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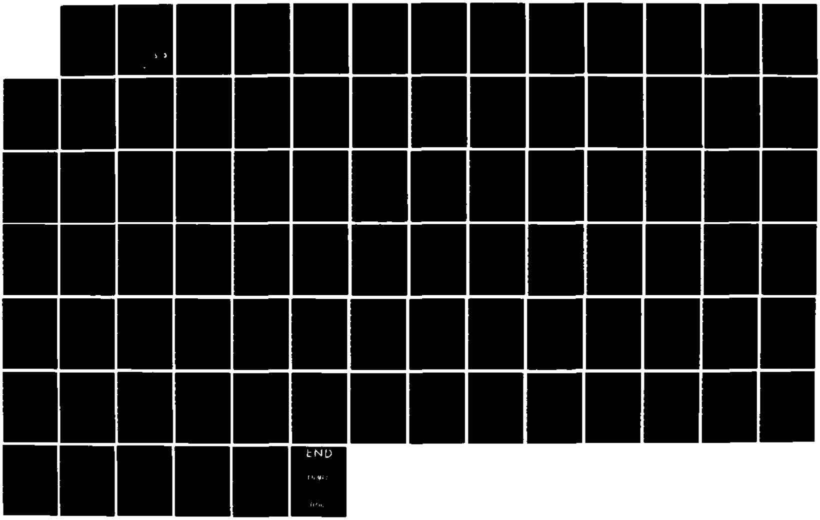

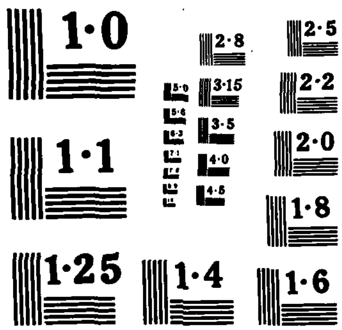
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# AN ALLOCATION AND REQUIREMENTS MODEL FOR USACE MANPOWER

Prepared by
Engineer Studies Center
US Army Corps of Engineers

December 1984

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The US Army Corps of Engineers (USACE) is presently developing new means to manage its manpower resources. The initial emphasis will be to create workload-based staffing standards. These standards will provide objective and statistically valid estimators of manpower by function. They will be invaluable in justifying manpower requirements. In the face of decreasing resources, however, of equal importance will be how manpower will be distributed across Corps organizations when there are manpower shortfalls. The methodology described in

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered) this report advocates linking disparate standards as well as funding and organizational considerations in a linear programming framework. The model will enable management to better understand the implications of resources allocations decisions. The report illustrates a prototype form of the methodology that utilizes existing requirements information. The prototype is structured, however, to easily assimilate standards when the model is implemented.

AN ALLOCATION AND REQUIREMENTS MODEL

FOR USACE MANPOWER

Prepared by
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US Army Corps of Engineers

December 1984

CONTENTS

ABSTRACT

In July 1982, the Engineer Studies Center was asked to assist the Directorate of Resource Management (then called the Resource Management Office) in improving ~~USACE~~ Army Corps of Engineers (USACE) manpower management procedures. A major part of ESC's initial involvement was to be the design and implementation of a mathematically-based methodology that among other things would allow Corps managers to: prioritize manpower assignments; consider function, organization, contractual, and appropriation features; and combine requirements and allocations in one integrated system. Several events occurred which shifted emphasis from methodology to standards development. Because of the promise of the system it was designing, ESC decided against simply abandoning the methodology. Instead, the progress that had been made would be documented and an example that would illustrate the desirable features of the model would be created. This report has a threefold purpose: to describe the events and considerations that argued against developing a new system prior to the availability of standards, to briefly define the linear programming approach, and to describe and illustrate the prototype allocations and requirements system that ESC believes satisfies USACE's stated needs. (A)

# AN ALLOCATION AND REQUIREMENTS MODEL

# FOR USACE MANPOWER

## I. INTRODUCTION

1. Purpose. The Manpower Allocations and Requirements Methodology Study (MARMS) has been concerned with improving the way the Corps of Engineers manages its most valuable resource--its people. While much of its effort has been devoted to implementing the Army's Manpower Staffing Standards System (MS-3) within the Corps, the Engineer Studies Center (ESC) was originally brought in to help the Directorate of Resource Management (DRM) develop a technique for allocating scarce manpower spaces.[1,2,3] The resultant system was to consider as many variables as possible, be mathematically based, and be computerized for ease of use. As the study proceeded, development of the allocations system took a back seat to ESC's investigation of alternative manpower requirement systems and to the development of a construction management staffing standard. This was primarily because the methodology was to integrate both requirements and allocations, and would necessarily use staffing standards (which are years from realization). Improvements made to other Corps' manpower systems (see paragraph 3) as well as the inability to anticipate the products of the standards program raised questions about the advisability of expending effort on the allocations system. From the general

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[1] Department of the Army, Headquarters, AR 570-5, Manpower and Equipment Control--Manpower Staffing Standards System, Washington, D. C., 15 May 1984.

[2] Department of the Army, US Army Corps of Engineers, Engineer Studies Center, Alternative Concepts for the Conduct of the MARM Study, Washington, D. C., December 1982.

[3] Department of the Army, US Army Corps of Engineers, Engineer Studies Center, Workload-based Staffing Standards (USACE Construction Function), Washington, D. C., August 1984.

wait-and-see attitude, ESC could only conclude that perhaps the time was not ripe for developing, much less implementing, a radically new allocations methodology. This report records the work that has been done up to now, in the event of renewed interest in the methodology's development.

2. Plan. In the summer of 1983, ESC prepared a study plan that outlined its intent to develop a prototype allocations system.[4]. The plan's admittedly ambitious schedule called for testing the concept by the end of the calendar year and turning the product over to DRM early in 1984 for implementation and improvements. The plan stressed that this schedule was optimistic and was dependent on the presumed availability of data and software support. Noteworthy, however, was the intent to design a methodology that would rely on existing systems and data for initial development, but would integrate standards as they became available.

3. Schedule Changes. Almost before it began, events began to overtake the allocations effort. Manpower changes at ESC prompted the dedication of all effort to the construction management standard. Only when that investigation concluded would work start again on developing the allocations methodology. That time was approaching when ESC briefed the results of the construction standard investigation to the Study Advisory Group (SAG) in April 1984. The SAG questioned the advisability of continuing with the allocations system in light of its ultimate reliance on standards, and the uncertainty over how long it would take to develop standards and what functions would ultimately prove susceptible. ESC had recognized the risk in a standards-only system; it had from the beginning, maintained that it was necessary to develop

[4]Department of the Army, US Army Corps of Engineers, Engineer Studies Center, Study Plan for a Linear Programming Approach to USACE Manpower Allocations and Requirements, Washington, D. C., June 1983.

a methodology that was not solely dependent on standards. The best system would be one that could be fielded now, but could accommodate standards as they are approved. Further complicating matters was the fact that Civil Works had just spent a great deal of time and effort improving its Resource Allocation Tables (RATs), which became the force configuration (FORCON) system. Civil Works was reluctant to consider a new methodology when it had high expectations for its own system. From past experience, ESC knew that without the wholehearted support of prospective users, the prognosis for yet another new system was not good. From these events, it seemed logical to suspend any major effort to implement an allocations and requirements system--at least for the foreseeable future. ESC therefore confined its work to developing a prototype that would illustrate the proposed methodology.

4. Scope of Report. As a result of the delays and doubts about the system's present practicality, ESC developed only a prototype to demonstrate the methodology; it must be considered far from an implementable system. Enough time was spent beyond preparation of the study plan for ESC to also have additional thoughts on the structure and capabilities of the system. This document therefore takes the form of a status report, illustrating the prototype and recording some ideas and directions that might be considered in any future work. If anything did result from the past year, it was a stronger belief that the Corps needs something comparable to what ESC had proposed for manpower management, now as well as at some indeterminate time in the future. The ideas reflected in this report may also be of value to those involved with improving present methods.

## II. ALLOCATIONS AND REQUIREMENTS SYSTEM

5. Original Perspective. From the beginning, ESC has taken a broad view on what should constitute an effective allocations and requirements methodology. Above all else, the final system should be a management tool and not merely another "reporting" vehicle. From discussions with potential users and the stated shortcomings of existing systems, there was clearly a need for a more objective and discriminating basis from which manpower decisions could be made. As an organization tasked to take a "systems approach" to problems, ESC's perspective saw the allocations problem as part of a family of related problems. Where to take cuts, how to prioritize out-of-cycle requests, and what the effects would be of a new program or policy were questions that had much in common with issues dealt with in deciding how to allocate manpower. ESC saw within one specific problem--allocations--an opportunity to develop a system that could have broad application.

6. System Needs. Among the characteristics that were originally requested for the methodology, the following were most important: provide a single, integrated manpower system; treat resource distribution mathematically; allow requirements prioritization; use existing data until standards are available; preserve organizational functional distinctions; and permit analysis of manpower reductions. This is an ambitious list. While usability and simplicity are always goals for any system, some problems resist trivial solutions. To treat as many different organizations doing different things, as proposed for the allocations methodology, requires sizable amounts of data and computational support. Data acquisition and verification alone could eventually be measured in manyears. This system is a major undertaking. The idea of being able to analyze many related problems arose when one thing

became apparent to ESC--the interdependency of requirements and allocations. Looking ahead to the time when workload-based staffing standards would be available, quite a large amount of data would be used to develop requirements estimates. Since prioritizing requirements is necessarily part of determining how to allocate scarce resources, it seemed obvious that the allocations process is inherently dependent on requirement estimates, and therefore on the standards and workload data from which they are derived. (The Air Force and Navy have more mature requirements systems, but ESC could find no evidence that either had taken the natural next step of imbedding it in a combined requirements and allocations framework. Allocations seemed largely done through negotiation and past experience, just as USACE presently does.) The real impetus for linking both aspects of the manpower problem is the ultimate use one expects from the system. The perceived need to analyze the efficacy of alternate allocations in the face of changes in requirement priorities argued for a single means to deal with both. Allocations subsumes requirements estimation (although the reverse is not true). It became increasingly obvious that what was needed was a means to measure the impact of different allocations on whole organizations. To do this, one must have a framework that considers the interrelationships between competing or cooperating elements, something that considers organization dynamics--a model. The Corps uses models to measure the benefits of different water basin projects or to evaluate the effects of adding to the inland waterway system.[5] While organizational dynamics do not obey physical laws of nature, there is enough cause

[5]Department of the Army, US Army Corps of Engineers, Engineer Institute for Water Resources, Regional Development Impacts Linear Programming-Economic Base Model (LPEB), Draft prepared by Lewis and Associates, Washington, D. C., September 1982.

and effect to attempt to model such dynamics as a working system so the effects of different manpower and resource decisions can be tested.

7. Selecting a Methodology. The study plan described the steps ESC planned to use to develop and implement the system. Linear programming (LP) as a modeling tool was to be used as the basis for ESC's approach. ESC has had experience with LP and knows it is an extremely powerful conceptual as well as analytic technique. While often thought of as strictly an "optimizing" algorithm, LP requires definition of the "system" before it can calculate any optimal posture for that system (see Annex A). ESC's past experience with LP somewhat biased its selection of LP as the underlying modeling technique; there are no contentions that other ways to build an allocations and requirements system are not possible. ESC believed, however, that the LP-based approach it proposed could support the types of uses envisioned for the system. Nothing has happened since publishing the study plan to change that opinion. In fact, the need for LP, or something like it, seems greater given what ESC learned on the field trips and during discussions made in connection with the standards development phase of MARMS. Annex B describes the prototype ESC constructed to illustrate the features and possibilities that an LP-based methodology can provide manpower planners.

8. Corps Considerations. To structure a model of Corps acitivities, several aspects or classes of data are of such overriding importance that their successful reduction to quantitative or qualitative expressions would be mandatory. The following paragraphs touch briefly on these major components.

a. The civil-military dichotomy. Corps employees know that part of the Corps is justified and paid for through military channels, while the remainder is given over, as a result of the Rivers and Harbors Act and other

ANNEX B

THE MARMS-LP PROTOTYPE

ANNEX B

THE MARMS-LP PROTOTYPE

i. Murtagh, B. A. and Saunders, M. A., MINOS User's Guide, Report SOL 77-9, Department of Operations Research, Stanford University, Stanford California, 1977.

j. Control Data Corporation, PDS/MaGen User Information Manual, Pub No. 840099000, 1978.

k. Sperry Univac Corporation, Sperry Univac 1100 Series GAMMA 3.4 Programmer Reference Manual, UP-8199 REV 1, 1977.

LAST PAGE OF ANNEX A

and designed to be run on minicomputers as well as mainframes (see references h and i in paragraph 5). The latter alternative, however, does not provide the rich user environment or features such as matrix generation languages and report writers that are found in the multipurpose commercial LP systems (see references j and k in paragraph 5).

5. References.


a. Dantzig, G. B., Linear Programming and Extensions, Princeton University Press, New Jersey, 1963.

b. Orchard-Hays, William, Advanced Linear-Programming Computing Techniques, New York, New York: McGraw-Hill Book Company, 1968.

c. Murtagh, Bruce A., Advanced Linear Programming: Computation and Practice, New York, New York: McGraw-Hill International Book Company, 1982.

d. Wagner, H. M., Principles of Operations Research, Second Edition, New York, New York: Prentice-Hall, Date Unknown.

e. Sperry Univac Corporation, Sperry Univac 1100 Series Functional Mathematical Programming System (FMPS) Programmer Reference Manual, UP-8198.1, 1981.

f. IBM Corporation, IBM Mathematical Programming System Extended (MPSX/370) Reference Manual, No. SH19-1095-1, 1976.

g. Control Data Corporation, Apex-IV Reference Manual, Pub No. 84002550, 1982.

h. Marsten, R. E., The Design of the XMP Linear Programming Library, ACM Transactions on Mathematical Software, Vol 7, No 4, December 1981, pages 481-497.

3. Futher Readings. It is not the purpose of this discussion to be a tutorial on the fine points of LP or even as an exposition of the details of the simplex algorithm. There are many books and periodicals devoted to this subject that can be consulted by the interested reader. There are several texts that might serve as starting points. The inventor of the simplex and therefore the father of LP was Dantzig; his book (see reference a in paragraph 5) was the first devoted to the subject, and while a bit dated, still contains useful examples of the types of problems solved and the essence of his solution algorithm. For those interested in understanding the typical computer-based LP systems, Orchard-Hays' book (see reference b in paragraph 5) is a good treatment by one who worked on many of the original computer codes. Wagner (see reference d in paragraph 5), while being a general text on OR, covers many of the general and special subclasses of LP applications. Finally, the recent book by Murtagh (see reference c in paragraph 5) is aimed at users who are or anticipate using LP in actual problem settings and so it gives equal treatment to both the solution algorithms and the practical considerations in reducing problems to LP formulations and then solving these problems on computer-based systems.

4. LP Systems. Since, as stated above, solving an LP problem compels a user to have access to a computer package, we might mention a few of the systems that are available. The first category would be the large commercial systems found on large mainframe computers. Univac has FMPS (see reference e in paragraph 5), IBM has MPSX (see reference f in paragraph 5), and Control Data Corporation has Apex-IV (see reference g in paragraph 5). For those who might not have access to these large machines, there are several LP packages that have been developed within academic circles that are written in FORTRAN

additional stipulation that each variable x(i) is either positive or equal to zero. Since the variables x(i) are neither raised to a power (e.g., squaring x(i)) or cross-multiplied (as in the familiar quadratic equation where $(x-1)*(y-x)=xy-y+x-x^2$), all relations and equations are linear representations of the variables and the constants found in c and A.

2. Application. Of course LP is not of interest solely as a concise statement of a problem. LP subsumes both the problem formulation and the process used to solve it. In problems where there are hundreds of rows within the constraint matrix and possibly thousands of variables to consider (where each can take on any value between zero and infinity), it would clearly tax the ability of one or many individuals to determine which of the infinitely many solutions is truly optimal. Happily an algorithm exists that quarantees that an optimal solution (assuming one exists) can be found in a finite number of steps. The simplex algorithm (and its variations) is one if not the most important tools that has arisen in the field of operations research. While providing a mechanism for an efficient solution search, it does, however, incur a rather substantial computational burden. Even small problems require too much time if done by hand. Coincidentally, LP was conceived at the same time that the first computers were being constructed. Had it not been for the availability of the computational power these machines provided, the simplex algorithm would surely have been deemed theoretically elegant but of little practical importance in solving all but the most trivial problems. Research into compact and efficient computer codes during the past three decades has enabled practitioners to obtain LP packages for most mainframe and minicomputer systems. Problems of hundreds and even thousands of rows can be solved in minutes.

# ANNEX A

## LINEAR PROGRAMMING

1. The Linear Program Problem. The linear program (LP) is one of the general problem class called mathematical programs. The LP is generally stated in the following way:

$$\text{maximize } f(x) = cx$$

$$\text{subject to } Ax = b \text{ and } x \geq 0$$

Where A is an m x n matrix; b is an m-vector;

and c, x, and 0 are n-vectors.

For those perhaps unfamiliar with matrix notation, the above can also be stated as follows:

maximize c(1)*x(1)+c(2)*x(2)+.....+c(n)*x(n)

subject to

a(1,1)*x(1)+a(1,2)*x(2)+.....+a(1,n)*x(n) = b(1)

a(2,1)*x(1)+a(2,2)*x(2)+.....+a(2,n)*x(n) = b(2)

. . .

. . .

. . .

a(m,1)*x(1)+a(m,2)*x(2)+.....+a(m,n)*x(n) = b(m)

with x(i) $\geq$ 0 i=1,n.

Usually the function f(x)=cx to be maximized is called the objective; the matrix A is called the constraint matrix; and b as a result of its placement is called the right-hand side. The problem is really a simple one despite what some might feel from the above admittedly mathematical representations. Simply stated, the LP seeks to determine what values the variables x(1), x(2),..., and x(n) must take for f(x) to be its lowest value, while at the same time assuring that the equations defined by Ax=b still hold and with the

# ANNEX A

# LINEAR PROGRAMMING

passe. Certainly the promise of the early sixties' management scientists to solve every problem using scientific methods was not realized. Yet, complicated problems generally defy simple solutions. In fact, the LP methodology adopted here actually espouses the simplest mathematical model that can be theorized. Since guidance to ESC ordained a mathematically based allocations and requirements method, the LP-based model seems therefore an appropriate response.

