Information Report FF-X-69

December 1978

# AIRPRO

# AN AIR TANKER PRODUCTIVITY COMPUTER SIMULATION MODEL

# APPLICATION

by

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This report is one of a series describing AIRPRO. Other reports in this series are:

The Fortran Program (Summary, Documentation),
Information Report FF-X-64, August 1977

The Equations (Summary, Documentation),
Information Report FF-X-66, January, 1978

Air Tanker Systems
Information Report FF-X-67, December 1978

Validation
Information Report FF-X-68, December 1978

## ABSTRACT

This report discusses the application of results generated by AIRPRO to specific air tanker problems in the Province of New Brunswick. First, the fire environment of the province is described, followed by an overview of the current air tanker system. The effectiveness of the S2D Snow Commander as an air tanker is briefly considered. This is followed by a determination of the optimum fleet size in the province. Finally, the possibility of using alternate air tankers is considered. The report ends with a series of conclusions relative to air tanker operations in New Brunswick.

## RESUME

Ce rapport traite de la mise en application des résultats tirés du programme AIRPRO et ayant trait à des problèmes spécifiques reliés à l'utilisation des avions-citernes au Nouveau-Brunswick. Les auteurs font tout d'abord une description des facteurs du milieu qui agissent sur les incendies forestiers dans cette province et donnent un vue d'ensemble du système actuel d'utilisation des avions-citernes. Ils examinent brièvement le rendement de l'appareil S2D Snow Commander utilisé comme avion-citerne et déterminent ensuite le nombre optimal d'appareils requis pour répondre au besoin de la province. Ils étudient ensuite la possibilité d'utiliser d'autres types d'aéronefs. En conclusion, ce rapport fait état d'une série de recommandations ayant trait aux opérations impliquant des avions-citernes au Nouveau-Brunswick.

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## ACKNOWLEDGEMENTS

The authors wish to thank those without whose contribution, this project could not have succeeded. Without initial financial support by the FIRESCOPE project of the U.S. Forest Service Fire laboratory, Riverside, California, the project might not have been started. Without the continued support of the Director of the Forest Fire Research Institute, Mr. D.E. Williams, the project certainly would not have been completed. To: Drs. Bruce Bare, Brian Mar, Robert Meir, Gerrard Schreuder and Stewart Pickford of the University of Washington, who gave freely of their time and advice, providing constructive suggestions throughout, thank you.

Without the considerable efforts of the typists, Mrs. Audrey Laing and Mrs. Sandra Cybulski, this report would not be readable. Finally, we would like to thank Mr. Neil Bruce, for finding all those little errors that everyone else seems to miss. Ultimately, the authors accept responsibility for everything contained in this document, including all errors of commission or omission.

## PREFACE

The reader will note the absence of metric units. Model development took place over a four-year period, with metric conversion being instituted at the mid-point of the process. It was decided that the development process would be needlessly complicated by a conversion to metric units. As a result, this report employs English units. The model is being converted to metric units for future applications.

# AIRPRO

## AN AIR TANKER PRODUCTIVITY COMPUTER SIMULATION MODEL

## APPLICATION

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## 1. Introduction

The true measure of the worth of a model is its ability to solve real-world problems. This report is, therefore, devoted to the application of results generated by AIRPRO to specific problems in the province of New Brunswick.

### A. The New Brunswick Fire Environment

New Brunswick, one of Canada's Maritime Provinces, encompasses 27,633 square miles and has a population of 634,500[1]. The forests are of the Acadian type which can best be described as mixtures of conifers and hardwooods, interspersed with valley farms. The predominant conifers are the Spruces, Balsam fir, and some Pines, while the predominant hardwoods are Birches, Maples and Poplars.

During the period from 1961 to 1966, New Brunswick experienced an average of 502 forest fires per year or 18.1 fires per 1,000 square miles per fire season. This is 3.7 times greater than the provincial average for all of Canada (4.9 fires per 1,000 square miles per season) during the same period (Lockman, 1969). The fire occurrence distribution taken from Simard (1975) is shown in Fig. 1. It ranges from a low of less than 2 to a high of more than 30 fires per thousand square miles per season. There is a crescent shaped ridge in the northwest section of the province which follows one of the primary highway arteries. There are also occurrence peaks in the vicinity of the cities of St. John and Moncton. There is a low occurrence zone in the central highlands.

The fire climate of New Brunswick does not vary by a great deal when examined on a large scale. Data from Simard (1974) indicate that the average FWI for June, July, and August varies from a low of 5, along the southern coast and northern border, to a high of 10, in the interior. Data published by Simard and Valenzuela (1972) indicate that the provincial average FWI of 5.9 for the entire fire season (April through October) is about 40% lower than that for all provinces (8.2).

