NIST Technical Note 1708

Initial Reconnaissance of the 2011 Wildland-Urban Interface Fires in Amarillo, Texas

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National Institute of Standards and Technology • U.S. Department of Commerce

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Abstract

On February 27, 2011, a fire began in the outskirts of Amarillo, Texas, that destroyed or damaged buildings in three housing developments. The National Institute of Standards and Technology (NIST), as part of its Disaster and Failure Studies Program, deployed a team within 44 hours to conduct an initial reconnaissance to document the fire event loses and fire behavior. The deployment was conducted jointly with the Texas Forest Service (TFS). Of interest to the NIST deployment was the fire behavior and effects on fire losses of topographical features, structure construction and defensive actions. The two communities initially evaluated were the Willow Creek South Complex and the Tanglewood Complex. Within 72 hours after data collection initiation, the Tanglewood fire became the focus of the deployment. Additionally, destroyed and damaged structure data were collected to support the local and state damage assessment efforts. The Tanglewood Complex wildland-urban interface (WUI) fire was responsible for the destruction of approximately 101 structures including 35 residences.

The NIST WUI field data collection method was used for the first time in a field deployment where it was integrated into the Incident Command System, logistics and standard operating procedures (SOPs). Field measurements included structure particulars, specifically building construction materials, type of combustibles and proximity of combustibles to the structure, and damage to wildland and residential vegetation. Documentation included over 29 000 photographs. The data collection and initial analysis was conducted jointly with TFS.

The overall objectives of this study are to establish the likely technical factor or factors responsible for the damage, failure, and/or successful performance of buildings and/or infrastructure in the aftermath of the fire, and to recommend, as necessary, specific improvements to standards, codes, and practices based on study findings. This study also may be used to define areas of future research.

This summary report addresses the particulars of the deployment and the data collection methodology used. Additionally, this report provides a summary of the primary structures lost. A second more detailed technical report will provide the event timeline reconstruction and general fire behavior observations as well as investigate the impacts of structure attributes, landscaping characteristics, topographical features and wildland fire exposure on structure survivability.

KEY WORDS: Wildland Urban Interface, WUI, fire behavior, community fires, Amarillo fires, WUI data collection methodology

1. Introduction

The National Institute of Standards and Technology (NIST) is working to reduce the risk to buildings and communities at the wildland-urban interface (WUI) posed by wildland fires through improvements to building and fire standards, codes, and practices based upon findings from studies of these events. NIST has statutory authority to deploy teams of technical experts to conduct disaster studies under the NIST Organic Act as amended by America Competes Act of 2010 and the Fire Prevention and Control Act (1974). NIST deployed a team to conduct an Initial Reconnaissance of the wildland fires that broke out near Amarillo, Texas on February 27, 2011. The fires destroyed homes and other structures in three developed areas and have been named by the Texas Fire Service (TFS) the Willow Creek Fire, the Tanglewood Fire and the Country Club Fire.

An Initial Reconnaissance is a field study at the disaster or failure site to gather information and to determine if a Full Reconnaissance study is warranted. The two objectives of the Initial Reconnaissance where aimed at:

(1) Establishing the likely technical factor or factors responsible for the damage, failure, and/or successful performance of buildings and/or infrastructure in the aftermath of a disaster or failure event.

The focus of the field study was on fire behavior and the effects on fire losses of topographical features, structure construction and the effects of defensive actions taken to control the fire. The two communities initially evaluated were the Willow Creek South Complex and the Tanglewood Complex. The Tanglewood Complex became the focus of the deployment within 72 hours after data collection began. Additionally, destroyed and damaged structure data were collected to support the local and state damage assessment efforts.

(2) Recommending, as necessary, specific improvements to standards, codes, and practices as well as any research and other appropriate actions based on study findings.

The NIST WUI field data collection method was used for the first time in the field and evaluated as to how well it could be integrated into the Incident Command System, logistics and standard operating procedures (SOPs).

