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THESIS

**ARMY RESERVE ENLISTED AGGREGATE FLOW
MODEL**

by

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June 2006

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ARMY RESERVE ENLISTED AGGREGATE FLOW MODEL

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Submitted in partial fulfillment of the
requirements for the degree of

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ABSTRACT

Recent world events have affected the rates at which the United States Army Reserve (USAR) recruits and retains enlisted members. As these rates fluctuate, it becomes difficult for the USAR to forecast its recruiting requirements.

This thesis describes a statistical model and an associated software tool designed to provide precise forecasts of aggregate USAR enlisted personnel trends. In particular, the tool can assist in forecasting specific USAR enlisted end strength requirements using aggregate accession, retention and attrition rates. Entitled the Army Reserve Enlisted Aggregate Flow Model (AREAFM), the tool uses a Markov Growth Model and, for the purposes of this thesis, it is standardized using fiscal year 2001 (FY01) through FY03 data and validated with FY04 data.

The AREFM is intended for annual use in forecasting the number of enlisted accessions required to achieve USAR end strength. The model can also be used to evaluate how adjustments in accession, promotion and attrition rates, perhaps as the result of changes in USAR manpower policies or current events, might affect the assigned strength.

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LIST OF ACRONYMS

AIT	Advanced Individual Training
AR	Army Regulations
AREAFM	Army Reserve Enlisted Aggregate Flow Model
ARNG	Army National Guard
AR-PERSCOM	Army Reserve- Personnel Command (Currently HRC)
BT or BCT	Basic Training or Basic Combat Training
CAR	Chief, Army Reserve
CLG	Civil Life Gain
DA	Department of the Army
DCSPER	Deputy Chief of Staff for Personnel
DMDC	Defense Manpower Data Center
DMOSQ	Duty Military Occupation Specialty Qualification
ESO	End Strength Objective
ETS	Expiration Term of Service (ETS)
FORSCOM	United States Army Forces Command
FY	Fiscal Year
HRC	Human Resources Command
HRD	Human Resources Department
IET	Initial Entry Training
IMA	Individual Mobilization Augmentee
IRR	Individual Ready Reserve
MAPE	Mean Absolute Percent Error
MOS	Military Occupational Specialty
MOSQ	Military Occupational Specialty Qualified
MSO	Military Service Obligation
NPS	Non-Prior Service
OASD(RA)	Office of the Assistant Secretary of Defense, Reserve Affairs

OCAR	Office of the Chief, Army Reserve
OCAR- RTD	Office of the Chief, Army Reserve, Retention Transition Division
PAM	Pamphlet
PCS	Permanent Change of Station
PS	Prior Service
RA	Regular Army
RC	Reserve Component
RFPB	Reserve Forces Policy Board
RRC	Reserve Readiness Centers
SL	Skill Level
SSN	Social Security Number
TIG	Time in Grade
TIS	Time in Service
TPU	Troop Program Unit
USAR	United States Army Reserve
USARC	United States Army Reserve Command
USAREC	United States Army Recruiting Command

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EXECUTIVE SUMMARY

Recent world events have affected the rates at which the United States Army Reserve (USAR) recruits and retains enlisted members. As these rates fluctuate, it becomes difficult for the USAR to forecast its recruiting requirements.

This thesis describes a statistical model and an associated software tool designed to provide precise forecasts of aggregate USAR enlisted personnel trends. In particular, the tool can assist in forecasting specific USAR enlisted end strength requirements using aggregate accession, retention and attrition rates. Entitled the Army Reserve Enlisted Aggregate Flow Model (AREAFM), the tool uses a Markov Growth Model and, for the purposes of this thesis, it is standardized using fiscal year 2001 (FY01) through FY03 data and validated with FY04 data.

The AREAFM predictions are based on recent assigned strength and a three-year average of promotion, accession, and attrition rates. Predictions include numbers of recruits required to meet authorized end strength and how future assigned strength changes with actual number of recruits. The three-year averages rates lower prediction errors by smoothing the variability of yearly data.

The AREAFM is intended for annual use in forecasting the number of enlisted accessions required to achieve USAR end strength. The model can also be used to evaluate how adjustments in accession, promotion and attrition rates, perhaps as the result of changes in USAR manpower policies or current events, might affect the assigned strength.

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I. INTRODUCTION

A. BACKGROUND

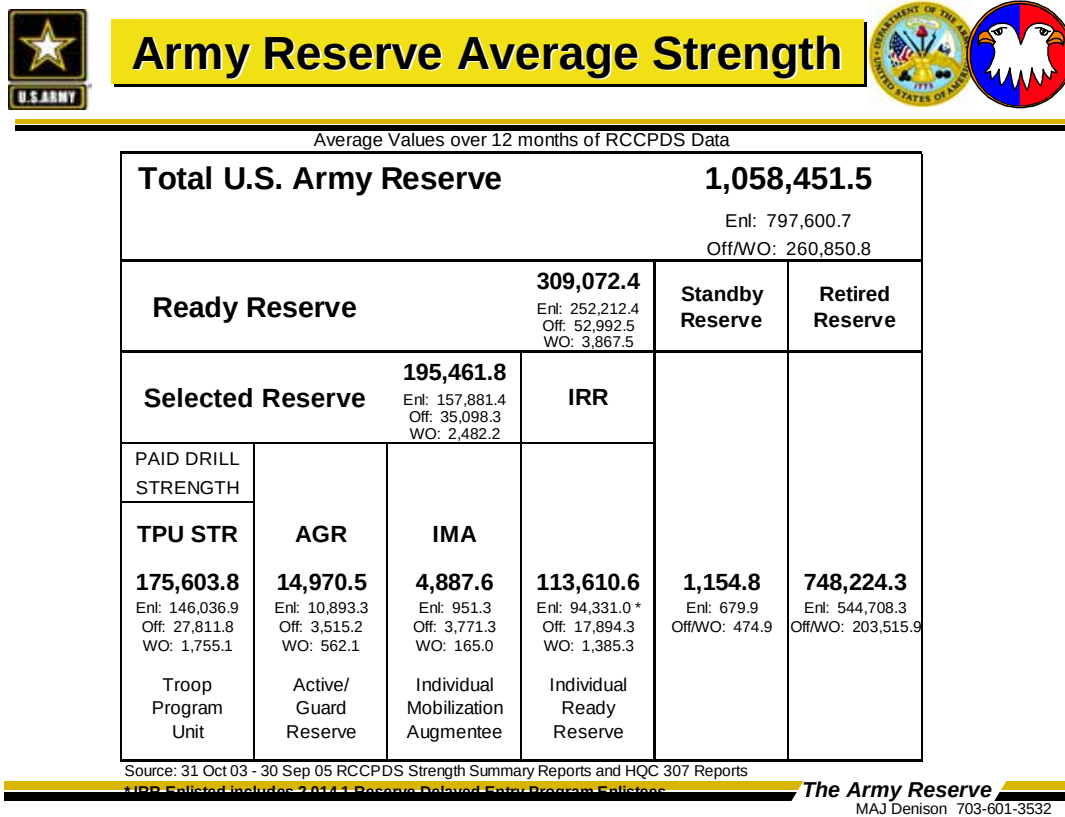
The United States Army Reserve (USAR) is a key element of the Department of the Army's multi-component force. The Army Reserve's primary mission is to provide trained and ready personnel with the skills necessary to support and defend the nation during peacetime, emergencies, and war. The effective management of an enlisted personnel inventory is essential for the proper support of this mission. The term "personnel inventory" refers to the management of personnel by rank and military occupational specialty (MOS) to ensure the proper balance of skills at all levels. In this thesis, the goal is to predict the annual number of incoming personnel required to achieve the USAR required end strength.

1. USAR Force Size and Structure

The USAR consists of more than one million soldiers. As shown in Figure 1, the total USAR consists of Ready Reserve, Standby Reserve, and the Retired Reserve. Retired Reserve consists of soldiers who have completed more than twenty years of USAR service but have not yet reached the age of 60. The Standby Reserve soldiers are not required to take part in any Army Reserve training and are not assigned to units.

The Ready Reserve category consists of the Selected Reserve and the Individual Ready Reserve (IRR) soldiers. The IRR soldiers continue a commitment in the USAR without a unit assignment. The Selected Reserve category consists of three subsets: the Troop Program Unit (TPU), the Active Guard and Reserve (AGR) and the Individual Mobilization Augmentee (IMA). The IMA soldiers are similar to the IRR soldiers but participate with multiple units in order to complete their commitment to the USAR. The AGRs are full-time soldiers with the same pay and benefits as their active-duty counterparts. A TPU is not a unit but a drilling soldier who must complete at least twelve days of annual training per year and one weekend a month of training. This thesis focuses on the TPU soldiers.

Figure 1. Army Reserve Average Strength



(Denison, 2005)

2. Characterizing USAR Soldiers

To join the USAR, an individual is “accessed” into the USAR. Accession means an increase in USAR strength by means of adding a new individual. Soldiers joining the USAR are classified as either non-prior service (NPS) or prior service (PS). In accordance with Army Regulation (AR) 601-210, chapter 3, paragraph 3-2 (b(2)), inductees are considered prior service if they have more than 180 days of active service. Prior service soldiers generally enter the USAR at the same paygrade they held upon discharge from active service. For inductees without prior service, AR 601-210, chapter 2, paragraph 2-18 states that NPS accession into the Army Reserve is limited up to the paygrade of E4.

Each soldier in the USAR has a Military Occupational Specialty (MOS). Every MOS has anywhere from one to five skill levels depending on the types of duty positions

it encompasses. The skill levels include all nine ranks. Paygrades in the Army Reserve are the same as the Active Army. They are commonly denoted E1 through E9, each of which connects with a specific enlisted rank (see Table 1). For purposes of this thesis, characterization of every individual in the USAR is by his or her paygrade.

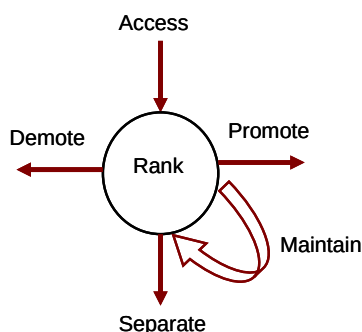
Table 1. Army Enlisted Ranks and Paygrades

Rank	Paygrade
Private	E1 or E2
Private First Class	E3
Specialist	E4
Corporal	E4
Sergeant	E5
Staff Sergeant	E6
Sergeant First Class	E7
Master Sergeant	E8
First Sergeant	E8
Sergeant Major	E9

B. THE USAR MANPOWER SYSTEM

The USAR manpower system (Figure 2) begins with an accession of an individual into the USAR. Each year, within the manpower system, three possible events may occur to a TPU soldier. He or she can: (1) maintain the current rank and remain within the TPU system, (2) receive either a promotion or a demotion, or (3) separate from TPU status. In separating from the TPU status, a soldier might simply move to another reserve category or separate completely from the USAR. The Army Reserve Enlisted Aggregate Flow Model only captures one of these events per soldier per year because the data used is aggregated at the yearly level.

Figure 2. USAR Manpower System



Maintaining TPU manpower strength in the Army Reserve is different from the Active Component Army. The Active Component Army has the flexibility to move soldiers from one location to another in order to fill vacant positions. In contrast, the USAR does not have that flexibility and, in fact, most reservists do not travel outside of a 75-mile radius to attend their weekend training.

C. FORECASTING USAR PERSONNEL REQUIREMENTS

Recent world events have affected the USAR recruitment and the retention rates of enlisted members. As rates fluctuate, it becomes increasingly difficult for the USAR to forecast recruiting requirements. Currently, there is no model for forecasting the required number soldiers to meet the end strength requirements of the USAR. Moreover, given the differences between the Army Reserve and Active Component Army, the Active Component Army's tools are not immediately applicable or adaptable to the Army Reserve's mission. The Office of the Chief, Army Reserve (OCAR), has requested a model that forecasts personnel trends for the aggregate force, to focus future efforts on assisting with setting targets for accessions, retention and attrition.

Manpower responsibilities and the associated management models are disbursed throughout various levels of command within the active Army and the Army Reserve. The United States Army Recruiting command (USAREC) focuses on the accession aspect of the manpower system for both the Active Component and the Army Reserves. OCAR determines Army Reserve policy and oversees the reserves at the aggregate level.

The United States Army Reserve Command (USARC) reviews and verifies qualification of the manpower system. Finally, the Human Resource Command (HRC) – St Louis focuses on the manpower system’s day-to-day management. Figure 3 illustrates the reporting relationships between the organizations.