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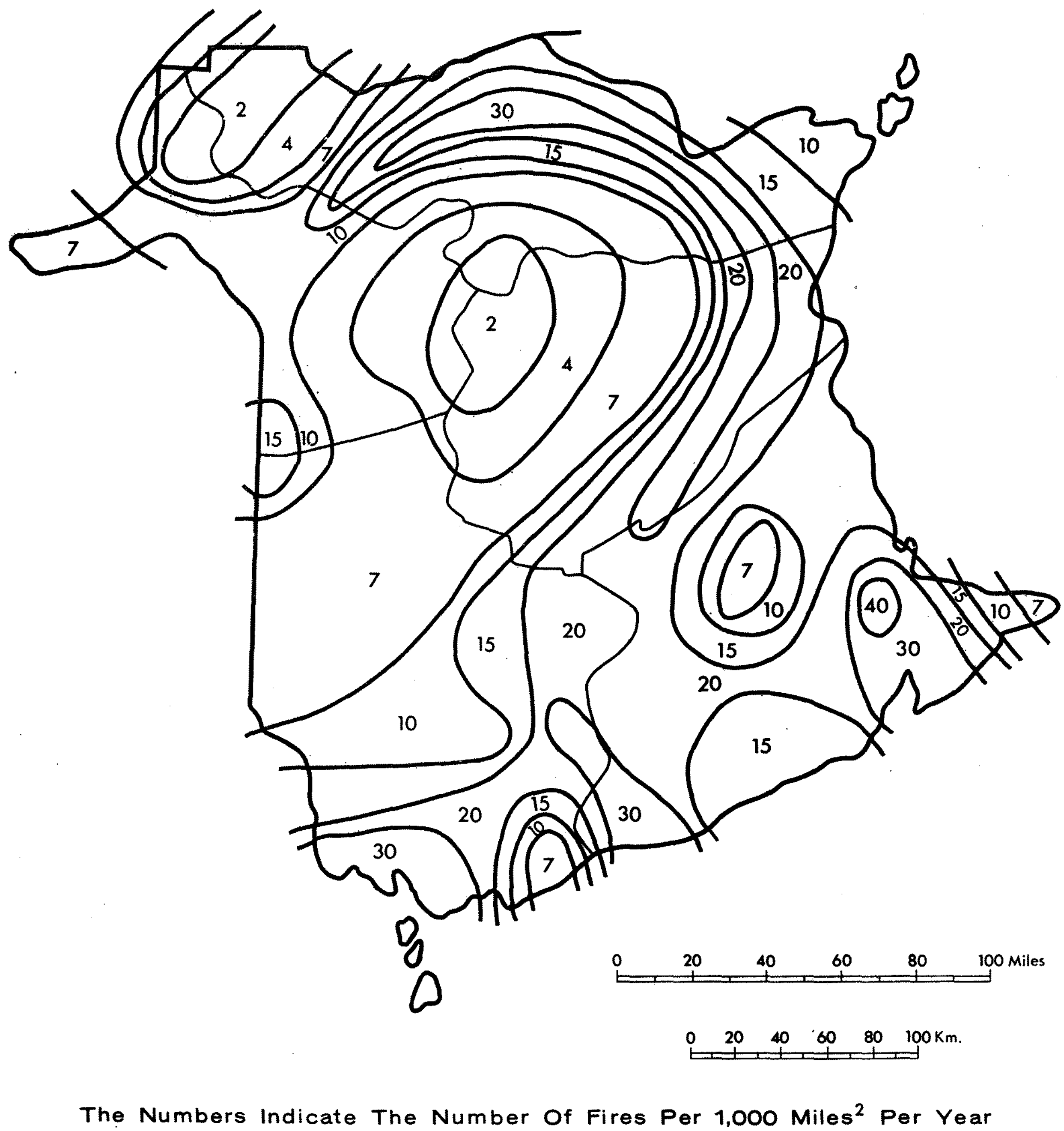
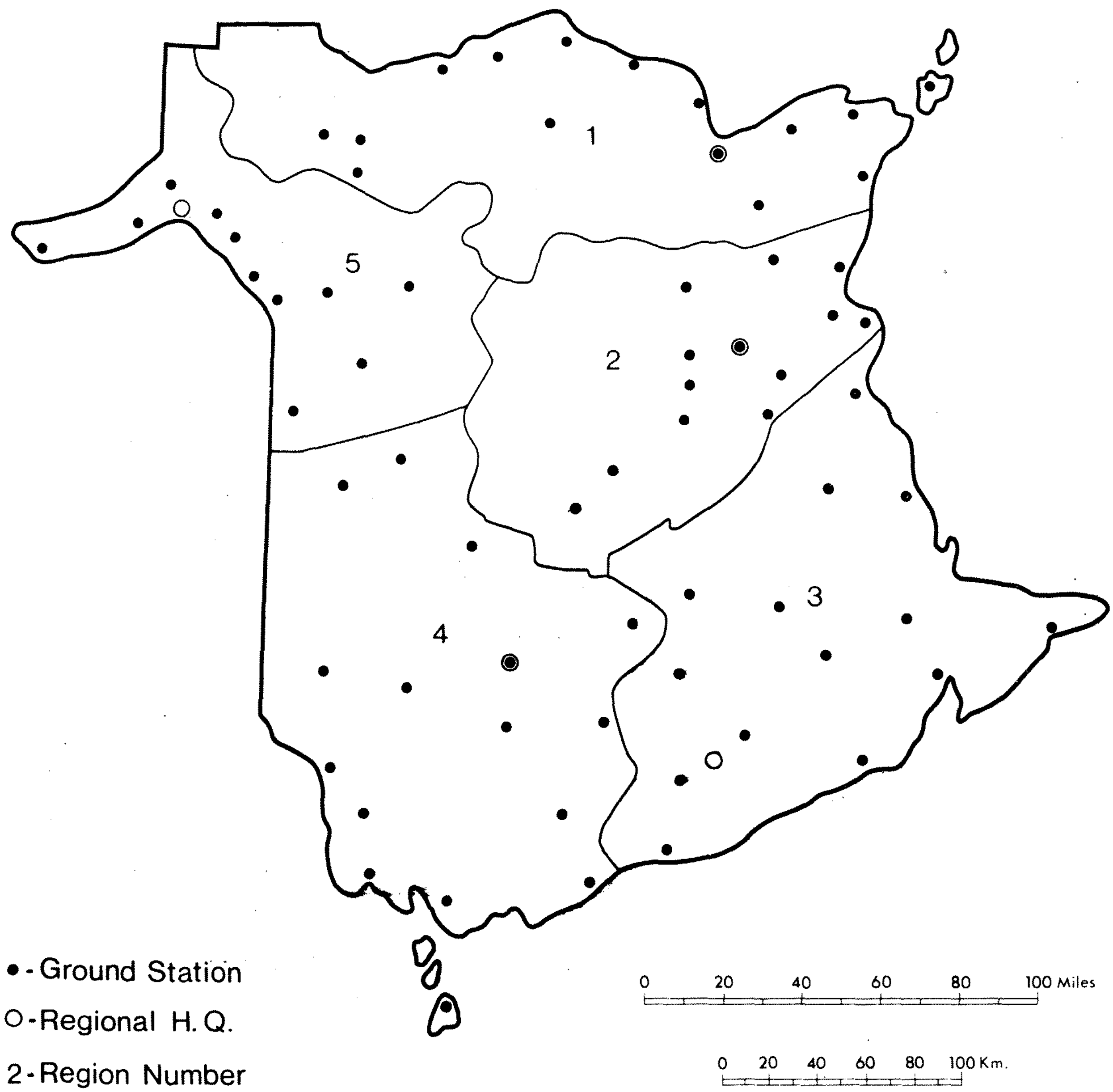
1 Statistics Canada, 1971 Census Report.