The NIST WUI field data collection method is being developed as a first generation tool for improved risk assessment and risk mitigation in WUI communities vulnerable to wildfires. These tools will be developed and tested through a coordinated effort that includes laboratory and field measurements, physics-based fire behavior models, and economic cost analysis models.

In 2007, the NIST WUI Team was invited by the California Department of Forestry and Fire Prevention (CAL FIRE) to collect post-incident data from the October 2007 fires in California. The NIST WUI Team initiated a case study within the Witch Fire perimeter.

The case study[1] focused on The Trails development at Rancho Bernardo, 40 km (25 miles) north of the City of San Diego. There were 274 homes in The Trails, including 245 within the fire perimeter. Seventy four homes were completely destroyed and 16 were partially damaged. The NIST data collection effort was designed to provide the necessary information to characterize the fire approach from the wildlands, the effects of fire within the community and the defensive actions that were taken. The intent was to collect sufficient information, not only to characterize the overall fire behavior in the WUI, but also to provide a foundation for future case studies such as the one described in this report. Following the Witch/Guejito fire data collection and analysis effort, NIST developed a two phase data collection methodology.

The Texas Fire Service also has been conducting WUI case studies. Since 2006, the Texas team has conducted five case studies: the Cross Plains Fire, Significant Fire Report, Wilderness Ridge Fire, Montague Complex and 1148 Complex.[2] NIST and TFS worked together in October 2010 to train TFS personnel in the NIST WUI data collection methodology. The NIST hardware was pre-staged in Texas and several field training exercises were conducted to maintain data collection proficiency. The fires burning around Amarillo in February 2011 provided a unique opportunity for NIST and TFS to document the WUI fire event losses and fire behavior.

Field measurements were made at the Willow Creek and Tanglewood Complex fires. (A third fire in the Amarillo area, refered to as The Country Club fire, was not studied because of the limited damage to structures.) The report focuses primarily on the Tanglewood Complex fire. Data collected included structure particulars, specifically roof type, proximity and type of combustibles to the structure, and damage to wildland and residential vegetation. The data collected included over 29,000 photographs. This summary report will address the particulars of the joint NIST[3]/TFS efforts and the data collection methodology, including information on 35 destroyed structures. A second more detailed technical report will provide the reconstruction of the event timeline and general fire behavior observations as well as document the effects on structure survivability of structure attributes, landscaping characteristics, topographical features and wildland fire exposure.

2. Location of Fires

The fire perimeters and general locations of structural losses/damage of the Willow Creek fire, Tanglewood Complex fire and Country Club fire are shown in Figure 1. Structural

[1] Alexander Maranghides and William Mell, "A Case Study of a Community Affected by the Witch and Guejito Wildland Fires," Fire Technology, Volume 47, Number 2, 379-420, April 2011.

[2] Texas Forest Service Case studies, http://texasforestservice.tamu.edu/main/popup.aspx?id=10080&terms=Case+studies

[3] The field deployed NIST Team consisted of Alexander Maranghides, Glenn Forney. The remote NIST team consisted of Ruddy Mell, Derek McNamara (McNamara Consulting), and Jason Trook (Coeur D'Alene Indian Tribe)

losses and damage for the Willow Creek fire were confined to the southeastern portion of the fire, as shown in Figure 2. Losses for the Tanglewood Complex fire were confined largely to the northern portion of the fire with one structure damaged and one structure destroyed near the southeastern area, near the fire origin (Figure 3). The focus of this report is the Tanglewood Complex fire. The decision to focus on the Tanglewood Complex was based on initial reconnaissance of extensive defensive actions at Willow Creek. Extensive defensive actions reduce the usability of the data set for assessing structure ignition and fire spread information. Additionally, a significant number of losses from the Willow Creek fire were to mobile homes, a point of interest to the NIST WUI effort, but not currently under study.

The Tanglewood Complex fire ignited in the vicinity of the western intersection of Palomino Dr. and Pinto Dr. According to the Randle County Sheriff's Department, the source of ignition remained indeterminate as of April 19, 2011. The 911 dispatch was received at 13:44[4] and the TFS dispatch was contacted at 16:32. Fire suppression activities continued into the early morning hours of February 28, 2011.