LAST PAGE OF MAIN PAPER

obligations, do 20 percent of his design by contract, minimize the change in personnel in several functions, and also examine a 5-percent reduction in the size of the district. He could ask all these questions at once in GP, and be able to weight or prioritize the different goals. Another obvious extension would be to address the interrelationship of organizations in the Corps. It would be relatively easy to formulate a problem that considered all the districts within a division, and allowed for work to be performed across district boundaries. Another possible extension is to use the methodology as a quasi-utilization system. To do this, however, would require a supporting workload and personnel tracking system that is not currently available within the Corps.

12. Quo Vadis? ESC feels that methodology embodied in the prototype offers a powerful tool to manpower planners. The prototype is for demonstration and there is no suggestion to implement it in its present form. Much work remains. At the very least, several things would have to be done. First, a more thorough statistical analysis must be performed on existing data to compute better requirements and relationships (e.g., ESC took the functions for the prototype directly from the 1983 RAT. Civil Works has gone to FORCON, presumably to obtain better functional breakouts. Corps Stratification or the MARMS functional definitions might be other, more detailed alternatives to investigate). Second, is the need to give the users in the field and at USACE an introduction to LP that would overcome any reluctance to use the system. Finally, the staff element that would assume responsibility for monitoring the development and maintenance of the methodology would have to be nominated. One additional comment concerns what seems to be a fashionable notion in some staff elements--that operations research techniques have become

## III. IMPLEMENTATION

10. Proponency. The need for a better allocations methodology was originally requested by DRM. It seems, however, that the actual requirements and allocations processes occur in other directorates and out in the field. This has influenced how ESC approached development. Would a new methodology displace existing Civil Works and Military Construction systems completely? Workload standards will take time to develop and are expected to cover less than two-thirds of the Corps, at best. The remaining "unstandardized" components will still be asked to estimate requirements. The people generating these estimates now will no doubt do so in the future, and very likely do so using similar methods. If a new methodology is adopted, it should be used to unify rather than fragment the decision process. While DRM will control standards development, and perhaps model maintenance, it does not seem likely that either Civil Works or Military Construction would or should relinquish responsibility for requirements determination.

11. Extensions. ESC's prototype attempts to illustrate the capabilities of an LP-based methodology. The type of analysis that can be performed using it seems to be beyond anything currently available to Corps managers. There are, however, other possibilities that would make the methodology even more powerful. The foremost would be to change the basic problem formulation such that it was selecting a solution based on more than one criteria (see Annex B). Using a rather straightforward formulation change, the model could solve multi-objective problems, sometimes also called goal programming (GP). This would enable a user to consider different objectives at the same time, rather than having to do separate analyses of each objective and comparing the results. For example, suppose the decisionmaker wanted to maximize

9. Decomposition. Before one can understand a system, one must understand its parts and how they interact. To best understand how an automobile works, a shop student takes an engine apart and then puts it back together. Since ESC seeks to build an operating "allocations" system, it must understand how the "pieces" of the Corps interact before it can hope to build an inclusive model. A systems "mechanic" would like to be able to characterize the Corps in a flowchart, network diagram, or input/output matrix which emphasizes resource and information flow and modification. The model builder can generally only accumulate knowledge of the system under study; he or she should not be expected to generate new knowledge. Unfortunately, the key ingredient for decomposing the Corps' structure in this way is lacking; there is no accurate data base that enables one to measure how work moves through the districts and divisions in terms of activities performed and resources consumed. There are many initiatives underway which could improve this situation: the Corps' staffing standards program, FORCON, the Information Systems Plan for OCE, and the Army Performance Oriented Reviews and Standards Program (APORs). If these efforts are all successful, there should be a much better quantitative and statistical data base that would enable better analysis of the Corps than can currently be conducted.

amount of work that is not done in-house, but these levels are not legislatively mandated.

d. The Corps heirarchy. Of immediate interest to this study is the USACE HQ-Division-District heirarchy (excluding field operating agencies (FOAs) and Army Engineer TOEs). Manpower planning is performed at all three levels. As with any multitiered organization, the perspectives that the planners take at different levels are not the same. In the districts, where most of the work actually gets done, the focus is on the details of individual projects. At HQ, the managers must take a broad view; consequently, they are not overly concerned with individual project details. The allocations and requirements systems should, if possible, assist users, no matter what level they are in the heirarchy. A common methodology would promote utilization and enhance maintenance.

e. Spaces or faces? One of the artifacts of the civil-military dichotomy is the Corps' dual system for counting manpower. The military side essentially counts the number of authorized people it has on the payroll at the end of the year. Overhires and other devices can be used to augment the military side of the house as long as the year-end figure is not violated, and there is money enough to pay for the extra workers. On the civil side, there is much less flexibility. Full-time equivalents (FTEs) measure the amount of work done. This approach is much more restrictive and therefore more controllable, than the military end-strength method.

f. Position. Much of the work that the Corps does is subject to climate and other local environmental conditions. Many seasonal workers are employed, primarily in the summer; these part-time employees need to be considered as well as persons in full-time permanent positions.

legislation, to activities that have no relation to traditional Army activities--i.e., Civil Works. The Corps theoretically has a dual structure of separate but similar services and overhead supporting both programs. Of course, the distinction between military or civil blurs in the field, where the pressure of time will circumvent policy. Nonetheless, the separateness must be dealt with in ESC's system, since manpower ceilings are usually separate, rather than combined.

b. Dollars. One of the Corps' paramount concerns is money. Unlike other Government entities, Corps personnel are paid out of charges assessed against particular accounts. While these rates (e.g., an S&A rate of 5.5 percent) are not statutorily binding, the Corps plans much of its work around these figures. Salaries, overhead, and similar debits are made from these charges. While manpower standards are necessary to justify manpower requirements, Corps people must be paid as well as justified. These two processes must be considered together if any usable manpower planning system is to be accepted.

c. Contracting. The Corps of Engineers manages construction; it does not, generally, construct projects with in-house labor. Although it may be managing multimillion dollar projects, much of the money is passed on to the private sector contractors who do the building, dredging, and so forth. There is, however, another type of contracting that affects manpower perhaps even more. It is used when the Corps elects to contract for work which it normally performs in-house (e.g., engineering, operations, or planning). This confounds the workload standard program since it means that work which would be used to generate manpower requirements may legitimately be put out for contract. There are historical- or policy-directed percentage targets for the

1. Purpose. This annex will describe the prototype allocations and requirements model that ESC has constructed. The principal purpose of the prototype is demonstration of the application of an LP approach to defining data needs and solving manpower allocation problems. The model that ESC has developed will be described; the data that was used for the example will be defined; and an application using a district will be portrayed.

2. Assumptions. The construction of a model that simulates Corps manpower requirements to analyze different allocations is not a trivial task. As said in the main paper, ESC interpreted the need for a well-founded allocations system to be a related but separable problem from the manpower standards work that has received so much interest and staffing. ESC understood, however, that even if successful, standards would not cover every position in the Corps. Therefore, there would always be a need for a supplemental methodology to estimate some requirements. Since ESC intended to link requirements to allocations within the model, it would have to treat standards and any supplemental methods together in the final design. The LP-based approach offered the possibility of developing a working allocations system that could integrate standards as they became available. In the work performed in developing the prototype, ESC did not attempt to fabricate fictitious standards in lieu of having validated ones. Instead, it concentrated on constructing a model that would use existing data and methods which were also likely to be the supplemental techniques mentioned above. ESC recognized that good data tying workload (i.e., nondollars) to requirements was not presently available. What was available was the dollar-based system embodied in the RATs for Civil Works and the highly aggregated dollar-dependent system used within military construction. Faced with constructing a working prototype and having limited

resources to develop the model, much less embark on a major data collection and analysis venture, ESC relied essentially on the 1983 RAT data for its statistical data. The prototype, therefore, concentrates solely on civil functions and costs, but inclusion of analogous logic and data for the military side of the house appears to be straightforward. The military program has fewer types of activities involved, and there is a greater reliance on contracting.

3. Model Conventions. Annex A of this document gave the mathematical definition of a linear program. The prototype will be defined in that form. Realize that there is nothing unalterable about the formulation presented below. In fact, development of the model should be iterative where additions and enhancements occur as a consequence of gaining more familiarity with the model. (NB: we are not representing a physical process that is well understood and obeys physical laws. Instead we are dealing with theorizing a series of relationships that somehow captures the relationships among people, functions, and type of dollar expenditure.) The extensions to the model described in the main paper would have been attempted had time and data limitations not intervened.

4. Model Constituents. The easiest way to describe the model is to express it in a way that corresponds to the LP definition given in Annex A. This will be done by defining all variables, dimensions, model coefficients, input data, and equations that comprise the model.

a. Dimensions. The following paragraphs will refer to arrays and vectors of different size. There are three possible dimensions:

| | |
|---|---|
| N := (1,2,3,...,N) | where N is the total number of appropriations identified for the organization (can be defined in appn-(cat\|cat-class\|cat-class-subclass)) |
| I := (1,2,3,...,I) | where I is the number of functions (currently 15) |
| J := (1,2,3,...,J) | where J is the number of appn-category pairs defined by the 'N' input appropriations (max J is currently 53) |

b. Structural variables. The LP technique we are using describes a process in terms of relationships among different structural elements. The relationships are our equations (infra) and the elements our variables (also referred to as structurals). Figure B-1 represents the required and optional variables used in defining and solving problems.

MODEL VARIABLES

| Variable | Size | Status | Definition |
|---|---|---|---|
| A | N | Required | Amount of appropriation obligated |
| F | I | Required | Functional equivalent of the obligations |
| D | I | Required | Direct labor dollars |
| K | I | Optional | Contract service dollars |
| O | I | Required | Overhead associated with a function |
| M | I | Required | In-house function manyears |
| S | J | Optional | When input appropriation shows class (and subclass), dollars are rolled up into an appn-cat; s(j) would be the aggregated number |

Figure B-1

c. Coefficient arrays. Recall that in the definition of the LP (Annex A), the array A was referred to as the constraint array. It represented the constants a(1,1), a(1,2), etc., which with the variables formed the equations of the model. In building an LP model, determining these constants usually takes up the bulk of the analysis. Figure B-2 defines the coefficient arrays that comprise the constraint environment.

CONSTRAINT VARIABLES

| Variable | Size | Status | Definition |
|---|---|---|---|
| T | I,J | Required | The critical data determines functional requirements from programmed appropriation |
| W | N | Required | The priority weight vector used to prioritize projects |
| H | I | Required | Generates overhead requirements as a function of in-house strength |
| P | I | Required | Functional per-capita costs |
| L | I | Optional | Contract supervision rates |
| V | I | Required | Portion of functional dollars for Corps' value added services |

Figure B-2

d. Input. In actual application, much of the data required for execution of the model will be found in the data arrays defined above and would be used by each district without modification. Before a user could exercise the model, the data that is specific to his organization must be collected. That input centers on the actual planned appropriations, and any personnel or contracting limits that constrain the levels of the structural variables. For the prototype, Figure B-3 defines the user-specific information required to run the model.

RIGHT-HAND SIDE VARIABLES

| Variable | Size | Status | Definition |
|---|---|---|---|
| G | N | Required | Net available dollars for the appropriation-cat(-class(-subclass)) |
| QF | I | Optional | Maximum percentage of organization a function can be |
| QK | I | Optional | Max percentage of function that can be contracted out |
| B | I | Optional | Max size of function |
| B | 1 | Optional | Max size of organization |

Figure B-3

5. Defining the Model.

a. The objective row. Given the potentially infinite number of feasible solutions to a problem stated in LP format, a metric is necessary to find the best possible answer. This is referred to as the objective function and is important to the decisionmaker because it controls the solution the LP process will compute. In the prototype, there were several possible ways to express an objective. The maximization of obligations was selected, but for special circumstances other possibilities exist (see Extensions infra). The objective function is as follows:

$$\text{Maximize} \qquad w(n)*a(n) \qquad (n=1,2,3,..,N)$$

(NB: For our example, the weights/priorities are all set to +1.0 indicating that all appropriations or projects are of equal importance. This may, of course, not be realistic and in practice the user could manipulate the weights to ensure that priority work is accomplished.)

b. The constraints.

(1) Appropriation amounts. The first set of constraints assures that the amount obligated, A(n), does not exceed the net available.

$$A(n) \leq g(n) \qquad (n=1,2,3,\ldots,N)$$

(2) Appropriation to functions. The key portion of this model (and the one where workload-based standards would apply when developed) is the translation of appropriations into the expected functional components. Two forms are given. The first applies when the net available appropriation, g(n), is in appropriation-category form (e.g., the three-character code 'A 1'). The other situation occurs when the input further identifies the available appropriation in terms of either class or class-subclass (e.g., the four-character code 'ER12' or the five-character code 'ER121'). In that case the appropriations must be rolled up by appropriation-categories since the input/ output array, T, is defined only at that level. In other words, the A vector is aggregated into the S vector.

$$\text{(a)} \quad v(i)*t(i,n)*a(n) = f(i) \qquad (i=1,2,\ldots,I;n=1,2,\ldots,N)$$

$$\text{(b)} \quad v(i)*t(i,j)*s(j) = f(i) \qquad (i=1,2,\ldots,I;j=1,2,\ldots,J \text{ and } \left\{ s(j)=\sum a(n) \text{ for all appropriations n in category } j \right\}$$

(3) Disposition of functional dollars. Functional dollars are spent in three areas: direct labor, contract labor, and overhead.

$$f(i) = d(i) + k(i) + o(i) \qquad (i=1,2,\ldots,I)$$

(4) Overhead calculation. Overhead is calculated for each function and is a function of the amount spent for direct labor.

$$h(i) * d(i) = o(i) \qquad (i=1,2,\ldots,I)$$

(5) Contract limitations. Contracting of services that can be performed in-house is a feature of the model. The user may or may not permit contracting to occur. If contracting is 'turned on,' the user may set limits, $Qk(i)$, on the percentage that contracting may represent of the total functional obligation.

$$K(i) \leq Qk(i) * f(i) \qquad (i=1,2,\ldots,I)$$

(6) Functional proportion limits. Another optional feature of the model is the ability to set limitations on the functional manyears that are computed. One form is to limit the size of any function to a proportion of the total organization's computed manyears.

$$m(i) \,/\, (m(1)+m(2)+..+m(I)) \leq Qf(i) \qquad (i=1,2,\ldots,I)$$

(7) Manyear determination. In this prototype, dollars are used to determine manpower requirements. The actual calculation for each function takes the amount computed for direct labor divided by the per-capita cost of that function's manyears, plus the supervisory manyears per thousand dollars of contracts administered, times the amount contracted out for that function.

$$(1/p(i)) * d(i) + l(i) * k(i) = m(i) \qquad (i=1,2,\ldots,I)$$

(8) Function size. Another optional constraint on manpower is to explicitly set an upper bound on the size of any function.

$$m(i) \leq b(i) \qquad (i=1,2,\ldots,I)$$

(9) Organization size. Just as the size of any of the component functions may be capped, so may the overall size of the organization (i.e., the sum of all $m(i)$ may be prohibited from rising above a specific level).

$$m(1)+m(2)+\ldots+m(I) \leq b$$

c. Data tables. As is the case in the development of any model, there is a requirement for data that comprise the structure of the model. LP applications typically define problems with large dimensionality (i.e., 500 rows and 2000 columns). In practice, there are usually few non-zero entries, and the matrix is therefore quite sparse. The non-zero entries can typically be grouped together (e.g., in the prototype the per-capita costs and overhead rates are given for each function). In fact, the grouping of non-zero values can often be conveniently represented outside the LP as tables. The computed non-zero values for the prototype are summarized in the tables described below. The following paragraphs describe the data that were largely extracted from the 1983 RAT file and were used to develop the structure of the LP.

(1) Function codes and titles. Within the prototype, manpower and activities are defined in terms of the RAT functions. The symbolic labels used for row and column names allow the identification of which function is involved using just a single alphabetic character. Figure B-4 translates the character code into a short function title.

(2) The input/output matrix. As said above, the prototype was constrained to take on a form that was compatible with existing manpower requirement data. The RAT was the major requirements system used within Civil Works. It linked functional manpower needs with projected appropriations. The data base was analyzed with the intent to develop the necessary data to be able to convert the appropriation "input" into functional "output." The 15 functions identified within the RAT were deemed acceptable, but a decision had to be made concerning the appropriation level. The cost data could be viewed as a heirarchy of appropriation, category, class, and subclass data. A further distinction could be made as to whether the data are considered at the

FUNCTION CODES

| | |
|---|---|
| A | ADMNOH |
| X | ADMNDR |
| K | PLAN |
| L | ENGR |
| H | PRGDEV |
| N | R. E. |
| Q | CONSTR |
| D | DREDG |
| V | NAVIG |
| F | FLDCNT |
| P | HYDPOW |
| T | NATRES |
| G | REGUL |
| U | EMGMGT |
| Z | X-FNC |

Figure B-4

district or division headquarters level, or alternatively at aggregated levels for either whole divisions or even corps-wide. After examining the form of the data and observing the great variability in how different organizations broke out their costs in the RATs, it was decided to use distributions based on an aggregate of districts (but not division headquarters) at the appropriation and category level. Figure B-5 therefore represents the expected distribution of appropriation-category dollars (i.e., a three-character identifier) across the functions as observed in district organizations.

(3) Functional manpower costs. Within the model, it is necessary to convert functional dollars into manpower requirements. The RATs carried estimates of seasonal and full-time spaces and workyears. Since the major concern presently is in FTEs, the model is stated in terms of full-time workyears that can be paid for with estimated dollars. It was theorized that the functions should reflect the different cost structure associated with administrative, technical, and operations positions. Therefore, regression analyses were conducted to come up with a figure that would best represent a per-capita cost for each function. Figure B-6 shows the results of those analyses.