**Figure 1 Fire Occurrence Distribution in New Brunswick**




The Numbers Indicate The Number Of Fires Per 1,000 Miles$^2$ Per Year

**Figure 2** **Ground Station Distribution in New Brunswick**



New Brunswick has a relatively dense network of initial attack ground stations. These are plotted in Fig. 2. The 69 stations each have an average area of responsibility covering approximately 400 square miles. Thus, the average fire-to-ground base distance would be on the order of 10 to 15 miles. Further, a higher than average population density (23 persons per square mile vs. 10 for all provinces combined) implies a higher than average density of roads and more rapid than average public detection of fires. Both of these conditions would tend to facilitate rapid initial attack.

The fire environment of New Brunswick can be summarized as follows:

- A lower-than-average fire behavior problem[2].
- A higher than average fire occurrence density.
- A lower than average fire climate severity.
- A denser than average ground station network.

One method (admittedly crude) of integrating the fire environment and control system effectiveness is to measure average fire size. Average fire size in New Brunswick for the period under study was 31 acres, or one-eighth of that for all provinces combined (261 acres - Lockman, 1969). Thus, the ameliorating effects of the positive factors combined with very rapid initial attack outweigh the detrimental effects of the higher than average fire occurrence. The obvious implication of the preceding arguments is that the demand for air tanker activity in New Brunswick will likely be minimal, relative to what might be expected in a majority of provinces across Canada. This point should be borne in mind as we consider results generated by the model for New Brunswick.

## B. The New Brunswick Air Tanker System

New Brunswick has a relatively dense network of small airstrips used for the Spruce-budworm spray program. The set of airstrips used for the air tanker study are plotted in Fig. 3. The 29 land-based airstrips service an average area of 953 square miles each, or an area about 31 miles on a side. There is one central base (Dunphy - no. 19) from which all initial dispatches are made. Subsequent land-based drops are made from the nearest usable airstrip. A central water-base (Fredericton - A) was added for purposes of the study to investigate the effectiveness of water-based air tankers. Subsequent water-based drops are made from the nearest usable lake.

