Study of Potential Benefits
Of
Geographic Information Systems
For
Large Fire Incident Management

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Introduction

The use of Geographic Information System (GIS) technology has increased dramatically over the past 10 to 15 years in a wide range of venues. GIS is both an analysis and a display technology, meaning it can be used to both track information and display it in a variety of graphic formats. Most often, these graphic formats are maps that visually represent the data "behind the scenes."

GIS naturally fits with a wide range of natural resource decision making, from land suitability analyses to optimal road location, and from recreation and cultural resource management to fire planning, suppression, and management efforts. The USDA Forest Service has begun to implement GIS technology in this latter role. As with the introduction and use of any tool or technology, questions arise as to the benefits of such an introduction.

This document reports on a study structured to address this question. It begins with an Executive Summary, intended for the reader interested in an overview of the study and its findings. A more detailed discussion of the study process and findings follows the Summary.

Executive Summary

Project Overview

The goals of the study were to evaluate the use of GIS technology as a tool in reducing large fire costs, and to identify the benefits of GIS to incident management efforts. These goals were identified in the Pacific Southwest Region FY 97-98 Fire and Aviation Management Strategic Plan (Item 4.14).

Only "large fires" were considered in this study.[1] The participants in the study were all members of incident command teams based in California and included individuals employed by federal and local government agencies. Existing literature on this topic was reviewed for both content and to limit the focus of this project.

Both quantitative and qualitative benefits were examined and discussed. As no two fires are the same, and as no single fire can be fought twice, a direct cost comparison of fire management efforts using GIS vs. fire management efforts not using GIS is impossible and traditional "cost-benefit" analysis methods were not applicable. However, both real and potential tangible benefits were identified.

Qualitative benefits were more readily apparent, and the potential benefits identified by fire incident personnel were abundant. Qualitative benefits include any item which was seen to make fire management efforts "better" - from more rapidly identifying fire direction to more easily providing information to the public.

A multi-phase approach was used to gather information for this study. The phases consisted of a planning meeting, a survey, and a set of personal interviews and discussions with incident command team members from throughout California.

Project Findings

The participants in this study overwhelmingly agreed that GIS would be a useful tool for large fire management. It would be a complement to existing tools, providing information that is not available now, and allowing certain information to be gathered in a more timely or cost effective manner than it can currently be collected. They believed GIS would put accurate information in the hands of those who need it, when and where they need it. Better information leads to better decision making, which in turn leads to fighting a fire more effectively, efficiently and safely. It will also facilitate the public information portion of fire management, freeing valuable resources for other efforts.

An indication that GIS is a technology desired by fire incident team members, rather than one being forced upon them was the number of people suggesting ways to use the technology. Although all new tools require user training, fire management personnel see this tool and can think of how to apply it to their tasks - unlike many technologies where the user often has no idea of why they might want to use the product at hand even if they know how the software works.

[1] See page 9 for a definition of a large fire.

The complete list of fire suppression and incident management tasks in which a GIS would be beneficial, as well as the technical details of what GIS "layers" (datasets) are needed to create these improvements is found later in this document.
Examples of benefits identified include:

- Saving money by not performing unnecessary tasks ($2 million in Palm Fire, 1997);
- Improving safety by accurately identifying hazardous areas;
- Improving crew confidence in management decisions by confirming human observations with hard data;
- Saving time by reducing the extent of physical reconnaissance efforts;
- Reducing individual "learning curves" as new fire management personnel are brought into a fire, or as the scope of a fire broadens across jurisdictions.

Impediments to the realization of these benefits do exist and need remediation before GIS can achieve its potential as a useful tool. Some of these impediments are:

- Data quality and availability;
- Hardware and software availability;
- Hardware rugged enough to handle the conditions;
- Sufficient education and awareness;
- Procurement procedures that stifle innovation and the acquisition of tools.

Potential remedies and solutions for these problems are:

- Greater budgetary support for GIS in the fire community;
- Through interagency cooperation, create a seamless geospatial database for wildland fire management irrespective of agency jurisdiction and borders;
- Emphasize the development of technology transfer applications that make GIS easier to use and more accessible to the fire community;
- Add GIS awareness training to the Situation Unit Leader training program that would introduce the power of GIS as a fire management tool and provide descriptions of the available national or regional data sets;
- Full integration of GIS and fire planning staff;
- Land management and fire management staff should work closely on the integration of GIS within their respective areas of responsibility;
- Add a computer specialist to national teams who would provide computer system support and GIS expertise.

In summary, the study findings were that GIS can be an excellent tool for improving fire management efforts. Before this potential can be fully achieved, the technology must be more fully implemented and users educated as to both how and why to use GIS. As GIS use becomes more commonplace, these same questions should be revisited to provide more information about how fire incident team members actually use and benefit from GIS, as well as continuing to address future obstacles that may occur.

Detailed Project Overview

Study Objectives

The goals of the study were to evaluate the use of GIS technology as a tool in reducing large fire costs, and to identify the benefit of GIS to incident management efforts. These goals were identified in the Pacific Southwest Region FY 97-98 Fire and Aviation Management Strategic Plan (Item 4.14).

The study sought to identify GIS contributions to wildland fire management, and, to the extent possible, quantify them in terms of measurable values. Non-economic and non-quantifiable benefits were to be ascertained and accounted for as well. Study participants were to consist of Forest Service and non-Forest Service personnel involved in incident command situations, with care taken not to assemble a group consisting exclusively of "friends" of GIS. The final result of the study was to be a report providing both testimonial evidence and economic analysis of the benefits of GIS.

Literature Review

Geographic Information System (GIS) technology has emerged in the last 15 years as a new and powerful approach to address a wide range of spatially-related decision-making issues. As early as the mid-1980's reported applications of GIS technology encompassed a variety of analytical and cartographic venues, from tourism (Li 1987) to aquaculture (Kapetsky, *et al*. 1987). Over time, this field has expanded in terms of both applications and theoretical development. This development can be at least partially traced in the increasing number of textbooks in the field ranging from Burrough (1986) through Aronoff (1989) to Maguire, *et al*. (1991), Bernhardsen (1992), and Burrough and McDonnell (1998). In applications, in 1991 the General Accounting Office estimated that federal agency expenditures on GIS would increase by 60% from fiscal year 1990 to fiscal year 1992 (USGAO 1991a).

The fundamental spatial nature of natural resources has led to a widespread adoption and use of GIS technology by natural resource managers. In 1991 the two largest federal agency uses of GIS were the management of natural resources and environmental assessment and monitoring (USGAO 1991a). Forestry applications of GIS have ranged from investigation of wildland-urban interfaces (Greenberg and Bradley 1997) to black bear habitat use (van Manen and Pelton 1997). Wildland fire related uses of GIS include burned area emergency rehabilitation area identification (Lachowski *et al*. 1997) and fire simulation modeling (Green *et al.* 1995) and (Finney 1998).

Early in the growth of GIS adoption and development, various authors identified a need and a framework for applying benefit-cost analysis to GIS. Benefit-cost analysis has a long history of theoretical development and applications. Mishan (1976) serves as a classic and standard textbook in this field, with Boardman *et. al.* (1996) serving as an example of a more recent textbook on this topic. In forestry and natural resources, the concepts of benefit-cost analysis have been addressed by Davis (1954), Gregory (1972 and 1987), and Davis and Johnson (1987).

As early as 1987, Prisley and Mead presented a framework for analyzing the implementation of GIS. They identified three classes of benefits: those attributable to increased efficiency (doing current tasks faster), greater effectiveness (making better decisions), and intangible and unanticipated benefits (benefits not expected but realized as a result of technology adoption). The authors note that the difficulty of estimating these benefit types increases from efficiency to intangible, and that the latter two classes may be more qualitatively, rather than quantitatively, measured.

Dickinson (1989) presents a similar analytical framework, specifically noting that "Unfortunately, many of the benefits of the use of geographic information and GIS are not easily assigned a dollar value. These benefits are know as intangible benefits and are often reported as "better decision making,' 'better planning,' or 'better information.'" (p. 413). The author goes on to note that "It is believed that these intangible benefits offer higher value to the agency than do those benefits which are more easily reported in dollar terms (such as higher cost-performance or faster output of maps)." (p. 413).

Aronoff (1989) identifies five classes of benefits associated with GIS implementation:

- increased efficiency,
- new non-marketable services;
- new marketable services;
- better decisions; and
- intangible benefits.

Although Aronoff's schema provides additional refinement to the "tangible" and "intangible" structure proposed by other authors, his descriptions of these five classes fit within the two benefit model. Aronoff also notes the difficulty in quantifying non-marketable benefits, and the uncertainty associated with predicting the value of "better decisions". He indicates that limits exist in using cost-benefit analysis, in that in such work "There are many important factors that will not be included. It is not unusual for other considerations, completely separate from cost-benefits, to determine whether a system is acquired." (p.26).