[4] Radio Log, Randall County Sheriff Department.

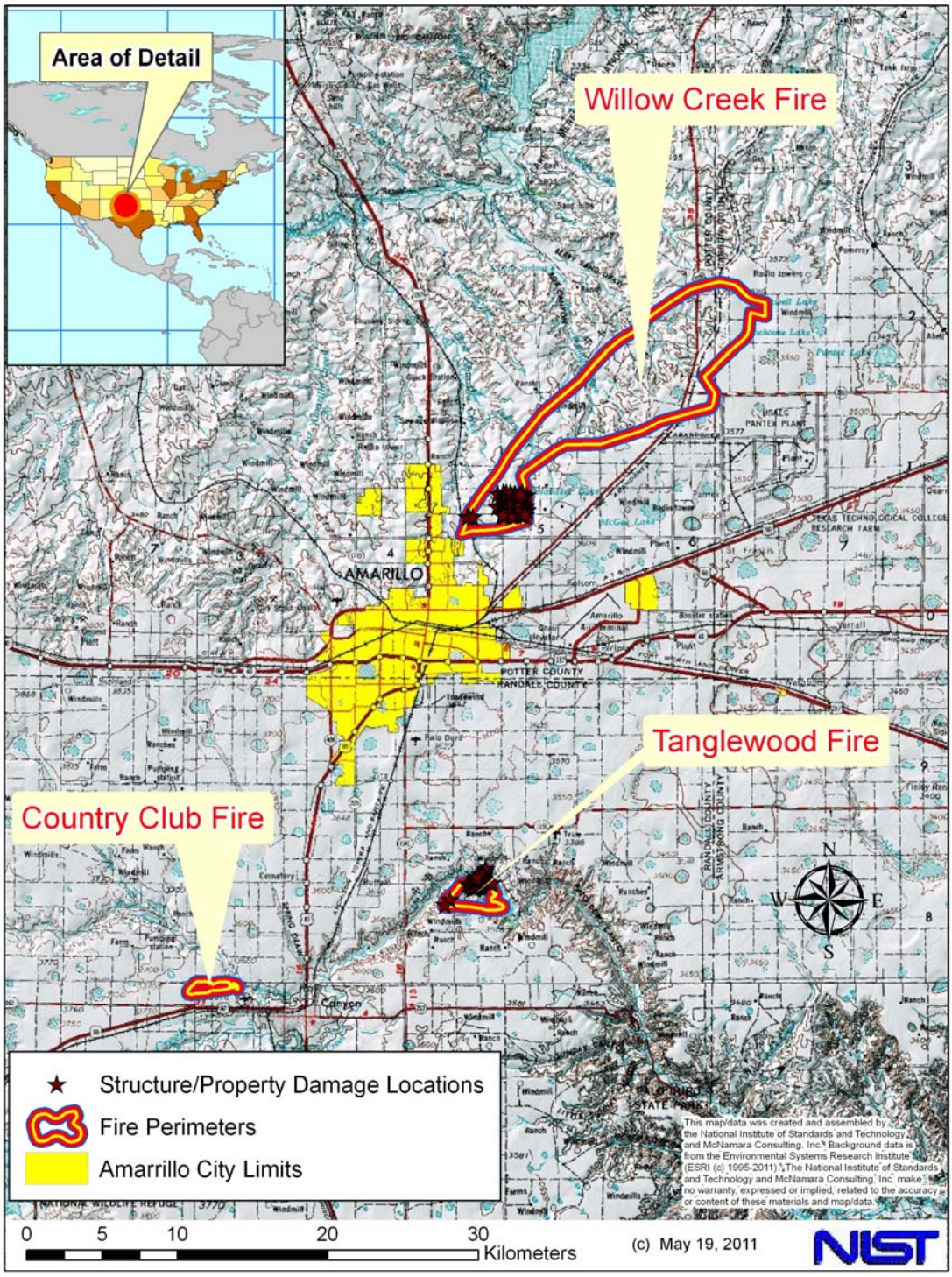


Figure 1 Location of fires around Amarillo, Texas.