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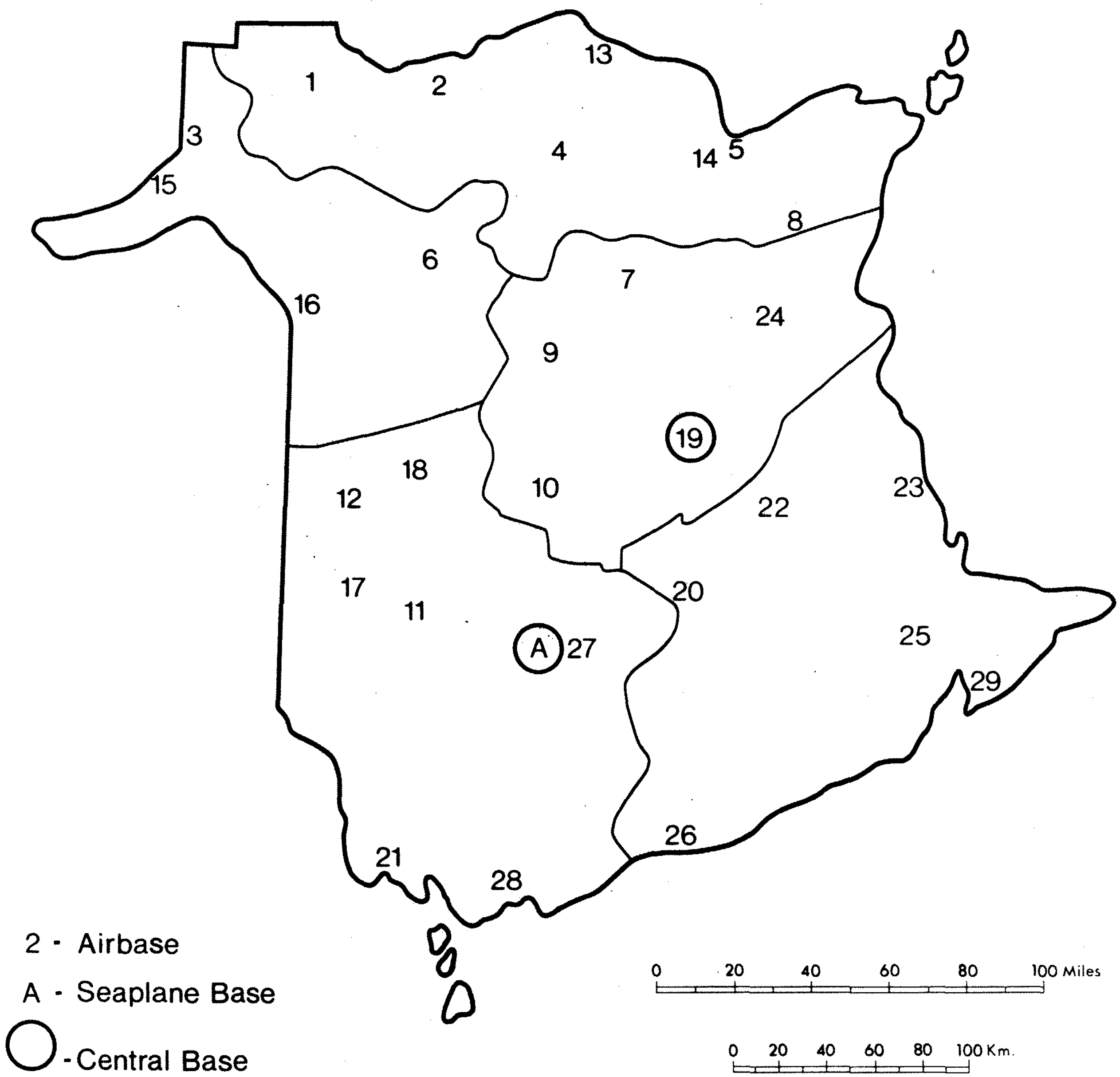
2 Based on work on file at the Forest Fire Research Institute.

**Figure 3 Airbase Distribution in New Brunswick**



Given the existing infrastructure and the fire environment, it is to be expected that the central feature of an air tanker system, which has evolved from field experience, would be small land-based agricultural aircraft. The province has, in fact, operated fleets of four to six Grumman Ag-Cats and Rockwell Snow Commanders for the past decade. This background leads to the specific questions posed by New Brunswick fire control officials.

1) Using the Rockwell S2D Snow Commander as the basic air tanker, what size of fleet would be optimum for the Province?

2) Should other types of air tankers be considered for fire control operations in New Brunswick?

The remainder of this report will be devoted to answering the above questions.

## 2. Evaluating the S2D Snow Commander

We begin by summarizing the effectiveness of an ideal air tanker system. Since the model does not incorporate fixed costs, the actual dollar saving would be less than that shown in Table 1. While the savings are not large, it should be emphasized that average fire size and average expenditure per fire in New Brunswick is one-tenth that for Canada as a whole. This strongly suggests that the results reported here are, in fact, a lower limit of what will be found when the analysis is extended to other regions.

Table 1 AIR TANKER SYSTEM EFFECTIVENESS

| Savings Per Year | Percent of Fire Control Total |
|---|---|
| $221,895* | 15.3% |
| 2,642 acres | 17.1% |
| 5,346 hours | 25.6% |

---

* Estimated June, 1978 dollars. June, 1963 = 77.2; Oct., 1977 = 165.0; current inflation = approx. 8%; (1.08 x 165.0)/77.2 = 2.25 times the output generated by the model, using 1961-1966 data.

Of the 3,010 fires processed by the model, 682 could be profitably attacked by air tankers. The S2D generated savings on

327 of the 682 air tanker fires (47.9%). Further, the S2D was the best air tanker on 73 or 10.7% of the air tanker fires. The S2D can be evaluated with the aid of a few statistics which are given in Table 2.

The average values in the S2D optimum column would be realized if the S2D were used only on those fires where it was the best aircraft. The average values listed in the S2D positive fires column are what would be realized in the field if a fleet of S2D's was employed for fire control. Such a fleet would successfully attack 48% of all air tanker fires and achieve 52% of the dollar saving attributable to an ideal fleet.

