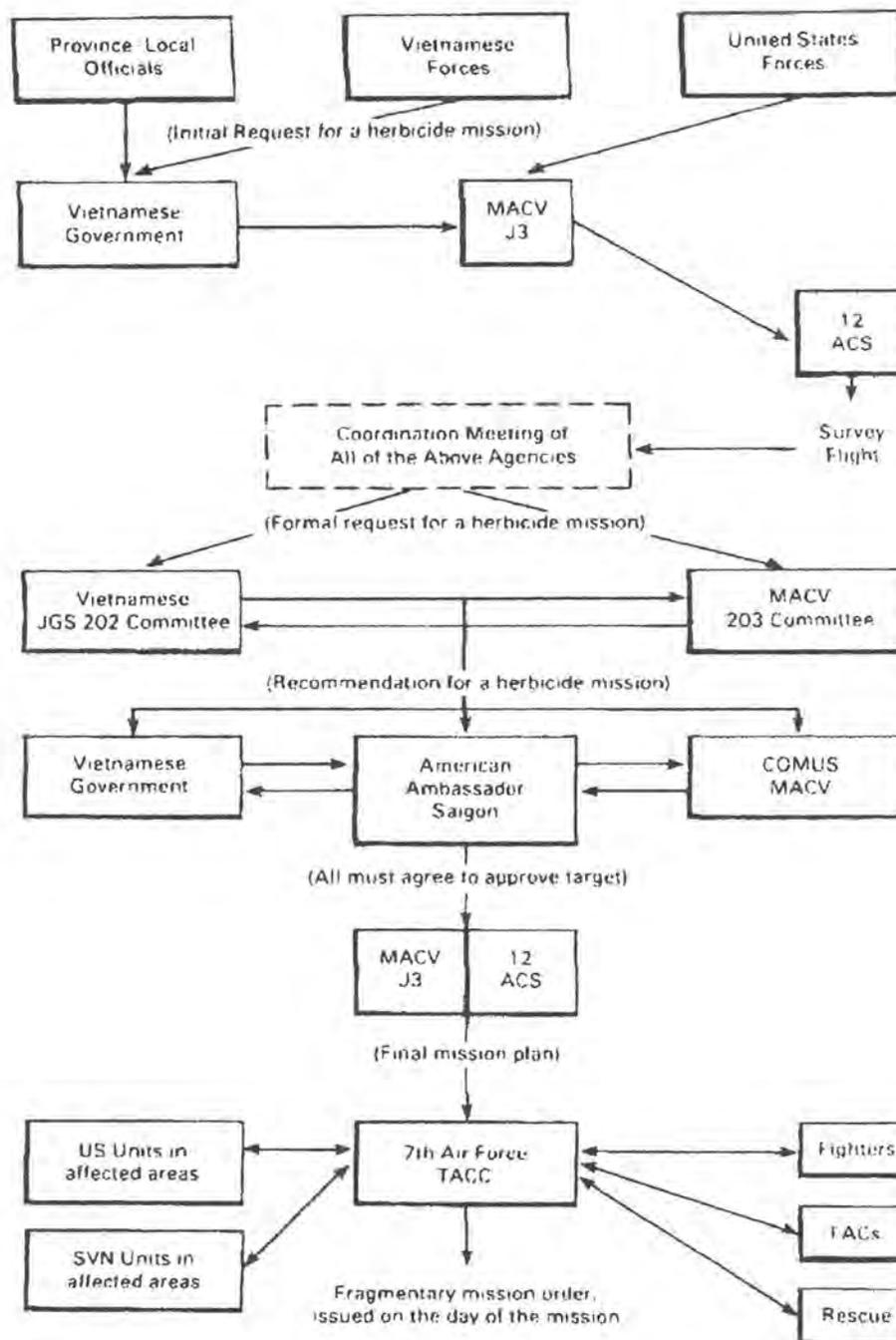
California. Procedures for obtaining water samples were discussed. The memo, however, did not give the results of any water samples, nor provide additional information on further activities related to the spill, other than corrective actions for the piping systems [Young and Andrews 2006].

### **3.7 MACV Directive 525-1: Herbicide Procedures and Operations**

The tactical herbicide program in South Vietnam was a joint United States – Government of Vietnam venture. Since the program carried with it the potential for generating serious political, economic, and psychological counter effects, it was conducted under an elaborate system of policy and operational control extending from the highest levels of both governments through intervening civil and military headquarters all the way down to the province level [Jefferson 1969].

Overall policy for herbicide operations in Vietnam was set forth in directives by the Military Assistance Command, Vietnam (MACV) and based on guidelines from the US Department of State and Department of Defense [Young, Cecil, and Guilmartin 2004]. The most important of these directives was MACV Directive 525-1, Herbicide Procedures and Operations [MACV 1969]. This directive was revised yearly during the peak years of tactical herbicide operations. Most importantly, the uses of all tactical herbicides by US and Free World Military Assistance Forces were governed by this directive [MACV 1969]. The Directive (and Annex K of the Directive) “prescribed policies, responsibilities, and procedures governing the operational employment of tactical herbicides within the Republic of Vietnam,” including all fixed wing, helicopter, and surface-based methods of herbicide application [MACV 1968; MACV 1969; Young, Cecil, and Guilmartin 2004].

The use of tactical herbicides for defoliation and crop destruction was primarily a Government of Vietnam operation that was supported by the US Government. A complex coordination process was involved in the approval of targets (see **Figure 3.16**). Initial requests of tactical herbicide projects often originated from Vietnamese province officials, and all such requests had to be approved by a Vietnamese Province Chief in accordance with Directive 525-1 [MACV 1969]. As noted in the flowchart (**Figure 3.16**), after the request was received it was referred to the Chief of the Joint General Staff (Chief, JGS), a Republic of Vietnam Armed Forces General Officer who headed a joint Army of the Republic of Vietnam (ARVN)/Republic of Vietnam Air Force (RVNAF) staff in Saigon (Vietnamese Forces and Vietnamese Government in the flowchart) [Cecil 1986]. Various tactical benefits and considerations supporting the project were required prior to the senior US Chemical Corps advisor issuing the documentation on the project (US Forces in the flowchart). The JCS request and Chemical Corps recommendation were then forwarded to the US Chemical Operations Division for analysis, staff coordination, evaluation and considerations of policy, logistics, and operational limitations [Young, Cecil, and Guilmartin 2004].



**Figure 3.16** Flowchart of combined United State/Vietnamese tactical herbicide target approval and directing order system in 1967 (Diagram courtesy of Cecil 1986)

Approval requests were presented simultaneously to the MACV 203 Committee and to the Vietnamese JCS 202 Committee (see flowchart), and if both Committees recommended the request, it was sent to the US Ambassador, the Commander of MACV, and to the Government of Vietnam (GVN) for final approval of the target [Cecil 1986]. A

coordination meeting was held in the province in which the project was to be conducted, during which the final mission plan would be agreed upon [Young, Cecil, and Guilmartin 2004]. Following the coordination meeting, MACV published the 'operations' order, and issued the 'execution' order, while the JCS requisitioned the tactical herbicide from appropriate GVN agencies [Young, Cecil, and Guilmartin 2004].

Directive 525-1 mandated that (1) defoliation and crop destruction missions were limited to areas of low population; (2) use of US assets for defoliation by fixed-wing aircraft and all and crop destruction operations required pre-approval from the MACV Commander, the US Ambassador, and the GVN; (3) use of US assets to accomplish GVN requests for defoliation by helicopter in support of (i) local base defense, (ii) clearance of small ambush sites and (iii) maintenance of deforested areas, required pre-approval from both the US and GVN; (4) use of US assets to accomplish surface-based spray operations required pre-approval from both the US and GVN; (5) care was to be taken in planning executing operations to prevent herbicide damage to rubber trees; and (6) a "no-spray zone of 2 km for helicopters and 5 km for fixed-wing delivery was to be maintained around active rubber plantations" [MACV 1968; MACV 1969].

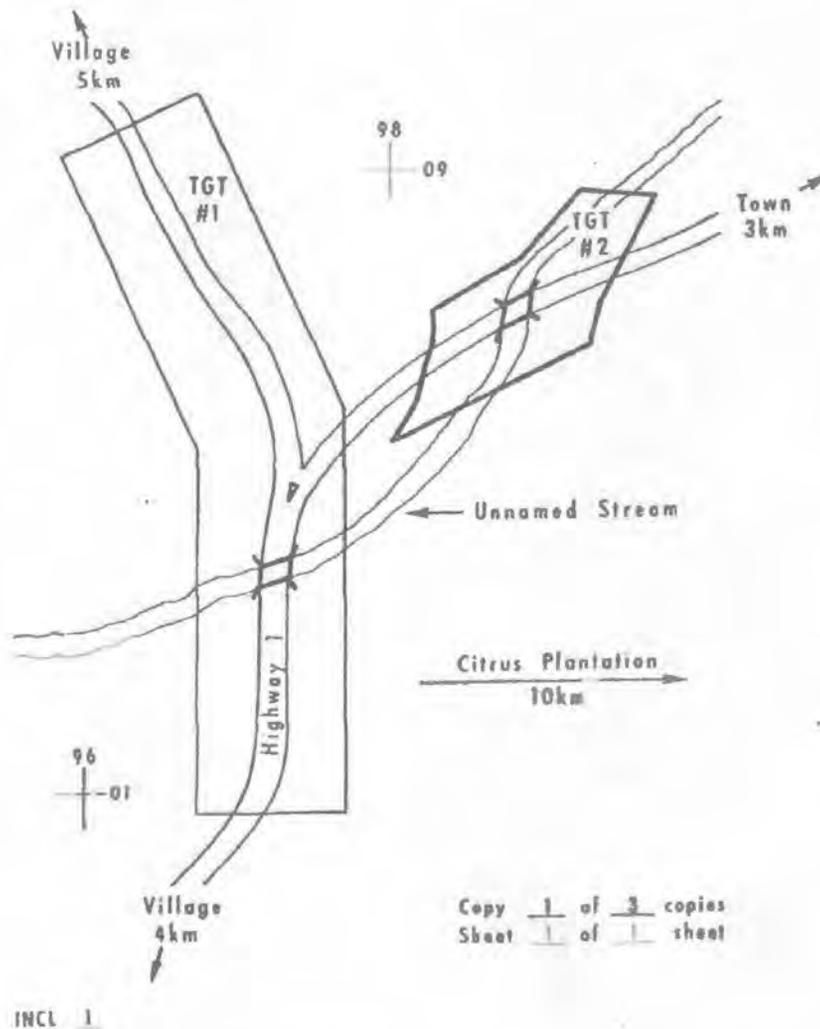
### **3.7 Post Approval Procedures in Operation RANCH HAND**

