LAW OFFICE OF MARC CHYTILO

ENVIRONMENTAL LAW

October 12, 2012

Ms. Doreen Farr, Chair
Santa Barbara County Board of Supervisors
105 E. Anapamu Street
Santa Barbara, California 93101

By Email to: sbcob@co.santa-barbara.ca.us

RE: Park Hill Estates Project, Appeal No. 12APL-00000-00015

Dear Chair Farr and Honorable Members of the Board of Supervisors:

Please accept the following comments, evidence and argument on behalf of the Channel Islands Chapter of the California Native Plants Society and the San Antonio Creek Home Owner Association, Appellants in this matter (Appellants).

Appellants are a statewide natural resources scientific organization recognized as an authority on native plants of California and a local community group of individuals and families specifically concerned about this Project.

Appellants believe the Project may not be approved under a Negative Declaration, as there is substantial evidence supporting a fair argument of potentially significant impacts to floral and faunal biological resources, cultural resources, geological resources, aesthetic values, traffic and circulation, and public health and safety from increased fire safety and evacuation risks. An EIR must be prepared to comply with CEQA. The EIR process, if properly done, will yield considerable information on how to best site, design and mitigate this project to avoid some of the significant impacts and mitigate the remainder. Significantly, the EIR will evaluate the evacuation capacity of the San Antonio Creek Road community in which the Project is proposed in the event of a fast-moving wildfire, applying the methodology that was developed in addressing large projects in another fire-prone and evacuation-capacity-constrained community, Mission Canyon.

Despite the Applicant's protestations, an EIR is required by law and is an appropriate and necessary planning tool for the County to evaluate and respond to the numerous impacts that are associated with this Project's proposed location.

We request that the Board of Supervisors uphold this appeal, find that there is substantial evidence supporting a fair argument of significant adverse environmental impacts, direct preparation of an EIR and take no action on the merits of the project until such time as the EIR is prepared and certified.

MARC CHYTILO
P.O. Box 92233 • Santa Barbara, California 93190
Phone: (805) 682-0585 • Fax: (805) 682-2379
Email: Marc@lomcsb.com

CEQA and the EIR Process

"The foremost principle under CEQA is that the Legislature intended the act 'to be interpreted in such manner as to afford the fullest possible protection to the environment within the reasonable scope of the statutory language.'" *The Pocket Protectors v. City of Sacramento* (2004) 124 Cal.App.4th 903, 926. "The EIR requirement is the heart of CEQA." Cal. Code Regs., tit. 14[1], § 15003 (a). An EIR identifies the significant effects a Project will have on the environment, identifies alternatives to the project, and indicates the manner in which the significant effects can be mitigated or avoided. Public Resources Code § 21002.1(a). Its purpose is to "inform the public and its responsible officials of the environmental consequences of their decisions *before* they are made", protecting the environment as well as informed self-government. *Citizens for Goleta Valley v. Board of Supervisors of Santa Barbara County* (1990) 52 Cal. 3d 553, 564.

CEQA "creates a low threshold requirement for initial preparation of an EIR and reflects a preference for resolving doubts in favor of environmental review when the question is whether any such review is warranted." *League for Protection of Oakland's Architectural and Historic Resources v. City of Oakland* (1997) 52 Cal. App. 4th 896, 904-905; Public Resources Code § 21151. A public agency must prepare an EIR where it exercises discretion in modifying or conditioning a project that *may* have a significant effect on the environment. Public Resources Code §§ 21080 and 21100(a); CEQA Guidelines § 15357; *Quail Botanical Gardens Foundation, Inc. v. City of Encinitas et al.* (1994) 29 Cal.App.4th 1597, 1601; *Friends of Westwood, Inc. v. City of Los* Angeles (1987) 191 Cal. App. 3d 259, 269 ("'ministerial' is limited to those approvals which can be legally compelled without substantial modification or change.")

Significant effect on the environment' means a substantial, or potentially substantial, adverse change in the environment." Public Resources Code § 21068. Under CEQA, there is a "rebuttable presumption [that] any substantial, negative aesthetic effect is to be considered a significant environmental impact for CEQA purposes." *Quail Botanical,* 29 Cal.App.4th at 1604. Further "it is inherent in the meaning of the word 'aesthetic' that any substantial, negative effect of a project on view and other features of beauty could constitute a 'significant' environmental impact under CEQA." *Quail Botanical,* 29 Cal.App.4th at 1604. Impacts to private as well as public views may be significant under CEQA. *Ocean View Estates Homeowners Ass'n Inc. v. Montecito Water District* (2004) 116 Cal. App. 4th 396, 402.

A court reviews a public agency's compliance with CEQA for prejudicial abuse of discretion. Code of Civil Procedure § 1094.5(b); Pub. Resources Code, §§ 21168, 21168.5. Abuse of discretion is established where the agency fails to proceed in the manner required by law, the decision is not supported by the findings, or the findings are not supported by the

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[1] This code section referred to hereafter as the "CEQA Guidelines" or "Guidelines."

evidence. Code of Civil Procedure § 1094.5(b). Judicial review of whether the agency has employed the correct procedures is determined de novo and the court must “scrupulously enforce all legislatively mandated CEQA requirements.” *Vineyard Area Citizens for Responsible Growth, Inc. v. City of Rancho Cordova* (2007) 40 Cal.App.4th, 412, 435 (quoting *Citizens for Goleta Valley v. Board of Supervisors of Santa Barbara County* (1990) 52 Cal. 3d 553, 564). The agency’s failure to comply with mandatory procedures is presumptively prejudicial and the decision must be set aside. *Schoen v. Department of Forestry & Fire Protection* (1997) 58 Cal.App.4th 556, 565.

CEQA’s Fair Argument Test

Whether an agency abused its discretion in adopting a negative declaration is reviewed under the “fair argument” test. *Stanislaus Audubon Society, Inc. v. County of Stanislaus* (1995) 33 Cal.App.4th 144, 150-151. Pursuant to this test, an agency is required to prepare an EIR instead of a negative declaration if the record contains substantial evidence supporting a fair argument that the project *may* have a significant effect on the environment. *League for Protection,* 52 Cal. App. 4th at 904. This test does not require that the evidence received by the agency affirmatively prove that significant environmental impacts *will* occur, only that there is a *reasonably possibility* that they will occur. *Sundstrom v. County of Mendocino* (1988) 202 Cal. App. 3d 296, 309. Moreover, “[i]f there was substantial evidence that the proposed project might have a significant environmental impact, evidence to the contrary is not sufficient to support a decision to dispense with preparation of an EIR and adopt a negative declaration.” *Sundstrom,* 202 Cal. App. 3d at 310 (quoting *Friends of "B" Street v. City of Hayward* (1980) 106 Cal.App.3d 988, 1002).

The “fair argument” test derives from Public Resources Code section 21151, which “creates a low threshold requirement for initial preparation of an EIR and reflects a preference for resolving doubts in favor of environmental review when the question is whether any such review is warranted.” *League for Protection,* 52 Cal. App. 4th at 904-905. Whether the evidence in the record supports a fair argument of significant effects is a question of law and the Court does not defer to the agency’s decision. *Sierra Club v. County of Sonoma* (1992) 6 Cal. App. 4th 1307, 1318 (“deference to the agency's determination is not appropriate and its decision not to require an EIR can be upheld only when there is no credible evidence to the contrary.”)

“Substantial evidence . . . means enough relevant information and reasonable inferences from this information that a fair argument can be made to support a conclusion, even though other conclusions might also be reached.” CEQA Guidelines, § 15384 (a). “Substantial evidence shall include facts, reasonable assumptions predicated upon facts, and expert opinion supported by facts.” *Id.* at subd. (b); Pub. Resources Code § 21080 (e)(1)-(2). The fact based opinions of agency staff and decisionmakers, stemming from experience in their respective fields, are considered substantial evidence for a fair argument. *Pocket Protectors,* 124 Cal.App.4th at 932; *Stanislaus Audubon Society,* 33 Cal. App. 4th at 155 (probable impacts recognized by the planning department and at least one member of the planning commission, based on professional opinion and consideration of other development projects, constituted substantial evidence supporting a fair argument that the project would have significant growth inducing impacts). Additionally, "[r]elevant personal observations of area residents on nontechnical subjects may qualify as substantial evidence for a fair argument." *Pocket Protectors,* 124 Cal. App. 4th at 928; *Ocean View Estates,* 116 Cal.App.4th at 402. Argument, speculation, unsubstantiated opinion or narrative, and clearly inaccurate or erroneous evidence does not constitute substantial evidence. Pub. Resources Code § 21080 (e)(1)-(2).

"[I]f substantial evidence supports a fair argument that the proposed project conflicts with policies [adopted for the purpose of avoiding or mitigating an environmental effect] this constitutes grounds for requiring an EIR." *Pocket Protectors,* 124 Cal.App.4th at 930; CEQA Guidelines, App. G, § IX (b). In *Pocket Protectors,* a case with significant factual parallels to the case at bar, comments by a City planner, the Planning Commission, two City Council members and an architect that the project did not comply with applicable policies constituted substantial evidence requiring an EIR. *Id.* at 931-932.

Where a court determines that there is substantial evidence in the record that the project may have a significant effect on the environment, the agency's adoption of a negative declaration must be set aside because the agency abused its discretion in failing to proceed in the manner required by law. *League for Protection,* 52 Cal. App. 4th at 905; *Quail Botanical*, 29 Cal.App.4th at 1602. Moreover, while the absence of evidence in the record on a particular issue does not automatically give rise to a fair argument that a project may have a significant effect on the environment, an agency "should not be allowed to hide behind its own failure to gather relevant data" and "[d]eficiencies in the record may actually enlarge the scope of fair argument by lending a logical plausibility to a wider range of inferences." *Sundstrom*, 202 Cal. App. 3d at 311.

The County's Process for This Mitigated Negative Declaration Is Deeply Flawed

The applicant has caused, and the County allowed the Mitigated Negative Declaration process to be abused. The applicant does not appear to be willing to play by the rules of Mitigated Negative Declarations, and for this reason the County should simply direct preparation of an EIR.

CEQA carves out a particular narrow exemption for projects that have the potential to cause one or more significant impacts, but for which the applicant voluntarily agrees to incorporate into the Project Description revisions to the Project that cause the Project as proposed to cause no potentially significant impacts. Public Resources Code § 21080(c). CEQA Guidelines § 15070(b)(1) allows use of a MND when initial study identifies potentially significant impacts but "revisions in the project plans or proposals made by or agreed to by the project applicant **before** a proposed mitigated negative declaration and initial study are released for public review would avoid the effects or mitigate the effects to a point where **clearly no significant effects would occur**." (Emphasis added).

This applicant has not complied with CEQA's authority authorizing the Mitigated Negative Declaration, but instead has played fast and loose with CEQA, the planning process, and the affected community. This is the second version of the project, and it has had three different MNDs so far. (June 17, 2011, October 14, 2011, August 16, 2012). The applicant's threatening and provocative letters to various County officials and their gamesmanship during the land use permitting process is a clear abuse of the MND process as authorized by CEQA. For example, the applicant offered to add the funding for emergency access roadway widening only after the version 2 project's second MND had been circulated and he received no approvals. The applicant actually asserted that his pledge of roadway funding was conditional upon no one filing an appeal of the Planning Commission approvals as an apparent tactic to chill public participation in this project's review process. An Mitigated Negative Declaration is only appropriate when the project has been designed to avoid or self-mitigate all impacts, and all such avoidance and mitigation measures are integrated into the Project Description.

Staff has become an unwitting accomplice to this pattern and practice CEQA violation in crafting and imposing new mitigation measures and revising the conditions of approval accordingly after the initial study and MND has been circulated. For example, Pad heights were lowered as an overt mitigation measures in the third version of the MND, and this version of the MND contained a "recommended mitigation measure that would require pre-construction surveys for any active nest and roost sites at the time of construction and avoidance as necessary." (Proposed Final MND 10/14/2011 at page 37.) MNDs do not contain recommended mitigation measures - they are required to be self-mitigating. In a move apparently to prevent the use of a portion of the undeveloped area for creation of habitat, in October 2011 the applicant declared that 1.5 acres would be used for passive recreation. Id, page 37. In this way, the Project Description was improperly manipulated to prevent the project from self-mitigating, at least partially, and expanded to project to include the creation of grassland habitat on lands in the coastal zone.

CEQA authorizes use of a MND when a project, as proposed, is designed to avoid impacts and is self mitigating through the Project Description, not project conditioning. Public Resources Code § 21080(c). Santa Barbara County's June 2010 CEQA Procedural Guidelines make clear the MND process is supposed to involve applicant agreement to any and all mitigation measures as elements of a Project Description that is finalized prior to public review. ("Furthermore, mitigations forming the basis of a finding of no significant impact must be accepted in writing by the applicant or lead department proposing the project, and incorporated into the project description **before** the proposed negative declaration is released for public review.") (At page 13, emphasis added.) This applicant has abused that authority and seeks to impose incremental changes to the project as nominally as possible to do as little as necessary to gain approval. The county has condoned that process, violating the spirit and purposes of CEQA and the MND process and subjected the community to an expensive, capricious and poorly-governed process. This applicant's abuse of the MND process should not be further condoned - this project requires a full EIR.

II. SPECIFIC IMPACT ISSUES

1. Visual Impacts and aesthetic

The record contains substantial evidence supporting a fair argument that the Project will cause a potentially significant impact to visual resources.

The County's 2008 CEQA Threshold Manual[2] uses the following criteria in assessing a project's aesthetic impacts: a) would the project obstruct any scenic vista or view open to the public or create an aesthetically offensive site open to public view? b) would the project change the visual character of an area? c) would the project cause glare or night lighting which may affect adjoining areas?

CEQA establishes that a Project's impacts to private views must be considered when the Project also affects public views. *Ocean View Estates Homeowner's Association v. Montecito Water District* (2004) 116 Cal.App.4th 396. The testimony of lay individuals concerning impacts to scenic visual resources and aesthetics is considered substantial evidence that supports a fair argument. Id., 116 Cal.App.4th at 402, citing *Oro Fino Gold Mining Corp. v. County of El Dorado* (1990) 225 Cal. App. 3d 872, 882 (personal observations on nontechnical issues such as visual impacts can constitute substantial evidence). Substantial evidence in the record supporting a fair argument that the Project may cause significant visual impacts is found in the multitude of comments to the Planning Commission and your Board of Supervisors at previous hearings by people that drive, walk and bike by the site, and from that perspective view the property from the street. Additionally, there is ample public testimony from adjacent residents of view blockage that currently have unobstructed views of the Pacific Ocean, sunsets and the coastal ridges of the Santa Ynez Mountains. The Project would introduce buildings in areas that are currently unobstructed open space, blocking views and introducing structures to an undeveloped open space, completely changing the character of the area and introducing nighttime lighting and glare from windows and finished surfaces. The natural rolling topography will be replaced by a flattened, tiered site, changing the character of the site and area. Because this substantial evidence exists in the record, the County may not utilize an MND. *League for Protection,* 52 Cal. App. 4th at 905.

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[2] CEQA requires agencies to adopt CEQA procedures (Pub. Resources Code § 21082) and recommends the use of thresholds of significance in the determination of the significance of environmental effects (Guidelines § 15064.7(a)).

Additionally, the site's unique geological formations, an expression of the rare fanglomerate soil and bedrock, provides a unique visual feature that will be destroyed by the project's extensive grading. One exposed bedrock formation containing a historically and culturally significant mortar will remain with an angular ten foot square buffer zone and chain link fence in the front yard of one of the lots.

Destruction of the unique boulder field without considering its visual significance is another significant project impact evidenced simply by the Project plans. As noted *supra*, the County's failure to identify and analyze impacts expands the scope of inquiry regarding a potentially significant impact. *Sundstrom*, 202 Cal. App. 3d at 311 ("[d]eficiencies in the record may actually enlarge the scope of fair argument by lending a logical plausibility to a wider range of inferences.").

Based on County CEQA Thresholds, this project plainly trigger a finding of potential significant visual impact. Scenic views and vistas are blocked, the character of the site will be irrevocably changed, and sources of light and glare will be introduced where today there are none. Imposing setbacks to retain tunnel views of scenic landscapes and vistas between buildings fails to mitigate this impact to insignificance - views through and over buildings can be equally offensive to aesthetic sensibilities.

For these reasons, visual resources must be evaluated in an EIR for this Project.

2. Cultural Resources

a. Failure to evaluate the potential historic significance of the site

The County's and the MND's assessment of cultural resources and the cultural history of the site is inadequate, further reducing the threshold for preparation of an EIR. Representatives of the Chumash have requested additional site survey work and monitoring of all earthwork. Instead, the conditions require only monitoring within 50 feet of the mortar rock and, outside that area, only that the work be stopped if the contractors encounter archaeological resources. This is a wholly ineffective and unrealistic condition. If no one is monitoring, nothing will be found unless in involves something obvious and irrefutable, such as a skull. Artifacts will not be noticed by heavy equipment operators in the absence of trained monitors. The site has a mortar rock, so is a known site of pre-historic occupation.

CEQA requires the County to evaluate the potential historic significance of the site and its eligibility for listing in the California Register of Historic Places or if it is otherwise historically significant. Guidelines § 15064.5(c)(1). The MND is silent on this analysis, and thus is inadequate.

b. County pattern and practice allowing destruction is potential resources prior to survey

Significantly, the applicant's venders disturbed the site by drilling a considerable number of soil test holes to bedrock during the site investigation phase without the presence of an archaeologist or monitor. Thus the applicant themselves has disturbed the archaeological integrity of the site before any cultural survey work was performed. The potential destruction of cultural resources prior to survey reflects a County pattern and practice of enabling the disturbance and destruction of known potentially significant cultural and historical resources before survey work is allowed. Where cultural resources are known and self evident, it is an abuse of discretion to allow drilling of test holes that will impact any resources in the affected soil column without trained monitors on site.

c. Inexplicable changes to cultural impact significance

Revisions to the MND between the 7/1/2011 version to the version before your Board show that the significance of cultural resources was elevated from less than significant to less than significant with mitigation, but there are absolutely no changes to the mitigation measures. The County is employing a capricious and irrational approach to these historic resources.

3. <u>Geological Resources</u>

County CEQA Thresholds and the initial study checklist mandate inquiry into whether a Project would result in "destruction, covering or modification of an unique geological . . . or physical feature.

The MND overlooked the presence of fanglomerate geological formations surfacing on the parcel. Fanglomerate outcroppings are considered to be unique geological features, according to the San Marcos Foothills EIR. Preserve at San Marcos DEIR, May 2004, page 4.4-8, attached as Exhibit 1. The fanglomerate boulders on this site are similarly unique geological features, and must be evaluated as such. The MND's omission of any acknowledgement of this County-identified geological resource on a similar parcel reflects another inadequacy of the MND and triggers the need for EIR analysis of this resource and the Project's impacts thereto.

Additionally, the fanglomerate boulders on the Project site constitute potentially significant biological resources (see below) and present CEQA-significant topographical relief and aesthetic value to an otherwise largely planer landscape.

Since the Park Hills Estates MND overlooked this unique geological resource in the chart at page 52 and discussion at page 53 ("There are no unique geological features located on the project site"), the MND may not be approved.

4. Biological Resources:

As reflected in the comments of David Magney Environmental Consulting (DMEC) dated 11/28/11 to the draft MND, the comments of your Board, Director Glenn Russell, members of the Planning Commission and in the submitted supplemental DMEC letter attached hereto and other submittals and information presented to your Board of Supervisors, there is overwhelming evidence of both the inadequacy of the biological resources survey work and analysis as well as substantial evidence of a potentially significant impact to biological resources.

a. Inadequate floral survey methodology

As detailed in DMEC's 11/28/11 letter, the survey methods failed to comply with state and local guidelines for evaluating biological resources. The failure to comply with such applicable CEQA methods constitutes an abuse of discretion.

Additionally, inadequate survey work further lowers the burden for establishing a potentially significant impact. *Sundstrom,* 202 Cal. App. 3d at 311 ("[d]eficiencies in the record may actually enlarge the scope of fair argument by lending a logical plausibility to a wider range of inferences."). The failure to recognize the fanglomerate complex and the diversity and habitat it can provide further taints the adequacy of the analysis. It is appellants' belief, based on resources found present in association with fanglomerate formations at San Marcos Foothills, known populations of plants and associations between those plants and locally significant animals (such as native and non-native grasslands and the white-tailed kite) that the Project site contains biological resources of significance that were overlooked by the applicant's biologists.

b. Faunal resources survey inadequacies

Surveys of birds and animals conducted in 1998 indicated the site is used as a foraging site for the Fish and Wildlife Service-designated Species of Management Concern white-tailed kites. Kites roost and breed in the riparian areas on both immediate sides of the project site, as well as on the San Marcos Foothills parcel to the east. These locally significant raptors are experiencing a decline as a result of projects with improper analysis just like this project, "due to the loss, fragmentation, and more frequent disturbance of their nesting and foraging areas." MND page 32. The county cannot simply adopt prior Statement of Overriding Considerations from a nineteen year old General Plan as a surrogate for the required analysis of this proejct's cumulative impacts on white-tailed kite populations. The MND explains a County biologist was on the site for 2 days during non-foraging hours (10 am to 5 pm), didn't see any kites, and the analysis ceased at that point. Inexplicably, there is no further discussion or analysis of the Project's admitted impacts to the foraging behavior of the white-tailed kites that the biologist observed using the site.

Similarly, the expected presence of a California Species of Special Concern, the pallid bat, for both roosting and foraging was completely ignored. No followup survey work was performed, and it appears the County is prepared to allow this species' population to similarly whither away. This project and/or cumulative impact must be disclosed.

In the discussion of the cumulative impacts of the loss of bird foraging habitat, the MND references the Goleta Community Plan EIR, references the Class 1 impacts from the cumulative loss of bird foraging habitat, and concludes the Statement of Overriding Considerations for that project serves as CEQA analysis 19 years later. This project's environmental review document must use the current conditions for the environmental baseline and cannot rely on an antiquated General Plan EIR to override impacts from this project using a MND. The MND is only available if there is no potentially significant impact. Public Resources Code § 21080(c). Based on reliance upon a Statement of Overriding Considerations for this project's impacts, the MND is not appropriate.

c. New Information and impacts: Road through oak woodland

The revision to the Project Description and MND's mitigation measures fails to address the potentially significant impacts of these changes. As such it is inadequate.

The Project Description was revised to include the installation of a roadway widening and rehabilitation project. While Appellants believe it is necessary and appropriate to widen this roadway to address fire safety risks if the project is to proceed, this cannot and does not vitiate CEQA's requirement that the impacts of mitigation measures be considered in the environmental review document. Guidelines § 15126.4(a)(1)(D); *Stevens v City of Glendale* (1981) 125 Cal. App. 3d 986.

The emergency access/egress roadway widening project will occur in and under the canopy of an oak woodland, on steep slopes and on highly erosive and unstable soils. Widening the roadway even to 16' width requires a 36" retaining wall on a steep hillside, however a 16' wide emergency access roadway is far below County Fire Department Development Standard # 1 widths and may actually create additional hazards by inducing evacuees to attempt to evacuate by this route and become stuck or immobilized in an area of high fuel loads, increasing the probability of death. See Scott Franklin letter, Exhibit 7. See also Declaration of Jeffrey Nelson, 8/5/2011, ¶ 6 ("the connection with the park is the most direct and closest emergency access of this neighborhood.") [Declaration part of this Project's file at Santa Barbara County Planning and Development Department, incorporated herein by reference.]

If the emergency access roadway into Tucker's Grove were widened to the Development Standard width of 24', a massive engineered retaining wall will be required in several locations based on the comments made by the Project Engineer Bob Flowers and County Public Works Department Will Robertson representative during a site visit conducted on October 11, 2012. A number of coast live oaks will necessarily be directly impacted and/or removed as part of any widening project. See David Magney Letter, 10/11/12, Exhibit 8.

d. New Information and impacts: Coastal blufftop grasslands mitigation

County policy and ecological principles require that mitigation for a biological impact be as close as possible to the geographic location of the impact and the type of habitat impacted. Neither issue is addressed in the MND, and thus the inadequacy and impacts associated with the proposed grasslands mitigation has not been disclosed. The failure to do so in an environmental review document violates CEQA and is an abuse of discretion.

The 2007 project approval created compensatory grasslands habitat on site, but today the applicant is refusing allow even a portion of the increased mitigation burden to occur on-site. The applicant is refusing to acquire and perform compensatory mitigation on like-kind habitat - inland native grasslands on slightly-sloped fanglomerate terrain. Instead compensatory mitigation is proposed to occur in an different habitat type - coastal bluff habitat several miles away.

Compensatory habitat on site provides the greatest assurances that the ecology impacted by the project will be replicated, and animals that rely on the habitat to be impacted will find similar alternative habitat nearby. The MND acknowledges that the white-tail kite and likely the pallid bat rely on this site for foraging. There is no evidence that these populations will move to the alternative restoration site to forage, indeed that is unlikely. So these populations will suffer additional harm from the gradual decimation of their essential habitat.

The MND must identify and evaluate the specifics of the campus mitigation program - identifying the specific area, the type of habitat and values that will be established, compared to the habitat values that will be lost on the project site. The MND must address the impacts from the restoration project itself, including impacts to existing habitat, if any. The restored lands should be subject to a permanent legal protection, ideally in the form of a conservation easement. Perpetual maintenance of the off-site restored area must be assured as a project condition, and an entity must accept responsibility for maintenance of the restored habitat. Monitoring of success is required. A study of the other animal species that are intended to and likely to benefit from the created habitat. Assessment of the need to increase mitigation ratios to compensate for the diminished effect of the compensatory habitat must be considered as habitat created miles away in a different ecosystem has less compensatory biological value than habitat created on-site and in-kind.

The MND is inadequate for its failure to address the potentially significant impacts from the creation of compensatory grasslands habitat on UCSB’s lands. See also DMEC Letter, 10/11/12, Exhibit 8.

5. Fire Hazard:

The Fire safety hazard issues are the biggest project impact, and is framed by the fact that fire hazard is the single most significant land use constraint and public safety hazard in Santa Barbara foothill communities. The fire risk is substantial, causing a very high "life-safety risk."

a. The Project Exposes Occupants and Structures to significant Risk of Loss

> Appendix G Environmental Checklist asks the question whether the project:
> *h) Expose people or structures to a significant risk of loss, injury or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?*

As explained by FEMA:

> Developments in urban/wildland interface areas often face high fire risk because of the combination of high fire hazard (high vegetative fuel loads) and limited fire suppression capabilities. Unfortunately, occupants in many wildland/urban interface areas may also face high life-safety risk. High life-safety risk arises because of high fire risk, especially from large fires that may spread quickly and block evacuation. Life-safety risk in interface areas is often exacerbated by limited numbers of roads (in the worst case, only one access road) that may be narrow and winding and subject to blockage by a wildland fire.

Federal Emergency Management Agency, Guidance For Wildland/Urban Interface Fire Mitigation Projects, June 2006, Prepared by URS, at page 2 (attached as Exhibit 2).

In evaluating that risk, FEMA Notes:

> Fire risk, the threat to the built environment and to people, depends on fire hazard (the probability and severity of fires) but also on the inventory of structures and people in fire-prone areas. High fire hazard areas pose a high risk to structures and people only to the extent that development is present in the high fire hazard areas.
>
> For life-safety, fire risk also depends strongly on the response time and access and egress routes from developed areas in high fire hazard areas. **Life-safety risk may be substantially exacerbated in areas with limited access and egress because residents (or firefighters) may be trapped by rapidly spreading wildland/urban interface fires.** The worst-case situation is an isolated development with only a single road for access/egress.

> **Areas at highest risk for wildland/urban interface fires have a combination of high fire hazard (fuel loads, weather, topography), a high level of development (population), and limited access and egress routes.**

Id., at page 6 (emphasis added).

Mr. Franklin offers an account of the risks and nature of wildfires. Between his testimony and the FEMA report at Exhibit 2, there can be little doubt the project exposes occupants to substantial risk of wildland fires by virtue of the location of the project.

Thus appellants have affirmatively demonstrated the project may have a significant impact under this threshold.

b. The MND skirts the fire risk issues

The MND's treatment of wildland fire hazards clearly downplays fire safety issues. Rather than performing an independent evaluation of fire risk issues, the MND reports on the concerns of neighbors.

In evaluating Fire Risk and public health and safety issues, the County has neglected to adopt any form of CEQA thresholds to guide applicants, the public or decisionmakers in assessing local fire safety risks. Given that the majority of the County's landmass is designated a high fire hazard area and we have a robust history of vicious wildfires, this inaction contributes to poorly defined environmental analysis and capricious environmental review documents that address wildfire safety issues erratically and dictate that residents concerned for their personal safety retain experts to guide them through an ill-defined environmental review process.

The State's Appendix G to the CEQA Guidelines includes the following:

> *VII. HAZARDS AND HAZARDOUS MATERIALS* -- *Would the project:*
>
> *g) Impair implementation of or physically interfere with an adopted emergency response plan or emergency evacuation plan?*
>
> *h) Expose people or structures to a significant risk of loss, injury or death involving wildland fires, including where wildlands are adjacent to urbanized areas or where residences are intermixed with wildlands?*
>
> *XV. TRANSPORTATION/TRAFFIC* -- *Would the project:*
> *e) Result in inadequate emergency access?*

Tellingly, the MND did not ask any of these questions.

In fact, rather than even accept that fire safety is a legitimate land use planning issue, the MND recites simply that that the two closest fire stations have three person shifts, but then lays the onus for this issue on the community.

> "Local residents remain concerned regarding adequate emergency access for developments within this area based on their experiences with the 1990 Painted Cave Fire and more recent evacuations associated with the Gap Fire and Jesusita Fire. During the Painted Cave Fire area residents crowded neighborhood roadways in an attempt to reach safety as emergency vehicles and personnel were simultaneously engaging in protection services. Area residents have expressed concern regarding future development and associated increases in residents and vehicles. They are concerned that these increases would result in increased fire hazards and increasing the difficulty of evacuating area residents during a fire or other emergency." MND at 46.

If adequate, the MND would have been preceded by an internal initial study that had already responded to the applicable CEQA Thresholds (from Appendix G in the absence of local Thresholds) and secured the appropriate revisions into the Project Description to ensure that the Project is "self-mitigating" and qualified for treatment under Public Resources Code § 21080(c) and Guidelines §§ 15070 and 15071. The above-quoted text demonstrates that wildfire safety is not an issue of concern in the County land use permitting and environmental review process, at least for this project.

Of course, in response to public concern in an issue of life or death, the issue did get addressed, but only sofar as necessary to provide a paper response to stated concerns. There is no meaningful analysis of evacuation capacity issues whatsoever. The MND does not count the number of homes that use San Antonio Creek Road as an emergency evacuation path, does not assess the adequacy or capacity of that roadway to accommodate emergency traffic, does not acknowledge that in the event of a wind-driven wildfire, the northern end of San Antonio Creek Road (intersecting with SR 154) will be closed for use to allow fire responder equipment access (as occurred in Gap and Jesusita fires) and in any case, residents would be foolhardy to drive into oncoming flames to escape them. As a practical matter, the entire San Antonio Creek Road community has only one available emergency access path, down Via Los Santos to a stop sign-controlled 4 way intersection, Old San Marcos Road to a stop light controlled intersection, and onto Cathedral Oaks Road. The MND does not acknowledge all the other communities that would also be evacuating to Cathedral Oaks Road, nor that there is no direct way to exit due south from Old San Marcos Road to Highway 101, but that evacuating traffic must then turn south on Turnpike Road, via a stop-light controlled intersection and in concert with thousands of other evacuees and vehicles.

The testimony of Scott Franklin, experienced fire expert and attached hereto as Exhibit 7, notes that the nature of sundowner-wind driven wildfires in the project area is for winds to blow north to south. He observes that San Antonio Creek Road is not a viable emergency egress during wildfire conditions, as people will not drive towards a flame front when trying to evacuate, and that the northern part of the road is more typically used for fire equipment access. Id. Mr. Franklin also contends the 14' to 16' wide roadway to Tucker's Grove is not adequate as an access way, and could create public safety hazards. This testimony establishes that the project does not have the two emergency egress points, calling into question compliance with DevStd FIRE-GV-1.3.

c. Area evacuation capacity is inadequate and the MND is deficient for failure to study the issue

Although the MND does not address the adequacy of evacuation capacity, that topic has been studied extensively in other Santa Barbara County foothill communities. While there is no direct study of the San Antonio Creek Road region, the studies and experience demonstrate that evacuation capacity is limited throughout Santa Barbara foothills.

The MND does not acknowledge that other foothill communities have been the subject of empirical evacuation capacity analysis, despite this information and all of these studies having been presented to the planning staff in other proceedings. One early local analysis was Modeling Small Area Evacuation: Can existing transportation infrastructure impede public safety, Richard Church and Ryan Sexton, UCSB, for California Department of Transportation , April 2002. This study examined the factors involved in emergency evacuation of residential areas and refined the concept of a Clearing Time Estimate (CTE). The MND is silent on CTE, but this is a core aspect of evacuation planning in foothill communities.

In 2005 Professor Tom Cova evaluated community evacuation methods and studied how they could be qualified and evaluated. He theorized that such mass evacuations of wildfire-exposed foothill communities was comparable to the evaluation of the emergency exit capacity for a building. His study, entitled Public Safety in the Urban-Wildland Interface: Should Fire-Prone Communities Have a Maximum Occupancy?, Thomas Cova, Natural Hazards Review, August 2005, is attached as Exhibit 4.

The analysis was refined further in the 2007 Emergency Planning in the Urban-Wildland Interface: Subdivision-Level Analysis of Wildfire Evacuations, Brian Wolshon, and Emile Marchive III, Journal of Urban Planning and Development, March 2007, attached as Exhibit 5. This paper reviewed the effects of different exit paths and other aspects of an emergency evacuation on clearing time.

The final source of clear analysis of this issue is a Supplemental Traffic Simulation for Fire Evacuation Analysis for Mission Canyon Community Plan, Fehr & Peers, February 2011, prepared for the County of Santa Barbara and attached hereto as Exhibit 6 . This study ran several model runs of fires of differing intensity and developed an Optimized Traffic Control Plan for Mission Canyon. That analysis identified a series of specific actions that could be undertaken to increase evacuation capacity.

While the specifics of these studies have variable direct application to the Park Hills Estates MND and the effects that the Project will have on the existing roadway network, they set certain parameters that are applicable. This study looked at and compared moderate and high intensity fire evacuation scenarios under existing and future conditions. See pages 3 & 4. Tables 2 & 3 of Exhibit 6 tabulates the "systemwide travel statistics results for evacuation scenarios" under existing and optimized traffic controls. The report found that under the different scenarios, some fraction of residents would still be evacuating at the 2 hour mark. For the high intensity fire evacuation, a large fraction were not out in time, so traffic control optimization was employed. Notably, average speed during evacuations ranged from 8.7 to 4 mph.

These studies establish that it is certainly possible to evaluate the evacuation capacity of foothill residential communities with limited emergency egress. They could further provide rough tools for evaluating potential impacts and/or refined models for how impacts could be qualified. Applying the VMT and speed of evacuation assessments from Exhibit 6, and the effect that traffic controls have on evaluation (the project area having more traffic controls than Mission Canyon) it is clear the San Antonio Creek Road area would take a considerable length of time to evacuate, and adding more residents will increase the time to evacuate. According to the applicant, the project would add more than 5% to the population of residences and people in the project area that need to evacuate on the same single road. This provides a foundation of substantial evidence supporting the conclusion the Project will result in inadequate emergency access.

d. Climate change and increased wildfire risk factors

Climate Change has had, and is reliably predicted to have important and relevant changes to precipitation patterns in the region that increase fire probability and risk.

The United States Forest Service's general scientific prediction of climate change effects is that "the Western United States gets wetter winters and warmer summers throughout the 21st Century (as compared to current conditions.)" Exhibit 9, United States Forest Service, Pacific Northwest Research Station Science Update, Western Forests, Fire Risk, and Climate Change, Issue 6, January 2004, page 1. The increased winter precipitation would result in faster growth of vegetation, and increased fuel loads. Id. Summers would be equally or more hot and dry, increasing fire risks. Id. The effects of these climate changes can be modeled. Id., p. 5. "When we run the models for 100 years out into the future, we get woody expansion in the West and increased fire." Id., p. 7, citations omitted. "In six of seven future scenarios run [through the model], the West gets wetter through the 21st Century, and woody and grass fuels increase." Id.

"Although the West would be wetter, Western Summers would be hotter than now. With more fuels available, in occasional dry fire years fires would burn more area and more biomass than in even recent severe fire seasons." Id.

Concern over the effect of climate change on wildfire frequency and severity extends into national and international reports from the United States Department of State, which refer directly to increased risks to structures in the wildland mix and wildland interface. "Increased fire frequency would likely be a threat not only to the natural land cover, but to the many residential structures being built in vulnerable suburban and rural areas, and later would increase vulnerability to mudslides as a result of denuded hills." United States Department of State, United States Climate Action Report – 2002, Third National Communication of the United States of America Under the United Nations Framework Convention on Climate Change, May 2002, p. 91.

There is thus substantial evidence that weather and precipitation patterns will likely become more extreme as a result of global climate change. Wetter winters will accelerate vegetation growth, and longer, hotter fire seasons increase the probability and consequence of wildfires. The project's environmental review documents must address this factor in evaluating the safety risks associated with the project. As it now stands, the project site is exposed to considerable risk with excessive vegetation in adjacent canyons to the east and west, routine down canyon winds during high fire risk seasons, and constrained evacuation capacity. Future climatic conditions are reasonably and consistently predicted to increase fuel loads and result in longer, hotter fire seasons. The studies demonstrate a potentially significant impacts by providing substantial evidence that fire risks will increase as a result of global climate change.

6. <u>Open Space Action Plan Consistency</u>

The County has not made the mandatory findings pertaining to its Open Space Element and the Open Space Action Plan. Specifically, Government Code § 65564 establishes that "Every local open-space plan shall contain an action program consisting of specific programs which the legislative body intends to pursue in implementing its open-space plan. Government Code § 65566 provides that "Any action by a county or city by which open-space land or any interest therein is acquired or disposed of or its use restricted or regulated, whether or not pursuant to this part, must be consistent with the local open-space plan." Government Code § 65567 dictates that "No building permit may be issued, no subdivision map approved, and no open-space zoning ordinance adopted, unless the proposed construction, subdivision or ordinance is consistent with the local open-space plan."

These provisions establish that the County has an on-going duty to maintain its open space element, to adopt and implement a unified open space action program, and to ensure that actions affecting open space lands are consistent. The project is located on open space lands that will be subject to regulation should this project be approved. Significantly, the project involves a subdivision map and therefore a finding of Open Space Plan consistency is mandatory.

7. Conclusion

The MND associated with this project is flawed in many respects. Appellants have presented substantial evidence supporting a fair argument of a potentially significant impact in the form of expert opinion, from application of the thresholds, and from documentary evidence of potential impacts.

Additionally, Appellant has identified numerous instances where the MND simply failed to adequately address substantive environmental issues and relied on an incomplete or technically inadequate analysis. For this issue, the courts clearly impose a burden on the County. "The agency should not be allowed to hide behind its own failure to gather relevant data." *Sunstrom v. County of Mendocino* (1988) 202 Cal. App. 3d 296, 311. "While a fair argument of environmental impact must be based on substantial evidence, mechanical application of this rule would defeat the purpose of CEQA where the local agency has failed to undertake an adequate initial study." *Id.* In this case, like *Sunstrom*, the initial study that was supposed to integrate the necessary Project revisions and mitigation measures into the project was deeply flawed. The product was an inadequate MND and a poorly managed environmental review process that has frustrated all parties to it. CEQA is clear, this circumstance requires an EIR, and that is the relief we request of your Board of Supervisors.

Sincerely,

Marc Chytilo

Park Hills Estates, version 2
Appellants' Exhibits List

Exhibit	Description
1.	Preserve at San Marcos Draft Environmental Impact Report, May 2004, excerpts
2.	Guidance For Wildland/Urban Interface Fire Mitigation Projects, Prepared by URS Group, Inc. for the Federal Emergency Management Agency, June 2006
3.	Modeling Small Area Evacuation: Can existing transportation infrastructure impede public safety, Richard Church and Ryan Sexton, UCSB, for California Department of Transportation , April 2002

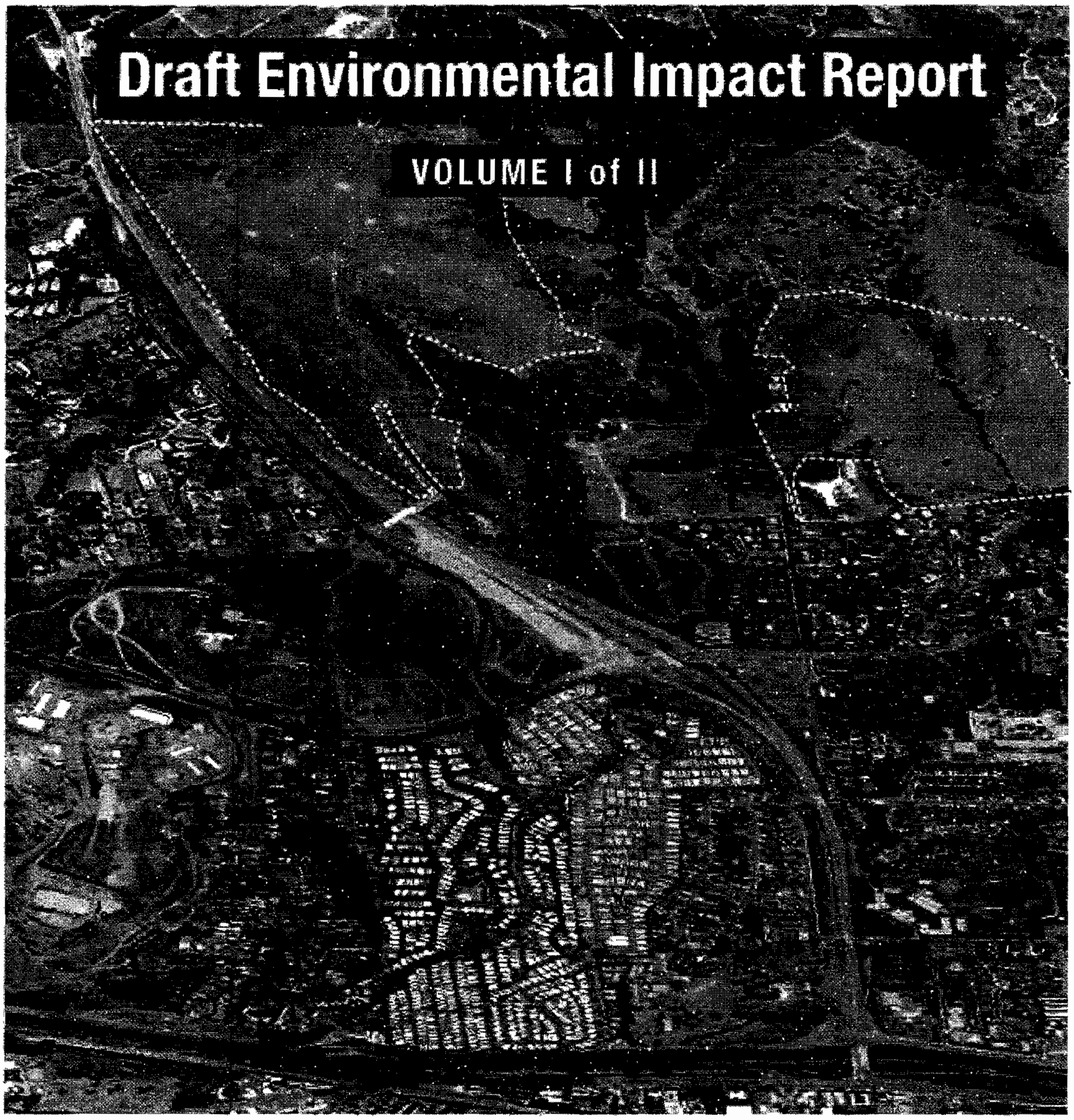
4. Public Safety in the Urban-Wildland Interface: Should Fire-Prone Communities Have a Maximum Occupancy?, Thomas Cova, Natural Hazards Review, August 2005
5. Emergency Planning in the Urban-Wildland Interface: Subdivision-Level Analysis of Wildfire Evacuations, Brian Wolshon, and Emile Marchive III, Journal of Urban Planning and Development, March 2007
6. Supplemental Traffic Simulation for Fire Evacuation Analysis for Mission Canyon Community Plan, Fehr & Peers, February 2011, prepared for the County of Santa Barbara
7. Letter, Scott E. Franklin to Santa Barbara County Board of Supervisors, 10/12/12, re: Park Hills Estates project and fire impact analysis
8. Letter, David Magney of David Magney Environmental Consulting to Chair Farr and Board of Supervisors, 10/11/12, re: Park Hills Estates supplemental testimony on biological impacts.
9. United States Forest Service, Pacific Northwest Research Station Science Update, Western Forests, Fire Risk, and Climate Change, Issue 6, January 2004

Exhibit 1

THE PRESERVE AT SAN MARCOS DEVELOPMENT

Draft Environmental Impact Report

VOLUME I of II



PREPARED FOR:

County of Santa Barbara
Planning and Development
123 East Anapamu Street, Santa Barbara, California 93101
Attn: Alan Hanson, AICP
(805) 568-2000

PREPARED BY:

Envicom Corporation
28328 Agoura Road, Agoura Hills, California 91301

MAY 2004

EXHIBIT 1

Rock Outcrops (Boulder Fields)

The area of fanglomerate geologic deposits on the foothills of the Santa Ynez Mountains, and especially within the Terrace area, exhibits numerous outcroppings of sandstone boulders, presumably left in place as the surrounding surfaces have eroded away. No recognized community classification has been forwarded by any standard state or agency entity to describe this situation, or to the specific elements of vegetation that characterize them. Nonetheless, previous reports have identified their presence and unique features. They are discussed here because they must be viewed as an integral part of the upland areas that support herbaceous grassland vegetation, and to some small extent, scrub and brushland vegetation. In addition, the boulder fields are restricted to these upland areas and are not found in abundance in other locations. Comprised of sandstone, the outcrops themselves support little in the way of vascular plant species, but they have been observed to support nonvascular plants, especially lichens. The report by DMEC (1998) lists not less than 24 lichen species associated with rock outcrops. Two moss species tentatively identified as *Bryum* spp. in the DMEC report were not associated with the rock outcrops, however. Although a substantial number of additional bryophytes were noted on the project site during the recent surveys (Envicom 2003), these rocks were also found to be rather depauperate in bryophytes, with most occurrences instead associated with soils and trees.

Scrub and Brushland Communities

Upland

California Sagebrush Scrub

California sagebrush scrub occurs in moderate amounts on both the Terrace and Meadow areas. This is a type of Coastal Scrub that is dominated by California sagebrush (*Artemisia californica*), with scattered sawtooth goldenbush (*Hazardia squarrosa*), coastal isocoma (*Isocoma menziesii*), California encelia (*Encelia californica*), and coyote brush (*Baccharis pilularis*). This community has a low stature, and ranges from rather dense, to open and intergrading with grasslands. Where it is open, the understory is enriched with native perennial grasses including foothill needlegrass (*Nassella lepida*) and coast melic (*Melica imperfecta*), as well as soap plant (*Chlorogalum pomeridianum*), California everlasting (*Gnaphalium californicum*), golden-yarrow (*Eriophyllum confertiflorum*), western verbena (*Verbena lasiostachys*), an occasional goldenback fern (*Pentagramma triangularis*), and annuals such as common eucrypta (*Eucrypta chrysanthemifolia*) and wand chicory (*Stephanomeria virgata*).

Coyote Brush Scrub

Coyote brush (*Baccharis pilularis*) is the dominant shrub in these areas, mainly occurring in the Terrace area. Associated species are frequently the same as those discussed above for California sagebrush scrub, and again, the stands can be rather dense to open, with a grassland matrix comprising the spaces between the shrubs.