Figure 3. Levels of Manpower

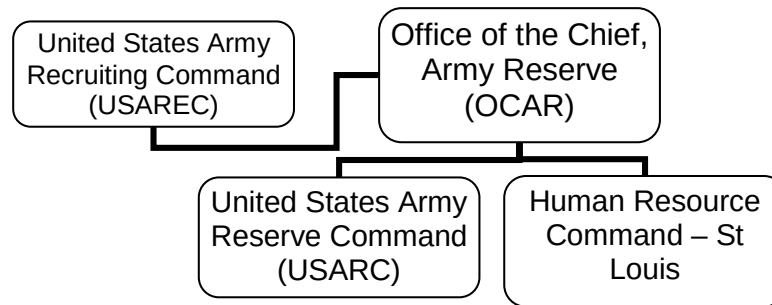


Figure 4 illustrates the areas of emphasis within the major commands of the Army Reserve. The Army Reserve Enlisted Aggregate Flow Model developed in this thesis focuses on the OCAR area of policy and resources at the aggregate level.

Figure 4. Army Reserve Command Layout

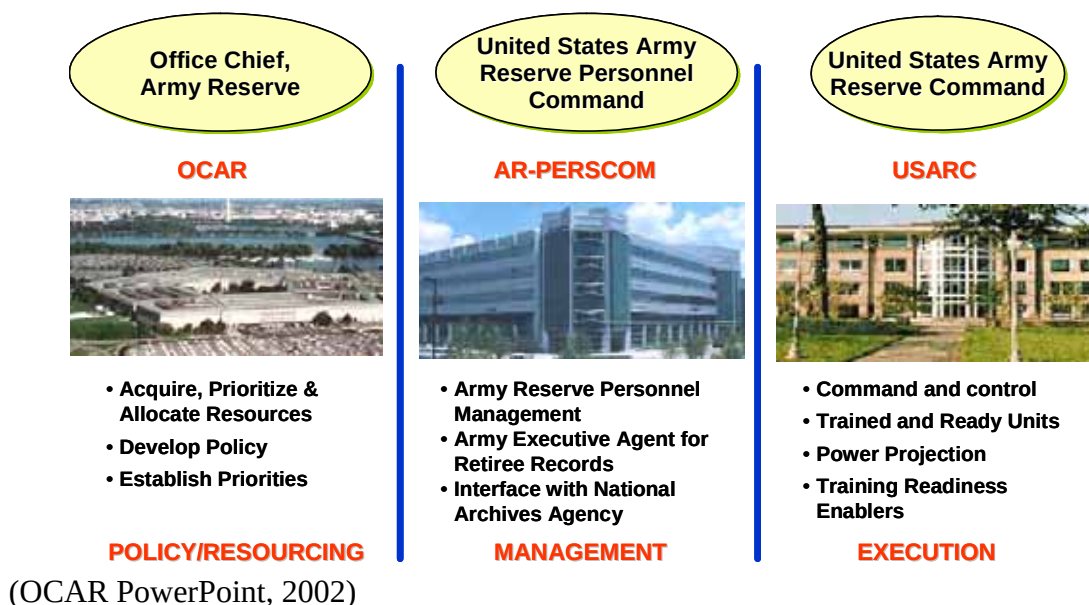
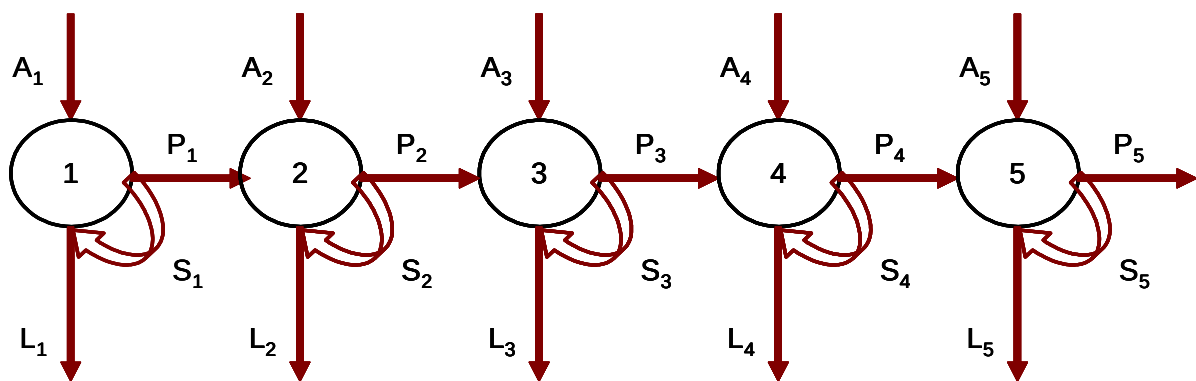


Figure 5, defined by Human Resources Department (HRD-OCAR), is an illustration of possible flows of personnel within and between the five skill levels previously mentioned. Each node represents one of the five skill levels and has between four to five arcs, which represent the possible ways personnel can flow within and between the five skill levels. The A arcs represent all of the accessions that enter into a certain skill level. The S arcs represent a soldier remaining in the current skill level. The P arcs represent a soldier promoted to the next skill level. The L arcs represent the loss of a soldier from the specific skill level and the reserve system.

Figure 5. HRD-OCAR Notional Skill Level Enlisted Flow Model



- 1 through 5 represents the skill levels
 - A's represent accessions by grade
 - S's represent reenlistments by grade
 - P's represent promotions by grade
 - L's represent term losses (retirement/ETS) by grade
- (Denison, email, August 2005)

D. SCOPE OF THESIS

The Manpower Planning and Strength Reporting Branch, Human Resources Department, OCAR, requested an aggregate flow model for the enlisted TPU population that incorporated the following factors: NPS accessions, PS accessions, attrition, promotions, reenlistment, and end of term losses.

This thesis presents such a model, entitled the Army Reserve Enlisted Aggregate Flow Model (AREAFM), and the associated software tool, created in response to HRD-OCAR's request. In contrast to the skill level orientation originally posited by HRD-

OCAR, the Army Reserve Enlisted Aggregate Flow Model developed in this thesis uses enlisted ranks for the nodes rather than skill level. This allows the AREAFM to forecast by ranks rather than skill level (which combines ranks).

Using statistical modeling techniques, the AREAFM can assist OCAR in forecasting specific USAR end strength requirements using aggregate accession, retention and attrition rates. In so doing, it will support USAR manpower management decisions via more precise forecasting of aggregate personnel trends.

E. THESIS OUTLINE

Chapter II provides a review of the existing literature and previous results. Chapter III describes the methodology and the initial formulation of the Army Reserve Enlisted Aggregate Flow Model, including its formulation as a Markov Growth Model. Chapter IV describes how the Army Reserve Aggregate Flow Model was implemented and provides instructions for using the software. Chapter V discusses the modeling results for forecasting the enlisted TPU in the Army Reserve and compares the results of using rates based on three-year average and on one year's data. Chapter VI provides conclusions and recommendations for future studies.

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II. RELATED WORK

A literature review of relevant manpower studies revealed two monographs relating to Army Reserve manpower by the RAND Corporation. *The Readiness Enhancement Model* (Shukiar 1996) addresses projecting the enlisted inventory by four categories: NPS Qualified, NPS Non-Qualified, PS Qualified, and PS Non-Qualified. An important difference between Shukiar's model and the Army Reserve Enlisted Aggregate Flow Model is the definition of NPS and PS. To determine whether a soldier is PS, Shukiar's model uses the following qualification.

A prior-service (PS) RC member is one with approximately two or more years of previous Active Component service. (Shukiar 1996)

This is appropriate for those soldiers who enter the USAR directly from the Active Army. However, if a TPU reservist leaves the reserves, but later re-joins the reserves, then according to this definition he or she is not considered PS.

As was previously discussed, in the Army Reserve Enlisted Aggregate Flow Model PS is defined in accordance with Army Regulation (AR) 601-210, chapter 3, paragraph 3-2 (b(2)). In particular, a soldier is classified as PS if he or she has had previous service (Active, Reserve, or Guard) in any component (Army, Navy, Air Force, Marines, and Coast Guard) with 180 days of active service.

In the second RAND monograph, *Modeling Reserve Recruiting*, Arkes and Kilburn (2005) looked at NPS and PS accessions at the USAREC level. As described in the following quote, at the time of the Arkes and Kilburn study there was a definite trend toward shrinking prior service accessions:

Reserve recruiting has faced a number of challenges in the last decade. Primary among the challenges have been the strength of the economy, which has made the civilian alternatives to the reserves appear more attractive, and the shrinking of the active force, which has meant a smaller prior-service (PS) pool from which to recruit (Arkes and Kilburn, 2005).

However, not only have the trends in PS recruiting changed because of the current conflict, but also the Arkes and Kilburn monograph examined accessions at a different level than OCAR.

There are three Naval Postgraduate School theses regarding to enlisted manpower modeling. Two of the theses address optimizing enlisted manpower and assignments for the Active Duty side of the force only. *Optimizing United States Marine Corps Enlisted Assignments* (Tivnan, 1998) assesses placement of active duty enlisted in the proper vacancies. As discussed in the background section of this chapter, the Army Reserves does not have the flexibility to move TPU soldiers from one location to another in order to fill vacancies. *Optimizing Active Guard Reserve Enlisted Manpower* (Schrews, 2002) modeled the AGR enlisted force in the Army Reserve only, while the Army Reserve Enlisted Aggregate Flow Model developed herein models TPU soldiers.

The third Naval Postgraduate thesis, *Development of Spreadsheet Models for Forecasting Manpower Stocks and Flows* (Earl, 1998) develops a spreadsheet model similar to the one in this thesis. The Markov Growth Model used in the Army Reserve Enlisted Aggregate Flow Model is an extension to Earl's Markov Chain Model.

III. METHODOLOGY

As was described in the Introduction chapter, the objective of this thesis is to develop a model for use in forecasting the annual number of accessions required to achieve a specific USAR end strength. Additionally, the model must be flexible enough for adjustments to accession, promotion, and attrition rates to facilitate evaluating how changes to USAR enlisted manpower policies and current events affect the force end strength.

This chapter first introduces the basic ideas and terminology of Markov Chains and Markov Growth models. Then the applications of these models to the Army Reserve Enlisted Aggregate Flow Model are discussed. Finally, the assumptions, limitations, and the data for the AREAFM are discussed.

A. MARKOV GROWTH MODELS

The Army Reserve Enlisted Aggregate Flow Model is based on a Markov Growth Model. Such models are useful for predicting a manpower system that has personnel entering the system, moving within the system, and departing from the system. In this application, the Markov Growth Model was used to model the flow of Army Reserve personnel into, out of, and through the various pay grades.

1. Markov Chain Models versus Markov Growth Models

A Markov Chain Model is a closed system in which there are no gains or losses. This system is characterized by two sets of quantities: (1) “stocks,” which are the numbers of people in each category at any particular time, and (2) “flows,” which are the numbers of people who move between pairs of categories (or “states”) over an interval of time (Bartholomew, 1982). The system is said to be in “steady state” if the number of people in each state does not change over time.

The “transition matrix” specifies each of the conditional probabilities associated with moving from one state to another. For example, in the transition matrix below, P_{12} is the probability that an individual currently in a present state S_1 will be in S_2 in the future.

Transition Matrix

$$\begin{array}{c} \text{Future State} \\ S_1 \quad S_2 \quad S_3 \\ \text{Present State } S_1 \left(\begin{array}{ccc} P_{11} & P_{12} & P_{13} \\ S_2 \left(\begin{array}{ccc} P_{21} & P_{22} & P_{23} \\ S_3 \left(\begin{array}{ccc} P_{31} & P_{32} & P_{33} \end{array} \right) \end{array} \right) \end{array} \right) \end{array}$$

(Bartholomew, 1982)

In a Markov Chain, the probabilities in each row sum to one. That is, $\sum_j P_{ij} = 1$ for all j . What this means is that an individual in state S_i must transition to one of the other states according to the probabilities in the row for S_i . We could also say that such a system is “closed” since the individuals cannot enter or exit the system, but only shuttle between states.

The Markov Growth Model is a generalization of the Markov Chain Model. In the Markov Growth Model, the transition matrix is an “open system,” so the rows of the transition matrix add up to less than one. Bartholomew (1982) describes an open system as follows:

The state of a system is a fundamental concept in the theory of stochastic processes. In social applications, this term may be applied to an individual or to the system as a whole. Social systems will be classified as closed or open. An open system has both gains and losses. The Markov Property requires that knowledge of the current state of the system provides all of the information relevant to predicting its future. (Bartholomew, 1982)

The Markov Growth Model is $\sum_j P_{ij} < 1$ for all of j . As with a Markov Chain, an individual in state S_i moves to state S_j with probability of P_{ij} . However, transitions into

and out of the system are possible. The notation $S_j(t)$ is used to denote the number of people in state j at time $t = 0, 1, 2, \dots$ (Bartholomew, 1982). Figure 6 is an example of a Markov Growth Model.