RANCH HAND operations and targeting personnel met weekly with the chemical operations section of MACV to discuss these requests and schedule survey flights over proposed areas. The survey sorties were necessary to identify actual target locations for the individual missions, and to plan optimum attack routes, and were flown by single, unescorted UC-123s (the unarmed transport aircraft used for the spray program) manned by the RANCH HAND chief or assistant chief of targeting, a copilot, a navigator from targeting, and an Army Chemical Corps officer [Cecil 1986; Young, Cecil, and Guilmartin 2004]. After flying reconnaissance over the proposed area, a coordination meeting was held in the field with the province chief, local military commanders, MACV and ARVN, representatives of the 7<sup>th</sup> Air Force and RANCH HAND. Details of target requests, intelligence data, and target particulars were worked out. A target overlay map of the proposed mission was prepared. **Figure 3.17** was an example of a target overlay for a defoliation request [MACV 1968]. Following the meeting, formal target requests were prepared and forwarded to Saigon for clearance by RVN and US authorities. After consultation with the South Vietnamese military and government officials, final approval authority over targets belonged to the Commander, MACV, and the American Ambassador [Cecil 1986].

### **3.8 Coordinating RANCH HAND Spray Missions**

Once a particular target area (referred to as a target box) was approved, the RANCH HAND commander and his targeting officer, together with MACV staff members, determined the most effective mission dates and requested implementing orders. Hostile ground fire was such a hazard to the UC-123 aircraft that in January 1965, approval was given to prestrike targets with fighter aircraft in advance of impending tactical herbicide missions [McConnell 1970]. After January 1965, defoliation was considered a strike

Target Overlay: Defoliation Request No: ONE Targets No: 1 & 2  
 Reference: Map, South Vietnam, 1:50,000, Sheet 5000, 5010



**Figure 3.17** Example of a target overlay (MACV 1968)

mission and was always accompanied by a Forward Air Controller (FAC) and escort fighters. Close-in fighter support was a vital part of planning and it reduced to some extent the deadly hazard poised to RANCH HAND personnel and aircraft by ground fire from opposing forces. The Targeting Officer determined the type of aircraft fighter support needed for the particular area, planned the individual missions, prepared necessary target charts, and drafted the order requests for submission to TACC (Tactical Air Control Center). The tactics for an individual target run were first considered during target scheduling. In selecting the optimum run, the Targeting Officer weighed such factors as terrain, the size and geometry of the target and restrictions on the approach and

departure to it [Jefferson 1969]. If possible, the run was planned to be straight and continuous since multiple passes in the same area increased exposure to ground fire. The Targeting Officer insured that the formation would not be boxed in a canyon on mountain runs even if an engine were lost, and he tried to have the sun at the formation's back since it was low on the horizon. He also made judgment on the defenses likely to be encountered, based on past experience in the target area and information from the coordination meeting, intelligence and FAC from the area when available [Jefferson 1969].

The day prior to the mission, TACC coordinated the FAC, fighter and rescue support through the Direct Air Support Center (DASC) and issued the approved mission order (fragmentary, or "frag" order) (see flowchart, **Figure 3.16**). TACC in coordination with DASC sent out warning messages to field forces of the impending mission. The target box was declared a "free fire zone", thus indicating that the supporting fighter aircraft could drop ordnance on the target area with only clearance from the Forward Air Controller [Collins 1967; Buckingham 1982].

### **3.9 Encountering a Hostile Environment**

Spray missions for both defoliation and crop destruction were conducted in extremely hostile environments. That was the concept for the use of herbicides – remove the vegetative cover and food sources used by the enemy. The ground fire received by the RANCH HAND aircraft was from enemy troops (Viet Cong and North Vietnamese Army) [Collins 1967]. Although the C-123 "Provider" was a tough and dependable aircraft, it was never designed to withstand the harsh combat environment of the RANCH HAND mission in South Vietnam. Significant modifications were made to protect the crew, the spray systems, and the aircraft. The volunteer crews of Operation RANCH HAND had no manuals or guidance documents on how to perform their missions; they learned from day-to-day operations and from their mistakes. Their tactics and strategies were intended to minimize their time on target while maximizing the effectiveness of the herbicide selected for that target. The continual refinements to the aircraft and modifications of the tactics and procedures were necessary to minimize aircraft battle damage and crew injury during spray operations [Cecil 1986].

Responding to the increase in battle damage, especially in the cockpit areas, during missions in 1965, RANCH HAND crewmembers began using flying helmets equipped with a clear visor that could be lowered to protect the eyes. Used in place of the standard radio headset while on the spray run, the helmet, together with a flax jacket, offered pilots and navigators extra protection from flying shrapnel and glass. Twice in December 1965 this protection allowed crews to complete runs despite cockpit damage, although it did not prevent them from receiving minor wounds [Cecil 1986]. Because of enemy antiaircraft fire, and at the suggestion of RANCH HAND crews, Doron armor "half moon" cut-outs were installed in front of the instrument panels to provide limited "head-on" protection for the cockpit area. [Doron armor was a highly engineered nonmetallic lightweight armor of laminated fiberglass and nylon.] In addition, an open-topped box, one meter on each side, constructed of two 1.5-cm thick sheets of Doron armor was

installed at the spray operator's position to afford him some protection against ground fire [Buckingham 1982]. Armor was also placed around the pump motor fuel tank, and a fire extinguisher installed nearby to reduce the risk of a ground fire hit causing an internal fire [Buckingham 1982].

In the first years of RANCH HAND Operations, the UC-123s had retained the unpainted silver finish of the original aluminum skin, a finish marred only by red-primed patches resulting from repair of frequent enemy hits. In January 1966, Air Force Headquarters directed the repainting of all combat aircraft in a camouflage scheme of mottled browns, greens and yellows in irregular patterns. The purpose of the new camouflage color scheme was to make the aircraft harder to see, particularly when dispersed on the ground. Because of the camouflage, Forward Air Controllers (FACs) and supporting fighters had trouble in distinguishing the spray planes at low-level when they did not have their spray turned on. By adding a fluorescent red stripe (in 1967) on top of the wings of the UC-123s, the planes could be spotted more easily by their escorts [Buckingham 1982].

Numerous emergencies occurred which required the crews of the UC-123 to rapidly *dump* their herbicide. Such action had to be taken very quickly when an engine quit – approximately 5,000 kg of herbicide greatly reduced the ability of the remaining engine to keep the aircraft from stalling. Hence, in the A/A 45Y-1 Internal Modular Dispenser System a 25-cm emergency dump valve was installed, replacing the 12.5-cm value previously used. This allowed the flight engineer to more rapidly empty the entire 1000-gallon (3,785-liter) tank [Collins 1967].

In May 1968 RANCH HAND received the first UC-123K, a converted UC-123B. The K-model modifications consisted of the installation of two J-85-17 jet engines to supplement the two radial piston engines, a modulated anti-skid braking system, and a combination stall warning and angle of attack indicator. The additional thrust provided by the jets greatly increased the aircraft's ability to tolerate the loss of an engine, while the extra airspeed and rate of climb reduced vulnerability to ground fire by enabling the spray planes to spend less time at low altitude increasing safety margins during operations over mountainous terrain. To enable the spray delivery system to keep pace with the higher-flying speeds, the UC-123Ks also received a larger spray pump and a flow meter to regulate the deposition rate at a constant three gallons per acre, regardless of the plane's speed [Buckingham 1982; Cecil 1986].

The tactics used on spray missions varied with target type and depended generally on weather, target terrain, and the amount of ground resistance expected. If the weather was clear, the spray aircraft remained at altitude (915 meters AGL) and then rapidly descended at about 760 meters per minute to spray altitude (45 meters AGL). If ceilings were low, a low-level approach was made to reach the "spray-on" point. If terrain permitted, one long straight run was made. Other spray patterns included flying a race-track pattern, or a "Plum Tree" tactic, which involved making 90 – 270 degree turns at the end of the target area. If the target was "hot", the spray aircraft made one pass and then diverted to another target for the rest of the mission. In mountainous country, a lead

aircraft flew at a slightly higher altitude, where visibility was greater, and thus was able to lead the other spray aircraft along the road or trail. Another technique involved throwing smoke grenades to mark the road before starting the run. The procedure was to fly from smoke-point to smoke-point [Collins 1967].