While the individual statistics presented in Table 2 are self-explanatory, a few comments on the trends would be in order. If all S2D fires are compared with those fires where the S2D was best, it can be seen that productivity for the former is lower. Flying distance is the major variable in determining the number of drops per hour and the quantity of retardant dropped per hour. The average fire-to-central-base distance for the S2D fires was 28 miles, in contrast to an average distance for all fires of 59 miles. Thus, the preceding observations implies that the S2D is best suited to shorter flying distances. That such differences would be noted in New Brunswick is somewhat unexpected, given the dense air base distribution. Note, however, that practical limitations dictate a single central dispatch base. Further, when the S2D was the best aircraft, 90% of all fires were fought with a single aircraft, while in 57% of the cases only one drop was made. These statistics imply that for the S2D, the fire-to-central base flying time is far more important in determining productivity than the fire-to-reload base flying time.

Table 2 PRODUCTIVITY, PRODUCTION, AND EFFECTIVENESS FOR THE S2D SNOW COMMANDER IN NEW BRUNSWICK

| | S2D Optimum | S2D Positive | Optimum Air Tanker |
|---|---|---|---|
| Drops per hour | 2.1 | 1.4 | 3.2 |
| Gallons per hour (Imp.) | 536 | 360 | 1,452 |
| Line held per hour (ft.) | 191 | * | 637 |
| Drops per fire | 1.6 | 4.0 | 4.6 |
| Gallons per fire (Imp.) | 411 | 1,002 | 2,053 |
| Line held per fire (ft.) | 149 | * | 802 |
| Dollar saving per fire ($) | 309 | 893 | 1,932 |
| Area saving per fire (ac.) | 0.9 | 24.1 | 23.0 |
| Time saving per fire (hr.) | 10.3 | 18.6 | 23.2 |
| Number of fires per year | 12.2 | 54.5 | 113.7 |

* Not tabulated

This finding is strongly reinforced by the results of a preproduction run where aircraft were allowed to initially takeoff from the nearest usable base. When it was decided that such a scheme is totally impractical, the model was modified to require initial takeoff from the central base, as is currently done in the field. When the latter restriction was added, use of the S2D by the model dropped by 75%, a clear indication of the sensitivity of the aircraft to flying distance.

In contrast to the preceding, the data in Table 2 indicate that both production and savings increases significantly when comparing all S2D fires to those where the S2D was best. The clear indication is that the S2D was best on smaller more easily controlled fires. Specifically, average fire size for the S2D fires was one acre, while for all S2D fires it was 10 acres.

In general, the best use of the S2D Snow Commander for forest fire control in New Brunswick would be in a relatively minor role - on small fires close to an air base. While the S2D can be used on half of all air tanker fires, other, larger aircraft are superior when longer flying distances or larger fires are involved. Alternative aircraft will be considered subsequently.

## 3. Optimum Fleet Size

The optimum air tanker fleet size can be determined by comparing the marginal saving attributable to each additional aircraft with the fixed cost of owning, maintaining, and operating the aircraft[3]. If the saving exceeds the fixed cost, an additional aircraft is economically justifiable. The process of adding aircraft continues until the fixed cost of an additional air tanker exceeds its expected marginal saving, thus yielding the optimum fleet size. In determining the marginal saving attributable to each additional air tanker, two factors have to be considered: the increased saving of additional air tankers on individual fires and the requirement for additional aircraft due to simultaneous fire occurrence.

The first factor is considered directly by the model. The fact that a single aircraft was chosen as best by the model on 90% of the fires on which the S2D was best precluded the use of increased saving for additional aircraft on individual fires being used to estimate fleet size. On this limited basis, the marginal saving for the second S2D ($8,398 per year) was insufficient to justify its acquisition. In contrast, the saving for the first aircraft was greater than the total fixed cost of three S2D air tankers. An analysis of the effect of simultaneous fire occurrence on fleet size was clearly warranted.

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[3] The variable cost of operating an air tanker is included inthe calculation of dollar saving.

A data file was prepared in which the results of the production run were arranged in chronological order. A separate program (SIMFIR), which used the chronological data as input, tabulated savings attributable to additional aircraft, while prohibiting simultaneous dispatch to two or more fires. In other words, if one or more air tankers were in the air fighting one fire and a second (or third, etc.) fire occurred, the number of aircraft required became the sum of all aircraft needed on all fires at the same time. The marginal saving attributable to each additional aircraft was tabulated. The results are shown in Column 1 of Table 3.

Column 2 lists the fixed cost per aircraft, Column 3 lists the additional cost of meeting the minimum contract guarantee per aircraft, while Column 4 lists the total fixed cost[4]. It was estimated that a minimum return of $22,200 per aircraft, per year would have to be guaranteed to a commercial operator. This amounts to approximately 100 hours of flying time per aircraft. Noting that the entire fleet would fly an average of 161 hours per year, it is clear that the provision of a minimum return is a significant part of the total cost. The true fixed cost (Col. 3) was determined by multiplying the total guaranteed minimum by 0.49. This relative value is based on data provided by Simard and Forester (1972) for the S2D Snow Commander.

Column 5 lists the cumulative saving based on variable cost only (model output). Column 6 lists the cumulative fixed cost, while column 7 lists the cumulative saving based on total cost. In fact, the actual saving would be less than that indicated in Column 7, since air tanker system administrative cost also has to be deducted from the saving.