Bernhardsen (1992) describes a benefit-cost approach for analyzing GIS investments, identifying both "tangible" and "intangible" benefits associated with GIS adoption. Tangible benefits closely resemble those efficiency benefits described by other authors, while the intangible benefits include those types of benefits also described as intangible or effectiveness-related by other authors.

Gillespie (1991) identified two classes of GIS benefits: those associated with efficiency increases and those increased effectiveness. He went on to note that "Effectiveness benefits depend on the value of the unique GIS output." (p. 84). In 1992, he further noted the difficulty in estimating effectiveness benefits. As a result, he indicates that traditional benefit-cost analysis would tend to result in serious underestimation of the value of GIS (Gillespie 1992). Worrall (1994) presents a comprehensive lists of efficiency and effectiveness benefits attributable to GIS use as part of a review of GIS implementation. Worrall specifically points out that productivity gains associated with GIS administration are tied to personnel policies and the use of the time previously spent in those activities replaced by the GIS.

In practice, various authors have reported results of GIS use in a benefit-cost context. Gillespie (1992) estimated a 75% variable cost saving when using a GIS over manual methods, resulting in major efficiency savings for the Federal government. He also preliminarily estimated effectiveness benefits in the "…billions of dollars" (p. 263). The US Government Accounting Office (1992) reported USDA Forest Service estimates of a cost avoidance of approximately $1.5 billion resulting from the adoption of GIS technology, as compared to estimated costs totaling $312 million. However, Worrall (1994) as part of a review of cost-benefit analyses of GIS implementation in local governments in the United Kingdom, concluded "…that some GIS implementations are more an act of faith than the result of a period of critical evaluation." (p. 545).

The growth in use of GIS in a wide variety of fields at least partially supports Worrall's (1994) conclusions about the implementation of GIS. Although GIS program implementation has come under scrutiny (USGAO 1990,1991b), GIS implementation has proceeded. In terms of investment strategies, GIS shares characteristics with other information technologies (IT). Successful IT investments require the involvement of senior management, an overall mission focus, and a comprehensive IT investment approach (OMB 1995). The GAO (1997) notes the importance of developing performance measures for the impact of IT, and that the success of such a process rests on the need to begin with the basics, including the "…delivery of reliable cost effective, high quality IT products and services…" and "…internal customer satisfaction…." (p. 14).

As early as 1992 Gillespie observed that "The greatest benefits of GIS technology come from its ability to enable agencies to do things they either could not or would not do without GIS." (p. 263). However, the author continues, noting that the "Reliance on traditional cost-benefit studies will probably tend to slow the adoption of GIS and lead to an underinvestment in the technology." (p. 263). But Worrall (1994) identified the "'GIS paradox': while many perceive, financially, that they cannot afford GIS, they realise that, strategically and operationally, they cannot afford not to acquire GIS." (p. 563). Such findings leave organizations in somewhat of a quandary with respect to the use of GIS technology: the most important benefits of GIS implementations are those most difficult to quantify, and the inability to quantify such benefits may result in a reluctance to make the kinds of investments needed to achieve the key benefits attributable to such investments of allowing organizations to become more effective.

One alternative for moving out of such a quandary, lies in a mixed analytical approach to determining the benefits and costs of GIS implementation. Such an approach would focus on providing a quantitative estimate of the more straightforward efficiency benefits of GIS implementation, while providing a more qualitative estimate of the effective benefits. Using such an approach would allow for the capture of the wide range of benefits that GIS implementation can generate for an organization, while recognizing the well-documented difficulties inherent in effectiveness benefit quantification. Realizing the benefits of GIS implementation requires the successful implementation of GIS technology. As noted above (USGAO 1997), the successful implementation of any IT requires that GIS products meet customer needs. For GIS products, such needs would include accuracy, precision, cost, and timeliness of delivery.

Methods and Procedures

A multi-phase approach was used to collect information for this report. These phases were:

- Initial scoping meeting;
- Survey questionnaire of type one team members;
- Subsequent focus groups and interviews.

The literature review suggests that quantifying the tangible benefits associated with the use of GIS technology in large incident management situations would be, at best, difficult. Furthermore, an analysis confined to just this aspect of benefits would ignore perhaps the richest source of benefits: the intangible and non-quantifiable. The contractor’s extensive GIS experience confirms these conclusions. Therefore, in an attempt to capture both benefits types, and to meet study objectives, we adopted the multi-phased approach noted above.

Initial Scoping meeting
The objectives of the initial focus group were to create guidelines for the economic analysis, and to identify participants in surveys and subsequent focus group meetings. A secondary objective was to identify the steps taken during a wildland fire and where GIS could play, or currently plays, a role in the process.

Survey
A questionnaire survey form was developed from the information that was derived from the initial focus group. Drafts of the survey were reviewed by Forest Service personnel. The design allowed the participants to select from provided answer sets, to rank various items and to provide limited additional information. This design permitted the use of a tabular database to store the answers and lent itself to statistical analysis. The survey was sent out to incident command team members, each of the participants had five weeks to respond. A copy of the survey can be found in Appendix II.

Subsequent focus groups
The purpose of subsequent focus groups and one on one interviews was to determine qualitative information and example situations that could not be provided for in the questionnaire format. The focus groups' participants represented different areas of the incident command structure of fire management teams currently in place. To facilitate the focus group meetings, the literature review and survey results were presented, along with information regarding BAER (Burned Area Rehabilitation) efforts. For more information on BAER, see Appendix III. The participants were then asked to provide examples of intangible and tangible benefits of GIS on large fires. Roadblocks to GIS implementation within the fire community and potential solutions to identified obstacles were also discussed. Three different formats were used to gather focus group feedback: meeting, conference calls, and individual phone interviews.

Results of Each Project Phase

Initial Scoping Meeting

The initial focus group was composed of a small group of Forest Service fire management and contractor personnel (Appendix A). The discussion, held at the contractor's office, lasted for over four hours on June 18, 1998. As described above, the objective of this meeting was to determine the scope of the rest of the study. Thus, this small group of individuals focused their efforts on determining the use—current and potential—of GIS in large fire incident management.

The discussions of this group generated four key results, each of which are discussed in more detail below:

1. Focused the project on the uses of GIS for large fire incident management;

2. Identified the mapping "production function" associated with large fire incident management;

3. Identified the current and potential uses of GIS in the mapping production function; and

4. Identified key mapping elements associated with large fire incident management, and their characteristics.

1. Focused Project

There are several circumstances in which GIS could prove beneficial within wildland fire management. In the pre-fire stages these include fuels management and risk and hazard assessment. During an active fire GIS can track line construction and produces briefing maps portraying the incident. Post-fire GIS can be used as a monitoring tool and to update fuel layers. In order to most effectively use limited project resources the scope of the project was limited to large fire incident management. By narrowing the scope, the project could focus on the needs of incident management teams between the time a fire starts and when it is controlled, and finally out.

The definition of a large fire used in this study came from a previous cost benefit study for Fire Time and Accounting Systems. A large fire was described as:

- Organization camp incident;
- Average duration of 6 days;
- Approximately 40 crews with 800 casual employees;
- Aproximately100 overhead – regular government employees;
- 135 items of equipment ordered.

2. Identified the mapping production function

Large incident fires require multiple map products (Table 1, following page), from initial attack location to final BAER (Burned Area Emergency Rehabilitation) analysis. In general terms, these map products are currently hand-derived, and serve individualized functions.

In addition to these map products, the group identified four other map types that could provide incident managers with valuable information to aid in decision making:

- Maps of fuels in incident area
- Maps of potential fire behavior, including FARSITE outputs
- Fire history map
- Three-dimensional maps of incident area

3. Identified the current and potential uses of GIS in the mapping production function

As illustrated in Table 1, GIS already plays a role in the development of some of the maps currently used in large incident management activities but is not in widespread use. The group noted that large incident management teams generally have better access to and availability of GIS than local incident teams. Throughout the specification of the map product production function, the group frequently noted the value and importance of having GIS as an analytical and decision support tool in incident management. But the group also quite clearly identified two key and interrelated points that limit the use of GIS in large incident management: data availability and response time.

The nature of large fire incidents places a premium on speed in response. Therefore, to be used effectively, GIS data layers must be both complete and quickly available for the incident command team and fire staff. It was pointed out that the Forest Service in California has extremely current and complete GIS data layers. Although this was acknowledged, it was further noted that internal organizational issues seem to have prevented these data layers from becoming fully available Service-wide.