Despite the aircraft modifications and the continuing efforts to develop tactics that would provide an additional margin of safety, the most effective means of protecting the RANCH HAND aircraft and crews was the supporting role of fighter aircraft. By mid-1964, hostile ground fire became more intense, and the RANCH HAND missions became extremely hazardous. Since the need to assign fighter aircraft to escort and support the defoliation project had not yet been recognized, the spray aircraft were entirely defenseless. Although RANCH HAND aircraft received heavy automatic-weapons fire from the ground with increasing regularity, it was not until January 1965 that approval was granted to pre-strike targets with fighter aircraft and to provide a fighter escort for the spray aircraft. From that point forward, close-in fighter support was a vital part of the defoliation program and made a significant contribution toward minimizing the effect of ground fire against defoliation aircraft, although it could not entirely eliminate losses of aircraft and crew. Almost half of the aircrew members assigned to RANCH HAND in December 1965 had been wounded at least once and the aircraft had a total of nearly 800 hits; one of the older planes, nicknamed the "Leper Colony" had been hit 230 times and its occupants had earned eight Purple Heart medals. During its nine years of operation, RANCH HAND aircraft received more than 5,000 hits, lost nine spray aircraft to hostile fire and had 28 RANCH HAND personnel die in combat [Buckingham 1982; Cecil 1986].

### **3.10 The critical role of the Forward Air Controller**

The Air Force basic work unit was a Tactical Air Control Party (TACP), and was an autonomous Air Force unit co-located with the US Army. It was comprised at a minimum of an officer, the Air Liaison Officer or the Forward Air Controller (FAC), and who was assigned to an Army unit, and the ROMAD (Radio Operator Maintenance Drive), an enlisted member of the TACP who was a mobile (jeep) radio operator. Both the FAC and the ROMAD had radio equipment for UHF (ultra high frequency) and VHF (very high frequency) communications [TASG 1969]. The Forward Air Controller had major responsibilities for the executing the RANCH HAND mission. The FAC flew a single-engine observation aircraft (e.g., O-1/E/F, "Bird Dog"), and was generally based at the nearest Tactical Operations Center (TOC) to the target area, and was the individual most familiar with the Area of Operations (AO), or his Tactical Area of Responsibility (TAOR) [TASG 1969; Boyne 2000]. When the FAC received a frag order, he established his "call sign" that would be recognized by the pilot and navigator of the lead RANCH HAND aircraft, the accompanying fighter escort, and with the ROMAD who kept in constant contact with any ground forces (including special operation units) that potentially could be near the target box. Within the Corps Area, e.g., II Corps, the FACs kept their own call signs that were readily recognized by ground troops and pilots [TASG 1969; Flanagan, 1992].

Usually, one or two hours prior to the RANCH HAND mission, the FAC arrived at the target coordinates and made observations on the weather, landmarks, and if there were observable hostile forces in the area. Since the target area was a “free fire zone”, the FAC, in coordination with the ROMAD, ensured that there were no friendly (allied or US) forces in the target area. If there were any imminent operations or the presence of friendly forces in the area, the FAC would force cancellation, or modification of the spray mission to an alternative target. Since CBU ordnance had about a two percent dud rate, it was frequently necessary for ground commanders to deny clearance for movement of friendly troops through the area [Cecil 1986]. Hence, the approval procedures for a mission “cautioned” field commanders not to send friendly troops immediately into areas sprayed because of this unexploded ordnance [Flanagan 1992]. This action prevented accidental attack on friendly forces by the escorting fighters, and kept field forces from entering the area after the use of CBU (cluster bomb unit) or other heavy suppression munitions [TASG 1969; Cecil 1986; Flanagan 1992].

### 3.11 Executing the Spray Mission

The FAC coordinated the approaching RANCH HAND aircraft and the accompanying fighter support. If the weather in the target area was not acceptable (e.g., wind greater than 10 knots, rain, poor visibility), the FAC cancelled the mission or sent the aircraft to the alternative target. If the mission was to be executed, the FAC marked the start of the target by the use of a rocket that produced a plume of white smoke visible through the trees [TASG 1969]. The RANCH HAND aircraft descended to the appropriate altitude and air speed and the lead pilot called “spray on” at the start of the spray run. All aircraft in a mission simultaneously turned on their spray systems and continued spraying until the lead pilot called “spray off”. If the target area was known to be a “hot target” (hostile ground force present), or if the RANCH HAND aircraft received ground fire, the FAC instructed the fighter aircraft to deliver its ordnance at the location where the RANCH HAND aircraft received the ground fire [TASG 1969]. The FAC stayed in the target area until the RANCH HAND and fighter aircraft departed the target area. If either the RANCH HAND or fighter aircraft were crippled or crashed, the FAC via the ROMAD, requested air rescue (helicopter) assistance [Flanagan 1992]. Thus the role of the FAC was critical to essentially every RANCH HAND mission that occurred after November 1963.

During July 1968, RANCH HAND developed more fully the tactic called “heavy suppression” to counter increased ground fire over heavily defended targets (Buckingham, 1982). Frequently when RANCH HAND aircraft flew over such targets, between four and twelve fighter aircraft accompanied the spray planes. On the day prior to the mission, the pilots of the RANCH HAND and fighter aircraft would meet and decide on specific tactics. When heavy suppression was involved, fighters would strike *strong points in the target area with 500- or 750-pound bombs two or three minutes before the UC-123s began their spray run.* When the spray run began, fighters would fly slightly ahead of and parallel to the spray planes and drop antipersonnel CBUs to force any gunners on the ground to stay under cover until the spray formation had passed (Buckingham 1982). **Figure 3.18** was a photograph showing a fighter aircraft delivering

ordnance on a target prior to the arrival of the RANCH HAND aircraft. The fighter aircraft frequently deployed CBU-12s containing white phosphorus that were not only an added deadly “heavy suppression” munitions, but they also provided a “cloud of smoke” to hide the approaching RANCH HAND aircraft.



**Figure 3.18** Three RANCH HAND aircraft spraying at 150 feet above the ground were masked from enemy fire by CBU smoke to the right of the run. Meanwhile a fighter aircraft, barely visible above the hills, had just laid CBU to the left of the planned spray run. This photograph was taken in Northern II Corps in 1967 (Photograph courtesy of the Plant Sciences Laboratories, Fort Detrick, Maryland)

As previous noted, in 1967 RANCH HAND personnel painted a red identification stripe across the top of the UC-123's wings to help fighter aircraft and forward air controllers see the camouflaged RANCH HAND planes more easily against the background of the South Vietnamese jungle (Buckingham, 1982). **Figure 3.19** was a photograph of RANCH HAND aircraft with the red stripe.

### **3.12 Preparation of the Daily Air Activity Report (DAAR)**

The fundamental data on RANCH HAND tactical herbicide operations came from paper records (Daily Air Activity Reports, DAAR) containing data from the missions that were flown [DMA 1970]. **Figure 3.20** was a photograph of a DAAR describing three spray missions that occurred on 6 July 1968 in Vietnam. The DAAR included the date of the mission (s), call sign, base of origin, project number, UTM coordinates and target type (e.g., enemy line of communication, base camp, crop destruction), type and quantity of

herbicide, total



**Figure 3.19** A photograph of four UC-123K aircraft “heading down” to the target. Note the bright red band across the upper surface of the wings. This was to identify RANCH HAND aircraft by the fighter aircraft that would meet them at the target area. The photograph was taken over II Corps, 23 August 1969 (Photo courtesy of J. Ray Frank, Frederick, Maryland)

flying time, number of hits (from enemy ground fire), reason if mission aborted, target information (temperature, wind, condition, indicated air speed of aircraft), and remarks [Cecil, 1986]. However, not all information, especially remarks, was transferred to the the Chemical Corps HERBICIDE REPORTING SYSTEM (HERBS). The content of the HERBS system included the province(s) in which the mission was flown; the mission project number; UTM coordinates covered by the mission with identifying additions to identify each UTM point as a stop, turn, or start coordinate; the type of herbicide used; the number of gallons sprayed; the type of mission; the number of hits received during a run; and, the number of aborts attributable to maintenance, weather, battle damage, and other factors. The completeness and accuracy of the data were entirely dependent upon the quality of information obtained from the field units and forwarded to the Chemical Operations Division [Cecil 2006].

**Figure 3.20** was a photograph of a DAAR of the 12<sup>th</sup> ACS (Air Commando Squadron) daily record of three “missions” which occurred on 6 July 1968. Specific daily missions were known as “lifts” and were designated by alphabetical letters that were also used as part of the formation call sign; that is, the first mission from Bien Hoa each day was the “Alpha” lift with the radio call sign “Cowboy Alpha”; (later it was changed to “Hades Alpha”). Typically, show time (arrival time of the aircrews at the flightline) for the Alpha



occurred on 6 July 1968 during the Vietnam War (Courtesy of the Air Force Historical Center, Maxwell AFB, Alabama)

distance of the target from the launch base. After returning from the first target, the Alphacrews would rebrief and relaunch at 0900 to 0930 hours to another target. This second mission by this crew would become "Charlie lift". The Bravo crew was also turned around for a second mission and would become the "Delta lift".

During the "good weather" season in I Corps, a project might be augmented with additional aircraft to allow four or five missions instead of two. Thus, if sufficient aircraft and crews were available, and target approval had been obtained, additional missions were scheduled as "Echo", "Hotel", "India", "Juliet" and "Kilo" lifts. Generally three or four aircraft constituted a "lift". In the enclosed mission record, notice that "Hotel" and "India" originated from Da Nang (DAD) and were "on target" at 0715, and 0640 hours, respectively, indicating that on the date (6 July), at least 18 aircraft were launched before daybreak (in this case, "Hotel" and "India" had wheels up at 0526 and 0529 hours, respectively). Lift "Hotel" had a target that was an enemy line of communication (LOC), while "India" lift was against a crop target. "Juliet" left Da Nang at the same time, but had a target almost 4 hours away; the VC base camp was an alternate target. "Hotel" and "India" were part of the same project. Only "India" received ground fire. The lead aircraft received 4 hits, the second (of three) received 1, and the last aircraft over the target received 8 hits. Note that the run for "Hotel" was delayed due to the FAC (Forward Air Controller) working the run for "India". Fighters expended munitions for both "Hotel" and "India" targets. "Juliet" lift encountered extreme turbulence on a ridgeline and called "spray off" after 50 seconds. No hits were taken, fighters arrived 30 minutes late, but no munitions expended. All three missions sprayed Agent Orange, but since "Juliet" lift sprayed for only 50 seconds, the data on quantity of herbicide sprayed (3,000 gallons) was probably incorrectly reported. Note also that the UTM coordinates provided a "start" and a "stop", but the alphanumeric indicators in the UTM coordinates for the "Hotel" mission confirmed that it did not follow a straight line (a third set of coordinates). The "Hotel" mission was in the mountainous terrain of I Corps, and the flights likely followed the contours of the terrain. The "India" target was crop destruction and this likely required the crew to repeatedly turn off and on the spray system and make frequent turns, and this is not noted in the UTM coordinates [Cecil 2006].