Figure 6. Example of a Markov Growth Model: A Simplified AREAFM

Transition Matrix	Paygrade1	Paygrade2	Paygrade3		r	Lambda
Paygrade1	0.5	0.3	0		0.5	68
Paygrade2	0.1	0.5	0.3		0.3	
Paygrade3	0	0.1	0.5		0.2	

	Steady State	S(0)	S1	S2	S3	S4	S5	S6
Paygrade1	90	100	94	92	91	91	91	91
Paygrade2	114	100	110	113	114	114	114	114
Paygrade3	95	100	94	93	94	95	95	95
Total	300	300	298	298	299	299	300	300

Figure 6 illustrates how the Markov Growth Model is applied to a simplified AREAFM. The transition matrix is shown in the upper left, where “Paygrade1,” “Paygrade2,” and “Paygrade3” are the states. The r vector represents the proportion of recruits allocated to each paygrade. In the above example, 50% of recruits are allocated to the Paygrade1, 30% to Paygrade2, and 20% to Paygrade3. Lambda is the number of recruits that enter the system.

Denoting the vector of the number of individuals in each state at time t as $S(t)$, then at the next time increment

$$S(t+1) = P^T * S(t) + \lambda * r$$

where P is the transition matrix.

In addition, the steady state formula for the system is:

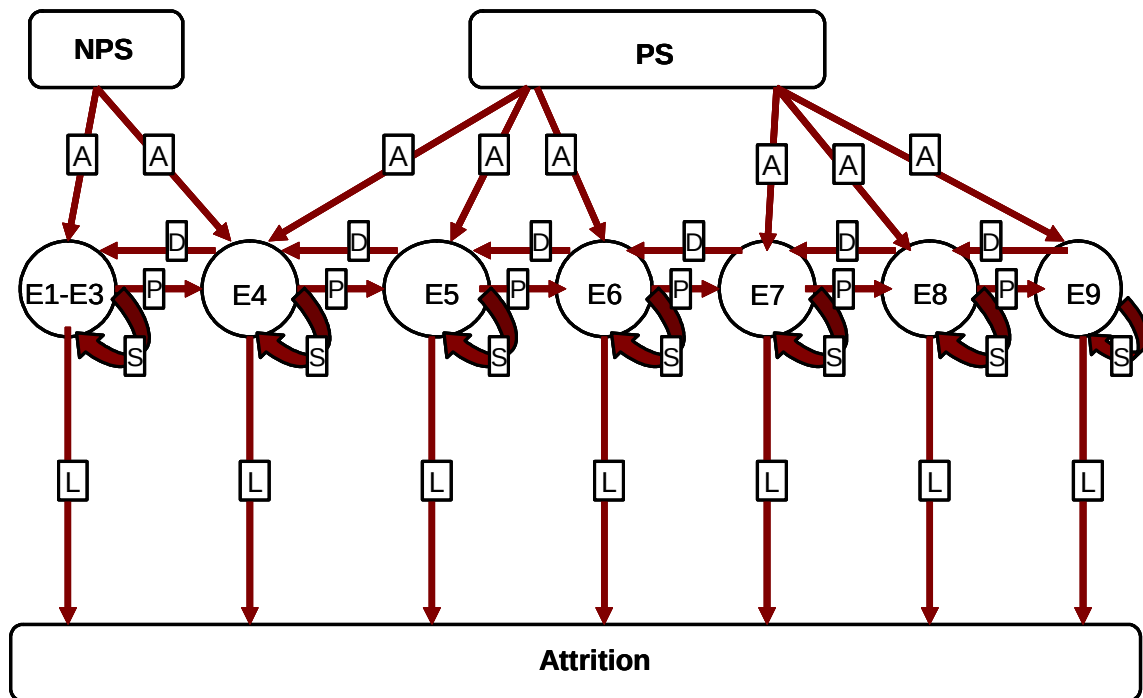
$$S(t) = \lambda [I - P^T]^{-1} r$$

where I is the identity matrix. (Bartholomew and Forbes, 1981)

2. Applying the Markov Growth Model

As stated in Chapter I, personnel enlisted TPU flows are modeled by grade. As shown in Figure 7, the mechanisms that generate flow within the model start with the accession (NPS and PS) of soldiers into each paygrade. The next action for any soldier is either staying in the current paygrade, receiving a promotion from one paygrade to the next paygrade, or receiving a demotion to the previous paygrade. The last action at any paygrade is leaving the TPU system by attrition. Attrition as defined for this model include all forms of separation from the Army Reserve as a TPU such as retirement, ETS, death, going to another service, going to active-duty, etc. Unlike Figure 5, Figure 7 reflects demotions, thus creating an additional arc exiting from the last six nodes.

Figure 7. Enlisted TPU Aggregate Flow



A = Accessions from either NPS or PS

P = Promotion

D = Demotions

S = Sustain (maintains current rank)

L = Loss of any kind (ex: retirement, Expiration term of service (ETS), death, etc). If a soldier leaves the reserves as a TPU, even to enter another branch or the active component, it is considered a loss.

Figure 8. Transition Matrix and r vector for AREAFM

Transition Matrix									
	E3	E4	E5	E6	E7	E8	E9	r	Lambda
E3	0.1959	0.4377	0.0000	0.0000	0.0000	0.0000	0.0000	0.6251	48936
E4	0.0143	0.5099	0.1719	0.0000	0.0000	0.0000	0.0000	0.2294	
E5	0.0000	0.0252	0.5593	0.2015	0.0000	0.0000	0.0000	0.0978	
E6	0.0000	0.0000	0.0205	0.7018	0.1280	0.0000	0.0000	0.0328	
E7	0.0000	0.0000	0.0000	0.0132	0.7974	0.0781	0.0000	0.0110	
E8	0.0000	0.0000	0.0000	0.0000	0.0042	0.8268	0.0360	0.0034	
E9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0069	0.8463	0.0006	

Figure 8 shows the estimated transition matrix of the Army Reserves Enlisted Aggregate Flow Model. The vector of r represents the accession rates allocated to each state. The transition matrix consists of promotion, demotion, and retention rates, since attrition rates are not included the rows are less than one. The calculation of the retention rates, highlighted in green, consists of the attrition, promotion and demotion rates. Probabilities in the cells immediately to the right of the highlighted cells are the promotion rates and those to the left are the demotion rates. Chapter IV describes how the various rates in the transition matrix were calculated.

3. Limitations and Assumptions

The Army Reserve Enlisted Aggregate Flow Model reflects enlisted TPU soldiers; therefore, this model does not forecast other types of soldiers in the reserves such as AGRs.

The Army Reserves are not authorized E1 and E2 positions, so all E1 through E3 soldiers recruited are placed in E3 positions. Thus, E1 through E3 are combined within the Army Reserve Enlisted Aggregate Flow Model.

Some errors were found in the data and those that could be were corrected. However, because of limited information available on individual soldiers, many records that looked anomalous were not corrected because insufficient information was available to be sure that the observed anomalies were, in fact, errors.

Promotion and demotion rates beyond one paygrade are not included in this model since those percentages are negligible. Table 2 shows the promotion and demotion rates for all ranks. This includes promotions and/or demotions from one rank, two ranks, three ranks, all the way up to four ranks in one year.

Table 2. Percentage of Promotions and Demotions per Year

Values	Percentage
Promotion	14.22%
Promotion 2 Ranks	0.25%
Promotion 3 Ranks	0.01%
Promotion 4 Ranks	0.00%
Demotion	0.93%
Demotion 2 Ranks	0.04%
Demotion 3 Ranks	0.01%
Demotion 4 Ranks	0.00%

The model assumes that the promotion/demotion, accession, and attrition rates derived from the past three years will persist to the next year. That is, out of necessity, the model assumes that the various rates in the near future are like those of the recent past.

In addition, because the AREAFM is based on a Markov model-base methodology, it assumes that an individual's transition to a future state depends on his or her present state and is independent of the past states. This means in the aggregate, how individuals arrive at a particular state does not affect how they will transition to a future state.

B. DATA

The data used in the Army Reserve Enlisted Aggregate Flow Model came from two sources: (1) Enlisted Database (OCAR) and (2) Attrition Database (OCAR).

1. Enlisted Data

The enlisted data was extracted from an OCAR database. Data was available for every enlisted TPU member in the Army Reserves. The data contains 24 fields on each individual enlisted member for each year. This includes their social security number, reserve obligation, grade, military education, and how many years credited for retirement. Appendix A lists all fields available in this database. Enlisted personnel data was extracted for 2001 to 2004.

Fields used for Army Reserve Enlisted Aggregate Flow Model are:

SSN = Social Security Number
ASOF = Effective Date of Soldier's Record
GRADE = Rank

2. Attrition Data

The attrition data was extracted from an OCAR database. The OCAR database was created to track accessions and attrition within the reserves. The ten fields within this database consist of SSN, how an individual entered the reserves (NPS or PS), the paygrade in which he or she entered and left the reserves, and the date upon which the loss or gain action completed. Appendix A lists all fields available in this database.

Fields used in Army Reserve Enlisted Aggregate Flow Model are:

SSN = Social Security Number
GAIN_PSNPS = gain either NPS or PS
GAIN_GRADE = Enlisted grade at time of gain into reserve
LOSS_GRADE = Enlisted grade at time of loss from reserve
GAINDATE = date gained into reserves year/month
LOSSDATE = date lost from the Reserves

The original data extraction was by gain date from FY01 through FY04

3. Data Analysis

A careful evaluation of the data was conducted to minimize and resolve missing and questionable data. This was done by visualization of the data in both Clementine and Access. Tallies were created of the data in the same software to verify counts of the individual ranks. The overall numbers of errors were sufficiently small at the aggregate level so as not to affect the model or conclusions.¹

Any records with obvious errors in the data were corrected. For example, one soldier in the database went from E7 one year to E3 the next year and then back to E7 the following year. This was presumably a data input error in the middle year and it was corrected before modeling. The total number of records corrected was 97. There were

¹ Data was also obtained from the Defense Manpower Data Center (DMDC). However, significant discrepancies were found with the higher ranks' data, especially the E9's. For example, there should have been approximately 14,000 E9s in the ten years of data that was obtained – but only 109 were in the data. So the DMDC data was not used in the Army Reserve Enlisted Aggregate Flow Model.

624,444 enlisted records for the FY01 to FY04, so the number of corrected records was less than 0.015% percent of all records. Out of necessity, because of limited information available on individual soldiers, the rest of the records were assumed correct.

As discussed in the previous chapter, only promotions and demotions up or down one rank were modeled. The number of promotions beyond one rank equaled 1,579 and the number of demotions beyond one rank equaled 284 totaling 1,863 records to review. Overall, the percentage of promotions and/or demotions beyond one rank is 1.9%, which is negligible. This rate was calculated by $\frac{\text{Promotion and demotion} \geq 2 \text{ ranks}}{\text{All Promotions and Demotions}}$.

The attrition data consists of 154,598 records for the FY01 to FY04. The main discrepancies noted were the number of E5s to E9s labeled with an NPS accession versus a PS accession. This is not consistent with the AR 601-210 as discussed earlier. The total number of the discrepancies is 474, which is less than 0.31%. In the Army Reserve Enlisted Aggregate Flow Model, the records with discrepancies were omitted.

IV. MODEL IMPLEMENTATION

The model described in the previous chapter was implemented using Microsoft Access, Microsoft Excel, and Clementine 8.0. Microsoft Access was used to store the data and do quick calculations on the entire data set. Clementine was used to perform data mining to verify data accuracy and calculate the various rates used in the Army Reserve Enlisted Aggregate Flow Model. The Army Reserve Enlisted Aggregate Flow Model itself is implemented in Excel.

A. AN OVERVIEW OF CLEMENTINE

AREAFM uses three different rates: promotion/demotion, accession and attrition. These rates are all calculated using the Clementine software program. Before describing specific Clementine “streams” that are used for the calculations, it will be helpful to describe a generic Clementine stream.