Table 1. *Summary of map types used in a large fire suppression incident management.*

Map Type	Description/Use	Update Frequency	GIS Use: Current or Potential
Incident Response a.k.a. "Briefing Maps"	Visual summary of accomplishments, resource locations, areas of responsibilities, controlled and uncontrolled line segments	Twice per 24 hrs	Potential
Public Briefing	Summarize general fire location, controlled areas, and potential fire spread; at large scale.	Once per 24 hrs	Potential
Fire Spread Progression	Generally hand drawn consecutive perimeter map based on topographic map coverage	Twice per 24 hrs	Some current
Transportation System	Hand drawn map identifying road location/type, potential drop and vehicle assembly points, potential helispots, and control points (*e.g.* bridges, gates)	Once per incident, unless fire grows substantially	Potential
Land Ownership and Protection Responsibilities	Land ownership, fire responsibility allocation and cost apportionment within fireshed, also including structures (by type/location) and other improvements (*e.g.* power lines), and cultural resources	As needed	Potential
Pilot Briefing	Air hazards, fire location and perimeter, helispot locations.	Once per 24 hrs, or as needed	Potential
Shift Maps	Smaller versions of briefing maps used by field crews	Twice per 24 hrs	
Suppression Damage	Hand compiled and drawn summary of resource damage attributable to fire suppression activities	Once per incident, at close.	Potential
Amount and Type of Line	Summary of type of fire line constructed by slope and soils type	Once per incident, at close.	Potential
Fire Intensity for BAER	Summary of fuel consumption, cultural resource damage, improvements and protection system damage, resource loss. Used as basis for BAER response planning	Once per incident, at close.	Potential
Radio Frequency Coverage	Identification of clear signal areas and potential radio transmission "dead spots"	Once per incident	Potential

4. Identified key mapping elements

The group proceeded to identify five map products where GIS could play a key role in improving management decision making:

- Briefing maps
- Fire spread/progression maps
- Transportation maps
- Land ownership maps
- BAER

The "Briefing" maps were then analyzed in more detail to determine the current and potential role of GIS in the production of these map products (Table 2).

Table 2. *Map use and actual and potential use of GIS by briefing type*

Briefing Type	Map Used	GIS Used	GIS Potential
Weather	Sometimes	No	?
Current Situation	Yes, 100%	Sometimes (25%)	Yes
Expected Situation	Sometimes	Sometimes (5%)	Yes
Division Assignments	Yes, 100%	Sometimes (5%)	Yes
Safety	No	No	Maybe
Transportation/logistics	Yes, 100%	Sometimes (25%)	Yes
Communications	No	No	Yes
Air Operations	No	No	No
Finance	No	No	No
Public	Yes	Sometimes (25%)	Yes

The group discussed the use of such map products within the context of three day (extended attack) and six day (large incident) average duration fires. Overall, the group felt that the same map products would be used in both situations, with the potential exceptions of the Wildland Fire Situation Analysis (WFSA) and BAER activities; which would require different products due to their specific requirements. Otherwise, three and six day fires would generally have the same requirements, but with greater complexity and sophistication.

Survey

The survey was developed from information gathered in the initial scoping meeting. The survey was sent to approximately 150 individuals during the week of September 7, 1998. Responses were due back within five weeks of when the survey was sent. Thirty-five percent (53) of the surveys were returned and tabulated. A copy of the survey and corresponding responses can be found in Appendix II. It is important to note that not all respondents answered all of the questions and there are minor fluctuations in the total number of respondents to each question.

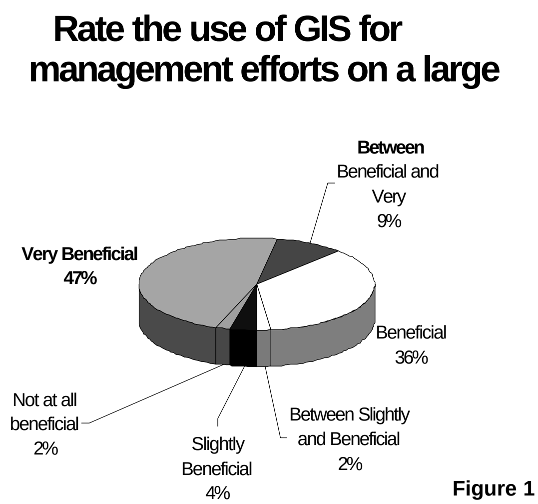

Figure 1

Forty-eight of 52 respondents, an overwhelming 92 percent, said that GIS is beneficial to very beneficial for incident management efforts on large fires (Figure 1). As a situation unit leader commented, "one of the best tools I can have is a GIS system."

The survey then asked the respondents to rank the usefulness of GIS in each step of incident command response. For the majority (14 of 16) of the tasks listed, seventy percent or more of the survey participants currently use GIS or believe that GIS would help in the management of large wildland fires. (Figure 2)

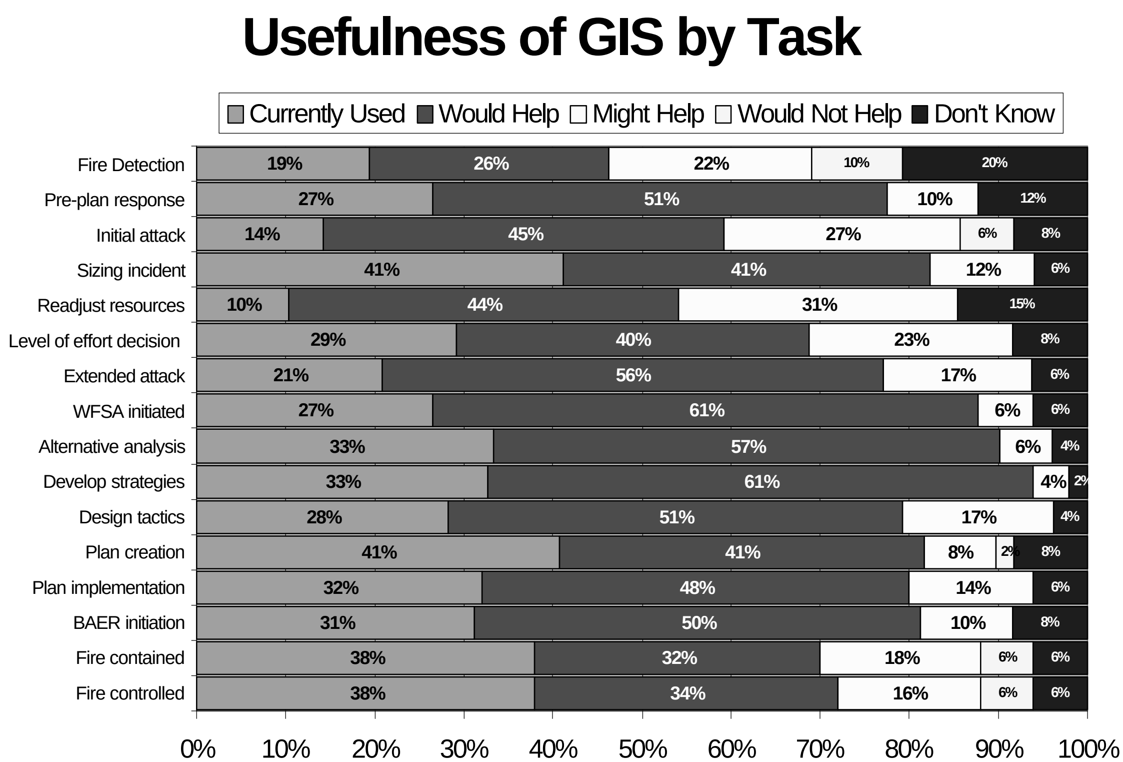

Figure 2

When ranking the importance of GIS layers for fire management, the top five layers for the survey respondents are: structure types and groupings, fuels, fire perimeters, and ownership. (Figure 3) There was some confusion by the respondents in the interpretation of the map accuracy part of the question. Due the confusion the results of the question were dropped.