The DAARS provide both a source of detailed information and ample evidence that the detailed procedures and policies for the RANCH HAND missions were strictly observed [Young, Cecil, and Guilmartin 2004]. Although the DAARS data did not permit reliable conclusions that troops on the ground were not directly sprayed during a spray mission, they did cite reasons for aborted or cancelled missions, such as due to "friendly forces in the area." **Table 3.5** is a listing and numbers of cancellations taken from DAARS for RANCH HAND missions conducted between January 1967 and December 1970 [Cecil 2006].

**Table 3.5** Data from RANCH HAND Daily Air Activities Reports (DAARs) citing reasons for the cancellation of missions [Cecil 2006]

RANCH HAND TARGET CANCELLATIONS 1967—1970					
Time Period (Jan.—Dec.)	1967	1968	1969	1970	Total
<b>Scheduled Missions</b>	2030	1697	1542	425	<b>5,694</b>
<b>Missions not checked by DAARS</b>	611	467	117	11	<b>1,206</b>
<b>Targets cancelled for:</b>					
Weather, general	539	704	600	130	<b>1,973</b>
High temperature or high winds	135	85	112	10	<b>342</b>
Friendly troops in the area	18	39	30	9	<b>96</b>
Cnx by DASC, reason not given	23	6	0	0	<b>29</b>
Cnx by TACC, reason not given	21	68	76	41	<b>206</b>
FAC not available on target	26	46	47	24	<b>143</b>
Fighter escort not available on target	27	12	25	8	<b>72</b>
Cnx by US military field unit	7	10	39	6	<b>62</b>
Cnx by ARVN military field unit	1	7	21	2	<b>31</b>
Due battle damage or high threat	19	21	24	2	<b>66</b>
Due maintenance malfunction	71	42	63	23	<b>199</b>
Due to other than other above reasons	40	18	29	9	<b>96</b>
Cnx/not authorized by higher HQ	6	8	34	25	<b>73</b>
Never being approved/never scheduled	8	19	12	6	<b>45</b>
Unknown cause	21	50	36	9	<b>116</b>
<b>Totals</b>	<b>962</b>	<b>1135</b>	<b>1148</b>	<b>304</b>	<b>3,549</b>

As noted in Table 3.5, DAARS were available for 4,488 of the scheduled 5,694 missions

from January 1967 through December of 1970. Approximately 52% all missions cancelled were due to unfavorable weather conditions. Clearly the very narrow range of conditions under which spraying could have taken place, and the extreme variation in weather conditions over South Vietnam, especially during the monsoon seasons were the primary cause of the weather related cancellations. Almost 5% of all missions were cancelled because either the FAC or the fighter escorts were not available in the target area. Cancellation by various controlling agencies accounted for approximately 10% of the cancellations. Cecil concluded that although the DAARs did not indicate, it was probably safe to assume that most of these cancellations were the result of being unable to obtain fire-on-fire clearances as a result of friendly troops in or scheduled to be in the target area. It should be remembered that the elaborate clearance procedures in place were there for the protection of the spray aircraft and crew, rather than any concern that friendly forces would be harmed by exposure to the tactical herbicides. These procedures also protected friendly troops from the danger of accidental harm from "friendly" fire [Cecil 2006]. The fact that a postwar study by the US military indicated that no friendly casualties resulted from RANCH HAND operations also was evidence that regulations were strictly adhered to [Young, Cecil, and Guilmartin 2004].

### **3.13 Other Herbicide Requests**

Defoliating a zone around the outside circumference of an installation/base became the responsibility of the Allied ground commander whose TAOR (Tactical Area of Responsibility) was confined to the base. The desiccant/defoliation (Blue, White, or Orange) request was prepared and documented by the base civil engineer, using a set checklist [Fox 1979]. It was then processed through US military channels to the senior US Army headquarters in the Corps Tactical Zone (CTZ). If approved there, it was sent on to the ARVN Commanding General of the same CTZ for military approval and political clearance. Senior US Army advisors affiliated with the Army Chemical Corps at ARVN corps and division level were delegated authority to approve requests in which the dispersal of the tactical herbicides was limited to hand or ground-based power-spray methods [MACV 1968; MACV 1969; Fox 1979]. If aerial delivery was desired, the requests could only be approved at the MACV or JCS (Joint Chiefs of Staff) level.

As noted, authorization for herbicide missions by helicopter or surface spraying from riverboats, trucks, and hand-operated backpacks was delegated to the RVN and US authorities at the Corps level, but the responsibility for the actual spraying remained with the US Army Chemical Corps. These operations required only the approval of the unit commanders or senior advisors. "Free-spraying" areas, including the DMZ at the 17th parallel and the first 100 m outside base camps, were also exempt from MACV regulations. This delegation of authority for spraying to the Corps level reduced the lag time that existed from proposal to completion of small defoliation projects conducted around depots, airfields, and outposts [NRC 1974; Collins 1967]. Because these helicopter and ground sprays were less rigidly controlled than fixed-wing aerial sprayings, the record keeping of such sprays by the Army Chemical Corps was not as systematic as those of Operation RANCH HAND [IOM 1994].

To clarify, the Base Civil Engineer had responsibility for preparing the requests to the Army Chemical Corps for the spraying of "tactical" herbicides around (outside) the base perimeters. Within the military base, the Base Civil Engineer also had the responsibility for all pest control programs, this included weed and brush control around base facilities, housing, ditches etc. The pesticides used in these operations were those approved by the Armed Forces Pest Control Board and had GSA assigned Federal Stock Numbers, and thus could be purchased at the direction of the Base Civil Engineer [AFPCB 1974]. All available pesticides that could be purchased by the Base Civil Engineer would have been listed in the Department of Army Supply Bulletins for Pesticides [Lambert 1963]. Tactical herbicides were not designated for use on US military installations [AFPCB 1974].

### **3.14 The Role of the Army Chemical Corps**

Although the RANCH HAND units (i.e., the 12th Air Commando Squadron of the 7th Air Force) had the primary responsibility for tactical herbicide operations in South Vietnam, the Army Chemical Corps staffed the Chemical Operations Branch, US Army, MACV. The MACV Chemical Operations Branch, exercised command supervision, coordination, liaison and control of all US and Allied forces in support of defoliation and chemical crop destruction operations in the RVN, including all aerial herbicide defoliation and crop destruction missions such as Operation RANCH HAND [Warren 1968].

The duties of the Chemical Operations Branch included determining and assessing the quantity of herbicide, including Agent Orange, required for all defoliation and chemical crop destruction missions in South Vietnam. The Branch had supervisory authority over requests for and release/dispensation of all herbicides for use in military operations. This included oversight authority over the promulgation, administration, regulation, and enforcement of rules, guidelines, procedures and directives with respect to the handling, use, and administration of all tactical herbicides. As noted earlier, MACV Directives 525-1 and 525-1, Annex K, Chemical and Herbicide Operation, were the primary directives governing tactical herbicide use and operations in South Vietnam [MACV 1968; MACV 1969].

Twenty-two US Army Chemical Corps units were assigned to South Vietnam during the years between 1965 and 1973 [Thomas and Kang 1990; Dalager and Kang 1997]. These units were responsible for the storage, preparation and spraying of tactical herbicides around the perimeters of base camps and aerial spraying from helicopters in Vietnam. Using hand, vehicle-mounted equipment, and H-34 helicopters, the Army Chemical Corps conducted spray operations, such as defoliation around Special Forces camps; clearance of perimeters surrounding airfields, depots, and other bases; and small scale crop destruction [Thomas and Kang 1990; Warren 1968]. The Army Chemical Corps was responsible for 4-5% of the herbicides applied in South Vietnam. Almost 2,900 men served in the Army Chemical Corps in South Vietnam during the period from July 1965 to March 1973 [Dalager and Kang 1997]. It should be noted that US Army Chemical

Corps personnel were also responsible for the storage, handling, mixing, and application of riot control agents (tear gas), and burning agents (napalm). They had the opportunity for exposure to numerous other chemicals used in warfare as well as diesel and jet fuel and other solvents used for equipment cleaning and maintenance [Thomas and Kang 1990].

Although Army Chemical Corps personnel conducted spray operations, other units and individuals handled or sprayed herbicides around bases or lines of communication. As previously noted, the first 100 meters outside base camps were “free-spraying” areas. Engineering personnel required the use of herbicides for removal of underbrush and dense growth in constructing support bases. The Chemical Corps was generally called upon to support these operations. Most military bases had vehicle-mounted and backpack spray units available for use in routine vegetation control programs [NRC 1974; Cecil 1986; IOM 1994]. More than 100 helicopter spray equipment units were used in the RVN [Young 1988].