Figure 9. Basic Clementine Stream

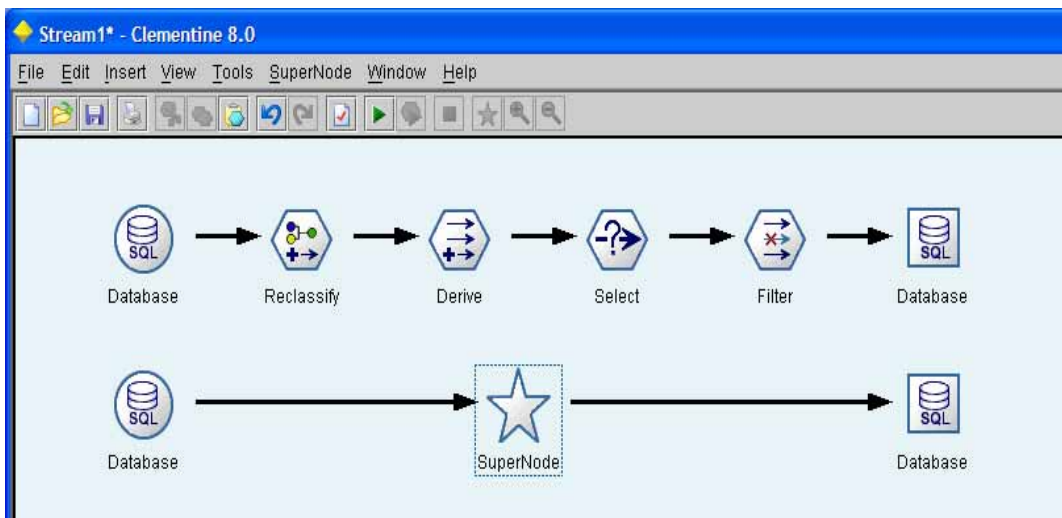


Figure 9 depicts two generic Clementine streams. The first stream focused on is the top stream. All Clementine streams can consist of three basic types of nodes: (1) source node (circle icon)- uploads the data into Clementine, (2) process node (hexagon

icon) – allows the user to perform calculations and management of the data, and (3) terminal or output node (square icon) – outputs the data either into a table in Clementine or a database outside of Clementine.

The following quote describe the various types of process nodes: reclassify node, derive node, select node, and filter node.

The reclassify node enables the transformation from one set of discrete values to another. Reclassification is useful for collapsing categories or regrouping data for analysis. One of the most powerful features in Clementine is the ability to modify data values and derive new fields from existing data. Using the Derive node, you can create six types of new fields from one or more existing fields. You can use Select nodes to select or discard a subset of records from the data stream based on a specific condition. Filter nodes have three functions: (1) To filter or discard fields from records that pass through them, (2) to rename fields, and (3) to map fields from one source to another. (SPSS Inc., 2003)

The lower stream in Figure 9 combines the four process nodes in the first section into a SuperNode (star icon). Further access to the process nodes is through the SuperNode.

Creating a Clementine stream allows users to easily write programs that access, manipulate, calculate, and output data via a user-friendly graphical interface. Clementine will connect to a data source and process the data in accordance with the instructions in the stream, eventually outputting information in the desired format.

B. CREATING THE RATES

The AREAFM promotion and attrition rates were calculated from the enlisted data and accession rates were calculated from the accession data. This section describes how these rates were calculated in Clementine.

1. Promotion Rates

Promotion and demotion rates were calculated by summing the promotions or demotions for a particular rank for a particular year and then dividing it by the total number of soldiers within the specified rank for that year. An example of the formula for the promotion rates is:

$$\text{E3 Promotion Rate for FY_X} = \frac{\text{\# of E3 soldiers promoted to E4 in FY_X}}{\text{Total \# of E3s in FY_X}}$$

The Clementine stream for the promotion rates has two streams. The first stream creates necessary fields to determine the promotion rates. The second stream outputs the fields into a text file for use in Excel.

Figure 10. Promotion Clementine Stream

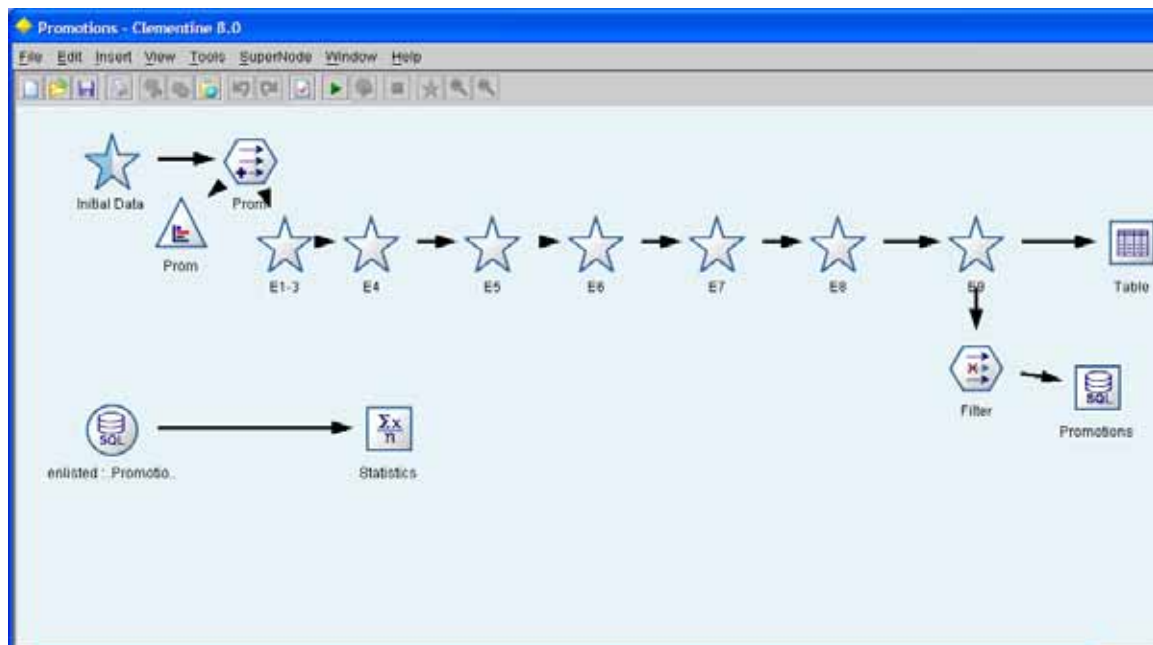


Figure 10 shows the Promotion stream that assists in the creation of promotion rates. The first stream starts with the SuperNode labeled Initial Data, which uploads and modifies the data.

Figure 11. Promotion Clementine Stream : Initial Data SuperNode

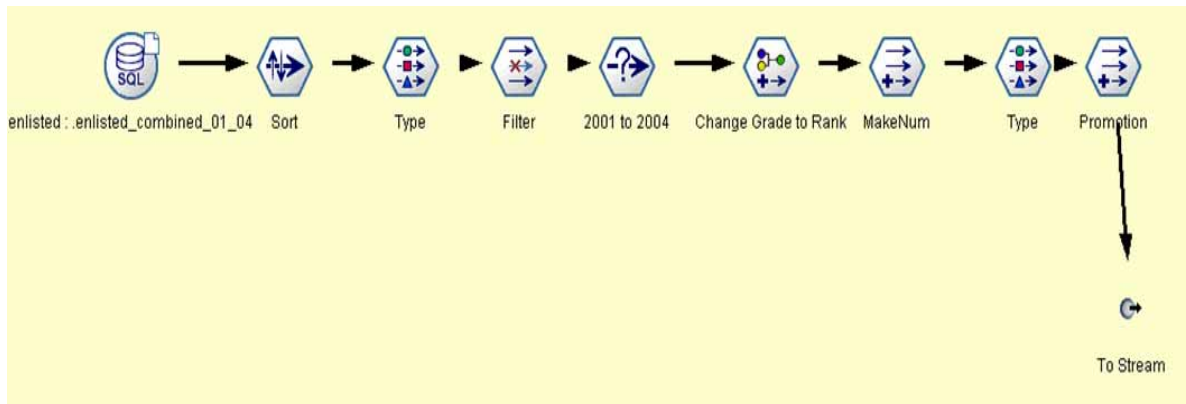


Figure 11 shows the nodes built within the Initial Data SuperNode. Proceeding through the stream from left to right:

- The first node is a source node that connects Clementine with the enlisted data. The next two nodes allow the user a logical order in which to view the data.
- The Filter node removes fields not required for this stream (see Appendix A for all fields available). The only fields retrieved are the SSN (to match each record), the “as-of date” which is the date they are in the reserves (example 200109, 200209), and the grade which is the current grade of each soldier in the “as of date.”
- The next node selects the data used in this model. Since the enlisted data is only from 2001 to 2004, this node is not necessary for the current three-year average model, but if a larger database were attached or the model were built only using one year for comparison this node would be required.
- The Reclassify node, labeled Change Grade to Rank, changes the ranks into paygrades for ease in application. Also, this node combines E1 through E3 into one rank (E3) for this model.
- The Derive node creates a field changing the paygrades into numbers for simple management.
- The Type node verifies that described characteristics of the data are correct and allow Clementine to process the data.
- Another Derive node, labeled Promotion, calculates for each soldier whether a promotion or demotion occurred.

Figure 12. Promotion Clementine Stream Promotion Node Formula

Formula:
 if SSN = @OFFSET(SSN,1) then @DIFF1(MakeNum) else 0 endif

Figure 12 shows the formula used in the Promotion node to calculate whether a soldier was promoted or demoted. In the formula, if the SSNs match – that is, if this record refers to the same soldier as the preceding record – the system subtracts the number in the MakeNum field of the record above from that of the selected record. If the SSNs do not match that is, if an incoming record refers to a new soldier, a zero is placed in the Promotion field. As a result, positive numbers equal promotions and negative numbers equal demotions.

After the initial data SuperNode (Figure 10), a derive node, labeled Prom, is placed that looks at the calculations from the Promotion node and labels them with appropriate Promotion, Demotions, and Nothing to assist with visualization of the data. After the first run of this Promotion stream, updates to the labels were made to capture the promotion and demotion beyond one rank.

Figure 13. Promotion Clementine Stream Distribution Node

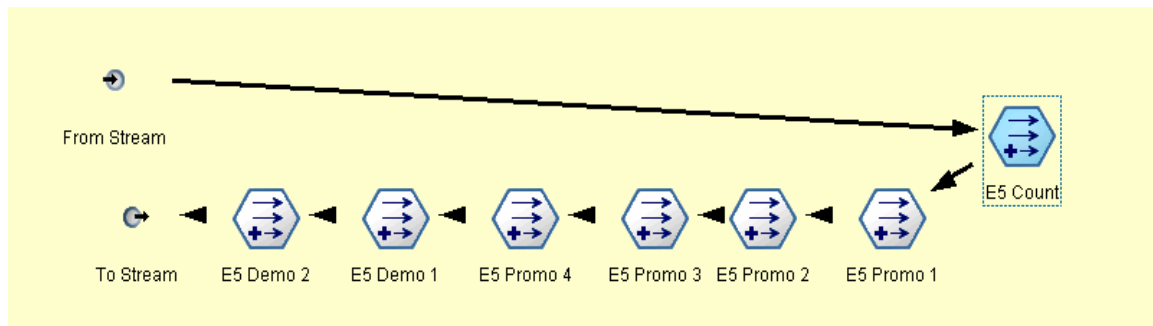
Value ▲	Proportion	%	Count
\$null\$		0.0	2
Dem2		0.04	239
Dem3		0.01	37
Dem4		0.0	8
Demotion		0.93	5810
Nothing		84.55	527968
Prom2		0.25	1536
Prom3		0.01	35
Prom4		0.0	8
Promotion		14.22	88801

To evaluate different promotion categories a distribution node was placed within the Promotion stream. Figure 13 shows the results of the promotion areas. Promotions

and demotions beyond one rank make up less than 2 percent of the overall promotions and demotions, and as a result, they are omitted in the model.

Each enlisted rank has a SuperNode as shown in Figure 10. Each SuperNode counts promotions, demotions, and soldiers within the rank. Figure 14 is an E5 SuperNode example.

Figure 14. Promotion Clementine Stream E5 SuperNode



The stream in Figure 14 begins with a derive node labeled E5 Count. This node counts all E5's within the database from FY01 through FY03. The formula is to place a one in the E5 Count Field if the MakeNum field is equal to five and the ASOF field is not equal to 200409, or else place a zero in the field. All other SuperNodes operate identically except E1 through E3 in the count and promotion nodes. The E1 through E3 node counts only the E2 and E3 since within 1 year they are the only ranks in this node that might promote to E4. An E1 promotion to E4 is unlikely and not considered for Army Reserve Enlisted Aggregate Flow Model.