Mixed Scrub

Mixed scrub occurs on both the Terrace and Meadow areas, primarily associated with slopes adjacent to the major drainages. In contrast to the California Sagebrush and Coyote brush dominated areas previously discussed, mixed scrub contains a greater assemblage of species, and frequently no single species dominates. In addition to California sagebrush (*Artemisia californica*) and coyote brush (*Baccharis pilularis*), additional coastal scrub associates include sawtooth goldenbush (*Hazardia squarrosa*), purple sage (*Salvia leucophylla*), and lemonadeberry (*Rhus integrifolia*). The structure of the stands is typically dense and includes a few woody associates of chaparral such as redberry (*Rhamnus crocea*), bush mallow (*Malacothamnus fasciculatus*), toyon (*Heteromeles arbutifolia*) and

Exhibit 2

BENEFIT-COST ANALYSIS TOOLKIT

GUIDANCE FOR WILDLAND/URBAN INTERFACE FIRE MITIGATION PROJECTS

Prepared for
The Federal Emergency Management Agency
500 C Street, SW
Washington, DC 20472

June 2006

URS Group, Inc.
200 Orchard Ridge Drive, Suite 101
Gaithersburg, Maryland 20878

URS Project No. 15702304.00100

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Figures

1. OVERVIEW OF FIRE TYPES

This section contains a review of technical fire issues, because none of the existing FEMA BCA guidance manuals covers these issues or fire mitigation projects. Fires are often grouped into three types: structure fires, wildland fires, and wildland/urban interface fires.

Structure fires involve one or more buildings and are typically managed by local fire departments. In managing structure fires, fire department priorities are to:

1. Minimize casualties
2. Prevent a single structure fire from spreading to other structures
3. Minimize damage to the structure and contents

The annual number of structure fires in the United States has been steadily declining for many decades due to improved building codes, widespread use of smoke and fire detectors, and improved fire suppression capability (water supply, equipment, communications, and mutual aid).

Wildland fires involve vegetation as the predominant fuel and are typically managed by a combination of Federal, State, and local fire agencies. Historically, wildland fire suppression strategy focused on minimizing the acreage burned. In recent years, however, fire suppression strategy for wildland fires has evolved substantially in two important aspects. First, wildland fires are being recognized as part of the natural ecology and natural life cycles of wildlands. Fires create open spaces with different habitats for both plants and animals than existed previously. Second, the emphasis on maximum suppression of wildland fires has resulted in many fires being smaller than would naturally occur. Because of the reduction in frequent, smaller fires, many wildland areas have developed extraordinarily high fuel loads. Thus, the potential for very large, catastrophic wildland fires may actually be increased by the effective suppression of smaller fires. In recent years, evolving strategies for dealing with wildland fires have focused more attention on fuel management. Strategies include more controlled burns and greater tolerance for allowing smaller fires to burn, with the objective of reducing fuel loads of smaller vegetation and thus reducing the potential for larger fires.

In **wildland/urban interface fires**, the fuel load consists of both vegetation and structures. This section focuses predominantly on wildland/urban interface fires. These fires are generally the primary focus of FEMA-funded mitigation projects because they may pose a substantial threat to both property and life-safety and are often of a magnitude that exceeds local fire suppression response capabilities.

2. WILDLAND/URBAN INTERFACE FIRES

In many communities, recent patterns of development have led to increasing numbers of homes being built in areas subject to wildland fires. Development in areas subject to wildland fires may pose high levels of life-safety risk for occupants as well as high levels of fire risk for homes and other structures.

Urban or suburban areas may have a significant amount of landscaping and other vegetation. However, in such areas the fuel load of flammable vegetation is not continuous, but rather is broken by paved areas, open space, and areas of mowed, often irrigated, grassy areas with low fuel loads. In these areas, most of the significant fires are single-structure fires. The combination of separations between structures, various types of firebreaks, and low total vegetative fuel loads make the risk of fire spreading much lower than in wildland areas. Furthermore, most developed areas in urban and suburban areas have water systems with sufficient capacities to provide water for fire suppression as well as organized fire departments that typically respond quickly to fires, with personnel and apparatus to control fires effectively. Thus, in such areas the risk of a single structure fire spreading to involve multiple structures is generally quite low.

Areas subject to wildland/urban interface fires have very different fire hazard characteristics. The defining characteristic of the wildland/urban interface area is that structures are built in areas with essentially continuous (and often high) vegetative fuel loads and are, therefore, subject to wildland fires. When wildland fires occur, they tend to spread quickly, and structures in these areas may become little more than additional fuel sources.

The fire risk to structures and occupants in wildland/urban interface areas may be high not only because of the high vegetative fuel loads but also because fire suppression resources are typically more limited than in urban or suburban areas. Homes in wildland/urban interface areas most commonly use wells rather than municipal water supplies. Thus, the availability of water for fire suppression is often severely limited. Reduced availability of water resources makes it more likely that a small wildland fire or a single structure fire in an urban/wildland interface area will spread before it can be extinguished.

Furthermore, because many developments in interface areas have relatively low populations and are some distance from population centers, the availability of firefighting personnel and apparatus is generally lower than in more populated areas, and response times are typically much longer. The longer response times arise in part because of greater travel distances and times, but also because most fire departments in lower population density areas are entirely or largely composed of volunteer staff. Response times from volunteer staff fire departments are typically longer than response times for career staff departments, where fire stations are staffed continuously. In some cases, narrow winding roads also impede access by firefighting apparatus. As with water supplies, the reduced availability of firefighting personnel and apparatus and the longer response times increase the probability that a small wildland fire or a single structure fire in an urban/wildland interface area will spread before it can be extinguished.

Developments in urban/wildland interface areas often face high fire risk because of the combination of high fire hazard (high vegetative fuel loads) and limited fire suppression capabilities. Unfortunately, occupants in many wildland/urban interface areas may also face high life-safety risk. High life-safety risk arises because of high fire risk, especially from large fires that may spread quickly and block evacuation. Life-safety risk in interface areas is often exacerbated by limited numbers of roads (in the worst case, only one access road) that may be narrow and winding and subject to blockage by a wildland fire.

Life-safety risk in interface areas is also exacerbated by homeowners' reluctance to evacuate homes quickly. Instead, homeowners often try to protect their homes with limited fire suppression resources. Such efforts generally are minimally effective. For example, the water flow from a garden hose is too small to control even a single structure fire (once the structure is engulfed by flames) and is particularly ineffective on a wildland fire. Unfortunately, homeowners who delay evacuation in an attempt to save their homes often place their lives in grave jeopardy.

Major fires in the urban/wildland interface have the potential for vast destruction and very high casualties. For example, the October 20, 1991, East Bay Fire in Oakland, California, burned 1,600 acres with 25 fatalities, 150 injuries, and over 3,300 single-family homes and 450 apartment units destroyed. Total damages were over $1.5 billion. This fire was fueled by very high vegetative fuel loads and occurred on an unusually hot, dry, windy day. The fire spread extremely quickly, with over 800 homes engulfed within the first hour, and completely overwhelmed initial fire suppression efforts.

In October 1991, rural counties near Spokane, Washington, experienced 92 separate fires that burned about 35,000 acres and 114 homes. Between October 25 and November 3, 1993, 21 large wildland fires broke out in California. These fires burned over 189,000 acres and destroyed over 1,100 structures with 3 fatalities and hundreds of injuries. The highest number of recorded casualties is from a wildland/urban interface fire in U.S. history occurred in 1871 in Peshtigo, Wisconsin. This fire burned over 1.2 million acres and killed over 1,200 people. These examples dramatically illustrate the potential for fire disasters in the urban/wildland interface area.

3. WILDLAND/URBAN FIRE HAZARD FACTORS

The term “fire hazard” refers to the probability and severity of fires. Fire hazard characteristics for wildland/urban interface fires are identical to those for wildland fires. In effect, wildland/urban interface fires are wildland fires with additional fuel load from structures. The hazard depends on the following factors:

- Fuel loads
- Moisture content
- Fuel continuity
- Weather
- Local topography
- Suppression capabilities (resources and access)

Several parameters define the fire potential of vegetation. Vegetative **fuel loads** are typically expressed as tons per acre. The greater the fuel loading, the greater the amount of energy that will be released in a fire. Vegetative fuels are also classified by burn index, which is a measure of the amount of energy per pound of fuel. Fuels may also be classified by potential duration of burning. For example, wildfires fueled by grass may spread very quickly, but grass contains relatively little fuel energy and tends to burn out quickly. Wildfires fueled by larger vegetation (trees or a high density of woody plants) may spread more slowly, but larger vegetation contains more fuel energy and tends to burn for a longer duration.

Moisture content of vegetative fuels is an important determinant of wildland fire potential. The lower the moisture content is, the greater the fire potential. Moisture content at any specific time depends on antecedent (before the specific time) weather conditions. The moisture content of larger fuels depends on prior weather conditions over periods of several weeks or even months. The moisture content of smaller fuels (brush) depends on prior weather conditions over several days or a week or two. The moisture content of very small fuels (e.g., grasses) depends largely on prior weather conditions over a few hours or a day or two.

Fire hazards posed by vegetative fuel loads also depend on **fuel continuity**, both horizontally and vertically. Horizontal continuity, the distribution of fuels over the landscape, strongly affects the spread and containment of wildfires in a given geographic area. Vertical continuity of fuels, the linkage between fuels at ground level and tree crowns, also affects the fire potential. Forests with strong ladder fuels (understory growth between ground fuels and tree crowns) are more likely to have major fires involving tree crowns. Forests with limited ground fuels and little or no ladder fuels are much more likely to experience minor ground fires without a fire involving tree crowns.

Weather has a significant effect on wildland fire potential. Weather conditions of high temperatures, low humidity, and high winds may greatly accelerate the spread of a wildland fire and make containment difficult or impossible. Changes in weather conditions can accelerate a fire's spreading rate. Many casualties have occurred when firefighting personnel are trapped by sudden bursts of fire spread in response to changes in wind conditions. For many larger fires, containment is often possible only with favorable weather changes, such as a drop in temperature, reduced winds, or significant rainfall. Past weather is also an important factor in fire hazard levels. In drought conditions, the moisture content of vegetative fuels is much lower than under normal or wet conditions, and the level of fire hazard may be much higher than normal.

Local topography influences the spread of wildfires. Fires burn much more quickly up-slope than down-slope. Doubling a slope approximately doubles the rate of fire spread. Canyons, gulches, and other local topographic effect can act as chimneys, intensifying fires in certain areas. Fires tend to slow at ridge tops, and ridge tops are often chosen as locations for firebreaks.

Suppression of wildland fires depends on the three primary factors that govern fire potential: vegetative fuel load, weather, and topography. High fuel loads; hot, dry, windy weather; and steep slopes increase fire potential and make fire suppression more difficult. Conversely, low fuel loads; cool, moist weather with low winds; and gentle slopes make fire suppression easier.

In addition, fire suppression depends on two other important factors: availability of fire suppression resources and access. Fire suppression resources include firefighting personnel, equipment and apparatus, as well as water and chemical fire suppressants. The greater the availability of fire suppression resources, the more likely a given fire will be contained quickly. Fire suppression also depends on access. Fires in remote areas without road access are more difficult to fight and harder to contain than are fires with better access for fire suppression crews and apparatus.

In the 1930s, wildfires consumed an average of 40 to 50 million acres per year in the contiguous United States, according to U.S. Forest Service (USFS) estimates (USFS, *Managing the Impact of Wildfires on Communities and the Environment*, September 8, 2000). By the 1970s, the average acreage burned had been reduced to about 5 million acres per year. Over this time period, fire suppression efforts were dramatically increased, and firefighting tactics and equipment became more sophisticated and effective. For the 11 Western states, the average acreage burned per year since 1970 remained relatively constant at about 3.5 million acres per year.

However, due to more effective suppression of wildland fires, the patterns and characteristics of wildland fires are changing. Vegetation species that would have normally been minimized by frequent fires have become more dominant. Over time, many species have become susceptible to disease and insects, leading to an increase in dead and dying trees. The resulting accumulation of debris has created fuel loads than promote intense, rapidly spreading fires. In many areas, the introduction of non-native species has added to the fuel load. Traditional patterns of logging and fire suppression have also changed the characteristics of forests. Older forests were typically less dense, with smaller numbers of larger, more fire-resistant trees. Newer forests are denser with larger numbers of smaller, less fire-resistant trees. Over the last several decades, the combination of these effects has resulted in many recent wildland fires that are hotter, faster, and larger than those experienced in the past.

4. DIFFERENCES BETWEEN FIRE HAZARD AND OTHER NATURAL HAZARDS

There are two significant differences between fire hazards and the other natural hazards. First, for most natural hazards, the annual probability of hazard events is essentially constant over time. That is, the probability of a given location experiencing a major flood, hurricane, or earthquake does not vary significantly from one year to the next. However, the level of fire hazard depends strongly on weather history. Fire hazard levels may be significantly higher during periods of drought than during normal or wet periods.

Second, most hazards have a range of severity. For a given location, flood depths and velocities may vary, or a hurricane may be Storm Class 2 or Storm Class 5. For wildland/urban interface fires, the level of severity is usually “burn” or “not burn.” Once a wildland/urban interface fire burns through a developed area, homes that are ignited are generally a complete loss. This lack of range differs significantly from single structure fires in urban or suburban areas, where intermediate levels of fire damage are common.

5. COMPONENTS OF WILDLAND/URBAN INTERFACE FIRE RISK

In general, the term “risk” means the threat to the built environment and people. For wildland/urban interface fires, the main components of risk include:

- Casualties (deaths and injuries)
- Physical damages to buildings and contents
- Physical damages to infrastructure
- Loss of function (economic impacts)

Physical damages and casualty impacts of wildland/urban interface fires are clearly understood. Wildland/urban interface fires cause physical damages to buildings, contents, and infrastructure and may result in casualties. Although the physical damages and casualties arising from wildland/urban interface fires may be severe, it is very important to recognize that wildland/urban interface fires may also cause significant economic impacts on affected communities when damage results in loss of function of buildings and infrastructure. In some cases, the economic impact of such loss of function may be comparable, or even greater, to the economic impact of physical damages.

Examples of economic impacts arising from wildland/urban interface fire damage include the following:

1. **Displacement Costs.** Displacement costs represent the costs of temporary quarters when occupants (residential, commercial, or public buildings) are displaced to temporary

quarters while damage is repaired. Displacement costs include rent; other monthly costs of displacement, such as furniture rentals and other extra costs; and one-time costs, such as moving costs and utility hookup fees.

2. **Loss of public services.** Losses of public services are valued at the cost of providing service plus a continuity premium for services that are critical to the immediate disaster response and recovery. Detailed guidance on how to value the benefits of avoiding loss of public services is given in the FEMA “What is a Benefit?” document. (For a copy of “What is a Benefit?” refer to the Guidance Documents main folder on the *FEMA Mitigation BCA Toolkit CD*). This draft guidance includes continuity premiums and functional downtimes for police, fire, and medical facilities as well as guidance on how to value loss of services for EOCs and emergency shelters.
3. **Business and rental income losses.**
4. **Economic impacts of loss of transportation and utility services.** “What is a Benefit?” includes detailed guidance on how to value the economic impacts of traffic delays or detours from road and bridge closures and how to value the economic impacts of loss of electric power, potable water, and wastewater services.

6. WILDLAND/URBAN INTERFACE FIRE HAZARD DATA

6.1 Background Information

Fire risk, the threat to the built environment and to people, depends on fire hazard (the probability and severity of fires) but also on the inventory of structures and people in fire-prone areas. High fire hazard areas pose a high risk to structures and people only to the extent that development is present in the high fire hazard areas.

For life-safety, fire risk also depends strongly on the response time and access and egress routes from developed areas in high fire hazard areas. Life-safety risk may be substantially exacerbated in areas with limited access and egress because residents (or firefighters) may be trapped by rapidly spreading wildland/urban interface fires. The worst-case situation is an isolated development with only a single road for access/egress.

Areas at highest risk for wildland/urban interface fires have a combination of high fire hazard (fuel loads, weather, topography), a high level of development (population), and limited access and egress routes.

Overall, the level of fire hazard for wildland or wildland/urban interface fires is highest in the Western states. Many portions of states in the Rocky Mountain area westward to the Pacific Coast have a combination of characteristics that yield a high wildland fire hazard. These factors include substantial vegetative fuel loads, prolonged periods of hot, dry, windy weather conditions, and areas of steep slopes that exacerbate fire spread and limit fire suppression efforts.

In general, most areas in the Central and Eastern United States have lower levels of wildland fire hazard because of lower fuel loads (Plains states) and generally wetter climatic conditions. However, especially during periods of drought, many areas in the Central and Eastern United States do have a significant level of fire risk for wildland or wildland/urban interface fires. For example, the potential for major fires in the Central and Eastern United States is well illustrated by numerous large fires in Florida in recent years.

6.2 National Fire Hazard Maps

Several quantitative and semi-quantitative measures can be applied to the level of fire hazard. Most of these measures have been developed by the USFS in cooperation with other fire agencies. National maps of these fire hazard measures are available at the USFS website (http://www.fs.fed.us/). These maps are updated very frequently, in some cases daily. All of the USFS Fire Danger maps and related technical maps are viewable at the website by going to Fire & Aviation, then Fire Information: Outlooks, Fire Maps, and Stats, then National Fire Maps (http://www.nifc.gov/firemaps.html), then select Large Fire Locations. The Large Incidents map, additional fire maps, and information are also available from the USFS Remote Sensing Applications Center (http://www.fs.fed.us/eng/rsac/index.html), then select Active Fire Maps (http://activefiremaps.fs.fed.us/). For reference, the USFS website also has an extensive glossary of fire-related terms, which may be helpful for those unfamiliar with fire terminology and nomenclature.

A sample national Fire Danger Map is shown in Figure 1.

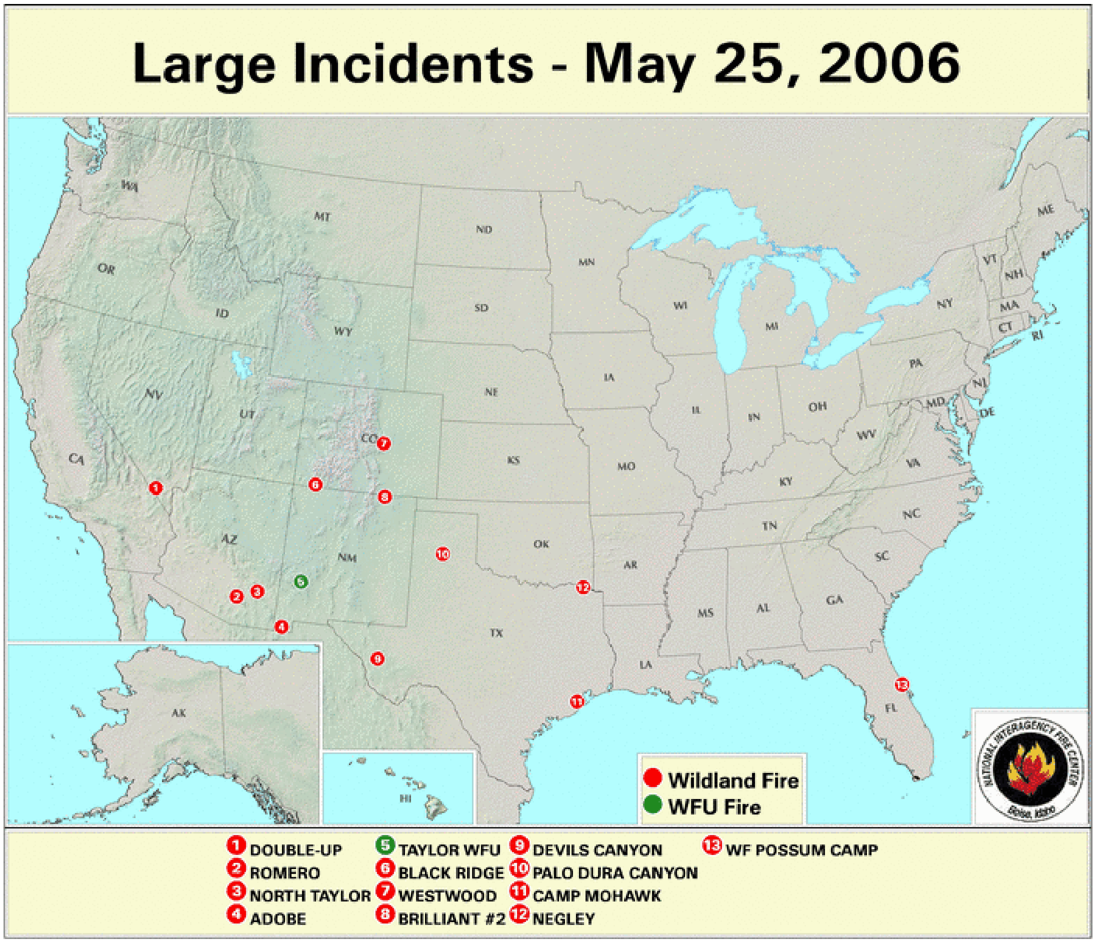


Figure 1: Sample National Fire Danger Map.

Note that National Fire Danger Maps reflect specific fire conditions as of the map date. Areas at substantial long-term risk for wildland fires may not be marked as high fire danger areas on any specific map, depending on time of year and local weather conditions.

The spatial resolution of the web-published maps is relatively low. For example, the Oregon data are based on about 90 reporting stations scattered across the state. Thus, these maps are intended to show regional differences in the level of fire hazard, rather than detailed local differences. However, as a regional guide to fire hazard levels, these maps are useful and readily accessible.

The most useful measures of serious fire danger are briefly reviewed below.

6.3 Observed Fire Danger Class Maps

"Fire Danger Class" is a five-level fire danger classification system that is based largely on moisture content in fuels and weather conditions (temperature, humidity, wind). Daily, nationwide maps are viewable and printable from the USFS website (http://www.wfas.us/content/view/17/32/). This fire danger classification is used for purposes such as restricting campfires and outdoor burning and is widely reported in the media. The levels of danger and their color codes are defined below.

- **LOW (Dark Green).** Fuels do not ignite readily from small firebrands, although more intense heat sources, such as lightning, may start many fires in areas with decayed or dried wood. Fires in open cured grassland may burn freely a few hours after rain, but woods fires spread slowly by creeping or smoldering and burn in irregular fingers. There is little danger of spotting.
- **MODERATE (Light Green or Blue).** Fires can start from most accidental causes; but, with the exception of lightning fires in some areas, the number of starts is generally low. Fires in open-cured grassland will burn briskly and spread rapidly on windy days. Timber fires spread slowly to moderately fast. The average fire is of moderate intensity, although heavy concentrations of fuel, especially draped fuel, may burn hot. Short-distance spotting may occur but is not persistent. Fires are not likely to become serious, and control is relatively easy.
- **HIGH (Yellow).** All fine dead fuels ignite readily and fires start easily from most causes. Unattended brush and campfires are likely to escape. Fires spread rapidly and short-distance spotting is common. High-intensity burning may develop on slopes or in concentrations of fine fuel. Fires may become serious and their control difficult, unless they are attacked successfully while small.
- **VERY HIGH (Orange).** Fires start easily from all causes and, immediately after ignition, spread rapidly and increase quickly in intensity. Spot fires are a constant danger. Fires burning in light fuels may quickly develop high-intensity characteristics such as long-distance spotting and fire whirlwinds when they reach heavier fuels.
- **EXTREME (Red).** Fires start quickly, spread furiously, and burn intensely. All fires are potentially serious. Development into high-intensity burning will occur from smaller fires and will usually be faster than in the very high danger class. Direct attack is rarely possible and may be dangerous, except immediately after ignition. Fires that develop

headway in heavy slash or in conifer stands may be unmanageable while the extreme burning condition lasts. Under these conditions, the only effective and safe control action is on the flanks until the weather changes or the fuel supply lessens.

The U.S. Fire Service (USFS) website has numerous other national fire maps that are of interest to fire service professionals and fire researchers (http://www.wfas.net/). A few of these maps are briefly summarized below.

1. The **Fire Potential Index Map** (http://www.wfas.us/content/view/25/40/) is an experimental product that portrays a more quantitative measure of fire danger than the Fire Danger Classification map discussed above.
2. **Dead Fuel Moisture Maps** (http://www.wfas.us/content/view/23/38/) portray estimates of moisture content in 10-hour, 100-hour, and 1,000-hour time lag fuels. A fuel's time lag is proportional to its diameter and is the time it takes to lose approximately 2/3 of the difference between its initial and equilibrium moisture content (local environmental conditions, assuming local conditions remain constant). The 10-hour (1/4- to 1-inch diameter) fuels are grasses whose moisture content depends primarily on rainfall, temperature, humidity, and wind conditions. The 1,000-hour (3- to 8-inch diameter) fuels involve medium to large trees whose moisture content depends on weather conditions for much longer periods. These maps provide another quantitative measure of the level of fire hazard. The lower the moisture content, the more rapidly fires spread and the more intensely they burn, for any given level of fuel load, slope, and current weather conditions.
3. **Keetch-Byram Drought Index Maps** (http://www.wfas.us/content/view/32/49/) show a quantitative measure on the amount of water missing from soils and vegetation due to drought conditions. This index is based on mathematical relationships between current and recent weather conditions and potential or expected fire behavior. The index scale ranges from 0 to 800, with higher numbers representing progressively more serious droughts (lower moisture contents).
4. **Greenness Maps** (http://www.wfas.us/content/view/30/47/) include four technical maps indicating the level of greenness in vegetation, which is another measure of fire potential.
5. **The National Fire Danger Rating Fuel Model Map** (http://www.wfas.us/content/view/29/44/) portrays detailed fuel models for various types of vegetation to rate fire danger across large geographic areas (not for fire behavior assessment at any specific site).

7. FIRE HAZARD ESTIMATES FOR BCAs

The first step in evaluating the level of fire hazard for a potential mitigation project is to review the national fire hazard maps discussed above. If the project site is in a high or moderately high fire hazard area, then more detailed, site-specific evaluations may be necessary. The national fire hazard maps present a general picture of the levels of fire hazard, which vary with time of year and weather conditions for each location.

A BCA requires a quantitative measure of the level of fire hazard. Quantitative measures of fire hazard can be determined by estimating the annual probability that a given acre of wildland or wildland/urban interface area will burn. This probability can be calculated from historical data.

However, major wildland or wildland/urban interface fires are relatively infrequent events. Thus, a given small area may not have a documented history of such fires. However, the absence of previous wildland or wildland urban interface fires in a specific area does not necessarily mean that the level of fire risk is low. If similar nearby areas *do* have a history of fires, then the area of interest may also logically be inferred to be at a similar level of fire hazard.

Quantitative estimates of the probability of wildland or wildland/urban interface fires may be determined using the following suggested methodology:

1. Determine a large geographic area around the potential project site with similar fire hazard characteristics (vegetation, weather, and slopes). This area may be a single county, several contiguous counties, or a large portion of a state.
2. Determine the size of the sample area in Step 1 above. Convert the area measured in square miles to acres by multiplying by 640 acres per square mile.
3. Gather historical data on wildland fires in the sample area over as long a period as possible, including the number of acres burned in each fire.
4. Divide the total number of acres burned over the time period by the number of years. For example, if a total 900,000 acres burned in 47 fires over 25 years, then the average number of acres burned per year is 900,000 divided by 25, or 36,000 acres per year.
5. Divide the average number of acres burned per year by the total area of the sample area in acres. For example, if the study area is 5,000,000 acres and the average number of acres burned per year is 36,000, then the annual probability of burning is 36,000 divided by 5,000,000, or 0.0072.

The long-term average probability of burning, as calculated above, is probably the best available quantitative measure of the level of fire hazard for any given area, absent very detailed technical local studies of fire hazards.

8. CONSIDERATIONS FOR WILDLAND/URBAN INTERFACE FIRE BCA

These categories of information are essential for any wildland/urban interface fire BCA:

1. Fire hazard data
2. Building (or other facility) characteristics
3. Economic impacts

8.1 Fire Hazard Data

For any fire mitigation project site, the level of fire hazard can be ascertained by reviewing the national fire hazard maps discussed above. In making such assessments, it is important to recognize that the level of fire hazard for any location varies with time of season and weather conditions. Thus, evaluations of the level of fire hazard must include a range of historical fire hazard data to develop an accurate picture.

The second step, as discussed above, is to gather historical fire data for a sample area of a similar fire hazard level around the project site. The annual burn probability can be calculated from this data.

8.2 Building or Other Facility Characteristics

To some extent, building (or other facility) characteristics are less important for evaluation of fire mitigation projects than for other natural hazards. Unless a structure is built completely of non-flammable, non-heat-vulnerable materials, which is extremely rare, all structures will burn when exposed to wildland/urban interface fires.

Most structures are highly vulnerable to burning when exposed to wildland/urban interface fires. This includes not only wood frame structures but also steel, concrete, and masonry structures, all of which commonly have flammable interior building elements and contents. Windows typically fail when exposed to the high heat of fires and thus provide fire entry routes into buildings.

The building characteristics of structures that are comprehensively designed and built to be fire-resistant (note: fire-resistant does not mean fireproof) are an exception to the general rule when evaluating fire mitigation projects. Such structures have non-flammable roofs, non-flammable exterior cladding such as stucco, designs to minimize trapping points for embers, fire resistant screens over openings, and fire-resistant glass. Communities built to fire-safe standards have lower risk of catastrophic wildland/urban interface fires, especially when fire-safe landscaping practices are carefully followed.

As for any mitigation project, function and occupancy levels are important factors for evaluating fire mitigation projects. Areas that contain important buildings (or other facilities) with critical functions and/or high occupancy areas are commonly given high priority for fire mitigation projects.

8.3 Economic Impacts

The value of infrastructure and timber value for the area directly impacted by the proposed mitigation project may be evaluated and estimated for the BCA.

9. FIRE MITIGATION PROJECTS

There are three common types of mitigation projects for wildland/urban interface fires:

- Fire-safe practices for structures and landscaping
- Vegetative fuel load management
- Enhancement of fire suppression capabilities

Fire-safe practices for structures and landscaping include fire-resistant roof materials, exterior wall coverings, windows and other building openings, and decks and fire-resistant landscape practices near structures.

Vegetative fuel load management projects include vegetation removal, controlled burns, and construction of firebreaks.

Enhancement of fire suppression capability projects include adding to fire suppression water supplies, equipment, communications and emergency planning, and response training.

10. BCA BASICS FOR WILDLAND/URBAN INTERFACE FIRE MITIGATION PROJECTS

The BCA of a wildland/urban interface fire mitigation project is similar to BCAs for the more common mitigation projects (e.g., flood mitigation projects), and the same general concepts and principles apply. For fire mitigation projects, the same four-step process applies as for any hazard mitigation project:

1. **Determine Fire Hazard for the Project Site (i.e., the frequency [probability] and severity of fires)**
   a) Use the national fire data maps (see Fire Hazard Data section above) to determine areas of high fire hazard.
   b) Refine the preliminary estimate of fire hazard by gathering data on historic wildland or wildland/urban interface fires to determine specific areas of high fire hazard.
   c) Quantify the level of fire hazard by determining the annual probability of burning, following the suggested approach discussed in Sections 7 and 8. This approach includes defining a sample area, gathering data on the total number of acres burned over a time period, and calculating the annual probability. This calculation is most easily done using the Fire BCA Module (see Section 11, Fire Module).
2. **Estimate Damages and Losses Before Mitigation**
   a) Determine the number and value of structures in the mitigation project area.
   b) Estimate typical contents values using approaches similar to those used for flood mitigation projects. For residential structures, the standard contents value is 30% of building replacement value.
   c) Estimate the expected damages to infrastructure (e.g., power and telecommunications lines) if an area burns, using documented local data.
   d) Estimate the casualty reduction, which may be a significant benefit for some fire mitigation projects. For the at-risk population directly protected by the proposed fire mitigation project, use the typical death and injury rates suggested in Section 12, Evaluating Wildland/Urban Interface Fire Mitigation Projects.
3. **Estimate Damages and Loses After Mitigation (by estimating the effectiveness of the mitigation project using the following guidelines)**
   a) Fire mitigation actions never completely eliminate the possibility of future fire losses. Rather, mitigation actions reduce, to varying extents, the potential for fire damages and losses.
   b) For structures, comprehensive implementation of fire-safe building and landscape practices may reduce fire losses by up to 50%. More modest, partial measures are unlikely to reduce fire losses by more than 10% or 20%.
   c) Similarly, very comprehensive vegetation management programs to reduce fuel loads, in combination with enhanced firebreaks and other measures, might reduce fire losses by up to 50%. More modest, partial measures are unlikely to reduce fire losses by more than 10% or 20%.

4. **Calculate Benefits (taking into account the project useful life and the discount rate of 7%)**
    a) Many fire mitigation projects have a short useful life. For example, augmented firebreaks, vegetation control effects, and controlled burns are likely to be effective for no more than 1-2 years, or at the most 5 years, because vegetative fuel loads will regenerate in a few years unless such efforts are ongoing.
    b) Some fire mitigation projects, such as installing fire-resistant roofs, have a longer project useful life. For such projects, a 30-year project useful life may be appropriate. For the few fire mitigation projects that are truly permanent projects, such as permanent increases in water supplies for fire suppression, a 100-year project useful life may be appropriate.
    c) If proposed mitigation projects have ongoing annual maintenance costs, then such costs must be included in the BCA.

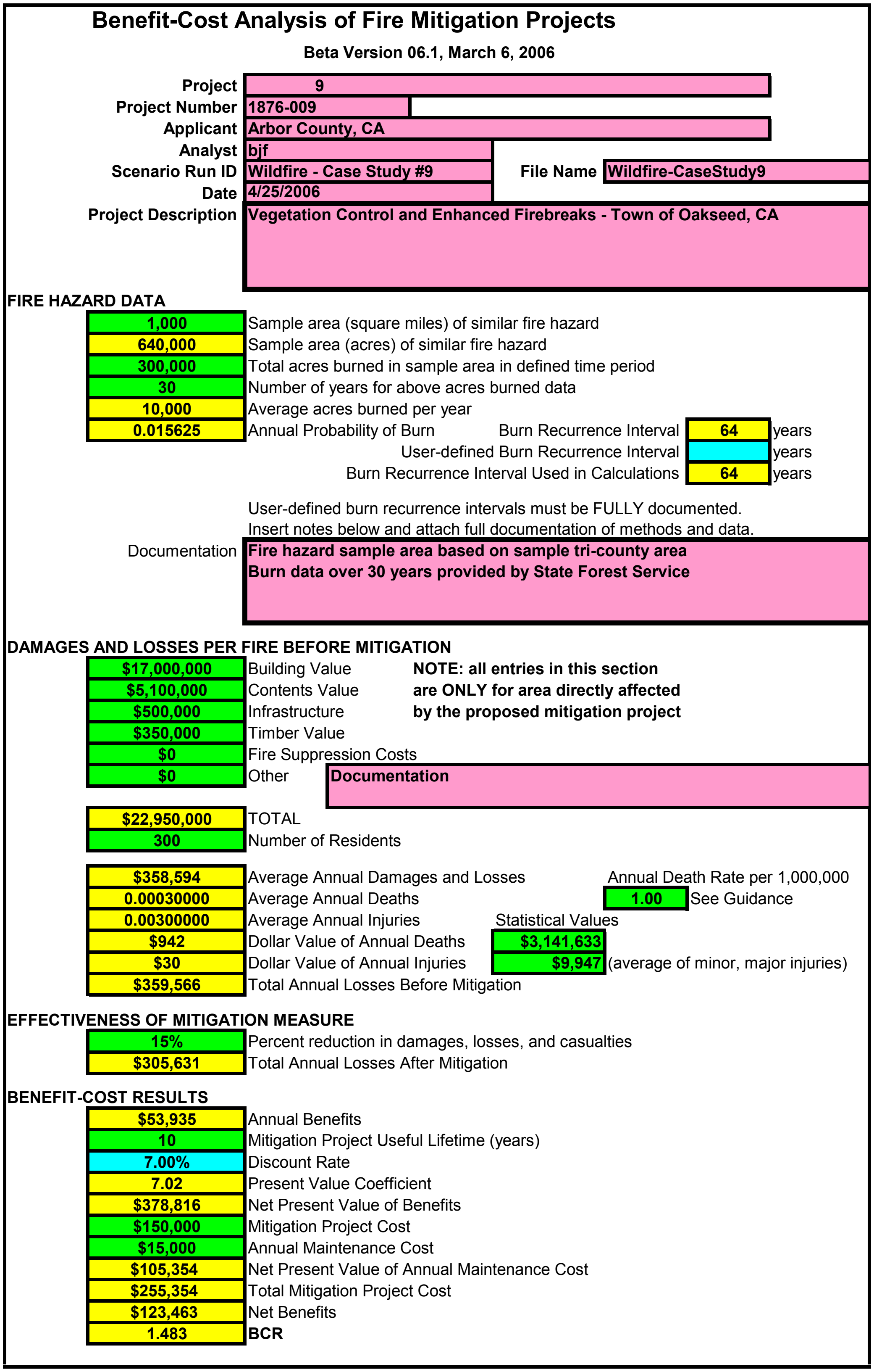
BCAs of fire mitigation projects are specialized and require a moderate amount of technical expertise, including familiarity with commonly used fire nomenclature and an understanding of common mitigation measures for fires. Analysts without fire experience are, therefore, encouraged to consult with technical experts who are familiar with wildland/urban interface fire issues.

11. FIRE MODULE

BCAs of fire mitigation projects are prepared using the frequency-damage approach, which is the approach used in the Riverine LD Module. Although the module is labeled “flood,” it can actually be used for any hazard for which damage estimates can be expressed in relationship to frequency, including wildland/urban interface fires, ice storms, landslides, and many other types of hazards.

Alternatively, a new module has been developed specifically for evaluation of wildland/urban interface fire mitigation projects: BCA of Fire Mitigation Projects. A sample printout of this new module is shown in Figure 2.

The fire module is a simple, one-page BCA Module that provides a calculation template for entering historical fire data to determine the annual probability of burning, along with entries to facilitate estimates of damages and losses before and after mitigation. The module also includes the net present value calculation necessary for all BCAs and a calculation of the BCR.



Benefit-Cost Analysis of Fire Mitigation Projects

Beta Version 06.1, March 6, 2006

Project	9		
Project Number	1876-009		
Applicant	Arbor County, CA		
Analyst	bjf		
Scenario Run ID	Wildfire - Case Study #9	**File Name**	Wildfire-CaseStudy9
Date	4/25/2006		
Project Description	Vegetation Control and Enhanced Firebreaks - Town of Oakseed, CA		

FIRE HAZARD DATA

1,000	Sample area (square miles) of similar fire hazard			
640,000	Sample area (acres) of similar fire hazard			
300,000	Total acres burned in sample area in defined time period			
30	Number of years for above acres burned data			
10,000	Average acres burned per year			
0.015625	Annual Probability of Burn	Burn Recurrence Interval	64	years
		User-defined Burn Recurrence Interval		years
		Burn Recurrence Interval Used in Calculations	64	years

User-defined burn recurrence intervals must be FULLY documented.
Insert notes below and attach full documentation of methods and data.

Documentation **Fire hazard sample area based on sample tri-county area**
Burn data over 30 years provided by State Forest Service

DAMAGES AND LOSSES PER FIRE BEFORE MITIGATION

NOTE: all entries in this section are ONLY for area directly affected by the proposed mitigation project

$17,000,000	Building Value	
$5,100,000	Contents Value	
$500,000	Infrastructure	
$350,000	Timber Value	
$0	Fire Suppression Costs	
$0	Other	**Documentation**
$22,950,000	TOTAL	
300	Number of Residents	

$358,594	Average Annual Damages and Losses		Annual Death Rate per 1,000,000	
0.00030000	Average Annual Deaths		1.00	See Guidance
0.00300000	Average Annual Injuries	Statistical Values		
$942	Dollar Value of Annual Deaths	$3,141,633		
$30	Dollar Value of Annual Injuries	$9,947	(average of minor, major injuries)	
$359,566	Total Annual Losses Before Mitigation			

EFFECTIVENESS OF MITIGATION MEASURE

15%	Percent reduction in damages, losses, and casualties
$305,631	Total Annual Losses After Mitigation

BENEFIT-COST RESULTS

$53,935	Annual Benefits
10	Mitigation Project Useful Lifetime (years)
7.00%	Discount Rate
7.02	Present Value Coefficient
$378,816	Net Present Value of Benefits
$150,000	Mitigation Project Cost
$15,000	Annual Maintenance Cost
$105,354	Net Present Value of Annual Maintenance Cost
$255,354	Total Mitigation Project Cost
$123,463	Net Benefits
1.483	**BCR**

Figure 2: Sample of Wildland/Urban Interface Fire Mitigation Evaluation

12. EVALUATING WILDLAND/URBAN INTERFACE FIRE MITIGATION PROJECTS

For a community considering fire mitigation projects, there are two considerations:

1. The level of fire hazard and fire risk (i.e., the frequency and severity of fires and the amount of development and population in fire-prone areas) must be high enough in a given community to warrant the consideration of fire mitigation projects.
    - If the fire risk is high, the community may wish to make fire mitigation a high priority and implement a widespread mitigation program.
    - If the fire risk is moderate, the community may wish to consider only a few fire mitigation projects.
    - If fire risk is low, the community may wish to focus mitigation efforts on other hazards that pose a more significant threat to the community.
2. How the community identifies the best fire mitigation projects if the level of fire hazard and fire risk are sufficiently high to warrant consideration.

Methods to evaluate the level of fire hazard and fire risk are given in the following section, which outlines a useful three-step process to help communities identify the most effective fire mitigation projects.

- Step 1: Determine the level of fire risk.
- Step 2: Determine high priority areas for fire mitigation.
- Step 3: Determine the best mitigation projects for the highest priority areas.

12.1 Step 1: Determine the Level of Fire Risk

The level of fire hazard can be estimated using the methods discussed in Sections 7 and 8. This calculation can be done using the Fire BCA Module shown above.

12.2 Step 2: Determine High Priority Areas for Fire Mitigation

Developments in wildland/urban interface areas with the same general level of fire hazard face a range of fire risk levels, depending on a number of factors. Developments that have all or most of the following attributes are at the highest level of risk:

1. High vegetative fuel loads, with a high degree of continuity of fuel load (i.e., few significant firebreaks). Risk may be particularly high if the fuel load is grass, brush, and smaller trees, subject to being at very low moisture levels during short drought periods.
2. Steeper slopes or slopes at higher elevations, which cause fires to spread more rapidly than in flatter terrain.
3. Limited fire suppression capacity, including limited water supply for fire suppression purposes, limited firefighting personnel and apparatus, and long response times for fire alarms.
4. Limited access for firefighting apparatus and limited evacuation routes for residents at risk.

5. Construction of structures with flammable materials.
6. Lack of maintenance of firebreaks and defensible zones around structures.

Areas that have all or many of the above high-risk characteristics are likely candidates for high-priority fire mitigation projects.

12.3 Step 3: Determine the Best Mitigation Projects for the Highest Priority Areas

This section outlines suggested strategies for reducing the level of risk to both property and life-safety in wildland/urban interface development areas that may be at high risk from wildland/urban interface fires.

Note: The determination of effective fire mitigation projects for a specific location requires considerable fire expertise. The general guidance below is for information and reference only.

The suggested mitigation strategies have four elements:

- Reduce the probability of fire ignitions
- Reduce the probability that small fires will spread
- Minimize the life-safety risk
- Minimize property damage
- Reduce the Probability of Fire Ignitions

Efforts to reduce the probability of fire ignitions should focus on man-made causes of ignition through a combination of fire prevention education, enforcement, and other actions. Fire prevention education actions could include efforts to heighten public awareness of fire dangers, especially during high danger time periods, and better education about fire-safe practices, such as careful disposal of smoking materials and adhering to restrictions on burning rubbish and debris. Fire prevention enforcement actions could include strict enforcement of burning restrictions and vigorous investigation and prosecution of arson cases. An important physical action to reduce the probability of ignitions is to maintain or upgrade tree-trimming operations around power lines to minimize fires started by sparking from lines to vegetative fuels.

12.4 Reduce the Probability That Small Fires Will Spread

Possible mitigation actions to reduce the probability that small fires will spread include enhancement of water supply and fire suppression capabilities for high-risk areas, expansion of existing firebreaks, creation of new firebreaks, and expanding defensible spaces around structures in wildland/urban interface areas.

Larger scale efforts to reduce the probability of large fires include various types of vegetation management programs and controlled burn programs.

12.5 Minimize Property Damage

The education and action items discussed above may help to reduce future property damages by reducing the number of fire ignitions and by reducing the probability that a small fire will spread. In addition, specific fire-safe building practices should be implemented or enforced vigorously.

Fire-safe building practices have two main elements: design of structures and creation of defensible spaces around structures.

The National Fire Protection Association (NFPA) has a "Firewise" communities program with an informative website (http://www.firewise.org/). The Firewise website lists publications and videos for local officials and homeowners to help understand, evaluate, and improve the fire-safety of structures at risk from wildland/urban interface fires. The construction and landscaping checklists are particularly recommended as concise summaries of the primary fire-safe designs and practices for homeowners at risk from wildland/urban interface fires.

The NFPA Firewise Construction Checklist makes the following recommendations:

1. Site homes on terrain that is as level as possible, at least 30 feet back from cliffs or ridge lines.
2. Build homes with fire-resistant roofing materials, such as Class-A asphalt shingles, slate or clay tiles, concrete or cement products, or metal.
3. Build homes with fire-resistant exterior wall cladding, such as masonry or stucco.
4. Consider the size and materials for windows; smaller panes hold up better than larger ones, double pane and tempered glass windows are more fire-resistant than single pane windows; plastic skylights can melt and allow access for burning embers.
5. Prevent sparks and embers from entering vents by covering them with wire mesh no larger than 1/8 inch, and minimize places to trap embers on decks and other attached structures.
6. Keep roofs, eaves, and gutters free of flammable debris.

The NFPA's Firewise Landscaping Checklist includes the following recommendations, based on a four-zone planning concept around the house:

1. Zone 1 should be a well-irrigated area of closely mowed grass or non-flammable landscaping materials, such as decorative stone, at least 30 feet in all directions around the home.
2. Zone 2 should be a further-irrigated buffer zone with only a limited number of low-growing, fire-resistant plants.
3. Zone 3, further from the house, can include low-growing plants and well-spaced, well-pruned trees, keeping the total vegetative fuel load as low as possible.
4. Zone 4 is the natural area around the above three landscaped zones. This area should be thinned selectively, with removal of highly flammable vegetation and ladder fuels that can spread a grass fire upward into treetops.

12.6 Minimize Life-Safety Risk

The mitigation actions above may help to minimize life-safety risk by helping to reduce the number of ignitions, by reducing the probability that small fires will spread, and by encouraging more fire-safe practices in building construction and landscaping. These practices are meritorious for reducing fire hazards to structures. However, they may also give homeowners a false sense of life-safety security. A false sense of security may encourage people to stay in homes at risk during wildfires, rather than evacuating immediately at the first fire warning.

The most important action to minimize life-safety risk during wildland/urban interface fires is immediate evacuation. Reducing life-safety risk requires public education and emergency planning to encourage and expedite warnings and evacuations (voluntary or mandatory).

Life-safety risk during wildland/urban interface fires is exacerbated by limited evacuation routes. Improving evacuation roads (widening, straightening) and, most importantly, providing as many alternate evacuation routes as possible can significantly reduce evacuation times and lower the probability that residents seeking to evacuate may be trapped by fire-blocked routes.

Quantitatively, the life-safety risk posed by wildland/urban interface fires is generally low. The national annual fire death rate is 12.3 per million people (NFPA report, *U.S. Fire Deaths by State*, August 2002; http://www.nfpa.org/index.asp). Of these deaths, more than 80% are in residential buildings.

NFPA fire casualty data do not include separate statistics for casualties from wildland or wildland/urban interface fires. However, civilian deaths in such fires are relatively rare. Many large fires result in few or no deaths. Even major fires, such as the Oakland Hills fire that burned over 3,300 structures, caused only 25 deaths. A rough estimate is that annual civilian deaths from wildland/urban interface fires average only one or two dozen per year.

As a rough estimate, approximately 10% of the population of the United States may live in areas of high or moderately high risk of wildland/urban interface fires. With this estimate and the approximate annual death rate (above), the annual death risk for residents in areas prone to wildland/urban interface fires is approximately 1 per million. Reported civilian fire injuries (NFPA report, *Fire Loss in the United States During 2002*, http://www.nfpa.org/assets/files/pdf/OSfireloss02.PDF), are about 5½ times the death rate. However, civilian fire injuries are substantially underreported to fire authorities. Therefore, the actual fire injury rate may be approximately 10 times the death rate. This approximate ratio of deaths to injuries is probably applicable also to wildland/urban interface fires. Therefore, the annual fire injury rate for residents in areas prone to wildland/urban interface fires is estimated to be approximately 1 per 100,000.