Various ground delivery systems also were used by the Army Chemical Corps in the RVN for control of vegetation in limited areas. Most of these units were towed or mounted on vehicles. One unit that was routinely used was the buffalo turbine. It developed a windblast with a velocity up to 240 kilometer/hour at 280 cubic meters per minute volume. When the herbicide was injected into the air blast, it was essentially “shot” at the foliage. The buffalo turbine was useful for roadside spraying and applications of perimeter defenses. Under favorable wind conditions, this ground system could effectively spray a swath 75 meters in width. The herbicides of choice in these operations were Blue and Orange [Young 1988; Warren 1968]. The hand spray units, used on the smallest vegetation-control projects consisted of a backpack type dispenser with a capacity of approximately 11 liters.

Commercial herbicides were usually readily available at US installations throughout the RVN. These herbicides were used in on-base programs under the control of the Base Civil Engineer, and included Bromacil, Tandex, Monuron, Diuron, and Dalapon (Irish, Darrow, and Minarik 1969). However, it was a common practice that the dregs (remaining 4 to 6 liters in the bottom) from the 208-liter tactical herbicide drums were pumped into smaller drums and sent by the Army Chemical Corps to many bases and military camps for control of perimeter foliage [Young et al 1978]. As previously noted, Phu Cat and Nha Trang became “turn around” facilities from mid-1968 through November 1969 for RANCH HAND aircraft. As a result, significant quantities of tactical herbicides were received at these two bases. The dregs from these drums provided an easily accessible supply of herbicides in II Corps [Young and Andrews 2006]. However, approval was required for their use, including the use in the “Free-spray” area [MACV 1968]. **Figure 3.21** was a photograph an Army UH-34 Helicopter spraying Agent Blue adjacent to the perimeter of an Air Base. **Figure 3.22** was a photograph of a modified spray rig mounted in a C-47 spraying Agent Blue on the perimeter at Phan Rang Air Base. **Figure 3.23** was a photograph taken of a crop destruction mission carried out by the Army Chemical Corps using a UH-34 Helicopter mounted with the HIDAL Spray System.



**Figure 3.21** A photograph of the Army UH-34 Helicopter (shown in **Figure 3.6**) spraying Agent Blue adjacent to the base perimeter at Tan Son Nhut Air Base. The presence of tranh grass and other weedy species that grew to a height of 2 meters were most easily controlled by the aerial applications of Agent Blue (courtesy of US Army Chemical Corps)



**Figure 3.22** A photograph of the base perimeter of Phan Rang Air Base at the time of aerial application of Agent Blue by the use of a modified spray rig mounted in the cargo bay and door of a C-47. Notice the “in-depth” wire fencing (i.e., two rows consisting of three lines of fence, each one meter apart). Because the base bordered civilian dwellings, this fence arrangement was intended to keep civilians from inadvertently entering base perimeter areas (photograph courtesy of US Army Chemical Corps)



**Figure 3.23** A photograph of a US Army Chemical Corps UH-34 Helicopter conducting a crop destruction mission in II Corps, August 1969 (Photograph courtesy of J. Ray Frank, Frederick, Maryland)

### **3.15 Herbicide Operations in the Individual Combat Tactical Zones**

Providing support for RVN, U.S., and Free World Military Assistance Forces was a major responsibility of the RANCH HAND operation [Cecil 1986; Buckingham 1982; Clary 1971; Warren 1968; Collins 1967]. Four nations (the United States, Australia, New Zealand, and the Republic of Korea) committed most of the combat troops deployed to support the RVN from 1962 to 1973. The United States deployed 2.64 million military personnel to Southeast Asia during the Vietnam War. US Forces were deployed throughout the RVN [Young, 2001]. The United States Marine Corps (USMC) was primarily located in I Corps, while US Army units deployed in each of the CTZs and conducted most II, III, and IV Corps military operations staged by American troops. Australia and New Zealand jointly deployed approximately 46,850 combat troops, and they were primarily located in III Corps. The Republic of Korea (ROK) deployed approximately 312,850 combat troops, and they were primarily located in the coastal areas of II Corps [Larson and Collins 1975; Young 2002]. Thailand also provided a small contingent in addition to making several air bases available for US use.

The vast majority of missions involving Agents Orange and White occurred in late 1967 through June of 1969 and were targeted in the northern provinces bordering Laos and Cambodia (I and II Corps). The greatest number of missions was flown on targets in Kontum Province. The plans for these missions were outlined in an August 1966 Report

on "Chemical Defoliation of the Ho Chi Minh Trail" [IDA 1966]. The requirements for those missions were so great that in mid-1968, RANCH HAND began using a turn-around facility at Phu Cat and Nha Trang. Those two bases in II Corps were used as points for loading fuel and herbicides. The RANCH HAND squadron's newly deployed UC-123K's would take off from Bien Hoa Air Base in III Corps on their first mission of the day against targets in northern areas of II Corps, and after spraying, land at Nha Trang. With their fuel and herbicide replenished, they would then spray another target before returning to Bien Hoa. The UC-123K's from Da Nang would re-service for fuel and herbicide at Phu Cat before returning to targets on the Ho Chi Minh Trail after which they would return to Da Nang [Cecil 1986].

Infrequently, and at the request of RVN province chiefs and local commanders, RANCH HAND aircraft sprayed targets on Route 1 and the railroad in Phu Yen Province (II Corps). These actions reduced ambushes against train and road convoys between Tuy Hoa and Qui Nhon [Buckingham 1982]. **Figure 3.24** was photograph of a mission of four aircraft (four sorties) spraying Highway 1 south of Qui Nhon. **Figure 3.25** was a photograph of a single aircraft (sortie) spraying vegetation along the east side of Highway 1 south of Tuy Hoa in Phu Yen Province. **Figure 3.26** was a photograph of a defoliated section of Highway 19 between An Khe and Pleiku.



**Figure 3.24** A photograph of four UC-123B aircraft (four sorties) spraying Highway 1 south of Qui Nhon. This photograph was taken on 14 December 1963. The tactical herbicide was Purple and it was disseminated at a rate of 14 liters/hectares (Photograph courtesy of the Plant Sciences Laboratory, Fort Detrick, Frederick, Maryland)



**Figure 3.25** This photograph of a single RANCH HAND UC-123B sortie spraying vegetation along the east (in this N/S oriented view) side of Highway 1, south of Tuy Hoa in Phu Yen Providence in early 1965. Note the west side of the highway had been previously sprayed (Photograph courtesy of Plant Sciences Laboratory, Fort Detrick, Frederick, Maryland)



**Figure 3.26** A photograph of the effects of a four to six sortie RANCH HAND defoliation mission flown in the spring of 1967 near Highway 19 between An Khe and Pleiku. The herbicide was likely Agent White because of the vegetation type found in the An Khe Pass area (Photograph was taken on 31 October 1967, courtesy of J.Ray Frank, Frederick, Maryland)

Although defoliation missions in II Corps were primarily confined to areas adjacent to the Laos and Cambodia borders, crop destruction missions were frequently conducted in Binh Dinh, Kontum, and Khanh Hoa Provinces. For example, in August 1965, forty sorties were flown against crop targets in Binh Dinh and Kontum Provinces, and in September 1965, sixty-seven sorties were flown against crop targets in Binh Dinh, Kontum, and Khanh Hoa Provinces. In 1967, numerous missions against crop targets occurred west of Highway 1 between Tuy Hoa and Qui Nhon, and between Phu Cat and Quang Ngai [Buckingham 1982; Cecil 1986]. The herbicide of choice was Agent Blue.

Larsen and Collins [1975], in discussing South Korean pacification efforts conducted in II Corps, noted that ROK forces were against using defoliants to destroy rice crops. The ROK military units furnished external defense and fire support for four air bases in II Corps: Phu Cat (ROK Capital Division), Tuy Hoa (ROK 28th Regimental Combat Team), and Cam Ranh Bay and Phan Rang (30th Regiment, ROK 9th Division). All four of these bases were located next to settlements. The concentrations of civilian dwellings afforded the enemy an absolute tactical advantage since they provided cover and concealment up to the threshold of each base [Larsen and Collins 1975]. These conditions also seriously restricted defense forces by prohibiting or limiting free fire zones and the placement of exclusion areas (e.g., land mines) around base perimeters [Fox 1979]. Thus, precautions to restrict inadvertent entry by civilians into base perimeters were limited to "in-depth" fencing and vegetation control.

At air bases, clearing approaches to the base was the first order of business. This meant defoliating a zone around the perimeter of the installation, an area outside the USAF's accepted base security/defense responsibility. It became the task of the Allied ground commander whose TAOR was confined to the base. As noted, in the cases of Phu Cat, Tuy Hoa, Cam Ranh Bay and Phan Rang, the ROK was assigned responsibilities for external defenses of those bases [Fox 1979].

The mangrove habitat, scattered primarily along the southern coastline of South Vietnam, occupied approximately 500,000 ha of inhospitable and seeming impenetrable swamp [Westing 1984]. However, the VC forces found it to be a safe haven from Allied forces; and, hence it was a target for vegetation control. The most intensive defoliation treatments of mangrove were applied in the Rung Sat Special Zone (III Corps), an area that surrounded the shipping channel into Saigon. Defoliation of the mangrove was started in 1966, but most of the defoliation flights were made after June 1967. A block of about 460 km<sup>2</sup> had been treated by the end of January 1967 [Tschirley 1969].