(4) Contract supervision. One of the devices that the Corps must use in order to accomplish its workload is to contract out certain tasks when in-house labor is overwhelmed and either space or FTE constraints prevents staff increases. While this augments capability, any contract entails extra administrative and supervisory overhead. Ideally we should have the impact across all functions of any contract let. Unfortunately the RAT data do not permit us to develop the true impact of contracting out. As a result, we arbitrarily asserted that some functions allow one individual to supervise

| | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A 1 | 0.0939 | 0.0082 | 0.6610 | 0.2126 | 0.0158 | 0.0072 | 0.0003 | 0.0007 | 0.0002 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| A 2 | 0.0915 | 0.0078 | 0.6800 | 0.2106 | 0.0067 | 0.0 | 0.0 | 0.0034 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| A 3 | 0.2000 | 0.0500 | 0.0 | 0.7500 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| A 4 | 0.0578 | 0.0125 | 0.2812 | 0.6218 | 0.0150 | 0.0080 | 0.0012 | 0.0 | 0.0 | 0.0026 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| A 5 | 0.2125 | 0.0037 | 0.5632 | 0.1447 | 0.0760 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| A 6 | 0.0692 | 0.0070 | 0.1945 | 0.6773 | 0.0189 | 0.0328 | 0.0 | 0.0002 | 0.0 | 0.0001 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| B 1 | 0.0663 | 0.0010 | 0.5184 | 0.3949 | 0.0153 | 0.0 | 0.0031 | 0.0010 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| B 2 | 0.0105 | 0.0021 | 0.0161 | 0.0453 | 0.0017 | 0.0314 | 0.8824 | 0.0032 | 0.0051 | 0.0 | 0.0 | 0.0001 | 0.0 | 0.0 | 0.0022 |
| B 4 | 0.0111 | 0.0012 | 0.0601 | 0.1529 | 0.0085 | 0.0002 | 0.7515 | 0.0006 | 0.0140 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| B 5 | 0.0174 | 0.0026 | 0.0256 | 0.1062 | 0.0042 | 0.1264 | 0.7114 | 0.0002 | 0.0001 | 0.0003 | 0.0 | 0.0 | 0.0 | 0.0006 | 0.0049 |
| B 6 | 0.0106 | 0.0022 | 0.0114 | 0.0887 | 0.0024 | 0.0341 | 0.8467 | 0.0 | 0.0002 | 0.0013 | 0.0009 | 0.0015 | 0.0 | 0.0 | 0.0 |
| B 7 | 0.0078 | 0.0009 | 0.1877 | 0.0612 | 0.0017 | 0.0007 | 0.6122 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1277 | 0.0 | 0.0 | 0.0 |
| B 8 | 0.0125 | 0.0032 | 0.0013 | 0.0468 | 0.0021 | 0.0024 | 0.9230 | 0.0 | 0.0 | 0.0086 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| C 1 | 0.0357 | 0.0056 | 0.0077 | 0.0388 | 0.0021 | 0.0055 | 0.0855 | 0.5571 | 0.2402 | 0.0002 | 0.0 | 0.0215 | 0.0 | 0.0001 | 0.0 |
| C 2 | 0.0626 | 0.0055 | 0.0125 | 0.1654 | 0.0035 | 0.0248 | 0.0359 | 0.0 | 0.0011 | 0.3904 | 0.0 | 0.2977 | 0.0 | 0.0006 | 0.0 |
| C 3 | 0.0693 | 0.0027 | 0.0186 | 0.0656 | 0.0037 | 0.0222 | 0.0380 | 0.0028 | 0.0571 | 0.0712 | 0.3162 | 0.3326 | 0.0 | 0.0 | 0.0 |
| C 4 | 0.0832 | 0.0053 | 0.0529 | 0.0301 | 0.0017 | 0.0004 | 0.0220 | 0.0090 | 0.2185 | 0.0 | 0.0 | 0.0 | 0.5769 | 0.0 | 0.0 |
| C 5 | 0.0778 | 0.0049 | 0.0277 | 0.0889 | 0.0011 | 0.0091 | 0.0251 | 0.0021 | 0.0269 | 0.0042 | 0.0 | 0.0002 | 0.0 | 0.7321 | 0.0 |
| D 1 | 0.0869 | 0.0027 | 0.0197 | 0.0527 | 0.0010 | 0.0019 | 0.0175 | 0.0 | 0.0060 | 0.0175 | 0.0 | 0.0 | 0.0 | 0.7941 | 0.0 |
| D 2 | 0.1151 | 0.0 | 0.0219 | 0.5282 | 0.0138 | 0.0 | 0.2992 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0219 | 0.0 |
| D 3 | 0.0036 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.9964 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| D 5 | 0.0086 | 0.0 | 0.0086 | 0.0231 | 0.0014 | 0.0431 | 0.9138 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0014 | 0.0 |
| E 1 | 0.6884 | 0.0 | 0.0859 | 0.1669 | 0.0 | 0.0 | 0.0588 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| E 4 | 0.0934 | 0.0461 | 0.0034 | 0.0 | 0.0 | 0.0 | 0.0236 | 0.0405 | 0.7390 | 0.0 | 0.0 | 0.0 | 0.0540 | 0.0 | 0.0 |
| E 5 | 0.0324 | 0.0032 | 0.9612 | 0.0032 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| EN1 | 0.0176 | 0.5426 | 0.3108 | 0.0098 | 0.0061 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| EP2 | 0.2237 | 0.0 | 0.4934 | 0.2763 | 0.0 | 0.0066 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ER3 | 0.0236 | 0.0090 | 0.0093 | 0.1179 | 0.0030 | 0.0267 | 0.8107 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| ES4 | 0.0387 | 0.0174 | 0.0058 | 0.2047 | 0.0020 | 0.0087 | 0.1826 | 0.2672 | 0.0115 | 0.1593 | 0.0 | 0.1022 | 0.0 | 0.0 | 0.0 |
| FD2 | 0.0195 | 0.0 | 0.0 | 0.0044 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0427 | 0.0 | 0.9334 | 0.0 | 0.0 | 0.0 |
| FW1 | 0.0 | 0.0 | 0.0 | 0.0411 | 0.0 | 0.0 | 0.9589 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| FW3 | 0.0010 | 0.0 | 0.0014 | 0.0206 | 0.0 | 0.0 | 0.9379 | 0.0 | 0.0390 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| VW9 | 0.2026 | 0.0 | 0.0340 | 0.1233 | 0.0006 | 0.1863 | 0.4533 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WC | 0.0949 | 0.0033 | 0.0041 | 0.1692 | 0.0 | 0.2410 | 0.1461 | 0.3409 | 0.0004 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WCA | 1.0000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WCC | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WCG | 1.0000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WCM | 0.0016 | 0.0019 | 0.1747 | 0.3446 | 0.0 | 0.0 | 0.0 | 0.4772 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WCP | 1.0000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WD | 0.0314 | 0.0067 | 0.0179 | 0.1441 | 0.0009 | 0.0595 | 0.4207 | 0.0814 | 0.2375 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WDA | 0.2249 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.7751 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WDB | 0.0823 | 0.0 | 0.1582 | 0.7595 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WDC | 0.0 | 0.0 | 0.0 | 1.0000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WDD | 0.0050 | 0.0 | 0.0009 | 0.0021 | 0.0002 | 0.0522 | 0.9396 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WDE | 0.0673 | 0.0047 | 0.0546 | 0.2135 | 0.0008 | 0.0 | 0.6590 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WDF | 0.1673 | 0.0 | 0.4503 | 0.3824 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WDN | 0.0005 | 0.0 | 0.0 | 0.0554 | 0.0 | 0.0 | 0.9441 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WDP | 0.0 | 0.0 | 0.0 | 0.9667 | 0.0 | 0.0333 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WDS | 0.1157 | 0.0150 | 0.0 | 0.0763 | 0.0200 | 0.0 | 0.7731 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WDW | 0.0057 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.8015 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1928 |
| WF | 0.0 | 0.0 | 0.0 | 1.0000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WFS | 0.0 | 0.0 | 0.6800 | 0.3200 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| WO1 | 0.0 | 0.0 | 1.0000 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

Figure B-5

FUNCTIONAL MANPOWER COSTS ($K)

| | | |
|---|---|---|
| A | ADMNOH | 18.91 |
| X | ADMNDR | 24.00 |
| K | PLAN | 31.45 |
| L | ENGR | 30.70 |
| H | PRGDEV | 28.87 |
| N | R. E. | 27.65 |
| Q | CONSTR | 30.28 |
| D | DREDG | 28.44 |
| V | NAVIG | 25.87 |
| F | FLDCNT | 24.38 |
| P | HYDPOW | 28.72 |
| T | NATRES | 22.83 |
| G | REGUL | 26.15 |
| U | EMGMGT | 33.22 |
| Z | X-FNC | 0.0 |

Figure B-6

$1 million while more technical functions permit only $250 thousand to be administered by an individual. Moreover, estimates of cross-functional impacts (e.g., administrative time (e.g., supply and counsel) spent on every contract) are ignored entirely in the prototype, but surely should be present in a working version (see Figure B-7).

(5) Overhead estimation. In addition to salaries, the Corps must also pay the various overhead expenses incurred in running organizations of many hundreds of people. In a manner similar to how the per-capita costs were estimated, regression analyses were made to obtain a relationship between direct labor dollars and overhead within each function (see Figure B-8).

(6) The value-added factor. Within the Corps one should distinguish two types of contracting cost. The first deals with making the decision to contract out tasks that might also be done by in-house personnel but for possible time constraints. The second type of contract amount deals with amounts that are not intended to be done by Corps personnel. This is best illustrated by the Government estimates for the labor and materials necessary to build a new facility. In trying to build the prototype, it was quickly seen that certain functions exhibit a high degree of the latter type of contracting. In an effort to calculate that portion of functional money reserved for Corps services, regression analyses were made. Figure B-9 gives the portions of a function attributed to the value-added Corps contribution.

(7) Caveats. The figures that have been explained above represent only the first iteration of the structural data that must be compiled for the model. Since 1983 (the timeframe of the data used here), Civil Works has gone through a refinement of the RAT requirements process and the resulting FORCON data should be better and more compatible with the needs of the LP

CONTRACT SUPERVISION RATES

| | | |
|---|---|---|
| A | ADMNOH | 0.0001 |
| X | ADMNDR | 0.0001 |
| K | PLAN | 0.0004 |
| L | ENGR | 0.0004 |
| H | PRGDEV | 0.0004 |
| N | R. E. | 0.0004 |
| Q | CONSTR | 0.0004 |
| D | DREDG | 0.0001 |
| V | NAVIG | 0.0001 |
| F | FLDCNT | 0.0001 |
| P | HYDPOW | 0.0001 |
| T | NATRES | 0.0001 |
| G | REGUL | 0.0001 |
| U | EMGMGT | 0.0001 |
| Z | X-FNC | 0.0001 |

Figure B-7

CASE 3--OBLIGATION RESULTS

| Appropriation | Obligation | Unexpended |
|---|---|---|
| A 110 | 1054.60544 | 795.39456 |
| A 120 | 0.00000 | 58.00000 |
| A 171 | 0.00000 | 6.30000 |
| A 186 | 0.00000 | 52.00000 |
| A 194 | 1550.00000 | 0.00000 |
| A 250 | 0.00000 | 90.00000 |
| A 451 | 1075.00000 | 0.00000 |
| A 651 | 53.00000 | 0.00000 |
| B 121 | 17.00000 | 0.00000 |
| B 151 | 8.00000 | 0.00000 |
| B 211 | 2250.00000 | 0.00000 |
| B 216 | 41.00000 | 0.00000 |
| B 420 | 90.00000 | 0.00000 |
| B 511 | 13352.00000 | 0.00000 |
| B 516 | 377.00000 | 0.00000 |
| B 517 | 433.00000 | 0.00000 |
| B 740 | 55.00000 | 0.00000 |
| C 111 | 20153.70565 | 1974.29435 |
| C 222 | 420.00000 | 0.00000 |
| C 430 | 0.00000 | 832.00000 |
| C 440 | 33.06627 | 2146.93373 |
| C 450 | 3258.00000 | 0.00000 |
| C 470 | 818.00000 | 0.00000 |
| C 500 | 70.00000 | 0.00000 |
| D 100 | 178.00000 | 0.00000 |
| E 420 | 0.00000 | 98.00000 |
| WDEPC | 1600.00000 | 0.00000 |
| TOTAL | 46886.37736 | |

Figure B-16

(c) Case 3. While the two previous cases were interesting, the Corps does not attempt to do everything in-house. Contracting for studies, engineering, dredging, etc. is standard operating procedure; thus, in Case 3, contracting is allowed. To also be realistic, limits are also placed on what portion of a function can be turned over to contractors. The results are dramatic. The amount obligated is almost $20 million greater than in Case 2. The percentage limits on relative function manyears was also turned back on, but now since contracting is done within each function, the proportionality constraints are not as binding. The output report indicates that while we have markedly improved over Case 2, there are opportunities to increase our obligations even more if certain contracting and function limits are relaxed. In particular, planning and navigation have large payoffs if the function proportion limits are increased. (See Appendix B-1, the large values associated with rows QMK under the row section column labeled 'dual activity.' This value, in an economic sense, gives an idea of how much the objective function will improve for an increase of one unit for the constraint. It is usually considered the marginal value of that binding constraint. At the very least, it tips the analyst off to possible changes to consider if improvement in the objective is still sought.) (See Figures B-16 and B-17.)

(d) Case 4. For this case two things were changed: the percentage function limits for planning and navigation were increased from 10 and 20 percent to 25 and 30 percent respectively. Otherwise all other data and parameters are the same as for Case 3. As a result and under the given parameters, all projects are obligated. There is, however, an accompanying increase in the number of manyears consumed--to 623. Clearly the 623 figure

CASE 2--RESOURCE ALLOCATIONS BY FUNCTIONS

| Function | $ Expended | $ Dir Labor | $ Overhead | Manyears |
|---|---|---|---|---|
| ADMNOH | 893.37476 | 587.74656 | 305.62820 | 31.09179 |
| ADMNDR | 119.82787 | 97.97864 | 21.84924 | 4.08571 |
| PLAN | 519.13420 | 401.18563 | 117.94856 | 12.75770 |
| ENGR | 1636.81015 | 1226.99413 | 409.81603 | 40.00000 |
| PRGDEV | 72.82383 | 58.87133 | 13.95250 | 2.03695 |
| R. E. | 250.73611 | 204.34891 | 46.38720 | 7.39743 |
| CONSTR | 1418.73502 | 1052.47406 | 366.26096 | 34.73164 |
| DR EDG | 2178.55113 | 994.31819 | 1184.23295 | 35.00000 |
| NAVIG | 3789.71582 | 2637.24139 | 1152.47443 | 102.06124 |
| FLDCNT | 8.62982 | 5.54259 | 3.08722 | 0.22725 |
| HYDPOW | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| NATRES | 286.07230 | 205.80742 | 80.26489 | 9.01436 |
| REGUL | 1554.97384 | 1047.12046 | 507.85338 | 40.00000 |
| EMGMGT | 199.14810 | 115.78379 | 83.36432 | 3.48509 |
| X-FNC | 47.95238 | 47.95238 | 0.00000 | 0.00000 |
| TOTAL | | | | 321.88916 |

Figure B-15

CASE 2--OBLIGATION RESULTS

| Appropriation | Obligation | Unexpended |
|---|---|---|
| A 110 | 0.00000 | 1850.00000 |
| A 120 | 0.00000 | 58.00000 |
| A 171 | 0.00000 | 6.30000 |
| A 186 | 0.00000 | 52.00000 |
| A 194 | 0.00000 | 1550.00000 |
| A 250 | 0.00000 | 90.00000 |
| A 451 | 0.00000 | 1075.00000 |
| A 651 | 0.00000 | 53.00000 |
| B 121 | 0.00000 | 17.00000 |
| B 151 | 0.00000 | 8.00000 |
| B 211 | 2250.00000 | 0.00000 |
| B 216 | 41.00000 | 0.00000 |
| B 420 | 0.00000 | 90.00000 |
| B 511 | 7947.58946 | 5404.41054 |
| B 516 | 377.00000 | 0.00000 |
| B 517 | 433.00000 | 0.00000 |
| B 740 | 55.00000 | 0.00000 |
| C 111 | 12967.70796 | 9160.29204 |
| C 222 | 0.00000 | 420.00000 |
| C 430 | 0.00000 | 832.00000 |
| C 440 | 0.00000 | 2180.00000 |
| C 450 | 1868.22317 | 1389.77683 |
| C 470 | 818.00000 | 0.00000 |
| C 500 | 70.00000 | 0.00000 |
| D 100 | 178.00000 | 0.00000 |
| E 420 | 98.00000 | 0.00000 |
| WDEPC | 0.00000 | 1600.00000 |
| TOTAL | 27103.52059 | |

Figure B-14

CASE 1--RESOURCE ALLOCATIONS BY FUNCTIONS

| Function | $ Expended | $ Dir Labor | $ Overhead | Manyears |
|---|---|---|---|---|
| ADMNOH | 1155.63806 | 760.28821 | 395.34985 | 40.21924 |
| ADMNDR | 143.28259 | 117.15666 | 26.12593 | 4.88543 |
| PLAN | 1637.67607 | 1265.59205 | 372.08402 | 40.24582 |
| ENGR | 3417.87765 | 2562.12719 | 855.75046 | 83.52533 |
| PRGDEV | 123.99539 | 100.23880 | 23.75659 | 3.46826 |
| R. E. | 389.49373 | 317.43580 | 72.05793 | 11.49117 |
| CONSTR | 2126.59564 | 1577.59322 | 549.00242 | 52.06058 |
| DREDG | 1665.78045 | 760.28319 | 905.49726 | 26.76197 |
| NAVIG | 2988.79810 | 2079.88737 | 908.91073 | 80.49164 |
| FLDCNT | 176.40615 | 113.29875 | 63.10740 | 4.64525 |
| HYDPOW | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| NATRES | 345.17800 | 248.32950 | 96.84850 | 10.87683 |
| REGUL | 1564.52993 | 1053.55554 | 510.97439 | 40.24582 |
| EMGMGT | 202.33611 | 117.63728 | 84.69883 | 3.54088 |
| X-FNC | 74.43399 | 74.43399 | 0.00000 | 0.00000 |
| TOTAL | | | | 402.45822 |

Figure B-13

CASE 1--OBLIGATION RESULTS

| Appropriation | Obligation | Unexpended |
|---|---|---|
| A 110 | 0.00000 | 1850.00000 |
| A 120 | 0.00000 | 58.00000 |
| A 171 | 0.00000 | 6.30000 |
| A 186 | 0.00000 | 52.00000 |
| A 194 | 876.24024 | 673.75976 |
| A 250 | 0.00000 | 90.00000 |
| A 451 | 1075.00000 | 0.00000 |
| A 651 | 53.00000 | 0.00000 |
| B 121 | 17.00000 | 0.00000 |
| B 151 | 8.00000 | 0.00000 |
| B 211 | 2250.00000 | 0.00000 |
| B 216 | 41.00000 | 0.00000 |
| B 420 | 90.00000 | 0.00000 |
| B 511 | 13352.00000 | 0.00000 |
| B 516 | 377.00000 | 0.00000 |
| B 517 | 433.00000 | 0.00000 |
| B 740 | 55.00000 | 0.00000 |
| C 111 | 9901.27519 | 12226.72481 |
| C 222 | 420.00000 | 0.00000 |
| C 430 | 832.00000 | 0.00000 |
| C 440 | 1061.96090 | 1118.03910 |
| C 450 | 0.00000 | 3258.00000 |
| C 470 | 818.00000 | 0.00000 |
| C 500 | 70.00000 | 0.00000 |
| D 100 | 178.00000 | 0.00000 |
| E 420 | 0.00000 | 98.00000 |
| WDEPC | 1600.00000 | 0.00000 |
| TOTAL | 33508.47632 | |

Figure B-12

means that \$.66 goes to planning, \$.21 goes to engineering, etc. (see Figure B-5). In Case 1, planning, navigation, and regulatory functions have all reached their maximum portions of the organization. (An important feature of the methodology is that the LP output gives marginal values that show how increasing the limits on these functions will greatly increase obligations.) The problem is that adding one additional dollar from any of the unobligated appropriations will mean that we will violate one or more of the functional percentage constraints (see Figures B-12 and B-13).