It is clear that based on economic efficiency alone, a fleet of three S2D Snow Commanders would be the optimal solution. Less than three aircraft are clearly undesirable because, in addition to the reduced savings, there would be insufficient funds available to administer the fleet. Similarly, five or more aircraft would not be justifiable. While some saving remains when the fifth aircraft is added, it is likely insufficient to pay administrative expenses. Six or more aircraft generate an overall loss for the air tanker system.

A four aircraft fleet has merits on grounds other than economic efficiency.

- An additional air tanker would be available to compensate for down-time due to maintenance. This was not considered in the model.

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4 Based on conversations with provincial fire control officials.

Table 3 EFFECT OF SIMULTANEOUS FIRES ON FLEET SIZE

| No. of Air Tankers | 1. Marginal Savings | 2. Fixed Cost | 3. Amount Needed to Meet Minimum | 4. Total Fixed Cost | 5. Cumulative Savings (Var. Cost) | 6. Cumulative Fixed Cost | 7. Cumulative Savings (Total Cost) | 8. Marginal Area Saved |
|---|---|---|---|---|---|---|---|---|
| 1 | 27,295 | 9,980 | 4,380 | 14,360 | 27,295 | 14,360 | 12,935 | 3,663 |
| 2 | 10,777 | 9,980 | 7,914 | 17,894 | 38,072 | 32,254 | 5,818 | 1,446 |
| 3 | 54,281 | 9,980 | 8,183 | 18,163 | 92,353 | 50,417 | 41,935 | 1,277 |
| 4 | 6,562 | 9,980 | 8,918 | 18,898 | 98,915 | 69,315 | 29,598 | 819 |
| 5 | 1,760 | 9,980 | 9,653 | 19,633 | 100,675 | 88,948 | 11,725 | 361 |
| 6 | 6,392 | 9,980 | 9,876 | 19,856 | 107,067 | 108,804 | - | 217 |
| 7 | 761 | 9,980 | 9,922 | 19,902 | 107,828 | 128,706 | - | 193 |
| 8 | 3,458 | 9,980 | 9,727 | 19,707 | 111,286 | 148,413 | - | 313 |
| 9 | 112 | 9,980 | 10,071 | 20,051 | 111,398 | 168,464 | - | 96 |
| 10 | 3,119 | 9,980 | 9,727 | 19,707 | 114,517 | 188,171 | - | 313 |

Up to 16 S2D Snow Commanders were required at one time to achieve the maximum possible saving. The marginal saving for 11 or more aircraft, however, was only $1,690.

- It might be possible to employ two initial attack air bases rather than one. As previously indicated, this could significantly increase the effectiveness of the S2D.
- An additional 819 acres would be saved each year. This is an additional benefit in that noneconomic amenities are not incorporated in the model.

While the saving attributable to a four aircraft fleet is less than that for a three aircraft fleet, enough remains to administer the system. The preceding noneconomic benefits might compensate for the reduction in overall savings. Such a decision, however, can only be made by fire control personnel. In conclusion, if the S2D Snow Commander is used, either a three or four air tanker fleet would be optimum for the province of New Brunswick.

## 4. Alternate Aircraft

It has been previously suggested that other aircraft have a significant role to play in New Brunswick fire control. In fact, of 26 different models tested, 14 were best on one or more fires per year, including the S2D. While such a varied mixture is clearly impractical, it indicates that the S2D is not the only aircraft suited to fire control in New Brunswick. The fact that a fleet of S2D aircraft can profitably attack only 48% of all air tanker fires, and realize only 52% of the total possible saving indicate that there are potentially significant gains to be made by using other types of air tankers, either in conjunction with, or instead of the S2D Snow Commander. Two comparisons will be made: the S2D versus other small land-based air tankers and small land-based aircraft versus other types.

### A. Small Land-Based Air Tankers

The model considered two small land-based aircraft in addition to the S2D Snow Commander. They are the TBM Avenger and the G-164A Ag-Cat. Table 4a presents a substitution matrix for the three small land-based aircraft. The saving for each air tanker, when each was best, is listed along the diagonal of the matrix. The two remaining entries in each column represent savings for the two inferior aircraft on the same set of fires. Note that the diagonal entry is always the largest in any column.

Table 4b lists the number of fires per year associated with the corresponding entry in Table 4a. The inferior aircraft generally have fewer fires because there are instances where these aircraft generated losses which were not counted in the tabulation.

If the entries across each row are summed, the total saving for each small land-based air tanker, on those fires where the generic type was best is obtained. Summing along the diagonal yields the total saving for the best combination only. Taking theindividual totals as a percentage of the overall sum for the type, the S2D can achieve 98% of the maximum saving, the G-164A achieves 90%, and the TBM achieves 76%. Thus, on those fires where small land-based aircraft are best, the S2D Snow Commander appears to be marginally superior to the G-164A Ag-Cat and the TBM Avenger. The small difference coupled with small sample sizes for the G-164A and the TBM imply that the difference is not likely to be statistically significant. As a result no test was undertaken.