Exhibit 3

Modeling Small Area Evacuation:
Can Existing Transportation Infrastructure Impede Public Safety?

www.ncgia.ucsb.edu/vital

VITAL

Vehicle Intelligence and Transportation Analysis Laboratory
National Center for Geographic Information and Analysis
University of California, Santa Barbara

Modeling Small Area Evacuation: Can Existing Transportation Infrastructure Impede Public Safety?

California Department of Transportation
Testbed Center for Interoperability
Task Order 3021

FINAL REPORT

Richard L. Church
Ryan Sexton
Vehicle Intelligence & Transportation Analysis Laboratory
University of California, Santa Barbara
www.ncgia.ucsb.edu/vital

April, 2002

Modeling small area evacuation: Can existing transportation infrastructure impede public safety?

Richard L. Church
Ryan M. Sexton

Vehicle Intelligence & Transportation Analysis Laboratory
and
Department of Geography
University of California at Santa Barbara
Santa Barbara, CA 93106-4060

Abstract

Interest in neighborhood evacuation was piqued by the evacuation disaster associated with the Oakland Hills fire of 1991. During that disaster, 25 people were killed. Many counties have now mapped high fire risk areas with the objective of developing special fire attack programs as well as evacuation plans. Much of the special interest has focused on what is termed the urban-wildland interface. Urbanizing development into high fire risk areas at this interface is at the highest risk of possible evacuation. Development on the interface has been increasing throughout the western United States. It is important that modeling techniques be explored to estimate this risk in such areas by estimating the time it would take to clear a residential neighborhood if an evacuation is needed. Previous work has proposed a simple formula called the clearing time estimate, or *CTE*, based upon a measure of bulk lane demand. Bulk lane demand represents the total vehicle demand leaving a neighborhood vs. the number of lanes of roadway leaving a neighborhood. It makes sense that neighborhoods with high bulk lane demand might have greater problems in evacuation than areas with low levels of bulk lane demand. Cova and Church (1997) have presented techniques to map areas based upon estimated bulk lane demands and have as a part of that work presented a map of potential evacuation vulnerability for the Santa Barbara, Ca. area. One of the areas in Santa Barbara that has a high bulk lane demand and falls within an acknowledged high fire risk area is the Mission Canyon neighborhood. The main arterial associated with this neighborhood is a Caltrans asset (State Highway 192). To test the efficacy of the bulk lane demand model, this report presents a special transportation simulation model that was developed for this neighborhood to test evacuation scenarios. The simulation model was developed using a special purpose micro-scale traffic simulation system, called Paramics. Results indicate that without special evacuation plans in place, this neighborhood may not be able to evacuate in a timely manner during a wildfire. This report concludes with a set of recommendations for both the neighborhood and small-scale evacuation in general

April, 2002

1. Introduction

Traditional transportation analysis focuses on the classical peak travel demands of weekday morning journey-to-work and afternoon journey-from-work trips. A focus on those times when traffic is at the peak makes sense when attempting to provide acceptable levels of service throughout the day. However, it is important to recognize that traffic modeling and transportation system capabilities have been analyzed within the context of special events or circumstances as well. One of these special event circumstances involves emergency evacuation. Typically, evacuation planning is associated with a well defined scenario, like a radioactive release from a nuclear power plant or the evacuation of a low lying coastal zone that might be subject to a hurricane. The possible event, such as an evacuation of the area that surrounds a power plant or the low lying coastal region, generally has a footprint that is relatively easy to define in advance. The zone or footprint that is defined for the possible evacuation scenario is called the evacuation planning zone (EPZ). Much of the focus of evacuation planning involving transportation systems, such as streets, roads and highways has been directed at well defined large areas, e.g. coastal cities, where a possible need for evacuation might occur and might involve large numbers of people. To clear such large areas may take many hours and require significant personnel resources, changes in signal operations, road closures, dedicated radio communications so that people are kept informed, preplanned staging areas for relief efforts, as well as many other elements. Recognition for the size of the evacuation problem and the need for advanced planning is the greatest for large EPZ areas.

The planning focus for events that may involve the evacuation of a small area typically center on personnel training and resource planning. For example, in California many communities have special program task forces for disaster planning that conduct mock drills involving many agencies and organizations to test communication systems, coordination and personnel skills in dealing with a special event. But, because the size and the location of a disaster event, like a hazardous material spill or a wildfire is hard to predict, the focus has been on general planning and mock drills rather than attempting to develop neighborhood specific evacuation plans. There are, however, growing concerns for ensuring that safe evacuation of small areas, like neighborhoods and building complexes, can take place. This is especially true for those places that may face higher risks of a disaster. This report addresses the problem of neighborhood evacuation modeling. Before we delve into modeling evacuation at that scale we will review evacuation modeling at other scales, like large EPZs. We then discuss how one might identify which neighborhoods should be considered candidates for evacuation planning. Finally we present an application of a micro-scale traffic simulation model to a neighborhood to estimate the extent to which a possible evacuation problem exists and discuss how such a model can be used to assist in evacuation planning and education. We give specific details of the simulation model applied to a high fire risk neighborhood of Santa Barbara, California and show that an evacuation at this small scale might easily overwhelm the ability of the local roads and streets to safely clear the neighborhood within an acceptable clearing time. We conclude with a set of recommendations.

2. Background

Emergency evacuation can be a life or death situation, where the lack of safe exit routes and the time that it might take to safely exit can be directly related to lives lost. For example, in 1991 25 people lost their lives while attempting to flee their Oakland Hills (CA) neighborhood during a wildfire. Most of these people lost their lives within the first 30 minutes of the fire as it raced through the neighborhood fanned by high winds. Depending on the type of event that precipitates the evacuation, like a wildland fire, some of the routes that people would normally take are obstructed in some way. Either the routes are too crowded, blocked by the disaster or damaged sufficiently enough to cause slower egress rates. An evacuation event can be defined according to a number of characteristics (e.g. one of three exits is blocked). It is common to define an event scenario as a set of specific characteristics. Scenarios are then defined to represent a range of possible instances of an event that underlies an evacuation. Each event scenario can then modeled to identify the likely outcome of the scenario as well as help craft evacuation plans, designate evacuation routes, and identify mitigation strategies.

Over the last two decades there has been considerable interest in modeling evacuation for a well-defined zone and event scenario, like the evacuation of a low lying coastal zone that may be subject to a hurricane surge. To analyze an evacuation scenario for a well-defined footprint, or EPZ, a number of different approaches have been used. They range from simple indices, e.g. the number of people on a ship divided by the number of seats provided in all life boats, to sophisticated simulation models. Most of the research has been concentrated on two distinct problems, evacuation of buildings and evacuation of large areas, like entire cities or coastal plains. Some of the earliest research on building evacuation was done by Chamlet, Francis and Saunders (1982). Their paper describes three models they developed to analyze clearing time, bottleneck locations, and general performance of a building in the event of an evacuation. The most important of these models is the dynamic model that represents the evacuation of a building as it evolves over time (Chamlet, Francis and Saunders 1982). With these models they were able to make general estimates of clearing time for a specific building. This paper has played an important role in subsequent research as people have used this work to facilitate research of their own. An example of this is found in Choi et al. (1988) where they expand the research of Chamlet et al. (1984) by taking variable arc capacities into consideration and modeling them as a network with side constraints. The focus of this work deals with the fact that congestion in a hallway, staircase or other passageway will cause slower rates of movement. Related optimizing network flow model research applied to evacuation includes, Choi, Francis, Hamacher, and Tufecki (1984), Horn, O'Callaghan and Garner (1998), Lovas (1998), Sherali (1991), and Tufekci and Kisko (1991).

As an alternative to network flow models inspired by Chalmet et al. (1982), researchers have also modeled building evacuation using simulation. For example, Feinberg and Johnson (1997) present a simulation procedure called 'FIRESCAP' that emphasizes behavioral characteristics of individuals in modeling an evacuation. They stress the importance of behavioral aspects such as cooperativeness, competitiveness and social constructs such as a pairs (e.g. married couples) or individuals. Their simulation model uses these behavioral characteristics as stochastic variables in a Monte Carlo sampling framework to create graphical snapshots of the evacuation evolving over time. Lovas (1998) has presented a model inspired by reliability theory where evacuees are modeled as discreet flow objects with certain attributes on a network represented by links and nodes. The EXODUS model, developed at the University of Greenwich by the Fire Safety Engineering Group, is a multi-agent, visual simulation model that has been developed to model people evacuating a building in great detail. EXODUS comprises five core interacting sub-models: the Occupant, Movement, Behavior, Toxicity and Hazard sub-models. Many papers have been written involving the use, validation, and effectiveness of EXODUS (see for example, Galea et al. (1996), Galea 1998, Cole (1996), Gwynne et al. (2001) and Owen et al. (1996)).

Evacuation modeling applied to large areas has involved the use of similar approaches. An excellent review of evacuation modeling applied to large areas can be found in Southworth (1991). Simulation has been the preferred tool of choice. Examples include OREMS, MASSVAC, and TEVACS. The Oak Ridge Evacuation Modeling System (OREMS) is an excellent example of a simulation model designed to analyze possible evacuation scenarios of large areas, where the road network involves major linkages like primary arterials and highways. Demands are based upon small areas or transportation analysis zones. The principal objective is to estimate clearing times and identify bottlenecks. MASSVAC is a simulation model designed for the analysis and evaluation of evacuation plans for urban areas threatened by natural disasters (Hobeika 1985). It is capable of simulating the flow on highway networks and identifying the available efficient routes from a hazard area to the nearest shelters and calculating the evacuation time for the network. Hobeika and Changkyun (1998) have extended MASVAC by integrating a user equilibrium (UE) assignment algorithm into MASSVAC. Han (1990) also developed a simulation model, called TEVACS, to analyze large-scale evacuation. This model was configured to specifically address the evacuation of large cities in Taiwan. Large cities in Taiwan do not rely predominantly on the automobile to evacuate. Instead there is a mix of autos, public transportation, motorcycles and bicycles that should be included in the model to truly address the problem. To handle the variety of modes in the evacuation, Han converts each mode into a universal unit called the PCU or Passenger Car Unit. These units are then used over routes with varying capacities to determine the time and scope of the egress. TEVACS is very flexible where many of the parameters can be changed and tested for their sensitivity in controlling an evacuation. Outputs from this model include network clearance time and a map of the identified traffic bottlenecks. Related research on evacuation using simulation includes that of Seagle, Duchessi and Belardo (1985), MacGregor (1991), Hara (1978), Hobeika and Jamei (1985) and Thompson and Marchant (1995).

Even though there has been considerable work in modeling evacuation, it has been directed to different geographical scales than that of a neighborhood, namely large areas like cities and small places like buildings. Cova and Church (1995) were the first to analyze the potential for evacuation difficulty at the neighborhood scale. Subsequent work by Cova and Church (1997) and Church and Cova (2000) described how to search for neighborhoods that might be particularly vulnerable to evacuation difficulty and how to develop maps of potential evacuation difficulty. They developed a network partitioning optimization model that can be used to look for small contiguous areas within a network that have a large resident population compared to exit capacity. In applying their model to Santa Barbara, they identified several neighborhoods that have disturbingly high ratios of demand to exit capacity and therefore may be particularity vulnerable to an evacuation disaster. With the exception of this work, evacuation modeling at the neighborhood scale has been basically ignored. Even though a neighborhood might have a high ratio of resident population to exit capacity, it is still important to estimate clearing time, just as is done for buildings and larger areas. Possible approaches for this include capacity analysis techniques from the highway capacity manual and simulation techniques. Since the most widely accepted tool to do this is simulation, it makes sense to take neighborhood at high risk and simulate an evacuation as a proof of concept. Unfortunately, existing network evacuation simulation models involving cars and trucks are not geared to the scale and details of the neighborhood. For example, the level of characterization of the neighborhood elements in a system such as MASVAC would not match the level of characterization needed to make the model accurate at a neighborhood scale. To do this would require a micro-scale, multi-agent transportation simulation model where individual vehicle behavior is modeled and where origin zones for traffic are represented by individual driveways. Micro-scale traffic simulation models have been developed, however, they have not been applied to a neighborhood evacuation problem. The main objective of this report is to present an application of a micro-scale transportation simulation model analyzing evacuation at the neighborhood scale. We will also discuss how such a modeling approach can be useful in not only characterizing the problem but search for mitigation strategies that may be useful in planning for a safe evacuation.

3. Identifying neighborhoods at risk and defining the EPZ

Little is known about small area evacuation as it is nearly impossible to measure accurately during an emergency (Church and Cova 2000). But, there has been an interest in looking for those areas that might be difficult to evacuate safely in an emergency. Church and Cova suggest that a neighborhood is vulnerable to an evacuation disaster if the demand to flee from a neighborhood overwhelms the capacity of the transport network to carry the traffic attempting to evacuate. They define the ratio of evacuation demand (in vehicles) to exit capacity (in numbers of exit lanes leaving the neighborhood) as bulk lane demand. They suggest that the higher the value of bulk lane demand, the longer it will take to clear the neighborhood in the event of an evacuation and the more vulnerable a neighborhood is in the event of an evacuation**.** Given this basic assumption, they developed an optimization model that can be used in conjunction with road network data and demographic data to find neighborhoods that have high levels of bulk lane demand. Essentially, their model delineates the neighborhood about a point (e.g. an intersection) that maximizes bulk lane demand. One may think of such a neighborhood as the one defined about the point that represents the greatest risk in evacuating in a timely manner. Thus, the model finds the worst case neighborhood about a point that has the highest bulk lane demand. By applying this model for selected intersections across a road network, it is possible to classify each street segment in terms of worst-case bulk lane demand values. Once this is done, a map of the network can be developed depicting evacuation difficulty across the network, like a flood plain map or a map of seismic risk. Cova and Church (1997) have presented a map of evacuation difficulty (or vulnerability to a timely evacuation) for the Santa Barbara area. Their model has now been used in other areas of southern California, Sardinia, Italy, and Australia.

Many types of location based risk exist. Examples, include earthquakes, floods, wildfire, tsunamis, landslides, avalanches, hurricanes, tornadoes, diseases, hazardous materials spills. The most common form of depicting location based risk is a map, e.g. a 100-year flood plain. Many communities and counties now publish maps of location based risk for different types of risk. For example, Jefferson County, Colorado has published a map of high fire risk areas within Jefferson County. The high fire risk areas involve an estimated population of 64,000. Given the size and number of people involved, they plan to develop evacuation plans for this region of the county, in the event that evacuation might be needed.

By superimposing a map of evacuation difficulty over a map of location based risk (like wildfire risk), one can identify those areas that face a higher than average probability of needing to evacuate and also display potential problems in evacuating (as estimated by bulk lane demand). Figure 1 gives a map of the Santa Barbara, California area with a highlighted neighborhood that has been identified previously by Cova and Church as having high bulk lane demand and is also recognized by the County of Santa Barbara Fire Department as in a high risk wildfire area. We suggest that small areas with both high location based risk and high bulk lane demand be targets for further evacuation analysis. Specifically, identifying small areas for detailed evacuation analysis or EPZs at the neighborhood scale can be accomplished by overlaying maps of location-based risk with maps of evacuation vulnerability. The remainder of this report will deal with modeling evacuation for this neighborhood as the EPZ.

4. Evacuation modeling using a micro-scale traffic simulation model

In this section we present an evacuation simulation model for the neighborhood that is depicted in Figure 1. The Mission Canyon neighborhood (MCN), as described above, lies within a high fire risk area. Both fire department personnel and homeowners have expressed concern for their safety, should a wildfire threaten their neighborhood. Before we discuss details of the simulation process, we need to discuss the assumptions under which this model and application was developed. First, it should be recognized that good data on small emergency evacuations does not exist. It is virtually impossible to collect traffic data in a residential neighborhood during an emergency evacuation without having a monitoring system deployed in advance. It should also be understood that the type of data normally collected in system monitoring and management falls short of the needs for data to fully characterize and model an evacuation event. Such characterizations include driver behavior under possible panic conditions, the degree to which the emergency overwhelms the environment (e.g. smoke limiting visibility), unusual driver behavior (e.g. leaving the roadway to cut across a landscaped lot), etc. This means that the issue of calibration is moot. That is, for all intents and purposes, calibration is not possible at the neighborhood scale for an evacuation event given the paucity of data. But a micro-scale traffic simulation model can be used under certain assumptions to estimate clearing time, for an emergency evacuation even when an accurate calibration is simply not possible. First, an orderly evacuation as modeled with a traffic simulation model (without driver panic) is likely to produce a neighborhood clearing time that is a lower bound on what might occur in the real event. The main reason for this is that accidents are more likely to occur when unpredictable behavior occurs. Accidents are the most likely element that will cause significant delay. Further, since environmental conditions like reduced visibility due to smoke is not added, simulated flow is likely to be faster and safer with less accidents. Thus, the simulation model can be used to estimate the best possible outcome. If the best possible outcome (as represented by clearing time to handle all vehicles leaving the neighborhood) is too high in comparison to the amount of time before an event like a wildfire overwhelms a neighborhood, then a major safety problem exists. If the opposite is true, then a neighborhood resident can have some degree of comfort that they will be able to safely leave if needed. The higher the estimated clearing time is under ideal conditions (e.g. no driver panic and no environmental restrictions) as compared to the time an event (like a wildfire) might overwhelm a neighborhood, the greater the possible problems in evacuation.

There are a wide variety of microscale simulation systems that have been developed to model traffic flow (e.g. see Smartest 2000). Some of these systems are stand alone modeling systems developed specifically for modeling traffic flow and others have been written as an application in a general purpose simulation system (e.g. THOREAU written in MODSIM (Glassco, et al. 1996). Although there are differences in capabilities in terms of available products, our choice was predicated in part by the California Department of Transportation (Caltrans). We developed a list of several possible candidates to use in this work. The Paramics software was one of the feasible candidates. Since Caltrans has deployed Paramics at each district office and wanted to have this simulation example available to districts, the Paramics software was used in this research. The remainder of this section specifies how the evacuation simulation was defined, in relatively general terms, as in most cases this type of model could be executed using one of several simulation products. Occasionally, Paramics specific issues are discussed, when important.

Typical microscale traffic simulation models simulate each vehicle with specific driving behavior. Each vehicle trip is modeled as a driver making a trip between an origin and a destination. The average number of trips made between origins and destinations are specified in advance for each origin-destination pair for each time period, where the interval of the time period can be specified as well (e.g. five minute, ten minute or fifteen minute time intervals). Each scenario is based upon a level of demand in terms of the number of vehicles leaving the neighborhood. For the work that we report here, we assumed that 30% of the demand leaves in the first 5 minutes, 50% leaves within the nest 5 minutes and 20% leaves within the next five minutes. For example, if an evacuation scenario was set up in which approximately 1000 cars were to exit the neighborhood, approximately 300 would begin their trip out of the neighborhood in the first five minutes, 500 in the next five minutes and 200 in the subsequent five minutes. Although this distribution could be changed, we defined this level of demand exertion with input and advice from neighborhood representatives. Such an event characteristic would be associated with a rather rapid acknowledgement of danger and taking care of last minute issues and then departing. For example, people may take their pets and gather a few belongings.

The MCN is depicted in figure 3, along with streets leading from the neighborhood. Foothill Road forms the southern boundary of the neighborhood. MCN is bordered on the west by Alamar Road. To the east, Mission Canyon Rd and Tunnel Road represent the boundaries. Exits for the MCN are depicted as the intersection at Mission Canyon and Foothill roads and Alamar and Foothill Roads. Eastbound traffic on Foothill Road beyond Mission Canyon Road is prevented as a road closure would be likely set up in the event of an evacuation (traveling further east along Foothill Road would be considered risky in the event of a wildfire). Traffic flow from Mission Canyon Road north of the Tunnel Road junction is depicted as an origin. This area is rather sparsely settled and may need to evacuate if the MCN needs to evacuate. Rather than depict this in minute detail, the demand from this area was handled as an aggregate flow. The destination zone associated with an evacuation is depicted in Figure 3, and represents westbound traffic on Foothill west of Alamar, Southbound traffic on Alamar just south of Foothill, and southbound traffic on Mission Canyon Road south of Foothill Road.

A major departure from most applications of a microscale simulation model is the spatial definition of an origin. Most transportation flow models are based upon the assumption that an origin-destination flow matrix exists between a set of transportation analysis zones (TAZ). TA Zones are generally defined as spatial entities of at least a few blocks to much larger areas, like a neighborhood. To represent the problem at a level of spatial detail that adequately characterizes the spatial distribution of demand within the neighborhood, we chose to define each household driveway as an origin for traffic flow.

For the MCN, there are 763 driveways or residential origins and one area origin (MCNorth) on Mission Canyon Road just north of the Tunnel Road junction as well as one destination zone. Together there are 765 zones. Traffic demand between each zone is specified in number of vehicles. Consequently the O-D matrix is 765 by 765, where most demands are set at zero. Flows from driveway zones to the exit zone were specified at specific levels (e.g. an average of 1 vehicle per household, an average of 1.5 vehicles per household, an average of 2 vehicles leaving per household, etc.). It should be recognized that some micro-scale simulation systems cannot handle an OD matrix that is nearly 800 by 800.

To characterize the road network, street elements were digitized in Paramics using air photos and a road network database. Elevations for the road network were taken from a elevation database that was provided by the Geology Department at UCSB. Elevations were accurate to less than a meter. Street slopes are needed as driver behavior changes when streets have a significant slope as well as curvature. Visibilities upon the approach to each intersections were considered key elements to represent relatively slow intersection approaches by drivers. All appropriate road intersection controls (e.g. stop signs) were coded as well as speed limits. In addition, common paths taken by drivers in the neighborhood were coded as preferred, as some street segments (although part of absolute shortest paths) were not typically chosen by drivers because they are steeper than many are comfortable using.

Paramics provides for dynamic information feedback on the part of drivers. For example, drivers can be given up-to-date information of shortest available routes (in terms of travel time) when departing from their driveway. Additionally, they can be given updated information periodically, so that they may balk after waiting in one queue and choose a different route. This option is called dynamic feedback. This type of information can help in reducing evacuation clearing time. The difference between having dynamic information updates and not represents the value added by having a special radio channel, broadcasting information so that the evacuation process can be speeded up, if some exits are available and under utilized. For the examples given here, we assumed dynamic feedback every minute to all drivers. We also selected driver behavior to be considerably more aggressive than the average driver.

Micro-scale simulation models that have been developed for traffic flow analysis do not simulate vehicles backing out of driveways. Often when drivers attempt such a maneuver, travel speeds along a street are low and traffic volume is low. It can be debated as to whether this is a needed capability in typical applications of such software (especially when modeling freeways and major arterials), however, this type of driving behavior can be important in modeling flow in a neighborhood, where most people typically back their cars out of the driveway and into the street. “Backing up and out of a driveway” can restrict traffic flow and significantly reduce street capacity. It would be desirable to simulate this action as well in an evacuation event. Any origin zone that generates traffic flow (in Paramics of other similar software) does so by simulating a vehicle moving into traffic going forward (not backing out into traffic). At first, this would seem to be a significant compromise in being able to model neighborhood evacuation realistically. However, modeling cars moving from a driveway and pulling forward into a street helps provide an estimate of the best possible performance of traffic flow in a neighborhood. Thus, if one wants to estimate the best possible clearing time, it would make sense to assume that cars pull forward onto the street from a driveway rather than back out into the street from a driveway. Further, it is recommended by the local fire department as well as the US Forest Service that in times of high fire risk, people should park in their driveways so that they can pull out onto the roadway instead of backing out. Consequently, this behavior is exactly what is recommended by educational literature.

In order to examine a broad scope of possible evacuation outcomes for the MCN, multiple scenarios were modeled. Each scenario represented a set of model assumptions. In modeling evacuation of the neighborhood, four principal variables were used:

1. The number of vehicles per household leaving the neighborhood: 1, 1.5, and 2 vehicles per household (even though car ownership per household is higher).
2. Opening an alternate exit: A dirt road that leads out of the neighborhood is currently closed. The neighborhood wanted to know what the impact of opening this road might have on evacuating the neighborhood.
3. Flow on Foothill Rd.: Foothill Rd. is probably the most important road in the entire network because every car must use it at some time in leaving the Mission Canyon neighborhood. If normal traffic is allowed on this road during an evacuation it will effect the clearing times.
4. Traffic Control: When traffic control is invoked, the critical intersections near the exits of the neighborhood are optimized. This involves converting some links to one-way with two lanes in each direction, and transforming intersections from a phase sharing system where cars take turns, to a system where traffic can move at all times. Such control is likely only when traffic control officers are present.

Using different values of the four principal variables, eighteen different scenarios were generated and modeled in our research. The results of the simulation is summarized in the next section

5. Results of the application to the Mission Canyon Neighborhood

For the different major characteristics underlying the evacuation simulation, eighteen different scenarios were defined, six each for different volume levels. Essentially, each scenario was based upon an assumed number of vehicles leaving each driveway, 1 car per driveway, 1.5 cars per driveway, and 2 cars per driveway. Even though car ownership per household may in many cases exceed 2 cars, we limited vehicles to at most 2 per household, as at any time during the day or night it is reasonable to believe that some fraction of the vehicles are not present. Also, since a demand level of 2 cars per driveway is large enough to create definite problems in a timely evacuation, higher levels would only exacerbate the problem. It is important to note that although the simulation model attempts to choose 2 departure times per driveway for such a simulation (i.e. 2 vehicles per driveway), such a level of demand is never exactly achieved as some driveways have zero vehicles departing, some have 1 vehicle departing and most have 2 vehicles departing. This discrepancy is caused by low OD volumes and the fact that the system is a stochastic model.

The results of the simulation runs are summarized in three tables, each concerning a given level of exit volume. Table 1 gives results of six evacuation scenarios involving 1 car leaving per driveway, Table 2 gives results for 1.5 cars leaving per driveway and Table 3 gives results for 2 cars leaving per driveway. For each scenario, the table gives the time taken for certain percentages of vehicles to clear the neighborhood and reach an exit. As an example, the first column in table 1 is associated with a scenario where the alternate ranch road is not open for evacuation traffic, some through traffic on Foothill Road is allowed to continue (note Foothill Road is a major corridor and closing Foothill Road to some through traffic would be difficult without appropriate levels of traffic control personnel), and no traffic control provisions at major exit intersections. For this simulation, it took approximately 21 minutes to clear the neighborhood. Note that for a similar scenario involving 2 vehicles leaving per driveway (Table 3), the clearing time was approximately 38 minutes, nearly double the amount of the 1 vehicle per driveway scenario. As this neighborhood is a similar size to the area within the 30 minute isochrone of the Oakland Hills fire, most would see that an evacuation would need to be accomplished safely within a shorter time than 30 minutes. It is easy to conclude that for several scenarios associated with minimal intervention, the estimated clearing time is too large and might lead to a disaster should an evacuation be needed.

An examination of the scenario results given in Table 1 2, and 3 suggest that traffic control at the critical intersections, providing for the additional ranch road exit, and controlling flow along Foothill Road, keeps evacuation clearing times at the lowest level for a given vehicle exiting volume per driveway. Overall, the results tend to suggest that a major evacuation problem exists without significant levels of intervention (i.e. traffic control) and education. First, education is needed so that neighborhood residents park their vehicles facing the street during high fire risk periods. Second, education is needed to convince residents that taking all of their vehicles may save some personal property, but may lead to loss of life (theirs or their neighbors). Without mitigating demand in terms of vehicles leaving the neighborhood during an evacuation event, this neighborhood is faces a serious risk of a disaster. Simply put, there is a chance that a fate similar to those who died in the Oakland Hills fire may befall those living in Mission Canyon. Finally residents can take action (e.g. clearing brush) that may mitigate the extreme conditions of a wildfire near their homes.

Figure 4 depicts several queues that form as vehicles attempt to leave the neighborhood. The simulation has now been used to demonstrate the problem to neighborhood residents as well as county employees using the graphical displays of Paramics. The results of this simulation along with considerable action on the part of the MC neighborhood homeowners association has been instrumental in convincing the county to initiate a door-to-door campaign to give people better information about evacuation and risk as well as schedule additional sheriff personnel for traffic management and patrol during weather events that trigger red flag alerts (i.e. weather and fuel moisture conditions that are associated with extreme high fire risk). These activities are a direct result of developing a better understanding of the potential evacuation difficulties that this neighborhood faces. The simulation model has also been instrumental in meetings so that a common understanding of what might happen can be visualized in real time.

6. Summary and Conclusions

In 1991, 25 people died while attempting to evacuate a neighborhood fire in a hillside neighborhood of Oakland, CA. While this event has piqued the interest of many people for safety, little if any work has been done to estimate evacuation risks at the neighborhood level. Previous work by Cova and Church (1997) and Church and Cova (2000) has led to an approach to estimate and map potential evacuation risk difficulty in terms of bulk lane demand. This report analyzes a neighborhood that was identified by Cova and Church (1997) that lies within a high fire risk area and also has a high value of bulk lane demand. This measure represents a ratio of exit demand to exit capacity. If bulk lane demand reaches 500 or more vehicles per exit lane, then clearing times can easily exceed 20 minutes or more. Once this level is reached, it is possible that the time taken by residents to clear the neighborhood is larger than the amount of time that an event such as a wildfire might overtake the neighborhood. This report presents details of a micro-scale traffic simulation model that was developed to analyze possible evacuation events for this neighborhood. Results of this model can be thought of as best case estimates for a given set of starting assumptions (i.e. characteristics of a scenario). Details of the simulation process have been presented along with results. The results suggest that without significant intervention policies, this neighborhood is at a significant risk of an evacuation disaster should a fast moving fire start close by.

A better understanding of what can be done for the neighborhood can be developed from results of the type of model presented in this report. First, it is important to encourage residents to use only the vehicles that they need, rather than attempting to save all of their cars from being destroyed. Evacuation clearing time can be significantly reduced by taking as few vehicles as possible and leaving the rest behind. This may make the difference between a safe and timely evacuation and a disaster with loss of life. Second, the simulation model can be used to help elevate awareness and educate both residents and county officials. With the aid of this program and persistent efforts on the part of neighborhood residents, county officials have developed plans to better educate residents and staff more personnel at time of greatest wildfire risk. Results of the simulation have also been used to bolster arguments by canyon residents for improving Foothill Road (State Highway 192), so that it can carry more traffic safely in the critical stretch between Mission Canyon Road and Alamar Road.

The results of this research give credence to communities using vulnerability mapping programs like that developed by Cova and Church coupled with a highly detailed evacuation analysis of vulnerable areas such as that presented in this report. This general approach can be used to: 1) identify areas of great risk, and 2) plan for the safety of the residents during an extreme event such as a wildfire. Either an evacuation plan can be crafted using the results of simulation or a plan for safe zones could be developed so that inhabitants need not risk their lives in attempting an evacuation. This general approach might also be useful in analyzing critical network elements and their role in public safety.

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Table 2: Evacuation clearing times for an average of 1 car leaving per driveway for the Mission Canyon neighborhood (results generated by Paramics)

Alternate Exit Open	No	no	No	yes	yes	Yes
Cars per Household	1	1	1	1	1	1
Flow along Foothill Rd.	Yes	No	No	yes	No	no
Traffic Control	none	Yes	None	none	yes	none
% of total vehicles cleared	time	Time	Time	time	time	time
50%	0:09:41	0:07:08	0:08:23	0:08:55	0:06:34	0:08:41
75%	0:14:27	0:10:15	0:12:04	0:14:10	0:09:42	0:12:41
90%	0:18:13	0:13:21	0:15:28	0:17:28	0:12:51	0:14:52
95%	0:19:51	0:14:45	0:16:44	0:18:33	0:13:45	0:16:01
100%	0:21:14	0:17:31	0:18:49	0:20:07	0:17:02	0:17:40
# vehicles cleared	time	Time	Time	time	time	time
200	0:05:07	0:04:50	0:04:57	0:04:48	0:04:11	0:05:16
400	0:09:34	0:07:33	0:09:14	0:09:12	0:06:57	0:09:34
600	0:14:06	0:11:27	0:13:41	0:14:27	0:10:24	0:13:53
800	0:20:53	N/A	N/A	N/A	N/A	N/A
1000	N/A	N/A	N/A	N/A	N/A	N/A
1200	N/A	N/A	N/A	N/A	N/A	N/A
1400	N/A	N/A	N/A	N/A	N/A	N/A
Average Number of Cars per minute	41.4	53.1	43.8	41.2	56.1	45.3

Table 2: Evacuation clearing times for an average of 1.5 cars leaving per driveway for the Mission Canyon neighborhood (results generated by Paramics)

Alternate Exit Open	no	no	no	yes	yes	yes
Cars per Household	1.5	1.5	1.5	1.5	1.5	1.5
Flow along Foothill Rd.	yes	No	no	yes	No	no
Traffic Control	none	Yes	none	none	yes	none
% of total vehicles cleared	time	Time	time	time	time	time
50%	0:13:08	0:08:01	0:11:54	0:11:56	0:07:50	0:11:29
75%	0:19:34	0:11:44	0:18:13	0:16:59	0:11:17	0:16:40
90%	0:24:28	0:15:36	0:22:53	0:20:53	0:14:34	0:19:52
95%	0:27:15	0:16:44	0:26:30	0:22:47	0:15:59	0:20:48
100%	0:30:27	0:19:01	0:29:10	0:24:57	0:17:51	0:23:03
# vehicles cleared	time	Time	time	time	time	time
200	0:05:00	0:03:38	0:04:59	0:04:41	0:03:45	0:04:42
400	0:09:17	0:06:15	0:08:51	0:08:34	0:06:01	0:08:32
600	0:13:36	0:08:46	0:13:13	0:12:13	0:08:29	0:12:29
800	0:17:45	0:11:30	0:17:39	0:15:45	0:11:01	0:16:22
1000	0:23:11	0:16:10	0:24:12	0:19:44	0:15:05	0:20:14
1200	N/A	N/A	N/A	N/A	N/A	N/A
1400	N/A	N/A	N/A	N/A	N/A	N/A
Average Number of Cars per minute	42.5	66.5	42.0	51.6	71.6	51.3

Table 3: Evacuation clearing times for an average of two cars leaving per driveway for the Mission Canyon neighborhood (results generated by Paramics)

Alternate Exit Open	no	no	no	yes	yes	yes
Cars per Household	2	2	2	2	2	2
Flow along Foothill Rd.	yes	No	no	yes	no	no
Traffic Control	none	Yes	none	none	yes	none
% of total vehicles cleared	time	Time	time	time	time	time
50%	0:17:27	0:09:14	0:15:43	0:15:09	0:09:06	0:13:48
75%	0:26:34	0:13:57	0:24:16	0:21:32	0:13:28	0:19:26
90%	0:33:26	0:18:08	0:30:25	0:26:42	0:17:05	0:23:42
95%	0:35:26	0:19:30	0:32:40	0:28:32	0:18:34	0:25:38
100%	0:38:32	0:23:36	0:34:58	0:31:39	0:21:28	0:29:09
# vehicles cleared	time	Time	time	time	time	time
200	0:04:40	0:03:31	0:04:43	0:04:38	0:03:30	0:04:38
400	0:08:35	0:05:58	0:08:47	0:08:24	0:05:37	0:08:24
600	0:12:49	0:07:59	0:12:59	0:12:10	0:07:43	0:11:47
800	0:17:37	0:09:57	0:16:55	0:15:39	0:09:50	0:14:57
1000	0:22:03	0:12:39	0:21:54	0:19:01	0:12:03	0:17:53
1200	0:26:56	0:16:01	0:26:53	0:22:28	0:14:54	0:21:21
1400	0:32:46	0:20:00	0:32:45	0:26:56	0:18:39	0:26:00
Average Number of Cars per minute	42.8	74.9	43.9	53.9	80.9	57.5

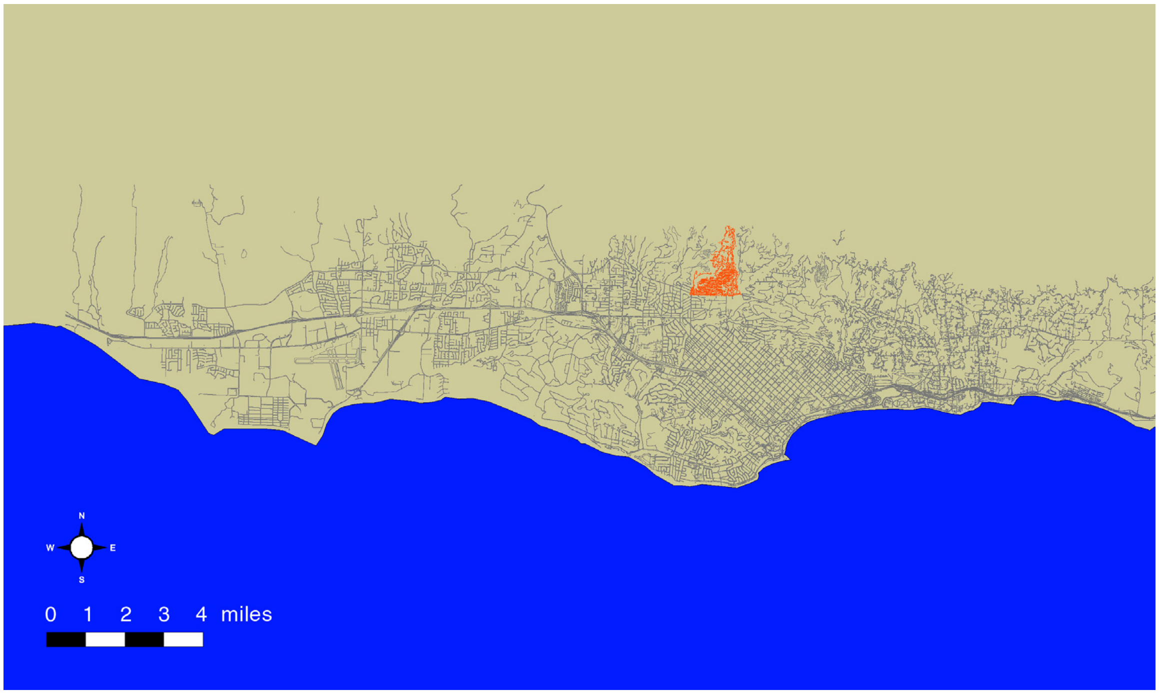

Figure 1: The Mission Canyon neighborhood depicted in Santa Barbara, California

Figure 2: House locations and street network of the Mission Canyon neighborhood

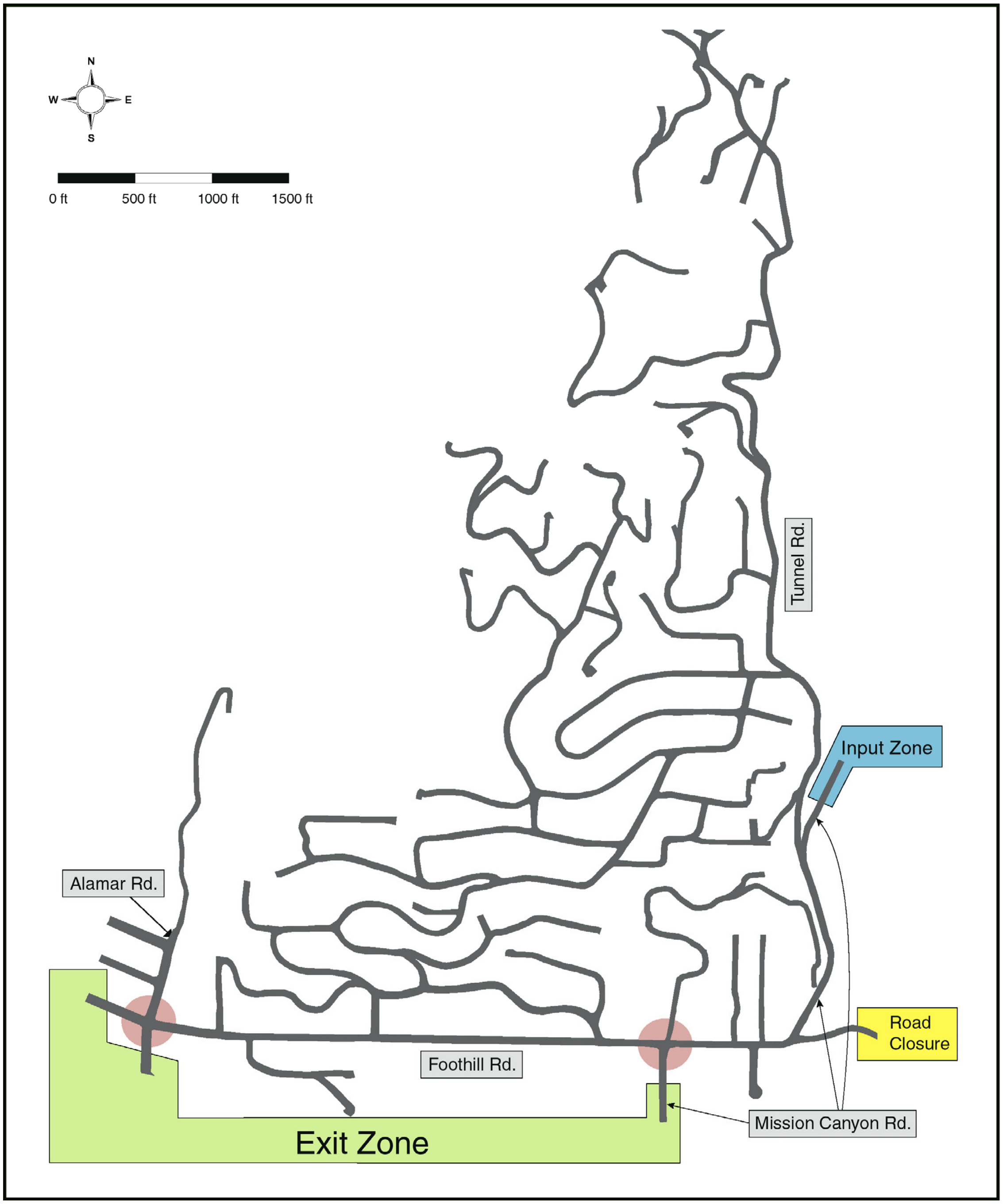

Figure 3: Major street intersections, exit zones, and road closure location for Mission Canyon

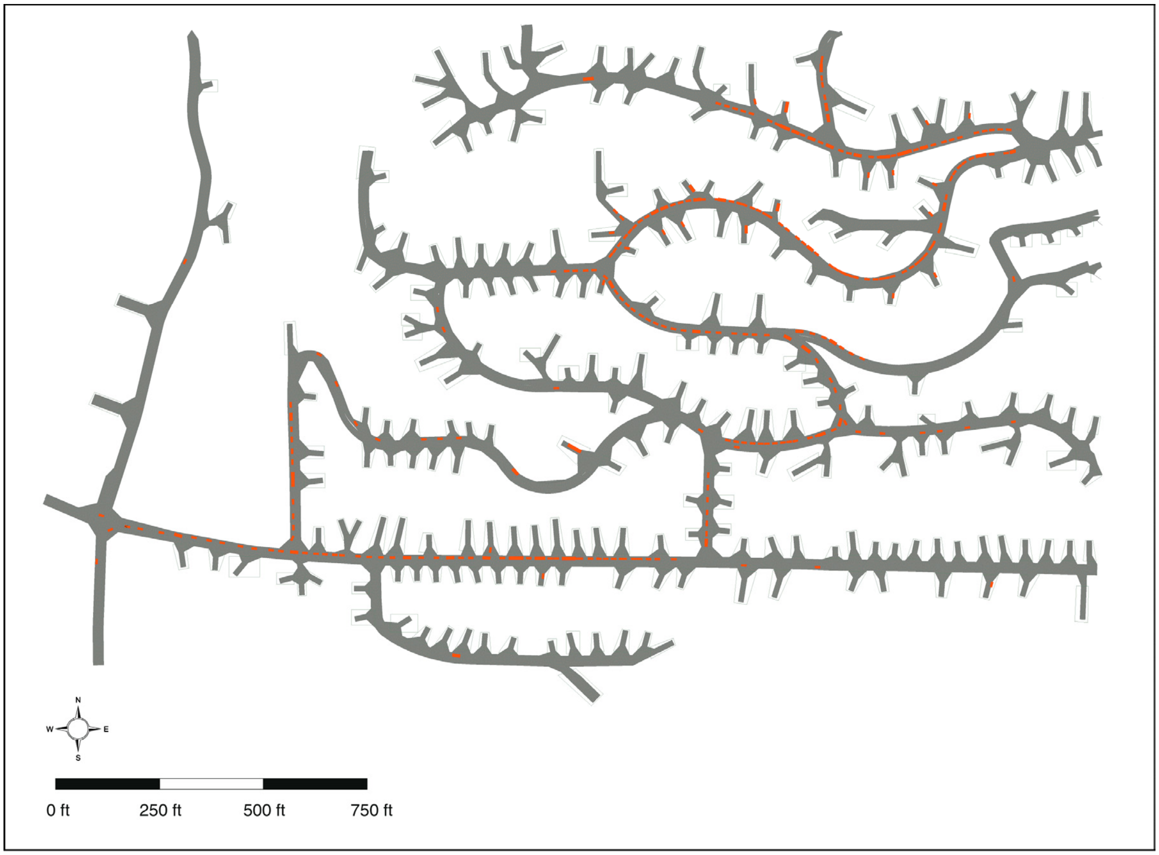

Figure 4: Congestion during a simulated evacuation event (Queues of cars can be seen in red).

Vehicle Intelligence and Transportation Analysis Laboratory
National Center for Geographic Information and Analysis
University of California, Santa Barbara CA 93106-4060

URL www.ncgia.ucsb.edu/vital
Phone +1.805.893.8992
E-mail vital@ncgia.ucsb.edu

Exhibit 4

Public Safety in the Urban–Wildland Interface: Should Fire-Prone Communities Have a Maximum Occupancy?

Thomas J. Cova[1]

Abstract: Residential development in fire-prone wildlands is a growing problem for land-use and emergency planners. In many areas housing is increasing without commensurate improvement in the primary road network. This compromises public safety, as minimum evacuation times are climbing in tandem with vegetation and structural fuels. Current evacuation codes for fire-prone communities require a minimum number of exits regardless of the number of households. This is not as sophisticated as building egress codes which link the maximum occupancy in an enclosed space with the required number, capacity, and arrangement of exits. This paper applies concepts from building codes to fire-prone areas to highlight limitations in existing community egress systems. Preliminary recommendations for improved community evacuation codes are also presented.

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CE Database subject headings: Fire hazards; Evacuation; Access roads; Traffic capacity; Transportation safety; Codes; Public safety; Transportation engineering.

Introduction

Residential development in fire-prone wildlands is a growing problem for land-use and emergency planners. Easy access to recreation, panoramic scenery, and lower property costs are enticing people to build homes in areas that would otherwise be considered wildlands. This development steadily increased in the United States from the mid 1940s, although local growth rates varied according to economic, demographic, and amenity factors (Davis 1990). At the same time, decades of fire suppression has resulted in a record abundance of fuel in and around many developments (Pyne 1997). This led the Forest Service to recently identify thousands of communities near federal lands as "at risk" to large conflagrations (U.S. Forest Service 2001).

The area where residential structures and fire-prone wildlands intermix is called the urban–wildland interface or wildland–urban interface (Cortner et al. 1990; Ewert 1993; Fried et al. 1999). In much of this area, homes are being added as the primary road network remains nearly unchanged. This is not surprising, as interface communities are often nestled in a topographic context that prohibits the construction of more than a few exiting roads. It is generally too expensive to build a road into a canyon, or onto a hillside, from every direction. Also, residents prefer less access because it reduces nonresident traffic. A common road-network addition is a culdesac that branches off an existing road to add more homes.

Incremental planning in fire-prone areas has a number of adverse impacts (e.g., wildfire effects, open space decline), but the focus in this paper is evacuation egress. "Egress" is defined as a means of exiting, and it can be viewed as accessibility out of an area in an evacuation. When a wildfire threatens a community, residents generally evacuate in a condensed time either voluntarily or by order. In past urban wildfires with short warning time, limited egress has proven to be a problem ("Charing cross bottleneck was a big killer" 1991; Office of Emergency Services 1992). Sheltering-in-place is a competitive protective action when there is not enough time to escape or a homeowner wishes to remain behind to protect property, but it is much less tested than evacuation in wildfires. However given increasing housing densities in fire-prone areas without commensurate improvements in the primary road network, the case for sheltering-in-place is gaining ground. This leads to an important question: "How many households is too many?" Or alternatively, "What is the maximum occupancy of a fire-prone community?"