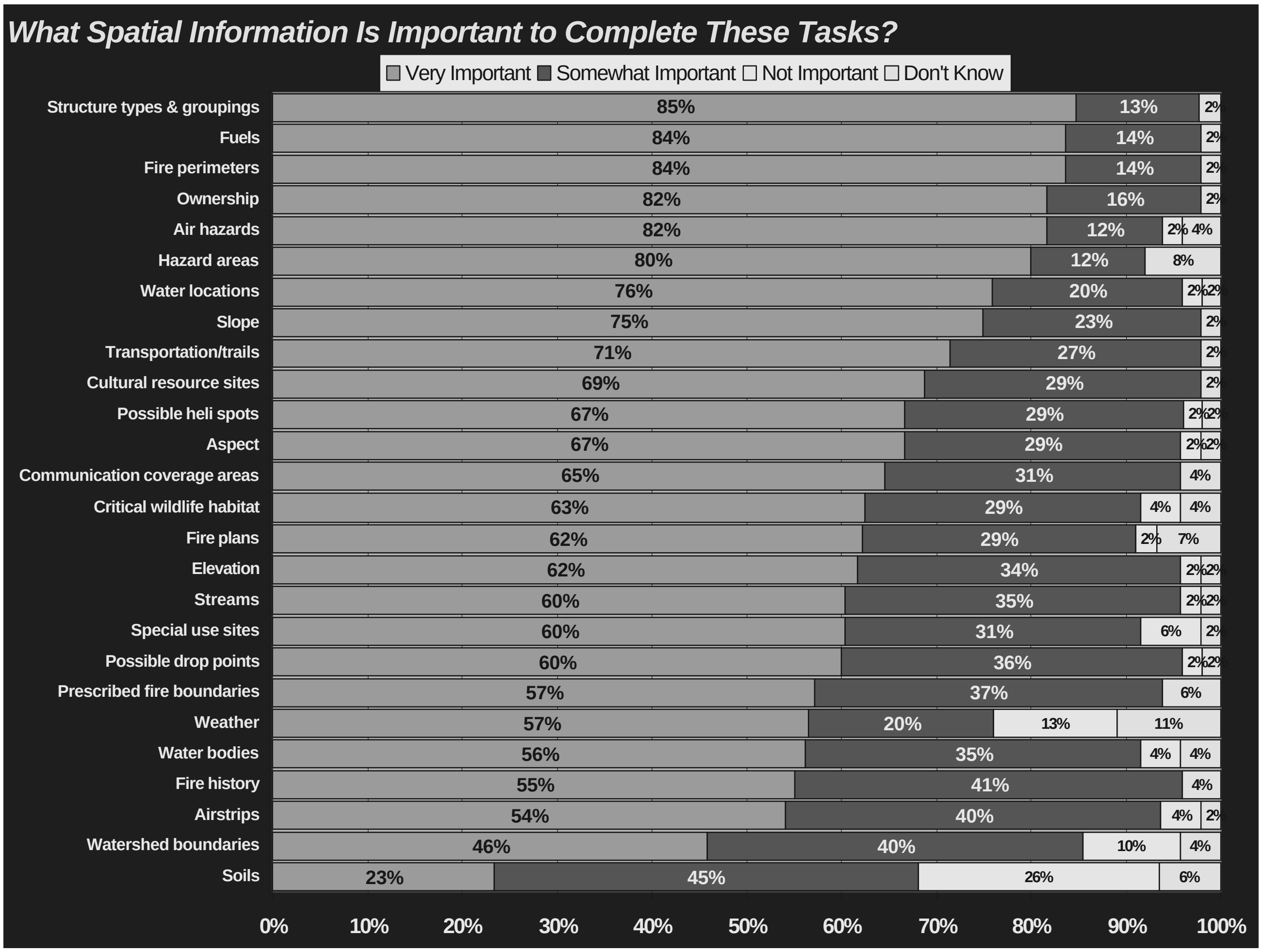

Figure 3

A majority of survey respondents believe that a fire of 1000 acres is approximately the point at which GIS becomes useful. But many would still find GIS a useful tool on fires that involve less acreage. (Figure 4)

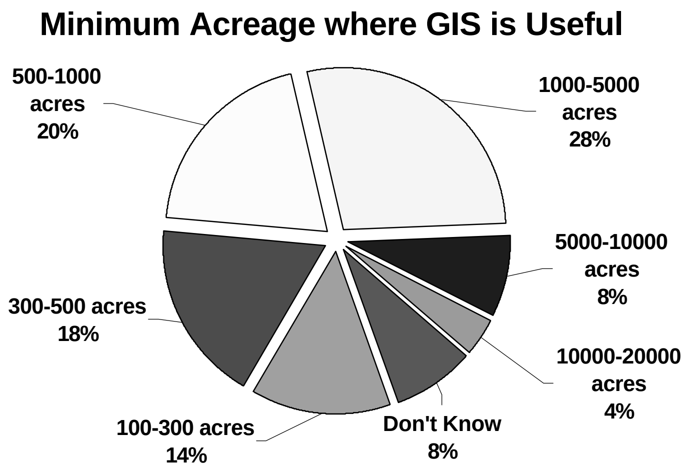

Figure 4

92 percent, or 48 of 52, respondents rate GIS as a beneficial to very beneficial public relations tool as compared to the information that is currently provided to the public. (Figure 5) Another survey comment noted that "GIS is able to provide a more detailed map to the public and educate them on what we are doing and why we are spending that kind of money."

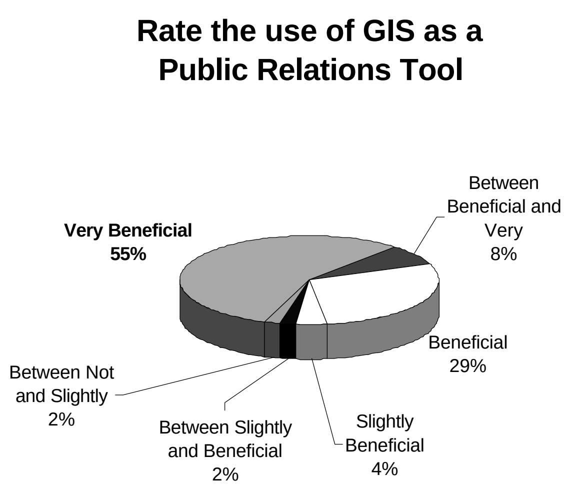

Figure 5

In response to the question that asked what technologies they would like to see available in conjunction with GIS a majority said GPS (Global Positioning Systems) would be useful. Digital weather information updates and infrared images of the fire came in a close second. (Figure 6)

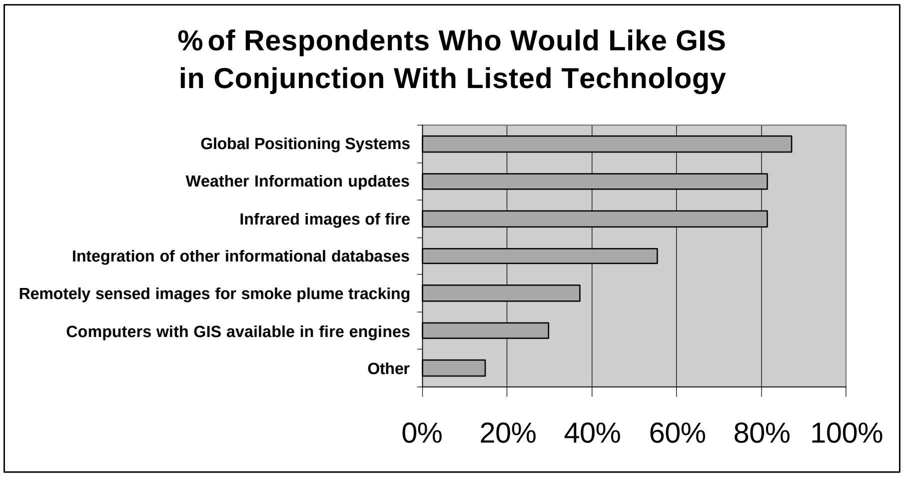

Figure 6

There was some confusion over the question dealing with cost saving by activity. Some of the respondents added in the cost to produce the layers while others did not consider this cost. To present the results of this question the categories were collapsed down into three categories: Some savings, Increased cost or no savings, and Unknown. (Figure 7)