(b) Case 2. In this case, rather than the percentage limits, ceilings are placed on the actual manyears that can be expended in each function. The results are even worse than in Case 1. Now only \$27 million are obligated and only 322 manyears are expended. Several functions have hit their upper limits (planning, dredging, and regulatory). Once again the idea of proportionality must be remembered in analyzing these results. In the real world there are several ways to get around this. The most obvious, contracting, will be addressed below. Another possibility might be borrowed labor. This could work in two ways: the work could be performed by another district (or division) that had excess capability, or in-house manyears from other functions might be used, presumably with reduced efficiency. The latter possibilities are not addressed in the prototype, but certainly deserve exploration if further work is authorized. (An interesting situation occurs if all constraints are removed and contracting is not permitted. The results would give the total in-house manyears necessary to obligate all monies. It thus gives the pure requirements given the forecasted workload and presumably based on valid requirement standards.) (See Figures B-14 and B-15.)

extracted from the output reports of the model. Two figures accompany each case: the first shows how much of each project (appropriation) was obligated and how much is left unspent (the shortfall), given the constraints in force; the second shows how the dollars are actually distributed across the functions and how much went to pay for direct labor, contract services (when allowed), and district overhead, as well as the number of manyears that the direct dollars paid for. Seven cases are detailed but no conclusion should be made about the results. The cases are presented to show the method; further analysis and development is required before implementation could be considered. The few manmonths of effort that went into designing the prototype and conducting statistical analysis to derive model values would have to be greatly expanded.

(a) Case 1. In this example, the original New York data were used and the only constraint was that the functions fall within the FRATLM limits for permissable percent of organization strength. (Appendix B-1 contains an example of the standard LP solution file. The reader is to be reassured that in practice, reports would be designed that would extract the solution data and format it in appropriate displays.) Since manpower requirements are of primary interest, the following discussions will focus on comparing obligations and manyear determinations. Getting back to Case 1, despite the fact that the only limitations are percentage caps on the functions, we only obligate $33.5 million and use 402 manyears of effort. It would seem that with no limit on manyears, every appropriation should be obligated. The explanation lies in one of the fundamental premises of LP--proportionality. What this means is that changes to any variable are always reflected in constant ratios. Taking appropriation-category "A 1", every dollar obligated

SAMPLE MPS INPUT FILE

```
NAME                                                  NEW YORK EXAMPLE
ROWS
 N   OBJECT                                                        (1)
 L   AVA 110
 L   AVA 120
 L   AVA 171
 .    .
 E   TRTOX$
 E   TRTOK$
 .    .
 .    .
 E   CNVFTOMY                                                      (2)
 E   CNVPTOMY
 .    .
COLUMNS
     INA 110            OBJECT                  1.0000             (3)
     INA 110            AVA 110                 1.0000
        .                  .                      .
        .                  .                      .
     AGA 6              TRTOK$                  0.1945
     AGA 6              TRTOL$                  0.6773             (4)
        .                  .                      .
        .                  .                      .
     EXPK$              ALOK$                  -1.0000
RHS
     RHS                AVA 110              1850.0000             (5)
     RHS                AVA 120                58.0000
     RHS                AVA 171                 6.3000
        .                  .                      .
        .                  .                      .
     RHS                SIZORG                421.0000             (6)
ENDATA
```

NOTES:

(1) OBJECT is the name of the objective row; N means it is free to take on any value.

(2) CNV*T)MY := convert function * to manyears (F is flood control).

(3) Variable IN* (here * := 'A 110') has weight of 1.0000 in the objective row OBJECT.

(4) Convert appropriation into functional equivalent. Here 67.73% of each 'A 6' dollar goes to Engineering.

(5) The right-hand side, RHS, has a value of 1850 in row AVA 110 (i.e., there is $1850K net available for A 110).

(6) The right-hand side, RHS, has a value of 421 in row SIZORG (i.e., the organization must not exceed 421).

Figure B-11

NEW YORK DISTRICT--LP INPUT

NEW YORK EXAMPLE WITH FULL APPN CODES (FROM 1983 RATs)

```
27  5                              /* NEW YORK DISTRICT
   A 110          1850.            /* NAVIGATION STUDIES
   A 120            58.            /* FLOOD DAMAGE PREV STUDIES
   A 171            63             /* DAMS
   A 186            52.            /* PLANNING ASSIST TO STATES
   A 194          1550.            /* FLOOD DAMAGE PREV - LOCAL
   A 250            90.            /* FLOOD PLAIN MANGMT SERVICES
   A 451          1075.            /*
   A 651            53.            /*
   B 121            17.            /* ADV E&D (CHANNELS AND HARBORS)
   B 151             8.            /* ADV E&D (LOCAL FLOOD PROT)
   B 211          2250.            /* NAVIG PROJECTS (SPEC AUTH)
   B 216            41.            /* NAVIG PROJECTS (NORMAL)
   B 420            90.            /* BEACH EROSION (NORMAL)
   B 511         13352.            /* FLOOD CONTROL (SPEC AUTH)
   B 516           377.            /* FLOOD CONTROL (NORMAL)
   B 517           433.            /* FLOOD CONTROL (EMERGENCY PROT)
   B 740            55.            /* AQUATIC PLANTS
   C 111         22128.            /* NAVIGATION REG CHANNELS & HARBORS
   C 222           420.            /* FLOOD CONTROL INSPECTION
   C 430           832.            /* NAVIG PROJECTS (OBSTRUCTIONS)
   C 440          2180.            /* GENERAL REGULATORY
   C 450          3258.            /* DRIFT REMOVAL
   C 470           818.            /* PROJECT CONDITION SURVEYS
   C 500            70.            /* NEPA
   D 100           178.            /* FLOOD CONTROL & COASTAL EMERG
   E 420            98.            /* DISTRICT OPERATIONS
   WDEPC          1600.            /* WORK FOR EPC
```

FACTORS

| FNC-ORG | FPOPLM | FRATLM | RMXCON |
|---|---|---|---|
| A | 100. | .20 | .05 |
| X | 0. | .05 | .05 |
| K | 120. | .10 | .25 |
| L | 40. | .30 | .20 |
| H | 20. | .05 | .0 |
| N | 10. | .05 | .50 |
| Q | 80. | .15 | .15 |
| D | 35. | .10 | .50 |
| V | 150. | .20 | .30 |
| F | 10. | .10 | .30 |
| P | 0. | .10 | .0 |
| T | 0. | .10 | .30 |
| G | 40. | .10 | .0 |
| U | 8. | .05 | .0 |
| Z | 0. | .05 | .0 |

Population Limit 421.

Figure B-10

contracted out. Note that these figures are not unalterable. In fact, the constraints that they imply may or may not be applied depending on the needs of the user.

(2) Generating the problem. Having compiled the input data (i.e., New York data, see Figure B-10), defined the equations representing the model, and derived the coefficients of those equations, it now remains to put these data together in a form that an LP package on a computer can understand. On large commercial systems there are usually programs that enable a user to enter data in tabular form and to convert that data into the format that the LP system expects. Over the years the MPS form for describing a problem has become the industry standard. Unfortunately ESC did not have ready access to a large mainframe-based system. It did have, however, a very serviceable system, MINOS, that required the input to be in the standard MPS format and produced output in the same form as the large commercial systems. One of the distinguishing features of both input and output is the use of symbolic names for row and column labels (mentioned here in anticipation of sample reports that will follow). The symbolic names can and should permit a user to generate descriptive labels for the rows and columns that greatly aid in debugging and interpreting results. A program was written that read in the data, asked the user which options or contraints were to apply, and generated the required MPS input file (see Figure B-11).

(3) Sample results. The following paragraphs describe how a New York manpower planner might approach the problem of manpower requirements and allocation. It proceeds step by step (cases) showing results and indicating what the analyst might observe and what he could do in reaction to his findings. The figures that accompany each case description contain data

prototype. Unfortunately those data were not available to ESC when the prototype was being developed.

(8) Completing the model. The prototype has now been defined in terms of its objective function, the equations or relations that show the interrelationships of the variables, and finally the variables themselves. (Most textbook representations of the completed LP problem show only the coefficients of the variables to facilitate manipulation. This is usually called the detached coefficient form since the variables are implicit in the column representation of the problem.) All that remains to be done before submitting the problem for solution is to define the right-hand side values which are particular to each district or division under study.

d. An example.

(1) Initial district data. To demonstrate the general capabilities of the prototype, the New York District was chosen as a test case. There was no significance in its selection--any district would have sufficed. What was then used for New York was the actual information that appeared in the 1983 RAT submission. Appropriations are in appn-cat-class-subclass detail to show how the model will accept the full appropriation ID and then roll them up to appn-cat level. The remaining user input for New York represents possible answer-limiting information. The initial values for FPOPLIM are upper limits on the number of manyears that a function can reach. It was calculated by examining the actual manyears listed for New York and adding a buffer of 10 to 20 percent. The FRATLM column gives the approximate fraction of the total district (taking Corps-wide values) that each function represents, again with a few points added. Finally, the RMXCON is also derived from Corps-wide estimates on the usual amount of possible in-house services that are typically

CORPS VALUE-ADDED RATES

| | | |
|---|---|---|
| A | ADMNOH | 1.0 |
| X | ADMNDR | 1.0 |
| K | PLAN | 1.0 |
| L | ENGR | 1.0 |
| H | PRGDEV | 1.0 |
| N | R. E. | 0.2 |
| Q | CONSTR | 0.15 |
| D | DREDG | 0.30 |
| V | NAVIG | 1.0 |
| F | FLDCNT | 1.0 |
| P | HYDPOW | 1.0 |
| T | NATRES | 1.0 |
| G | REGUL | 1.0 |
| U | EMGMGT | 1.0 |
| Z | X-FNC | 1.0 |

Figure B-9

OVERHEAD GENERATION

| | | |
|---|---|---|
| A | ADMNOH | 0.520 |
| X | ADMNDR | 0.223 |
| K | PLAN | 0.294 |
| L | ENGR | 0.334 |
| H | PRGDEV | 0.237 |
| N | R. E. | 0.227 |
| Q | CONSTR | 0.348 |
| D | DREDG | 1.191 |
| V | NAVIG | 0.437 |
| F | FLDCNT | 0.557 |
| P | HYDPOW | 0.427 |
| T | NATRES | 0.39 |
| G | REGUL | 0.485 |
| U | EMGMGT | 0.72 |
| Z | X-FNC | 0.0 |

Figure B-8

CASE 3--RESOURCE ALLOCATIONS BY FUNCTIONS

| Function | $ Expended | $ Dir Labor | $ Contract | $ Overhead | Manyears |
|---|---|---|---|---|---|
| ADMNOH | 1800.18240 | 1184.33054 | 0.00000 | 615.85186 | 62.65108 |
| ADMNDR | 222.27345 | 181.74444 | 0.00000 | 40.52901 | 7.57874 |
| PLAN | 2932.97587 | 1699.94741 | 733.24397 | 499.78449 | 54.35162 |
| ENGR | 4225.17519 | 3167.29776 | 0.00000 | 1057.87743 | 103.25389 |
| PRGDEV | 175.20874 | 141.64005 | 0.00000 | 33.56869 | 4.90075 |
| R. E. | 403.33083 | 328.71298 | 0.00000 | 74.61785 | 11.89941 |
| CONSTR | 2262.43718 | 1678.36588 | 0.00000 | 584.07131 | 55.38607 |
| DREDG | 3383.07926 | 1544.08000 | 0.00000 | 1838.99926 | 54.35162 |
| NAVIG | 5757.04491 | 2804.40625 | 1727.11320 | 1225.52546 | 108.70323 |
| FLDCNT | 178.45664 | 114.61570 | 0.00000 | 63.84094 | 4.69924 |
| HYDPOW | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| NATRES | 565.60524 | 406.91025 | 0.00000 | 158.69499 | 17.82267 |
| REGUL | 2370.51986 | 1422.14015 | 258.64180 | 689.73791 | 54.35162 |
| EMGMGT | 203.36135 | 118.23335 | 0.00000 | 85.12800 | 3.55882 |
| X-FNC | 74.43399 | 0.00000 | 74.43399 | 0.00000 | 0.00744 |
| TOTAL | | | | | 543.51619 |

Figure B-17

is unreasonably high since the actual RAT figure was only 421. Examining the output indicates that only a few functions are contracting work (planning and navigation are both at maximum contracting levels). The logical next step is to limit the number of in-house manyears to see if contracting can cover the unaccomplished work (see Figures B-18 and B-19).

(e) Case 5. Case 5 shows what happens when the organization is confined to the 421 manyears that were indicated in the 1983 RAT. Obligations have decreased by $3 million but in-house manyears have been reduced by over 200 spaces. Examining Figure B-21 shows the great increase in contracting across all functions. Examining the figures also shows other interesting results. The appropriations that have not been obligated are disproportionately in the general investigation accounts. Also there is no in-house program development, regulatory, or emergency management (the direct labor payments for those functions are all zero). The only manyears in those functions are attributable to contract supervisory needs. Clearly this is an unacceptable situation. Those functions should in fact be predominately in-house. Examination of the input file showed how this occurred. The matrix generation program placed no contractual ceiling on functions that had a zero entry for RMXCON (see Figure B-3 for RMXCON values). This was a valid convention for converting input information into MPS declarations, but it clearly defined an unrealistic situation that had to be corrected. Another observation not immediately evident in Figures B-20 and B-21 (but evident in the actual output reports) is that functions are contracting out to the maximum. Thus, while we must decrease our reliance on contracting for the three functions mentioned above, we must also anticipate that it will probably have major impact because there is no slack within contracting as there was in Case 3 (see Figures B-20 and B-21).