Maximum occupancies are well defined and enforced in building safety, and it is common to see the maximum number of people allowed in an assembly hall posted clearly on the wall. This concept has not been applied to community development in fire-prone areas, although the broader terms of "access" and "egress" appear in contemporary codes (National Fire Protection Association 2002; International Fire Codes Institute 2003). Egress standards are currently defined in terms of minimum exit-road widths, or a minimum number of exits, without regard to how many people might rely on the exits. This is less sophisticated than building egress codes which link the maximum expected occupancy of an enclosed space with the required number, capacity, and arrangement of exits (Coté and Harrington 2003). Building egress codes have been hard earned over nearly a century of research, refinement, and loss of life (Richardson 2003).

The purpose of this paper is to apply egress concepts drawn from building fire safety to community egress in fire-prone areas. Although these concepts and codes were originally developed for

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[1] Associate Professor, Dept. of Geography, Center for Natural and Technological Hazards, Univ. of Utah, 260 S. Central Campus Dr., Rm. 270, Salt Lake City, UT 84112-9155. E-mail: cova@geog.utah.edu

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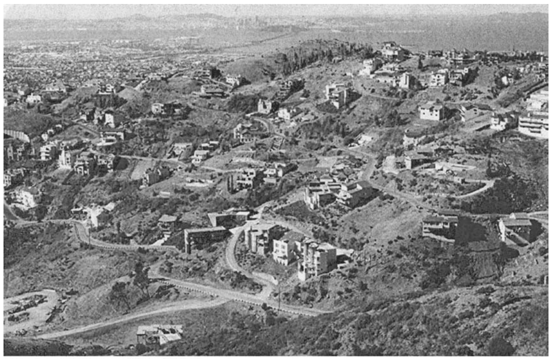


(Date: October 20, 1995)

Fig. 1. Looking west at narrow roads surrounding 1991 Oakland–Berkeley fire origin

small-scale, indoor spaces, they have potential utility in fire-prone communities. The first section reviews background on the growing urban–wildland egress problem. The next section reviews basic means-of-egress concepts defined in building codes. A method is presented to compare community egress systems based on concepts and standards from building safety that includes preliminary recommendations for new community egress codes. The paper concludes with a discussion of improvements that can be made to community egress systems.

Growing Urban–Wildland Egress Problem

Representative Communities

There are literally thousands of fire-prone communities in the West with a static road network and steadily increasing housing stock. This section briefly examines 2 representative examples. To date, the dominant focus of planners and residents in these communities has been structure protection with much less attention focused on egress issues. This may be due to the fact that property loss in wildfires is much more common than loss of life. Poor egress in interface communities is generally the result of narrow roads, irregular intersections, and few exits. In most of these areas the likelihood of an extreme fire is increasing in tandem with the vulnerability created by steadily climbing minimum evacuation times. Without fire to rejuvenate the ecological system, vegetation advances toward its fire recurrence interval as home construction adds additional fuel, residents, and vulnerability (Rodrigue 1993; Radke 1995; Cohen 2000; Cutter 2003).

Buckingham, Oakland, Calif.

Fig. 1 shows the neighborhood at the origin of the 1991 Oakland–Berkeley Fire 4 years after the fire. Without vegetation to obscure the view, it is clear that the road network is a maze of narrow streets. The photo was taken during the initial rebuilding process when hazard abatement procedures were being considered. At the time of the fire there were 337 homes in this neighborhood with four exits. The fire blocked the two primary exits in its first 1/2 h (Tunnel Road east and west), leaving the remaining residents two narrow, uphill exits. Most of these residents chose to leave on Charing Cross Road, a 13 ft wide afterthought that was not designed to handle this volume. Many of the fatalities (Fig. 2) were residents caught in or near their cars at the end of a traffic queue when the fire passed.

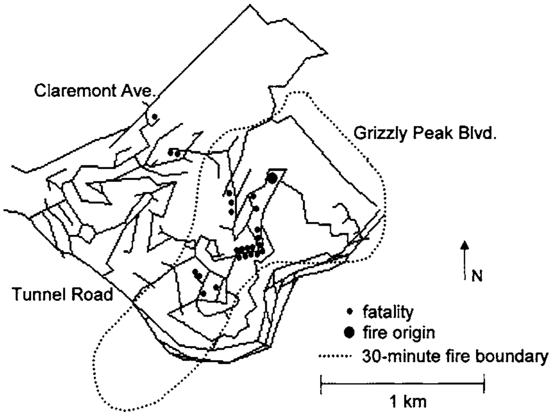
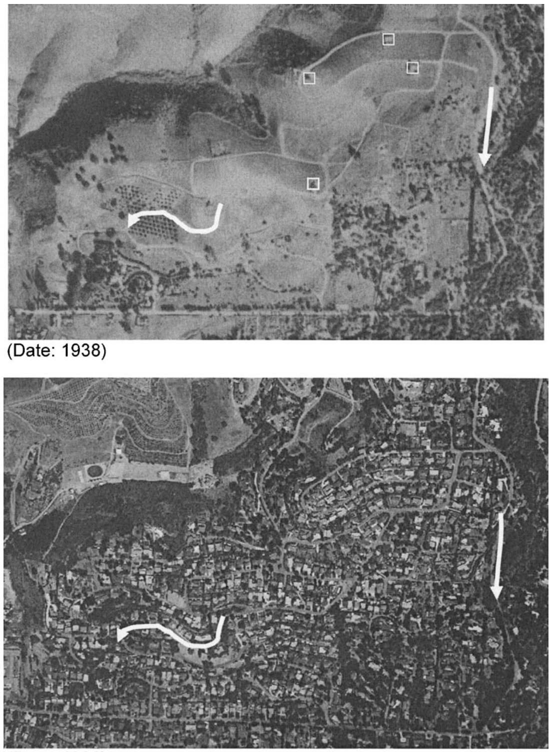


Fig. 2. Fatalities, fire origin, and approximate 30 min fire boundary in 1991 Oakland–Berkeley fire

Mission Canyon, Santa Barbara, Calif.

Mission Canyon is a community just northwest of downtown Santa Barbara, Calif. that is adjacent to a chaparral ecosystem. The basic road network geometry was established in the 1930s and has changed little since (Fig. 3). In 1938 there were four households in the upper canyon using two exits (shown in white), but by 1990 there were more than 400 households relying on the same two exits. All households north the two exits (above) must use one of these two exits to leave, but households south of these exits (below) have more exiting options. The area was originally grasslands, but today it contains a significant amount of flammable, non-native vegetation (e.g., Eucalyptus) intermixed with wood structures. Prior evacuation studies have concluded that



(Date: 1938)

(Date: 1990)

Fig. 3. Mission Canyon in 1938 (4 homes, 2 exits in white) and 1990 (400+homes, same 2 exits in white)

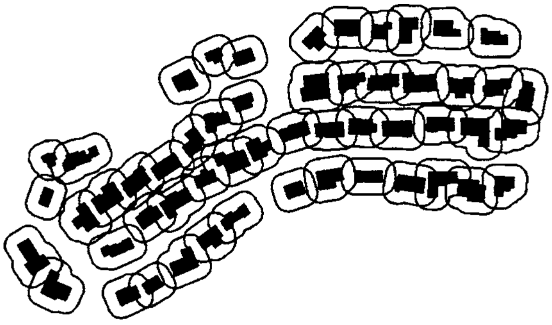


Fig. 4. Overlapping home ignition zones in fire-prone neighborhood (30 ft defensible-space buffer)

clearing upper Mission Canyon in the event of a wildfire would be relatively difficult (Cova and Church 1997; Law 1997; Church and Sexton 2002).

Protective Actions in Wildfires

Protective actions in a wildfire differ from a building fire in that sheltering-in-place in a structure, water body or safe zone (e.g., parking lot or golf course) is possible. This distinction is important because it means that evacuating a community may not be the best protective action in some cases (Krusel and Petris 1992). However, these cases can be difficult to assess during an event. Given more than enough time to evacuate, this is generally the best option for protecting life. If there is little to no time to evacuate, sheltering-in-place is likely the best option because evacuees risk being overcome by the fire in transit with much less protection than offered by a shelter. In the middle lies a gray area where evacuating may be the best option. As strongly as many experts feel about this issue (Wilson and Ferguson 1984; Decker 1995; Packman 1995; Oaks 2000), the uncertainty associated with a scenario can be too great to definitively state the best protective action. It depends on the quality of a shelter, road network geometry, fire intensity, wind speed and direction, visibility, travel demand, water availability and many other factors that are difficult to assess and synthesize under pressure.

A key hurdle in advising people to shelter-in-place in their homes is that not all structures are defensible. A defensible structure offers its occupants sufficient protection to withstand a passing wildfire. This is embodied in the concept of a "home ignition zone," or the area immediately surrounding a structure where ignition is feasible (Cohen 2000). Structures are not defensible if their ignition zones contain substantial fuel, adjacent ignition zones overlap, or both. If ignition zones overlap, then creating a defensible space would require homeowners to clear their neighbors' vegetation (Fig. 4). In other words, the wood structures in this figure are not defensible and an ignition chain reaction is possible. In cases where structures are sufficiently spaced, vegetation and other fuel within the home ignition zone can also render a structure indefensible. This is common because residents in these areas generally embrace trees and the amenities they provide. In dense, residential areas with wood structures, overlapping ignition zones and few viable shelters or safe zones, providing residents with sufficient egress is a critical issue.

Building Egress Codes

Early History

The concept of a maximum occupancy originated in an area of study called "means of egress." A means-of-egress is defined as, "… a continuous and unobstructed way of travel from any point in a building or structure to a public way consisting of three distinct parts: the exit access, exit, and exit discharge (Coté and Harrington 2003, p. 99)." Means-of-egress studies and associated codes incorporate all aspects of evacuating a building from stairway capacities and known crowd behavior under varying density to the proper illumination of exit signs. In setting standards for an enclosed space, an analyst can either examine the number, capacity, and arrangement of exits and calculate a maximum occupancy or, alternatively, examine the expected maximum occupancy and construct the required minimum egress. In either case, state-of-the-art egress standards and methods link occupancy to the number, capacity, and arrangement of exits.

Building egress standards can be traced to an occupancy–density study conducted by Rudolph Miller around 1910 in Manhattan (Nelson 2003). Miller's objective was to tabulate the density of workers per floor in 500 workshops and factories. This resulted in a wide range of densities from 19 to 500 ft^2 per person with the average for all floors at 107 ft^2 per person. In 1913 the National Fire Protection Association established the "Committee on Safety to Life" to study egress and formulate standards with a particular focus on advancing the principle of apportioning means-of-egress to the number of occupants in a building. One of the first egress standards was set by the New York Department of Labor in 1914 which limited the occupancy on each floor to 14 persons for every 22 in. of stair width. In 1935 the National Bureau of Standards published, "Design and construction of building exits," an important work in the history of building egress codes. One finding was that egress codes varied widely in regards to how many exits are needed, where they should be, and their required characteristics. Five different methods were discovered for determining required exits widths, and the report concluded with a new method that required stairwells have sufficient capacity to handle an evacuation of the most populated floor, the current method used in North American codes (Nelson 2003).

Modern Building Egress Codes

Contemporary methods for calculating a maximum occupancy for a building, floor, or meeting room are simple, but the number of possible building space uses and exit types is extensive (Coté and Harrington 2003). For example, the 2003 Life Safety Code© includes detailed exit-capacity adjustments (in persons) for stairways based on the presence, size and positioning of handrails, as well as ramp-capacity adjustments that incorporate ascending or descending slope (National Fire Protection Association 2003). In general, occupant load and building geometry determine the required number, location, and capacity of exits. An important aspect of a means-of-egress is that, "it is only as good as its most constricting component." Furthermore, a good design principle for an egress system is balance among exits because one or more might be lost in a fire.

A central concept in determining building egress is that of an occupant load factor. Occupant load factors are upper limits on density that vary with the use of the space. In other words, the nature of the use of a space determines its allowable density. For example, a "residential apartment building use" is allowed a gross

Table 1. Occupant Load Factors from Life Safety Code®[a]

Use	m^2 per person	ft^2 per person
Assembly use		
Concentrated, without fixed seating	0.65 net	7 net
Less concentrated, without fixed seating	1.4 net	15 net
Educational use		
Classrooms	1.9 net	20 net
Shops, laboratories, vocational rooms	4.6 net	50 net
Day Care use	3.3 net	35 net
Residential use		
Hotels and dorms	18.6 gross	200 gross
Apartment buildings	18.6 gross	200 gross
Industrial use		
General and high hazard	9.3 gross	100 gross

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density of 200 ft^2 per person while a "concentrated assembly (without fixed seating) use" allows a much higher net density of 7 ft^2 per person (Table 1). "Net" density refers to rooms, and "gross" density refers to floors or an entire building. Defining the maximum density for an indoor space based on its use is valuable because it bypasses the need to conduct an empirical occupancy study for every building. Occupant load factors derived from the table are then used in conjunction with the area of a meeting room or floor to design the means-of-egress system and also to trigger provisions like the need for a sprinkler system.

The required number, capacity, and arrangement of exits are determined using the occupancy load, the use of the space, and simple geometric rules. The required number of exits for each story is determined with a step function based on the use of the space and the occupancy load. Stories with less than 500 occupants require a minimum of two exits, those with between 500 and 1,000 require at least three exits, and more than 1,000 occupants requires at least four. A capacity-factor table specifies the minimum width for stairways and horizontal exits based on the use of the space. Most indoor activities require stairwells to have 0.3 in. of width for each person on the floor with the greatest number of occupants, but areas with hazardous contents require 0.7 in. per person, a much greater capacity (Table 2).

The linear relationship between the maximum number of occupants and exit widths was originally proposed by Pauls (1974) and widely adopted in North America. For example, a stairwell 44 in. wide has a capacity of (44 in./0.3 in. per person) = 147 persons for most floor uses (Table 2). If the occupancy of the floor is expected to exceed 147, then the stairwell capacity is insufficient and the maximum occupancy must be lowered or the stairwell egress capacity must be increased. The arrangement of the exits is determined using a simple geometric rule called the "one-half diagonal rule" that states that two exits shall not be located closer than one half the length of the maximum diagonal dimension of the area served (Fig. 5). This requires exits to be sufficiently remote so as to prevent a fire from blocking more than one. For example, if the maximum diagonal distance across a room with two exits is 60 ft., then the exits must be at least 30 ft. apart. Finally, an arbitrary distance cutoff is used to ensure that no building occupant is too far from an exit.

Table 2. Capacity Factors from Life Safety Code®[a]

	Stairwells (width per person)		Level components and ramps (width per person)	
Area	(mm)	(in.)	(mm)	(in.)
Board and care	10	0.4	5	0.2
Board and care, sprinklered	7.6	0.3	5	0.2
Health care, nonsprinklered	15	0.6	13	0.5
High hazard contents	18	0.7	10	0.4
All others	7.6	0.3	5	0.2

[a]Reprinted with permission from NFPA 101-2003, *Life Safety Code*®, Copyright © 2003, National Fire Protection Association, Quincy, Mass. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

Community Egress Codes

Despite the tremendous fire hazard in many interface communities, few studies have been done on residential densities in fire-prone areas (Theobald 2001; Schmidt et al. 2002; Cova et al. 2004). There is certainly nothing as complete as Nelson's (2003) longitudinal study of Washington D.C. federal building occupancy densities from 1927 to 1969. Second, there are no road-capacity studies for fire-prone communities on par with Pauls' (1974) extensive research on doorway and stairwell capacities. Roads in interface communities can be very narrow, intersect at odd angles, and vary in width. The capacity of this type of road network in dense smoke is difficult to quantify but would likely be very low. Third, existing egress codes for fire-prone communities are very general and do not provide the elegant methods for comparing and testing egress systems found in the building safety codes. The following codes serve as representative examples of contemporary community egress codes (National Fire Protection Association 2002):

1. 5.1.2 Roads shall be designed and constructed to allow evacuation simultaneously with emergency response vehicles.
2. 5.1.3 Roads shall be not less than 6.1 m (20 ft) of unobstructed width with a 4.1 m (13.5 ft) vertical clearance.

While the intent of the codes is clear, they do not link the occupant load with the required minimum number, capacity, and arrangement of exits. Current codes also tend to overlook the furthest distance a household is from its closest exit as well as vulnerability owed to dense fuel along the exits. In general, standards for interface community access focus more on maintaining fire-fighter ingress than resident egress (International Fire Code Institute 2003). Given that it is easy to find growing interface communities with miles of tangled narrow roads, many residents, and few exits, improved egress codes are a growing need.

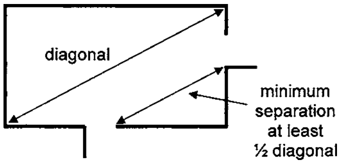


Fig. 5. One-half diagonal rule in building egress codes ensures that exits are sufficiently remote from one another

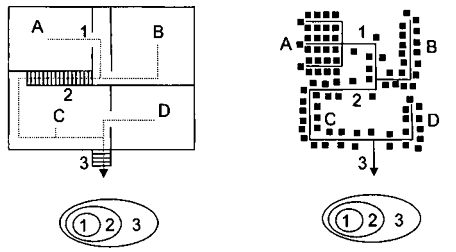
Differences in Community and Building Means-of-Egress Systems

Although there are many similarities between building and community egress systems, there are also significant differences. First, notification systems vary across communities (Sorensen 2000), whereas warning is generally issued with a siren, flashing lights, and a public address system in a building. For this reason, warning is nearly instantaneous and uniform in modern buildings, where it can take minutes to hours to warn all residents in a community, depending on the area, population density, and notification modes (e.g., reverse 911 or door to door). This has egress implications because the most constraining component in a community's egress system may simply be information, a vital yet scarce resource in most emergencies (Alexander 2002). However, slow notification can have benefits (if it is not too slow), as it can dampen household departure rates which reduces the likelihood of a traffic jam from a sudden burst of travel demand in a wildfire. Sudden bursts of travel demand are rare in evacuations but can lead to extreme stress when egress is constricted (Quarantelli et al. 1980; Chertkoff and Kushigian 1999), as in the case of the 1991 Oakland Fire.

Emergency manager behavior, population mobility, and human response are also important elements of an egress system. Emergency manager behavior is important because an incident commander generally decides who should evacuate and when they should leave (Lindell and Perry 1992). Mobility in a community context refers to the proportion of available drivers and vehicles in a population, whereas building evacuees are generally on foot or in a wheelchair. A glaring example of this constricting factor exists in many developing countries where mobility can be so low as to render regional evacuation infeasible (e.g., cyclones in Bangladesh). However, mobility can also cause problems if a highly mobile population leaves in a condensed amount of time and overloads an egress system.

Human response is also important, and evacuee behavior can be very different in wildfires than buildings. In building fires, occupants generally proceed directly out of the building or facility given sufficient egress, knowledge of the floor plan, and clear directions. In wildfires, there are family members, pets, horses, and livestock to evacuate, property to protect, and sheltering-in-place is always an option. These factors can dampen sudden spikes in egress demand but are more often a drawback in clearing an area quickly. In a building evacuation, the "walk, don't run" rule is used to dampen demand spikes and to reduce the likelihood of panic. Unfortunately, there are very few studies on wildfire evacuation behavior, but analogies can be drawn to evacuation behavior in other hazards that have been studied in greater depth (Perry 1985; Mileti and Sorensen 1990; Zelinsky and Kosinski 1991; Vogt and Sorensen 1992; Drabek 1996; Dow and Cutter 2002).

Perhaps the most obvious difference between building and community egress systems is the engineered components. Buildings have stairways, elevators, escalators, ramps, doors, handrails, and hallways, where communities have driveways, roads, intersections, stop signs, and traffic signals. Although these differences are significant, general concepts drawn from building codes may have value in a community context. One approach is to modify and extend building egress codes to achieve codes of comparable quality for communities.



Building evacuation plan with nested, constricting components
(a)

Community evacuation plan with nested, constricting components
(b)

Fig. 6. Comparing nested, constricting components in building egress system with similar ones in community

What is a Community "Exit"?

An initial geographic problem in designing codes for communities might be deemed "the community exit problem." In a building context, exits have a component referred to as the discharge that leads people to a public way outside the building. In other words, safety is defined as "outside" the room or building. Inside and outside are ambiguous concepts in a community context and difficult to specify. If a predefined emergency planning zone (EPZ) is centered on a known hazard like a nuclear power plant or chemical stockpile site (Sorensen et al. 1992), then safety can be defined as outside the EPZ. In wildfires the zone to evacuate is defined on-the-fly at the time of the event and may expand in any direction as the fire progresses. For this reason, setting egress codes in advance that relate occupancy load to exit capacities requires searching the set of all potential evacuation zones.

An insight drawn from building studies can aid in addressing this problem. As noted, "A means of egress is only as good as its most constricting component." In a road-network context, this is referred to as a "bottleneck." A bottleneck can be used to define the inside and outside of a community, as traversing one is similar to clearing an exit discharge in a building (Cova and Church 1997). In other words, once a vehicle has successfully traversed a bottleneck, it is no longer a constraint on travel. This means that the community exit problem can be viewed as a search for potential roadway bottlenecks. In a sense, this is the approach adopted by interface codes that require at least two exits, as this precipitates a search for communities with only one exit, a potential bottleneck.

One problem with requiring that communities have more than one exit is that a bottleneck can still exist. In short, more than one exit does not ensure that an egress system is sufficient. It depends on the number of occupants, the arrangement and capacity of the exits, and the concentration of travel demand in space and time. Adding to this problem, bottlenecks can be nested in communities as they can in buildings. Fig. 6 compares nested constricting components in a building egress system with similar constricting components in a community context. Neighborhood A is nested within bottlenecks 1, 2, and 3. A building's outer wall is the point at which nested constraining components terminate, but in a community context, components nest from a street segment to a neighborhood, city, region, and so on. This can be addressed by terminating the search for egress bottlenecks when the area constrained is larger than that likely to be evacuated in a wildfire.

Table 3. Proposed Load Factors for Interface Communities

Use	Road length per household (m)	Road length per vehicle (m)
Residential[a]		
Low wildfire hazard	12.5	6.3
Moderate wildfire hazard	16.7	8.3
High+ wildfire hazard	20.0	10.0
Residential and tourism[b]		
Low wildfire hazard	12.5	4.2
Moderate wildfire hazard	16.7	5.6
High+ wildfire hazard	20.0	6.7

[a] 2 vehicles per household.

[b] 3 vehicles per household.

Table 5. Proposed Capacity Factors for Interface Communities

Use	Minimum total exit capacity (vph per household)	Minimum evacuation time (h)
Residential[a]		
Low wildfire hazard	1	2
Medium wildfire hazard	2	1
High+wildfire hazard	4	0.5
Residential and tourism[b]		
Low wildfire hazard	1.5	2
Medium wildfire hazard	3	1
High+wildfire hazard	6	0.5

[a] 2 vehicles per household.

[b] 3 vehicles per household.

Improving Community Egress Codes

Methods

The focus in a community context is therefore on identifying constricting components in a means-of-egress system. Furthermore, to achieve a comprehensive code and associated methods, the most constricting component should be defined in terms of the expected maximum occupancy as well as the number, capacity, and arrangement of exits. This is accomplished in a building context with look-up tables and simple geometric rules like the one-half-diagonal rule. In this section, preliminary analogues for interface communities are proposed. Agreed-upon community egress tables and codes will take significant cooperation among planners, and this represents a more formidable hurdle in terms of code development and compliance than the technical concepts discussed here (Burby et al. 1998).

Tables 3–5 represent community look-up tables for residential loading factors and the minimum number and capacity of exits. Table 3 depicts preliminary recommendations for community-based load factors expressed in road length per household, where communities with a greater fire hazard are required to have a lower density. In other words, as fire hazard increases the maximum allowable household density along roads should decline (Fig. 7). This is analogous to building codes which require a lower occupant density for buildings that contain hazardous materials (Table 1). To avoid delimiting a community's boundary, which is very subjective, "density" was defined as the average length of road (e.g., street centerline) per household in kilometers. This can be viewed as the average number of driveways per unit length of road. This calculation requires two easily acquired inputs that can be objectively measured: the number of households and total road length in the community.

Table 4 represents the minimum number of exits required for a community, which is a step function of the number of households. Allowing communities with only one exit to have up to 50 households avoids classifying all culdesacs as noncompliant with a two-exit minimum code. Table 5 represents the required minimum (total) exit capacity expressed in vehicles per hour (vph) per household. This is analogous to the linear relationship between persons and stairwell width in North American building egress codes (Table 2). The basis for the minimum required vph per household is a desired minimum evacuation time. For example, if a community has a high fire hazard (or greater), then the minimum evacuation time should be at most 30 min (0.5 h). Assuming two registered drivers per household, this requires that the exits have a minimum capacity of 4 vph per household. So a community with 100 households would need a total exit capacity of at least 400 vph to allow the estimated 200 vehicles to leave in 1/2 h (200 vehicles/0.5 h=400 vph). This coarse approach to estimating minimum evacuation time can be better tested for a given community with a traffic simulation model (Cova and Johnson 2002).

In most fire-prone communities, the "use" of the space is residential, but in larger communities there may be businesses, schools, churches, community centers, and tourist attractions (e.g., lakes, botanical gardens, hiking trails). Facilities and attractions above and beyond residences are important because community occupancy may vary significantly when tourists and tran-

Table 4. Proposed Minimum-Exits Table for Interface Communities

Number of households	Minimum number of exiting roads	Maximum households per exit
1–50	1	50
51–300	2	150
301–600	3	200
601+	4	

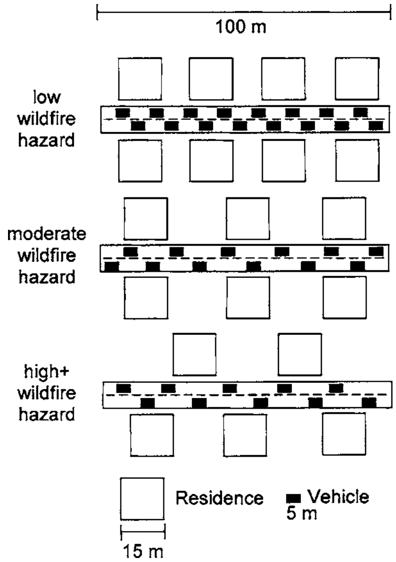


Fig. 7. Visual depiction of loading factor table for "residential use" assuming average of 2 registered drivers per home

sients are drawn (Drabek 1996). Furthermore, transient knowledge of the environment (e.g., evacuation routes) can be very poor. A community with a high degree of transients is analogous to an "assembly use" in building egress codes because occupants are generally unfamiliar with their environment. Table 5 requires a minimum capacity of 6 vph per household for high fire-hazard communities with tourism. So a community with 100 households and tourists would need a total exit capacity of at least 600 vph to allow the estimated 300 vehicles to leave in 1/2 h (300 vehicles/0.5 h=600 vph). The assumed mean number of vehicles per household can be adjusted, but standards should be set using the maximum probable occupancy in an area rather than the residents (and thus vehicles) recorded by the census.

Using Tables 3–5 in conjunction with a diagonal rule, a maximum-distance threshold and an exit-vulnerability rule, it is relatively straightforward to develop preliminary codes and compare community egress systems. For example:

1. Occupant load factor (density). The density of homes along the roads in any fire-prone community or portion thereof should not exceed that specified in Table 3.
2. Number of exits. The number of means-of-egress from any fire-prone community or portion thereof shall meet the minimum specified in Table 4.
3. Exit capacity. The total egress capacity from a fire-prone community or portion thereof shall meet the factors specified in Table 5.
4. Exit arrangement. The closest distance between any two points along any of the *n* exits from a fire-prone community must be at least $1/n$ the maximum diagonal distance across the community. The maximum diagonal of a community is defined as the greatest Euclidean distance between any two households that rely on the same exit set, and the minimum distance between exits is defined as the shortest Euclidean distance between any two points along two exiting roads.
5. Maximum exit distance. No household in a fire-prone community shall be further than 3 km by road from its closest exit. The maximum exit distance for a community is defined as the household with the greatest shortest-path distance on the road network to an exit discharge in the most constraining bottleneck set (i.e., the end of one of the exiting roads from the community).
6. Exit vulnerability (distance to fuel). Exits in a fire-prone community shall have a 30 ft buffer on each side that is clear of fuel.

An important aspect of this approach is that each recommended code is an independent test. This means that a community can meet or fail any subset of the codes. For example, a community might meet the density and minimum-number-of-exits codes but fall short of the exit-capacity code. The advantage of independent tests is that distinct limitations in a community's egress system can be highlighted separately. Fig. 8 depicts the proposed characteristics measured for Mission Canyon.

Table 5 provides the important link between expected maximum occupancy and required minimum exit capacity. An interesting aspect of this table is that it can be applied in reverse to calculate a community's maximum occupancy. For example, if a high-fire-hazard residential community (i.e., minimum evacuation time no greater than 30 min) has a total exit capacity of 1,000 vph in the most constraining bottleneck set, then from Table 5 the maximum occupancy would be (1,000 vph/4 vph *per household*)=250 households.

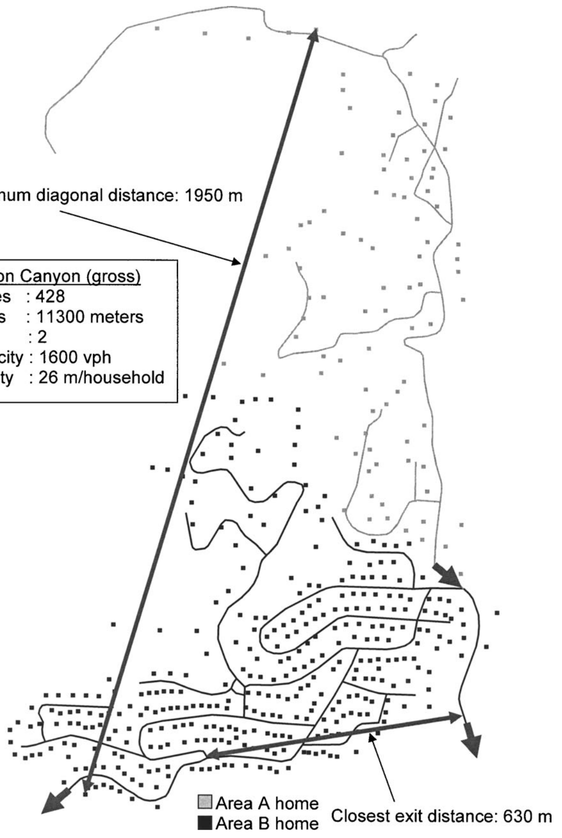


Fig. 8. Example (gross) egress calculations for Mission Canyon

Comparing Interface Communities

This section applies the proposed method to sample interface communities with high wildfire hazard, relatively low egress, and residential land use. A community with residential land use simplifies the estimation of occupant load by eliminating commercial, educational, and tourism activities. The inside (and outside) of each community is defined by the most constraining road-network bottleneck set. For example, if a community's most constraining bottleneck set is two exits, the calculations are for the households that would need to traverse one of these exits in an evacuation.

Perhaps the most involved calculation is for road capacity. This was crudely estimated using Eq. 8-3 in the *1997 highway capacity manual* (Transportation Research Board 1997):

$$\mathrm{SF}i = 2{,}800(v/c)_i f_d f_w f_g f_{\mathrm{HV}} \tag{1}$$

This equation states that a road's service flow rate (SF_i) in vehicles per hour (vph) is the product of the volume-to-capacity ratio for level-of-service i $(v/c)_i$ and a set of adjustment factors for directional traffic distribution f_d, lane and shoulder width f_w, grade f_g, and the presence of heavy vehicles f_{HV}. A narrow, mountainous road operating at level-of-service E (0.78) (maximum capacity) is assumed (for this analysis) with 100% of the traffic in one direction (0.71) on a 9 ft wide lane and 2 ft shoulder (0.70) heading downhill (1) with the possible 3% presence of large recreational vehicles (0.75) for an estimate of capacity per exit in clear visibility conditions with moderate demand rates of 814 vph (rounded to 800). In communities with uphill exits, wider roads or no recreational vehicles, this can be adjusted. Concentrated demand could greatly degrade this flow rate to level of service *F* where capacity can no longer be reliably estimated. Also, it should be noted that this number is very optimistic be-

Table 6. Data for Comparing Interface Community Egress Systems

Community	Homes	Exits	Road length (m)	Density (m per home)	Exit capacity (vph)	Max. diam. (m)	Exit separ. (m)	Max. dist. (m)	Exit fuel buffer
Buckingham[a]	337	4	5,293	16	3,200	1,040	85	430	No
Emigration Oaks	250	2	11,820	47	1,600	3,212	1,589	2,550	No
Summit Park	446	2	18,960	43	1,600	2,230	395	4,700	No
Mission Canyon	428	2	11,300	26	1,600	1,950	630	2,300	No
Area A (net)	60	1	4,576	76	800	1,520	NA[b]	1,750	No
Area B (net)	368	3	6,724	18	2,400	1,250	630	1,900	No

[a] 1991 data.

[b] Not applicable.

cause it does not consider driveways along a road or other merge points that may create flow turbulence.

Table 6 shows the raw data for the communities in the comparison which all have "high+" wildfire hazard during the fire season. Community fire hazard was grossly assigned based on the predominant vegetation and residential construction type. A community of wood structures intermixed with a combination of highly flammable vegetation (e.g., Gambel Oak or Eucalyptus) was assigned a "high+" wildfire hazard. Table 7 is derived from Table 6 and the recommended codes presented in the prior section by determining which aspects of each community are "compliant" (C) or "noncompliant" (N).

An interesting result of this comparison is that the neighborhood at the origin of the 1991 Oakland–Berkeley fire is compliant for three of the six egress tests. The number and total capacity of the exits, as well as the furthest distance from any home to its nearest exit were reasonable. The problem appears to have been the relatively high residential density, the close proximity of exits 1 and 3 (Fig. 9), and the tremendous amount of fuel along the exits. The neighborhood had been built to urban density with only 16 m of road per household (i.e., street centerline length), the most densely developed neighborhood in the comparison (Table 6). This means that in 1991 the neighborhood had a driveway, on average, every 16 m. This is very dense development for an area with extremely high fire hazard. The arrangement of the exits was also not ideal, as exits 1 and 3 were closer than 1/4 the maximum diagonal distance between the furthest two households relying on the exits. In 1991, exits 1 and 2 were blocked by the fire in its first 1/2 h, and most of the remaining residents chose exit 3 (Charing Cross Road). However, from the point of view of a wildfire, exits 1 and 3 are too close to one another to be considered genuinely separate means-of-egress, so a fire that blocks exit 1 is almost certain to block exit 3 which is just uphill, and this is what happened in 1991. Finally, there was a substantial amount of fuel along the exits, and this is what led exits 1 and 2 to be blocked by the fire so early in the event. However, all told, if this neighborhood had less than four exits the number of fatalities would likely have been much higher.

In regards to the other neighborhoods in comparison, it is easy to identify canyon and hillside neighborhoods in the West with relatively poor egress systems to varying degrees. Emigration Oaks is a neighborhood just East of Salt Lake City, Utah that has a reasonably good egress system, but it is an elongated community and the two exits are less than 1/2 its maximum diagonal distance (Cova and Johnson 2002). This resulted in the community being noncompliant in regards to exit arrangement. The community also has a substantial amount of highly flammable Gambel Oak lining the exit-road shoulders. Summit Park is a community on the Wasatch Mountain ridgeline between Salt Lake City and Park City. This neighborhood did very poorly, as it currently has 446 homes relying on two proximal exits that are lined with conifers. Mission Canyon in Santa Barbara, Calif. also scored poorly for the same reasons. To provide one example of "net" egress calculations for a community, Mission Canyon is divided into areas A (upper canyon) and B (lower canyon). Area A is not compliant in regards to the number of exits because it has 60 homes and only one exit, where Area B is too dense and does not

Table 7. Comparing Interface Communities Against Egress Standards[a]

Community	Density	Number of exits	Exit capacity	Exit arrange	Maximum exit distance	Exit fuel buffer
Buckingham, Oakland, Calif.[b]	N	C	C	N	C	N
Emigration Oaks, Utah	C	C	C	N	C	N
Summit Park, Utah	C	C	N	N	N	N
Mission Canyon, Calif.	C	N	N	N	N	N
Area A (net)	C	N	N	N	N	N
Area B (net)	N	C	N	C	N	N

[a] C=compliant, N=noncompliant.

[b] 1991 data.

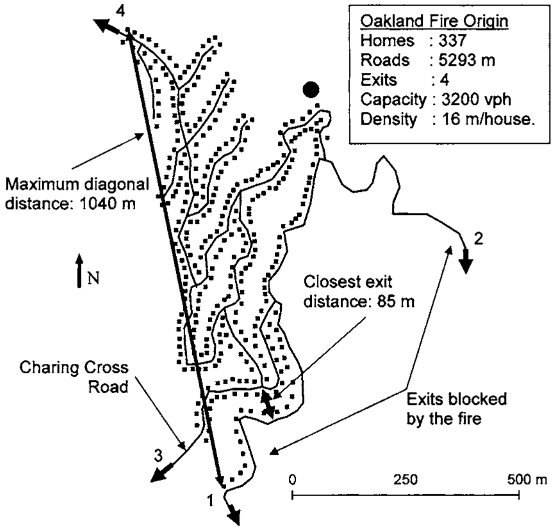


Fig. 9. Neighborhood at origin of Oakland–Berkeley fire in 1991

have sufficient exit capacity to serve its households. The main point with Tables 6 and 7 is simply that it is easy to identify neighborhoods with equal or greater fire hazard than the 1991 Oakland–Berkeley fire case and a more constrained egress system.

Urban and Emergency Planning Implications

The primary implication of developing a method comparable to building egress codes is that it is easy to identify fire-prone communities with relatively poor egress. The focus for urban and emergency planners should then turn to implementing new codes and improving egress systems. The proposed codes in the prior section can serve as a starting point and would need to be adjusted (or expanded) to work for a given locality. Also, despite the obvious limitations of the egress systems in the prior section, there are many actions that communities can take to improve their overall system (Plevel 1997). If a community has relatively poor egress, there are both demand-side and supply-side improvements (or adjustments) that can be implemented with varying cost (Burton et al. 1993). The focus in demand-side adjustments is reducing the concentration of vehicles in an evacuation in space and time to alleviate the need for egress capacity (e.g., supply). Example demand-side options include limiting the construction of new homes or businesses, limiting renters, constructing wildfire shelters, and identifying internal safe zones. Another demand-side adjustment is to require that structures be defensible so that residents can shelter-in-place. If a community can demonstrate that enough structures are defensible or there is sufficient public wildfire shelter or safe areas provided within the community, then the loading and capacity calculations could be adjusted to recognize that all not all residents will need to evacuate in a wildfire. This means that the following statement might be appended to each of the prior preliminary recommended codes:

"… unless a sufficient number and capacity of defensible structures, public shelters, or safe areas exist in the community for residents to shelter-in-place during a wildfire."

Supply-side adjustments to improve a community's egress system are also an option. This includes detailed evacuation route planning (i.e., Who will go where?) as well as reversing lanes and restricting turns at intersections to improve exit capacities (Wolshon 2001; Cova and Johnson 2003). Communities should also maintain their egress system. On-street parking restrictions can prevent low-capacity roads from becoming even lower, and clearing vegetation and other fuel along evacuation routes can minimize the loss of important exits during a wildfire. In cases where the egress system is severely substandard, widening roads or building new roads may be needed if more households are to be added.

Conclusion

Residential development in fire-prone areas is continuing without commensurate improvements to community-based transportation egress systems. This is only a small part of a much larger policy problem in fire-prone areas (Busenberg 2004), but it is an important one in protecting life. The codes presented in this paper would need to be integrated into a community's comprehensive hazard mitigation plan (Burby et al. 2000; Prater and Lindell 2000). However, the methods presented in this paper should help an analyst or planner in comparing community egress systems and possibly formulating codes. This may lead to improved community egress codes comparable to the higher-quality ones already in place for buildings. Limiting residential construction in low-egress, fire-prone areas with a "maximum occupancy" is not currently practiced but may be needed in some communities. If very few homes in a low-egress community are defensible and there is no safe zone or other public shelter, then limiting occupancy is one approach to maintaining public safety.

Economic pressure is strongly toward developing fire-prone communities to a density beyond which the egress system can safely handle in an urgent wildfire evacuation. The beneficiaries of new home development include new residents, developers, construction companies, and property tax collectors among many others. The parties that stand to lose include the residents who may perish in a wildfire, insurance companies, and the emergency managers challenged with the increasingly difficult task of protecting life and property in these rapidly growing areas. Thus, for political and economic reasons the methods presented in this paper may only find application in evacuation planning and comparing community egress systems. In the longer term, it is up to engineers and planners to ensure public safety in the urban–wildland interface by providing sufficient egress (or shelter) and educating residents on protective actions.

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Exhibit 5

Emergency Planning in the Urban-Wildland Interface: Subdivision-Level Analysis of Wildfire Evacuations

Brian Wolshon, Ph.D., P.E.[1]; and Emile Marchive III[2]

Abstract: This project was motivated by recent research that has advocated the need for a better understanding of and planning for evacuations of residential subdivisions under threat from wildfires. Prior work has suggested that the density of housing units and ineffective evacuation routing and egress may have contributed to fatalities in subdivisions in which residents were unable to evacuate when the need arose. To evaluate the effects of development density and street network layout, this study utilized simulation to represent and evaluate various evacuation scenarios at the neighborhood level under ranges of housing density and threat urgency. The results of this study illustrate the relationships between the traffic that can be accommodated by a roadway network; the location and number of egress points; and the time during which vehicles enter and exit the network. Most significantly, it showed how changes in traffic volume need to be accompanied by corresponding increases or decreases in time and/or egress capacity to move evacuees out of the threat zone. Similarly, changes in the network (i.e., adding and/or modifying the location of exits) were also shown to significantly decrease evacuation clearance times and increase the total exiting traffic.

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CE Database subject headings: Evacuation; Traffic management; Emergency services; Fires; Disasters.

Introduction

The continued spread of suburban growth and the desire by some to live further from urban population centers have pushed suburban growth into ever more rural areas. The construction of housing developments into the "urban-wildland interface" is especially appealing because of its aesthetic value, recreational access, and low cost (Cova 2005). The movement of people into these areas also presents a number of new challenges to both the natural and built environments. Although many people in these areas remain tied to urban centers for employment, education, and shopping, the capacity of and accessibility to transportation facilities often proves inadequate to serve the growing demand.

The growth in the urban-wildland interface also puts people in closer contact to potentially hazardous conditions not normally encountered in more conventional urban and suburban centers, including landslides, floods, and proximity to wild animals. Wildfires can also be a problem, particularly in the western United States where the combination of climate, vegetation, and geography has combined to make wildfires a normal part of the natural ecological cycle of growth, death, and regeneration for thousands of years. Unfortunately, many wildfires are also started, unintentionally and intentionally, by human activity. Given this combination of growing development and fire potential, it is not surprising that reports of homes destroyed or threatened by wildfires in formerly sparsely populated natural areas have become an annual occurrence. It is also unfortunate that significant losses of life have also accompanied several wildfires over the past 15–20 years.

One example of a particularly tragic wildfire occurred in 1991 near the Buckingham Subdivision in Oakland, Calif. and resulted in the deaths of 24 residents. Nine of these people were killed in or near their vehicles at the end of a traffic queue during the evacuation (Church and Sexton 2002). It has been suggested that traffic queues developed within the subdivision road network in part because of narrow roads, irregular intersections, and a lack of usable exits. Although the subdivision was constructed with four exits, two of them became blocked during the fire. This incident serves as a reminder of the importance of a proper roadway design and maintenance for emergency evacuations in urban-wildland interface areas.

A study by Cova (2005) examined issues associated with evacuations in urban-wildlife interface residential communities. Among the findings of this work was the suggestion that a combination of development densities; roadway network layout and capacity; and geography could be contributing to an inability of some communities from being able to evacuate in a safe and timely manner under certain wildfire scenarios. The author also theorized that planning considerations and design parameters used for the formation of evacuation egress routes for standalone buildings could be applied for the development of plans for the evacuation of entire residential subdivisions. Such measures could include limitations on the number and location of proposed dwelling units as well as requirements for the capacity and arrangement of evacuation exit points within the subdivision threat zone.

This paper presents the development and results of a case

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[1] Associate Professor, Dept. of Civil and Environmental Engineering, Louisiana State Univ., Baton Rouge, LA 70803-6405. E-mail: brian@rsip.lsu.edu

[2] Instructor and Doctoral Candidate, Dept. of Construction Management, Louisiana State Univ., Baton Rouge, LA 70803-6405. E-mail: marchive@lsu.edu

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study to evaluate the effects of some of these principles from the perspective of traffic flow analysis. In the research, the microscopic traffic simulation model Corridor Simulation (CORSIM) was used to model and evaluate the traffic conditions that would occur in a residential subdivision under several different combinations of evacuation urgencies, residential development densities, and road network and traffic routing scenarios. The subdivision used as the modeling basis of the study is located in the at-risk urban-wildland interface of Summit Park, Utah. Using the time required to exit the subdivision roadway network and other indicators of traffic flow efficiency, estimates of potential loss of life and evacuation efficiency were developed based on various design, hazard, and routing scenarios. Limits on the maximum number of evacuating vehicles were also estimated to demonstrate how such information could be used to demonstrate how such information could be used to evaluate the ability of similar existing and proposed subdivisions to safely evacuate.

Literature Review

The simulation of traffic under evacuation conditions has been ongoing for many years and has involved the application of many different modeling techniques. Most simulation efforts have been focused on the opposite ends of the analysis spectrum, i.e., large scale networks and small concentrated areas. This has been in large part a reflection of the two main types of traffic simulation platforms that have been available to analysts. At one end of the spectrum are the microscopic platforms. These systems are typically used to analyze the operation of small networks or specific locations in fine detail over relative short time durations. At the other end are the macroscopic modeling systems. Macro models are typically used for region-wide analyses over longer periods in which aggregated output statistics are adequate to address the needs of the study. A study by Southworth (1991) synthesized the range of micro- and macrolevel simulation models that were based on both general-purpose and special-purpose software that were used for the analysis of evacuation traffic.

At the microscopic level, programs like CORSIM and its precursor NETSIM have been popular platforms for the simulation of emergency traffic on smaller networks where it was possible to analyze specific aspects of flow conditions in detail. Microscopic simulation programs such as these have also been useful when simple traffic assignment assumptions were adequate to capture the essence of the system. They have also been employed for the analyses of smaller segments of much larger systems for hurricane evacuation (Theodoulou and Wolshon 2004; Lim and Wolshon 2005; Wolshon et al. 2006).

At the mesoscale and macroscopic level, models such as TRANSIMS (Gu 2004), NETVAC, DYNEV, MASSVAC, and Oak Ridge Evacuation Modeling System (OREMS) have been developed specifically for the simulation of evacuation traffic at a regional level. Among the advantages of some of these systems has been the integration of dynamic route assignment capability within large geographic areas rather than the simple route assignments used in earlier microlevel models. General-purpose simulation systems like the Simulation Language for Alternative Modeling (SLAM) have also been used to analyze traffic flow during various emergency scenarios. Systems like the Calculated Logical Evacuation and Response (CLEAR) and SNEM have been developed specifically for evacuations around nuclear power plants and other similar types of emergencies (Southworth 1991; Hobeika et al. 1994; Pidd and Mannering 1996; Urbanik 2000). One of the primary limitations of these types of models, however, was that they were often limited to the analyses of primary evacuation routes using simplified "common sense" assumptions.

Recently, microscopic simulation platforms have been applied for the analyses neighborhood-level evacuation. These included Cova and Johnson (2002), who recognized its potential utility for analyzing wildfire evacuations in Utah and Church and Sexton (2002), who used the *Paramics* program for similar analyses of at-risk neighborhoods in California. The neighborhood-level analyses of evacuation traffic discussed in this paper were undertaken using the CORSIM microscopic simulation platform. It was thought that CORSIM would be particularly useful for this purpose because it permits the loading of demand from within the neighborhood using individual source nodes (houses) arranged at locations throughout the network. Although initially tedious to code, it can also incorporate Monte Carlo processes that reflect various traffic loading rates, locations, and timing from various points within the network (FHwA 1997), which were ideal for the study described in this paper.