The following node (Figure 14), labeled E5 Promo 1, counts the promotions to the next rank. The formula places a one in the E5 Promo 1 Field if the MakeNum equals 6 and the Promotion field equals one, otherwise a zero is entered. This node looks at any record that is an E6 and whether or not they were promoted by one rank the previous year. A verification to match SSN is not required since the Promotion field has already used this information. When the Promotion field equals one, the soldier was promoted. This indicates the E5 from the previous record refers to the same soldier who has been

promoted to E6. Modifications to the formula allow calculation for each rank and all four levels of promotion. To create a node for another rank or number of promotions, the user would update the MakeNum field in the formula to specify the rank to which the promotion is made and substitute in the Promotion field a number from one to four depending on the number of jumps in rank to be captured. Demotion nodes are set up the same way except the Promotion field carries a value of negative one through four and the MakeNum field carries the rank to which a soldier is demoted. Some SuperNodes vary in the number of derive nodes. For example, E9 does not have any promotion Derive nodes since there is no promotion beyond E9 and E1 through E3 do not have demotion nodes since a soldier cannot be demoted past this combined rank.

Figure 10 shows an output table node downstream of the rank SuperNodes, to verify data. A filter node is placed in the Promotion stream to take out unnecessary fields (SSN, grade, etc). The remaining fields are the fields created from each individual rank SuperNode. The last node of the main section (label Promotions) is an output database node, which places the filtered data into the original Access database in integer form; the resulting data can then be connected to a Statistics node.

Figure 10 shows a new source database node labeled as enlisted:.Promotion in the lower stream. This node reads the new data created from the Promotions output node in section one. A Statistic node connects to the input database node to examine the data. The statistics created from this node are the Summation, Minimum, Maximum, Range, Variance, and Standard Deviation. The statistical data can be downloaded to a text file for use in the model.

A Visual Basic program (Appendix B) uploads the data from the text file into an Excel worksheet. The promotion rate sheet in Excel determines the promotion rate for each rank by computing the number of promotions divided by the total number of soldiers in each rank. Promotion and/or demotions beyond one rank are filtered out in the formula if they are below 1.5%.

Table 3. Promotion Rates

	Count	Prom1	Rate	Prom2	Rate	Prom3	Rate
E1-3	85514	37430	0.43771	1267	0.00000	32	0.00000
E4	143443	24659	0.17191	235	0.00000	3	0.00000
E5	76942	15507	0.20154	30	0.00000	0	0.00000
E6	57879	7408	0.12799	3	0.00000	0	0.00000
E7	40144	3135	0.07809	1	0.00000	0	0.00000
E8	18390	662	0.03600	0	0.00000	0	0.00000
E9	4204	0	0.00000	0	0.00000	0	0.00000

Table 3 shows (a portion of) the promotion rates as computed for Army Reserve Enlisted Aggregate Flow Model, see Appendix C for all promotion rates. Promotion or demotion rates beyond one rank are set to zero if the original rate is less than 1.5%.

2. Accession Rates

As with promotion and demotion rates, the AREAFM calculates accession rates by dividing the numbers of soldiers accessed into a selected rank in a particular year by the total number of soldiers accessed into the reserves for that year. An example of the formula for the attrition rates is:

$$\text{E4 Accession Rate for FY_X} = \frac{\# \text{ accessed into the Army Reserves as an E4 in FY_X}}{\text{Total \# accessed into the Army Reserves in FY_X}}$$

The Clementine stream that calculates the accession rates using the attrition database is shown in Figure 15. This stream is broken into three major sections comparing individually the three years of data and then combining them to have an average for a three-year period. The purpose in creating different sections was ease of use in extracting data for future projects. A user may change the year on an individual section and not affect the others. Each section operates the same way on a different year. For purposes of explanation, the fiscal year 2003 is shown in more detail.

Figure 15. Accession Clementine Stream

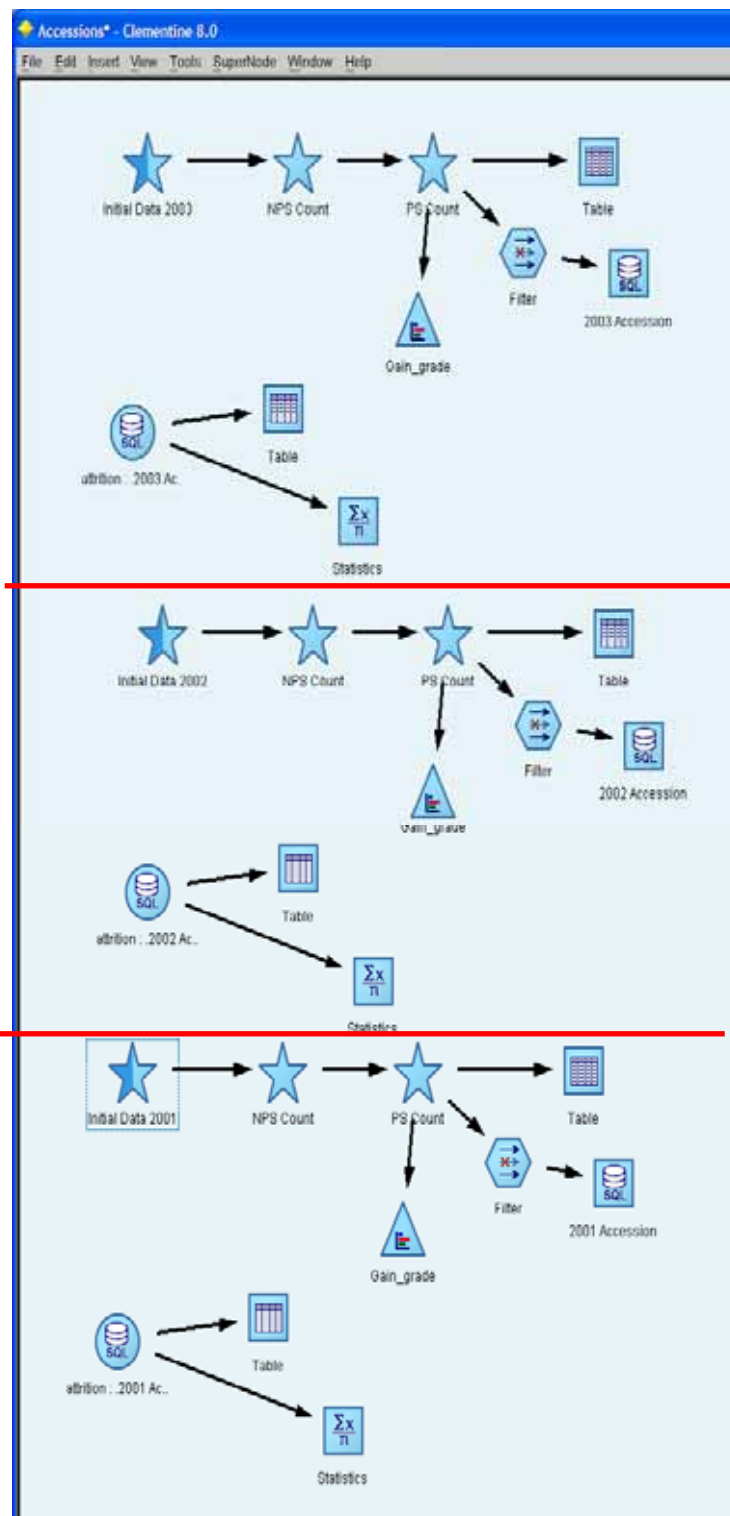


Figure 16. Accessions Clementine Stream Initial Data SuperNode

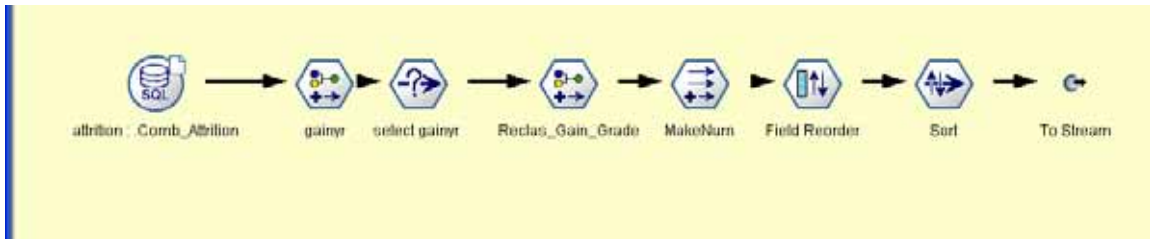
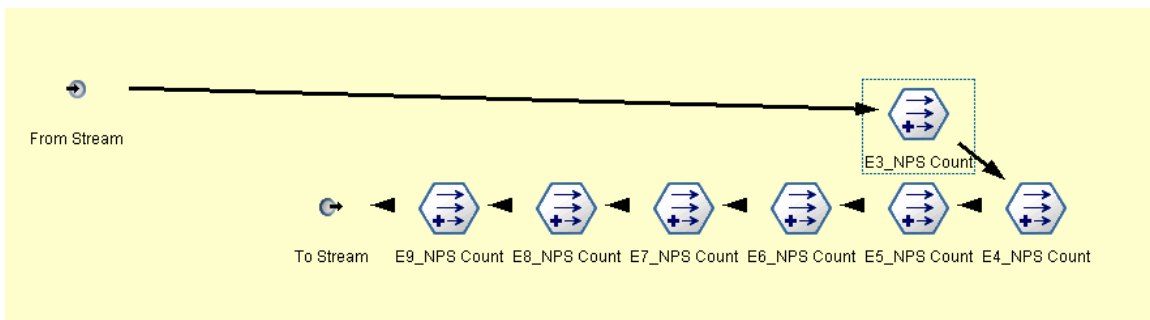


Figure 16 shows the Initial Data 2003 SuperNode containing the preliminary configuration of data to calculate how many NPS and PS entered the reserves. Via the database input node, data enters into the stream and unnecessary fields are filtered out. A reclassify node, labeled gainyr, is used to change the gaindate field into a year rather than a month and year for calculation of the data. A select node labeled select gainyr allows only records for the year of this section, which is 2003. A reclassify node, labeled Reclas_Gain_Grade, changes the gaining grade from two characters to one, which allows the derive node, labeled MakeNum, to change the character from the Reclas_Gain_Grade node into a number to facilitate calculations later on in the stream. The other two nodes allow the user a logical order in which to view the data.

In Figure 15, a SuperNode labeled NPS calculates how many NPS by grade entered in the selected year. The derive nodes within this SuperNode is illustrated in Figure 17.

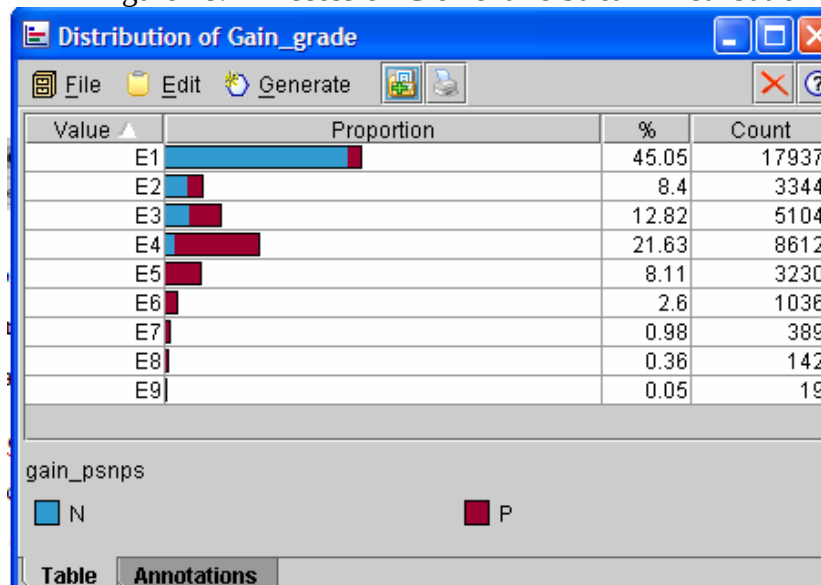
Figure 17. Accessions Clementine Stream NPS SuperNode



A representation of all the derive nodes in Figure 17 is E3_NPS Count Node. The formula places a one in the field if gain_psnps field equals N and the MakeNum field equals three; otherwise, it places a zero. The N represents NPS in the database and P represents PS. The other NPS derive nodes are set up in the same way, except that the MakeNum field is updated to the correct rank.