CASE 4--OBLIGATION RESULTS

| Appropriation | Obligation | Unexpended |
|---|---|---|
| A 110 | 1850.00000 | 0.00000 |
| A 120 | 58.00000 | 0.00000 |
| A 171 | 6.30000 | 0.00000 |
| A 186 | 52.00000 | 0.00000 |
| A 194 | 1550.00000 | 0.00000 |
| A 250 | 90.00000 | 0.00000 |
| A 451 | 1075.00000 | 0.00000 |
| A 651 | 53.00000 | 0.00000 |
| B 121 | 17.00000 | 0.00000 |
| B 151 | 8.00000 | 0.00000 |
| B 211 | 2250.00000 | 0.00000 |
| B 216 | 41.00000 | 0.00000 |
| B 420 | 90.00000 | 0.00000 |
| B 511 | 13352.00000 | 0.00000 |
| B 516 | 377.00000 | 0.00000 |
| B 517 | 433.00000 | 0.00000 |
| B 740 | 55.00000 | 0.00000 |
| C 111 | 22128.00000 | 0.00000 |
| C 222 | 420.00000 | 0.00000 |
| C 430 | 832.00000 | 0.00000 |
| C 440 | 2180.00000 | 0.00000 |
| C 450 | 3258.00000 | 0.00000 |
| C 470 | 818.00000 | 0.00000 |
| C 500 | 70.00000 | 0.00000 |
| D 100 | 178.00000 | 0.00000 |
| E 420 | 98.00000 | 0.00000 |
| WDEPC | 1600.00000 | 0.00000 |
| TOTAL | 52939.30000 | |

Figure B-18

CASE 4--RESOURCE ALLOCATIONS BY FUNCTIONS

| Function | $ Expended | $ Dir Labor | $ Contract | $ Overhead | Manyears |
|---|---|---|---|---|---|
| ADMNOH | 2221.50828 | 1461.51862 | 0.00000 | 759.98965 | 77.31433 |
| ADMNDR | 261.81354 | 214.07485 | 0.00000 | 47.73869 | 8.92692 |
| PLAN | 3769.92671 | 2185.04258 | 942.48168 | 642.40245 | 69.86133 |
| ENGR | 4604.22396 | 3451.44227 | 0.00000 | 1152.78169 | 112.51699 |
| PRGDEV | 199.42672 | 161.21804 | 0.00000 | 38.20867 | 5.57814 |
| R. E. | 407.07682 | 331.76595 | 0.00000 | 75.31087 | 12.00993 |
| CONSTR | 2297.88163 | 1704.65998 | 0.00000 | 593.22165 | 56.25378 |
| DREDG | 3722.48507 | 1698.98909 | 0.00000 | 2023.49598 | 59.80442 |
| NAVIG | 6954.77170 | 3387.85010 | 2086.43118 | 1480.49042 | 131.31844 |
| FLDCNT | 178.85150 | 114.86930 | 0.00000 | 63.98219 | 4.70964 |
| HYDPOW | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| NATRES | 608.05257 | 437.44790 | 0.00000 | 170.60467 | 19.16022 |
| REGUL | 4094.35839 | 1627.41863 | 1677.64181 | 789.29796 | 62.33515 |
| EMGMGT | 203.55878 | 118.34813 | 0.00000 | 85.21064 | 3.56228 |
| X-FNC | 74.43399 | 74.43399 | 0.00000 | 0.00000 | 0.00000 |
| TOTAL | | | | | 623.35157 |

Figure B-19

CASE 5--OBLIGATION RESULTS

| Appropriation | Obligation | Unexpended |
|---|---|---|
| A 110 | 0.00000 | 1850.00000 |
| A 120 | 0.00000 | 58.00000 |
| A 171 | 0.00000 | 6.30000 |
| A 186 | 0.00000 | 52.00000 |
| A 194 | 1343.84237 | 206.15763 |
| A 250 | 0.00000 | 90.00000 |
| A 451 | 1075.00000 | 0.00000 |
| A 651 | 53.00000 | 0.00000 |
| B 121 | 17.00000 | 0.00000 |
| B 151 | 8.00000 | 0.00000 |
| B 211 | 2250.00000 | 0.00000 |
| B 216 | 41.00000 | 0.00000 |
| B 420 | 90.00000 | 0.00000 |
| B 511 | 13352.00000 | 0.00000 |
| B 516 | 377.00000 | 0.00000 |
| B 517 | 433.00000 | 0.00000 |
| B 740 | 55.00000 | 0.00000 |
| C 111 | 21324.80763 | 803.19237 |
| C 222 | 420.00000 | 0.00000 |
| C 430 | 832.00000 | 0.00000 |
| C 440 | 2180.00000 | 0.00000 |
| C 450 | 3258.00000 | 0.00000 |
| C 470 | 818.00000 | 0.00000 |
| C 500 | 70.00000 | 0.00000 |
| D 100 | 178.00000 | 0.00000 |
| E 420 | 0.00000 | 98.00000 |
| WDEPC | 1600.00000 | 0.00000 |
| TOTAL | 49775.65000 | |

Figure B-20

CASE 5--RESOURCE ALLOCATIONS BY FUNCTIONS

| Function | $ Expended | $ Dir Labor | $ Contract | $ Overhead | Manyears |
|---|---|---|---|---|---|
| ADMNOH | 1971.45235 | 1232.15774 | 98.57261 | 640.72200 | 65.19099 |
| ADMNDR | 234.28171 | 181.98498 | 11.71409 | 40.58265 | 7.58994 |
| PLAN | 2266.21467 | 1313.49385 | 566.55367 | 386.16715 | 41.99572 |
| ENGR | 4092.24162 | 2454.11797 | 818.44828 | 819.67538 | 80.33161 |
| PRGDEV | 162.81219 | 0.00000 | 162.81219 | 0.00000 | 0.06512 |
| R. E. | 403.15186 | 164.28356 | 201.57593 | 37.29237 | 6.02769 |
| CONSTR | 2287.25777 | 1442.26200 | 343.08861 | 501.90716 | 47.73188 |
| DREDG | 3586.56135 | 818.47590 | 1793.28067 | 974.80478 | 28.98968 |
| NAVIG | 6688.98842 | 3258.38016 | 2006.69621 | 1423.91205 | 126.29998 |
| FLDCNT | 178.69086 | 80.33630 | 53.60725 | 44.74731 | 3.29915 |
| HYDPOW | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| NATRES | 590.78393 | 297.51711 | 177.23515 | 116.03167 | 13.04897 |
| REGUL | 4089.06639 | 0.00000 | 4089.06639 | 0.00000 | 0.40891 |
| EMGMGT | 203.47846 | 0.00000 | 203.47846 | 0.00000 | 0.02035 |
| X-FNC | 74.43399 | 74.43399 | 0.00000 | 0.00000 | 0.00000 |
| TOTAL | | | | | 421.00000 |

Figure B-21

(f) Case 6. To limit the amount that program development, regulatory, and emergency management functions could be contracted, the RMXCON values were changed to .01, 10, and 10 percent respectively. The results are rather interesting. Whereas the change of over 200 spaces in going from Case 4 to Case 5 only reduced obligations by $3 million, the changes to RMXCON have resulted in reducing obligations by over $4 million. Note also that the reduction is in the face of no change in the number of workyears. Figure B-22 shows something else interesting: the former concentration of unobligated monies in general investigations has now switched to operations and maintenance projects. Also, as in the previous case, all functions with contracting limits are at their upper bounds. To improve obligations, either additional manyears will have to be made available or the binding constraints will have to be changed, probably to allow more contracting (see Figures B-22 and B-23).

(g) Case 7. The final case presented here uses the same optional contraints as Cases 5 and 6: functional percentage limits, contracting allowed but not permitted to exceed specified percentages of functional expenditures, and the overall size of the organization must not exceed the 421 manyears found in the 1983 RATs. Changes were made to several function's contract percentage ceilings. Administrative (direct and overhead), navigation, flood control, natural resources, and regulatory ceilings were all raised to permit more contracting. Most of these changes were directed at functions in operations and maintenance to contract more in hopes of reducing the shortfalls observed in Case 6 for those projects and appropriations. The results show that the shortfall concentration in operations and maintenance has been mitigated, and overall obligations increased by $1 million, while the district's manyear total remained at 421. The analysis was stopped at this point

CASE 6--OBLIGATION RESULTS

| Appropriation | Obligation | Unexpended |
|---|---|---|
| A 110 | 1840.86352 | 9.13648 |
| A 120 | 58.00000 | 0.00000 |
| A 171 | 6.30000 | 0.00000 |
| A 186 | 52.00000 | 0.00000 |
| A 194 | 1550.00000 | 0.00000 |
| A 250 | 90.00000 | 0.00000 |
| A 451 | 1075.00000 | 0.00000 |
| A 651 | 53.00000 | 0.00000 |
| B 121 | 17.00000 | 0.00000 |
| B 151 | 8.00000 | 0.00000 |
| B 211 | 2250.00000 | 0.00000 |
| B 216 | 41.00000 | 0.00000 |
| B 420 | 90.00000 | 0.00000 |
| B 511 | 13352.00000 | 0.00000 |
| B 516 | 377.00000 | 0.00000 |
| B 517 | 433.00000 | 0.00000 |
| B 740 | 55.00000 | 0.00000 |
| C 111 | 22128.00000 | 0.00000 |
| C 222 | 420.00000 | 0.00000 |
| C 430 | 0.00000 | 832.00000 |
| C 440 | 0.00000 | 2180.00000 |
| C 450 | 0.00000 | 3258.00000 |
| C 470 | 0.00000 | 818.00000 |
| C 500 | 70.00000 | 0.00000 |
| D 100 | 178.00000 | 0.00000 |
| E 420 | 98.00000 | 0.00000 |
| WDEPC | 1600.00000 | 0.00000 |
| TOTAL | 45842.16352 | |

Figure B-22

CASE 6--RESOURCE ALLOCATIONS BY FUNCTIONS

| Function | $ Expended | $ Dir Labor | $ Contract | $ Overhead | Manyears |
|---|---|---|---|---|---|
| ADMNOH | 1630.92881 | 1019.33052 | 81.54644 | 530.05185 | 53.93073 |
| ADMNDR | 224.17223 | 174.13215 | 11.20861 | 38.83147 | 7.26243 |
| PLAN | 3388.93234 | 1964.21895 | 847.23309 | 577.48031 | 62.80104 |
| ENGR | 4388.93275 | 2632.04368 | 877.78650 | 879.10257 | 86.15572 |
| PRGDEV | 187.23276 | 151.34522 | 0.01872 | 35.86882 | 5.23655 |
| R. E. | 406.35523 | 165.58893 | 203.17761 | 37.58869 | 6.07559 |
| CONSTR | 2274.49123 | 1434.21188 | 341.17363 | 499.10572 | 47.46546 |
| DREDG | 3703.34565 | 845.12681 | 1851.67282 | 1006.54601 | 29.93363 |
| NAVIG | 5406.04195 | 2633.42358 | 1621.81233 | 1150.80604 | 102.07567 |
| FLDCNT | 178.85150 | 80.40852 | 53.65544 | 44.78754 | 3.30211 |
| HYDPOW | 0.00000 | 0.00000 | -0.00000 | 0.00000 | 0.00000 |
| NATRES | 608.05257 | 306.21355 | 182.41574 | 119.42328 | 13.43039 |
| REGUL | 5.29200 | 3.20727 | 0.52920 | 1.55553 | 0.12257 |
| EMGMGT | 203.55878 | 106.51332 | 20.35588 | 76.68958 | 3.20809 |
| X-FNC | 74.43399 | 74.43399 | 0.00000 | 0.00000 | 0.00000 |
| TOTAL | | | | | 421.00000 |

Figure B-23

although there were many more opportunities to try to achieve higher obligations, which was of course the primary objective for the model as formulated for this example. To proceed further would require familiarity with local conditions in New York (see Figures B-24 and B-25).

(4) Summary comparisons. Since manyears and obligations were the two features that essentially drove the analysis conducted above, the reader may examine Figures B-27 and B-28, which show the results for all cases. Preceding them, however, is Figure B-26, which gives the actual values extracted from the RATs for net available, contract, and overhead dollars as well as manyears. Also shown for net available dollars and manyears are the comparable results for Case 4 and Case 7 respectively. As is immediately evident, the LP has not reproduced the RAT. Close examination does show some similarities. The RAT and LP results essentially reversed the emphasis on planning and engineering manyears, but the sum of the two was fairly close, 118 versus 112.4. Dredging, construction, flood control, and emergency mangement were very close. Net construction dollars available were also essentially the same. (NB: that the LP estimates how much money goes into each function using factors applied against the amount of appropriations that are obligated.) Some values are quite different (e.g., the amount of work indicated for natural resources and regulatory is much more than the RAT estimated). It is not known what actually was realized in these areas for 1983, so the degree of wrongness and rightness of either estimator is not known. Further analysis might show several possibilities: the RAT estimates may not have been accurate; the differences between the LP and the RAT may be due to definition more than gross errors in the estimating relations; or as is quite likely, more work is called for in developing the interrelations,

CASE 7--OBLIGATION RESULTS

| Appropriation | Obligation | Unexpended |
|---|---|---|
| A 110 | 416.22233 | 1433.77767 |
| A 120 | 58.00000 | 0.00000 |
| A 171 | 6.30000 | 0.00000 |
| A 186 | 52.00000 | 0.00000 |
| A 194 | 1550.00000 | 0.00000 |
| A 250 | 90.00000 | 0.00000 |
| A 451 | 0.00000 | 1075.00000 |
| A 651 | 53.00000 | 0.00000 |
| B 121 | 17.00000 | 0.00000 |
| B 151 | 8.00000 | 0.00000 |
| B 211 | 2250.00000 | 0.00000 |
| B 216 | 41.00000 | 0.00000 |
| B 420 | 90.00000 | 0.00000 |
| B 511 | 13352.00000 | 0.00000 |
| B 516 | 377.00000 | 0.00000 |
| B 517 | 433.00000 | 0.00000 |
| B 740 | 55.00000 | 0.00000 |
| C 111 | 22128.00000 | 0.00000 |
| C 222 | 420.00000 | 0.00000 |
| C 430 | 832.00000 | 0.00000 |
| C 440 | 1883.51438 | 296.48562 |
| C 450 | 0.00000 | 3258.00000 |
| C 470 | 818.00000 | 0.00000 |
| C 500 | 70.00000 | 0.00000 |
| D 100 | 178.00000 | 0.00000 |
| E 420 | 98.00000 | 0.00000 |
| WDEPC | 1600.00000 | 0.00000 |
| TOTAL | 46876.03671 | |

Figure B-24

CASE 7--RESOURCE ALLOCATIONS BY FUNCTIONS

| unction | $ Expended | $ Dir Labor | $ Contract | $ Overhead | Manyears |
|---|---|---|---|---|---|
| ADMNOH | 1729.00839 | 1023.75499 | 172.90083 | 532.35257 | 54.17392 |
| ADMNDR | 217.78030 | 160.26351 | 21.77803 | 35.73876 | 6.68517 |
| PLAN | 2331.87756 | 1351.55194 | 582.96939 | 397.35623 | 43.21253 |
| ENGR | 3523.97788 | 2113.33011 | 704.79553 | 705.85224 | 69.17646 |
| PRGDEV | 154.60541 | 124.97167 | 0.01546 | 29.61828 | 4.32403 |
| R. E. | 402.99408 | 164.21927 | 201.49704 | 37.27777 | 6.02534 |
| CONSTR | 2285.93683 | 1441.42906 | 342.89047 | 501.61730 | 47.70431 |
| DREDG | 3712.60120 | 847.23898 | 1856.30060 | 1009.06162 | 30.00844 |
| NAVIG | 6177.82988 | 2579.46982 | 2471.13180 | 1127.22825 | 100.07259 |
| FLDCNT | 176.05650 | 67.84451 | 70.42259 | 37.78939 | 2.78867 |
| HYDPOW | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| NATRES | 608.05257 | 262.46875 | 243.22101 | 102.36281 | 11.52045 |
| REGUL | 2043.77604 | 1101.02418 | 408.75518 | 533.99668 | 42.10000 |
| EMGMGT | 203.55878 | 106.51332 | 20.35588 | 76.68958 | 3.20809 |
| X-FNC | 74.43399 | 74.43399 | 0.00000 | 0.00000 | 0.00000 |
| TOTAL | | | | | 421.00000 |

Figure B-25

ACTUAL 1983 RAT DATA FOR NEW YORK

| | Net$ | | | | Manyears | |
|---|---|---|---|---|---|---|
| 'unction | RAT | LP* | $Contract | $Overhead | RAT | LP** |
| ADMNOH | 2132 | 2221 | 0 | 439 | 68 | 54.2 |
| ADMNDR | 0 | 261 | 0 | 0 | 0 | 6.7 |
| PLAN | 5957 | 3769 | 2445 | 893 | 97 | 43.2 |
| ENGR | 1170 | 4604 | 329 | 206 | 21 | 69.2 |
| PRGDEV | 547 | 199 | 0 | 126 | 13 | 4.3 |
| R. E. | 47 | 2035 | 0 | 9 | 1 | 6.0 |
| CONSTR | 15246 | 15319 | 13130 | 524 | 56 | 47.7 |
| DREDG | 20260 | 12408 | 19176 | 489 | 26.5 | 30.0 |
| NAVIG | 5787 | 6954 | 525 | 2224 | 106 | 100.1 |
| FLDCNT | 150 | 178 | 0 | 36 | 3.3 | 2.8 |
| HYDPOW | 0 | 0 | 0 | 0 | 0 | 0.0 |
| NATRES | 0 | 608 | 0 | 0 | 0 | 11.5 |
| REGUL | 1504 | 4094 | 226 | 517 | 26 | 42.1 |
| EMGMGT | 196 | 203 | 0 | 78 | 3.2 | 3.2 |
| X-FNC | 0 | 74 | 0 | 0 | 0 | 0.0 |
| TOTAL | 52996 | 52939 | 35381 | 5541 | 421 | 421.0 |

*Taken from Case 4.
**Taken from Case 7.