Study Objective

The objective of this effort was to evaluate the evacuation preparedness of urban-wildland residential developments under wildfire threats by simulating traffic flow conditions that would likely result under a range of theoretical combinations of hazard timing and housing density scenario. The evaluation was used to assess the results based on measures such as vehicle queuing characteristics, the total outflow capacity, and the number of fatalities that could occur in the test network under various temporal and spatial evacuation demand conditions.

Based on prior wildfire evacuation events, it has been hypothesized that certain subdivision road network designs may have limited the ability of residents to evacuate in a timely manner, resulting in deaths and injuries. Since wildfires can move at different speeds and people receive and respond to evacuation warnings at different times, the movement of evacuees from their homes can vary widely. Additionally, roads can become impassable requiring alternate escape routes or an increase in the urgency at which an evacuation takes place. These conditions can create surges in demand that overwhelm the available capacity of the exit roadways resulting in potentially fatal travel delays.

Only recently have scenarios such as these been quantitatively and comparatively studied using modeling tools specifically designed for evaluating traffic flow, congestion, and delay. Most studies in this area have targeted geospatial referencing of neighborhoods as they pertain to the environment. They tend to concentrate on terms such as setback requirements, building materials to be used and to name a few. Traffic-specific microsimulation of neighborhood-scale evacuations has just begun to enter the field of planning as a focus. It is suggested that the knowledge gained from this work could be helpful to better understand relationships between the density of such developments and the requirements for determining the amount of advanced evacuation warning time needed to the clear subdivision as well as the number, arrangement, and capacity of evacuation egress points.

Study Approach

To reflect as realistic a condition as possible in the study, the actual urban-wildland interface neighborhood of the Summit Park subdivision in suburban Salt Lake City, Utah was used as the basis for the test road network. This neighborhood was not particularly similar or different from other such neighborhoods, however, the general road layout and exit arrangement was fairly typical of networks of this type. Summit Park is situated within a densely forested mountainous terrain adjacent to the Wasatch-Cache National Forest. During dry seasons this area is susceptible to wildfires. When fully developed, this neighborhood will incorporate 753 detached dwelling units. The street layout features two exits onto a local collector roadway and many of the local roads in this area are winding, narrow, and have steep gradients that can impede traffic.

Traffic Model and Measures of Effectiveness

CORSIM was selected to simulate traffic conditions based on its ability to effectively model the desired conditions as well as it wide acceptance in the traffic engineering. To construct the test traffic network, a series of links (streets) and nodes (intersections) were laid over an aerial photograph of the subdivision as shown in Fig. 1. The white line in Fig. 1 delineates the western boundary of the study area. Lots, appearing as rectangular boxes, to the right (west) of this boundary were excluded from the analysis since traffic from this area used a separate exit. The remainder of the lots were assumed to generate evacuation traffic.

To simplify the model and reduce computation time, all roads were assumed to be single-lane one-way streets oriented to direct traffic out of the neighborhood using one of two exit points. Each driveway entrance was represented by an entry node and free-flow speed on all internal subdivision roads was assumed to be 20 mi/hr. To evaluate movements and delays resulting from queues as traffic streams crossed or merged at intersections, output statistics were aggregated on the main exiting roads.

Pilot testing showed the need for five separate simulation runs to produce output statistics at a 95% level of confidence. Averaged values from each of the five runs were used in the analyses. The output measures of effectiveness (MOEs) in this study were selected to evaluate both the traffic conditions and the fatality potential for evacuees departing the network. Fatalities were assumed to occur for the occupants of any vehicle that did not clear the development exits within the fire approach period (explained later). MOEs were collected for both individual roadways and on a system-wide basis. The link-specific MOEs included the travel delay and maximum queue length for the aggregated sections of roadway shown in Fig. 2. These measures showed the amount of time spent below free-flow speed on the various roads and the extent of the congestion related queue buildup at various times on the primary and feeder streets within the network. The main network-wide MOE was the total travel time for the network. This was used to determine the number of and time required for vehicles to clear (or not clear) the threat area.

Hazard-Response Experiments

The goal of the experiments was to study a range of threat-response situations that could occur and assess how they would impact travel conditions within the network. The cross-combination of three key variables resulted in a total of 18 separate threat-response model cases. The three variables were used to develop the test experiments including the housing density within the subdivision, the urgency at which residents responded to an evacuation order, and a "local knowledge" that would allow drivers to seek alternate travel paths in the network when under emergency conditions. Each of these variables is discussed in the following sections.

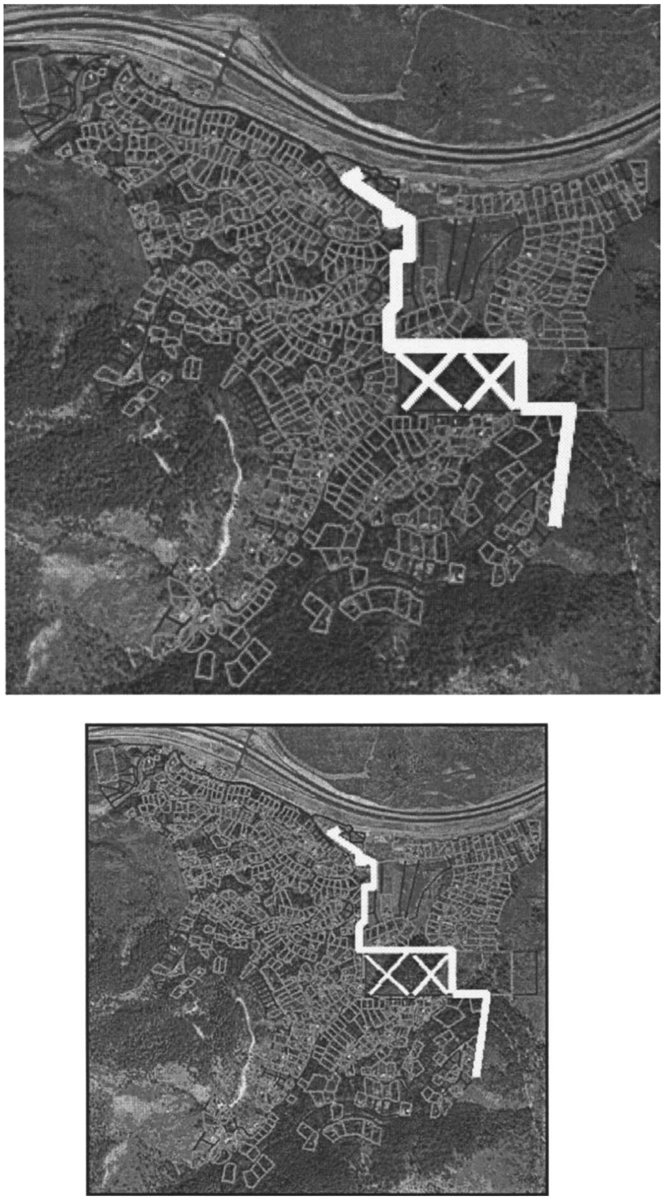

Fig. 1. Summit Park subdivision

Housing Density

The density of houses dictated the number of vehicles that would be generated during an evacuation. Obviously, the more dwelling units with a subdivision, the more evacuation traffic would be expected to be generated. To analyze the effect of increasing development densities (or perhaps to account for evacuations occurring at different times of the day), vehicle generation rates from each entry node were varied. Four loading rate cases were considered in this study, ranging from a low of 1.5 vehicles per node (where a node represented an individual household or group of households) to a high of five vehicles per node (vpn) during the simulation period. Rates of 2.5 and 3 vehicle per node were also used. These traffic generation rates were randomly assigned to the

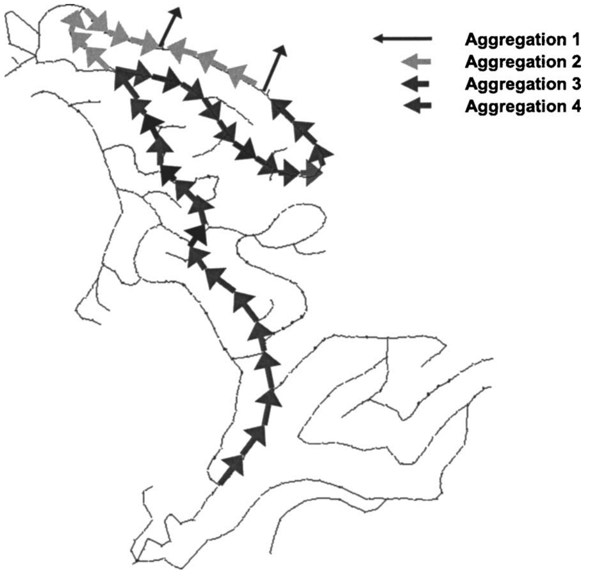

Fig. 2. Aggregation of primary links

753 nodes in the network so that traffic would enter the network at different times and places as they would likely to during an evacuation.

Evacuation Response Time

The response component dictated the length of the time that was required for evacuees to enter the network. These were deemed to be important because last-minute and urgent evacuations can cause sudden surges of demand on exit routes, causing congestion, and increasing overall average delay as evacuees queue at bottlenecks. "Urgent," "medium," and "slow" evacuation response scenarios are used in the study. These assumed total evacuation compliance by 30 min, 1 h, and 2 h, respectively. It should also be recognized that in reality, response time would also be a function of the movement of a wildfire, the ability of evacuation notices to be heard, and the mobilization time required for evacuees.

The response of any particular node within the network was assigned randomly similar to the way in which traffic generation rates were assigned to the nodes. However, here departure times were computed using assumptions similar in concept to those used by the U.S. Army Corps of Engineers (USACE) for hurricane evacuation (USACE 2000). Although hurricane evacuations often occur over many hours or even several days, the response relationship can be shortened to much shorter time windows to reflect a different type of hazard; in this case 30 min, 1, and 2 h.

Fig. 3 shows the curves used for the cumulative percentage of evacuees as a function of time. The steepest curve to the right of Fig. 3 represents an urgent evacuation in which 100% of the evacuees would depart their homes within 30 min, or by about 7:30 (assuming a 7:00 evacuation start time). By contrast, the rightmost curve shows the slow response in which all evacuees have not departed their homes until nearly 9:00, 2 h after the start of the evacuation. It should be noted that these curves also account for early movement of some evacuees. In evacuations with advanced warning it is typical to see about 10% of the evacuating population depart prior to an official order. In this case it was assumed that wary residents would be aware of the impending threat and depart prior to any official advisory. Since these curves have been interpolated from USACE graphical information they are also not smooth as would normally be expected.

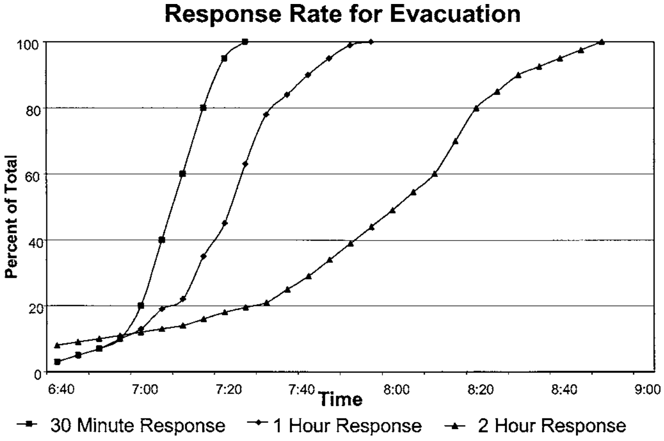

Fig. 3. Cumulative evacuation response curves

Route Selection

Local knowledge of a road network is often used by drivers seeking alternate routes around congestion. While these routes may be longer in distance they can offer shorter overall travel times. In this study, this phenomenon was introduced to evaluate the effect of routing choices to avoid segments in the network that were obviously congested during the evacuation. To evaluate the effect of such behavior, two sets of routing strategies were incorporated into the experiments.

The first routing strategy was the "Shortest Path" set of cases. These cases assumed that most (though not all) evacuees would select the shortest distance travel path. Because of the creation of congestion at high levels of traffic loading, Shortest Path scenarios were used only for loadings of 1.5 and 2.5 vehicles per entry node. The second routing scenarios were the "Alternate Path" cases. Under the Alternate Path scenario, it was assumed that half of the drivers would seek a shorter time travel path when confronted with congested (or potentially congested) conditions.

In the test network, two exit points were located at nearly equal distances from the primary subdivision collector road. From a route selection perspective, the main difference between the two was that one was on the main primary road and did not require any turns to reach it. The route to the second exit required one additional right turn and, because of the subdivision layout, was slightly more indirect requiring drivers to make a short "backtrack" before reaching the exit driveway. Based on this, it was assumed that 75% of the evacuees would choose the more direct primary route and only 25% would opt for the secondary route under noncongested conditions under the Shortest Path scenarios. In the Alternative Path scenarios, it was assumed that when confronted with clearly apparently or the potential for congested conditions, drivers would split evenly between the two exit paths. These cases are graphically illustrated in Fig. 4.

It should also be noted that early experimentation revealed that for the highest loading levels, 3.0 and 5.0 vehicles per node, the Shortest Path assumption would be illogical because it would force drivers to wait in queue even though it would be clear to them that the alternate path was uncongested. For this reason, these loading rates were only simulated assuming Alternative Path routing. All 18 combinations of the response, loading, and routing scenarios are summarized in Table 1.

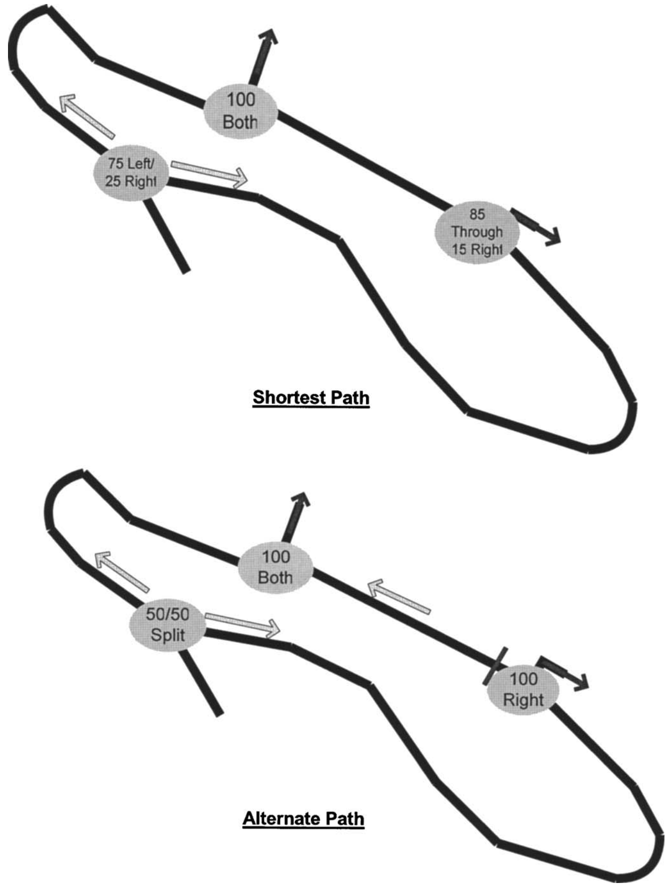

Fig. 4. Route selection scenarios

Analysis and Results

Data generation and analysis focused on both spatial and temporal statistics related to the flow and delay characteristics under the various evacuation scenarios. The primary temporal traffic statistic collected for analysis was the travel time in the network. This measure included both the relative amount of time delay and the time required to clear the subdivision road network. Spatial statistics were used to determine where congestion was occurring in the network and how far queue backups extended upstream from the exit points. Such information was important to determine which exits could be blocked to evacuees and where secondary exit routes might be needed. To account for variation in driving conditions, each of the experiment cases was executed five times using different initial random number seeds. The values presented in this section reflect the statistics averaged from these runs.

Delay and Clearance

The evaluation of network travel delay and clearance time were undertaken based on the three response time loading scenarios (30 min, 1, and 2 h). Each of these scenarios included six separate experiments to reflect the six combinations of loading rate and local knowledge-based routing. Ultimately, the goal of the temporal analyses was to study the various threat-response combinations to determine how many vehicles would be able to evacuate under the conditions and, perhaps more critically, how many of them would not be able to evacuate. A summary of these results are presented in Table 2.

Table 1. Summary of Experimental Scenarios

Experiment	"Evacuation urgency" response time (h)	"Housing density" loading rate (vpn)	"Local knowledge" route assumption
1	0.5	1.5	Shortest path
2	0.5	1.5	Alternate path
3	0.5	2.5	Shortest path
4	0.5	2.5	Alternate path
5	0.5	3.0	Alternate path
6	0.5	5.0	Alternate path
7	1.0	1.5	Shortest path
8	1.0	1.5	Alternate path
9	1.0	2.5	Shortest path
10	1.0	2.5	Alternate path
11	1.0	3.0	Alternate path
12	1.0	5.0	Alternate path
13	2.0	1.5	Shortest path
14	2.0	1.5	Alternate path
15	2.0	2.5	Shortest path
16	2.0	2.5	Alternate path
17	2.0	3.0	Alternate path
18	2.0	5.0	Alternate path

Table 2 includes four statistics for each experiment. The first of these is the total number of vehicles that were generated in the network nodes during the various scenarios. These totals reflect the level of building density assumed in the system. For example, in comparing Experiments 1 and 3, one additional vehicle per entry node was assumed to have evacuated between these two scenarios (1.5 vpn compared to 2.5 vpn). As a result, the difference in the "total vehicles generated" between the two cases was on the order of 750 vehicles. The next column shows the time at which the last vehicle loaded into the network was able to evacuate the subdivision under each scenario. In this column it is apparent that, as expected, the less urgent evacuation loading scenarios resulted in somewhat longer clearance times.

The next two columns were the most important in this study. The "Vehicles unable to evacuate" suggests the risk involved for each scenario. Based on the assumptions of the study, occupants in vehicles unable to exit the network would be regarded as fatalities. It is clear that the most urgent evacuation scenarios resulted in the greatest number of vehicles unable to evacuate. This finding is also illustrated by Fig. 5 in which the number of vehicles unable to evacuate the subdivision is comparatively presented in terms of length of the evacuation period. In all cases, the loading and unloading evacuees into and out of the network would result in significantly more vehicles trapped in the network at the hazard arrival time. It is interesting to note that modest increases in evacuation lead time of just 30 min decreased the numbers of vehicles unable to evacuate (and their potential associated fatalities) by in some cases several hundred and by a factor of 3–5. As Fig. 5 shows, only the highest traffic loading scenario or lack of route choices would result in substantial numbers of vehicles unable to exit the subdivision road network. It was also apparent that the higher development densities also resulted in greater numbers of vehicles unable to exit. This finding was not surprising since, like the case of shorter evacuation times, increased volumes (60–80%) would also inundate the available roadway capacity. As more lead times were made available, however, this became less of an issue. With an additional 90 min, the

Table 2. Summary of Delay and Clearance Experiments

Evacuation response time (h)	Experiment[a]		Total vehicles generated	Time at which last vehicle exited system (a.m.)	Vehicles unable to evacuate	Maximum allowable vehicles
0.5	Shortest path	1	1,154	7:43	324	830
		3	1,908	8:04	988	920
		2	1,153	7:42	204	949
	Alternate path	4	1,907	7:53	642	1,265
		5	2,320	7:59	844	1,476
		6	3,842	8:36	1,646	1,788
1	Shortest path	7	1,067	8:09	25	1,042
		9	1,932	8:11	291	1,641
		8	1,067	8:09	26	1,041
	Alternate path	10	1,931	8:10	47	1,884
		11	2,089	8:11	70	2,019
		12	3,904	8:40	1,143	2,761
2	Shortest path	13	1,044	9:12	30	1,014
		15	1,757	9:12	51	1,706
		14	1,044	9:12	31	1,013
	Alternate path	16	1,756	9:12	50	1,706
		17	2,200	9:11	58	2,142
		18	3,715	9:14	159	3,556

[a] As shown in Table 1.

number of trapped vehicles decreased significantly from 664 to 21. This was also reflected in the rightmost column where the additional 90 min increased the number of vehicles able to get out from 90 to 692.

The "maximum allowable vehicles" column suggests the capacity of the network under each case. The values in this column represent the difference between the second and fourth columns and, from a planning standpoint, also suggest the maximum density of housing units that should be considered in a proposed development. For example, if the characteristics in an area were known to give limited warning times of an hour or less, then fewer vehicles will be able to evacuate than with longer lead times. A graphical comparison of these values is also presented in Fig. 6.

The Alternate Path experiments, used to test the effect of local knowledge during an evacuation, introduced an element of driver intelligence that would likely be apparent during an emergency as drivers would seek to better utilize the network. It should be noted that the testing of the effect of various driver routing assumptions are also currently under investigation in fine detail in several ongoing research studies on the effect of dynamic traffic assignment models on evacuation. The experiments showed that

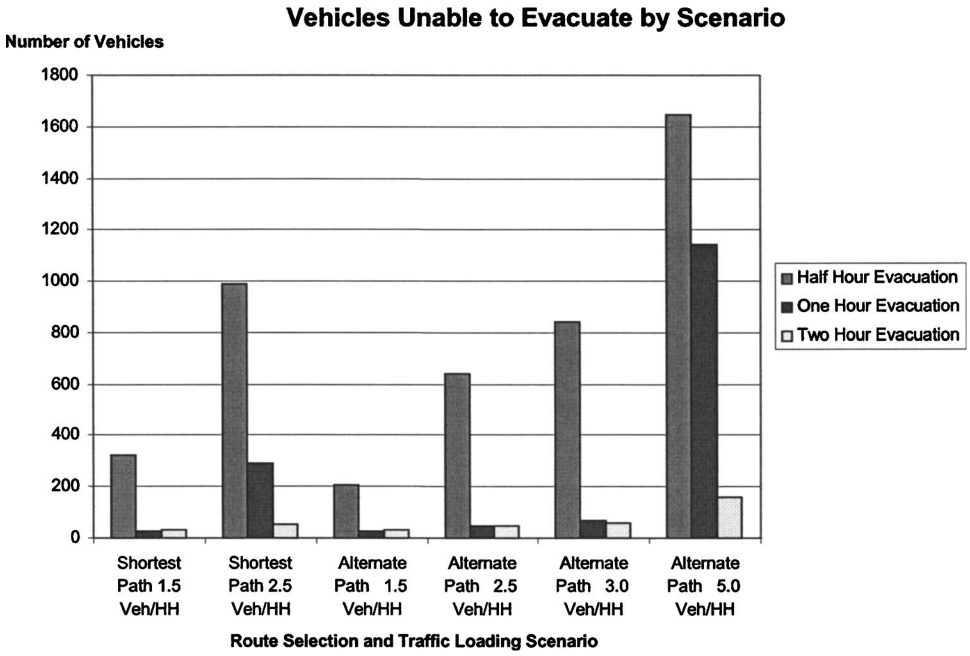

Fig. 5. Total number of vehicles unable to evacuate by scenario

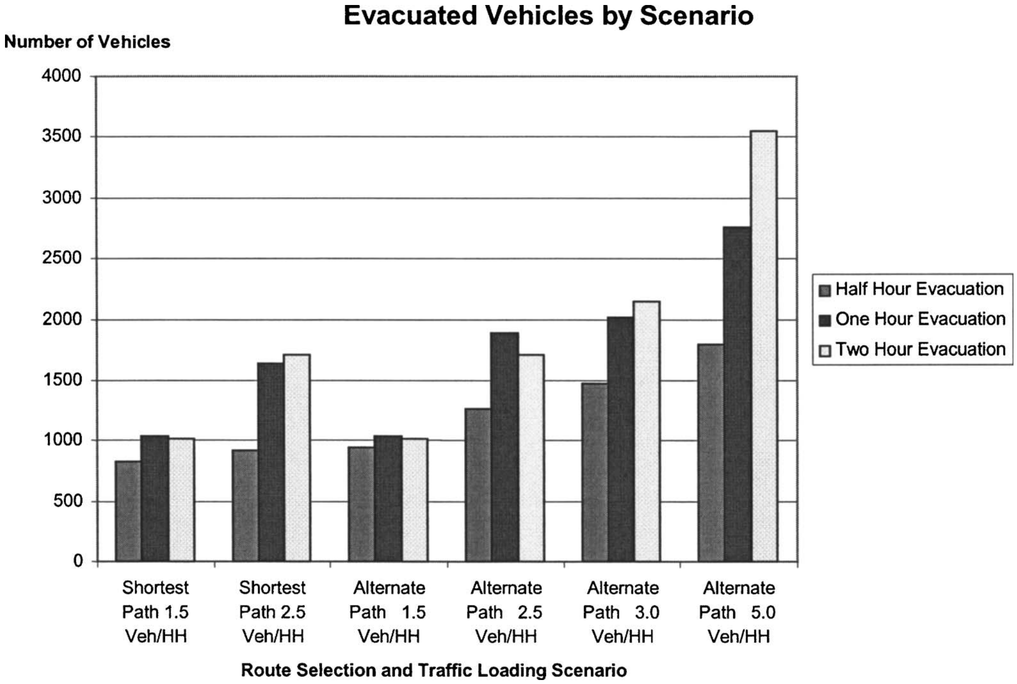

Fig. 6. Total number of evacuated vehicles by scenario

under the lower demand conditions, the Alternate Path routing resulted in levels of congestion and numbers of exiting and "trapped" vehicles that were generally similar to the corresponding Shortest Path scenarios. The primary reason for this was that in loading conditions below 1.5 vehicles per node vehicle flows were stable, with speeds at or near free flow levels, and no congestion was created. An exception to this was apparent between Experiments 1 and 2 of the "urgent" response scenario in which the number of vehicles unable to exit the network under the Alternate Path routing assumption was decreased by 120 vehicles from 324 to 204 and the Maximum allowable vehicles increased by 119 from 830 to 949 vehicles. Overall, however, it is clear that a 2 h evacuation duration permitted substantially more vehicles to be accommodated by the two exits in this test subdivision.

Queue Formation and Discharge

Table 3 summarizes the time taken for queues to reach their maximum length, the length of the maximum queue, and the maximum number of vehicles in queue for each scenario. The maximum queue lengths shown in Table 3 are also graphically compared in Fig. 7. Similar to the results of the prior analyses, the duration of the evacuation was the primary factor in the occurrence and extent of congestion within the network. Substantial queuing was apparent in every loading and routing case during an urgent (30 min) evacuation scenario. However, it was not until demand was increased to 5.0 vpn (Experiment 18) that extensive queuing became apparent for the 2 h evacuation scenarios. No measurable queues occurred when the evacuation event was apparent for these "slow" evacuations during any other loading or routing scenario (Experiments 13 through 17). This clearly suggests the significant benefits of advanced warning and the ability to temporally spread the loading and exiting of evacuees.

By contrast, Table 3 and Fig. 7 also show how the queuing was apparent during the shorter evacuation periods, in particular the "half-hour" urgent scenario. In each of the 30 min cases significant queuing was apparent. Some gains were made when evacuation times were increased to an hour. Under the lower 1.5 vpn scenarios (Experiments 7, 8, 13, and 14) queues were effectively eliminated. When vehicle loading was increased to 2.5 vpn (Experiments 9, 10, and 15), queue lengths were evident once again despite the additional 30 min of mobilization and clearance time.

Although it is clear that these volumes further inhibited the ability of evacuees to exit the subdivision, these additional experiments helped to define the limits of the ability to evacuate in this network. For example, Experiment 11, the 2 h 3.0 vpn scenario

Table 3. Summary of Queue Formation and Dissipation

Evacuation response time	Experiment[a]		Time to max. queue length (min)	Queue length	
				Feet	Vehicles
0.5	Shortest path	1	26	3,629	146
		3	31	6,301	252
		2	26	3,335	134
	Alternate path	4	31	6,054	242
		5	30	8,696	348
		6	31	8,696	348
1	Shortest path	7	38	<100	<4
		9	45	5,587	224
		8	None	<100	<4
	Alternate path	10	38	4,710	188
		11	61	8,204	328
		12	96	5,441	218
2	Shortest path	13	None	<100	<4
		15	34	<100	<4
		14	None	<100	<4
	Alternate path	16	None	<100	<4
		17	None	<100	<4
		18	39	5,441	218

Note: Queue lengths less than 100 ft/4 vehicles were not recorded.

[a] As shown in Table 1.

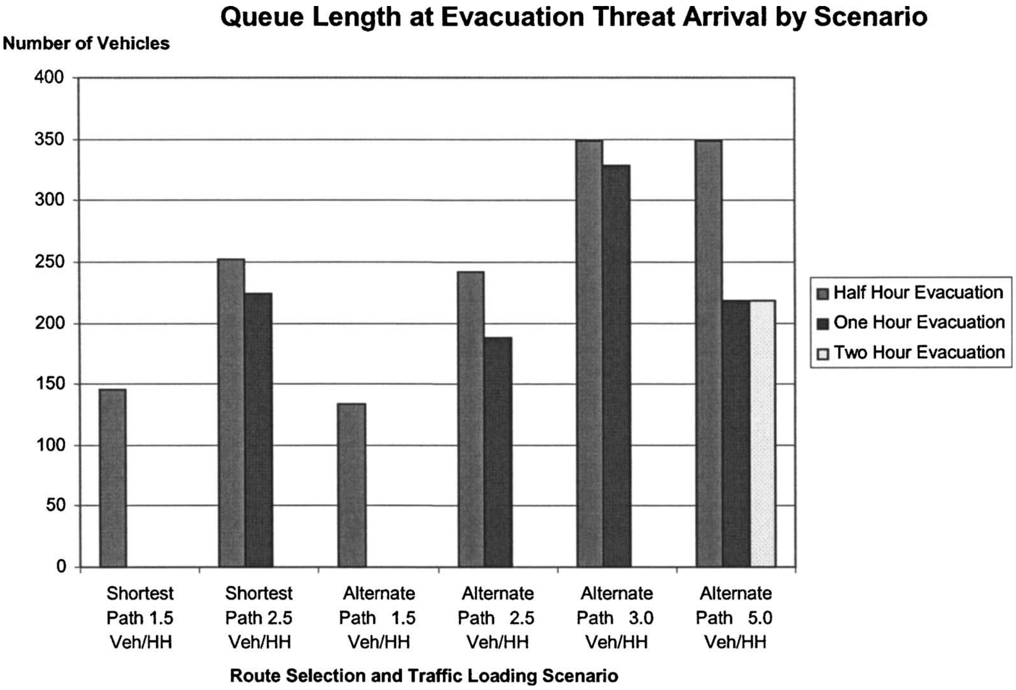

Fig. 7. Vehicles in queue at wildfire arrival by scenario

suggested that the network could support the evacuation of around 3,600 vehicles during a 1 h response scenario.

It was also hypothesized that another contributing factor to these differences was the layout of the subdivision. Once queues extended beyond the primary traffic dividing point, evacuees were prevented from accessing the route to the secondary exit. Since it would be reasonable to expect drivers to take more drastic actions like utilizing unoccupied opposing lanes during dire emergency conditions, these results also suggest that techniques such as reversible flow could also have application under such conditions.

Conclusion

This study was motivated by earlier work that suggested the need for a better understanding of and planning for the evacuation of residential subdivisions under threat from wildfires. These needs have grown more acute in recent times as demographic trends that have resulted in a growth of residential developments in urban-wildland interface areas, with prior tragic consequences. It has been suggested that the density of housing units and the limited attention paid to effective evacuation routing and egress may have contributed to fatalities in subdivisions in which residents were unable to evacuate when the need arose. It has further been hypothesized that an increased understanding of the traffic conditions that occur during evacuations of these types of developments could lead to better guidance for determining housing densities and designing road layouts that reduce risk and limit the chances for future disasters.

The study involved the development of a CORSIM traffic network to simulate critical aspects of residential development at levels of detail which are typically not undertaken at neighborhood-level traffic analyses. More important, it permitted the evaluation of a variety of conditions under ranges of population density and wildfire threat urgency.

The primary contribution of this work was to illustrate the general quantitative relationships that exist between evacuation urgency, housing density, and “local knowledge” during the evacuation of residential subdivisions. The study reveals clear and consistent evidence that there are limits to the ability to evacuate a residential area based on the amount of traffic generated and the amount of lead time and that a balance exists between the number of vehicles that can be accommodated by a roadway network of a given size, complexity, and number of egress points and the time duration during which these vehicles enter and exit the network.

Several important trends were clearly evident from the series of experiments undertaken in this study. First and foremost was the effect of gradual loading and unloading of the network. It was clear that scenarios that would require the subdivision to be evacuated in 30 min would be difficult to achieve. However, when an extra 30 min was provided the number of vehicles unable to exit the system dropped dramatically (as shown in Fig. 5). It was not until vehicle volumes were more than tripled that the evacuations became a significant problem. Another important issue that was identified was impact of the location of the two exits with respect to one another. Although the existence of a second route of egress helped to facilitate the evacuation, the fact that the only ability to access it was well after the confluence of the feeder streets into the primary exit route meant that it would be difficult to access once significant the evacuation was underway. Combined, all of these results suggest that increases or decreases in the amount of traffic volume need to be accompanied by a corresponding increase or decrease in the amount of time to transport these evacuees out of the threat zone and changes in the network (i.e., adding and/or modifying the location of exits) can significantly decrease evacuation clearance times and increase the total amount of exiting traffic.

Although the results presented here are specific to this test network, the general relationships in regard to the needs to temporally and spatially spread the loading of demand within a capacity constrained network are similar to experiences in other types of hazards and even over much larger geographic areas.

During hurricane evacuations, for example, it has been shown that sudden surges in demand result in considerably higher levels of congestion. While hurricanes are typically much slower moving than wildfires, they threaten larger geographic areas. Hurricane evacuees are also notorious for delaying their evacuation until they are reasonably sure they could be impacted. During the evacuation of New Orleans for Hurricane Ivan, major traffic congestion propagated upstream from the contraflow loading point just outside the city. A year later, after the changes were made to load the contraflow segment at several points over several miles, traffic flow was considerably improved in this area during the Hurricane Katrina evacuation. Similar types of behavior can also be observed at major sporting events in which thousands of fans depart a stadium at about the same time using a limited number of exits. This type of pedestrian congestion is lessened during one-sided contests when a larger percentage of fans leave prior to the game's conclusion as discussed by Cassidy (2002).

There are also some simple and effective methods that can be used to deal with the issues presented in this paper. Although seemingly obvious, many of them go unused because they are not necessarily a part of the normal development approval process or can be too costly. The most effective method is to increase the amount of lead time given to evacuees. This could be recognized with better wildfire detection, monitoring, and warning systems as well as through the application of fuel-free firebreak zones both around and within residential subdivisions in fire-prone urban-wildland areas. Another method would be to control the level of evacuation travel demand. This research showed the obvious fact that the fewer evacuating vehicles that need to exit a neighborhood, the faster an evacuation can occur. While it is recognized that the density of a development is one of the prime factors that govern the economic success of a project, perhaps more thought should be given to the risks associated with such planning decisions. Yet another method would be the use of more and strategically placed exits to reduce egress time. Innovative approaches proposed by Cova (2005), including the use of building-specific evacuation philosophies that propose a new view on determining the capacity, location, and number of exits to the domain of neighborhood-level evacuations is a very promising area of study and potentially effective practice and future research will investigate these concepts.

Acknowledgments

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Exhibit 6

SUPPLEMENTAL TRAFFIC SIMULATION
FOR
FIRE EVACUATION ANALYSIS FOR MISSION CANYON COMMUNITY PLAN

February 2011

Prepared for:

THE COUNTY OF SANTA BARBARA

Prepared by:

FEHR & PEERS
201 Santa Monica Boulevard, Suite 500
Santa Monica, California 90401
(310) 458-9916

Ref: SM10-2381

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IMPORTANT NOTICE

The data, analysis, recommendations and results presented herein have been prepared for the sole purpose of this project report. The evacuation scenarios are based on assumptions that may or may not represent real evacuation situations; this is not an operations plan for actual evacuation situations. The County of Santa Barbara and Fehr & Peers do not make any warranty, guarantee, certification or other representation with respect to the information contained herein if applied to any other project or for any other purpose without the prior written consent of the County of Santa Barbara and Fehr & Peers, which expressly denies any and all liability for damages or losses of any kind resulting from use of the information contained herein for any purposes other than this project.

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1. INTRODUCTION

The Mission Canyon Community Plan (MCCP) is in the designated wildland-urban interface area, where residential development is within and adjacent to highly flammable vegetation. The Plan Area has been designated by the California Department of Forestry and Fire Protection (CAL FIRE) as Very High and High Fire Hazard Severity Zones. The project area recently experienced evacuation orders and loss of structures due to the Tea Fire in November 2008 and the Jesusita Fire in May 2009, which severely impacted the Upper Mission Canyon neighborhoods. To increase fire safety in the Plan Area for existing residents and in anticipation of long-range development potential, the MCCP proposes various physical improvements to enhance fire prevention services and emergency circulation.

A micro-scale traffic simulation model was prepared to identify the bottlenecks and choke points during the evacuation process under existing conditions and with future buildout of the MCCP in accordance with CEQA. The traffic simulation model was used to estimate the time it would take to evacuate the Mission Canyon area under existing conditions and under future MCCP Buildout conditions. Areas adjacent to the Plan Area and cumulative traffic conditions were considered in the evacuation scenarios. The evacuation scenarios are based on assumptions that may or may not represent real evacuation situations and that this is not an operations plan for real evacuation situations. Fehr & Peers worked closely with County staff to prepare recommended measures to facilitate evacuation traffic flow for fire safety based on the experience learned from the recent Jesusita Fire and Tea Fire. The mitigation measures were incorporated in the Fire Protection section of the DEIR for the MCCP.

2. DEVELOPMENT OF EVACUATION SCENARIOS

The first step in developing a traffic simulation model for an evacuation analysis is to identify the assumptions for the evacuation scenarios to be tested. Fehr & Peers coordinated with County staff to determine the variables to be used to develop the evacuation scenarios based on evacuation routes and lessons learned from previous experiences during the Tea Fire of November 2008 and the Jesusita Fire of May 2009. The traffic simulation study and the evacuation scenarios assumed in *Modeling Small Area Evacuation* (Vehicle Intelligence and Transportation Analysis Laboratory at University of California Santa Barbara, April 2002), and other relevant studies such as *Santa Barbara I-Zone Major Incident Preplan* (July 2001) and the evacuation plans for the Santa Barbara Botanic Garden were used to collect relevant data and background information as part of this task.

The variables that are most likely to affect the traffic flow during a fire evacuation are summarized below:

ROADWAY CAPACITY AND CONDITIONS IN THE PLAN AREA

Roadway capacities, roadway widths, grade changes, speed limits and advisory speeds were obtained based on consultation with County staff and field observations. Potential evacuation routes consist of several major streets (i.e., Foothill Road, Mission Canyon Road, Tunnel Road, Las Canoas Road, Cheltenham Road) and multiple residential streets in the Plan Area. The key evacuations routes in the area are generally narrow and do not have paved shoulders, curbs, gutters, or sidewalks. The key roadways have fog line striping and portions are designated No Parking zones but the residential streets generally allow on-street parking which can often only allow one car to pass at a time. The average roadway width varies from 20 to 30 feet. The speed limit is generally 30 to 35 mph for secondary two-lane roadways and 20 to 25 mph for the residential collectors, with advised speeds of 15 mph for several locations with limited visibility due to horizontal curves or grade changes.

BACKGROUND TRAFFIC CONDITIONS

Depending on the timing of a fire, some vehicles may still travel on the roadways in the Plan Area prior to and during the evacuation. Based on consultation with the County staff and the lessons learned from the Jesusita Fire, the most challenging scenario for a fire evacuation is if a fire occurred during the afternoon commute period (between 5:00 and 6:00 PM) when the background traffic conditions[1] are at the peak, residents are returning home in the Plan Area, and other residents are exiting the area. If a fire occurs during the midday or late evening, significantly less traffic would be traveling on Foothill Road and other key roadways in the Plan Area and the time needed to evacuate the residents would be less. For this analysis, the traffic simulation assumed that the Fire Department received a report of a wildland fire in the late afternoon and notified the residents at 5:00 PM by an Emergency Telephone Notification System (ETNS) (also know as Reverse 911®), use of local media, and personnel knocking on doors. The background traffic volumes used in the traffic simulation were based on afternoon peak period traffic counts collected from 5:00 to 7:00 PM.

TRAFFIC CONTROL

The traffic control scenarios may vary depending on the timing and location of a fire, the weather conditions, and the traffic control equipment and particularly staff resources that could be rapidly deployed by the County, Caltrans and the City of Santa Barbara. Based on the fire evacuation experience from the Jesusita Fire and the Tea Fire, the State Highway Patrol and law enforcement deployed traffic control along Foothill Road and Mission Canyon Road within 30 to 45 minutes after being notified of the fire. Traffic control barriers were placed on Mission Canyon Road near Las Encinas (at Rocky Nook) and on Los Olivos near the City/County boundary to prohibit traffic entering the study area

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[1] The Santa Barbara Botanic Garden is open to the public from 9:00AM to 6:00 PM between March and October and from 9:00 AM to 5:00 PM between November and February. The background traffic conditions for the afternoon commute period (between 5:00 PM and 7:00 pm) may include some visitors and employees leaving the Botanic Garden on a typical weekday.

and redirect traffic to use alternative routes. For this analysis, the above-mentioned traffic control barriers were defined as the "Minimum Traffic Control" scenario.

NUMBER OF VEHICLES ENTERING AND LEAVING THE PLAN AREA

For the Mission Canyon Community Plan Area, each household has an average of 2.4 persons, which indicates the number of vehicles entering and exiting per household may vary from one to three during an evacuation. Depending on the intensity of the fire and the location of the traffic control points, the number of vehicles that could be allowed to enter the study area could change significantly. For this analysis, it was assumed that half of the households would each have one car returning home to pick up their children, elderly, animals, possessions, etc and no other vehicles would be able to return to the Plan Area due to traffic control within 30 to 45 minutes of the fire notification. In some circumstances, not every resident could return home due to traffic control, fire hazard, etc. Depending on the analysis scenario, between 1.5 and two vehicles per household were assumed to be exiting the Plan Area.

NUMBER OF PATRON AND EMPLOYEE VEHICLES FROM SANTA BARBARA BOTANIC GARDENS, THE SANTA BARBARA MUSEUM OF NATURAL HISTORY AND THE SANTA BARBARA WOMEN'S CLUB

Traffic generation and parking operations during normal weekday operations and special events were obtained from the Santa Barbara Museum of Natural History and the Women's Club staff. Trip generation data related to the Botanic Garden was obtained from *Santa Barbara Botanic Garden Vital Mission Plan Final EIR* (July 2009). Approximately 90 to 100 vehicles travel to the plan area to visit these three venues under normal weekday conditions, while up to 450 vehicles may visit these venues during special events, fully occupying the available on-site parking.

Based on consultation with the County Fire and Sheriff staff for the above variables, two potential evacuation scenarios were developed under existing conditions and under future 2030 MCCP Buildout conditions.

NUMBER OF VEHICLES FROM ADJACENT NEIGHBORHOODS THAT MAY USE THE ROADS IN THE PLAN AREA DURING THE FIRE EVACUATION

The previous fire experiences indicate that the evacuation area may cover a larger area than just the Mission Canyon Community. The evacuation traffic from adjacent areas could use the same routes as residents of the Mission Canyon Community. For example, Foothill Road and Mission Canyon Road may carry traffic from Las Canoas Road (like the Jesusita Fire) and Foothill Road, Mission Canyon Road, Mountain Drive and Alameda Padre Serra to Mission Canyon Road/North Los Olivos Road may serve traffic from adjacent City of Santa Barbara and Montecito neighborhoods (like the Tea Fire). This additional traffic from the neighborhoods to the east may potentially use the roadways in the Plan Area to evacuate. The timing and location of a fire and the amount of background traffic could adversely affect the evacuation time for the Mission Canyon Community residents.

FIRE EVACUATION SCENARIO 1: MODERATE INTENSITY

This scenario assumed that a fire requiring evacuation of the residents started in the Upper Mission Canyon area during the afternoon commute peak hour (at 5:00 PM). It was assumed that half of the households would each have one car returning home to pick up their children, elderly, pets, possessions, etc, and no other vehicles would be able to return to the Plan Area due to traffic control within 30 to 45 minutes of the fire notification. In addition, half of the households would have one vehicle exiting the area and the other half would have two vehicles exiting the area. This results in an average trip generation of 0.5 vehicles per household inbound and 1.5 vehicles per household outbound.

FIRE EVACUATION SCENARIO 2: HIGH INTENSITY

This scenario assumed a major fire (similar to Jesusita Fire scenario) occurred in the Upper Mission Canyon area and expanded to the Upper Las Canoas area requiring evacuation of both the Mission Canyon Community and the Santa Barbara City Foothills are in the afternoon commute peak hour (at 5:00 PM). This scenario also assumed full occupancy and evacuation of the visitors and employees of the Natural History Museum, Women's Club and Botanic Garden[2]. It was assumed that half of the households would have one car returning home, and all households would have two vehicles exiting the area (i.e., average trip generation rate of 0.5 vehicles per household inbound and 2.0 vehicles per household outbound).

Both analysis scenarios assumed deployment of "Minimum Traffic Control" as a baseline condition. The results were used to identify the potential traffic control strategies and roadway improvements (i.e., the Optimized Traffic Control) that could be provided under improved conditions.

Table 1 provides a summary of the assumptions and traffic forecasts for fire evacuation Scenarios 1 and 2.

TABLE 1. TRAFFIC FORECASTS FOR FIRE EVACUATION ANALYSIS SCENARIOS

Land Use Scenario	Existing (2009)		2030 MCCP Buildout	
Residential Units in the plan area	1,012 units		1172 units	
Fire Evacuation Assumptions	**Scenario 1 Moderate Intensity**	**Scenario 2 High Intensity**	**Scenario 1 Moderate Intensity**	**Scenario 2 High Intensity**
Total Inbound Residential Trips	506	506	586	586
Total Outbound Residential Trips	1,518	2,024	1,758	2,344
Number of trips to local events in Natural History Museum, Women's Club and Botanic Garden	90	450	90	450
Number of background commute trips on key roadways during the afternoon peak period from 5:00 to 7:00 PM (e.g., along Foothill Road, Mission Canyon Road (south) and Alamar Avenue)	2,450	2,450	3,100	3,100
Additional evacuated traffic from Upper Las Canoas neighborhoods and City of Santa Barbara Foothill area	NA	750	NA	750

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[2] Based on consultation with Botanic Garden staff, the Garden currently has a total of 116 parking spaces on-site. For the High Intensity scenario analysis, it was assumed that there were full house events in the Garden such that all 116 spaces were fully occupied and all 116 vehicles were to be evacuated from the Garden facilities within 30 to 45 minutes of the fire notification. Similarly, the Women's Club currently has 120 parking spaces on-site. The High Intensity analysis assumed that all 120 spaces were fully occupied and all 120 spaces were to be evacuated from the Club within 30 to 45 minutes of the fire notification. The Museum currently has 165 parking spaces. Based on consultation with County staff, when there were full house events in the Museum, overflow parking demand was often observed such that approximately 40 to 50 vehicles parked on the nearby residential streets. Therefore, for the High Intensity scenario analysis, it was assumed that approximately 215 vehicle were to be evacuated from the Museum.

3. TRAFFIC SIMULATION APPROACH

VISSIM, a micro-simulation model, was used to perform this task. VISSIM is a state-of-art microscopic, time step and behavior based simulation model, and has been widely used in numerous traffic operations projects, including evacuation studies. The VISSIM traffic simulation development consisted of the following seven steps.

STEP 1 – FIELD DATA COLLECTION

To understand the existing roadway segment operating conditions on Foothill Road (State Route 192) and the potential traffic diversion from Mission Canyon to other alternative routes as a result of fire traffic congestion, field observations and real-time travel time runs were conducted for the key roadways in the study area to measure the average travel time and travel speed under normal traffic conditions. Existing timing plans for the signalized study intersection at Alamar Avenue and Foothill Road were obtained from County and Caltrans staff and supplemented by the field observation data. This data was used to develop and calibrate the VISSIM traffic model to existing baseline traffic conditions.