Members of the Australian Army Training Team Vietnam (AATTV) were first deployed to Vietnam in 1962, and were located throughout South Vietnam as part of the Advisory effort. In 1965, the First Royal Australian Regiment (1 RAR) was deployed to an area adjacent to the Bien Hoa Air Base. This began the buildup of Australian and New Zealand Forces in the RVN [Sinclair, 1982]. In 1966, the First Australian Task Force (1 ATF) deployed to Nui Dat (Phuoc Tuy Province in III Corps), while an Australian Logistic Support Group was located at Vung Tau (also in Phuoc Tuy Province). The

Australian Forces saw the defoliation program as “*an important measure in helping to deprive the enemy of the advantages that he enjoyed through the use of natural vegetation for cover in Vietnam’s tropical environment*” [Sinclair 1982]. When the 1 ATF was in place in the Phuoc Tuy Sector, requests for defoliation by RANCH HAND aircraft involved more than 62 targets. Most of the early sorties were with Agent Orange, but after October 1967, Agent White became the predominant herbicide used in Phuoc Tuy [Sinclair 1982; Cecil 1986]. At both Nui Dat and Vung Tau, extensive aerial insecticide spraying programs were conducted by UC-123 insecticide aircraft (Operation FLYSWATTER) and by Australian aircraft [Sinclair 1982].

Targets in IV Corps were some of the first locations for spraying herbicides in South Vietnam. The first RANCH HAND missions in the RVN were flown during March 1962 against targets in the Ca Mau Peninsula. The Ca Mau peninsula was a temporary staging area for VC infiltration into the Mekong Delta and for attacks on local shipping and RVN naval patrol craft along the peninsula’s streams and canals [IOM 1994]. In June 1963, eight sorties dispensed 27,200 liters of herbicide on 46 km on the Ca Mau Peninsula [Buckingham 1982]. Defoliation operations in 1967 and early 1968 aided military operations conducted by the Army’s 9th Infantry Division by improving observation within formerly heavily forested jungle [US Army 1972].

Only recently has it been possible to assemble data from the Defense Supply Agency, the Air Force Logistics Command, and in some cases verification from the Chemical Companies, on the quantities of tactical herbicides disseminated in Vietnam during the Vietnam War [Young, Van Houten, and Andrews 2008]. These data are provided in **Table 3.6**. Differences in quantities of herbicide disseminated and areas treated in South Vietnam varied among individual sources [Irish, Darrow, and Minarik 1969; NRC 1974; Craig 1975; Young et al 1978; Westing 1976; Westing 1984; IOM 1994; Stellman et al 2003a]. Further discussion of both the quantities of herbicides and the estimated amount of dioxin disseminated in Vietnam are discussed in **Chapter 5**.

### **3.16 The Preparation, Accuracy, and Use of the Military Records**

As noted in the previous section, the data available on the use of herbicides in Vietnam was dependent upon the quality and quantities of records maintained by the administrative units that had responsibility for record keeping in Vietnam. Christian and White provided an excellent overview of battlefield records management and its relationship with Agent Orange [Christian and White 1983]. They noted that there were 12,000 linear meters of Vietnam War records that were returned to various archive centers in the United States. They reported that the records from Vietnam arrived in an assortment of conditions and in many different types of containers because “*the troops were fighting a war and were not worrying about such niceties, a price that was paid later in trying to find the records at the centers*” [Christian and White 1983].

**Table 3.6** Estimated Quantities of Tactical Herbicides Used in Vietnam, 1961—1972 based on Defense Supply Agency and Air Force Logistics Command Records

<b>Tactical Herbicide</b>	<b>Commercial Components</b>	<b>Number of Drums</b>	<b>Number of Liters</b>	<b>Years of Use</b>
<b>Agent Green</b>	2,4,5-T	365	75,920	<b>1962</b>
<b>Agent Pink</b>	2,4,5-T	1,130	235,040	<b>1961-64</b>
<b>Agent Purple</b>	2,4-D; 2,4,5-T	12,405	2,580,240	<b>1962-65</b>
<b>Agent Blue</b>	Cacodylic Acid	29,330	6,100,640	<b>1966-72</b>
<b>Agent White</b>	2,4-D; Picloram	104,800	21,798,400	<b>1966-72</b>
<b>Agent Orange<sup>2</sup></b>	2,4-D; 2,4,5-T	208,330	43,332,640	<b>1965-70</b>
<b>Total</b>		<b>356,360</b>	<b>74,122,880</b>	

The challenge facing retrieval of records pertaining to Agent Orange was three-fold [Christian and White 1983]. First, many of the records from early in the war may not have been retained because it was only late in the war that all records were frozen to prevent their destruction. Secondly, soldiers on one-year tours barely had time to organize their files before they were transferred and someone else took over. Moreover, the Vietnamese did some of the maintenance of records. Lastly, although it can be ascertained that the use of herbicides began in 1961, data for the period 1961 to 1964 was of little use because of the nature of the advisory role and the locations of the advisors for those years. *“To use military records, created for combat purposes in an entirely new and complex manner, e.g., for epidemiological studies, may not be accomplished within the capabilities of the existing records”* [Christian and White 1983].

In 1970, The United States Army’s Data Management Agency, DMA was tasked by MACV to support the Chemical Operations Division in developing an Automatic Data Processing system for processing and storing monthly herbicide mission activity data [DMA 1970]. The result of this effort was the HERBICIDE REPORTING SYSTEM (HERBS Tape), which was designed and implemented in May 1970. The objective of the HERBS system was to process the monthly worksheets prepared by the Chemical Operations Division from information received from the primary data sources (e.g., RANCH HAND Operations and Army Chemical Corps Projects); maintain a HERBS mission activity history file, updated monthly; and to produce the monthly update listings and any reports resulting from user requested file inquiries [DMA 1970]. Indeed, MACV used the HERBS system to respond to requests from organizations involved in ecological research, claims investigations, and general inquiries from the Department of Defense and the scientific community [DMA 1970]. The National Research Council of the National Academy of Sciences subsequently used these computer-generated tapes to

construct maps of crop destruction and defoliation missions throughout South Vietnam [NRC 1974].

The content of the HERBS system consisted of data from the missions that were flown. This included the province(s) in which the mission was flown; the mission project number; the universal transverse mercator points (UTM) covered by the mission with identifying additions to identify each UTM point as a stop, turn, or start coordinate; the type of agent used; the number of gallons sprayed; the type of mission; the number of hits received during a run; and, the number of aborts attributable to maintenance, weather, battle damage, and other factors [DMA 1970]. The completeness and accuracy of the data were entirely dependent upon the quality of information obtained from the field units and forwarded to the Chemical Operations Division.

In April 1971, the MITRE Corporation, at the request of the Defense Communications Agency, reported the results a data quality analysis of the HERBS data file [Heizer 1971]. On the basis of the data quality analysis, the following statements were made:

- a) 97 out of the 5,157 records (2%) in HERB 01, a cleaned-up version of the HERBS system tape, have missing data;
- b) 304 out of 5,157 records (6%) have serious transcription errors or serious measurement errors; and,
- c) 1,161 of the 5,060 (23%) records that do not have missing data, have track data that results in track length (distance sprayed by RANCH HAND aircraft) that is in error by 50%.

Statistically, the overall quality of the data was good and by using error curves, track length and track data could be adjusted to improve the data quality of a record, if it was considered necessary by the analyst [Heizer 1971]. The presumption by the author (and the Chemical Operations Division) was that the UTM coordinates provided in the data set were accurate. The National Research Council in 1974 [NRC 1974], the US Army and Joint Services Environmental Support Group in 1986 [ESG 1986], and Stellman et al in 2003 [Stellman et al 2003b] did subsequent updating of the HERBS tape. Interestingly, the Stellman's 2003 version of the HERBS Tape (S-NAS-HERBS), nor their publications contained any data or references to ground fire hits or battle damage. When records contained only a single coordinate, they "developed schemata to impute likely flight paths for many of the fixed-wing missions". Moreover, many of the UTM coordinate data were taken from the RANCH HAND project planning documents, rather than from the DAARs. Thus, in many cases they apparently recorded where missions were to occur, rather than where missions may have actually occurred [Stellman et al 2003b].

### 3.17 Other Sources of Herbicide Consumption Data

Researchers have used the HERBS data for some time to claim that much more herbicide was dispensed over the Vietnamese countryside than reported by the US military [Hatfield 2000]. Fortunately, the historical records of the RANCH HAND unit are available in the annexes of the quarterly historical reports of the 315<sup>th</sup> Air Commando Wing (later re-designated 315<sup>th</sup> Special Operations Wing, and then 315<sup>th</sup> Tactical Airlift Wing). These records reported the total amount of tactical herbicide actually issued from the herbicide supply depots. Although not broken down by herbicide type in the historical reports, these contemporary records provided usage comparison data with which to validate the data in **Table 3.6**.

To insure that transcription errors in the HERBS Tape did not contaminate comparisons to contemporary unit historical reports, Cecil randomly selected 15 months in which to do a line-by-line comparison of the HERBS Tape entries versus the available original DAARs and to correct any errors in the entries [Cecil 2006]. In addition, the revised HERBS Tape was expanded to include original mission information concerning the lift designator (thus identifying the base the mission launched from); the time-on-target; target number within the project; the number of sorties originally scheduled, sorties added, sorties actually launched, and sorties which effectively sprayed on target; spray track lengths to the nearest 0.1 km; type and cause of both primary and alternate target aborts; mission flying hours; number of ground fire hits on mission aircraft; and any amplifying entries from the "Remarks" section or elsewhere on the DAAR. These corrected and amplified segments of the HERBS Tapes have been referred to as the RANCH HAND Revised (RHR) Tapes [Cecil 2006].

The corrected RHR Tape quantities are compared in **Table 3.7** to the total herbicide expended by month or quarter from the RANCH HAND stocks as listed in the historical reports for the 15 selected months. In all cases the expenditure of herbicide on the RHR Tape exceeded the amount actually disbursed from stocks, validating the assumption that the DAAR practice of reporting fixed standardized amounts dispensed per plane resulted in over-reporting of herbicide dispensed [Cecil 2006].