In Figure 15, the SuperNode labeled PS Count calculates all of the PS by grade for the selected year. The stream operates like the NPS stream with one exception: within the formula, the gain_psnps field is equal to P rather than N. There are three output nodes (Figure 15). The first output node is a table to verify the data visually. A second output node is a distribution graph, labeled Gain_Grade, for visualization of data by rank and either NPS or PS. Figure 18 confirms that accessions are mainly into the ranks of E1 through E5.

Figure 18. Accession Clementine Stream Distribution Graph



The last output node, labeled 2003 Accessions, filters out any unnecessary fields and places a new table into the original database. Each section has another source database node, labeled Attrition: 2003 Accessions, connecting the new table created from the database output node. The last step is the Statistics node. This node calculates

statistical summaries of the data: total variance and standard deviation. The statistical data is sent to a text file for use in Excel.

In Excel, a similar Visual Basic procedure, slightly different than the one located in Appendix B is used. All data is placed into the spreadsheet by moving over a number of columns with one execution of the Visual Basic program. The data is copied into the accession rates spreadsheet (Table 4) which subsequently calculates the accession rates.

Table 4. Accession Rates

Accessions	2001	2002	2003	Ave	Total Accessions	Accession Rate
E1-E3	26292	26292	26385	26323	42113	0.0000
E4	10186	10186	8612	9661	Authorized	0.6251
E5	4560	4560	3230	4117	163520	0.2294
E6	1552	1552	1036	1380	Assigned	0.0978
E7	498	498	389	462	156361	0.0328
E8	147	147	142	145	Vacancies	0.0110
E9	28	28	19	25	7159	0.0034
						0.0006

Table 4 shows the accession rates configuration (Appendix C shows the breakout by NPS and PS). Accession Rates are calculated by summing the number of individuals accessed in each of the individual ranks and dividing by the total number of accessions. For example, the E1-3 accession rate is $26,323/42,113 = 0.6251$. In the Markov Growth Model, the accession rate column is the r vector described in Chapter III.

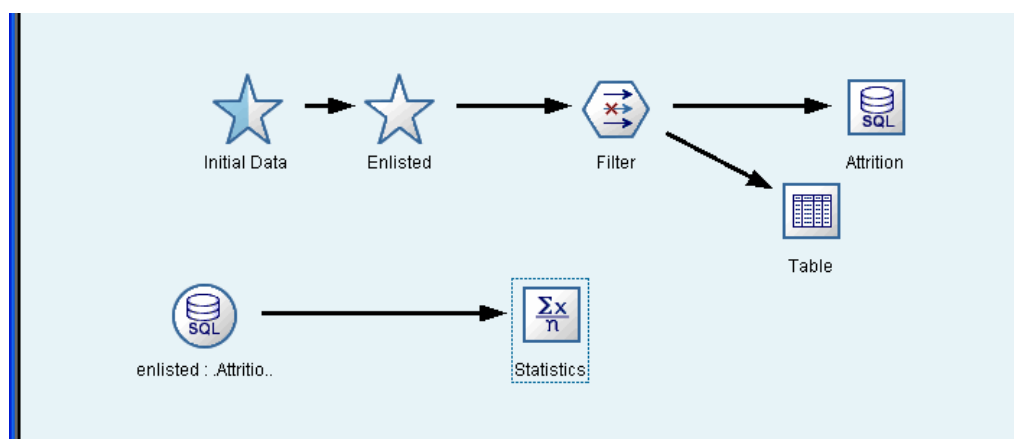
3. Attrition Rates

Attrition rates are calculated by summing the number of individuals in a particular rank who leave the reserves in a particular year divided by the total number of soldiers in that rank for that year. An example of the formula for the attrition rates is:

$$\text{E4 Attrition Rates for FY_X} = \frac{\# \text{ of E4s that left the Army Reserves FY_X}}{\text{Total \# that left the Army Reserves FY_X}}$$

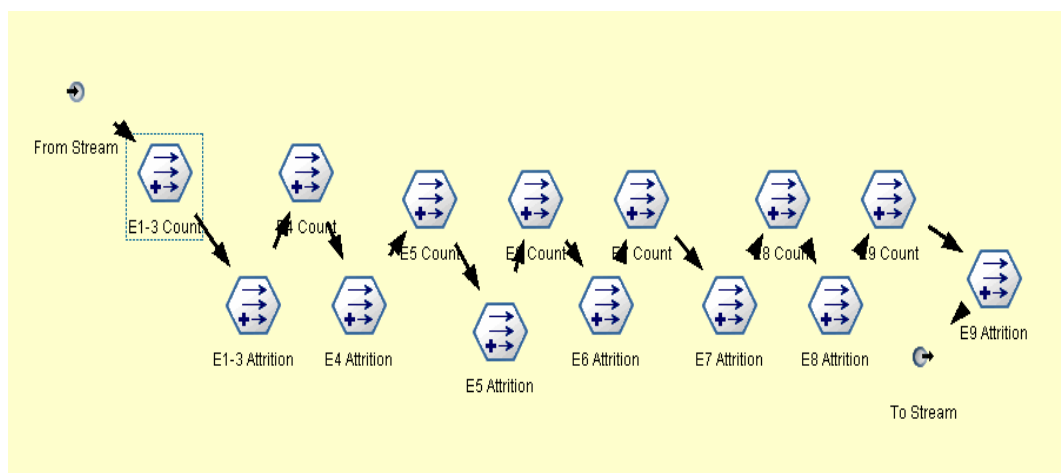
As previously stated, any soldier that leaves the Army Reserve is considered in this calculation. Figure 19 illustrates the Attrition Clementine Stream.

Figure 19. Attrition Clementine Stream



In Figure 19, the initial data node contains the same nodes as the promotion stream (Figure 10 and Figure 11). Figure 20 illustrates the SuperNode labeled Enlisted.

Figure 20. Attrition Clementine Stream Enlisted SuperNode



The Enlisted SuperNode has two nodes for every rank. The first node counts the number in each rank. The second node calculates how many in each rank have left the reserves.

An example is the E4 rank process. The first derive node for E4 is set up exactly like the count nodes in Figure 14. The second derive node for E4 calculates attrition numbers. Figure 21 illustrates the Clementine formula for this node.

Figure 21. Attrition Clementine Stream Enlisted SuperNode E4 Attrition Formula

```
Formula:  
if SSN != @OFFSET(SSN,-1) and MakeNum = 4 and ASOF != 200409 then  
1 else 0 endif
```

The formula in Figure 21 compares the current record's SSN with the record below it in the database. The formula places a one in the E4 Attrition field if the SSNs are not equal and the MakeNum equals four; otherwise, it places a zero. Similar to the promotion formula, this formula does not count the 200409 data. Unlike promotion rates, where the E1 through E3 node filters out the E1s, all three grades are counted in the E1 to E3 case.

The remaining nodes in Figure 19 are similar to those in both the promotion and attrition rates Clementine streams. The filter node takes out unnecessary fields for final calculations; the output database node creates a new table in the original database. This outputs all fields as integers for final calculations. A source database node from the enlisted data is inserted into the stream and a Statistic node attached. The Statistics node examines all fields looking at the sum, min, max, range, variance, and standard deviation. The Statistics node generates a text file for further examination.

The text file is inserted into an Excel spreadsheet. Attrition rates are computed as the number of soldiers leaving the reserves in a selected rank divided by the total number of soldiers remaining in that ranks, as shown in Table 5 (All three years are shown in Appendix C).

Table 5. Attrition Rates

Attrition Rate	
E1-E3	0.37
E4	0.30
E5	0.21
E6	0.15
E7	0.11
E8	0.13
E9	0.15

C. ARMY RESERVE ENLISTED AGGREGATE FLOW MODEL

The Army Reserve Enlisted Aggregate Flow Model uses the Markov Growth Model described in Chapter III in Excel to forecast personnel trends for the aggregate force. The model uses rates calculated using the prior three years of data to predict the number of accessions required to achieve the USAR end strength. The model is built in Excel to make updating straightforward for the user. Figure 22 illustrates the Excel interface for the Army Reserve Enlisted Aggregate Flow Model.

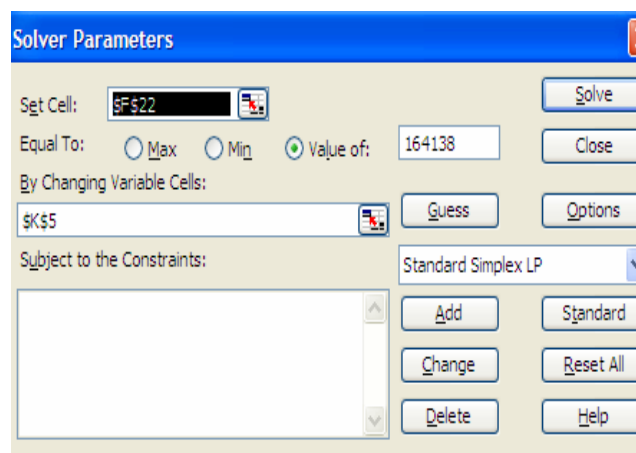
Figure 22. Army Reserve Enlisted Aggregate Flow Model

Transition Matrix									
	E3	E4	E5	E6	E7	E8	E9	r	Lambda
E3	0.1959	0.4377	0.0000	0.0000	0.0000	0.0000	0.0000	0.6251	48936
E4	0.0143	0.5099	0.1719	0.0000	0.0000	0.0000	0.0000	0.2294	
E5	0.0000	0.0252	0.5593	0.2015	0.0000	0.0000	0.0000	0.0978	
E6	0.0000	0.0000	0.0205	0.7018	0.1280	0.0000	0.0000	0.0328	
E7	0.0000	0.0000	0.0000	0.0132	0.7974	0.0781	0.0000	0.0110	
E8	0.0000	0.0000	0.0000	0.0000	0.0042	0.8268	0.0360	0.0034	
E9	0.0000	0.0000	0.0000	0.0000	0.0000	0.0069	0.8463	0.0006	
								165211	
								2003	2004
								2005	2006
								2007	2008
								2009	2010
								S(0)	S1
								S2	S3
								S4	S5
								S6	S7
E3	43724	39826	39175	39082	39079	39085	39091	39094	
E4	47021	54985	57391	58397	58916	59210	59383	59487	
E5	25513	27538	30062	31912	33147	33954	34480	34825	
E6	19561	20648	21825	23165	24485	25669	26670	27488	
E7	13176	13572	14028	14543	15125	15760	16418	17072	
E8	5974	6146	6320	6500	6688	6890	7107	7338	
E9	1392	1422	1454	1487	1522	1558	1595	1635	
Sum	156361	164138	170256	175086	178962	182125	184744	186938	
p(t)	48935.59								

The transition matrix holds the probabilities of a rank in current state to the future state as discussed in Chapter III. The r vector on the right contains the accession rates for each rank. Lambda is the number of recruits required. The Steady State vector on the

bottom indicates the end strength predicted by the model. In real-world situations, the steady state vector is difficult to achieve since policies and the current events are always changing. The last matrix is a series of vectors that give the numbers in each rank at a designated time. Army Reserve Enlisted Aggregate Flow Model starts with looking at $S(0)$ which is the year 2003 data. The $S(0)$ column contains the actual assigned soldiers for that year to forecast the previous years.

Figure 23. Markov Model Excel Solver



To solve for either the steady state or the $S(t+1)$ vector, Excel's solver (Figure 23) is used. This example predicts how many recruits are required to meet authorized strength for 2004. Set cell $\$F\22 is the total for $S(1)$. Instead of having the solver either maximize or minimize this cell a value of 164,138 is specified as the known authorized strength. To achieve this goal, the solver needs a variable cell to adjust such as the number of recruits or λ . Upon executing the solver, an optimized solution is found. For this example to reach authorized strength in 2004, the Army Reserves needs to recruit 48,936 recruits.

V. MODEL RESULTS

This chapter presents the results of AREAFM using the data described in Chapter III as implemented in the Excel model described in Chapter IV. The USAR is concerned with authorized strength and assigned strength. Authorized strength is the required end strength for the Army Reserve mandated by Congress, and assigned strength is the actual number of soldiers available. When predicting the number of recruits required, the target is authorized strength. Predicting the assigned strength is accomplished by making the number of recruits the target. The model's predictions are computed with Excel's solver.

This chapter first explains how the AREAFM was validated using Mean Absolute Percent Error to compare predicted FY04 assigned strength to actual FY04 assigned strength. It then discusses how the model can be used to predict the number of recruits needed to meet future USAR end strength requirements, and to predict assigned strength with a known number of recruits.

A. MODEL VALIDATION

The performance of the Army Reserve Enlisted Aggregate Flow Model using accession, retention, and attrition rates based on one year of data (FY03) and based on an average of three years of data (FY01-FY03) were both evaluated. The purpose of the comparison was to determine whether additional data, which would have the effect of smoothing the rates, would provide better (meaning more accurate) projections for the following years.