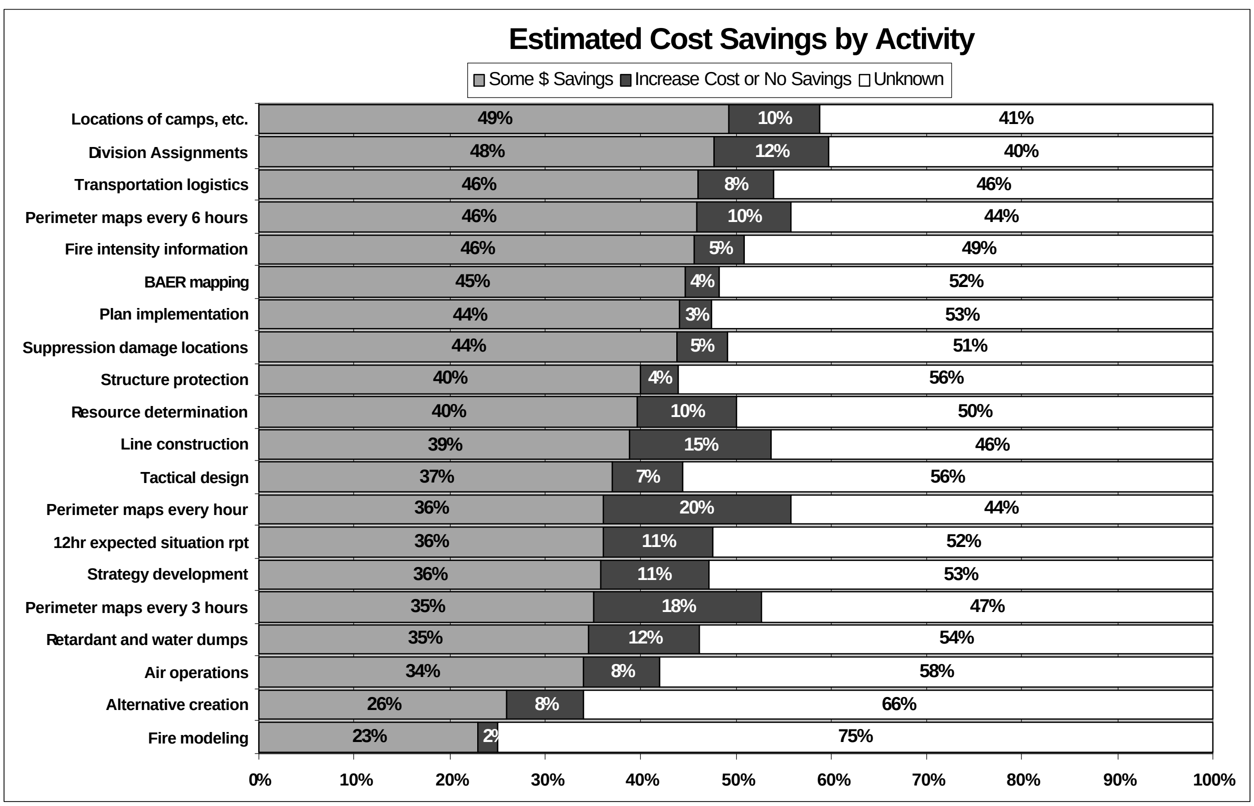

Figure 7

The question pertaining to the GIS layers that are currently available in the region was included to find out if the survey respondents knew what information is currently available. Each of the coverages listed is made available for every National Forest in Region 5. Many of the respondents knew of basic layers such as roads, streams, digital elevation models and coverages produced from them. (Table 3)

Administrative boundaries	32	Watershed boundaries	23	Landsat 30m imagery	7	Cultural resource sites	17
Aspect	24	Slope	25	Plantation units	14	Soils	19
Digital ortho quads	21	Digital elevation models	23	County boundaries	27	Ecological unit boundaries	10
Existing vegetation	30	Critical wildlife habitat	17	Recreation sites	21	Contours	24
Fire history	30	Streams	29	Roads	33	Roadless areas	15
Water bodies	30	Springs	14	Trails	26	Old growth areas	10
Land management plan areas	19	7.5 quad boundaries	24	Public land survey	16	Critical plant habitat	14
Mortality	5	Spot 10m imagery	8	Wilderness boundaries	28	Oil and gas leases	8
RNAs	9	Special use sites	10	Forest stand boundaries	12	Planning units	7

Table 3 *Note: Number of responses indicate how many knew of each layer*

The overall results of the survey indicate that GIS would be a helpful tool for type one incident management teams on large fires. GIS would facilitate many of their tasks; there are GIS layers that could provide important information for fire management, and GIS would be a very beneficial public information tool.

Subsequent Focus Groups

Three different formats were used to gather focus group feedback: meeting, conference calls, and individual phone interviews. The meeting was held on November 3, 1998 at the Regional Forest Service Fire and Aviation Management office at Mather Field, California. The conference call was held on December 2, 1998, and the phone interview took place on December 21, 1998. Focus group contributors can be found in Appendix I. The goal of these meetings were to access the knowledge and experience of the Forest Service personnel to provide richness and depth to the survey responses, for both the tangible and intangible benefits of GIS use.

The group began with a discussion of the dual role of GIS as both an “Intelligence” tool and as an “Informational” tool. The group then focused on four areas of intangible GIS benefits:

- The power of GIS as a briefing and debriefing tool;
- The role of GIS as a public information and marketing tool;
- The power of GIS in providing continuity in the planning efforts needed for a large fire; and
- The ability of GIS to assist in WFSA development.

Finally, the group concluded by identifying roadblocks that impede the successful implementation of GIS in large fire incident management, and identifying potential solutions to such obstacles.

GIS Roles: “Intelligence” and “Information”

While a GIS can certainly provides a plethora of information, more value can be realized from using GIS to provide *intelligence*. The group developed a working definition of intelligence as "having the right information at the right time for planning and decision making”. Given this definition, the participants went on to provide examples of where GIS provided, or could have provided, valuable intelligence in fire suppression.

- On the 20,000 acre “Palm Fire” over the July 4, 1994 weekend, the incident management team had access to limited GIS, GPS, infrared scanner information. Based on the intelligence about site conditions provided by the technology, the team made the decision to forego constructing fire lines along approximately 38% of the fire perimeter, even though structures were potentially at risk in the fire. Containment and control objectives were achieved, at a cost savings of some $2 million (33%) of a total suppression cost of $6 million.

- A 300-acre fire required a WFSA. An available GIS database provided fire history intelligence to help predict and plan the fire perimeter. Without the GIS database, the fire history would have not been known.

- On the 1994 "Blackwell Fire" in Idaho, part of the suppression activities included saving two communities. Progress of the fire was tracked by air, and upon the reconnaissance, the fire was found to be heading towards an old burn area. Upon reaching this area, the fire stopped. Fire history intelligence provided by a GIS could have saved time in the planning efforts by identifying an area where previous fire activities would work to aid fire control efforts, reducing the need for such expensive reconnaissance efforts.

- The terrain in the Florida fires of 1998 proved to be a challenge. Because the area was so flat - the difference between a ridge and a bay may be two feet - fire crews' ability to assess the fires behavior was hampered. The only thing visible was smoke.

  Through the use of GIS and remote sensing, maps were produced that showed the location of the fires relative to structures and communities. This allowed fire managers to track the progress of different fires and make better decisions on the placement of resources.

- On the 1998 Hopper fire in the Los Padres National Forest, the availability of GIS early in the process provided quick access to maps portraying the situation. This lead to faster and probably better fire management decisions. In this case GIS proved to be a valuable fire suppression tool.

- In the 1970's there was a lot of energy put into "pre-attacks". Pre-attacks provided fire managers information on water sources, possible camp locations, potential heli-bases and drop points, fire history, fire breaks, access, and structures which were laid over the top of topographic maps. This information was important for making good decisions in fire suppression efforts.

  Much of this information has not been transferred over to GIS and is predominantly out of date in its current format. If available this information would be important for pre-planning efforts, identifying risks, and coordinating resources

  The example cited was an effort in which GIS was combined with other information. By combining these datasets the BLM discovered specific characteristics of the typical fire. With this information, they were able to reduce the resources needed year round for fire suppression in the area.

These examples point out the value of GIS-generated information as intelligence: ***information that reached decision-makers at the right time and in the right form to assist in decision making***.

An individual went on to explain that GIS is different way of looking at fire management. GIS helps people visualize the situation and gives them a look at the big picture. It is basically a new language that is icon, or picture, oriented.

The incident commanders in the group had used GIS on a majority of the large fires they had responded to in the last two years. GIS has been used to determine fire location, rates of spread, intensities, and what is within the path of the fire. This has led to more confidence in the decisions they make on how to manage particular fires, and if fire management resources need to “size-up” or “size-down”. Furthermore, it is believed that GIS could be used to look ahead of the fire and put lines in where they best fit, back fire in areas well ahead of time, keep personnel out of hazardous areas or situations, and save money by not doing what does not need to be done.

In more generalized terms, appropriate GIS data can provide information to the WFSA process to help set priorities, allocate resources, and to evaluate the risks associated with alternative courses of action.

The group noted that due to the complex nature of wildland fire management, GIS could play very different roles on different size of fires. For instance, on fires that involve such issues as urban interfaces, concerns related to topography, or valuable historic and natural resources, GIS may prove to be a valuable decision support tool on even small, 100-300 acre, fires. But in wildland areas where these concerns don't exist, GIS may be more beneficial as a monitoring tool that will give fire managers information on rate of spread and resources necessary to manage the fire.

The group also noted that since GIS is relatively new and has not been used on many fires, evaluating the efficiency of GIS as actually used is extremely difficult. Basically, the use of GIS in incident management was felt to still be in the “experimental” stage

GIS as a Briefing and Debriefing Tool

Large fire incident response requires that many individuals know a great deal about a variety of topics, from base camp location to current fire perimeter. The group identified GIS as an important technology to allow for faster and more effective briefing of fire suppression personnel at all levels, from the incident command team to field crew leaders.

High quality maps included in briefings, as well as visual information in an easy to understand format, give a better sense of the issues on a particular incident. With high quality maps to facilitate information exchange among management and crew personnel, much of the speculation as to where the head of the fire is and how much line has been constructed. In addition, high quality maps with pertinent information result in more confidence in the management team and their decisions. All of these factors combine to create greater efficiency and improve safety.