The excess reported quantity varied from a high of 7.0 percent in February 1967 to a low of 0.8 percent in April 1970 and was obviously strongly influenced by the extent of activity by the RANCH HAND unit. The 2.60 percent average reported excess seems reasonable and there is no anticipated reason to expect it that it would not be valid for the remaining non-sampled months from 1965 to 1971 [Cecil 2006].

**Table 3.7** Comparison of data (in liters) from selected months of the RANCH HAND Revised Tape (RHR) to monthly data from the RANCH HAND Historical Reports [Cecil 2006]

Date	RHR Tape	Historical Report	Excess (+/-)
Jan 1967	1,637,777	1,564,491	+73,286
Feb 1967	1,473,017	1,381,864	+91,153
Mar 1967	1,292,339	2,247,103	+45,236
Jul 1967	1,675,021	1,650,041	+24,980
Sep 1967	1,549,520	1,516,776	+32,744
Jul 1968	1,613,152	1,558,643	+54,510
Oct 1968	1,090,577	1,068,118	+22,459
Jan-Mar 1969 <sup>1</sup>	4,757,878	4,684,540	+73,339
Oct 1969	1,472,146	1,435,617	+36,529
Jan-Mar 1970 <sup>1</sup>	2,390,581	2,356,516	+34,065
Apr 1970	428,508	425,102	+3,407
<b>Total</b>	<b>19,380,516</b>	<b>18,888,810</b>	<b>+491,706</b>

<sup>1</sup> Unit historical report was for quarter only, not broken down into separate months.

Other sources for error between procurement and consumption would have included the inevitable spillage involved in transferring the herbicides from the shipping drums to the bulk storage facilities and in servicing of aircraft. Residual chemical left in the drums after transfer to the bulk storage tanks was partially recovered by using drum drain racks. This amount of herbicide was reportedly used in some perimeter foliage control programs and thus may have been inadvertently counted twice by the accountability records. Undoubtedly some theft of herbicide and/or unpurged drums also took place. In addition, HERBS Tape quantity data for helicopter and ground equipment operations could not be validated. These unverified entries accounted for 2,823,246 liters of the total herbicide dispensed in Vietnam in 1965-71. When added to the corrected RHR Tape fixed-wing amounts, the total herbicide dispensed comes to 69,619,850 liters versus the procurement data of 71,231,680 liters estimated in the **Table 3.6** for Orange, White and Blue. The variances in individual herbicide amounts can possibly be explained by the failure of personnel to accurately report or transcribe which herbicide was used, a discrepancy noted in the 15-month sample check referred to earlier. However, 610,690 liters of White arrived in Vietnam in 1971 and was not accounted for in **Table 3.8**, a yearly comparison.

To further crosscheck the HERBS Tape entries against actual consumption, Cecil compared the total herbicide issued by RANCH HAND against the total amounts shown dispensed in the HERBS Tape by year (see **Table 3.8**) [Cecil 2006]. As noted earlier sampling and comparison with original DAARs have shown the HERBS data to have significant errors and omissions.

**Table 3.8** A by-year comparison between quantities of tactical herbicides reported on the HERBS Tape and data from RANCH HAND unit quarterly historical reports (in liters)

Year	HERBS Tape	RH Historical Rpt	Excess
1965 (after 18 Mar) <sup>1</sup>	1,887,122	1,839,944	+47,178
1966	9,940,260	9,842,066	+98,194
1967	19,124,209	18,436,802	+687,408
1968	17,971,385	17,563,924	+407,462
1969	16,487,705	16,147,802	+339,903
1970	3,345,413	3,202,669	+142,744
1971	7,192	7,192	+/- 0
Total	68,763,286	67,040,398	+1,722,888

<sup>1</sup> 1965 data does not include Purple herbicide sprayed prior to 19 March 1965

As **Table 3.8** indicated, annual over-reporting of herbicide dispensed by fixed-wing was as much as 4.45 percent and averaged 2.57 percent. This supports Cecil's earlier random sampling finding [Cecil 2006]. Adding the RANCH HAND total to the Blue, White, and Orange herbicides reportedly sprayed by ground units and helicopters in gave a total of 69,763,622 liters, which compared favorably with the available 69,511,840 noted earlier. Although the "unknown" entries for fixed-wing operations was proportionally included in the RANCH HAND adjustment, what could not be explained were the entries under 'ground' and 'helicopter' codes for 100,022 "unknown" liters since there are no other data sources with which to compare and verify those entries. Even more puzzling are the 366,958 liters the HERBS Tape claims were sprayed by "Unknown" type equipment. Without these "unknowns" procurement and disposition records can be reasonably correlated. Contemporary reports indicate that herbicides were dispensed by fixed-wing, helicopter and ground equipment only. {NOTE: the additions of 69,763,622 + 100,022 + 366,958 = 70,841,292 liters versus the procurement data in **Table 3.6** of 71,231,680 liters for Orange, White and Blue.} Stellman et al apparently choose to accept their corrected HERBS Tape data as opposed to the procurement records; however, they did not address the question of "unknown" herbicides or "unknown" delivery equipment [Stellman et al 2003a; Stellman et al 2003b].

Overall it appears that a major discrepancy involved in the question of herbicides procured versus herbicides dispensed or destroyed is one of records maintenance. Record keeping by the United States military in Vietnam was complicated by both the interface with South Vietnamese allies in joint or mixed operations and by the precipitate manner that terminated the war effort and resulted in the rapid pullout of Allied forces. Large numbers of records were either lost or trashed as American units left Southeast Asia. This makes the reconstruction of particular events in the combat zones difficult, if not impossible, especially when using records reconstituted and "reconstructed" fifteen to twenty-five years later. The second major problem, that of entries spraying "unknown"

herbicides and of entries using “unknown” equipment to do the spraying, may also be one of inaccurate records maintenance, but there is no alternate source of information available with which to positively confirm or deny these entries [Cecil 2006].

### 3.18 The Accuracy of Geographic Data

As noted the HERBS tape documented how much herbicide was sprayed, and where it was sprayed to accuracy identified by a set of six-digit UTM coordinates. The lead navigator had the task of verifying and reporting the coordinates of a RANCH HAND mission. In the early years through mid-1965, the 1:250,000 maps used for navigation were those prepared by the French, as was the language on the charts, although they were updated with photogrammetric data [Spey 2003; Young, Cecil, and Guilmartin 2004]. As one RANCH HAND pilot stated:

*“Unless there was a distinct landmark, we were in a eye ball situation (i.e., visual acquisition) where both the FAC (Forward Air Controller) and the lead pilot made their best guess as to where to start and stop a spray mission. We were sure that we were in the target box, but we could have been within one or two clicks (kilometers) of the planned coordinates. Although the maps improved after mid-1965, the accuracy when flying over triple canopy jungle and finding and placing the herbicide on target was like “marking a map with a grease pencil and then cutting it out with an ax!” [Spey 2003].*

Subsequently, electronic aids gave aircrews the relative bearing of their aircraft from a transmitter (always in friendly territory) and in some cases approximate distance, but were incapable of fixing the location of the aircraft with precision. To fix location within one nautical mile (1,850 m) for a plane 32 km from a TACAN transmitter would have been exceptional [Young, Cecil, and Guilmartin 2004]. Moreover, TACAN signals were not received at the low altitudes flown by RANCH HAND aircraft during a spray mission so the crew used visual orientation and, obviously, the instructions from the Forward Air Controller [Young, Cecil, and Guilmartin 2004].

The lead navigator and pilot had responsibility for documenting the mission coordinates, the type and volume of herbicide sprayed, and any ground fire they received. Unless these were specific reasons not to (i.e., aborted or alternate target), they reported “as planned” the UTM coordinates and volume sprayed [Spey, 2003]. Buckingham [1982] reported that the RANCH HAND navigators did their best to accurately report the location of their missions. For example, spraying targets in the mountain regions of I Corps and II Corps was a difficult job, even when the crews had accurate maps of the targeted roads and trails [Buckingham 1982]. It was some times impossible to follow the roads and trails at the desired spray altitude of 45-50 m. RANCH HAND developed three techniques for spraying these roads and trails:

- 1) One UC-123 would fly ahead of and higher than the plane delivering the herbicide. An effective tactic where the road or trail was clearly visible from an

altitude of about 450 meters, the lead aircraft would follow the road from its higher vantage point, and guide the spray aircraft. After one UC-123 had delivered its load of herbicide, the two aircraft switched roles so that the former lead would spray. Initially one flight of two aircraft would cover a 30-km length of road with one defoliated strip. In about a week, discoloration, easily visible from the air, marked the strip. Two RANCH HAND aircraft would then return and spray together, one on each side of the road, following the previously sprayed strip and widening the defoliated area to the required 250 m on both sides of the road.

2) When the road or trail was not clearly visible from any altitude, except for brief glimpses, the spray aircraft would first fly over the road or trail and throw out smoke grenades at intervals where they could see the road or trail. With the jungle canopy in some places reaching 50 – 60 m, it took about one minute for the smoke to rise to visible height. The RANCH HAND aircraft would then connect the columns of smoke with a strip of herbicide. This second method took a great deal more time than the first, and it was not as accurate. However, it did have the advantage of reducing the risk from enemy antiaircraft fire, since both aircraft were flying at a very low altitude.

3) The third, and least effective, technique RANCH HAND developed was not used unless the target absolutely required it. Using time and a heading from a known topographic feature, a navigator guided the spray planes over the target. Accuracy suffered because roads and trails were not always exactly where they were placed on the maps used by the navigator. This method, however, required the least amount of time over the target, and it was therefore the safest to use in the case of roads and trails with known gun emplacements [Buckingham 1982].