Table 4 SUBSTITUTION MATRIX FOR SMALL LAND-BASED AIR TANKERS

A. Dollar Savings per Year

| | S2D | TBM | G-164A | Total | % of Optimum |
|---|---|---|---|---|---|
| S2D | 3,797 | 136 | 366 | 4,299 | 0.98 |
| TBM | 2,843 | 186 | 289 | 3,318 | 0.76 |
| G-164A | 3,440 | 98 | 395 | 3,933 | 0.90 |
| | | | Optimum | 4,378 | |

B. Number of Fires per Year

| | S2D | TBM | G-164A | Total | % of Optimum |
|---|---|---|---|---|---|
| S2D | 12.8 | 1.3 | 1.2 | 15.3 | 1.00 |
| TBM | 5.3 | 1.3 | 7.4 | 7.4 | 0.48 |
| G-164A | 9.7 | 0.8 | 11.7 | 11.7 | 0.76 |
| | | | Optimum | 15.3 | |

The preceding comparison considered only a very small portion of the overall output. A more useful comparison would be that between the three small land-based aircraft on all fires where each generated savings. Appropriate statistics are listed in Table 5. Again, we see that the S2D generates the highest saving of the three small land-based aircraft in all categories. The other two aircraft are slightly more than 10% poorer in terms of effectiveness. Thus, of the three small land-based aircraft tested by the model, the S2D Snow Commander appears to be the best air tanker in New Brunswick, but its superiority over the other two is marginal. In terms of all fires fought, the TBM and G-164A Ag-Cat are virtually equal in overall effectiveness.

Table 5 ANNUAL SAVINGS FOR ALL FIRES ON WHICH SMALL LAND-BASED AIRCRAFT WERE USED

| | Dollar Savings | % of Optimum | Area Savings | % of Optimum | Time Savings | % of Optimum | Overall % of Optimum |
|---|---|---|---|---|---|---|---|
| S2D | $116,207 | 0.52 | 1,395 ac. | 0.53 | 1,078 hr. | 0.20 | 0.42 |
| TBM | $105,032 | 0.47 | 1,236 ac. | 0.47 | 955 hr. | 0.18 | 0.37 |
| G-164A | $100,197 | 0.45 | 1,295 ac. | 0.49 | 869 hr. | o.16 | 0.37 |
| Optimum savings | $221,895 | | 2,642 ac. | | 5,340 hr. | | |

The relative role of the three aircraft is indicated by the average fire-to-central-base distance and fire size associated with each. The G-164A Ag-Cat, which has the slowest flying speed had an average fire-to-base distance of 10 miles, compared to 28 miles for the S2D, and 24 miles for the TBM. Average fire perimeter for the TBM, which has the largest capacity of the three, was 1,021 feet, while for the S2D it was 536 feet and for the G-164A it was 834 feet. Thus, relative to the S2D, the G-164A was used closer to a base by the model, and the TBM was used on larger fires.

## B. Other Types of Air Tankers

The preceding analysis emphasizes small fires which are relatively close to the central base, as these are the types of fires best suited to attack by small land-based air tankers. It is clear, however, that most of the potential savings attributable to the use of air tankers is associated with larger fires at all fire-to-base distances. Thus, an evaluation of alternative air tanker types in New Brunswick is of potentially greater significance than the preceding analysis of small land-based aircraft. Each type will not be analyzed in the same detail as the S2D. Rather, the discussion will be limited to a superficial evaluation of effectiveness to determine the types which might warrant a more detailed analysis.

To determine the expected effectiveness of each air tanker type on all fires which can be successfully attacked, the average annual saving for the best model of each type is listed in Table 6. The ranking of each type for each class of savings was determined. An overall rank, based on an average of the three individual rankings is also shown in Table 6.

Three observations can be made, based on the data presented in Table 6. (1) The highest ranked type (medium water) appears to be clearly more effective than the remaining types. (2) The three lowest ranked types (small land, small and medium helicopters) appear to be clearly less effective than the remaining types. (3) The intermediate types do not differ markedly in overall effectiveness.

As was indicated in the discussion on optimum fleet size, fixed costs must be subtracted from the savings to make an air tanker acquisition decision. To compare the nine types, the annual saving attributable to one aircraft of the specific model that was best for each type is listed in Table 7. The use of only the first aircraft eliminates the complication of fleet size. The annual fixed cost for each air tanker is also listed in Table 7. The difference between the saving and fixed cost is the net saving. Note that this procedure ignores simultaneous occurrence, so that the absolute differences shown in Table 7 could not be achieved in the field. The results are useful, however, for ranking the aircraft.

Table 7 presents a totally different picture than Table 6. The two most effective air tankers in Table 6 (medium water-based and large helicopters) generate a net loss when fixed costs are included. In the case of medium water-based aircraft, substituting the PBY5A Canso for the Canadair CL-215 reduces the saving to $72,193 but an even larger reduction in fixed cost to $53,048 results in a positive net saving of $19,145. No large helicopter generated a positive net saving. The Martin Mars can be eliminated as being of academic interest only. The small helicopter can be eliminated as ineffective. While the Canso is effective, it is notably less so than the remaining four types as a primary air tanker.

Note that only one DC-6 or two Turbo-Beavers could be justified (based on savings attributable to the first air tanker). As noted with the S2D, three aircraft are far superior to one or two when the problem of simultaneous occurrence is considered. It may, therefore, be concluded that a medium land-based air tanker such as the A-26 is the best single air tanker for New Brunswick, with a small land-based aircraft such as the S2D Snow Commander being second best.