For example, a large fire where a new management team assumes control requires a "transition package" that includes a WFSA, weather, vegetation, fire history, and other information. The group agreed that a GIS-enhanced transition package could cut in half the time required for the new team to be "up to speed, from 24 hours to 12 hours. Such GIS enhancements were also thought to potentially generate considerable cost savings when transition from a Type II to a Type I incident management team was required.

A GIS, especially integrated with GPS, could help with briefings throughout the incident management hierarchy, reduce data errors in such activities as estimates of line construction, and help ensure data are not lost in transmission.

Beyond direct incident information management, the group also noted that GIS could provide a framework that would assist in documenting and passing along acquired knowledge from each fire incident. This incident or institutional history could play several roles. It could help assess decisions on a particular fire, assist in any possible litigation that result from a fire, be used on fires that are similar or occur in the same area to help determine logistics and tactics, assist in the testing and calibration of fire simulation models, and provide new fire management personnel with the opportunity to tap into the accumulated knowledge of those who have worked through similar situations in the past.

GIS as a Public Information and Marketing Tool

The group expressed the opinion that the Forest Service does a good job of fighting fires, but not as good a job of letting the public know how, or how well, it accomplishes these tasks. GIS-based map products would aid in this information dissemination process, allowing the public to be included, and thus become stakeholders, in the efforts.

An example given pertained to the Florida fires. GIS-produced maps were shared with the local agencies, commissioners, and media. Maps were also posted on the Internet so the public could have access to information about the fires in relation to their local community.

Such efforts could extend to pre-suppression work, through GIS derived map products tied to such models as FARSITE[2]. In addition, use of GIS, GPS, remote sensing imagery, etc., would demonstrate to the public that the Forest Service was indeed at the forefront of science through its appropriate use of the current and best technology.

[2] FARSITE is a fire simulation model.

As one participant noted, "Information capabilities are driving the need for more, faster, and better information." Fire incident managers are finding the demand for quick information about an incident has grown tremendously. The pressure to "report up" is coming from such sources as the media, regional offices, the Washington Office, Congress, and even the White House. GIS provides them with the ability to respond quickly and provide an easy to understand picture of the current situation. They have found that by providing a map of the current situation when "reporting up" alleviates some of the constant pressure for information and allows them to focus on the task at hand.

Incident managers have also found that the Multi-Agency Coordination Group is more likely to provide resources to incidents with easily understood information and graphics. Thus the incidents that have access to technology end up with more support.

GIS and Planning Continuity

The group expressed the belief that current fire suppression activities often occur outside the scope of larger land management activities in a local area. A fully integrated GIS could provide an opportunity to bring incident management into the larger sphere of the use of fire in wildland management.

GIS and the WFSA

Overall, GIS was seen as a valuable tool that could enhance the accuracy and timeliness of map products. This was especially true in the area of fire intensity maps that could become part of the larger "Wildland Fire Situation Analysis" (WFSA). The WFSA is a required operational planning document that guides the incident response team and helps determine the benefits and costs of fire suppression activities. GIS, if delivered in a timely fashion, was felt to have important benefits in the development of the WFSA.

Access to local GIS databases could also reduce the time required to develop incident planning products. For example, the use of GIS in the development of a WFSA could help ensure that fire control efforts better match with the fire situation, including political considerations, resource objectives, past fire history, etc. This would be especially important for non-local management teams.

WFSA is the cornerstone for fire suppression and provides the ground rules for fire management. It usually justifies the suppression efforts taking place. But its weaknesses include the lack a spatial component and that there is little or no pre-planing being done. GIS could remedy each of these issues.

Impediments to GIS Use

The group identified the following four issue areas as potential impediments to the successful use of GIS in incident management:

- Data quality and availability;
- Hardware and software availability;
- Education;
- Awareness.

Data must be of high quality and must be managed in a way to ease and facilitate its use, including quickly moving data from the specialist to the users. This is not always the case today. An example comes from the Florida fires. An incident management team had to wait three days for GIS data layers because the local GIS contact was not available and no one else understood the information.

Furthermore, an agency's corporate database tends to stop at the agency's boundaries. Given that fires move, often quite rapidly, across institutional land management boundaries, the partial nature of the available data limits its usefulness. This is a lesser problem in California, where the California Department of Forestry and the USDA Forest Service are cooperating in the creation of necessary information.

It is difficult to find affordable equipment that is portable and rugged enough to handle being transported and used in most wildland fire situations. The equipment used has to be transported across dirt roads and operate off of generators in hot, dry, dusty conditions. In addition, agency procurement procedures can stifle innovation in the acquisition and use of GIS tools. Both hardware and application software tools are difficult and time consuming to order. Such difficulties decrease the likelihood of the successful use of GIS.

More personnel training is need to capture the power of GIS, and more awareness of the capabilities of GIS is needed throughout the organization. To take advantage of this new tool, managers need to understand its significance. The group felt that many agency personnel view GIS as merely a map making tool, and do not understand the analytical power GIS possesses. As a result, incident management teams may not order up GIS as part of their response package because its use and value are misunderstood. Even though the military style Incident Command Structure works very well it does not currently include GIS as part of the structure.

Potential Remedies to Aid in GIS Implementation

In addition to greater budgetary support, the group offered up the following potential remedies to aid in the effective integration and use of GIS in incident management, based on the issue areas identified above.

First, more inter-agency, inter-government, and private land holder cooperation in data capture efforts for fire management is needed so that incident management efforts have a more complete database to use. Cooperation would ensure that the data is described in the same manner and not be limited to jurisdictional boundaries. Additionally, a computer specialist should be added to national teams. A specialist would be able to set up computer systems at fire camps and supply GIS expertise.

Second, the procurement process for GIS hardware and software needs to be streamlined and expedited. These processes should also facilitate continuity of support for GIS activities linked to hardware purchases.

Third, emphasis should be placed on the development of training programs to make GIS more accessible. Wildland fire management teams not only need to know how GIS can be an effective mapping tool but also an effective analysis tool. GIS needs to come out of the realm of specialist and become more of an everyday tool. Applications need to be easy to use and users need to be able to relate to the software. Fire based GIS application training on such programs as FARSITE would not only advance the use of a valuable program but also build an understanding of GIS.

And fourth, to increase awareness of the power of GIS, a GIS awareness component should be added to the Situation Unit Leader training program. Such a training course would provide an overview of GIS capabilities and insight as to what datasets are available. In addition, the GIS and fire planning staff members should coordinate projects to realize any possible cost savings. More opportunities should be created for land management and fire management personnel to work together to better integrate work, and to serve as a more effective advocates for GIS use.

Summary of results

The combined results of the literature review, scoping meeting, survey, and subsequent focus groups and telephone interview show that:

- Traditional cost-benefit analysis is not effective for decision making regarding GIS.
- The complex nature of wildland fire makes it difficult to evaluate the role and benefit of GIS on every fire;
- Currently, several aspects of large fire incident management require map production and that GIS is used very minimally for these functions.
- The spatial analysis and map producing capabilities found in GIS are both important.
- A majority of fire personnel on incident management teams consider GIS a useful and beneficial tool.
- Almost every fire suppression task would benefit from GIS and there were several geospatial layers identified that would be useful in accomplishing these tasks.
- Effective geospatial data layers must be complete, understood, and quickly available.
- GIS can provide, and has provided, valuable intelligence for fire suppression activities.
- GIS could provide the mechanism that would make transition of fire management responsibilities from one team to another much easier.
- Information capabilities are driving the need for better faster information.
- Briefing materials could greatly be improved with GIS and would result in:
    - More crew confidence in the management team;
    - Better understanding of the incident, which leads to a safer working environment;
    - The ability to provide better and quicker reports on the current situation to higher level management.

- As a public relations and marketing tool, GIS is very beneficial.
- GIS could provide a framework that would assist in passing along the institutional history of fire management and to train new wildland fire managers.
- Incident progression stored in a GIS could help settle damage claims or litigation.
- A fully integrated GIS could provide continuity in planning and create accountability where there currently is none.
- The analysis function of GIS can be used to predict fire behavior, analyze suppression efforts and reduce unnecessary effort, and identify hazardous situations.
- GIS needs to become an everyday tool with easy to use applications.
- GIS provides a new way of looking at wildland fire management that is not integrated into the current Incident Command Structure.

Impediments to GIS Use:

- Data quality and availability;
- Hardware and software availability;
- Hardware rugged enough to handle the conditions;
- Sufficient education and awareness;
- Procurement procedures that stifle innovation and the acquisition of tools.