The Mean Absolute Percent Error (MAPE) was used as the measure of the “goodness” of the predictions. The MAPE equals the sum of absolute values of the difference between predicted assigned strength and actual assigned strength divided by sum of the actual assigned strengths. The predicted assigned strength was calculated by adjusting λ with the actual number of recruited soldiers.

Table 6 compares the results of using three-year average and one-year rates.

Table 6. Mean Absolute Percent Error

Mean Absolute Percent Error	3 YR AVE	1 YEAR
Predicting Assigned End Strength using actual Number of Recruits	3.8%	6.0%

Both runs of the model using the one-year data and the three-year data are quite accurate. However, the three-year average rates are more accurate than the one-year by 2.2 percentage points.

Table 7 shows the actual numbers from both runs of the model and the percent difference between the predicted and actual assigned strength for four years' predictions.

Table 7. Predicted versus Actual Assigned Strength

		2002	2003	2004	2005
3-Year Average Rates	Predicted Assigned Strength	156461	156346	158132	138497
	Actual Assigned Strength	156056	157719	139783	137432
	Percent Difference	0.3%	0.9%	13.1%	0.8%
1-Year Average Rate	Predicted Assigned Strength	159773	160885	162368	142418
	Actual Assigned Strength	156056	157719	139783	137432
	Percent Difference	2.4%	2.0%	16.2%	3.6%

In Table 7, differences for the model using the 3-year average confirm the lower Mean Absolute Percent Error. Using a 3-year average decreases the variability of the

data, creating closer predictions to the actual assigned strength. The low MAPE and yearly percent differences, particularly using the three-year average rates, validate that the model accurately predicts end strength.

B. PREDICTING THE NUMBER OF RECRUITS TO MEET FUTURE END STRENGTH REQUIREMENTS

One function of the model is to predict the number of recruits required to meet future authorized/required end strength. The AREAFM generates the required number of recruits by paygrade with the assistance of the Excel's solver, as discussed in Chapter IV. The authorized strength from 2002 to 2010 was optimized by adjusting the λ , which is the required number of recruits.

Figure 24. Delta (Authorized Strength Minus Assigned Strength) Compared to Number of Predicted Recruits

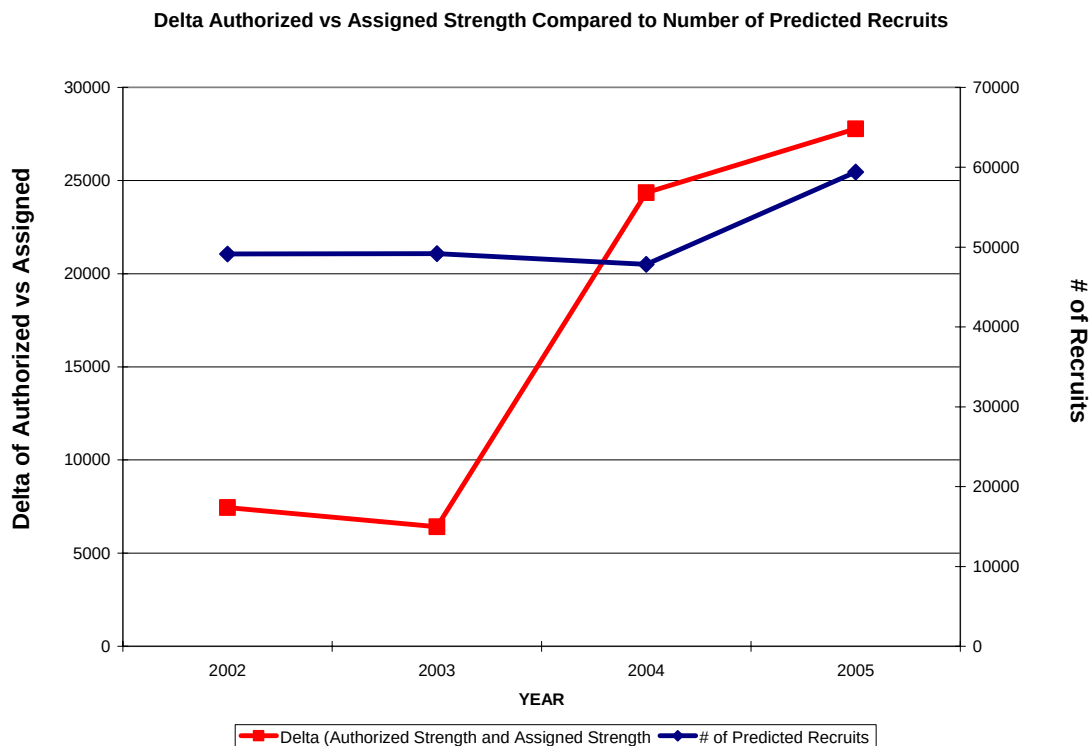


Figure 24 illustrates the delta of authorized versus assigned strength on the left-side axis over the last four years compared to the number of recruits on the right-side axis over nine years. The graph shows a correlation between the number of recruits required and the increase in the difference between the authorized and assigned strength. It is intuitively obvious that as the difference between the authorized and assigned strength increases, the number of required recruits increases.

Figure 25. Authorized Strength vs. Predicted Strength by Rank

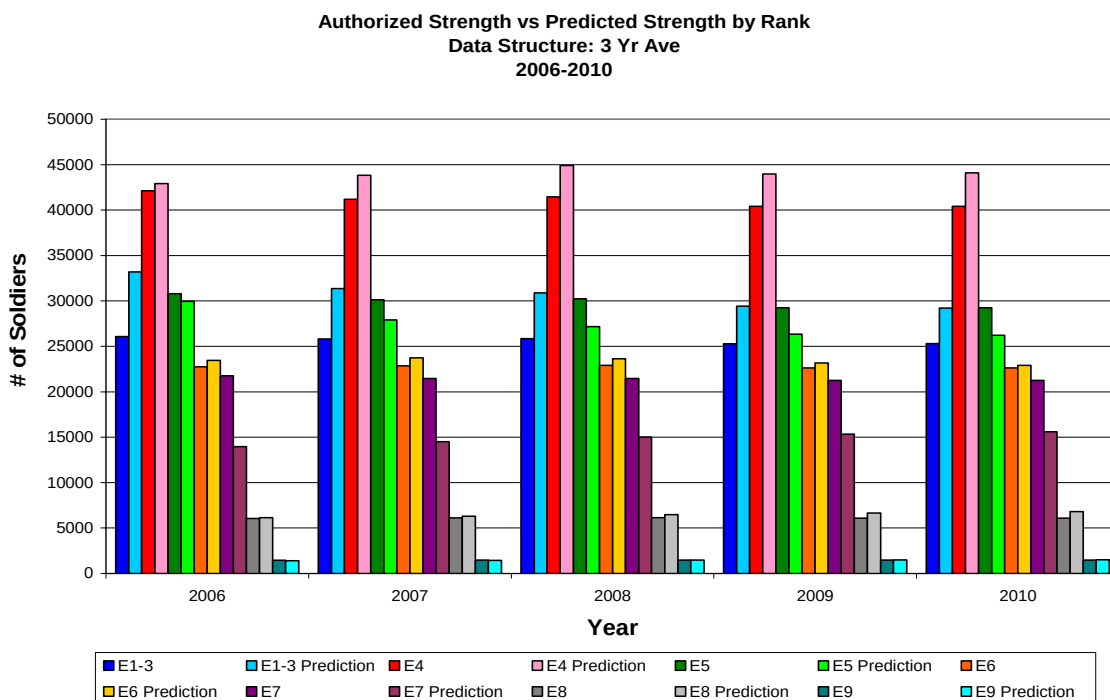


Figure 25 illustrates the authorized strength versus the predicted strength by rank. Each rank has two columns. The first column represents the authorized strength, the second, predicted strength for each rank. The lower ranks show prediction higher than the authorized strength. By adjusting recruits, and if accession, promotion and attrition rates stay the same, the achieved numbers are close to the authorized end strength.

The AREAFM provides accurate predictions of the number of required recruits to meet authorized end strength. The AREAFM confirms that if the Army Reserve is short in assigned strength one year, the next year more recruits are required to meet end strength.

C. PREDICTING ASSIGNED STRENGTH

The Army Reserve Enlisted Aggregate Flow Model can also be used to predict the assigned strength by setting λ to the actual number of recruits that entered the Army Reserves.

Figure 26. Predicted Assigned Strength Comparison

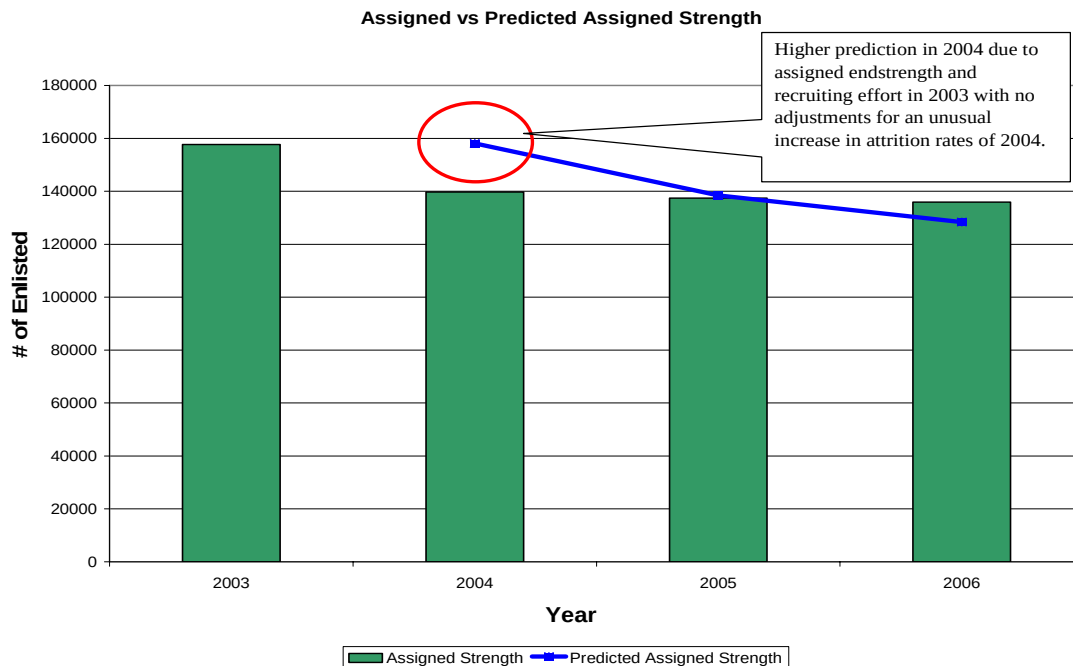


Figure 26 shows the predictions in assigned strength for FY04-FY06 compared to the actual assigned strength of FY03-FY06. The bars represent actual assigned end strength. The blue line represents the predicted assigned strengths using actual number of recruits. The highlighted area illustrates that the predicted assigned strength is higher than the actual assigned strength in 2004 because of the unusually large increase in attrition rates in 2004 resulting from the end of stop-loss. Thus, while the prediction

takes into account the current strength plus the actual number of recruits entering the system, it cannot capture or account for an unexpectedly large increase or decrease in the attrition rates.