The current management practice of operating five small land-based air tankers is not very different from the best strategy as determined by the model. This finding implies a high degree of concordance between the simulation model and field operations. The model is based on the author's interpretation of how air tanker systems operate, supported by empirical observations. Field practices are based on the perceptions of fire management personnel as to what works and what does not work

Table 6 ANNUAL SAVINGS BY AIR TANKER TYPE

| Type | No. of Fires* | Dollars ($) | Rank | Area (Ac.) | Rank | Time (Hr.) | Rank | Overall Rank |
|---|---|---|---|---|---|---|---|---|
| Small land | 47.2 | 116,207 | 7 | 1,396 | 7 | 1,078 | 8 | 7 |
| Medium land | 39.3 | 146,597 | 2 | 1,645 | 5 | 1,375 | 4 | 4 |
| Large land | 24.2 | 144,110 | 4 | 1,553 | 6 | 1,178 | 6 | 6 |
| Small water | 89.8 | 129,091 | 5 | 1,649 | 4 | 1,793 | 1 | 3 |
| Medium water | 50.2 | 166,171 | 1 | 1,923 | 3 | 1,689 | 2 | 1 |
| Large water | 15.5 | 128,084 | 6 | 2,024 | 1 | 1,324 | 5 | 5 |
| Small helicopter | 39.0 | 81,762 | 9 | 1,100 | 9 | 891 | 9 | 9 |
| Medium helicoper | 31.7 | 100,704 | 8 | 1,256 | 8 | 1,152 | 7 | 8 |
| Large helicopter | 31.0 | 145,243 | 3 | 1,989 | 2 | 1,451 | 3 | 2 |

* The number of fires successfully attacked by one aircraft of each type. The number of fires on which one aircraft was insufficient, but on which two or more aircraft were successful is not included. For large aircraft, the difference would be negligible. For the S2D, this difference is 7.3 fires per year.

Table 7 NET ANNUAL SAVINGS FOR NINE SELECTED AIR TANKERS

| | | $ Savings (1 Acft.) | Fixed Cost* | Net Savings | Rank | No. of Aircraft |
|---|---|---|---|---|---|---|
| S2D | Snow Commander | 82,963 | 24,280 | 58,683 | 2 | 3 |
| A-26 | Invader | 111,760 | 33,660 | 78,100 | 1 | 3 |
| DC-6 | | 132,771 | 81,180 | 51,591 | 3 | 1 |
| DHC-2-II | Turbo Beaver | 87,184 | 36,630 | 50,554 | 4 | 2 |
| CL-215 | | 138,542 | 251,625 | -113,083 | 8 | - |
| JRM3 | Mars | 106,695 | 94,875 | 11,820 | 6 | 1 |
| A-III | Alouette | 59,769 | 51,315 | 8,454 | 7 | 1 |
| 205A | | 125,105 | 87,780 | 37,325 | 5 | 1 |
| CH-47 | Chinook | 125,404 | 385,457 | -263,053 | 9 | - |

* For the sake of uniformity, the fixed costs are all adopted from data published by Simard (1972). These values may not agree with previously discussed data obtained from other sources. They are sufficiently accurate for comparison purposes. The fixed costs include pilots salaries, maintenance, depreciation, and insurance (50% of value), adjusted to 1978 dollars.

in their particular operating environment. The strong agreement between two solutions arrived at through widely disparate approaches lends considerable credibility to both procedures.

To determine the actual improvements that could be achieved with the A-26, a detailed analysis comparable to that for the S2D would have to be undertaken. The $20,000 increase for the first aircraft represents a one-third improvement relative to the S2D. This is more than a marginal increase. It appears sufficient to exceed the cost of change as well as the uncertainty associated with the results presented herein. It is therefore recommended that if a single type of aircraft is to be used as an air tanker in New Brunswick, a detailed analysis of the costs and benefits of switching from the S2D Snow Commander to the A-26 Invader be undertaken.

For the small fleet size which can be justified in New Brunswick, ownership of two types of air tankers is not likely to be practical. There is an intriguing possibility, however, in which the best of both worlds might be achieved. It was noted that the CL-215 is the most effective air tanker analyzed. A large fleet of CL-215's is owned and operated by a neighboring province. It would be mutually advantageous if New Brunswick could arrange to lease one or more CL-215's on an as-needed basis. By leasing the aircraft to an outside agency when it is not needed, the owning province could help defray part of the annual fixed cost. By not having to pay the total fixed cost, New Brunswick could afford to use this effective air tanker on the few fires each year where it is really needed. It is therefore recommended that formal arrangements for leasing CL- 215's on an as-needed basis be instituted.

## 5. Conclusions

To summarize, based on results generated by AIRPRO, the following conclusions can be drawn relative to air tanker operations in the province of New Brunswick.

1) The S2D Snow Commander is best suited to small fires close to the central base.

2) The S2D Snow Commander may be marginally better than the G-164A Ag-Cat and the TBM Avenger as an air tanker.

3) A fleet of either three or four S2D Snow Commander aircraft would be optimum.

4) The A-26 Invader is the most cost-effective air tanker.

In addition, the following recommendations are made with respect to air tanker operations in New Brunswick.

1) A detailed study of the costs and benefits of switching from the S2D Snow Commander to the A-26 Invader should be undertaken.

2) Formal arrangements for leasing one or more CL-215's on an as-needed basis should be instituted.

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