Figure B-26

| Appropr | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| TOTOBLIG | 33508.47632 | 27103.52059 | 46886.37736 | 52939.30000 | 49775.650 | 45842.16352 | 46876.03671 |
| A 110 | 0.00000 | 0.00000 | 1054.60544 | 1850.00000 | 0.000 | 1840.86352 | 416.22233 |
| A 120 | 0.00000 | 0.00000 | 0.00000 | 58.00000 | 0.000 | 58.00000 | 58.00000 |
| A 171 | 0.00000 | 0.00000 | 0.00000 | 6.30000 | 0.000 | 6.30000 | 6.30000 |
| A 186 | 0.00000 | 0.00000 | 0.00000 | 52.00000 | 0.000 | 52.00000 | 52.00000 |
| A 194 | 876.24024 | 0.00000 | 1550.00000 | 1550.00000 | 1343.842 | 1550.00000 | 1550.00000 |
| A 250 | 0.00000 | 0.00000 | 0.00000 | 90.00000 | 0.000 | 90.00000 | 90.00000 |
| A 451 | 1075.00000 | 0.00000 | 1075.00000 | 1075.00000 | 1075.000 | 1075.00000 | 0.00000 |
| A 651 | 53.00000 | 0.00000 | 53.00000 | 53.00000 | 53.000 | 53.00000 | 53.00000 |
| B 121 | 17.00000 | 0.00000 | 17.00000 | 17.00000 | 17.000 | 17.00000 | 17.00000 |
| B 151 | 8.00000 | 0.00000 | 8.00000 | 8.00000 | 8.000 | 8.00000 | 8.00000 |
| B 211 | 2250.00000 | 2250.00000 | 2250.00000 | 2250.00000 | 2250.000 | 2250.00000 | 2250.00000 |
| B 216 | 41.00000 | 41.00000 | 41.00000 | 41.00000 | 41.000 | 41.00000 | 41.00000 |
| B 420 | 90.00000 | 0.00000 | 90.00000 | 90.00000 | 90.000 | 90.00000 | 90.00000 |
| B 511 | 13352.00000 | 7947.58946 | 13352.00000 | 13352.00000 | 13352.000 | 13352.00000 | 13352.00000 |
| B 516 | 377.00000 | 377.00000 | 377.00000 | 377.00000 | 377.000 | 377.00000 | 377.00000 |
| B 517 | 433.00000 | 433.00000 | 433.00000 | 433.00000 | 433.000 | 433.00000 | 433.00000 |
| B 740 | 55.00000 | 55.00000 | 55.00000 | 55.00000 | 55.000 | 55.00000 | 55.00000 |
| C 111 | 9901.27519 | 12967.70796 | 20153.70565 | 22128.00000 | 21324.807 | 22128.00000 | 22128.00000 |
| C 222 | 420.00000 | 0.00000 | 420.00000 | 420.00000 | 420.000 | 420.00000 | 420.00000 |
| C 430 | 832.00000 | 0.00000 | 0.00000 | 832.00000 | 832.000 | 0.00000 | 832.00000 |
| C 440 | 1061.96090 | 0.00000 | 33.06627 | 2180.00000 | 2180.000 | 0.00000 | 1883.51438 |
| C 450 | 0.00000 | 1868.22317 | 3258.00000 | 3258.00000 | 3258.000 | 0.00000 | 0.00000 |
| C 470 | 818.00000 | 818.00000 | 818.00000 | 818.00000 | 818.000 | 0.00000 | 818.00000 |
| C 500 | 70.00000 | 70.00000 | 70.00000 | 70.00000 | 70.000 | 70.00000 | 70.00000 |
| D 100 | 178.00000 | 178.00000 | 178.00000 | 178.00000 | 178.000 | 178.00000 | 178.00000 |
| E 420 | 0.00000 | 98.00000 | 0.00000 | 98.00000 | 0.000 | 98.00000 | 98.00000 |
| WDEPC | 1600.00000 | 0.00000 | 1600.00000 | 1600.00000 | 1600.000 | 1600.00000 | 1600.00000 |

Figure B-27

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| A | 2 | INA 120 | LL | 0.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 133 |
| A | 3 | INA 171 | LL | 0.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 134 |
| A | 4 | INA 186 | LL | 0.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 135 |
| | 5 | INA 194 | BS | 1550.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 136 |
| D | 6 | INA 250 | BS | 0.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 137 |
| | 7 | INA 451 | BS | 1075.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 138 |
| | 8 | INA 651 | BS | 53.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 139 |
| | 9 | INB 121 | BS | 17.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 140 |
| | 10 | INB 151 | BS | 8.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 141 |
| | 11 | INB 211 | BS | 2250.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 142 |
| | 12 | INB 216 | BS | 41.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 143 |
| | 13 | INB 420 | BS | 90.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 144 |
| | 14 | INB 511 | BS | 13352.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 145 |
| | 15 | INB 516 | BS | 377.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 146 |
| | 16 | INB 517 | BS | 433.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 147 |
| | 17 | INB 740 | BS | 55.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 148 |
| | 18 | INC 111 | BS | 20153.70565 | 1.00000 | 0.00000 | NONE | 0.00000 | 149 |
| | 19 | INC 222 | BS | 420.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 150 |
| A | 20 | INC 430 | LL | 0.00000 | 1.00000 | 0.00000 | NONE | -0.00000 | 151 |
| | 21 | INC 440 | BS | 33.06627 | 1.00000 | 0.00000 | NONE | 0.00000 | 152 |
| | 22 | INC 450 | BS | 3258.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 153 |
| | 23 | INC 470 | BS | 818.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 154 |
| | 24 | INC 500 | BS | 70.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 155 |
| | 25 | IND 100 | BS | 178.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 156 |
| D | 26 | INE 420 | BS | -0.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 157 |
| | 27 | INWDEPC | BS | 1600.00000 | 1.00000 | 0.00000 | NONE | 0.00000 | 158 |
| | 28 | AGA 1 | BS | 2604.60544 | 0.00000 | 0.00000 | NONE | 0.00000 | 159 |
| | 29 | AGA 2 | LL | 0.00000 | 0.00000 | 0.00000 | NONE | -0.16037 | 160 |
| | 30 | AGA 4 | BS | 1075.00000 | 0.00000 | 0.00000 | NONE | 0.00000 | 161 |
| | 31 | AGA 6 | BS | 53.00000 | 0.00000 | 0.00000 | NONE | 0.00000 | 162 |
| | 32 | AGB 1 | BS | 25.00000 | 0.00000 | 0.00000 | NONE | 0.00000 | 163 |
| | 33 | AGB 2 | BS | 2291.00000 | 0.00000 | 0.00000 | NONE | 0.00000 | 164 |
| | 34 | AGB 4 | BS | 90.00000 | 0.00000 | 0.00000 | NONE | 0.00000 | 165 |
| | 35 | AGB 5 | BS | 14162.00000 | 0.00000 | 0.00000 | NONE | 0.00000 | 166 |
| | 36 | AGB 7 | BS | 55.00000 | 0.00000 | 0.00000 | NONE | 0.00000 | 167 |
| | 37 | AGC 1 | BS | 20153.70565 | 0.00000 | 0.00000 | NONE | -0.00000 | 168 |
| | 38 | AGC 2 | BS | 420.00000 | 0.00000 | 0.00000 | NONE | -0.00000 | 169 |
| | 39 | AGC 4 | BS | 4109.06627 | 0.00000 | 0.00000 | NONE | -0.00000 | 170 |
| | 40 | AGC 5 | BS | 70.00000 | 0.00000 | 0.00000 | NONE | -0.00000 | 171 |
| | 41 | AGD 1 | BS | 178.00000 | 0.00000 | 0.00000 | NONE | -0.00000 | 172 |
| | 42 | AGE 4 | LL | 0.00000 | 0.00000 | 0.00000 | NONE | -3.24321 | 173 |
| | 43 | AGWDE | BS | 1600.00000 | 0.00000 | 0.00000 | NONE | -0.00000 | 174 |
| | 44 | TOTOBLIG | BS | 46886.37736 | 0.00000 | 0.00000 | NONE | 0.00000 | 175 |
| | 45 | EXPA$ | BS | 1800.18240 | 0.00000 | 0.00000 | NONE | 0.00000 | 176 |

```
EXIT -- OPTIMAL SOLUTION FOUND.

NO. OF ITERATIONS                74      OBJECTIVE VALUE      4.6886377361689E+04

NORM OF X                 4.689E+04      NORM OF PI                     3.920E+02
```

```
 44  1  1  10 -5.8E-03   75   75  228  3.2E+01 -1.0E+00  43   166   206   3  8.84383385E+00
 45  1  1   9 -5.1E-03   43   43  149  1.6E+03  1.0E+00  44   176   207   3  8.66050602E+00
 46  1  1   9  1.7E-02  228  228  205  3.4E+01  1.2E-02  45   176   211   2  1.40799191E+00
 47  1  1  12  5.0E-01  246  246   75  2.6E-02 -1.2E+02  46   197   211   1  8.15633202E-01
 48  1  1   9  3.4E-03  235  235  246  1.3E+00  2.0E-02  46   199   214   1  8.02872227E-01
 49  1  1  11 -2.2E-03  129  129  235  5.6E+00 -2.3E-01  46   199   214   1  7.98618569E-01
 50  1  1   7 -1.5E-03   35   35  138  4.3E+02  1.0E+00  46   199   214   1  7.86360790E-01
 51  1  1   8 -1.5E-03   14   14  199  1.0E+02 -1.5E-03  46   199   220   1  1.49599458E-01

ITN   51 -- FEASIBLE SOLUTION.  OBJECTIVE =    1.002262217E+04

 52  2  1  30  6.0E+02  240  240   30  3.2E+00 -2.7E+02  47   222   220   0  1.19572286E+04
 53  2  1  23  6.2E+02  246  246  244  7.0E+00  8.7E-01  47   225   223   0  1.63157307E+04
 54  2  1  14 -1.4E+01   81   81  233  2.0E+02 -7.7E-01  47   244   226   0  1.91249302E+04
 55  2  1  13 -4.6E+00   30   30  136  9.1E+02  3.6E+00  48   254   230   0  2.33129034E+04
 56  2  1  25  2.6E+02  244  244  129  6.4E-01 -2.6E+02  49   258   236   0  2.34780000E+04
 57  2  1  10 -1.0E+00   11   11  244  3.3E+02 -1.9E-03  49   259   239   0  2.38097727E+04
 58  2  1  12 -2.9E+00   32   32  132  8.0E+00  1.0E+00  49   259   239   0  2.38328998E+04
 59  2  1  12 -2.9E+00    9    9  131  1.7E+01  1.0E+00  49   259   243   0  2.38820451E+04
 60  2  1  11 -2.8E+00   28   28  240  3.3E+02 -9.4E-03  50   260   243   0  2.48279234E+04

FACTORIZE     2    DEMAND      1    ITERATION    60    INFEAS      0    OBJECTV   2.482792343E+04
SLACKS       33    LINEAR     98    NONLINEAR     0    ELEMS     407    DENSITY   2.4
P4 BUMPS      5    SPIKES     14    CORE REQD  2022    L LIMIT  8398    U LIMIT  7848
LU BUMPS      5    SPIKES     14    AIJ ELEMS   302    L ELEMS   162    U ELEMS    61     F ELEMS     23   21.9
ITN   60 -- FEASIBLE SOLUTION.  OBJECTIVE =    2.482792343E+04

 ITN PH PP NOPT   DJ/RG  +SBS -SBS  -BS    STEP     PIVOT  NSPK    L     U NINF  SINF/OBJECTIVE
 61  2  1   8  3.4E+00  235  235   83  4.2E+02 -1.0E+00  14   162    61   0  2.62342428E+04
 62  2  1   7 -4.1E+00   42   42  133  3.0E+00  2.8E+00  15   164    91   0  2.62465067E+04
 63  2  1  21  2.5E+02  244  244  148  4.8E-01 -2.0E+02  16   165   146   0  2.63677453E+04
 64  2  1   7 -1.1E+00   37   37  246  5.2E+03 -3.0E-03  17   166   196   0  3.22862432E+04
 65  2  1  10 -6.9E+00   83   83  127  6.8E+02  5.2E-01  18   169   256   0  3.70203491E+04
 66  2  1  26  1.3E+03  240  240  235  3.3E+00  1.4E+02  19   173   256   0  4.13923564E+04
 67  2  1  13 -3.5E+00  148  148   42  9.8E+01  1.0E+00  19   177   292   0  4.17392749E+04
 68  2  1  12 -3.2E+00    1    1  240  4.7E+02 -7.5E-03  19   180   292   0  4.32665789E+04
 69  2  1   8  4.8E+00  233  233   81  3.3E+02 -9.9E-01  19   181   294   0  4.48272275E+04
 70  2  1   7 -2.2E+00   15   15  137  3.8E+02  1.0E+00  20   188   341   0  4.56753068E+04
 71  2  1   6 -2.0E+00   34   34  135  9.0E+01  1.0E+00  21   188   397   0  4.58597444E+04
 72  2  1   5 -1.8E+00   36   36  139  5.5E+01  1.0E+00  22   188   446   0  4.59598055E+04
 73  2  1   4 -4.3E-01  143  143  245  2.1E+03 -2.6E-03  23   188   496   0  4.68849739E+04
 74  2  1   1 -1.9E-02   89   89   74  7.4E+01  1.0E+00  24   197   547   0  4.68863774E+04

BIGGEST DJ =  4.547E-13    NORM RG =  0.000E-01    NORM PI =  3.920E+02
```

ITERATIONS
----------

```
CRASH OPTION  1
FREE ROWS     1     FREE COLS     0     PASS2 (E ROWS)    53     PASS3    24     REMAINDER    53

FACTORIZE     1    DEMAND      0    ITERATION      0    INFEAS       1    OBJECTV   0.000000000E-01
SLACKS       54    LINEAR     77    NONLINEAR      0    ELEMS      314    DENSITY   1.8
P4 BUMPS      0    SPIKES      0    CORE REQD   1976    L LIMIT   5679    U LIMIT 11358
LU BUMPS      0    SPIKES      0    AIJ ELEMS    260    L ELEMS     78    U ELEMS     1    F ELEMS      0    0.0
ITN     0 -- INFEASIBLE.  NUM =      5    SUM =    8.781299999E+03
```