STEP 2 – ROADWAY NETWORK SIMULATION DEVELOPMENT

The VISSIM traffic simulation model was coded to contain the major arterials and residential streets in the community Plan Area and other identified evacuation routes that would lead Mission Canyon residents to the safe zones during the evacuation. The VISSIM model roadway network includes the study intersections and study roadway segments selected for the MCCP impact analysis plus the key secondary roadways immediately adjacent to the study area that could be used as alternative evacuation routes. Roadway geometric data including lane configurations and traffic controls were gathered using aerial photographs, design plans, and/or field observations. The analysis used the posted speed limits for these roadways, with advisory speed of 15 mph or lower for several locations or intersections with visibility issues due to the horizontal curve or significant grade changes.

STEP 3 – ORIGIN AND DESTINATION ZONES

The residential areas and the neighborhoods immediately adjacent to the Plan Area (e.g. City of Santa Barbara Foothill area) were split into different origin zones based on location, driveway locations, nearby intersections and street system, as shown in Figure 1. For traffic simulation purposes, the Mission Canyon Community and the neighborhoods immediately adjacent to the Plan Area were grouped into approximately 100 zones. To measure the evacuation travel time between each residential zone, the final destination zone (or safe zone) was measured at the major intersections just south of the County and City boundary (e.g., Alamar Avenue at State Street and Los Olivos Street at Garden Street).

STEP 4 – ORIGIN-DESTINATION TRAFFIC FLOW

Travel routes were identified from each residential origin zone to the destination/safe zones. The traffic simulation applied a dynamic assignment process to maximize the systemwide performance. Dynamic assignment allowed vehicles to use either the shortest paths or detoured paths (when feasible) to avoid congestion.

STEP 5 – VARIABLES FOR EACH EVACUATION SCENARIO

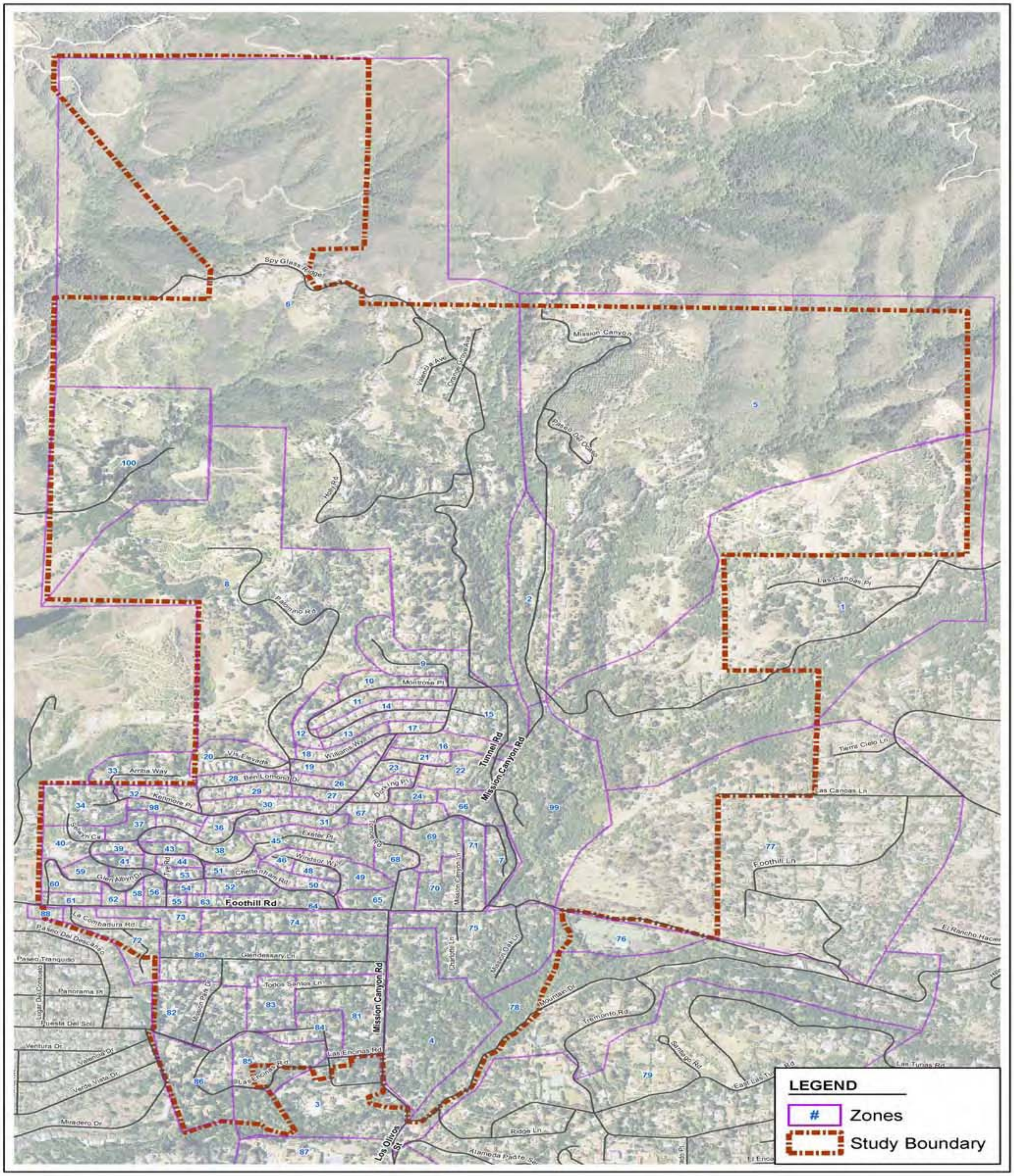
The roadway capacity, traffic control, traffic forecasts and traffic flows from adjacent areas as described above were included under fire evacuation Scenario 1 and Scenario 2 for existing and 2030 MCCP Buildout conditions.

STEP 6 – SYSTEMWIDE PERFORMANCE

After the simulation models were developed for the fire evacuation scenarios, a set of measures of effectiveness (MOEs) were used to analyze travel conditions under different fire evacuation patterns as summarized below.

- Estimated evacuation travel time for each neighborhood analysis zone in the Plan Area
- Number of vehicles evacuating from the Plan area and arriving at safe zones within 2 hours of fire notification
- Number of vehicles remaining in the plan area after 2 hours of fire notification
- Total delay hours for the entire Plan Area
- Vehicle miles traveled (VMT)
- Vehicle hours traveled (VHT)
- Average speed in miles per hour (mph)
- Vehicle hours of delay (VHD)

The simulation models were designed to simulate for a two-hour period starting from 5:00 PM and ending at 7:00 PM. The 2-hour analysis was intended to capture the peak background commute traffic and generally covered the staggered arrival and departures of multiple neighborhoods zones within and adjacent to the Plan area. Specifically, the 2-hour period covered the residents' response time of approximately 30 to 45 minutes for those who may already be at home to evacuate their houses, the estimated travel time from residences to the safe zone (destination) outside of the Plan area (which could vary from 5 minutes for Lower Foothill Road area to 30 minutes or more for Upper Mission Canyon area), and the travel time for those who try to return home to pick up their family and possessions, and then leave the Plan area.



FEHR & PEERS
TRANSPORTATION CONSULTANTS
March 1, 2010 SP
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FIRE EVACUATION TRAFFIC ANALYSIS ZONES
FIGURE 1

4. SIMULATION SCENARIOS

The following four fire evacuation scenarios[3] were developed and analyzed during the afternoon peak hour (5:00 – 6:00 PM) using VISSIM traffic simulation:

- Existing Scenario 1 Moderate Intensity: average residential trip generation rate of 0.5 vehicles per household inbound and 1 vehicle per household outbound with existing development
- 2030 MCCP Buildout Scenario 1 Moderate Intensity: the above assumptions plus an additional 160 single-family homes in the Plan Area and cumulative traffic growth
- Existing Scenario 2 High Intensity: average residential trip generation rate of 0.5 vehicles inbound and 2 vehicles outbound, plus additional traffic from the Upper Las Canoas Canyon neighborhoods and full occupancy events at the local venues
- 2030 MCCP Buildout Scenario 2 High Intensity: the above assumptions plus an additional 160 single-family homes and cumulative traffic growth

The analysis assumed that the “Minimum Traffic Control” program would be in place on Mission Canyon Road near Las Encinas (at Rocky Nook) and on Los Olivos in the vicinity of the Plan area to prohibit traffic entering the study area and redirect traffic to use alternative routes within 30 to 45 minutes of receiving fire notice to meter vehicles entering the plan area[4].

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[3] The above evacuation scenarios are based on assumptions that may or may not represent real evacuation situations and that this is not an operations plan for real evacuation situations.

[4] During the Jesusita Fire, a Unified Command of Los Padres National Forest, Santa Barbara County Fire Department and Santa Barbara City Fire Department were established by 2:30 pm, 45 minutes after the wildland fire was reported (CAL FIRE Green Sheet, May 2009).

5. SUMMARY OF FINDINGS

The system-wide travel statistics for the four simulation scenarios are summarized in Table 2 and are discussed below.

EXISTING CONDITIONS: MODERATE VS. HIGH INTENSITY EVACUATION SCENARIOS

As shown in Table 2, if a fire occurred in the Upper Mission Canyon area during the afternoon rush hour at 5:00 PM, the majority of the Mission Canyon residents could leave their houses within 45 minutes and be directed to safe destinations in the proximity to the Plan Area within the analysis period of 2-hours (by 7:00PM). This includes those may be home when the fire occur and could evacuate in the first 30 or 45 minutes and those who may not be home, but receive the fire notification, return home and finally evacuate from their homes. Approximately 2% of the vehicles (105 vehicles comprising of both Mission Canyon residents and background commute traffic) may still be traveling in the Plan Area after the 2-hour evacuation analysis period. Figure 2 illustrates the average travel time from each assigned neighborhood zone to the safe zone in the proximity of the Plan area.

As shown in Figure 2, due to the proximity of the potential fire, the Upper Mission Canyon area would be more likely to receive and respond to the Reverse 911® calls, and media and field unit warnings immediately, and leave their houses within 30 to 35 minutes. Their average travel time to reach the safe zones in the proximity of the Plan Area would range between 20 and 45 minutes. These vehicles would gradually fill the capacity of Mission Canyon Road, Tunnel Road and Foothill Road. The travel time for Mission Canyon Heights residents would range significantly depending on the location of their home. Once residents leave their houses within 30 to 45 minutes of receiving emergency notifications, those living in the lower part of Mission Canyon Heights with access to Foothill Road could exit the Plan Area and reach the City/County boundary within 10 to 20 minutes. For those residing on northern side of Mission Canyon Heights (e.g., Montrose Place, Williams Way, Ben Lomond Drive, Vista Elevada), travel times could range between 45 and 60 minutes due to downstream congestion and spillback queues from Foothill Road. Delay would also result from turning movement conflicts at the stop-controlled intersections along southbound Cheltenham Road.

Under Scenario 2 of High Intensity, if a fire required evacuation of the Upper Las Canoas neighborhoods and the local event venues (Botanic Garden, Women's Club and Natural History Museum), the majority of the Mission Canyon residents could be evacuated within the 2-hour analysis period. However, almost 730 vehicles (which could be a mix of Mission Canyon residents, background commute traffic, and traffic evacuated from the event venues) could still be traveling on the roads after the two-hour evacuation period.

Compared to Scenario 1 of Moderate Intensity, this High Intensity evacuation scenario could increase the total travel time (or VHT) by approximately 120 percent and the average speed could reduce from 9 mph to 4 mph. The average travel time shown on Figure 3 indicates that it would take an additional 10 to 15 minutes to evacuate the middle and northern areas of the Mission Canyon Heights neighborhoods than the southern area.

2030 MCCP BUILDOUT CONDITIONS: MODERATE VS. HIGH INTENSITY EVACUATION SCENARIOS

With the buildout of the plan area and the anticipated regional traffic growth over the next 20 years[5], an additional 1,000 vehicles would need to be evacuated in the Plan Area under Scenario 1 of Moderate Intensity. As shown in Table 2, the majority of Mission Canyon residents could leave their houses within 45 minutes and arrive at safe destinations (City/County boundary) within two hours, or before 7:00 PM.

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[5] Proposed 2030 Buildout includes the estimated traffic for the Botanic Garden based on Botanical Garden Santa Barbara Botanic Garden Vital Mission Plan FEIR (July 2009).

The overall traffic congestion, average travel speed and vehicle hours of delay would be worse than existing conditions under Scenario 1, and better than existing conditions Scenario 2 of High Intensity.

Similar to the resident response times and travel route patterns described under the existing fire scenario conditions, the Upper Mission Canyon would more likely to evacuate from the Plan Area and arrive at the City/County within 45 minutes. However, because Mission Canyon Road and Foothill Road would exceed capacity, the travel time from Upper Las Canoas Road would be impacted and travel times would increase to 45 to 60 minutes (rather than under 45 minutes). Those residing in the Mission Canyon Heights and Lower Foothill areas could experience additional delays of 15 to 30 minutes due to spillback queues from Foothill Road and turning movement conflicts at the stop-controlled intersections along southbound Cheltenham Road. The residents living on the northern and western side of Mission Canyon Heights may be delayed on the roads for 1 to 1.5 hours to exit the Plan Area. Those residing closer to Foothill Road or south of Foothill Road could exit the Plan Area within 45 minutes.

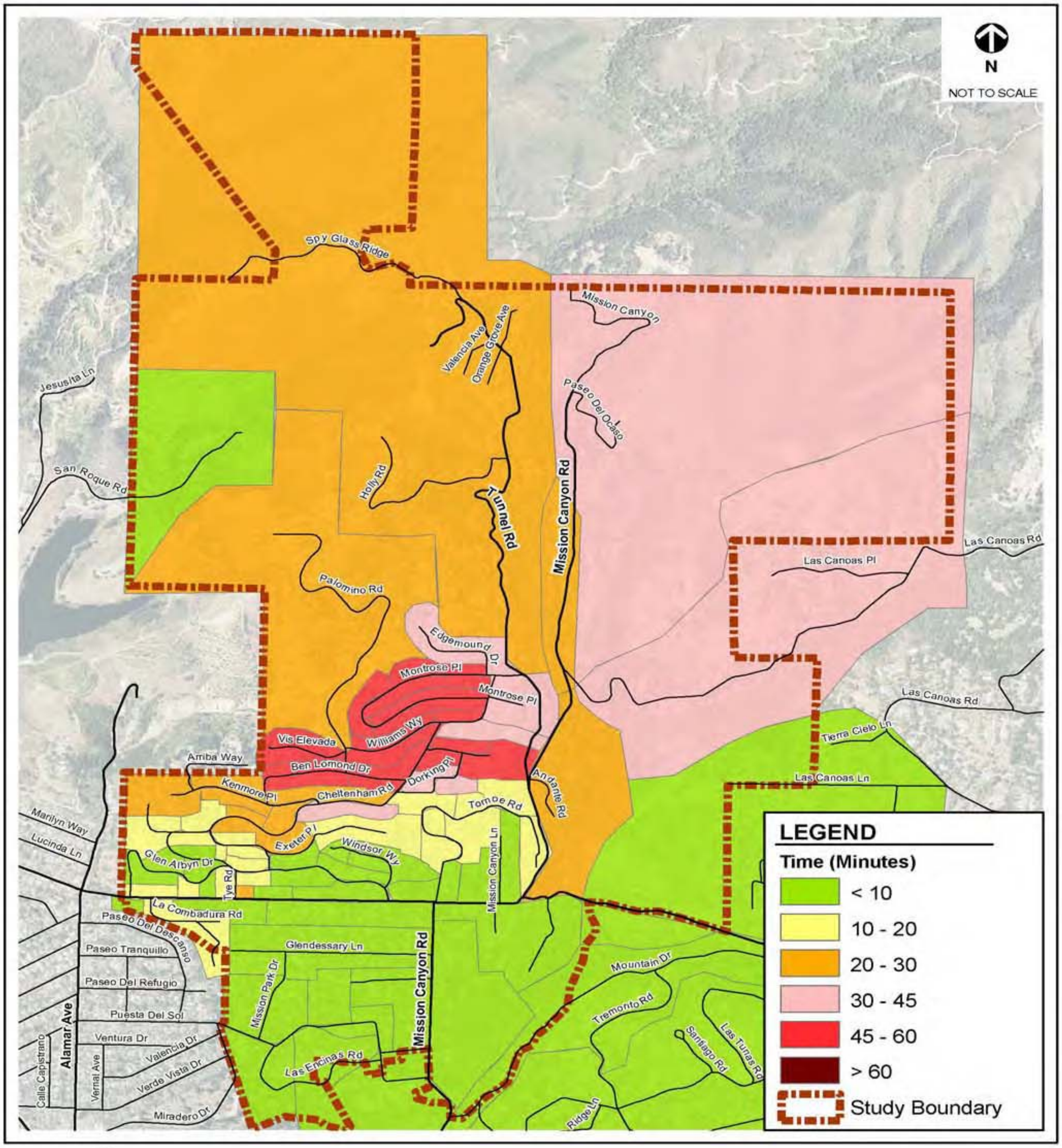
If a high-intensity (Scenario 2) fire occurred under 2030 MCCP Buildout conditions, approximately 80 percent of the vehicles in the Plan Area (a combination of Mission Canyon residents and background traffic) could be evacuated and rerouted within two hours. However, as shown in Table 2, about 785 vehicles would remain traveling on the roads to exit the Plan Area after the two hour evacuation period.

Compared to the 2030 Scenario 1 of Moderate Intensity results, the total travel time and total vehicle delay would increase by more than 100 percent. The average speed would be reduced from 8 mph to 4 mph. The travel time map shown in Figure 5 indicates that the evacuation travel time for the Upper Las Canoas neighborhoods would increase from 30 to 45 minutes to over one hour due to Las Canoas neighborhoods being directed to Mountain Drive as an alternative route for evacuation once Mission Canyon Road (north) and Foothill Road become overly congested due to evacuation traffic from the plan area. Also, the middle and the northern part of the Mission Canyon Heights would experience longer travel times due to the congestion at downstream intersections (e.g., Dorking Place, Williams Way, Cheltenham Road, Kenmore Place, etc).

Based on the review of the MOEs for Scenarios 1 and 2 under existing and 2030 MCCP Buildout conditions and visual inspection of the bottlenecks in each simulation model, an initial set of traffic control strategies and potential infrastructure improvements were developed to improve traffic flow conditions under existing and future conditions. The initial traffic recommendations were also evaluated in the traffic models and were refined after multiple iterations.

TABLE 2. SYSTEMWIDE TRAVEL STATISTICS RESULTS FOR EVACUATION SCENARIOS

Land Use Scenarios	**Existing (2009)**		**Future (2030) Buildout**	
Fire Evacuation Scenarios	**Scenario 1: Moderate Intensity**	**Scenario 2: High Intensity**	**Scenario 1: Moderate Intensity**	**Scenario 2: High Intensity**
Traffic Control Scenarios	**Minimum**	**Minimum**	**Minimum**	**Minimum**
Number of Vehicles Arrive Destinations within 2 hours (from 5 P.M. to 7 P.M.)	4,530	5,245	5,450	6,265
Number of Vehicles Remain Traveling in the Plan Area after 2 hours	105	730	130	785
Vehicle Miles Traveled (VMT)	8,745	9,192	10,575	11,570
Vehicle Hours Traveled (VHT)	1,030	2,281	1,230	2,900
Vehicles Hours of Delay (VHD)	690	1,925	860	2,440
Average Speed [mph]	8.7	4.2	8.4	4.0



FEHR & PEERS
TRANSPORTATION CONSULTANTS
March 5, 2010 SP
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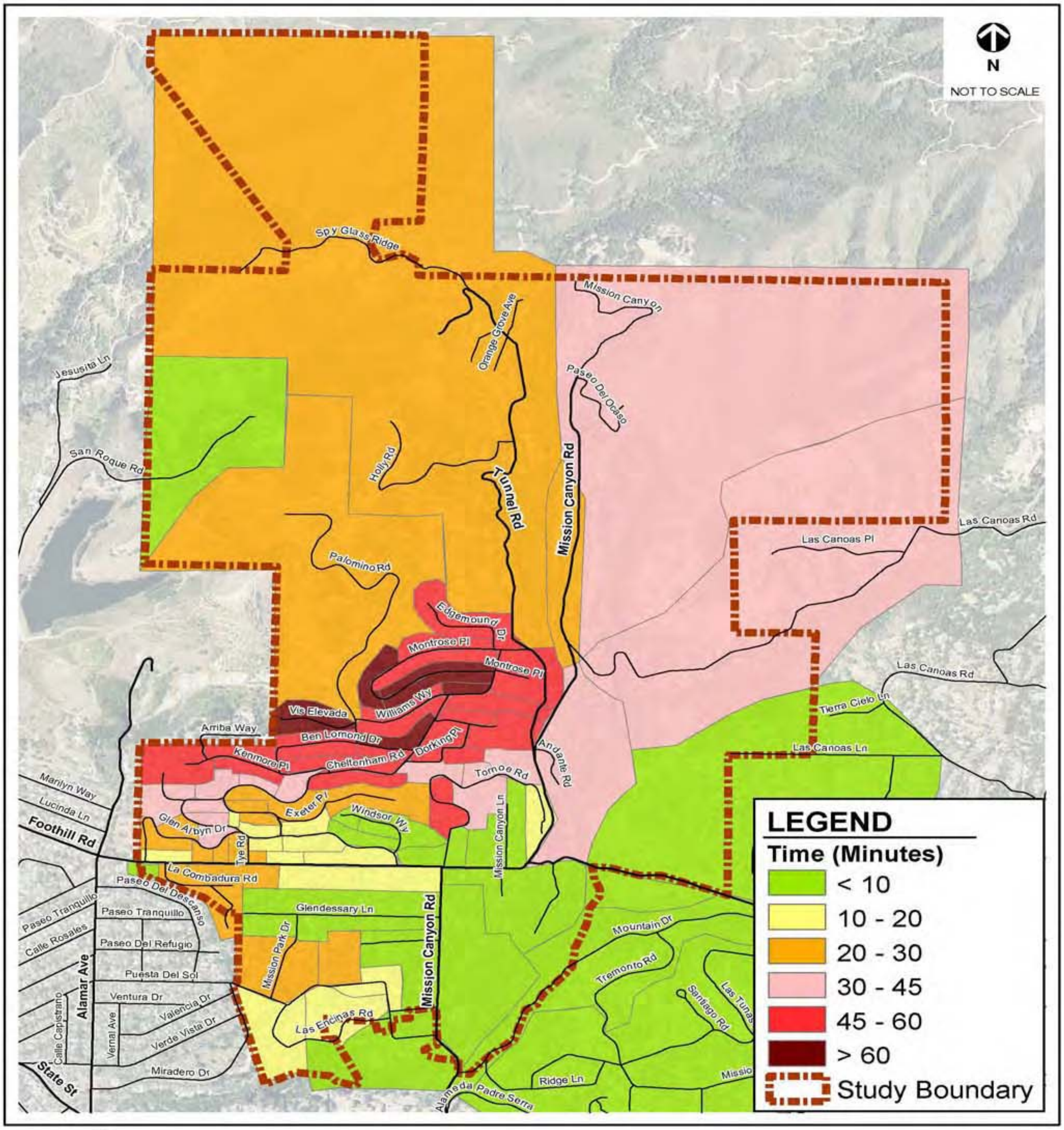
EVACUATION TRAVEL TIME FOR EXISTING SCENARIO 1: MODERATE INTENSITY

FIGURE 2



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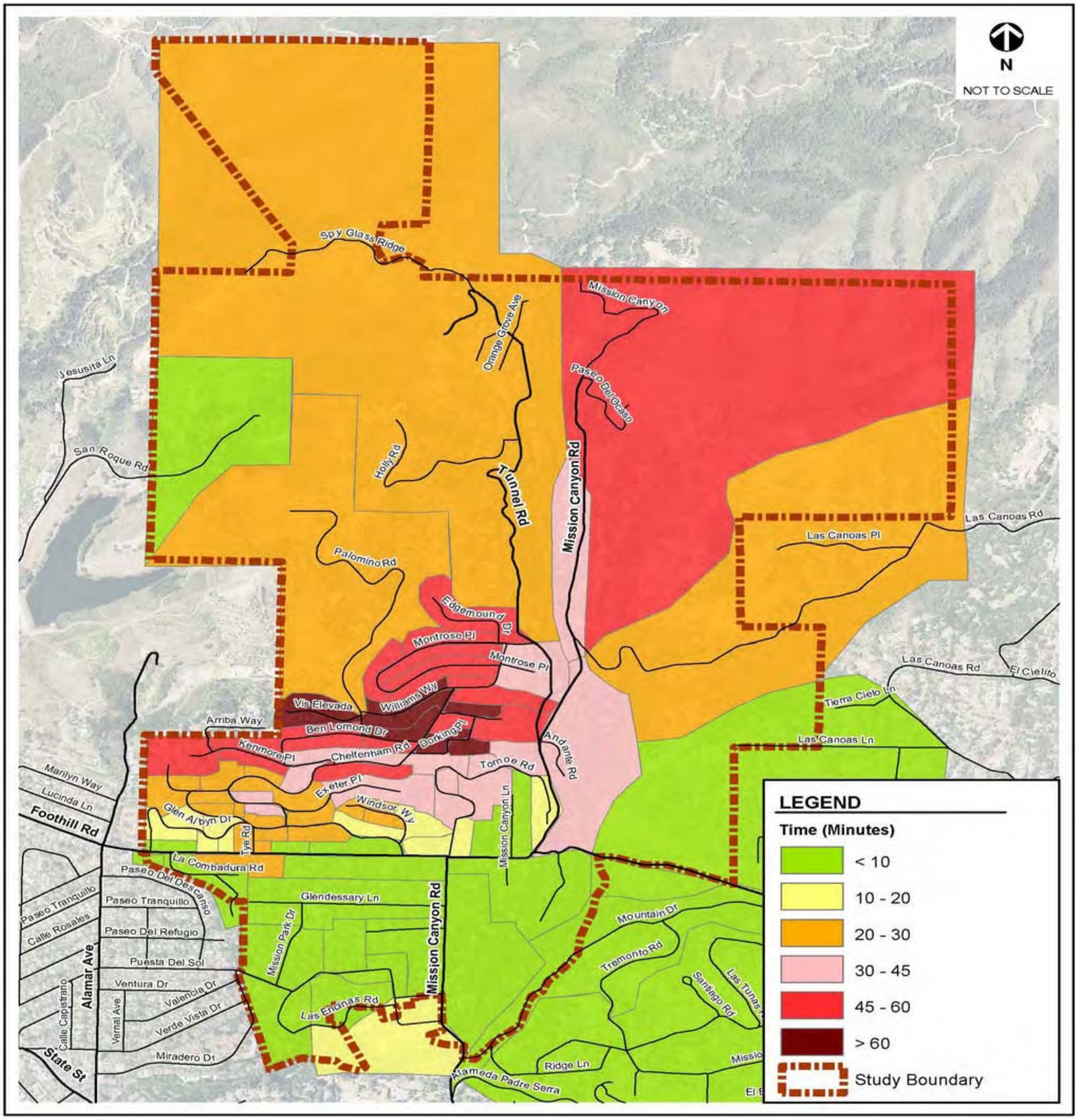
EVACUATION TRAVEL TIME FOR EXISTING SCENARIO 2: HIGH INTENSITY
FIGURE 3



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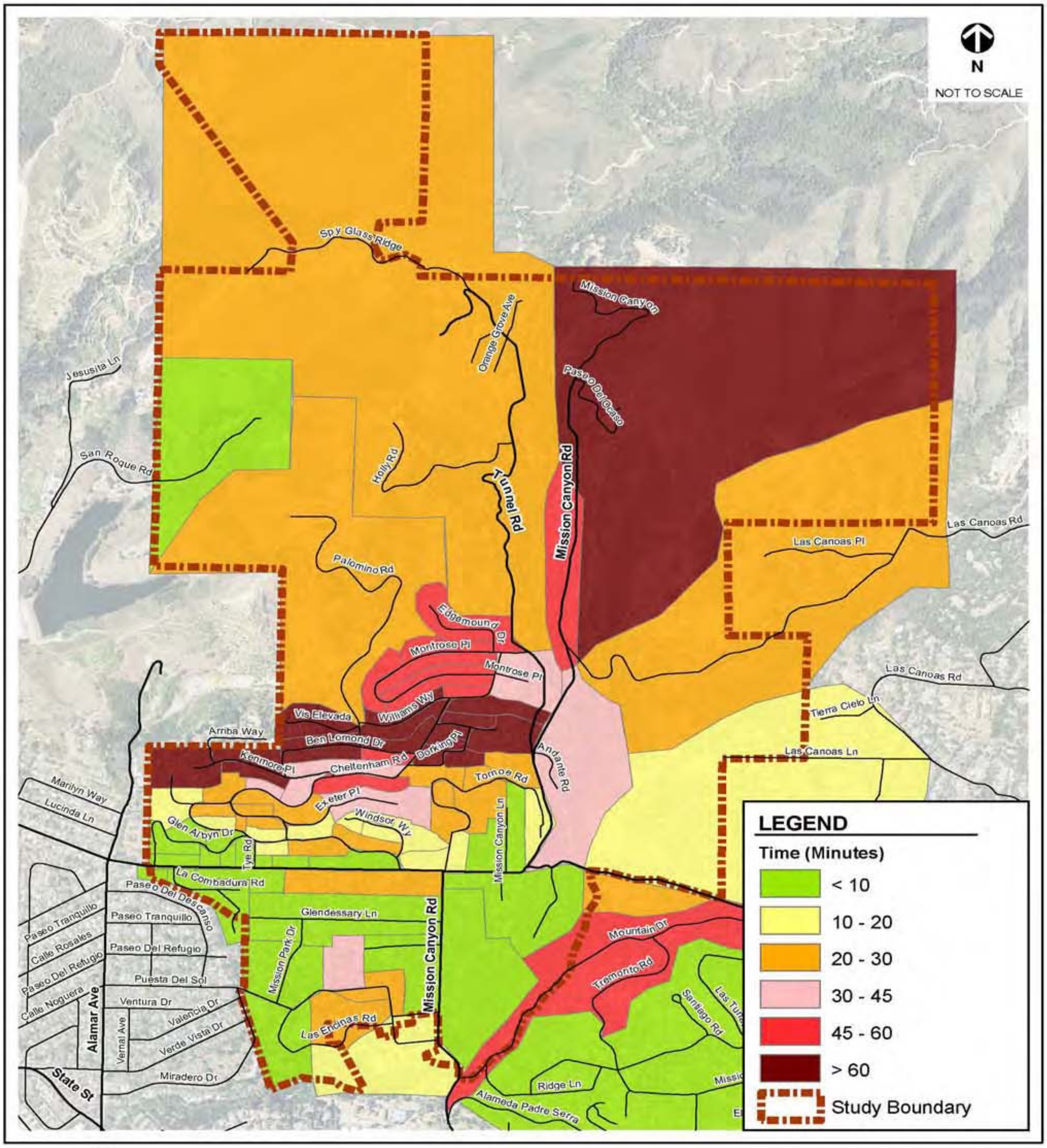
EVACUATION TRAVEL TIME
FOR 2030 MCCP BUILDOUT
SCENARIO 1: MODERATE INTENSITY
FIGURE 4



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EVACUATION TRAVEL TIME FOR 2030 MCCP BUILDOUT SCENARIO 2: HIGH INTENSITY

FIGURE 5

6. RECOMMENDATIONS

Based on a review of the systemwide performance for fire evacuation Scenarios 1 and 2 under existing and 2030 MCCP Buildout conditions[6] and visual inspection of the bottlenecks in each scenario, an initial set of traffic control strategies and potential infrastructure improvements were developed to improve the traffic flow conditions. The initial recommendations were analyzed using the VISSIM models and were refined through multiple iterations.

Current traffic control strategies were evaluated and additional traffic control strategies to improve traffic flow during a fire evacuation were developed consistent with proposed Mission Canyon Community Plan and existing Comprehensive Plan policies. The traffic control strategies may not fully mitigate the potentially significant ingress/egress and emergency access impacts relating to Fire Protection, Risk of Upset and Transportation/Circulation as stated in the Initial Study for the MCCP[7] based on a threshold of introducing buildout development in a high fire hazard area, but would reduce or compensate for potentially significant traffic impacts of the theoretical buildout of MCCP.

Potential measures to improve fire evacuation under existing and future conditions may include, but are not limited to, the following items. Figure 9 illustrates the locations of the recommendations.

CHANGE TRAFFIC CONTROLS DURING AN EVACUATION

Depending on the intensity and location of a fire, the number of vehicles that could be allowed to enter the study area could change significantly. Based on a review of the VISSIM simulation models, general traffic control strategies were developed and were included in the proposed "Optimized Traffic Control Plan." This Plan is intended to provide a "menu" for the Unified Command Team to choose from and combine when responding to fire evacuation scenarios, depending on the timing and location of a fire, the weather conditions, and the traffic control equipment and staff resources that could be provided jointly by the County, Caltrans and the City of Santa Barbara. Implementation of the traffic control plan would require coordination of the State, County and City law enforcement team, Caltrans, and both County and City Public Works and Traffic Divisions.

The Optimized Traffic Control Plan, given adequate incident staffing, may include the following items:

1. Set up cordoned traffic check points to meter the traffic entering the plan area at: Mission Canyon Road south of Mountain Drive (at Rocky Nook) and at Alameda Padre Serra (APS), Alamar Avenue at Puesta del Sol to meter northbound traffic, and Foothill Road at San Roque Road to meter eastbound traffic.

2. Redirect traffic along Foothill Road in the plan area to Alamar Avenue, Mission Canyon Road (south), and Mountain Drive (west).

3. Position law enforcement at Foothill Road at Alamar Avenue to facilitate the outbound traffic flow from Foothill Road to access Alamar southbound or to continue westbound on Foothill. Alternatively, an emergency signal timing plan for this location could be developed jointly by County, City and Caltrans staff and be activated during fire evacuation to allow a split phase for the westbound movement to provide additional green time to decrease congestion for westbound left-turning and through vehicles (by reducing green time for Alamar Avenue southbound approach and Foothill Road eastbound through movement).

4. Deploy law enforcement to facilitate the traffic flow at the following choke points resulting from current intersection stop controls:

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[6] The evacuation scenarios are based on assumptions that may or may not represent real evacuation situations and that this is not an operations plan for real evacuation situations.
[7] Mission Canyon Community Plan Initial Study June 2009.

- Foothill Road at Mission Canyon Road (north).
- Foothill Road at Mission Canyon Road (south)/Tornoe Road
- Mission Canyon Road (north) at Tunnel Road
- Mission Canyon Road (north) at Las Canoas Road
- Mission Canyon Road (south) at Mountain Drive
- Los Olivos Road at Alameda Padre Serra (APS)
- Tunnel Road at Montrose Place

The evacuation plan should be flexible to manage the inbound and outbound flow to allow as many as possible of the residents to return to their homes to pick up their children, elderly, pets, possessions, etc., without impacting exiting vehicles. With limited roadway capacity, the traffic control deployment would focus on maximizing system-wide performance and facilitating both the inbound and outbound traffic demand flow at the key bottlenecks. However, vehicles exiting the area should be granted priority to relieve congestion in the Upper Mission Canyon area and the adjacent Upper Las Canoas neighborhoods due to their proximity to a potential fire. For example, traffic control at the intersection of Mission Canyon Road (north) at Tunnel Road would focus on maximizing the southbound flow (outbound traffic), but would also allow some northbound movement so that residents can return home. Real-time communication between these traffic control stations would facilitate the continuous outbound flow along Mission Canyon Road and other evacuation paths in the northern and middle Mission Canyon Heights neighborhoods, but also allow limited inbound movement to help residents evacuate from their homes.

To measure the effectiveness of the traffic controls mentioned above along Mission Canyon Road (north and south) and Foothill Road, a VISSIM traffic simulation model was developed for Scenario 2 of the High Intensity conditions under the existing and future 2030 MCCP Buildout conditions. The systemwide MOEs are summarized in Table 3 and the estimated travel time data is presented in Figures 6 (for existing) and 7 (for 2030 MCCP Buildout conditions).

The implementation of additional traffic control would improve the overall travel time and vehicle hours of delay by 30 percent under existing conditions and by almost 20 percent under future 2030 MCCP Buildout conditions. As shown in Figure 6, the average travel time from the Upper Mission Canyon neighborhoods and Mission Canyon Heights to the safe zones in the proximity of the Plan Area could be reduced to less than 45 minutes under existing conditions. Under 2030 conditions, evacuation travel time of the Upper Mission Canyon residents could be reduced to an average of less than 45 minutes (several households in the Mission Canyon Heights may still take 60 minutes to arrive at safe destinations). Implementing the traffic control plan would increase traffic volumes and congestion on Mission Canyon Road and Alamar Avenue in the Lower Foothill area and impact access and travel time to and from the Lower Foothill neighborhoods. However, since the Lower Foothill neighborhoods are further away from the fire location, and have relatively more access points, they could be rerouted with additional traffic control.

Furthermore, if additional staff and traffic control equipment are available, the following five locations should also be considered as part of the traffic control program to facilitate traffic movement in the northern and middle parts of the Mission Canyon Heights area:

- Palomino Road at Williams Way/Vista Eleveda
- Cheltenham Road at Kenmore Place
- Cheltenham Road at Williams Way
- Cheltenham Road at Tye Road

If a high-intensity fire occurs while special events are being held at the Natural History Museum, the Woman’s Club, and the Botanic Garden, additional traffic control teams may be needed to facilitate turning movements in the vicinity of these driveway locations.

INCREASE ROADWAY CAPACITY BY PROVIDING SPOT WIDENING AT CRITICAL LOCATIONS TO ALLOW ADDITIONAL EVACUATION TRAFFIC CAPACITY

Application of such strategies, if feasible, would affect capacity of those evacuation routes, and eventually result in different evacuation time estimates for the Plan Area. Under 2030 MCCP Buildout conditions, if a high intensity fire scenario occurs, deployment of the "Optimized Traffic Control Plan" may not be fully sufficient to evacuate the entire Mission Canyon residents and the Upper Las Canoas neighborhoods within 45 minutes (as shown in Figure 7). Additional roadway spot improvements could be considered as part of the infrastructure improvements in the area and would require consultation with the adjacent City of Santa Barbara. These spot improvements could reduce the traffic congestion bottlenecks observed in the previous Jesusita and Tea Fire evacuation experiences. The proposed spot improvements locations include:

- Foothill Road and Mission Canyon Road/Tornoe Road intersection: Improve the east and south legs of the intersection to allow drivable shoulders and bike/pedestrian paths to be used for cars in an emergency with aid of traffic control. This may require removal of existing vegetation on these facilities.

- Los Olivos Street between Mountain Drive and APS: Improve this segment of Los Olivos Street in the southbound direction between both intersections to allow drivable shoulders and bike/pedestrian paths to be used for cars in an emergency with aid of traffic control. This may require removal of existing vegetation on these facilities.

Traffic simulation was also performed under 2030 MCCP buildout conditions assuming a high-intensity (Scenario 2) fire evacuation to measure the effectiveness of combining an additional traffic control deployments and the two proposed spot widening projects. The systemwide travel statistics results summarized in Table 6-1 show that the proposed spot widening project would increase system efficiency and allow an additional 400 vehicles to exit the study area within two hours. The travel time map shown in Figure 8 also suggests additional travel time improvements by 10 to 15 minutes for several zones in the Upper Mission Canyon Heights.

In addition, roadway shoulder improvements could be considered on Mission Canyon Road in the Plan Area, where feasible, to provide a turn-out zone for emergency vehicles to pass general traffic. Potential locations for consideration include:

- Mission Canyon (south)/Tornoe Road/Foothill Road
- Mission Canyon Road (south) & Las Encinas Road

As the Foothill Road in the Plan Area is the State Route 192, any improvement on the intersection of Mission Canyon (south)/Tornoe Road would require collaboration between the County and Caltrans.

DEVELOP NEW OR ALTERNATE ACCESS ROUTES

Based on discussions with the County staff, potential extension of private roadways to allow secondary alternative access could be considered if feasible. For example, extension of Holly Road to connect to San Roque Road), if feasible, may be beneficial for fire protection planning and may improve the evacuation travel time for the Upper Mission Canyon area and relieve the traffic congestion on Mission Canyon Road.

OTHER RECOMMENDED MEASURES

The following additional measures would also facilitate traffic flow during evacuations:

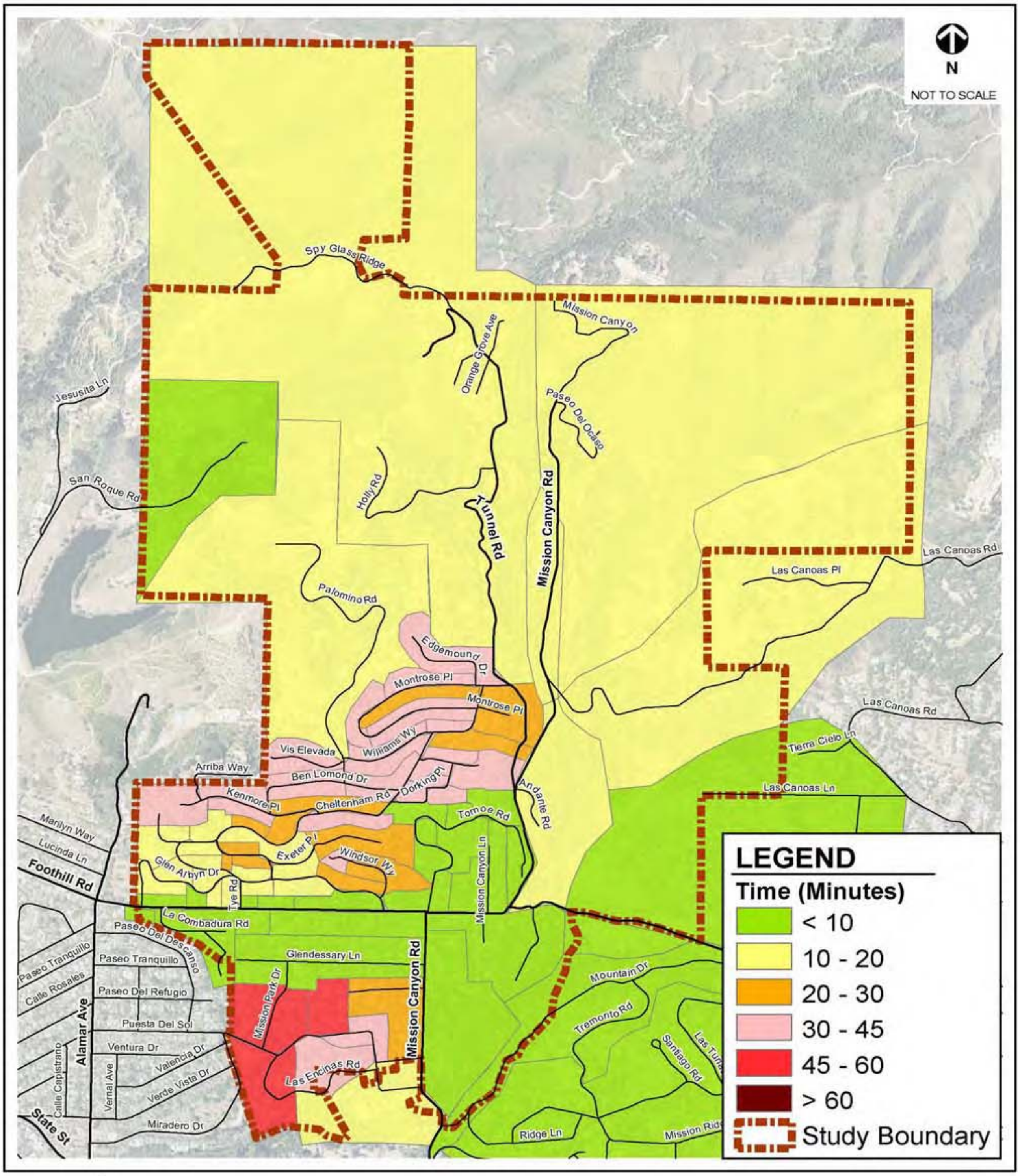
- Encouraged residents in the vicinity of the Plan Area to register cell phones etc. with the Reverse 911® system via County's website.