Potential Remedies and Solutions

- Greater budgetary support for GIS in the fire community;
- Through interagency cooperation create a seamless geospatial database for wildland fire management irrespective of agency jurisdiction and borders;
- Emphasize the development of technology transfer applications that make GIS easier to use and more accessible to the fire community;

- Add to the Situation Unit Leader training program GIS awareness training that would introduce them to the power of GIS as a mapping and analysis tool and provide descriptions of the available national or regional data sets;

- Full integration of GIS and fire planning staff;

- Land management and fire management staff should work closely to integrate GIS within their respective areas of responsibility;

- Add a computer specialist to national teams who would provide computer system support and GIS expertise.

In conclusion,

- GIS can, and has, provided quantitative, tangible benefits in large fire incident management (*e.g.* the $2 million cost savings attributed to GIS use on the Palm Fire), but predicting the occurrence and magnitude of such benefit events is problematic;

- As suggested in the literature and confirmed by this study, GIS can and does provide major intangible benefits associated with its use in large fire incident management. Key classes of intangible benefits include improved safety, improved public relations, reduced individual "learning curves", and more accurate and time planning.

- Real impediments exist that prevent the full realization of the power GIS can bring to large incident management; and

- Elimination of these impediments would help move GIS from the realm of the potential to the real in terms of full exploitation of benefits.

Opportunities for further study
The results of this study suggest the need for additional work in three issue areas.

First, given the impediments to GIS identified in this study, the development of a comprehensive GIS implementation plan appears timely. This implementation plan should roll out the technology in a manner to best realize the benefits described in this document.

Second, a comprehensive plan for the use of GIS beyond large incident management could provide a powerful basis for structuring GIS activities that would provide management synergies and increase the effectiveness of the agency.

Third, As GIS use becomes more commonplace, these same questions should be revisited to provide more information about how fire incident team members actually use and benefit from GIS, as well as continuing to address future obstacles which may occur.

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Appendix I

Meeting Participants

Initial Scoping Group

- Dorothy Albright. GIS Coordination, Fire and Aviation Management, R-5. USDA Forest Service.
- Ken Blonski. Assistant Director Fire and Aviation Management, R-5. USDA Forest Service.
- Jerry Clements. Emergency Operations Coordinator, North Zone, R-5. USDA Forest Service.
- Mike Dougherty. Emergency Operations Coordinator, South Zone, R-5. USDA Forest Service.

Focus Group Contributors

- Dorothy Albright. GIS Coordination, Fire and Aviation Management, R-5. USDA Forest Service.
- Ken Blonski. Assistant Director Fire and Aviation Management, R-5. USDA Forest Service.
- George Ewan. Emergency Operations Coordinator, South Zone, R-5. USDA Forest Service.
- Aaron Gelobter. Fire Management Officer, USDA Forest Service.
- Greg Greenhoe. Fire Management Officer, USDA Forest Service.
- Mike Maden. Fire Management Officer, USDA Forest Service
- Joe Millar. District Fire Management Officer, USDA Forest Service
- John Newman. Station Manager, Bureau of Land Management.
- Susie Stingley. Emergency Operations Coordinator, North Zone, R-5. USDA Forest Service.

Contract Representatives

Pacific Meridian Resources

- Paul Hardwick. Project Manager, Pacific Meridian Resources.
- Bruce Fox, Ph.D. Forest Management and Economics.
- Kass Green. Forest Economist, Pacific Meridian Resources.

Appendix II

Survey

Question 1 What is your position within the incident command structure?

Answer		Number of Responses
Fire behavior Analyst		2
Aviation Officer		3
Line Officer		3
Incident Commander		8
Public Information Officer		3
BAER Unit Leader		1
Safety Officer		2
Situation Unit Leader		2
Ground Support Unit Leader		1
Other		28
ADFMO	2	
Battlion Chief	1	
District Fire Mgmt Officer/Operat	1	
District Fuels Officer - Air Ops	1	
Div. Sup/Air Tactical Group Sup	1	
Div. Sup/Battalion Chief	1	
Division Supervisor	3	
Facalities	1	
Finance Section Chief	2	
Fire Captain/Supply Unit Leader	1	
GIS Mapping	1	
Operations Section Chief	4	
Park Ranger	1	
Plan Chief/Operations Chief	1	
Planning Section Chief	3	
Procurement Unit Leader	2	
Resource Unit Leader	2	
	28	

Question 2 Rate the use of GIS for incident management efforts on a large fire

Not at all beneficial		Slightly Beneficial		Beneficial		Very Beneficial
1	0	2	1	19	5	24

Question 3 *On what percentage of large fires did you use GIS in the last two years?*

Answer	*Number of Responses*
0-15%	11
15-30%	3
30-45%	3
45-60%	9
60-75%	3
75-90%	9
>90%	15

Question 4 *In each step of the fire response table please check if you know that GIS layers are currently used. If not, do you think they would be helpful, might be helpful, would not be helpful, or you just don't know.*

	GIS Currently Used	*GIS Would Help*	*GIS Might Help*	*GIS Would Not Help*	*Don't Know*
Fire Detection	9	13	11	5	10
Pre-plan response	13	25	5		6
Initial attack	7	22	13	3	4
Sizing incident	21	21	6		3
Readjust resources	5	21	15		7
Level of effort decision	14	19	11		4
Extended attack	10	27	8		3
WSFA initiated	13	30	3		3
Alternative analysis	17	29	3		2
Develop strategies	16	30	2		1
Design tactics	15	27	9		2
Plan creation	20	20	4	1	4
Plan implementation	16	24	7		3
BAER initiation	15	24	5		4
Fire contained	19	16	9	3	3
Fire controlled	19	17	8	3	3

Question 5 ***Please rank the importance of each piece of spatial information for fire suppression efforts on a large fire. If you think the spatial information is very or somewhat important, please identify what map accuracy would be appropriate for that piece of information.***

	Very Important	*Somewhat Important*	*Not Important*	*Don't Know*	*10 ft.*	*50 ft.*	*100 ft.*	*350 ft.*	*500 ft.*	*1000 ft.*
Fire plans	28	13	1	3	7	10	13	5	3	1
Prescribed fire boundaries	28	18		3	12	9	19	1	3	
Fire perimeters	41	7		1	12	17	16		1	
Hazard areas	40	6		4	21	11	13	1		
Fire history	27	20		2	4	8	17	11	5	
Air hazards	40	6	1	2	22	9	11	2	1	
Possible heli spots	34	15	1	1	12	12	18	4	1	
Possible drop points	30	18	1	1	11	10	18	6	1	
Transportation/trails	35	13		1	10	16	15	5	1	
Water locations	38	10	1	1	10	12	19	3	2	
Ownership	40	8		1	16	16	9	5	1	
Structure types & groupings	39	6		1	13	18	14	1		
Airstrips	26	19	2	1	6	9	12	5	8	4
Slope	36	11		1	11	14	14	1		
Aspect	32	14	1	1	9	14	14	1	2	
Elevation	29	16	1	1	11	16	14	1		
Soils	11	21	12	3	3	8	13	6	2	5
Cultural resource sites	33	14		1	22	12	8	1	1	
Critical wildlife habitat	30	14	2	2	14	7	12	4	5	1
Communication coverage areas	31	15		2	6	10	13	3	6	6
Water bodies	27	17	2	2	5	9	16	6	2	2
Fuels	41	7		1	10	6	18	1	6	1
Weather	26	9	6	5	7	6	6	2	4	8
Streams	29	17	1	1	8	9	15	5	4	
Watershed boundaries	22	19	5	2	6	8	13	3	8	3
Special use sites	29	15	3	1	10	11	12	3	6	

Question 6 ***If GIS layers were available, estimate the cost savings for the following activities.***

	Increase Cost	*No Savings*	*< $10K*	*$10 - 25K*	*$25 - 50K*	*$50 - 100K*	*> $100K*	*Unknown*
Line construction	2	6	1	4	3	4	3	25
Alternative creation	2	2	4		3	3	1	33
Resource determination	1	5	5	2	4		3	29
Strategy development		6	3	2	5	2	3	28
Tactical design		4	3	3	2	3	4	30
Plan implementation		2	5	6	2		2	31
BAER mapping	1	1	8	3	4		1	29
12hr expected situation report	1	6	5	2		1	1	32
Division Assignments	1	7	6	5		1	2	27
Transportation logistics	1	4	6	6	2	1		29
Air operations	1	3	1	2	4	1	7	29
Fire modeling	1		3	1	3	1	2	36
Perimeter maps every hour	11	1	1	3	1	1	2	27
Perimeter maps every 3 hours	9	1	3	2	1	2		27
Perimeter maps every 6 hours	4	2	6	5	2	2		27
Retardant and water dumps	2	4	2	2	5	2	4	28
Structure protection	2		2	2	3	2	10	28
Suppression damage locations	2	1	7	3	4	1	2	29
Fire intensity information		3	8	3	3	2	1	28
Locations of camps, water, drops,	1	5	6	6	3	2	1	26