| ITN | PH | PP | NOPT | DJ/RG | +SBS | -SBS | -BS | STEP | PIVOT | NSPK | L | U | NINF | SINF/OBJECTIVE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 1 | 13 | -1.0E+00 | 44 | 44 | 1 | 1.7E+03 | -1.0E+00 | 0 | 78 | 1 | 5 | 8.78130000E+03 |
| 2 | 1 | 1 | 33 | -2.7E+01 | 96 | 96 | 11 | 1.4E+00 | -2.9E+01 | 1 | 78 | 12 | 12 | 8.77013559E+03 |
| 3 | 1 | 1 | 37 | -5.5E+00 | 91 | 91 | 168 | 2.5E+00 | -5.5E+00 | 2 | 78 | 30 | 14 | 8.73297488E+03 |
| 4 | 1 | 1 | 36 | -5.4E+00 | 95 | 95 | 172 | 4.8E-01 | -5.4E+00 | 3 | 80 | 34 | 14 | 8.71969394E+03 |
| 5 | 1 | 1 | 35 | -5.2E+00 | 94 | 94 | 171 | 5.1E+00 | -5.2E+00 | 4 | 82 | 38 | 14 | 8.71717927E+03 |
| 6 | 1 | 1 | 34 | -4.4E+00 | 92 | 92 | 169 | 2.5E+02 | -4.4E+00 | 5 | 84 | 41 | 14 | 8.69152038E+03 |
| 7 | 1 | 1 | 33 | -4.0E+00 | 93 | 93 | 170 | 8.9E+01 | -4.0E+00 | 6 | 86 | 45 | 14 | 7.61651983E+03 |
| 8 | 1 | 1 | 32 | -3.7E+00 | 102 | 102 | 20 | 1.2E+03 | -5.3E+00 | 7 | 88 | 49 | 14 | 7.26910977E+03 |
| 9 | 1 | 1 | 31 | -3.6E+00 | 101 | 101 | 178 | 1.2E-03 | -3.6E+00 | 8 | 88 | 63 | 14 | 3.02496235E+03 |
| 10 | 1 | 1 | 30 | -3.3E+00 | 98 | 98 | 175 | 4.2E+02 | -3.3E+00 | 9 | 89 | 67 | 14 | 3.02495838E+03 |
| 11 | 1 | 1 | 29 | -2.9E+00 | 90 | 90 | 167 | 2.3E+02 | -2.9E+00 | 10 | 92 | 71 | 14 | 1.69430780E+03 |
| 12 | 1 | 1 | 32 | -1.8E+00 | 97 | 97 | 174 | 9.4E+00 | -1.8E+00 | 11 | 95 | 75 | 14 | 1.04048771E+03 |
| 13 | 1 | 1 | 30 | -1.0E+00 | 74 | 74 | 181 | 9.0E-02 | -1.0E+00 | 12 | 98 | 79 | 14 | 1.02349964E+03 |
| 14 | 1 | 1 | 28 | -1.0E+00 | 132 | 132 | 9 | 8.0E+00 | -1.0E+00 | 13 | 99 | 80 | 13 | 1.02340944E+03 |
| 15 | 1 | 1 | 26 | -1.0E+00 | 137 | 137 | 15 | 3.8E+02 | 1.0E+00 | 14 | 99 | 82 | 12 | 1.01540944E+03 |
| 16 | 1 | 1 | 25 | -1.0E+00 | 138 | 138 | 14 | 4.3E+02 | -1.0E+00 | 15 | 99 | 84 | 12 | 6.38409438E+02 |
| 17 | 1 | 1 | 23 | 1.0E+00 | 247 | 247 | 206 | 0.0E-01 | -1.0E+00 | 16 | 100 | 86 | 11 | 2.05409438E+02 |
| 18 | 1 | 1 | 22 | 1.0E+00 | 248 | 248 | 207 | 0.0E-01 | -1.0E+00 | 17 | 100 | 90 | 11 | 2.05409438E+02 |
| 19 | 1 | 1 | 21 | 1.0E+00 | 251 | 251 | 210 | 0.0E-01 | -1.0E+00 | 18 | 100 | 94 | 11 | 2.05409438E+02 |
| 20 | 1 | 1 | 20 | -1.0E+00 | 120 | 120 | 201 | 2.1E+01 | -5.0E-02 | 19 | 100 | 98 | 11 | 2.05409438E+02 |
| 21 | 1 | 1 | 26 | 3.0E+00 | 243 | 243 | 110 | 1.0E+00 | -1.0E+00 | 20 | 102 | 124 | 11 | 2.03388026E+02 |
| 22 | 1 | 1 | 25 | 4.0E+00 | 242 | 242 | 200 | 1.2E+00 | 6.0E+00 | 21 | 103 | 128 | 11 | 2.00470340E+02 |
| 23 | 1 | 1 | 25 | 3.0E+00 | 239 | 239 | 106 | 2.2E+00 | -1.0E+00 | 22 | 106 | 132 | 10 | 1.96980169E+02 |
| 24 | 1 | 1 | 25 | 3.0E+00 | 244 | 244 | 203 | 6.0E+00 | -1.0E+00 | 23 | 107 | 136 | 10 | 1.93526679E+02 |
| 25 | 1 | 1 | 23 | 2.0E+00 | 241 | 241 | 197 | 1.6E+01 | 1.3E+00 | 24 | 110 | 140 | 8 | 1.78245668E+02 |
| 26 | 1 | 1 | 29 | -2.0E+00 | 106 | 106 | 198 | 1.6E+00 | -1.0E+00 | 25 | 119 | 143 | 8 | 1.51322303E+02 |
| 27 | 1 | 1 | 27 | -2.0E+00 | 110 | 110 | 202 | 9.5E-02 | -1.0E+00 | 26 | 123 | 143 | 7 | 1.48123606E+02 |
| 28 | 1 | 1 | 25 | -1.7E-01 | 99 | 99 | 141 | 5.9E+01 | 7.2E+00 | 27 | 131 | 143 | 6 | 1.47933801E+02 |
| 29 | 1 | 1 | 21 | -2.4E+00 | 103 | 103 | 180 | 1.1E-01 | -2.4E+00 | 28 | 131 | 153 | 7 | 1.38134623E+02 |
| 30 | 1 | 1 | 21 | -8.1E-02 | 100 | 100 | 85 | 0.0E-01 | 3.3E+00 | 29 | 132 | 155 | 6 | 1.37878213E+02 |
| 31 | 1 | 1 | 20 | -2.7E-02 | 83 | 83 | 235 | 4.1E+02 | -1.0E+00 | 30 | 132 | 156 | 6 | 1.37878213E+02 |
| 32 | 1 | 1 | 20 | -2.6E-02 | 87 | 87 | 209 | 3.2E+03 | -2.6E-02 | 31 | 134 | 158 | 6 | 1.26867210E+02 |
| 33 | 1 | 1 | 21 | 2.5E-01 | 245 | 245 | 204 | 9.3E+00 | -1.2E+00 | 32 | 142 | 165 | 5 | 4.58824382E+01 |
| 34 | 1 | 1 | 20 | 2.0E-01 | 249 | 249 | 208 | 4.7E+00 | -1.2E+00 | 33 | 150 | 168 | 4 | 4.35669120E+01 |
| 35 | 1 | 1 | 19 | -2.4E-02 | 77 | 77 | 230 | 3.6E+02 | -1.0E+00 | 34 | 159 | 171 | 3 | 4.26336726E+01 |
| 36 | 1 | 1 | 18 | -1.2E-02 | 41 | 41 | 147 | 1.8E+02 | 1.0E+00 | 35 | 162 | 173 | 3 | 3.39411037E+01 |
| 37 | 1 | 1 | 17 | -1.1E-02 | 40 | 40 | 146 | 7.0E+01 | 1.0E+00 | 36 | 162 | 180 | 3 | 3.17662365E+01 |
| 38 | 1 | 1 | 16 | -1.1E-02 | 31 | 31 | 130 | 5.3E+01 | 1.0E+00 | 37 | 162 | 187 | 3 | 3.09677835E+01 |
| 39 | 1 | 1 | 15 | -7.9E-03 | 30 | 30 | 129 | 1.1E+03 | 1.0E+00 | 38 | 162 | 194 | 3 | 3.04063752E+01 |
| 40 | 1 | 1 | 14 | -7.8E-03 | 124 | 124 | 2 | 5.8E+01 | 1.0E+00 | 39 | 162 | 201 | 3 | 2.18903607E+01 |

```
--------
       1     NAME          NEW YORK EXAMPLE WIT
       2     ROWS
     134     COLUMNS
     611     RHS
     639     RANGES
     640     BOUNDS
     641     ENDATA


NAMES SELECTED
--------------
OBJECTIVE        OBJECT    (MAX)         1
RHS              RHS                    27
RANGES                                   0
BOUNDS                                   0


MATRIX STATISTICS
-----------------
                    TOTAL       NORMAL          FREE         FIXED       BOUNDED
ROWS                  131           52             1            78             0
COLUMNS               120          120             0             0             0

NO. OF MATRIX ELEMENTS          472      DENSITY         2.978
NO. OF REJECTED COEFFS            4       AIJTOL   1.00000E-10
BIGGEST AND SMALLEST COEFFS     1.19100E+00        1.00000E-04   (EXCLUDING OBJ AND RHS)

LENGTH OF ROW-NAME HASH TABLE               401
COLLISIONS DURING TABLE LOOKUP               86

PARTITION SIZE FOR PARTIAL PRICING          120
```

```
PARAMETERS
----------
MPS INPUT DATA.
ROW LIMIT.............        200    LIST LIMIT.............          0    LOWER BOUND DEFAULT....  0.00E-01
COLUMN LIMIT..........        600    ERROR MESSAGE LIMIT....         10    UPPER BOUND DEFAULT....  1.00E+20
ELEMENTS LIMIT (COEFFS)      3000    PHANTOM ELEMENTS.......          0    AIJ TOLERANCE..........  1.00E-10

FILES.
MPS FILE (INPUT FILE)..         0    OLD BASIS FILE (MAP)...          0    (CARD READER)..........         5
SOLUTION FILE..........         0    NEW BASIS FILE (MAP)...          0    (PRINTER)..............         6
INSERT FILE............         0    BACKUP BASIS FILE......          0    (SCRATCH FILE).........         8
PUNCH FILE.............         0    LOAD FILE..............          0    DUMP FILE..............         0

FREQUENCIES.
LOG ITERATIONS.........         1    CHECK ROW ERROR........         30    CYCLE LIMIT............         1
SAVE NEW BASIS MAP.....       100    FACTORIZE (INVERT).....         60    CYCLE TOLERANCE........  0.00E-01

LP PARAMETERS.
ITERATIONS LIMIT.......       600    FEASIBILITY TOLERANCE..   1.00E-05    PARTIAL PRICE FACTOR...         1
CRASH OPTION...........         1    DJ TOLERANCE...........   1.00E-06    MULTIPLE PRICE.........         0
WEIGHT ON OBJECTIVE....  0.00E-01    PIVOT TOLERANCE........   8.43E-08

NONLINEAR PROBLEMS.
NONLINEAR CONSTRAINTS..         0    SUPERBASICS LIMIT......          1    DERIVATIVE LEVEL.......         3
NONLINEAR JACOBIAN VARS         0    HESSIAN DIMENSION......          0    VERIFY LEVEL...........         0
NONLINEAR OBJECTIV VARS         0    LINESEARCH TOLERANCE...    0.01000    DIFFERENCE INTERVAL....  1.69E-07
PROBLEM NUMBER.........         0    REDUCED-GRADIENT TOL...    0.20000    CONJUGATE-GRADNT METHOD         1

AUGMENTED LAGRANGIAN.
JACOBIAN...............    SPARSE    MAJOR ITERATIONS LIMIT.         20    RADIUS OF CONVERGENCE..  1.00E-02
LAGRANGIAN.............       YES    MINOR ITERATIONS LIMIT.         40    ROW TOLERANCE..........  1.00E-05
PENALTY PARAMETER......  0.00E-01    COMPLETION.............       FULL

MISCELLANEOUS.
LU ROW TOLERANCE.......  1.00E-04    PRINT LEVEL..(JFLXI)...          1    IMBED..................       YES
LU COL TOLERANCE.......   0.10000    DEBUG LEVEL............          0    PRINT SPIKES...........        NO
LU MOD TOLERANCE.......   0.90000    UNBOUNDED OBJECTV VALUE   1.00E+20    UNBOUNDED STEP SIZE....  1.00E+10

NUMBER OF WORDS OF CORE AVAILABLE FOR WORKSPACE    25000
```

```
M I N O S     ---     VERSION  4.0     MAR  1981
= = = = =


SPECS FILE
----------
          BEGIN SPECS PORTION FOR MARMS TESTS      N YES YES YES N
               MAXIMIZE
               OBJECTIVE              =         OBJECT
               RHS                    =         RHS
               ROWS                   =         200
               COLS                   =         600
               ELEMENTS               =        3000
               LOG FREQUENCY          =            1
               SOLUTION               =         YES
          END
```

## APPENDIX B-1

## SAMPLE LINEAR PROGRAMMING OUTPUT

In developing this prototype, ESC used only those computational assets that were resident on ESC's in-house PRIME 750 computer. While it would be expected that a system such as the MARM-LP would necessarily use one of the large commercial LP systems, ESC implemented the prototype on a software system that is in the public domain. The Modular In-core Non-linear Optimization System (MINOS) consists of a library of state-of-the-art FORTRAN subroutines that can be used for both linear and non-linear problems. It expects input to be in standard MPS format and produces reports that parallel those found in MPSX and FMPS (See Annex A). The following pages show the typical output one can expect from an LP system. It must be kept in mind that this information is primarily directed at LP practitioners; reports that "decode" the results and present it in more readable terms would have to be developed using a report writer. The following example is the MINOS output report for Case 3 of the New York Example described in Annex B.

# APPENDIX B-1

# SAMPLE LINEAR PROGRAMMING OUTPUT

it would take to finish all the work. What work would he do? What functions would he reduce? What happens to the organization if an entire project is put on hold? The prototype is the first step in the process of creating a true manpower planning system.

LAST PAGE OF ANNEX B

(within certain limits) to obtain the best results. The input data and output reports capture the exact relations and assumptions that he used to reach a result. Of course we are not naive enough to think that the model's answers will be taken without question. Local conditions may defy quantification and preempt normal forecasts. The allocations and requirements model is above all else a tool for resource planning. It utilizes a powerful technique that enables a decisionmaker to understand the implications of contracting more or reducing strength by 10 percent. In general, one can make the following assessment of the allocations and requirements methodology:

a. It integrates many aspects of the manpower and resource planning problem into one system.

b. It reduces the problem to a definite structure where data, assumptions, and results are explicit.

c. It offers the decisionmaker the opportunity to prioritize and manipulate requirements and allocations respectively without denying the use of local considerations to influence results.

d. It can bridge the periods of present and future workload requirements generators.

e. It can track a myriad of considerations and variables (function, organization, in-house costs, contract, funding sources, and projects).

f. It considers all aspects and elements of the problem together and thus offers a decisionmaker a chance to make more informed decisions because he can now assess the global impact of a decision.

It is not hard to imagine how difficult it would otherwise be for a manpower planner or resource allocator to use individual manpower standards to calculate requirements, knowing that he would not be able to have all the manyears

SUMMARY OF RESULTS

| Case | Options: #FNC | %FNC | K | %K | #Org | Data Changes | Results: #Men | $Obligated |
|---|---|---|---|---|---|---|---|---|
| 1 | f | t | f | f | f | Original NY data | 402 | 33508 |
| 2 | t | f | f | f | f | Original NY data | 322 | 27104 |
| 3 | f | t | t | t | f | Original NY data | 544 | 46886 |
| 4 | f | t | t | t | f | FRATLM for K & V | 623 | 52939 |
| 5 | f | t | t | t | t | FRATLM for K & V | 421 | 49775 |
| 6 | f | t | t | t | t | RMXCON H, G, U | 421 | 45842 |
| 7 | f | t | t | t | t | RMXCON A,X,V,F,T,G | 421 | 46876 |

EXPLANATION:

1) Limiting features: planning, navigation, and regulatory functions are all at maximum percentage limits.
2) Limiting features: engineering, dredging, and regulatory are all at maximum manyear caps.
3) Limiting features: planning and navigation have hit maximum contracting amounts; and dredging, planning, navigation, and regulatory have hit maximum percentage limits.
4) Limiting features: planning and navigation are at maximum contracting limits; regulatory at maximum percentage limit.
5) Limiting features: all functions have contracted to maximum; but program development, regulatory, and emergency operations are essentially 100% contract rather than in-house.
6) Limiting features: all functions have contracted to maximum.
7) Limiting features: all functions have contracted to maximum; and regulatory is at maximum percentage limit.

OPTIONS:

#FNC := personnel limits placed on functions
%FNC := percentage
K := contracting allowed
%K := percentage limit placed on contracting
#org := personnel limit on New York District

(t=true/on; f=false/off)

Figure B-29

quantifications, and construction of the prototype into a mature modeling system. That will be a significant task, but the staffing standards program should generate much of the needed data. Figure B-29 shows which constraints were in force for each case and what interpretation could be made.

6. Conclusions. The above example was not expected to reproduce the actual RAT figures. Some of the numbers are surprisingly close to what New York determined it needed. Others are quite different. More likely is the need for a better requirements generator than the appropriation to function translation that is at the heart of this prototype. Remember that data were based on the averages observed across the entire Corps and only at the appropriation and category level. Perhaps better relations at more detailed levels could be derived (FORCON goes to sub-class distinctions). Eventually there will be workload-based standards to improve requirement generation. In the end, however, the systems developer will still have to consider the tradeoffs among detail, applicability, and validity. The current direction is away from the local estimation that characterized the RAT, and towards widely applicable workload-based standards. Better requirements information will mean better allocations can be made since the latter subsumes the former within the methodology. In fact, many of the decisions made concerning allocations are necessarily subjective (e.g., policy considerations), while a firmly grounded requirements generator can be more objective. The example above attempted to illustrate the type of information and analysis that is possible. The cases above were generated within the space of three hours, with the bulk of the time spent in examining output and deciding on what changes might improve the results. The time to 'crank' through the LP was only a couple of minutes. The manpower planner thus can concentrate on adjusting the model's parameters

CASE COMPARISON OF MANYEARS BY FUNCTION

| Function | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| ADMNOH | 40.21924 | 31.09179 | 62.65108 | 77.31433 | 65.19099 | 53.93073 | 54.17392 |
| ADMNDR | 4.88543 | 4.08571 | 7.57874 | 8.92692 | 7.58994 | 7.26243 | 6.68517 |
| PLAN | 40.24582 | 12.75770 | 54.35162 | 69.86133 | 41.99572 | 62.80104 | 43.21253 |
| ENGR | 83.52533 | 40.00000 | 103.25389 | 112.51699 | 80.33161 | 86.15572 | 69.17646 |
| PRGDEV | 3.46826 | 2.03695 | 4.90075 | 5.57814 | 0.06512 | 5.23655 | 4.32403 |
| R. E. | 11.49117 | 7.39743 | 11.89941 | 12.00993 | 6.02769 | 6.07559 | 6.02534 |
| CONSTR | 52.06058 | 34.73164 | 55.38607 | 56.25378 | 47.73188 | 47.46546 | 47.70431 |
| DREDG | 26.76197 | 35.00000 | 54.35162 | 59.80442 | 28.98968 | 29.93363 | 30.00844 |
| NAVIG | 80.49164 | 102.06124 | 108.70323 | 131.31844 | 126.29998 | 102.07567 | 100.07259 |
| FLDCNT | 4.64525 | 0.22725 | 4.69924 | 4.70964 | 3.29915 | 3.30211 | 2.78867 |
| HYDPOW | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| NATRES | 10.87683 | 9.01436 | 17.82267 | 19.16022 | 13.04897 | 13.43039 | 11.52045 |
| REGUL | 40.24582 | 40.00000 | 54.35162 | 62.33515 | 0.40891 | 0.12257 | 42.10000 |
| EMGMGT | 3.54088 | 3.48509 | 3.55882 | 3.56228 | 0.02035 | 3.20809 | 3.20809 |
| X-FNC | 0.00000 | 0.00744 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| TOTAL | 402.45822 | 321.88916 | 543.51619 | 623.35157 | 421.00000 | 421.00000 | 421.00000 |