- Policy recommendations for vegetation clearance on key evacuation routes in the Plan area.
- Use volunteers, trained residents for traffic control, and placing road markers that are visible in smoky, dark conditions

Final recommendations should incorporate the latest available fire evacuation strategies or measures for the Botanic Garden, Women's Club, the History Museum for the entire Plan area,

TABLE 3. SYSTEMWIDE TRAVEL STATISTICS RESULTS FOR EVACUATION SCENARIOS WITH OPTIMIZED TRAFFIC CONTROL

Land Use Scenarios	**Existing (2009)**			**Future (2030) Buildout**			
Fire Evacuation Scenarios	**Scenario 1: Moderate Intensity**	**Scenario 2: High Intensity**	**Scenario 2: High Intensity**	**Scenario 1: Moderate Intensity**	**Scenario 2: High Intensity**	**Scenario 2: High Intensity**	
Traffic Control Scenarios	**Minimum**	**Minimum**	**Optimized**	**Minimum**	**Minimum**	**Optimized**	**Optimized + Spot Widening**
Number of Vehicles Arrive Destinations within 2 hours (from 5 P.M. to 7 P.M.)	4,530	5,245	5,735	5,450	6,265	6,150	6,650
Number of Vehicles Remain Traveling in the Plan Area after 2 hours	105	730	130	130	785	475	50
Vehicle Miles Traveled (VMT)	8,745	9,192	9,870	10,575	11,570	10,625	11,520
Vehicle Hours Traveled (VHT)	1,030	2,281	1,680	1,230	2,900	2,380	1,800
Vehicles Hours of Delay (VHD)	690	1,925	1,280	860	2,440	1,960	1,340
Average Speed [mph]	8.7	4.2	5.8	8.4	4.0	5.9	6.4



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EVACUATION TRAVEL TIME FOR EXISTING SCENARIO 2: HIGH INTENSITY WITH OPTIMIZED TRAFFIC CONTROL PLAN

FIGURE 6

March 1, 2010 SP
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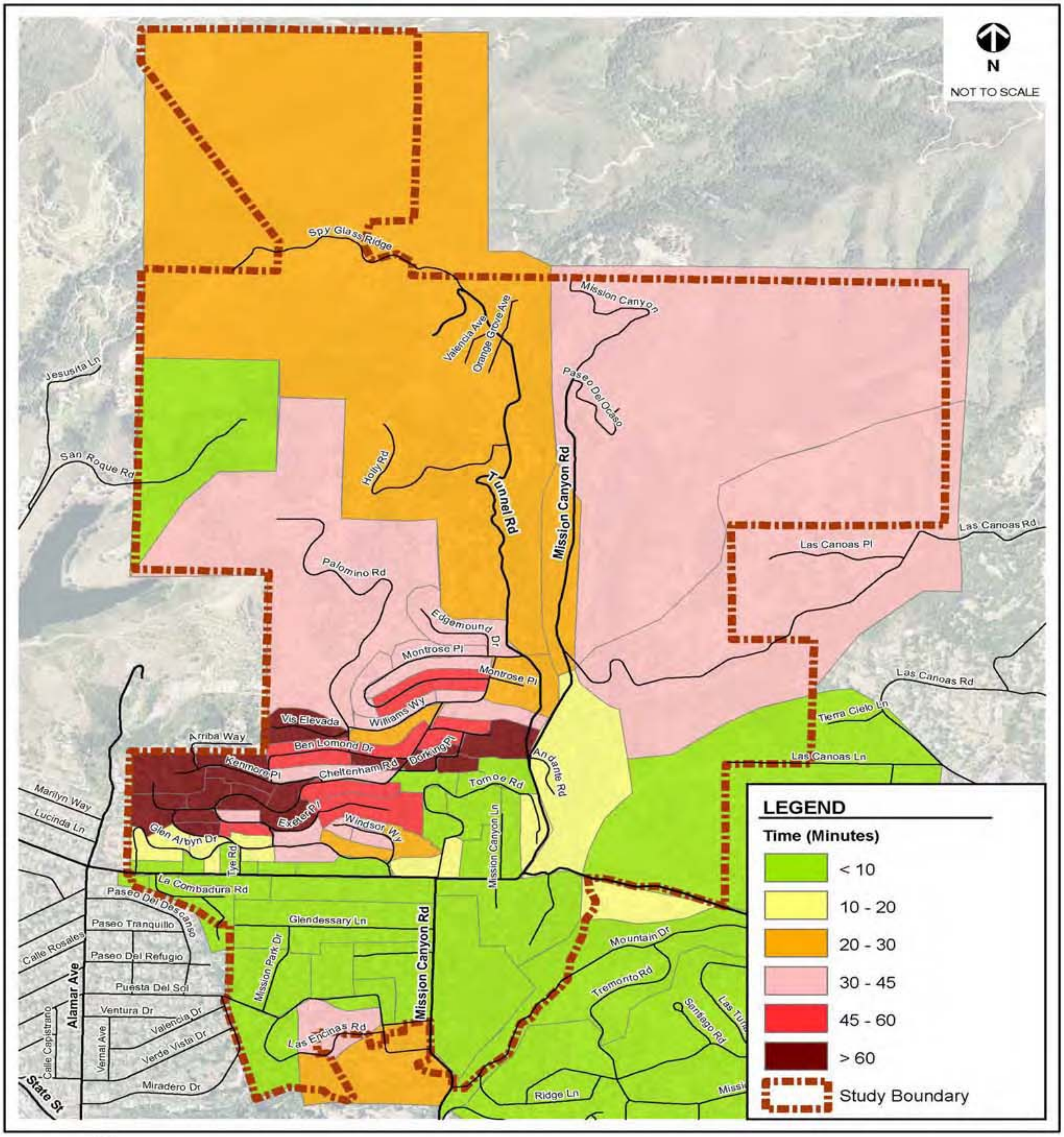

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March 1, 2010 SP
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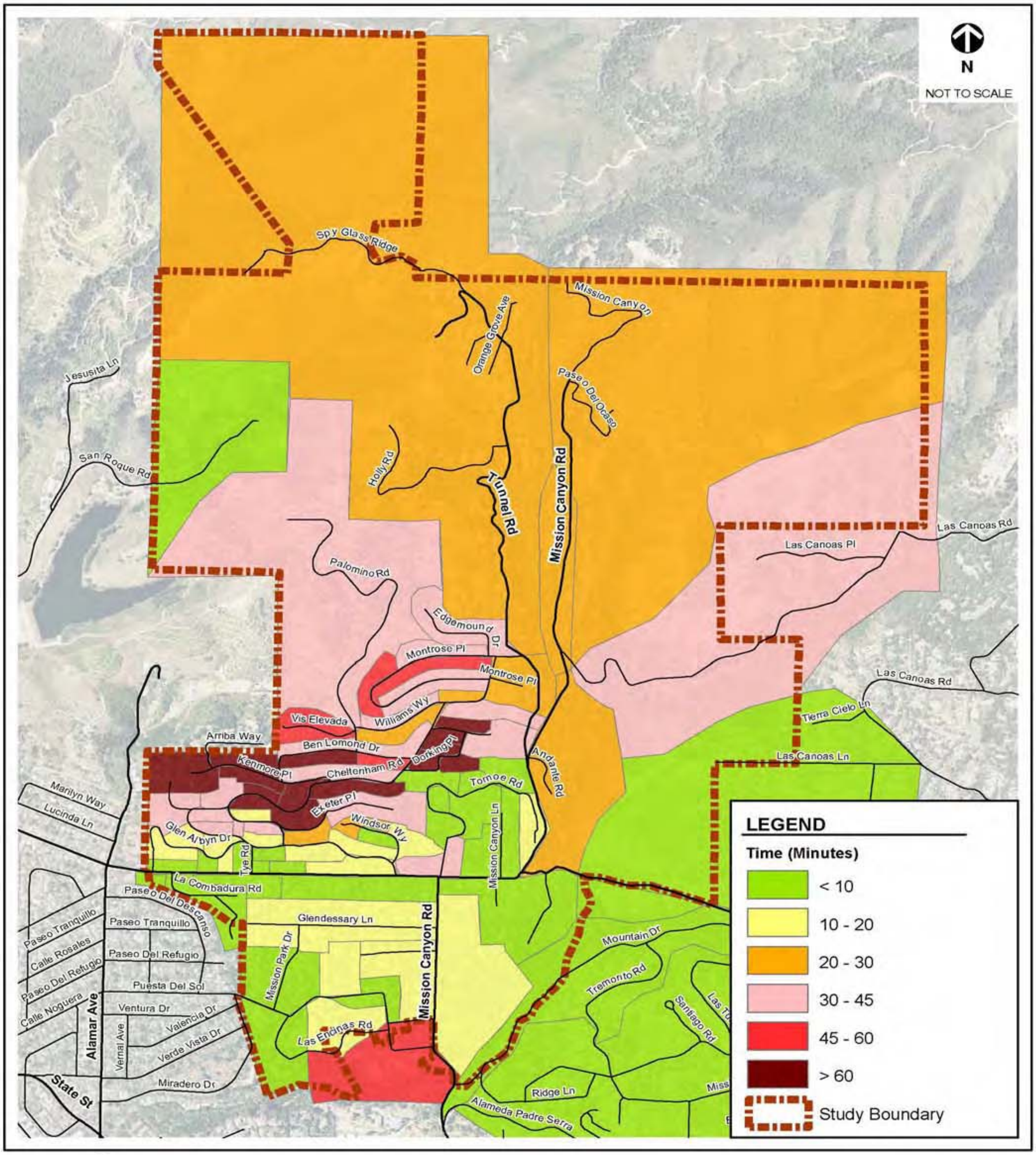
WorstCase_Optimize_FireEvac.mxd

EVACUATION TRAVEL TIME FOR 2030 MCCP BUILDOUT SCENARIO 2: HIGH INTENSITY WITH OPTIMIZED TRAFFIC CONTROL PLAN

FIGURE 7



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EVACUATION TRAVEL TIME FOR 2030 MCCP BUILDOUT SCENARIO 2: WITH OPTIMIZED TRAFFIC CONTROL PLAN AND SPOT WIDENING

FIGURE 8

March 1, 2010 SP
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Exhibit 7

Scott E. Franklin
International Consultant
Urban Wildland Fire Management
25059 Highspring Ave.
Santa Clarita, CA 91321
(661) 254-2376
Fax (661) 254-2376
Email: Scottfranklinfire@att.net
Web page: www.fireconsult.net

October 11, 2012

Chair Doreen Farr
Board of Supervisors
County of Santa Barbara
105 E. Anapamu Street
Santa Barbara, California 93101

RE: PARK HILL ESTATES
Case No. 12APL-00000-00015
4700 Via Los Santos, Goleta Area
APN 059-290-041

Supervisors:

This office has been retained by the Law Office of Marc Chytilo to provide a professional opinion on the adequacy of the Fire Safety Analysis in the Revised Final Mitigated Negative Declaration for the above-listed project, and specifically whether there is substantial evidence to support the conclusion that the project may have a significant impact under the California Environmental Quality Act. As described herein, I believe there is ample evidence concerning this project and the conditions from its location to conclude the project is very likely to cause a significant impact under CEQA.

1. Summary of Qualifications:

Former LA County firefighter, engineer, captain
Instructor for Cal-Fire, CDF and US Forest Service
Expert Consultation in Wildfire Protection Planning for existing and new development
36 years experience in fighting, studying and analyzing wildland fires
Member AEP
Personal experience in Santa Barbara County wild fire suppression evaluations in the San Marcos Pass area.
1964 “Coyote Fire”; 1990 “Painted Cave Fire”.
CV Attached

2. Documents Reviewed

In preparation for this letter, I reviewed the subject Mitigated Negative Declaration, the County Fire Department Memoranda on the project dated May 20, 2010 and December 9, 2011, the County Staff Reports associated with the project, drew upon my professional library and experience, and conferred with Marshall Eric Peterson at the County Fire Department. I have been on and near the site on numerous occasions, including the period immediately following the Painted Cave Fire in 1990.

I have also reviewed the applicable CEQA Thresholds as reflected in Appendix G of the CEQA Guidelines for the definition of a significant fire safety impact.

3. Background

The proposed development, located in the vicinity of 4700 Via Los Santos, Goleta Area of Santa Barbara County, is within a designated “High Hazard Fire Severity Zone” denoted by the California Department of Forestry and Fire (CAL-FIRE) and recognized by the County of Santa Barbara.

CAL-FIRE defines the process for developing the high fire hazard severity zone development as follows:

> “Fire Hazard is a way to measure the physical fire behavior so that people can predict the damage a fire is likely to cause. Fire hazard measurement includes the speed at which a wildfire moves, the amount of heat the fire produces, and most importantly, the burning fire brands that the fire sends ahead of the flaming front.
>
> The fire hazard model considers the wildland fuels. Fuel is that part of the natural vegetation that burns during the wildfire. The model also considers topography, especially the steepness of the slopes. Fires burn faster as they burn up-slope. Weather (temperature, humidity, and wind) has a significant influence on fire behavior. The model recognizes that some areas of California have more frequent and severe wildfires than other areas. Finally, the model considers the production of burning fire brands (embers) how far they move, and how receptive the landing site is to new fires.”

CAL-FIRE intends that the hazard maps would be used in defining appropriate building construction standards, setting defensible space requirements, establishing property development standards (including road widths) and in developing General Plans.
SOURCE:
http://www.fire.ca.gov/fire_prevention/fire_prevention_wildland_zones_development.php

In my experience, the designation of high fire hazard zone triggers the need for very careful evaluation of a proposed development's specific fire profile, as is typically addressed in a Project Fire Plan. Most development projects in the high fire hazard zone that I have reviewed include a Project Fire Plan as part of the project, and this is an important component of the project considered in the CEQA environmental review process. A Project Fire Plan will typically review issues such as appropriate fire construction practices and materials, defensible space requirements, vegetation types in the vicinity and proposed in the project landscaping, and other issues that pertain to the project's exposure to fire hazards and mitigation strategies. Depending on the project, a Project Fire Plan can also review evacuation routes, shelter in place opportunities, and other site-specific fire conditions and issues. The following counties within Southern California all require Fire Protection Plans for development within High Hazard Fire Severity Zones: Ventura, Los Angeles, Orange, San Bernardino, Riverside and San Diego.

It is my opinion that this project should have a Project Fire Plan to address these issues, which are largely overlooked in the Mitigated Negative Declaration. The project involves placing people and structures in an area with a significant risk of loss, injury or death from a wildland fire. Project conditions do not mandate compliance with state building and defensible space requirements, so there are no assurances these standards will be complied with. I believe in the absence of a Project Fire Plan, this project could have a significant CEQA impact from, for example, the use of improper building techniques and materials, inadequate construction phase fire preparations and contingencies, improper landscaping, fuel storage and similar issues that could either unnecessarily cause a fire, exacerbate a fire's severity, and/or expose occupants, other residents and/or fire fighting personnel to the hazards of a fire affecting the site.

Santa Barbara County has proposed to utilize a "Mitigated Negative Declaration" to satisfy the environmental impact disclosure requirements of the California Environmental Quality Act (CEQA). The "Mitigated Negative Declaration" prepared for this project under CEQA fails to identify and evaluate the following important fire safety, fuel load, fire behavior and meteorological facts:

1. Significant Terrain and Fuel conditions on lands near the proposed development. San Antonio Park and San Antonio Creek is adjacent on the east and possesses a heavy fuel load, and would directly impact the development, under down slope catastrophic wild fire conditions. The path of the 1990 "Painted Cave Fire" followed this route, resulting in the loss of many homes in the and near the project area.

2. Significant, predictable adverse meteorological conditions that occur with regularity in the project area. "Sundowner" in this area always blow from north to south, typically starting in late afternoon or early evening and continuing into the night. These winds have high temperature and low humidity and are typically gusty, carrying dust and debris. If a fire is started when Sundowners are blowing, as has been the case for most of the south coast catastrophic wildfires (Tea Fire, Gap Fire, Painted Cave Fire) the winds fan the flames, causing very tall flame heights, a fast moving flame front, and a

cascade of flying embers that blow ahead of the flame front, starting spot fires that are subsequently overtaken by the flame front. Visibility is typically compromised, and when these occur at the end of the work day, as with Tea and Painted Cave fires, residents often want to return to their homes to remove pets, assist family members, and secure important belongings.

3. A history of catastrophic wild fire impacts to the proposed project's site as well as impacts to the existing surrounding community. While some wildfires have periods where the flame front advances slowly, many in this area have periods where the flame front advances very quickly. This can be true at a fire's outset, as experienced at the Tea and Painted Cave fires.

It is my professional opinion that the MND is inadequate and that this project may cause significant adverse CEQA impacts based upon the following facts and conclusions:

1. The secondary access is inadequate. County policy requires two means of egress that are not impeded by fire, flood or earthquake. Goleta Community Plan Development Standard Fire-GV-1.3) The proposed use of San Antonio Creek Road to the north for emergency egress is inadequate in width to accommodate the short term, mass evacuation of residents, belongings and livestock under existing conditions (without the addition of 16 families and 32 vehicles), and more importantly, it is not tenable for evacuating residents to evacuate to the north in the face of a down slope, off-shore winds and a catastrophic wildfire event, facing 90 ft. flame lengths and very uncertain conditions. During recent fires in this area, Fire equipment has accessed the area from Highway 154, turning down Old San Marcos Road. CHP will typically close Highway 154 to civilian traffic to avoid vehicle conflicts and to be prepared to move quickly should the fire advance quickly rendering an area unsafe. CHP will not direct evacuation efforts to the north if the is an active flame front in that direction, which is most likely based on past experiences.

2. There is inadequate access/egress for emergency resources and fleeing residents/livestock, based upon minimal road width on the routes to the south. Existing access/egress to the area is currently at or beyond maximum safe capacity, depending on the necessary speed of the evacuations as demonstrated during recent Gap and Jesusita wildfires, where evacuation was spread out over time and aggressive flame behavior did not occur and threaten foothill residential communities at the very beginning of each fire.

3. The impact from additional project vehicle traffic under catastrophic wildfire conditions, 16 units equates to a minimum of 32 vehicles, is likely to contribute to a massive traffic problem in the event of a fast moving, sudden wildfire.

4. The project provides only one means of available, safe access/egress, to the south, and for that reason only, the Mitigated Negative Declaration is inadequate and the project is likely to cause a significant impact.

5. The proposed additional emergency access on the 14' wide unmaintained road through to Tucker's Grove Park from the end of San Antonio Creek Road is, in my opinion, unsafe in its current condition and may well be a death trap under worst-case conditions. If large numbers of vehicles attempt to evacuate under highly stressed conditions, there is a reasonably high probability that a vehicle may get stuck or go partially off the road. This is particularly true if vehicles are towing trailers on this road. This road has a sharp (90 degree) turn at the top, is steep, narrow, and has overhanging vegetation. It has no street lights or guard rail. There are two driveways that may mislead drivers, but dead end, potentially causing vehicles to have to back into a line of evacuating vehicles on an unfamiliar, narrow and steep road. If a vehicle backs too far, or swings too wide, it could go partially off the road and block the roadway, or go down the embankment. Under perfect and calm conditions it may be acceptable, and under the stressful conditions associated with a wildfire it could be very hazardous. County Fire Department Development Standard # 1 would indicate a 24' width is appropriate, and I believe that would provide the best opportunity for safe evacuation on this roadway. Fourteen feet, or even sixteen feet, is far too narrow for the safe operation as a reliable emergency egress route. In my opinion, it is unsafe and inappropriate to rely on this roadway as an emergency egress route and as a result of all the facts described above, I believe the area lacks sufficient emergency egress and access and adding 16 homes from the project will itself cause a significant additional impact to fire and public safety.

CATASTROPHIC WILDFIRE

San Antonio Canyon drainage has been identified as a "Historic Wildfire Corridor" (Painted Cave Fire 1990) as well as the more recent "Jesusita Fire" that was funneled toward San Antonio Creek drainage and lower San Marcos Pass.

These fires represent the threat to Santa Barbara as a result of annual episodes of "Sundowner Winds" that occur along the coastal drainage of the Santa Ynes mountain range, from Refugio Pass to Ventura County. Extreme air temperatures as well as wind speeds exceeding 50 mph accompany these weather episodes.

Wildfire emanating down canyon through San Antonio Park will directly impact the proposed development under "Santa Ana" or "Sundowner" weather conditions.

The BEHAVE Fire Behavior Fuel Modeling, a Fire prediction fuel monitoring system employed by wildfire professionals nationally as well as internationally, predicts flame lengths in excess of 90 ft. and spotting distance (flaming brands/embers) down wind in excess of 1 mile at and near the project site. These predictions are consistent with flame and spotting propagation observations of the "Painted Cave" fire. Depending on the fuel load at any time and other conditions, it is reasonable to expect that these flame lengths will be witnessed at this site at some point in the future.

Sundowner weather conditions provide air temperatures in excess of 100°F. and wind speeds in excess of 50 mph, as well as relative humidity below 10%. These extreme fire weather conditions provide the ingredients for the repeat of a catastrophic wildfire such as the Painted Cave fire at this site.

There presently exists no suppression method available to curtail the head of a catastrophic wildfire associated with the down slope, offshore sundowner event.

These facts support my conclusion that this project is likely to cause a significant impact to the fire safety of both its occupants and other residents to the area.

CONCLUSION

In my opinion, the "Park Hill Estates" development is likely to cause a significant impact to fire safety and should be denied based upon inadequate CEQA compliance regarding wildfire. Further, the project should be remanded back to the County Planning Department and Santa Barbara County Fire Department and an Environmental Impact Report, including an approved Project Fire Plan and Vegetation Management Plan, be required to address and mitigate the Extreme Fire potential. The project does not include conditions mandating compliance with Public Resources Code § 4291 or Chapter 7A of the California Building Code (addressing building practices in the wildland-urban interface). While buildings and structures are apparently not part of the instant Project Description, the lack of mandatory, project-based compliance with these building standards and similar controls for fire risk reduction purposes increases the probability the project will have a significant environmental impact due to unsafe fire conditions.

It is my expert opinion that this project as presently constituted would significantly impact the adjacent and surrounding residents located within the influence of the project area. The catastrophic wildfire potential due to heavy fuel loads and the presence of sundowner extreme weather conditions, inadequate access/egress all combine as substantial evidence supporting my conclusion that this project will cause a significant impact to fire safety of project occupants and surrounding residents.

Sincerely,

Scott E. Franklin

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Scott Franklin Consulting
Urban / Wildland Fire Management

Home | Professional Qualificiations | Scott's CV | Contact Scott

Scott's CV

Scott E. Franklin
International Consultant
Urban Wildland Fire Management
25059 Highspring Ave.
Santa Clarita, CA 91321
(661) 254-2376
Fax (661) 254-2376
email ScottFranklinFire@att.net
website http://www.fireconsult.net

OBJECTIVE

To provide services with regard to Urban-Wildland Fire Management planning, including vegetation, environmental impacts and land use; expert testimony concerning urban wildland fire protection, prevention, suppression and management.

PROFESSIONAL EXPERIENCE

1991-Present: Proprietor and manager of an independent consulting firm specializing in urban wildland interface -"I" Zone vegetative fuel treatment including prescribed fire, crushing and burning, vegetation clearing (mastification), strategic recycling and vegetation enhancement. Expert consultation regarding wildfire litigation.
1981-1991: Fire Captain and Vegetation Management Officer, County of Los Angeles Fire Dept. Developed and supervised Los Angeles County Prescribed Burn Program, burning over 32,000 acres of chaparral in the Areas of Santa Monica Mountains, including Bel-Air, Topanga Cyn., Santa Clarita Valley, San Gabriel Mountains, Whittier and Baldwin Hills.
1962-1981: Fire Captain, LACoFD; Fire suppression supervision and training.
1959-1962: Fire Apparatus Engineer, LACoFD; Responsible for driving specialized Wildland Fire equipment as well as structural fire apparatus.
1955-1959: Firefighter, LACoFD; working in wildland fire areas of Los Angeles County.

CERTIFICATION

Prescribed Fire Manager and Chaparral Management Instructor, California Dept. of Forestry (CALFIRE).
BEHAVE Fire Behavior and Fuel modeling System Instructor, CDF & USDA Forest Service.
Advanced Fire Behavior, S-490; CALFIRE & USDA.
Archaeological Site recognition; CALFIRE.
Smoke Management Techniques, CALFIRE.

PROFESSIONAL RECOGNITION AND AFFILIATIONS

2006-Present, San Diego County CEQA Consultant, Fire Protection Planning
2005-Present, Member Association of Environmental Professionals (AEP)
1993-94 Member, Wildfire Safety Panel, County of Los Angeles
1993-Present: Member, California Urban Forests Council.
1990-Present: Member, California Native Plant Society.

1978-82-Chairperson, California Water Commission.
1980 Member, Governor's Task force on Fire Flood Cycle.

SELECTED PUBLICATIONS, PRESENTATIONS AND REPORTS

1995 Presenter, Brush Fires in California - Fuel Management, Fire Behavior and Prescribed Burning. U.C. Irvine.
1995 Presenter to IAWF, Chaparral Management Techniques for Development: Public and Government Perceptions. Coeur d'Alene ID.
1993 Presenter to IBAMA, Brazil. Wildland Fire and Management Techniques, Brasilia Brazil.
1992 Presenter to Assoc. of Bay Area Govnts (ABAG) Oakland Hills Fire - Liability and Fuel management Issues. Oakland, CA.
1990 Presenter to the University of Menendez, The Role of Fire in Mediterranean Type Ecosystems, Valencia, Spain.
Fremontia, October 1993 Chaparral Management Techniques: An Environmental Perspective.
California's I Zone 1996-Urban wildland Fire prevention and Mitigation :Fuel Management. Prepared for California Department of Forestry and Fire Protection, State Fire Marshal.

INNOVATIONS

Developed Fire Service/Community participation for brush removal and hazard abatement in Los Angeles County.
Developed Fuel Management techniques to reduce chaparral fuel loading in and around Wildland Urban Interface Communities.

AREAS OF INTEREST

Preparation of Fire Safe planning Criteria for residential development in the wildland Urban Interface.
Chaparral Management in an Urbanized setting, with specific attention to environmental concerns.
Expert Assessment, Urban Wildland Fire Litigation.

REFERENCES AND TESTIMONY

California Department of Forestry and Fire Protection (CALFIRE)
County of Los Angeles Fire Dept.
City of Los Angeles Fire Dept.
Santa Barbara County Fire Dept.
San Bernardino City Fire Dept.
San Diego County Department of Planning and Land use
City of Laguna Beach Fire Dept
Collins Law Firm, Santa Monica, CA

Development Projects: Roger Van Wert Project Expediter (310) 850-5675
In excess of ten projects in Los Angeles County termed "High Risk"
Michael Huff, Dudek & Associates: (760) 947-5147 (City of Chula Vista, CA)
Peter Hummel, Anchor Environmental, Seattle, WA (Sedgwick Reserve, UC Santa Barbara)
John Polito, Project Expediter, (805) 494-0764
Michael Williams, PhD, Sedgwick Reserve Director (805) 686-1941
Dr. Phil Riggan USDA-forest Service, Fire Lab, Riverside, CA

Exhibit 8

David Magney Environmental Consulting
P.O. Box 1346, Ojai, California 93024-1346 * E-mail: david@magney.org
805/646-6045 Voice * 805/646-6975 FAX
www.magney.org

11 October 2012

Chair Farr
Board of Supervisors
County of Santa Barbara
105 E Anapamu Street
Santa Barbara, CA 93101

Subject: Appeal of Park Hill Estates Decision by Santa Barbara County Planning Commission (10TRM-00000-00001; Appeal No. 12APL-0000-00015)

Dear Chair Farr and Board of Supervisors:

David Magney Environmental Consulting (DMEC) was contracted by the San Antonio Creek and Park Highlands Homeowners Associations and on behalf of the California Native Plant Society (CNPS) to review and provide comments on the Draft and Final Mitigated Negative Declaration (MND), focusing on biological resources. Previous letters in the record provided general and specific comments on the MND and supporting documents. DMEC also commented before the Santa Barbara Planning Commission on this issue.

The Park Hill Estates project site is approximately 14.7 acres, located on a gently sloping terrace containing natural vegetation in the Goleta Valley. The site has never been developed, although it is surrounded by residential development. The project applicant is proposing to build 16 single-family homes and related facilities on 16 new lots, currently reduced to 14 single-family homes.

Credentials as an Expert on Biological Resource Issues

DMEC has been in business since July 1997, specializing in biological resource assessments, CEQA, and wetlands (including delineation, impact assessment, and mitigation planning). DMEC is owned by Mr. David L. Magney, who is a biologist and geographer, specializing in botanical resources and wetlands. Mr. Magney has been consulting full time since 1985, working for Dames & Moore, Jones & Stokes Associates, Fugro West, Inc., and ENSR before establishing DMEC.

I am an expert in conducting biological resource surveys and assessing project-related impacts to those resources. I have served as a U.S. Department of Justice expert witness as a botanist in the U.S. EPA vs. Adam Bros. wetlands violation case in northern Santa Barbara County. I have been placed on the certified biologists lists for Santa Barbara County, Ventura County, City of Malibu, County of Merced, and Los Angeles County's list of qualified biologists to work in Sensitive Ecological Areas. I am the consulting biologist for the City of Rancho Palos Verdes and have been designated as a Qualified Biologist by the U.S. Bureau of Land Management. I am a Certified Arborist by the International Society of Arboriculture. I am qualified to conduct wetland functional assessments using the U.S. Army Corps of Engineers' (Corps) Hydrogeomorphic Assessment Method (HGM) and served on the Corps' A-team to develop a depressional HGM model for vernal pool wetlands in the Central Valley region of California. I serve on the Los Angeles County Environmental Review Board. I am a member of the CNPS Rare Plant Program Committee, CNPS Vegetation Program Committee, and CNPS Locally Rare Plant Working Group.

I have written CEQA documents that have withstood legal scrutiny and critically reviewed CEQA documents, particularly biological resources sections that have been successfully found to be deficient by California courts, with my reviews providing substantial evidence to support the legal challenges. My CEQA documents and critical reviews are always based on facts and supported by substantial evidence and my best professional judgments based on substantial evidence and experience.

Points in Fact

The Park Hill Estates project site is dominated by herbaceous (grasslands) and scrub vegetation that is in a relatively natural condition. Approximately 3 acres has been mapped as native perennial grassland dominated by *Stipa pulchra* (Purple Needlegrass).

The area of *Stipa*-dominated grassland habitat onsite has increased substantially since they were originally mapped.

The grasslands onsite occur on Milpitas stony fine sandy loam soil, 9-15 percent slope, an unusual and highly restricted landform and soil type in California. There are only 2,047 acres of Milpitas stony fine sandy loam, 9-15 percent slopes, soil (MdD mapping symbol) in Santa Barbara County as mapped by the Natural Resources Conservation Service (Shipman et al. 1981[1]), with only 136 acres of it on 2-9 percent slopes, and 1,934 acres on steeper slopes, the later both typically supporting scrub vegetation, not grasslands. The Milpitas soil series is relatively shallow and course-grained, and is classified as a thermic Mollic Paloxeralfs. The vast majority of Milpitas stony fine sandy loam soil, 9-15 percent slope, soils along the Santa Barbara south coast have been developed, most of it occurring in the Santa Barbara and Montecito area, as shown on the map below. (Shipman et al. 1981.)

Mitigation for impacts to native grassland habitats are proposed to occur on UCSB property near Coal Oil Point, on a coastal terrace. The soils near Coal Oil Point on UCSB property where the proposed offsite contains Concepcion and Diablo soils, not Milpitas. The Milpitas soils are derived from bedrock while the Concepcion soils are derived from alluvium and have a claypan, and are classified as thermic Xeric Argiabolls. Diablo soils are derived from residuum weathered from mudstone and/or soft shale, and are classified as thermic Chromic Pelloxererts. Neither are the same as, or similar to, Milpitas soils.

Soil conditions of a mitigation site are one of the most basic considerations that must be accounted for to achieve mitigation success (Bakker & Berendse 1999[2], Maywald & Doan-Crider[3]).

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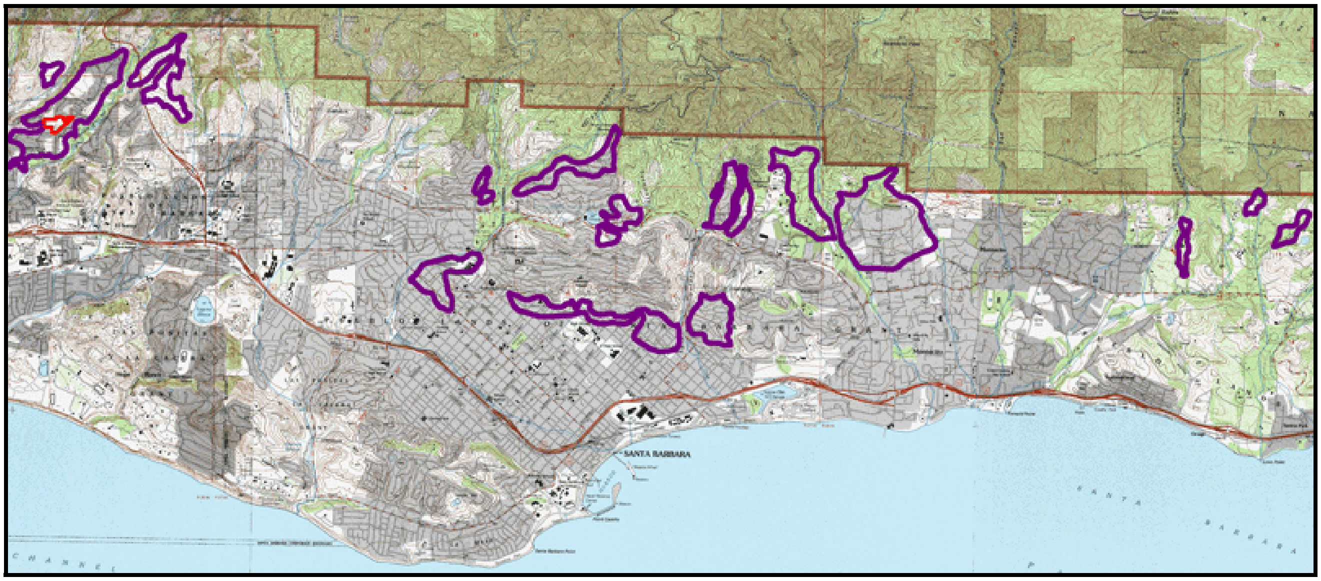
[1] Shipman, G.E., D.F. Rabey, and L.D. Mann. 1981. Soil Survey of Santa Barbara County, California, South Coastal Part. U.S. Department of Agriculture, Soil Conservation Service and Forest Service, in cooperation with the University of California Agricultural Experiment Station. Washington DC.

[2] Bakker, J.P., and F. Berendse. 1999. Constraints in the Restoration of Ecological Diversity in Grassland and Heathland Communities. *Trends in Ecology &Evolution* 14(2):63-68.

[3] Maywald, P.D., and D. Doan-Crider. Post 2004. Restoration Manual for Native Habitats of South Texas. Ceasar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Texas.



Map of majority of areas containing Milpitas stony fine sandy loam, 9-15% slope soils (MdD – purple areas). Red area is Park Hill Estates property. Most of this soil mapping unit has already been developed. The gray areas on the topo map background indicated developed lands. Some of the non-gray areas have since been developed as well.

Native grassland habitats are rare and are to be protected in Santa Barbara County, and mitigation for impacts to these habitats should occur onsite (Santa Barbara County 2006[4]).

The Park Hill Estates development project has been approved by the Santa Barbara County Planning Commission contrary to Santa Barbara County's Environmental Thresholds and Guidelines Manual (2006) by allowing offsite mitigation on UCSB property.

No assessment of project impacts on invertebrate wildlife was ever conducted.

No assessment of project impacts on the lichen flora was ever conducted.

No assessment of offsite mitigation sites have ever been conducted.

The baseline studies on the biological resources of the project site are over 12 years old.

Baseline field surveys for plants and wildlife were not performed according to current standard survey methods and protocols (DMEC 2011a[5], 2011b[6], 2012[7].

New components of the proposed project are now being considered, i.e. expansion of the fire access road through Tucker's Grove Park, which would impact mature Coast Live Oak and other trees and Coastal Sage Scrub vegetation, which have not been evaluated pursuant to CEQA.

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[4] Santa Barbara County. 2006. Environmental Thresholds and Guidelines Manual. First published May 1992. Planning and Development Department, Santa Barbara, California.

[5] David Magney Environmental Consulting. 2011a. Comment letter to Alex Tuttle regarding Park Hill Estates Draft MND v.2 (10TRM-00000-00001). 18 July 2011. Ojai, California, on behalf of the San Antonio Creek and Park Highlands Homeowners Associations, Santa Barbara, California.

[6] David Magney Environmental Consulting. 2011b. Comment letter to Alex Tuttle regarding Park Hill Estates Proposed Final MND v.2 (10TRM-00000-00001). 30 November 2011. Ojai, California, on behalf of the San Antonio Creek and Park Highlands Homeowners Associations, Santa Barbara, California.

[7] David Magney Environmental Consulting. 2012. Comment letter to Santa Barbara County Planning Commission regarding Park Hill Estates Proposed Final MND v.2 (10TRM-00000-00001). 25 January 2012. Ojai, California, on behalf of the San Antonio Creek and Park Highlands Homeowners Associations, Santa Barbara, California.

Substantial Evidence

DMEC has placed substantial evidence into the record regarding:

- Inadequate biological resource surveys and assessments (outdated, not performed according to any standard protocols, not all project components surveyed);
- Project mitigation for impacts to grassland habitat not to be conducted according to County policies;
- Failure to identify and assess all biological resources present onsite; and
- Mischaracterization of baseline conditions.

Evidence for these have been presented in DMEC's letters in the record and are summarized here.

Expert Opinions Based on Facts

Several specific and general issues have been raised by DMEC during the CEQA review process, and include the following:

Evaluation of Project Site Resources

The Santa Barbara County Environmental Thresholds Guidelines Manual, on Page 36, states that a **resource inventory must be conducted** [emphasis added] to determine if the site supports resident species or migratory species and whether any special-status species are present. It also requires a determination of site resource condition and quality, and how biologically productive it is, and what is its viability.

No systematic surveys of the project site have ever been conducted to establish and published survey protocols for vascular plants or wildlife species present onsite. A botanical inventory was conducted in March of 1998, and supplemented with observations during surveys focused on mapping vegetation during April 2011, August and October 2010. Wildlife surveys were only conducted for vertebrate species in late fall/early winter 1998. No surveys were ever conducted for nonvascular plants or invertebrates.

The criteria used to determine habitat condition/quality were not provided; and claims are made, at least indirectly, that grassland habitats not dominated by native species have little value, and are not considered valuable or important habitat. No criteria have been provided as to how the biologists that have assessed the Park Hill Estates project site determined the significance of the grasslands onsite not dominated by native plant species.

CEQA requires that substantial evidence be provided to support conclusions about the biological resources present at a project site and how a proposed project would directly or indirectly impact the biological resources. Below are quotes from the Governor's Office of Planning and Research, CEQA Technical Advice Series: Mitigated Negative Declarations (OPR 2012[8]) that are relevant to the Park Hill Estates project:

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[8] State of California, Governor's Office of Planning and Research (OPR), CEQA Technical Advice Series: Mitigated Negative Declarations (http://ceres.ca.gov/ceqa/more/tas/mit_neg_dec/neg_decs.html)

"CEQA requires that the Lead Agency, through its initial study, review the whole of a project….The decision to prepare a mitigated Negative Declaration (and a Negative Declaration for that matter) must be grounded in an objective, good faith effort on the part of the Lead Agency to review the project's potential for significant impacts (*Sundstrom v. County of Mendocino*, supra).

"The original determination made on the basis of the initial study whether to prepare either a Negative Declaration or an EIR is subject to the "fair argument" test (*Laurel Heights Improvement Assoc. v. U.C. Regents* (1993) 47 Cal.4th 376). In other words, if a fair argument can be raised on the basis of "substantial evidence" in the record that the project may have a significant adverse environmental impact - even if evidence also exists to the contrary - then an EIR is required. A Negative Declaration is authorized when the Lead Agency determines that no substantial evidence exists supporting a fair argument of significant effect. A mitigated Negative Declaration applies when changes to the project or other mitigation measures are imposed which such that all potentially significant effects are avoided or reduced to a level of insignificance.

"SB 919 adds to CEQA a definition of the term "substantial evidence" (subdivision (e), Section 21080). Although this does not affect application of the fair argument standard, it provides the Lead Agency a means by which to gauge the quality of evidence discovered during its review of a project. Similarly, a court examining the actions of the Lead Agency now has a consistent standard by which to judge the quality of the evidence which was before the Agency.

"Pursuant to Section 21080, substantial evidence includes "facts, reasonable assumptions predicated upon facts, and expert opinion supported by facts." It does not include "argument, speculation, unsubstantiated opinion or narrative, evidence which is clearly inaccurate or erroneous, or evidence of social or economic impacts which do not contribute to, or are not caused by, physical impacts on the environment." Further, public controversy over the possible environmental effects of a project is not sufficient reason to require an EIR "if there is no substantial evidence in light of the whole record before the lead agency that the project may have a significant effect on the environment" (Section 21082.2).

"There are two prerequisites to using a mitigated Negative Declaration:

1. All potentially significant effects of the project can and will be avoided or mitigated to a level of insignificance by project revisions or other requirements imposed on the project. A mitigated Negative Declaration is based on the premise that the project will not result in a significant effect. For example, suppose a project would increase traffic from Level of Service (LOS) B to LOS D where local guidelines have identified LOS D as the threshold for significance. If mitigation can reduce the impact to LOS C, then the project's impact would not be considered significant.
2. The project changes and mitigation measures must be agreed to or made by the proponent before the draft Negative Declaration is circulated for public review and comment. In other words, the draft document must reflect the revised project, with changes and mitigation measures. A few agencies apparently require proponents to submit a new project description before the draft mitigated Negative Declaration is released. This procedure is not required by CEQA if the proponent has otherwise agreed to or made the revisions and mitigations. However, requiring or allowing an applicant to adopt prospective mitigation measures which [sic] are to be recommended in a future study, but which are not incorporated into the project before the proposed Negative Declaration is released for public review, is not [emphasis added] allowed (*Sundstrom v. County of Mendocino,* supra).

"A key question for the Lead Agency is: What level of mitigation or project revision is sufficient to avoid or eliminate a potential significant effect? There is no ironclad answer which [sic] would apply in every instance. The answer depends upon the specific situation; the Lead Agency must use its own independent and objective judgment, based on the information before it, to determine that "clearly no significant effect on the environment would occur" (Section 21064.5). Further, there must be evidence in the record as a whole to support that conclusion.

"Pursuant to Section 15370 of the CEQA Guidelines, mitigation includes:

"(a) Avoiding the impact altogether by not taking a certain action or parts of an action.

"(b) Minimizing impacts by limiting the degree or magnitude of the action and its implementation.

"(c) Rectifying the impact by repairing, rehabilitating, or restoring the impacted environment.

"(d) Reducing or eliminating the impact over time by preservation and maintenance operations during the life of the action.

"(e) Compensating for the impact by replacing or providing substitute resources or environments."

"Project revisions may include such things as changes in design, location, operations, or scope. Effective project revisions will perform any or all of the above functions (a) through (e).

"Effective mitigation measures are those written in clear, declaratory language specifying what is required to be done, how it is to be done, when it is to be done, and who will be responsible for doing it. The words "will" and "shall" are preferred to "may" and "should" when directing an action. Furthermore, measures must be feasible to undertake and complete. Avoid measures that are conditional upon feasibility (i.e., required only "when feasible"), rather than applied directly or at a specified project stage. Also avoid deferred mitigation and mitigation measures consisting of monitoring and future studies not tied to performance standards and contingency plans (*Sundstrom v. County of Mendocino,* supra).

"Upon adopting a mitigated Negative Declaration, the Lead Agency must make both of the following findings:

1. Revisions in the project plans or proposals made by, or agreed to by, the applicant before the proposed negative declaration and initial study are released for public review would avoid the effects or mitigate the effects to a point where clearly no significant effect on the environment would occur.
2. There is no substantial evidence in light of the whole record before the public agency that the project, as revised, may have a significant effect on the environment.
   (Sections 21064.5 and 21080(c))."

The paragraphs below will provide substantial evidence that the County has failed to adequately document what biological resources are present, how the project will impact those resources, and how it has not evaluated all components of the project as required by CEQA when using a MND.

Botanical Survey and Methods

Botanical survey protocols were not followed. The project Mitigated Negative Declaration (MND) states that the protocols were "largely" followed without any explanation as to what parts of the protocols were or not followed. "Largely" doesn't cut it. The survey protocols were established for a reason, and need to be followed in their entirety. Biologists don't get to pick-and-choose which parts we want to follow for whatever reason. Any deviation from the protocols needs to be identified and explained, and what the ramifications are of the failure to fully comply with them. None of that was done.

The "primary" botanical survey of the project site was performed in March of 1998, almost 14 years ago now. Additional surveys have been conducted onsite since then, but focusing only on mapping and characterizing the vegetation onsite, not surveying for special-status species, and then those surveys were mostly conducted during the summer. No surveys have ever been conducted during the winter, mid- or late-spring, or early summer when many plant species are identifiable but not so during March or August. Watershed Environmental (1999[9]) supports this on Page 9 of their report,

> "It should also be understood that one site visit to record taxa will only give a snapshot in time of species present. Additional surveys performed later in the season would likely result in finding additional taxa as late-developing plants emerge and flower".

Since the 1998 botanical survey, the list of plants considered rare in California (as compiled by the California Native Plant Society) has been updated in print once and at least annually electronically since. Furthermore, surveys for whole groups of plants were not considered. The failure to follow the botanical survey protocols and the age of the botanical surveys leaves the assessment of the botanical resources inadequate to satisfy CEQA assessment requirements.

Nonvascular Plants (bryophytes and lichens)

Nonvascular plants, which include bryophytes and lichens, are part of the botanical resources; however, they were not considered at all for this project. There is no evidence that surveys for mosses, liverworts, hornworts, or lichens were ever conducted. Numerous species are indeed present, some of which may be rare; however, they have been ignored. A total of 59 lichen species have been identified as occurring on similar habitat at the former Bridle Ridge project site just east of SR154, some of which are rare in Santa Barbara County. The MND is inadequate until these resources have been surveyed and assessed, as described in my previous letters.

Wildlife

The only focused surveys for wildlife were conducted by VJS Biological back in 1998, focusing on vertebrate wildlife species. There is no mention whatsoever about invertebrate wildlife surveys or species, a broad group of wildlife that contains magnitudes more species than represented by vertebrates, and make up the biggest part of wildlife biodiversity onsite. One specific group of wildlife that I have been researching over the last 8 years are the terrestrial gastropods (snails). We have a great diversity of native gastropods in California, including Santa Barbara County, which as at least eight (8) are known from the mainland part of the county, with two species endemic to Santa Barbara County. Another two are formally tracked by the California Natural Diversity Database and considered rare. No surveys for terrestrial gastropods, much less for any other invertebrate species, were ever conducted for this project even though suitable habitat is present. This oversight must be corrected.

The fact that several raptor species use the project site for foraging and roosting, without deference to habitats dominated by native plant species, is evidence that all the grassland types onsite are of at least equal value or importance to those species. No evidence has been provided to suggest that the raptors that use the site differentiate between the grassland habitat types, using them equally.

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[9] Watershed Environmental. 1999. Botanical Inventory/Native Grassland Survey, 4700 Via Los Santos Road (APN 59-290-041), Santa Barbara, California. March 1999. Santa Barbara, California. Prepared for County of Santa Barbara, Planning and Development Department, Santa Barbara, California.

Without evidence to the contrary, if the County considers foraging habitat important to raptors using the site, it must consider the loss of all of the grassland types onsite as a significant impact and require full mitigation for the loss of them if an MND is to be used.

Grassland Habitat Characterization

The grasslands onsite have yet to be accurately characterized. Most of the 14.87-acre site is dominated by herbaceous vegetation generally referred to as grassland. The County has long focused on those grasslands in Santa Barbara County dominated by the native perennial bunchgrass, Purple Needlegrass. I formally described this plant community in a scientific journal, *Crossossoma*, in 1992. Grasslands of all types are of critical concern in California because, like wetlands, we have already lost well over 95% of them, and they are critical habitat to many species of plants and wildlife, such as the White-tailed Kite, to name just one species. The developer's consultant and the County continues to mischaracterize the grasslands onsite as of low ecological value because they contain many non-native grasses and forbs.

Transects, plots, and relevé data have been sampled onsite, with a good summary provided in Table 2 on Page 29-30 of the MND; however, that sampling has failed to follow basic scientific methods to obtain meaningful results. Frankly, the work has not met minimum scientific standards in several respects, which I detailed in my previous letters to the County. Statistically valid sampling has never been conducted onsite; however, the County has made conclusions on that sampling, resulting in erroneous statements and conclusions about the grasslands present onsite.

The grasslands have been mischaracterized and the functions performed by the grassland habitat onsite have been ignored or greatly minimized in a biased manner. The primary reason scientists follow protocols is to remove or minimize the bias of the scientists performing the sampling and assessments. Watershed Environmental and the County violated the rules, which are intended to minimize unintentional bias. Watershed Environmental sampled 73 quadrats along five (5) transects. None of the sampling followed statistically valid protocols. Therefore, the results are suspect at best, and invalid at worst. Certainly, they cannot be used to make unbiased conclusions about what is present at the project site.

Vegetation Mapping

The vegetation sampling is a necessary part of the mapping of the resources. Boundaries are drawn, which are arbitrary decisions unless those boundaries are determined by rigorous sampling, to demark one type from another. A fair amount of data were collected by Watershed Environmental and the County Biologist, albeit not necessarily at the appropriate times of the year; however, those plots, transects, and relevé plot areas have not been delineated on any map, or at least not on any made available to the public for review. Without knowing where sampling occurred (except for Watershed Environmental's 1998 work), precisely, it is impossible for the public to compare or check the accuracy of what sampling was performed or how those data were converted to a map.

The sampling is a valuable tool to help the mapper decide where to draw the line between mapping units. Without the sampling data, the maps presented are simply biased presentations of what the person perceives to be present. The fact that the County biologist disagreed with the boundaries of Purple Needlegrass Grassland, as mapped by Watershed Environmental, illustrates the biases of both. Without detailed, statistically valid sampling to support the boundaries, another biologist, like myself, would almost certainly have different boundaries, based on my own biases. To summarize my main point on this issue, you can't have accurate mapping without clearly defined criteria, and those criteria, for grasslands, must be supported by on-the-ground sampling that would survive statistical tests. Otherwise, the resulting maps are sampling biased opinions and are not substantial evidence as required by CEQA.

General Plan Policies and Environmental Thresholds

The County has adopted several policies as part of its General Plan to protect biological resources. I want to talk about two polices here: Bio-GV-1 and DevStd BIO-GV-22.2.

Policy Bio-GV-1 requires the County to provide protection to important or sensitive environmental resources and habitats. Evidence has been provided that the grassland (including rock outcrops) vegetation onsite are considered a sensitive environmental resource, because of the habitat it provides to wildlife and plants, and do to their scarcity. The County has narrowly focused their assessment on grasslands dominated by Purple Needlegrass without the benefit of unbiased data that are statistically valid. Even those areas onsite dominated by nonnative herbaceous species provide most of the functions all grasslands provide; however, they have been entirely discounted as important by the County because of a bias against the nonnative species (a bias I share). However, that bias is misapplied in the case of habitat function.

All the grassland areas of the project site, regardless of which species are dominant, provide valuable and important foraging habitat for a whole sweet of raptor and migratory bird species, as well as other vertebrate and invertebrate species. This fact in itself is reason enough to consider all the grassland habitats onsite to be considered a sensitive environmental habitat, warranting protection onsite.

Policy DevStd BIO-GV-22.2 requires any offsite mitigation site be given "a permanent protective easement". The impacts to a portion of the grasslands impacted is proposed to be mitigated on property owned by the University of California. Has the University stated that it is willing to accept a conservation easement on their property? Not likely.

Goleta Community Plan BIO-GV-1.1 (5) on page 193 states, "Areas that are structurally important in protecting natural landforms and species…".