Figure 27. Assigned Strength (Current) vs. Predicted Assigned Strength over 9 years

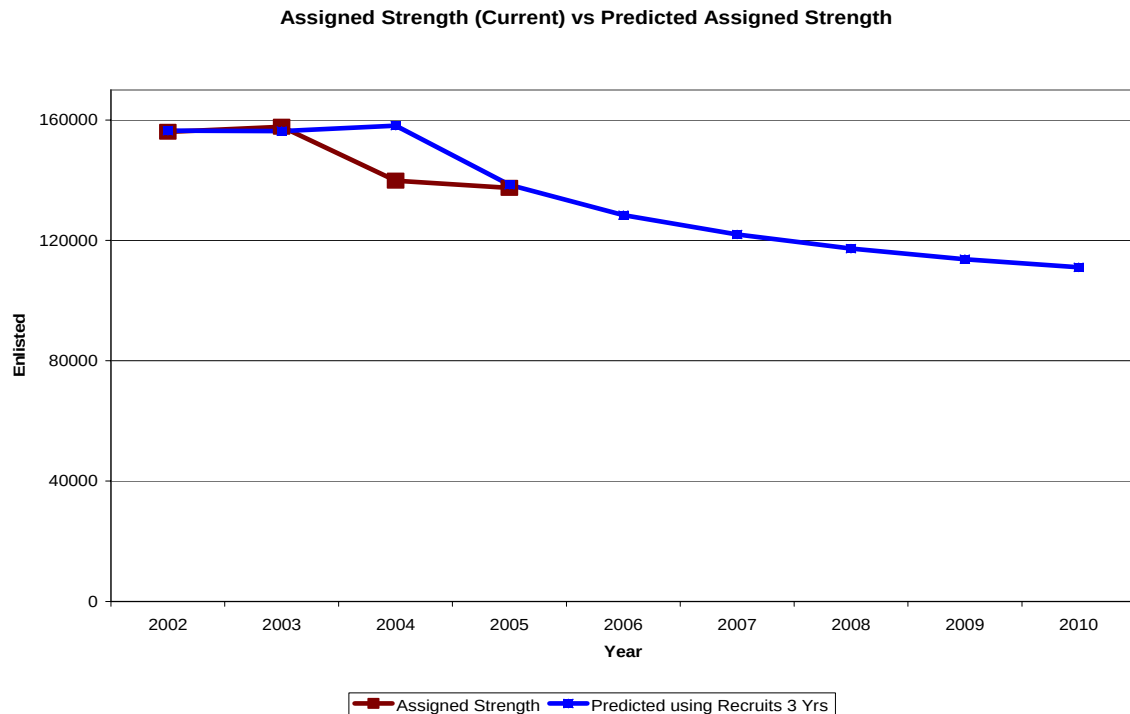


Figure 27 illustrates the same information as Figure 26 except for a nine-year period. The blue line represents the predicted assigned strength using the actual number of recruits for an adjusted λ . Again, this shows that there is a delay in the predictions when an unusually large increase in attrition takes place in a certain year. As the number of recruits decrease, so does the number of predicted assigned strength. After 2005, the predictions start to smooth out.

As previously stated in the model validation section, and as illustrated here, prediction of assigned strength using the actual number of recruits is a valid use for this model. Applying the AREAFM in this manner could be particularly useful for answering, for example, how current recruiting efforts will affect the USAR end strength in the future.

VI. CONCLUSIONS AND RECOMMENDATIONS

The Army Reserve's priority mission is in providing trained and ready personnel with skills necessary to support the nation during peacetime, emergencies, and war. Essential to the proper support of this mission is the effective management of enlisted personnel inventory.

To assist OCAR with this mission, the Army Reserve Enlisted Aggregate Flow Model was created. The AREAFM is based on a Markov Growth Model methodology and is useful for forecasting the number of recruits required to meet authorized end strength and predicting assigned strength with specific number of recruits.

In this thesis, the model was validated using Mean Absolute Percent Error to compare predicted FY04 assigned strength to actual FY04 assigned strength. It then examined how the model could be used to predict the number of recruits needed to meet future USAR end strength requirements, as well as to predict assigned strength with a known number of recruits.

In particular, in this thesis the numbers of annual USAR accessions for fiscal years 2002 to 2010 necessary to maintain aggregate end strength were computed. The AREAFM confirms the simple intuition that if the Army Reserve is short in assigned strength one year, the next year more recruits are required to meet end strength.

This research identified a number of areas and topics for future studies. They include:

- The use of the AREAFM to study the effects of specific accession, retention, and attrition rates on future end strengths. Use of this analysis can assist OCAR in testing specific USAR personnel policies.
- With adaptation, the AREAFM could be used to predict other categories in the Army Reserve personnel inventory. The main categories to consider are the officer TPUs and the AGRs, both enlisted and officers. Necessary

adaptations will include updating the promotion, accession, and attrition rate for the specific category, and for officers, modifying the paygrade levels.

- The AREAFM only incorporates promotions and/or demotions up or down one rank. Should significant increase or decrease in the promotion rates become noticeable in the future, the AREAFM could be modified to incorporate other promotions and/or demotions.
- Further research into the lack of enlisted TPU promotion data at any aggregate level needs to be conducted. Promotion data managed at the Reserve Readiness Center (RRC) level makes it difficult to evaluate the promotion rates created at the aggregate level through the enlisted database. An analysis is required on the feasibility of updating this policy on the handling of enlisted TPU promotion information.

APPENDIX A. DATABASE FIELDS

Army Reserve Enlisted Aggregate Flow Model Database Fields:

Enlisted Database (OCAR):

SSN	Social Security Number
ACT_DTY_CL	Active Duty Call up
AFQT	Armed Forces Qualification Test
ASOF	data date
CUM_RET_PTS	Cumulative Retirement Points
DOB_YM	Date of Birth Year/Month
INT_GN_RES	Initial Gain into Reserves
INT_MIL_SVC	Initial Gain into Military Service
ETS_YM	End Term of Service Year/Month
RR_OBL	Ready Reserve Obligation
ETS	End Term of Service
GENDER	Sex
GRADE	Rank
GRADE_C	Grade Code
MILEDL	Military Education Level
MILTECH	Binary if Military Technician
NAME	Soldiers Name
PEBD	Pay Entry Basic Date
RACE	Race Code
RET_YR	Retirement Year
SEP_RSN	Separation Reason
SEP_TP	Separation Type
TWENTYYR_CERT	Twenty year certificate
YRS_CRE_RES_RET	Years Credited to Reserve Retirement

Attrition Database:

SSN	Social Security Number
GAIN_PSNPS	Gain either NPS or PS
GAIN_GRADE	Enlisted Grade Gained into reserve
LOSS_GRADE	Enlisted Grade Lost from reserve
GAINDATE	Date Gained into reserves year/month
LOSS_MPARSN	Loss Manpower Account Reason
LOSS_MPATYPE	Loss Manpower Account Type
LOSS_RCMS	Loss Removal Cost Management System
LOSSDATE	Date Lost from the Reserves
MONTHS	How Many Months in Reserve before Loss

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APPENDIX B. VISUAL BASIC PROGRAM FOR RATES

This Visual Basic program imports the promotion information from the text file into Excel and then copies it into another sheet for calculation. This code is modified slightly to import the accession data into Excel by changing the destination range to import the data and update the name of the text document where the information is being received.

```
Sub Button2_Click()  
" Button2_Click Macro  
' Macro recorded 4/3/2006 by tkginther  
' Sheets("Copied Data from Text").Select  
  Range("A1:D388").Select  
  Selection.ClearContents  
  Sheets("Copied Data from Text").Select  
  Range("A1").Select  
  With ActiveSheet.QueryTables.Add(Connection:= _  
Settings\Admin\My Documents\NPS\Thesis\Working Thesis\Promotion_stats.txt" _  
    , Destination:=Range("A1"))  
    .Name = "Promotion_stats"  
    .FieldNames = True  
    .RowNumbers = False  
    .FillAdjacentFormulas = False  
    .PreserveFormatting = True  
    .RefreshOnFileOpen = False  
    .RefreshStyle = xlInsertDeleteCells  
    .SavePassword = False  
    .SaveData = True  
    .AdjustColumnWidth = True  
    .RefreshPeriod = 0  
    .TextFilePromptOnRefresh = False  
    .TextFilePlatform = 437  
    .TextFileStartRow = 1  
    .TextFileParseType = xlDelimited  
    .TextFileTextQualifier = xlTextQualifierDoubleQuote  
    .TextFileConsecutiveDelimiter = True  
    .TextFileTabDelimiter = True  
    .TextFileSemicolonDelimiter = False  
    .TextFileCommaDelimiter = False  
    .TextFileSpaceDelimiter = True  
    .TextFileColumnDataTypes = Array(1, 1, 1)  
    .TextFileTrailingMinusNumbers = True
```

```
.Refresh BackgroundQuery:=False  
  
End With  
Range("A1:D386").Select  
Selection.Copy  
Sheets("Data from Text").Select  
Range("A1").Select  
ActiveSheet.Paste  
  
End Sub
```

APPENDIX C. CALCULATED RATES

Below are the rates used in the final AREAFM. Each rate shown reflects the three-year average rates for promotion, demotion, accession, and attrition rates.

Promotion Rates:

Promotion and Demotion Rates for Enlisted at the Aggregate Level									
	Count	Prom1	Rate	Prom2	Rate	Prom3	Rate	Prom4	Rate
E1-3	85514	37430	43.77%	1267	1.48%	32	0.04%	7	0.01%
E4	143443	24659	17.19%	235	0.16%	3	0.00%	1	0.00%
E5	76942	15507	20.15%	30	0.04%	0	0.00%	0	0.00%
E6	57879	7408	12.80%	3	0.01%	0	0.00%	0	0.00%
E7	40144	3135	7.81%	1	0.00%	0	0.00%	0	0.00%
E8	18390	662	3.60%	0	0.00%	0	0.00%	0	0.00%
E9	4204	0	0.00%	0	0.00%	0	0.00%	0	0.00%
	Count	Demo1	Rate	Demo2	Rate	Demo3	Rate	Demo4	Rate
E1-3	85514	0	0.00%	0	0.00%	0	0.00%	0	0.00%
E4	143443	2047	1.43%	0	0.00%	0	0.00%	0	0.00%
E5	76942	1939	2.52%	226	0.29%	0	0.00%	0	0.00%
E6	57879	1187	2.05%	7	0.01%	36	0.06%	0	0.00%
E7	40144	530	1.32%	4	0.01%	0	0.00%	8	0.02%
E8	18390	78	0.42%	1	0.01%	1	0.01%	0	0.00%
E9	4204	29	0.69%	1	0.02%	0	0.00%	0	0.00%
Promotion and Demotion Rates for Enlisted at the Aggregate Level With more than one rank promotion and demotion a zero is placed if less than 1.5% used in model									
	Count	Prom1	Rate	Prom2	Rate	Prom3	Rate	Prom4	Rate
E1-3	85514	37430	43.77%	1267	0.00%	32	0.00%	7	0.00%
E4	143443	24659	17.19%	235	0.00%	3	0.00%	1	0.00%
E5	76942	15507	20.15%	30	0.00%	0	0.00%	0	0.00%
E6	57879	7408	12.80%	3	0.00%	0	0.00%	0	0.00%
E7	40144	3135	7.81%	1	0.00%	0	0.00%	0	0.00%
E8	18390	662	3.60%	0	0.00%	0	0.00%	0	0.00%
E9	4204	0	0.00%	0	0.00%	0	0.00%	0	0.00%
	Count	Demo1	Rate	Demo2	Rate	Demo3	Rate	Demo4	Rate
E1-3	85514	0	0.00%	0	0.00%	0	0.00%	0	0.00%
E4	143443	2047	1.43%	0	0.00%	0	0.00%	0	0.00%
E5	76942	1939	2.52%	226	0.00%	0	0.00%	0	0.00%
E6	57879	1187	2.05%	7	0.00%	36	0.00%	0	0.00%
E7	40144	530	1.32%	4	0.00%	0	0.00%	8	0.00%
E8	18390	78	0.42%	1	0.00%	1	0.00%	0	0.00%
E9	4204	29	0.69%	1	0.00%	0	0.00%	0	0.00%
Percentage									
1.5%									
Prom1	Promotion of one rank			Demo1	Demotion of one rank				
Prom2	Promotion of two ranks			Demo2	Demotion of two ranks				
Prom3	Promotion of three ranks			Demo3	Demotion of three ranks				
Prom4	Promotion of four ranks			Demo4	Demotion of four ranks				

Accession Rates:

Attrition Rate broken into NPS and PS

NPS	2001	2002	2003	Ave	NPS accessions
E1-E3	20,151	20,151	20,898	20,400	21,292
E4	894	894	889	892	
E5	-	-	-	-	
E6	-	-	-	-	
E7	-	-	-	-	
E8	-	-	-	-	
E9	-	-	-	-	

PS	2001	2002	2003	Ave	PS Accessions
E1-E3	6,141	6,141	5,487	5,923	20,821
E4	9,292	9,292	7,723	8,769	
E5	4,560	4,560	3,230	4,117	
E6	1,552	1,552	1,036	1,380	
E7	498	498	389	462	
E8	147	147	142	145	
E9	28	28	19	25	

NPS = Non-Prior Service

PS = Prior Service

Attrition Rates:

Attrition Rate	2001	2002	2003	3 Yr Ave
E1-3	37.3%	36.0%	34.7%	39.3%
E4	37.4%	30.9%	25.1%	36.2%
E5	24.9%	21.6%	18.1%	24.9%
E6	16.1%	14.6%	13.5%	17.5%
E7	11.5%	11.4%	11.0%	15.6%
E8	10.8%	11.5%	18.7%	18.1%
E9	11.9%	15.7%	16.6%	16.9%

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