Figure B-28

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 46 | EXPX$ | BS | 222.27345 | 0.00000 | 0.00000 | NONE | 0.00000 | 177 |
| | 47 | EXPK$ | BS | 2932.97587 | 0.00000 | 0.00000 | NONE | 0.00000 | 178 |
| | 48 | EXPL$ | BS | 4225.17519 | 0.00000 | 0.00000 | NONE | 0.00000 | 179 |
| | 49 | EXPH$ | BS | 175.20874 | 0.00000 | 0.00000 | NONE | 0.00000 | 180 |
| | 50 | EXPN$ | BS | 403.33083 | 0.00000 | 0.00000 | NONE | 0.00000 | 181 |
| | 51 | EXPQ$ | BS | 2262.43718 | 0.00000 | 0.00000 | NONE | 0.00000 | 182 |
| | 52 | EXPD$ | BS | 3383.07926 | 0.00000 | 0.00000 | NONE | 0.00000 | 183 |
| | 53 | EXPV$ | BS | 5757.04491 | 0.00000 | 0.00000 | NONE | 0.00000 | 184 |
| | 54 | EXPF$ | BS | 178.45664 | 0.00000 | 0.00000 | NONE | 0.00000 | 185 |
| D | 55 | EXPP$ | BS | 0.00000 | 0.00000 | 0.00000 | NONE | 0.00000 | 186 |
| | 56 | EXPT$ | BS | 565.60524 | 0.00000 | 0.00000 | NONE | 0.00000 | 187 |
| | 57 | EXPG$ | BS | 2370.51986 | 0.00000 | 0.00000 | NONE | 0.00000 | 188 |
| | 58 | EXPU$ | BS | 203.36135 | 0.00000 | 0.00000 | NONE | 0.00000 | 189 |
| | 59 | EXPZ$ | BS | 74.43399 | 0.00000 | 0.00000 | NONE | 0.00000 | 190 |
| | 60 | DLAB$A | BS | 1184.33054 | 0.00000 | 0.00000 | NONE | -0.00000 | 191 |
| | 61 | DLAB$X | BS | 181.74444 | 0.00000 | 0.00000 | NONE | 0.00000 | 192 |
| | 62 | DLAB$K | BS | 1699.94741 | 0.00000 | 0.00000 | NONE | 0.00000 | 193 |
| | 63 | DLAB$L | BS | 3167.29776 | 0.00000 | 0.00000 | NONE | 0.00000 | 194 |
| | 64 | DLAB$H | BS | 141.64005 | 0.00000 | 0.00000 | NONE | -0.00000 | 195 |
| | 65 | DLAB$N | BS | 328.71298 | 0.00000 | 0.00000 | NONE | -0.00000 | 196 |
| | 66 | DLAB$Q | BS | 1678.36588 | 0.00000 | 0.00000 | NONE | 0.00000 | 197 |
| | 67 | DLAB$D | BS | 1544.08000 | 0.00000 | 0.00000 | NONE | 0.00000 | 198 |
| | 68 | DLAB$V | BS | 2804.40625 | 0.00000 | 0.00000 | NONE | 0.00000 | 199 |
| | 69 | DLAB$F | BS | 114.61570 | 0.00000 | 0.00000 | NONE | 0.00000 | 200 |
| D | 70 | DLAB$P | BS | 0.00000 | 0.00000 | 0.00000 | NONE | 0.00000 | 201 |
| | 71 | DLAB$T | BS | 406.91025 | 0.00000 | 0.00000 | NONE | -0.00000 | 202 |
| | 72 | DLAB$G | BS | 1422.14015 | 0.00000 | 0.00000 | NONE | 0.00000 | 203 |
| | 73 | DLAB$U | BS | 118.23335 | 0.00000 | 0.00000 | NONE | -0.00000 | 204 |
| | 74 | DLAB$Z | LL | 0.00000 | 0.00000 | 0.00000 | NONE | -0.01885 | 205 |
| | 75 | KLAB$A | LL | 0.00000 | 0.00000 | 0.00000 | NONE | -6.54302 | 206 |
| | 76 | KLAB$X | LL | 0.00000 | 0.00000 | 0.00000 | NONE | -6.40988 | 207 |
| | 77 | KLAB$K | BS | 733.24397 | 0.00000 | 0.00000 | NONE | 0.00000 | 208 |
| | 78 | KLAB$L | LL | 0.00000 | 0.00000 | 0.00000 | NONE | -4.53221 | 209 |
| | 79 | KLAB$H | LL | 0.00000 | 0.00000 | 0.00000 | NONE | -5.19836 | 210 |
| | 80 | KLAB$N | LL | 0.00000 | 0.00000 | 0.00000 | NONE | -5.48721 | 211 |
| | 81 | KLAB$Q | LL | 0.00000 | 0.00000 | 0.00000 | NONE | -4.54031 | 212 |
| | 82 | KLAB$D | LL | 0.00000 | 0.00000 | 0.00000 | NONE | -0.32232 | 213 |
| | 83 | KLAB$V | BS | 1727.11320 | 0.00000 | 0.00000 | NONE | 0.00000 | 214 |
| | 84 | KLAB$F | LL | 0.00000 | 0.00000 | 0.00000 | NONE | -4.94605 | 215 |
| | 85 | KLAB$P | LL | 0.00000 | 0.00000 | 0.00000 | NONE | -4.57917 | 216 |
| | 86 | KLAB$T | LL | 0.00000 | 0.00000 | 0.00000 | NONE | -5.92236 | 217 |
| | 87 | KLAB$G | BS | 258.64180 | 0.00000 | 0.00000 | NONE | 0.00000 | 218 |
| | 88 | KLAB$U | LL | 0.00000 | 0.00000 | 0.00000 | NONE | -3.28069 | 219 |
| | 89 | KLAB$Z | BS | 74.43399 | 0.00000 | 0.00000 | NONE | -0.00000 | 220 |
| | 90 | OH$A | BS | 615.85186 | 0.00000 | 0.00000 | NONE | 0.00000 | 221 |
| | 91 | OH$X | BS | 40.52901 | 0.00000 | 0.00000 | NONE | 0.00000 | 222 |
| | 92 | OH$K | BS | 499.78449 | 0.00000 | 0.00000 | NONE | 0.00000 | 223 |
| | 93 | OH$L | BS | 1057.87743 | 0.00000 | 0.00000 | NONE | 0.00000 | 224 |
| | 94 | OH$H | BS | 33.56869 | 0.00000 | 0.00000 | NONE | 0.00000 | 225 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 95 | OH$N | BS | 74.61785 | 0.00000 | 0.00000 | NONE | 0.00000 | 226 |
| | 96 | OH$Q | BS | 584.07131 | 0.00000 | 0.00000 | NONE | 0.00000 | 227 |
| | 97 | OH$D | BS | 1838.99926 | 0.00000 | 0.00000 | NONE | 0.00000 | 228 |
| | 98 | OH$V | BS | 1225.52546 | 0.00000 | 0.00000 | NONE | 0.00000 | 229 |
| | 99 | OH$F | BS | 63.84094 | 0.00000 | 0.00000 | NONE | 0.00000 | 230 |
| D | 100 | OH$P | BS | 0.00000 | 0.00000 | 0.00000 | NONE | 0.00000 | 231 |
| | 101 | OH$T | BS | 158.69499 | 0.00000 | 0.00000 | NONE | 0.00000 | 232 |
| | 102 | OH$G | BS | 689.73791 | 0.00000 | 0.00000 | NONE | 0.00000 | 233 |
| | 103 | OH$U | BS | 85.12800 | 0.00000 | 0.00000 | NONE | 0.00000 | 234 |
| D | 104 | OH$Z | BS | 0.00000 | 0.00000 | 0.00000 | NONE | 0.00000 | 235 |
| | 105 | MYA | BS | 62.65108 | 0.00000 | 0.00000 | NONE | 0.00000 | 236 |
| | 106 | MYX | BS | 7.57874 | 0.00000 | 0.00000 | NONE | 0.00000 | 237 |
| | 107 | MYK | BS | 54.35162 | 0.00000 | 0.00000 | NONE | 0.00000 | 238 |
| | 108 | MYL | BS | 103.25389 | 0.00000 | 0.00000 | NONE | 0.00000 | 239 |
| | 109 | MYH | BS | 4.90075 | 0.00000 | 0.00000 | NONE | 0.00000 | 240 |
| | 110 | MYN | BS | 11.89941 | 0.00000 | 0.00000 | NONE | 0.00000 | 241 |
| | 111 | MYQ | BS | 55.38607 | 0.00000 | 0.00000 | NONE | 0.00000 | 242 |
| | 112 | MYD | BS | 54.35162 | 0.00000 | 0.00000 | NONE | 0.00000 | 243 |
| | 113 | MYV | BS | 108.70323 | 0.00000 | 0.00000 | NONE | 0.00000 | 244 |
| | 114 | MYF | BS | 4.69924 | 0.00000 | 0.00000 | NONE | 0.00000 | 245 |
| D | 115 | MYP | BS | 0.00000 | 0.00000 | 0.00000 | NONE | 0.00000 | 246 |
| | 116 | MYT | BS | 17.82267 | 0.00000 | 0.00000 | NONE | 0.00000 | 247 |
| | 117 | MYG | BS | 54.35162 | 0.00000 | 0.00000 | NONE | 0.00000 | 248 |
| | 118 | MYU | BS | 3.55882 | 0.00000 | 0.00000 | NONE | 0.00000 | 249 |
| | 119 | MYZ | BS | 0.00744 | 0.00000 | 0.00000 | NONE | 0.00000 | 250 |
| | 120 | TOTPOP | BS | 543.51619 | 0.00000 | 0.00000 | NONE | 0.00000 | 251 |
| | 121 | RHS | EQ | -1.00000 | 0.00000 | -1.00000 | -1.00000 | -46886.37736 | 252 |

ENDRUN

PROBLEM NAME NEW YORK OBJECTIVE VALUE 4.6886377362E+04

STATUS OPTIMAL SOLN ITERATION 74 SUPERBASICS 0

OBJECTIVE OBJECT (MAX)
RHS RHS
RANGES
BOUNDS

SECTION 1 - ROWS

| | NUMBER | ...ROW.. | AT | ...ACTIVITY... | SLACK ACTIVITY | ..LOWER LIMIT. | ..UPPER LIMIT. | .DUAL ACTIVITY | ..I |
|---|---|---|---|---|---|---|---|---|---|
| | 122 | OBJECT | BS | 46886.37736 | -46886.37736 | NONE | NONE | 1.00000 | 1 |
| | 123 | AVA 110 | BS | 1054.60544 | 795.39456 | NONE | 1850.00000 | 0.00000 | 2 |
| | 124 | AVA 120 | BS | 0.00000 | 58.00000 | NONE | 58.00000 | 0.00000 | 3 |
| | 125 | AVA 171 | BS | 0.00000 | 6.30000 | NONE | 6.30000 | 0.00000 | 4 |
| | 126 | AVA 186 | BS | 0.00000 | 52.00000 | NONE | 52.00000 | 0.00000 | 5 |
| A | 127 | AVA 194 | UL | 1550.00000 | 0.00000 | NONE | 1550.00000 | -0.00000 | 6 |
| | 128 | AVA 250 | BS | 0.00000 | 90.00000 | NONE | 90.00000 | 0.00000 | 7 |
| | 129 | AVA 451 | UL | 1075.00000 | 0.00000 | NONE | 1075.00000 | -3.26161 | 8 |
| | 130 | AVA 651 | UL | 53.00000 | 0.00000 | NONE | 53.00000 | -3.95102 | 9 |
| | 131 | AVB 121 | UL | 17.00000 | 0.00000 | NONE | 17.00000 | -1.19662 | 10 |
| | 132 | AVB 151 | UL | 8.00000 | 0.00000 | NONE | 8.00000 | -1.19662 | 11 |
| | 133 | AVB 211 | UL | 2250.00000 | 0.00000 | NONE | 2250.00000 | -1.84492 | 12 |
| | 134 | AVB 216 | UL | 41.00000 | 0.00000 | NONE | 41.00000 | -1.84492 | 13 |
| | 135 | AVB 420 | UL | 90.00000 | 0.00000 | NONE | 90.00000 | -2.00345 | 14 |
| | 136 | AVB 511 | UL | 13352.00000 | 0.00000 | NONE | 13352.00000 | -2.17245 | 15 |
| | 137 | AVB 516 | UL | 377.00000 | 0.00000 | NONE | 377.00000 | -2.17245 | 16 |
| | 138 | AVB 517 | UL | 433.00000 | 0.00000 | NONE | 433.00000 | -2.17245 | 17 |
| | 139 | AVB 740 | UL | 55.00000 | 0.00000 | NONE | 55.00000 | -1.75333 | 18 |
| | 140 | AVC 111 | BS | 20153.70565 | 1974.29435 | NONE | 22128.00000 | 0.00000 | 19 |
| | 141 | AVC 222 | UL | 420.00000 | 0.00000 | NONE | 420.00000 | -5.92895 | 20 |
| | 142 | AVC 430 | BS | 0.00000 | 832.00000 | NONE | 832.00000 | 0.00000 | 21 |
| | 143 | AVC 440 | BS | 33.06627 | 2146.93373 | NONE | 2180.00000 | 0.00000 | 22 |
| A | 144 | AVC 450 | UL | 3258.00000 | 0.00000 | NONE | 3258.00000 | 0.00000 | 23 |
| A | 145 | AVC 470 | UL | 818.00000 | 0.00000 | NONE | 818.00000 | 0.00000 | 24 |
| | 146 | AVC 500 | UL | 70.00000 | 0.00000 | NONE | 70.00000 | -4.12030 | 25 |
| | 147 | AVD 100 | UL | 178.00000 | 0.00000 | NONE | 178.00000 | -4.43347 | 26 |
| | 148 | AVE 420 | BS | 0.00000 | 98.00000 | NONE | 98.00000 | -0.00000 | 27 |
| | 149 | AVWDEPC | UL | 1600.00000 | 0.00000 | NONE | 1600.00000 | -2.68963 | 28 |
| | 150 | TOA 1 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 29 |
| | 151 | TOA 2 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 30 |
| | 152 | TOA 4 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -2.26161 | 31 |
| | 153 | TOA 6 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -2.95102 | 32 |
| | 154 | TOB 1 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -0.19662 | 33 |
| | 155 | TOB 2 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -0.84492 | 34 |
| | 156 | TOB 4 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -1.00345 | 35 |
| | 157 | TOB 5 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -1.17245 | 36 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 158 | TOB 7 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -0.75333 | 37 |
| | 159 | TOC 1 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 38 |
| | 160 | TOC 2 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -4.92895 | 39 |
| | 161 | TOC 4 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 40 |
| | 162 | TOC 5 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -3.12030 | 41 |
| | 163 | TOD 1 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -3.43347 | 42 |
| | 164 | TOE 4 | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 1.00000 | 43 |
| | 165 | TOWDE | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -1.68963 | 44 |
| A | 166 | SUMAPPN | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 45 |
| | 167 | TRTOA$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 6.56187 | 46 |
| | 168 | TRTOX$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 6.42873 | 47 |
| | 169 | TRTOK$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -4.14257 | 48 |
| | 170 | TRTOL$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 4.60763 | 49 |
| | 171 | TRTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.27378 | 50 |
| | 172 | TRTON$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.56262 | 51 |
| | 173 | TRTOQ$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 4.61572 | 52 |
| | 174 | TRTOD$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.32434 | 53 |
| | 175 | TRTOV$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -6.98031 | 54 |
| | 176 | TRTOF$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 4.96491 | 55 |
| | 177 | TRTOP$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 4.59802 | 56 |
| | 178 | TRTOT$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.94121 | 57 |
| A | 179 | TRTOG$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 58 |
| | 180 | TRTOU$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 3.29954 | 59 |
| | 181 | TRTOZ$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.01885 | 60 |
| | 182 | ALOA$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -6.56187 | 61 |
| | 183 | ALOX$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -6.42873 | 62 |
| | 184 | ALOK$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.49362 | 63 |
| | 185 | ALOL$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -4.60763 | 64 |
| | 186 | ALOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -5.27378 | 65 |
| | 187 | ALON$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -5.56262 | 66 |
| | 188 | ALOQ$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -4.61572 | 67 |
| | 189 | ALOD$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -0.32434 | 68 |
| | 190 | ALOV$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 9.95602 | 69 |
| | 191 | ALOF$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -4.96491 | 70 |
| | 192 | ALOP$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -4.59802 | 71 |
| | 193 | ALOT$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -5.94121 | 72 |
| A | 194 | ALOG$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 73 |
| | 195 | ALOU$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -3.29954 | 74 |
| | 196 | ALOZ$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -0.01885 | 75 |
| | 197 | CNVATOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 188.54535 | 76 |
| | 198 | CNVXTOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 188.54535 | 77 |
| | 199 | CNVKTOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -223.54559 | 78 |
| | 200 | CNVLTOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 188.54535 | 79 |
| | 201 | CNVHTOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 188.54535 | 80 |
| | 202 | CNVNTOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 188.54535 | 81 |
| | 203 | CNVQTOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 188.54535 | 82 |
| | 204 | CNVDTOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 20.18848 | 83 |
| | 205 | CNVVTOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -369.68489 | 84 |
| | 206 | CNVFTOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 188.54535 | 85 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 207 | CNVPTOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 188.54535 | 86 |
| | 208 | CNVTTOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 188.54535 | 87 |
| A | 209 | CNVGTOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 88 |
| | 210 | CNVUTOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 188.54535 | 89 |
| | 211 | CNVZTOMY | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 188.54535 | 90 |
| | 212 | SUMALLFN | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -188.54535 | 91 |
| | 213 | TRATOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -6.56187 | 92 |
| | 214 | TRXTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -6.42873 | 93 |
| | 215 | TRKTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 5.49362 | 94 |
| | 216 | TRLTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -4.60763 | 95 |
| | 217 | TRHTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -5.27378 | 96 |
| | 218 | TRNTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -5.56262 | 97 |
| | 219 | TRQTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -4.61572 | 98 |
| | 220 | TRDTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -0.32434 | 99 |
| | 221 | TRVTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 9.95602 | 100 |
| | 222 | TRFTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -4.96491 | 101 |
| | 223 | TRPTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -4.59802 | 102 |
| | 224 | TRTTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -5.94121 | 103 |
| A | 225 | TRGTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 0.00000 | 104 |
| | 226 | TRUTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -3.29954 | 105 |
| | 227 | TRZTOH$ | EQ | 0.00000 | 0.00000 | 0.00000 | 0.00000 | -0.01885 | 106 |
| | 228 | KLIMA% | BS | 90.00911 | -90.00911 | 0.00000 | NONE | 0.00000 | 107 |
| | 229 | KLIMX% | BS | 11.11367 | -11.11367 | 0.00000 | NONE | 0.00000 | 108 |
| | 230 | KLIMK% | LL | 0.00000 | 0.00000 | 0.00000 | NONE | 5.40421 | 109 |
| | 231 | KLIML% | BS | 845.03499 | -845.03499 | 0.00000 | NONE | 0.00000 | 110 |
| | 232 | KLIMN% | BS | 201.66541 | -201.66541 | 0.00000 | NONE | 0.00000 | 111 |
| | 233 | KLIMQ% | BS | 339.36552 | -339.36552 | 0.00000 | NONE | 0.00000 | 112 |
| | 234 | KLIMD% | BS | 1691.53963 | -1691.53963 | 0.00000 | NONE | 0.00000 | 113 |
| | 235 | KLIMV% | LL | 0.00000 | 0.00000 | 0.00000 | NONE | 9.91905 | 114 |
| | 236 | KLIMF% | BS | 53.53698 | -53.53698 | 0.00000 | NONE | 0.00000 | 115 |
| | 237 | KLIMT% | BS | 169.68155 | -169.68155 | 0.00000 | NONE | 0.00000 | 116 |
| | 238 | QMA% | BS | 46.05215 | -46.05215 | 0.00000 | NONE | 0.00000 | 117 |
| | 239 | QMX% | BS | 19.59706 | -19.59706 | 0.00000 | NONE | 0.00000 | 118 |
| | 240 | QMK% | LL | 0.00000 | 0.00000 | 0.00000 | NONE | 412.09094 | 119 |
| | 241 | QML% | BS | 59.80095 | -59.80095 | 0.00000 | NONE | 0.00000 | 120 |
| | 242 | QMH% | BS | 22.27506 | -22.27506 | 0.00000 | NONE | 0.00000 | 121 |
| | 243 | QMN% | BS | 15.27640 | -15.27640 | 0.00000 | NONE | 0.00000 | 122 |
| | 244 | QMQ% | BS | 26.14134 | -26.14134 | 0.00000 | NONE | -0.00000 | 123 |
| | 245 | QMD% | LL | 0.00000 | 0.00000 | 0.00000 | NONE | 168.35687 | 124 |
| | 246 | QMV% | LL | 0.00000 | 0.00000 | 0.00000 | NONE | 558.23024 | 125 |
| | 247 | QMF% | BS | 49.65237 | -49.65237 | 0.00000 | NONE | 0.00000 | 126 |
| | 248 | QMP% | BS | 54.35162 | -54.35162 | 0.00000 | NONE | 0.00000 | 127 |
| | 249 | QMT% | BS | 36.52895 | -36.52895 | 0.00000 | NONE | 0.00000 | 128 |
| | 250 | QMG% | LL | 0.00000 | 0.00000 | 0.00000 | NONE | 188.54535 | 129 |
| | 251 | QMU% | BS | 23.61698 | -23.61698 | 0.00000 | NONE | 0.00000 | 130 |
| | 252 | QMZ% | BS | 27.16836 | -27.16836 | 0.00000 | NONE | 0.00000 | 131 |

LAST PAGE OF REPORT

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8-85

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