Santa Barbara County Environmental Thresholds D.3.(2).a. states that "a native grassland is defined as an area where native grassland species comprise 10 percent or more of the total relative cover". Footnote 5 associated with that definition states,

> "Native grasslands which [sic] are dominated by perennial bunch grasses such as purple needlegrass (*Stipa pulchra*) tend to be patchy (the individual plants and groups of plants tend to be distributed in patches). Therefore, for example, where a high density of small patches occur in an area of one acre, the whole acre should be delineated if native grassland species comprise 10 percent or more of the total relative cover, rather than merely delineating the patches that would sum to less than one acre".

Environmental Thresholds **Mitigation Hierarchy** states that Avoidance of the impact should be primary, followed by onsite mitigation, and lastly, offsite mitigation.

Mitigation Proposed

The applicant is proposing to mitigate for all impacts to sensitive grassland habitat offsite, on property owned by the University of California. First, the amount to be mitigated is too low, in that most, if not all the grasslands onsite should be treated as sensitive habitat, requiring mitigation. Even if you only require mitigation for the amount stated, the West Campus Bluffs site already contains native habitat with development to on two sides, with the ocean to the south, and is no more defensible then preserving habitat onsite. Second, the soils on the two sites are quite different, with the project site consisting of stony sandy loam and the West Campus Bluffs site primarily containing clay soils. Microclimates of the two sites are also quite different, and the County or the developer's consultants have never conducted any sort of analysis of site suitability or defensibility. The geomorphic landforms of the two sites are quite different. Furthermore, the offsite mitigation plan has not been made available to the public for review. There are many unanswered questions about this. Based on the information I have gathered, I do not believe that the West Campus Bluffs site is appropriate for mitigating impacts to grassland habitats found at the project site, certainly not to a level of less than significant.

Furthermore, the West Campus Bluffs site in currently in a "natural" condition and used by raptors for foraging. The West Campus Bluffs cannot be used as a mitigation site for the loss of foraging raptors because it is already "at capacity". That is, foraging raptors already use the site, and there is not room for the raptors currently foraging at the Park Hill Estates site to move to the West Campus Bluffs site. The loss of foraging habitat is left unmitigated, with is not permitted when using an MND. An EIR is the only vehicle available to allow such impacts to go unmitigated.

I disagree with Mr. Nelson's belief that onsite preservation is not preferred. It is preferred, and it is feasible. Reconfiguration of the parcels can significantly reduce onsite impacts and reduce mitigation requirements. The retention basin represents an excellent opportunity for onsite mitigation if designed properly and if it was not allowed to be used for active recreation.

The bioswales proposed also offer opportunities for habitat restoration, or at least for providing habitat for a number of wildlife species that currently use the property, if designed properly.

Mitigation Preserve Design

The design of any mitigation site or habitat preservation site must take into account a number of factors, such as: viability, maintenance, defensibility, and influence from surrounding area (edge effect). These are all influence by the purpose of the preserve, which must be the overriding consideration. The use of island biogeography theory has been used to argue for or against large versus small preserve designs (Higgs 1981[10]). Issue of concern depend on the objectives of the preserve. Single site preserves, regardless of their size, are at risk from stochastic events. Smaller, scattered sites reduce that risk. For maintaining a population of a particular species is dependent on the requirements of that species.

All Project Components Must Be Evaluated

CEQA requires that all components and sites associated with a project must be assessed as part of the CEQA review process, particularly when using a MND. The offsite mitigation site, West Campus Bluffs,

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[10] Higgs, A.J. 1981. Island Biogeography Theory and Nature Reserve Design. *Journal of Biogeography* 8:117-124.

has never been assessed or evaluated. No biological surveys have been conducted of the mitigation site. The feasibility or appropriateness of the site has never been formally assessed. As stated above, I believe that some aspects of the West Campus Bluffs site make it inappropriate as a mitigation site for establishing native grassland habitat. This also applies to the use of the site as mitigation for foraging raptors.

Expert Opinions Based on Professional Experience

In my expert opinion, the proposed development project would result in substantial adverse effects on sensitive habitats without sufficient mitigation proposed that has been demonstrated to likely or feasibly mitigate those impacts. Resources so affected include:

- Native grasslands;
- Lichen flora;
- Raptor foraging habitat; and
- Mature native oak trees.

These impacts would conflict with local policies and ordinances protecting biological resources.

In order to rectify these failings and discrepancies, the appeal should be upheld and the project be required to evaluate all resources issues through the preparation of an Environmental Impact Report. Use of a MND is not appropriate because of the residual or infeasible mitigation measures and the lack of assessment of several specific biological resources.

Thank you for considering these comments.

Sincerely,

David L. Magney
President/ISA Certified Arborist

cc: Marc Chytilo, Esq.
Danny Vickers, San Antonio Creek and Park Highlands Homeowners Associations
David M. Brown, CNPS Channel Islands Chapter Conservation Committee Chairman

Exhibit 9

Pacific
Northwest
Research
Station

Science Update

WESTERN FORESTS, FIRE RISK, AND CLIMATE CHANGE

IN SUMMARY

Climate warming may first show up in forests as increased growth, which occurs as warmer temperatures, increased carbon dioxide, and more precipitation encourage higher rates of photosynthesis. The second way that climate change may show up in forests is through changes in disturbance regimes—the long-term patterns of fire, drought, insects, and diseases that are basic to forest development.

Advanced computer models are producing the first national-scale simulations of how ecosystems and fire regimes could change in the 21st century. In six of seven future scenarios run through one model, the Western United States gets wetter winters and warmer summers throughout the 21st century (as compared to current climate), with expanded woody growth across the West and thus, increased fire risk. These results have been used in national and global assessments of global climate change.

The computer model can now produce 7-month forecasts of possible fire risks for the conterminous United States, made possible by incorporating year-to-year changes in climate, fuel loadings, and moisture into the model. The accuracy of 2002 and 2003 forecasts has validated the model's approach, suggesting it can eventually be a useful planning tool for fire managers.

Research results were produced by scientists from the USDA Forest Service Pacific Northwest (PNW) Research Station, working with others from Oregon State University and from around the world. The team's research has led to the key insight that fire and fuel load issues in Western forests are linked to global carbon balance issues. The full story is inside.

United States Department of Agriculture

Forest Service

Pacific Northwest Research Station

http://www.fs.fed.us/pnw

Issue 6
January 2004

Key Findings

- Along with fire suppression, a strong climate change signal is associated with woody expansion in the West—the spread of juniper into grasslands and increased understory growth in conifer forests. The woody expansion is projected to continue throughout the 21st century owing to continuing climate change and elevated levels of carbon dioxide in the atmosphere. Although total precipitation is projected to increase, most will fall in the traditional wet season and summers are likely to be hotter and longer than they are currently. Thus increased precipitation would contribute to woody expansion but likely would not reduce summer fire risk.
- Climate variability is strongly related to when, and in which region, large fires have occurred over the last 100 years, in the conterminous United States. Large fires associated with climate patterns include the 1910 Idaho fires, 1988 Yellowstone fires, and 2002 Biscuit Fire in southwest Oregon.
- The MC1 model produces 3- to 7-month forecasts of fire risk for the conterminous United States. The forecasts are the first national-scale, high-resolution forecasts of fire risks in the United States that incorporate climate-driven, year-to-year changes in fuel loadings and moisture characteristics. As fire risk forecasts are further validated and improved, they may become useful tools for managers.
- In the conterminous United States, ecosystems were a likely source of carbon to the atmosphere through much of the 20th century because of several major droughts. (This analysis does not include timber harvest, car and factory emissions, cities, or other human impacts on carbon release.) When the climate regime shifted in the mid-1970s to a multidecadal wet period, simulations suggest that the natural U.S. ecosystems became a net sink for carbon, meaning that more carbon was pulled into ecosystems than was released into the atmosphere. Much of this carbon was stored as woody growth in the West.
- The fire and fuel load issues in Western forests are linked to global carbon balance issues. Carbon budgets will likely become part of forest management planning. Challenges would be to:
  - (1) In the West, reduce wildfire risk even as fuel loads increase because of increased seasonal precipitation.
  - (2) In the Southeast, reduce risk of rapid conversion of forests to savannas and grasslands.
  - (3) In the entire United States, balance carbon storage in forests with reducing fire risks from fuel accumulation.

How does long-term climate change affect forests and other ecosystems?

The most obvious effect is the slow migration of forests. Over the millennia, forests have retreated southward during ice ages and shifted slowly as glaciers retreated and rainfall patterns changed.

Climate change affects forests in other ways, however—ways both less obvious and more immediate. The research problem of understanding these influences was approached by the Mapped Atmosphere-Plant-Soil System (MAPSS) team led by Ron Neilson, in PNW Research Station's Managing Disturbance Regimes Program. The project was named the vegetation/ecosystem modeling and analysis project.

The team built a computer model that predicts the potential vegetation that would grow naturally in an area if there were no agriculture or cities. For potential vegetation, climate (water and temperature) and soils are the most important factors affecting large-scale patterns of what grows where, and how fast it grows. Vegetation was classified in broad types, such as "coniferous forest" and "temperate deciduous forest."

"The original model was a steady-state model," explains Jim Lenihan, fire and ecosystem modeler on the team. "The computer 'drew' the map under average climate conditions for the conterminous United States."

Computer models can incorporate enormous amounts of data and apply complicated sets of equations and rules to the data, a process involving millions of calculations (see sidebar on facing page). The MAPSS model, a steady-state model, includes a set of equations not only for basic water input such as rain, snow, and snowmelt, but also for factors such as plant transpiration, soil infiltration, leaf form, and even leaf fall. MAPSS calculates the type of vegetation that could grow in a place (if there were no human influence), its density in a ratio of leaf area to ground area, and a water balance, including soil moisture and runoff.

Purpose of PNW Science Update

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Valerie Rapp, writer and editor
vrapp@fs.fed.us

Send change of address information to
pnw_pnwpubs@fs.fed.us

What Computer Modeling Can—and Cannot—Do

Controlled experiments on forests and climate change would require controlling all variables, including weather, over a large landscape for decades. Because that would be impossible, scientists use computer models as tools to study climate change. No single model can simulate everything. Scientists design different types of models to study climate, ecosystems, vegetation dynamics, and biogeography, and increasingly, scientists are linking these models to study interactions among factors.

To build ecosystem models, scientists use field and laboratory findings about carbon, water, and nitrogen interactions in ecosystems. For example, trees generally respond to elevated levels of carbon dioxide with increased rates of photosynthesis and tree growth, although a scarcity of nutrients, particularly soil nitrogen, can limit this growth. Water-use efficiency typically increases in carbon dioxide-enriched atmospheres. Elevated carbon dioxide may alter tree resistance to pests and even influence the rates of decomposition in soils. The models incorporate data on trees' responses to carbon dioxide, weather patterns, climate patterns, ocean surface temperatures, and so forth. Temperature warming alone would not cause the woody expansion predicted by models; the elevated level of carbon dioxide is a key factor in the simulations. Data also exist on how human activities affect specific drivers of climate, such as greenhouse gases.

Each type of model is built from databases and experimental findings relevant for its area, such as climate or vegetation. A computer model is a synthesis of the best available existing information. Using their best knowledge, scientists develop a set of mathematical rules, or algorithms, by which the computer model will run its simulations. This work can require terabytes of hard-drive space (1 terabyte equals 1,000 gigabytes) for database storage, and immense computing power to perform the intricate calculations. Quality control, peer review, cooperation among research teams, and validation are all crucial for credible results. Scientists look for areas of consensus among scenarios produced by different models, and work to identify areas of uncertainty.

Scientists use climate change models to find correlations and trends, and to analyze future scenarios, varying degrees of temperature increase and other conditions. Computer models **can** forecast the likely effects of different scenarios, giving people the chance to compare outcomes. Computer models **cannot** predict specific events; too many chance happenings, such as fire starts by lightning or people, are involved. Models will never become "fortunetellers."

MAPSS also produces what scientists call "spatially explicit" results—maps. The first maps showed potential forests and other ecosystems for current conditions. Next the team used MAPSS to redraw the maps, by using changed climate scenarios and research findings about how trees respond to these changes (see sidebar above). The so-called "greenhouse gases" (carbon dioxide, methane, nitrous oxide, and others) are increasing. The increased levels of these gases may be driving general climate warming, with warmer temperatures and more precipitation, conditions that can be ideal for plant growth.

The expansion of juniper woodlands and ingrowth of other species into ponderosa pine forests likely have a strong climate signal.

"Climate change shows up in forests first as changes in growth," says team leader Ron Neilson, bioclimatologist. Under warming climate scenarios, interior Western forests would likely have more precipitation, but it would fall mainly in the traditional October-April wet season. Summers would still be hot and dry, and may be even hotter and longer than they are now.

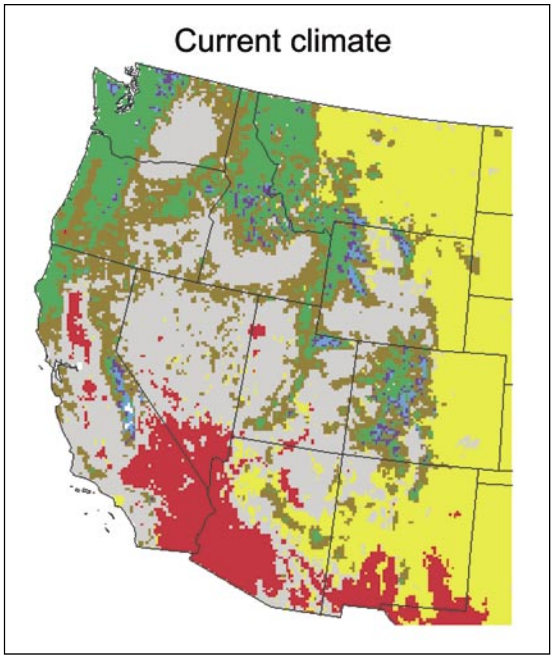
The MAPSS result for one future climate scenario shows a massive increase in woody vegetation across the Western United States, with expanded woody areas in eastern Oregon, many parts of the Great Basin, and other parts of the West. Many deserts in New Mexico, Arizona, and southeastern California would turn to grasslands. In Pacific Northwest coniferous forests, the broadleaf component would increase. In mountain ranges across the country, most forest zones would shift upslope, and subalpine and alpine life zones could be eliminated. In interior West mountain ranges, low-elevation forests now limited by aridity could expand into grasslands as precipitation increased. (See maps on next page.) Other ecosystem models may produce different results.

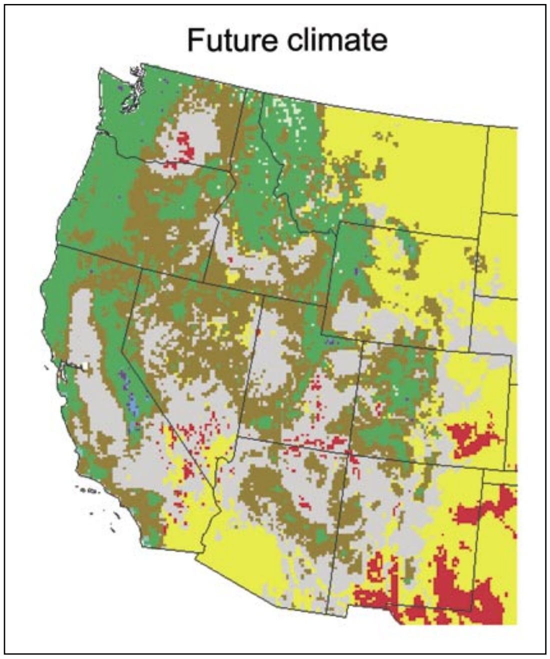
MAPSS simulations were used in national and global assessments of global climate change. The team modeled vegetation changes and led the analysis for North American forests in major federal reports on climate change. They also modeled global vegetation change for the intergovernmental panel on climate change (IPCC), part of the United Nations.

What we're seeing in the Western United States, team members point out, matches MAPSS results. The expansion of juniper woodlands and ingrowth of other species into ponderosa pine forests likely have a strong climate signal, and may not be due to fire suppression alone.

The second way that climate change shows up in forests is through changes in disturbance regimes—the long-term patterns of fire, drought, insects, and diseases that are basic to forest development. To find this connection, the team had to transform MAPSS into a dynamic model.

"Our steady-state MAPSS model could show scenarios for different conditions," Neilson explains, "but it didn't show how ecosystems would get there." A dynamic model would be more like the real world.

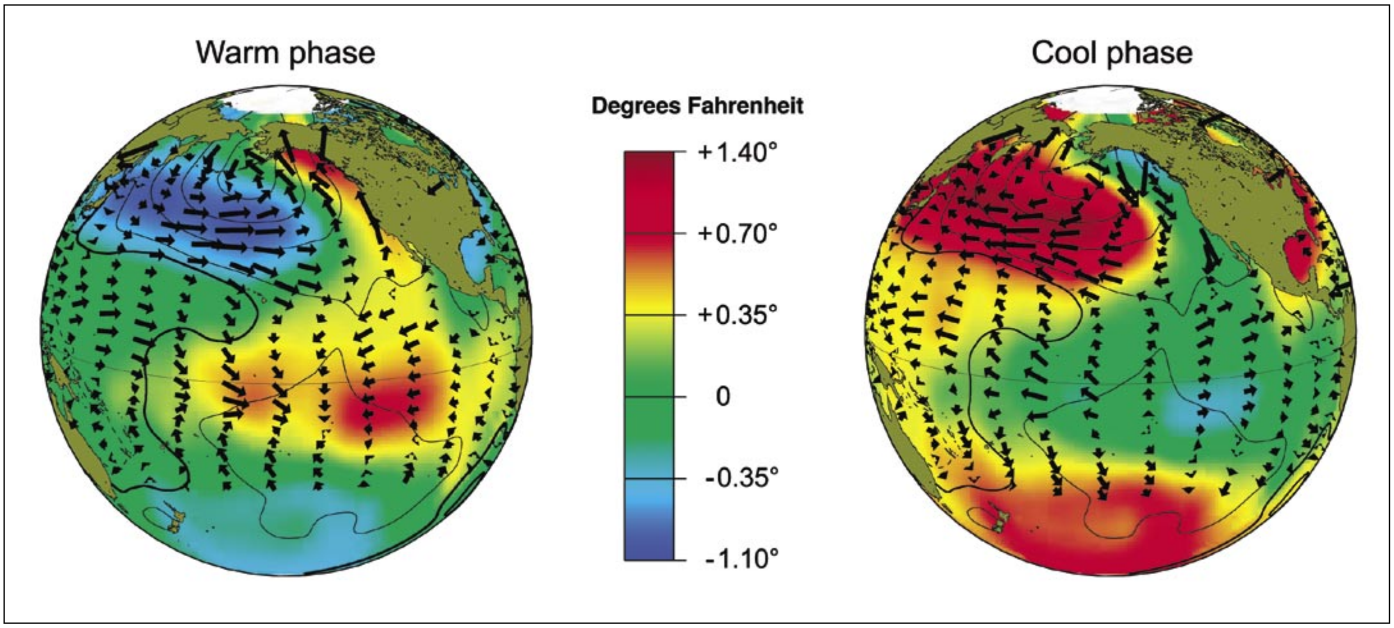




The MAPSS map on the left shows vegetation types that would grow naturally in the Western United States, under current climate, if there were no agriculture or cities. The MAPSS map on the right simulates potential vegetation distributions under the future climate scenario produced by the Canadian Global Coupled Model (CGCM1), with about 12 °F warming and a 22 percent increase in precipitation.

Principal vegetation types shown are:

green—coniferous forest
tan—savanna/woodland
gray—shrub/woodland
yellow—grasslands
red—arid lands.



The Pacific decadal oscillation, http://jisao.washington.edu/pdo

The Pacific decadal oscillation (PDO) is a long-lived pattern of sea surface temperature variability in the Pacific Ocean. The arrows and temperatures are the deviations from normal, with arrows representing wind deviations at the ocean surface. Ocean current deviations tend to be in the same direction as the winds.

How can scientists tell that climate variations are related to fire regimes?

The team's first dynamic model, MC1, used data simulated by climate models that included data from oceans and the atmosphere along with associated time lags and feedback loops. "Ocean surface temperatures are a key driver of climate," says Neilson. The Pacific, Arctic, and North Atlantic Oceans all have shifts in their surface temperatures, and all three influence climate regimes over the conterminous United States.

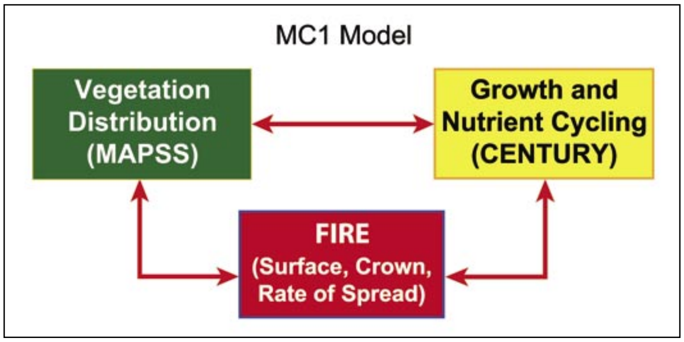
"The Pacific, however, is the largest ocean by far, and it has the most effect on climate," says Neilson. The Pacific decadal oscillation (PDO) is an index of sea surface temperature shifts, and the PDO has changed phase every few decades since people have been able to measure it. And, Neilson points out, "The climate regime shifts match beautifully with the PDO shifts."

An oceanic regime shift in the mid-1970s was a major influence on the climate regime shift that brought a period of wet years to Western states. These wet years encouraged the woody expansion in the interior West. The Pacific Ocean temperature records show a "hiccup" in 1988–89 when the PDO plunged into its "cool" phase for 2 years, in the middle of a two-decade-long "warm" phase. The Arctic and Atlantic Oceans also changed phases in 1988–89, but their changes have persisted. Since the 1988–89 changes, U.S. climate has swung through an El Niño wet period and back to a deep drought from 2000 to 2003.

“Any time there’s a switch in climate regimes, it produces a pulse of extreme events, whether droughts, fires, or floods,” continues Neilson. After the switch, the new climate regime still has yearly oscillations.

The heat source affecting ocean surface temperatures is the atmosphere, so more carbon dioxide in the atmosphere means warmer ocean surfaces. Also, with rapidly increasing global temperatures, climate variability may increase, causing cool decades along with warm ones.

Fire also plays an enormous role in changing ecosystems. To include the influence of fire, the team combined the MAPSS model with CENTURY, a biogeochemical model produced by a team at Colorado State University. Dominique Bachelet, biogeochemist on the team, explains that the combined MC1 model is able to simulate carbon, nutrient, and water cycles within ecosystems. It uses the data generated by climate models and then simulates the vegetation response. An attached fire model simulates the impacts of fire on ecosystem processes.



In the fully interactive MC1 model, all three boxes shown are “talking” to each other. MC1 is unique among vegetation models because it simulates fire over broad scales, and it changes plant distribution, growth, and nutrient cycling in response to simulated climate changes. These dynamics come closer to simulating real-world complexity.

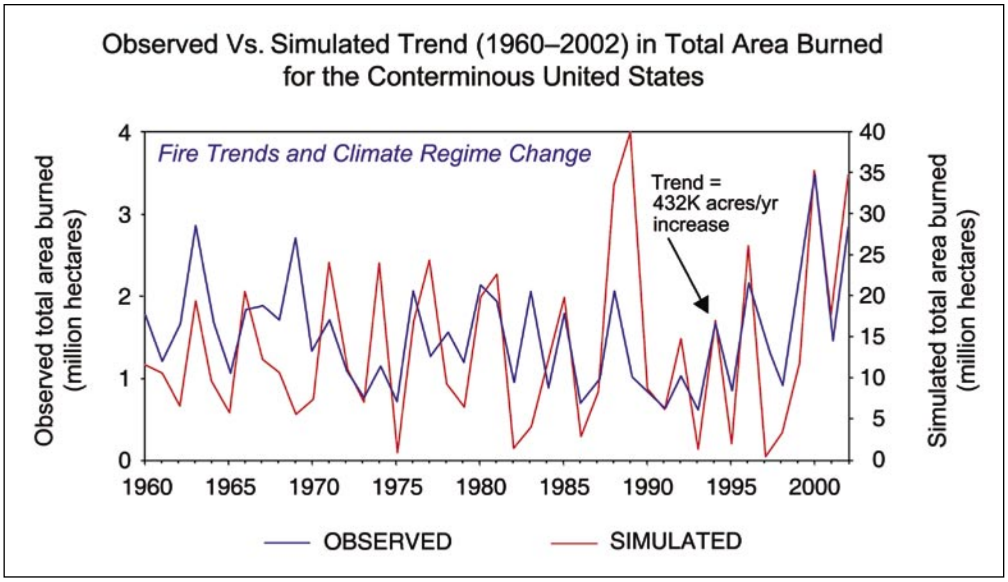
MC1 includes the growth, productivity, and decomposition dynamics that go on in ecosystems.

“After the model simulates a fire,” says Lenihan, “it goes back into the growth and nutrient part of the model.”

The model’s first validation was a test against historical records. MC1 was given no information on the fires that had occurred in the 20th century and did not have fire suppression as a factor, but only climate information, including comprehensive weather data from 1895.

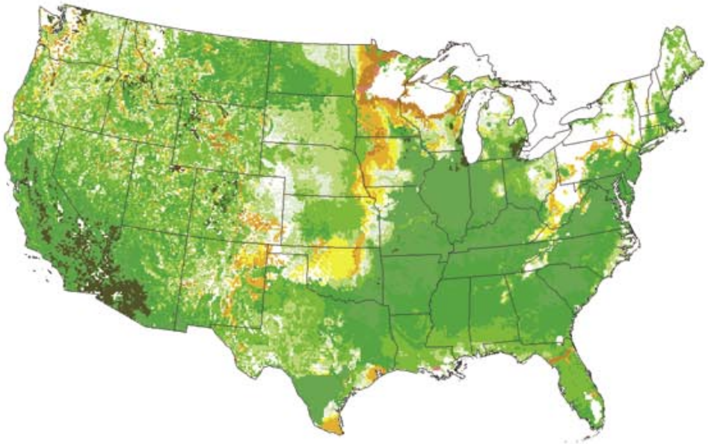
“MC1 accurately simulated the fire pulses of the last 100 years, with the big fires in the same areas as actually occurred,” says Neilson. “It simulated the 1910 fires in Idaho, and it nailed Yellowstone in 1988. It was in the ballpark on the Tillamook Burn of the 1930s and a year early on the Biscuit Fire in southwest Oregon, which actually burned in 2002.”

Thus MC1 was able to simulate 20th-century fire pulses, regions, and timing in the conterminous United States, based on climate signals alone. The major discrepancy was that the model showed burned areas about 10 times the acres actually burned. Lower actual burned acreage was likely due in large part to fire suppression.

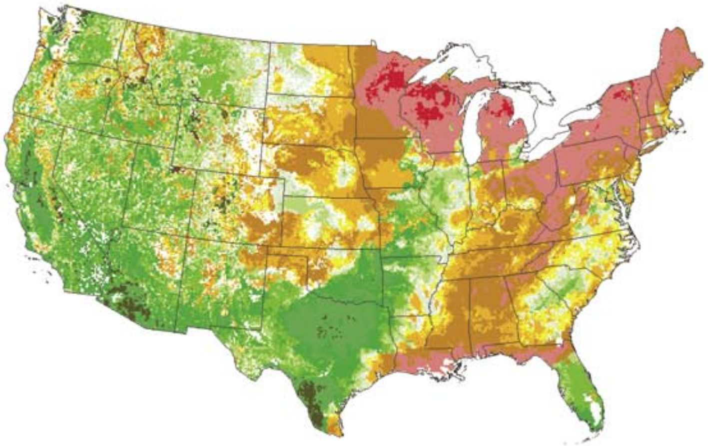


This graph shows the fire trends that MC1 simulated over the conterminous United States for a 40-year period (red line) based on climate information alone, with no fire suppression or fire ignition data. Simulated trends closely matched actual fire pulses (blue line) but at a much greater magnitude.

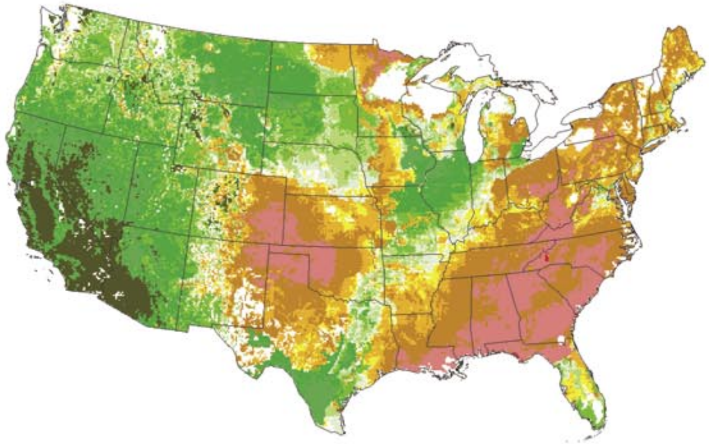
Vegetation Density Changes Under Potential Future Warming (MAPSS Simulations)



Small warming (5 °F, 22% increase in precipitation): The biosphere greens up; a sink for carbon (negative feedback).



Modest warming (7.5 °F, 18% increase in precipitation): Drought regions expand into previously greening regions. Carbon balance is near a threshold.



Considerable warming (9 °F, 22% increase in precipitation): Drought regions expand more. The biosphere becomes a source of carbon (positive feedback).

In six of seven scenarios, the West gets wetter, fostering woody expansion and increase of fuels. Colors show simulated changes in vegetation density for three climate change scenarios. Greens show increasing vegetation density, and tans-oranges-reds show decreasing density. In the conterminous United States, ecosystems might "green up" or increase in vegetation density under low levels of global warming, as shown in the top scenario. With considerable global warming, ecosystems may "brown down" or decrease in vegetation density in the East and much of the Great Plains, but the West could continue to get wetter, as shown in the bottom scenario.

The test against the historical record was a tremendous validation of the MC1 model. MC1's forecast for the next 100 years, then, might be of great interest.

What does MC1 forecast for the 21st century?

MC1 is now producing the first national-scale simulations of ecosystem and fire regime changes in the 21st century under various climate scenarios. The model uses actual climate data from 1895 to today. For simulated future climate data, the scientists use outputs from climate forecasting models.


Juniper woodlands now cover over 5 million acres in eastern Oregon, compared to less than half a million acres in 1936. Climate change likely would expand the range of some tree species but decrease the area covered by others.

"When we run the models for 100 years out into the future, we get woody expansion in the West and increased fire," says Neilson. "In six of seven future scenarios run through MAPSS, the West gets wetter throughout the 21st century, and woody and grass fuels increase." (See maps of three scenarios on previous page.) MC1, the dynamic model, has been run for two of the seven scenarios and results are comparable with the results from MAPSS, the equilibrium model.

In six of seven future scenarios, the West gets wetter throughout the 21st century, and Western summers would be hotter than now.

Although the West would be wetter, Western summers would be hotter than now. With more fuels available, in occasional dry years fires would burn both more area and more biomass than in even recent severe fire seasons. Fire risk could also increase significantly in Eastern U.S. forests if climate gets hot and dry enough, but farms, roads, and cities likely would block fire spread and reduce the actual acres burned from the catastrophic potential.

Under most climate warming scenarios, background fire levels would increase over most of the West. Fire levels would decrease only on the west side of the Pacific Northwest, where fuels would likely increase but forests would be wet enough that fire levels would change little.

In the interior West, dry forest and woodland communities, such as ponderosa pine forests and juniper communities, would likely cover more area than now. Climate suitable for Douglas-fir would extend to new areas, meaning that Douglas-fir might expand its range farther eastward from the Cascade Range and Sierra Nevada Range, and northward along the western Canadian coast into Alaska. "Simulation results show potentially suitable habitat," adds Neilson. "The model doesn't take into account species' actual seed dispersal abilities and people's land uses."

The hottest scenarios would occur if greenhouse gases, mainly carbon dioxide and methane, reached particularly high levels in the Earth's atmosphere. The more carbon that could be stored in solid form—all life forms living or dead contain carbon—the less climate warming would occur.

Is carbon storage in forests a possible way to slow global warming?

Enhanced carbon storage in ecosystems is, in fact, a major goal of the federal program to address climate change. But another forest policy is to reduce fuels and thus fire risk in the West, a policy that can release stored carbon. This key observation links the fire and fuels issue in the West to the global carbon change issue. The two issues are fundamentally coupled, yet the proposed solutions are seemingly opposed.

Carbon moves continually between solid and gaseous states. "Global ecosystems breathe carbon in during the summer, as plants grow. They breathe out in the winter, when decomposition exceeds growth," explains Neilson. "On average, 60 gigatons of carbon go into the air each year as ecosystems release carbon into the atmosphere. About 62.5 gigatons of carbon are pulled out of the atmosphere when the global ecosystem 'breathes in.' " The 2.5 excess gigatons of carbon "breathed in" are stored as new growth in trees and other plants, in essence stored as structured carbon, a process known as "sequestration."

"Our research suggests there is a threshold temperature, below which the biosphere greens up and stores carbon, but above which the biosphere becomes a source of carbon through drought, dieback, and fires, essentially a browndown."

Carbon sequestration in forests is currently a major component in international negotiations to limit greenhouse gas emissions. "But we need to understand the natural changes in the carbon budget before we can figure out if sequestration policies would be effective," comments Neilson.

The MAPSS team members use their models to study cumulative carbon change in U.S. ecosystems (simulating them as unmanaged ecosystems). Through most of the 20th century, simulated U.S. ecosystems were a net source of carbon to the atmosphere. But with a 1977 climate regime shift, the MC1 model suggests that natural U.S. ecosystems became a net carbon sink, owing to forest growth and woody expansion in the West. In addition, forests growing back on old farmland in the East are sequestering carbon. (This finding covers only carbon cycles in ecosystems, not car and factory emissions.)

In the Western United States, the conundrum would be how to balance carbon storage with reducing fuels and fire risk.

Fire Risk Forecasting, One Year at a Time

MC1 forecast potential for large fires in southwest Oregon in 2002. The Biscuit Fire, started by lightning in July, burned about 500,000 acres in the area.

In some ways, it's easier to forecast climate for a century than it is to forecast for 1, 2, or 5 years, timespans affected by El Niño–La Niña oscillations. "Although we had originally developed MC1 for long-term simulations," says Neilson, "we thought that with its fire component, it was technically sound to use for near-term forecasting."

The National Fire Plan funded the team's research into near-term fire risk forecasting. MC1 uses huge climate databases, with actual observed climate data covering the whole country from 1895 to the present. Climate databases are brought up to date each month.

For near-term forecasts, the team uses 6-month weather forecasts produced by three global climate models. Each climate model is built on different assumptions, but all three take into account fully dynamic oceans, including current sea surface temperatures and short-term anomalies such as El Niño. The three models then forecast global climate over the next 6 to 7 months, each model using its own set of rules and algorithms. Because the climate models also use different formats and measures, Ray Drapek, MAPSS modeler and geographic information systems scientist on the team, must convert these data into suitable formats for MC1.

"Since MC1 is not 'smart' enough yet to know that fires need ignition sources, I program the model with rules that trigger fires," explains Lenihan.

With all the preparation work done, the team runs the three climate forecast scenarios through MC1. The results are the first national-scale, high-resolution forecasts of fire risks in the United States that incorporate climate-driven year-to-year changes in fuel loadings and moisture characteristics. "Areas of consensus are evident under all three scenarios," remarks Neilson, "and this indicates a higher probability of accuracy."

MC1 produces 3- to 7-month forecasts of possible fire risks for the conterminous United States. In 2002, one of the worst fire seasons in decades, the model accurately predicted the fire susceptibility in the Southwest early in the season and extreme fire hazard in the Pacific Northwest later in the season.

For 2003, the model forecast that large fires could occur in southernmost Arizona, where in fact the disastrous Aspen Fire burned across nearly 85,000 acres and destroyed 333 homes and structures. It also forecast large fires in northern Montana, which occurred, including a fire in Glacier National Park that caused an evacuation of the park. MC1 forecast the approximate location of the B & B complex fires in Oregon and it forecast fires in southern California. However, because the model does not yet incorporate Santa Ana winds, it did not forecast the severity and extent of the late-season wildfire disaster in southern California.

"We're pushing the envelope in using the long-term climate models to produce near-term fire risk forecasting," comments Lenihan. By comparing actual events to their forecasts, the team sees where the model needs improvement.

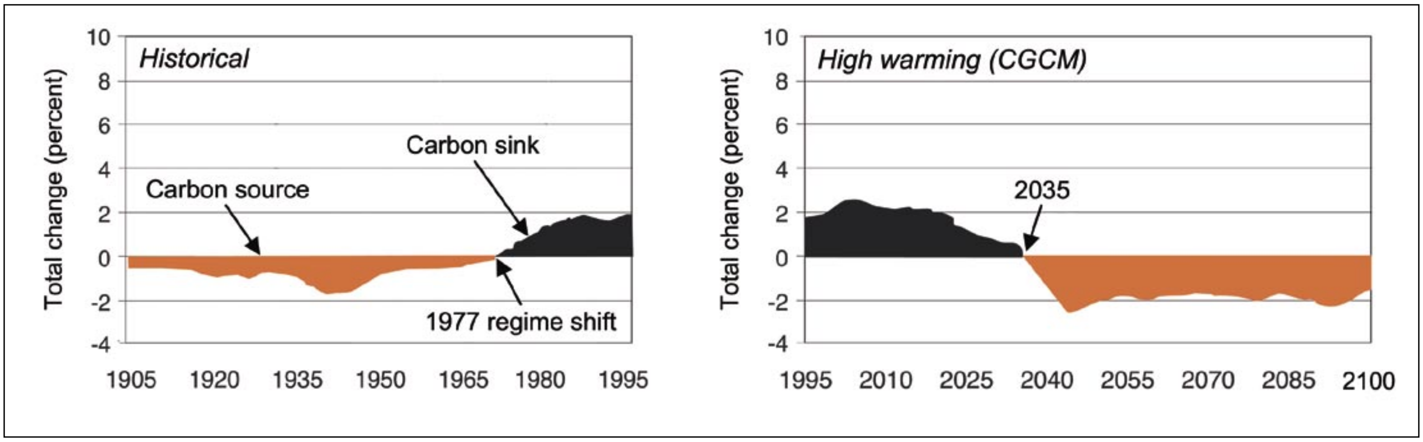
Currently they are building virtual bridges between MC1 and forest growth and yield models. More complete databases of actual fuels on the ground would be useful, and links to insect and disease simulations and land-use databases could be added in the future. Changing the grid cells to a smaller scale than currently used could mean a hundredfold increase in the data volume, but would enable forecasting for Western basin and range geography.

The accuracy of 2002 and 2003 forecasts has validated the model's approach, suggesting it can eventually be a useful planning tool for fire managers. But, the team cautions, the model should still be considered experimental. "Right now, we're barely comfortable going out 7 months with our forecasts," cautions Neilson.

Simulations for the 21st century project that for the next several decades, U.S. ecosystems would sequester so much carbon that even with increased fires, more carbon would be stored than would be burned off with fire. "Our research suggests there is a threshold temperature, below which the biosphere greens up and stores carbon, but above which the biosphere becomes a source of carbon through drought, dieback, and fires, essentially a browndown. If this occurs," says Neilson, "the biosphere in the United States would shift from net carbon storage to net carbon release, largely due to forest dieback in the Eastern United States." MC1 forecasts that point would be reached about mid-21st century under very warm scenarios, and much later in the century under other scenarios.

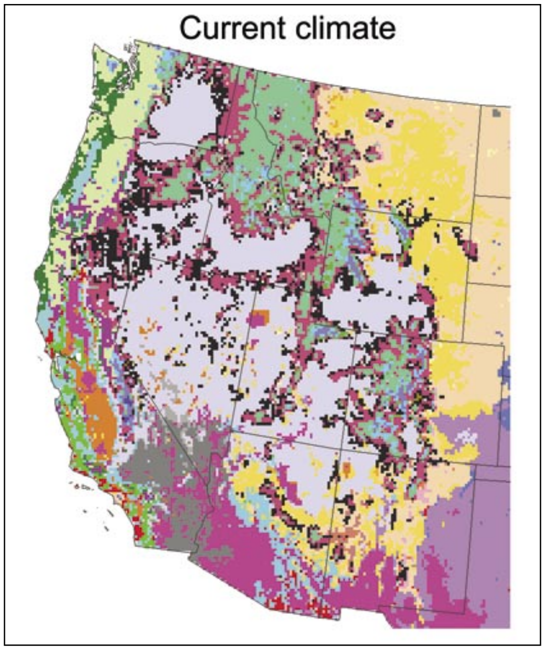
Two ways exist to limit the amount of carbon in the atmosphere, and thus reduce global warming. One way is to limit carbon dioxide emissions generated from burning fossil fuels.

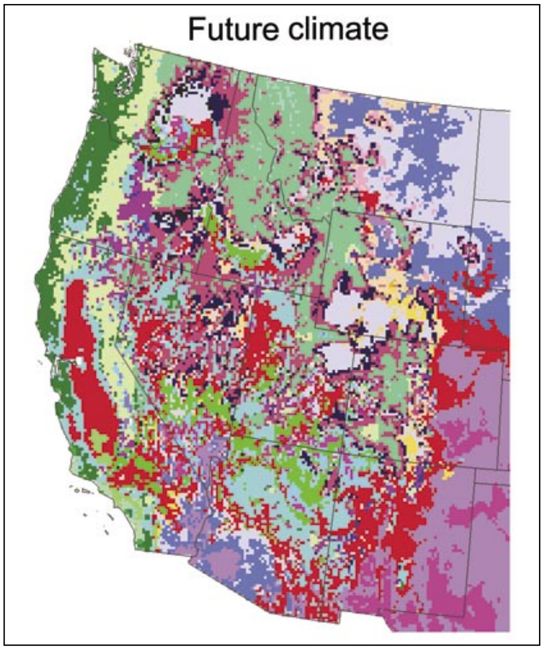
The second way is to sequester more carbon in ecosystems or bury it in geologic structures. In the Western United States, however, the conundrum would be how to balance carbon storage with reducing fuels and fire risk.



Ecosystems in the United States released more carbon than they stored until about 1977. Since 1977, ecosystems have been a net sink of carbon, owing mainly to forest growth. Under a high warming scenario (Canadian Global Coupled Model), the ecosystems would become a net source of carbon to the atmosphere again about 2035, owing to drought and fire.

Prescribed burning reduces fire hazard—but releases carbon gases into the atmosphere. Balancing the carbon budget may become a consideration in forest management.





Under a high warming scenario, the extensive sagebrush areas of the interior West could be replaced by many types of ecosystems. On the two maps:

gray—sagebrush shrub-steppe ecosystems (which currently cover extensive areas)

greens—forest and woodland types

black and maroon—ponderosa pine savannas and juniper woodlands

other colors—other forest, shrub, and grassland types.

How could forest managers respond to large-scale climate change?

A district ranger cannot control climate influences on forests. He or she can, however, manage forests with climate influences in mind. Some key issues are:

Fuels in the wildland-urban interface. When people and communities are threatened by fires, it makes little difference whether climate or past fire suppression caused the hazard. "Most likely, managers would still want to reduce fuels in the wildland-urban interface," comments Neilson.

Forest resilience to climate change. Resource managers routinely make decisions to change forest structure for a number of reasons. New reasons might include managing forests to be more resilient to drought, long hot summers, and insect and disease outbreaks. The anticipation of possible climate changes might affect decisions on which tree species to plant.

Balance of carbon storage and fuel management. Balancing the carbon budget may become a management consideration. Neilson lists some options. "If you burn fuels to reduce fire risk, you pump carbon into the atmosphere. If you use the wood as biofuels, you can offset some use of fossil fuels. If you can treat fuels in a way that keeps carbon stored, such as wood products, you can increase the carbon stored."

"Reducing wildfire risk and storing carbon seem to be in conflict with each other," Neilson points out, "challenging managers to find ways to do both."

What thresholds might we cross in the future?

To ecologists, a threshold is the point at which an ecosystem switches from one response to another, such as the greenup-to-browndown scenario. Neilson describes other thresholds that may be reached if the simulations are accurate.

"The Southeastern United States appears to be among the most sensitive regions in the world to increasing temperatures. It could convert from forest to savanna or grassland through drought, insect infestation, and massive fire."

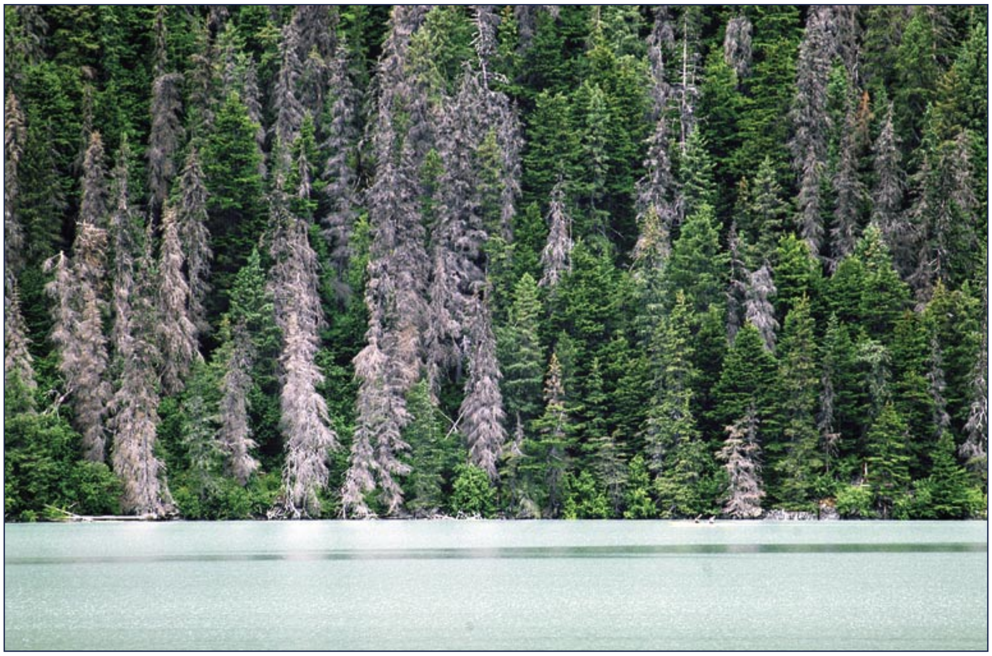
"Once a certain temperature threshold is reached in the Great Basin, species may move northward rapidly and ecosystems might change quickly. The sagebrush ecosystem could be reduced from millions of acres to isolated areas in southwest Wyoming, eastern Washington, and a few other pockets. If this occurs, it would probably be disastrous for the sage grouse and some other species, but beneficial for others. The extensive sagebrush areas of the interior West would be replaced with many types of forests and woodlands."

"We can try to enforce the ecological status quo, which will be increasingly difficult. We can sit back and let change happen. Or, we can manage for change."

Neilson adds, "We may need to rethink what ecosystems in the interior West will look like. Reducing fuels to pre-European settlement levels may be a misplaced goal. We would be trying to restore against a strong climate signal, like trying to push the tide back out into the ocean."

Even the best models can offer only best-science simulations. The world, and nature, are full of surprises. Neilson acknowledges the uncertainty.

"We have three options. We can try to enforce the ecological status quo, which will be increasingly difficult. We can sit back and let change happen. Or, we can manage for change."



Climate fluctuations have cascading effects on forests. On Alaska's Kenai Peninsula, an area loved by anglers, kayakers, and hikers, years of drought and warmer temperatures led to a spruce bark beetle outbreak that killed millions of spruce trees.

For Further Reading

Note: The September 2001 issue of *BioScience* Vol. 51(9) is a special issue with articles on the forest sector analysis of the national assessment of the potential consequences of climate variability and change.

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U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. Mapped atmosphere-plant-soil system (MAPSS). http://www.fs.fed.us/pnw/corvallis/mdr/mapss. (1 October 2003).

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Contacts

Ron Neilson, rneilson@fs.fed.us, Managing Disturbance Regimes Program, PNW Research Station.

Jim Lenihan, jlenihan@fs.fed.us, Managing Disturbance Regimes Program, PNW Research Station.

Ray Drapek, rdrapek@fs.fed.us, Managing Disturbance Regimes Program, PNW Research Station.

Dominique Bachelet, bachelet@fsl.orst.edu, Oregon State University.

Credits:

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