Question 7 ***How beneficial would maps produced from GIS be as a public information tool compared to the information that is currently provided to the public?***

Not at all beneficial — *Slightly Beneficial* — *Beneficial* — *Very Beneficial*

1 **0** **2** **1** **15** **4** **28**

Question 8 *At what size fire do you feel using GIS becomes more beneficial than not having it available?*

Answer	*Number of Responses*
100-300 acres	7
300-500 acres	9
500-1000 acres	10
1000-5000 acres	14
5000-10000 acres	4
10000-20000 acres	2
Don't Know	4

Question 9 *Place a check next to the GIS layers that you know are currently available within the Region.*

Answer	*Responses*	*Answer*	*Responses*	*Answer*	*Responses*
Administrative boundaries	32	Streams	29	Forest stand boundaries	12
Aspect	24	Springs	14	Cultural resource sites	17
Digital Ortho Quads	21	7.5 quad boundaries	24	Soils	19
Existing vegetation	30	Spot 10M imagery	8	Ecological unit boundaries	10
Fire history	30	Special use sites	10	Contours	24
Water bodies	30	Landsat 30M imagery	7	Roadless Areas	15
Land Mgmt plan areas	19	Plantation Units	14	Critical Plant habitat	14
Mortality	5	County boundaries	27	Oil and Gas Leases	8
RNAs	9	Recreation sites	21	Planning Units	7
Watershed boundaries	23	Roads	33	Old growth areas	10
Slope	25	Trails	26		
Digital elevation models	23	Public land survey	16		
Critical wildlife habitat	17	Wilderness boundaries	28		

Note: Number of responses indicate how many knew of each layer

Question 10 ***GIS has the ability to link several technologies. If GIS was available to you on a large fire please check which technologies you would like to have available to you.***

Answer	*Number of Responses*
Global Positioning Systems	46
Infrared images of fire	43
Weather Information updates	43
Integration of other informational databases	30
Computers with GIS available in fire engines	15
Remotely sensed images for smoke plume tracking	20
Other	8

Appendix III

BAER (Burned Area Emergency Rehabilitation) Findings

The results of the following BAER pilot study were presented at the focus group meeting to demonstrate how one portion of the fire management team was using GIS and remote sensing for faster and more accurate information to accomplish their job more efficiently. The pilot project was conducted by the Remote Sensing Applications Center (RSAC) and Pacific Meridian Resources in cooperation with the regional geometronics and remote sensing programs.

The Burned Area Emergency Rehabilitation (BAER) program of the USDA Forest Service requires a quick assessment of watershed conditions within large wildfire areas (over 300 acres) to determine if threats to life, property, or natural resource values have been created as the result of the fire. If emergency conditions exist, rehabilitation measures are prescribed to reduce, or eliminate potential threats. A map of burn intensity for the fire area is one of the tools used in determining whether emergency conditions exist. The current method to gather information about the burn intensity of the effected watersheds is through sketch mapping, and ground verification. Recently developed digital camera technology combined with global positioning systems and geographic information systems allows specialists to gather the information needed by BAER teams in a fast, accurate and cost effective way. The USDA Forest Service Pacific Southwest Region has applied these technologies to a fire on the Mendocino National Forest in northern California. This resulted in a 20 percent increase in accuracy of burn intensity classification, and more precise location of areas of similar burn intensity. These improvements assisted in the refinement of the identification of potential flood source areas within the burned area, and thereby more efficient prescription of emergency treatment measures.

Mapping burn intensity is a critical step in the survey because it determines the flooding potential and the specific flood sources within the burned area. *Burn intensity* refers to the fire’s effects on the watershed, not necessarily to the intensity of the fire as defined by flame height, canopy consumption, or rate of spread. Burn intensity is the key measure of the severity of the fire’s impact on the ecosystem.

Many demands are placed on a burn intensity map: the fire’s effects on the watershed must be mapped quickly and cost-effectively; the map must be accessible both on paper and as a layer in a GIS to the people who assess the watershed and implement the rehabilitation program; it needs to be available at varying scales for visual overlay and display with other resource information, such as watershed boundaries, prefire vegetation, soils, and wildlife habitat.

A careful plan is needed to map fire intensities accurately and ensure an efficient rehabilitation process. Well before a fire breaks out, land managers need to have the following items:

1. Access to geospatial data for a potential fire area;
2. Computers and other equipment that will be used for collecting, processing, and displaying data;
3. A team of trained people who can make field observations, collect image data, capture the data and GIS analysis, and produce the necessary prescriptions;
4. A mobilization plan to start the assessment as soon as the team can reach the burn area.

The Tools

A color infrared digital camera (Kodak DCS 420) coupled with a global positioning system (GPS) was used to "image" a portion of the Fork Fire on the Mendocino National Forest in northern California. The digital camera stores the images on a digital disk instead of on film. A GPS unit captures location information (latitude, longitude, and elevation) to help locate the approximate center of each digital image. The location information is used to plot flight lines, which can be used in conjunction with other GIS layers to determine the location of images in relation to landscape features.

The digital camera provided images of the burned area. Additional information or base layers, such as prefire vegetation, soils, and topography, were needed to properly map the different burn intensities. Available was the corporate geospatial database for the Forest Service Pacific Southwest Region, collected and maintained by the Mendocino National Forest and the Remote Sensing Laboratory in Sacramento.

The Process

As the Fork Fire was being brought under control, five flight lines were laid out over a 30,000 acre portion of the Middle Creek watershed. Flight plans were input into GPS navigation software to assist the airplane navigator and ensure proper coverage. Processing the digital camera imagery included georeferencing images to a common base and then mosaicing all the frames into a contiguous coverage for the fire area. A mosaic consisting of 110 digital images was assembled and registered to SPOT panchromatic satellite imagery.

While the image acquisition process was under way, burn intensity mappers, who traditionally would have been sketch mapping the area from a helicopter, instead had time to make more ground observations. GPS data collectors were loaded with a soils-based data dictionary to help team specialists record important burn intensity parameters. Observations included the amount and degree of litter consumed, depth and color of ash, changes in soil structure and soil crusting, fire-induced water repellency, size and amount of live fuels consumed, and site characteristics (such as percent surface rock, prefire vegetation type, slope aspect, and soil type). All ground observation points were logged in the portable GPS unit for later electronic overlay with the digital image of the burned area.

The Burn Intensity Map

The burn intensity map for the Middle Creek watershed was prepared using a variety of information, including field notes, GPS data points, aerial overview, the mosaic of digital images printed at a scale of 1:24,000, and information from the Mendocino National Forest database on prefire vegetation, streams, and topography. Polygons of burn intensity were manually delineated on the image mosaic. A digital version of the mosaic was used on a workstation to observe specific locations in more detail. The minimum polygon size was about 20 acres, with most polygons in the range of several hundred acres.

The process of integrating ground and aerial observations with the digital camera imagery produced a map of burn intensity. It was helpful to interface the digital image with prefire vegetation and topographic information from the GIS. For example, on the image the areas of burned shrub communities looked similar to the severely burned forested areas. Ground observations of representative shrub communities, however, indicated only moderate burn intensity. By using the GIS to overlay the shrub areas on the image, mappers could distinguish moderately burned areas from intensively burned forest.

Results

It was advantageous to have the digital map early in the process. The display of digital data speeded up the process of identifying critical areas within the burn to focus the team's limited and expensive field time. The wildlife biologist, for example, could immediately identify how much critical habitat areas burned at high intensity, if any. The hydrologist could quickly calculate percent of watershed in high burn intensity condition, as well as identify where in the watershed those conditions occur. The archaeologist could overlay burn intensity with heritage resources.

The burn intensity map serves as a proxy for cover and runoff factors for use in erosion and runoff models. The burn intensity map, soils layer, and slope groupings from digital elevation models are used in the Universal Soil Loss Equation. The soil scientist could overlay the burn intensity map with the GIS data layers of soil erosion groups and slope groups and quickly derive the areas of various burn intensity soil-slope combination figures needed for calculating predicted soil loss, which is part of the program's cost-benefit analysis requirement. This part of the project is currently under development.

The digital camera work was done in parallel with the regular BAER effort. As a result, two burn intensity maps were created - one by the previous methodology, one by the new methodology and their accuracy could be compared. Based on a number of ground observations, a 20 percent improvement in accuracy was realized with the new methodology.

In addition to realizing a 20 percent improvement in mapping accuracy, the Pacific Southwest Region estimates it saved $250,000 on rehabilitation for the Fork Fire, in part because of this test project. The imagery can be readily acquired and made available through commercial sources, as the Pacific Southwest Region is currently doing. If the new technology is implemented on a wider scale, it may save lives, property, significant resource values, and taxpayer dollars by more precisely and accurately placing emergency treatments in burned watersheds.