Dr. George Lathrop, the Principal Investigator of the Air Force Health Study, the study of the men who served in Operation RANCH HAND concluded:

*"The map coordinates of the HERBS tapes are largely accurate, but many are inaccurate and based on the guesstimates of RANCH HAND pilots and navigators who were under extreme combat or terrain-flying stress. Straight-line approximations or multi-leg zig-zag patterns can only be viewed as gross approximations of many of the missions in Vietnam. This error source can only be adequately factored into the probabilistic approach (for epidemiological studies) by the use of crude assumptions" [Lathrop 1988].*

John Flanagan, a Forward Air Controller for many RANCH HAND missions, described the difficulties in tracking locations in the Vietnamese jungles in his book 'Vietnam Above the Treetops':

*This stuff is thick! There are no holes except where the jungle is growing back in some of the grassland area. Some parts of War Zone C had apparently been*

*cultivated at one point. Now the dense elephant grass and bamboo were reclaiming any open are. But 90 percent of the area was double- and triple-jungle canopy” [Flanagan 1992].*

### **3.19 Alternate Methods of Clearing Vegetation**

Anecdotal reports by soldiers of exposure to tactical herbicides commonly mention cleared, barren landscapes [Young, Cecil, and Guilmartin 2004]. A widely held misconception was that all clearance of vegetation was accomplished by means of tactical herbicides. Simpler and more direct mechanical methods were frequently used, and a special unit of the US Army Corps of Engineers was created for clearing jungle vegetation by means of a variety of mechanical equipment ranging from the ‘Rome plow’, a large bulldozer equipment with a special tree-cutting blade and an armored cab, to chain saws, hand axes, machetes, and even diesel fuel incineration [Ploger 1974; Young, Cecil, and Guilmartin 2004]. **Figure 3.27** was a photograph of a US Army Corps of Engineers’ Rome plows clearing vegetation in III Corps.



**Figure 3.27** A photograph of US Army Corps of Engineers using Rome plows to clear vegetation in III Corps, Vietnam (Photograph courtesy of J. Ray Frank, Frederick, Maryland)

As noted by a military historian:

*“From a strategic standpoint, the cumulative effects of land-clearing operations in Vietnam had a decided impact as the enemy was forced increasingly to adjust to the*

*disappearance of his operational bases or to interdiction of connecting trails...This greatly improved capability of allied forces to operate through vast areas once concealed by dense jungle...represented dramatic progress, not only in a strict military sense but also in terms of pacification and economic development" [Ploger 1974].*

### **3.20 Insecticides and Operation FLYSWATTER**

The deployment beginning in 1965 of major US combat forces into South Vietnam found them unprepared for the disease-ridden conditions they encountered. Despite the weekly use of prophylactic chloroquine-primaquine pills, 5 to 50% of American soldiers coming off early field developed malaria [Kiel 1968]. Compounding the threat to Allied troops in South Vietnam was the discovery of chloroquine-resistant *Plasmodium falciparum* carried by the anopheles mosquito [Kiel 1968]. The only course of action was to implement effective control programs for the mosquito. Although both the Navy and the Army experimented with low volume dispersal of malathion insecticide, an organophosphate insecticide, the use of helicopters did not adequately contain the spread of malaria. In late 1966, Headquarters USAF recommended the modification of one of the UC-123 defoliation planes to an insecticide-spray configuration to counter the anopheles mosquito [Cecil and Young 2008]. The ability of the UC-123 to cover large areas (up to 6,500 ha) made it the ideal aircraft for base and urban area treatment. Operation FLYSWATTER commenced on 6 March 1967. The mission was supported at Bien Hoa by the US Army's Preventive Medicine Unit, and at Da Nang by the US Navy Preventive Medicine Unit located on the USMC base. The UC-123 aircraft had been washed of all herbicides and equipped with the finer-orifice nozzles need for insecticide work [Cecil 1986; Cecil and Young 2008].

From March 1967 through February 1972, from one to three UC-123 RANCH HAND aircraft were used to spray initially 57% malathion, but later 95% malathion, for mosquito and malaria control [MACV 1970; Cecil and Young 2008]. As noted earlier, the insecticide-spraying aircraft could be distinguished from the herbicide-spraying aircraft because they were not camouflaged. **Figure 3.28** were photographs of the "Silver Spray Birds" as they were commonly called. The aircraft routinely sprayed insecticide adjacent to military and civilian installations, as well as in areas where military operations were in progress, or about to commence [Young, Cecil, and Guilmartin, 2004].

By 1970, routine malathion treatment was being applied to 14 bases and their adjacent South Vietnamese cities, and the re-spray interval had been reduced from every fourteen days to every nine days [Cecil 1986]. The major military bases that received insecticide applications were listed in **Table 3.9** [Collins 1967; Cecil 1986; Fox 1979]. The anecdotal reports of direct spraying of troops in Vietnam with tactical herbicides likely reflect the RANCH HAND mission of spraying insecticide for mosquito control at regular intervals from March 1967 through February 1972 [Young, Cecil, and Guilmartin, 2004].



**Figure 3.28** Photographs of “Silver Spray Birds” which were RANCH HAND UC-123 B/K aircraft dedicated to the spraying of insecticide for mosquito control. Each aircraft could spray more than 6,000 hectares and routinely treated 14 bases and their adjacent Vietnamese cities every nine days. Re-servicing was available at the air bases at Cam Ranh Bay, Bien Hoa and Da Nang (Photographs courtesy of J. Ray Frank, Frederick, Maryland)

**Table 3.9** Major US and Allied Forces Bases Receiving Insecticide Applications

Base	Province	Corps	Base	Province	Corps
Da Nang	Quang Nam	I	Qui Nhon	Binh Dinh	II
Bien Hoa	Bien Hoa	III	Nha Trang	Khanh Hoa	II
Pleiku	Pleiku	II	Cam Ranh Bay	Khanh Hoa	II
Quang Tri	Quang Tri	I	Phan Rang	Ninh Tuan	II
Tan Son Nhut	Capital Special Zone		Binh Tuy	Binh Tuy	III
Phu Cat	Phu Yen	II	Vung Tau	Phouc Tuy	III
Tuy Hoa	Phu Yen	II	Nui Dat	Phouc Tuy	III

In August and September 1969, a group of scientists from the Plant Sciences Laboratory, Fort Detrick visited numerous locations in I Corps around the city of Da Nang in response to claims by Vietnamese farmers that their crops had been injured by indiscriminate spraying of herbicides [Darrow 1969]. The following two notes were taken from their trip report:

*"The group then visited a Catholic Church in the hamlet Cam He. The priest claimed that their crops were killed by herbicide spray planes. His description of the planes as silver indicated that he had seen the insecticide spray planes used for mosquito control. Careful inspection showed that slight herbicide damage was evidence on papaya and mango trees. The damage was probably caused by fumes from empty drums of agent ORANGE which were kept less than 20 feet from damaged plants. Sensitive weeds in close proximity also had herbicide symptoms. No evidence of damage caused by aerial applications of herbicides was noted" [Darrow 1969].*

*"On 30 August the group visited a vegetable growing area at An Hai, east of Da Nang City. The growers were washing off all of the vegetable plants to prevent herbicide damage. This procedure was instituted after the people had seen a silver spray plane fly over, supposedly spraying herbicide. The plane was the mosquito control spray plane which was spraying the insecticide malathion. Several small beds of seedling lettuce were damaged by a damping off plant pathogen but no herbicide damage was observed on any of the vegetable crops in the area" [Darrow 1969].*

The best estimate of the total volume of malathion that was sprayed in the RVN between 1966 and 1972 was 3.5 million liters [Cecil 1986]. Westing similarly estimated that 3 million kg of malathion were sprayed on approximately 6 million hectares of South Vietnam [Westing 1984].

### **3.20 Termination of Herbicide Use**

The concept of using chemical herbicides to alter the combat environment in the Vietnam War was new, particularly in its broad scope and in light of the extensive tropical vegetation that faced Allied troops. The history of warfare is one of innovation and discovery as the participants continually find new and more effective weapons with which to exact mayhem upon each other. The unique weapon involving herbicides was different only in that the primary goal was to improve combat visibility so that allied troops could effectively cope with the jungle guerrilla war they were faced with. The question of amounts of expendable supplies used to accomplish this goal was one for the logisticians at major headquarters, not the soldiers in the field. It should come as no surprise that the daily activity reports were more general than exact and that the individuals involved were more concerned with those things directly involving their health and well being. The young men of RANCH HAND who daily flew slow, unarmed and unarmored transport planes at tree-top level while subject to enemy ground fire were more concerned with how well they placed their herbicides on the assigned targets than upon the exact amounts dispensed. This is not to disparage the important work of those concerned with procurement and movement of supplies, but recognition of the priorities placed on record keeping by those in the front lines [Cecil 2006].

On 13 September 1971, because of emerging scientific studies indicating that dioxin was teratogenic (i.e., causing birth defects in laboratory mice) and that Agent Orange was contaminated with dioxin, DOD Secretary Melvin Laird ordered all remaining stocks of

Agent Orange (and Orange II) in the RVN returned to the United States as quickly as possible after the US Embassy negotiated a formal transfer of title from the RVN Government. On 31 October 1971, all tactical herbicide activities under US control were terminated, with insecticide operations for mosquito abatement continuing by the USAF and US Army into 1972. The removal of all remaining Orange in South Vietnam by the 7th Air Force was completed in April 1972 (Operation PACER IVY) when approximately 5.2 million liters (25,220 drums) were off-loaded on Johnston Island in the Central Pacific Ocean. Operation PACER HO (Herbicide Orange), the destruction of the Agent Orange using at-sea incineration, was conducted from June through August 1977. **Chapter 4** describes Operation PACER IVY and Operation PACER HO.

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