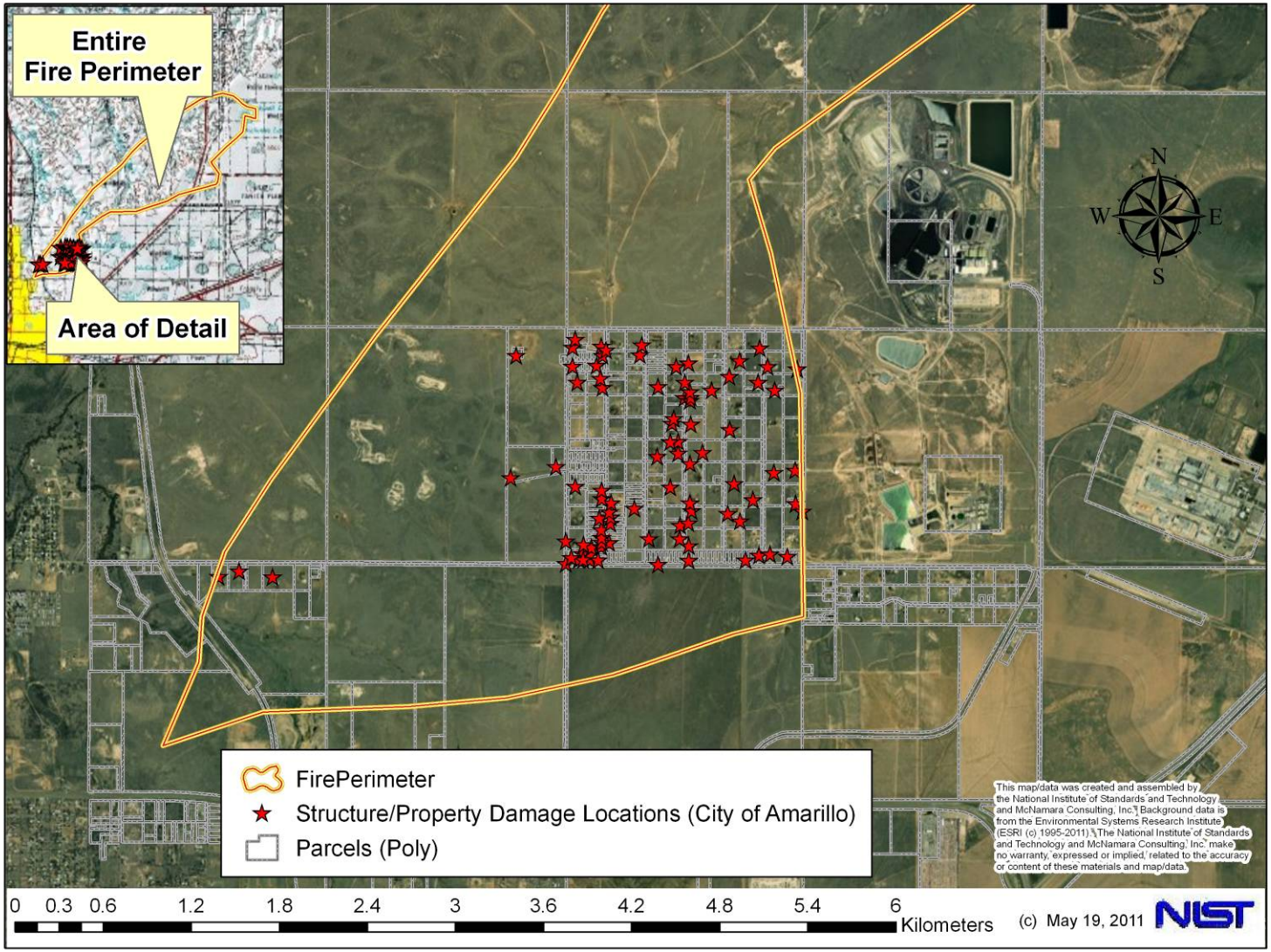


Figure 2 Willow Creek Fire portraying area of property damage.

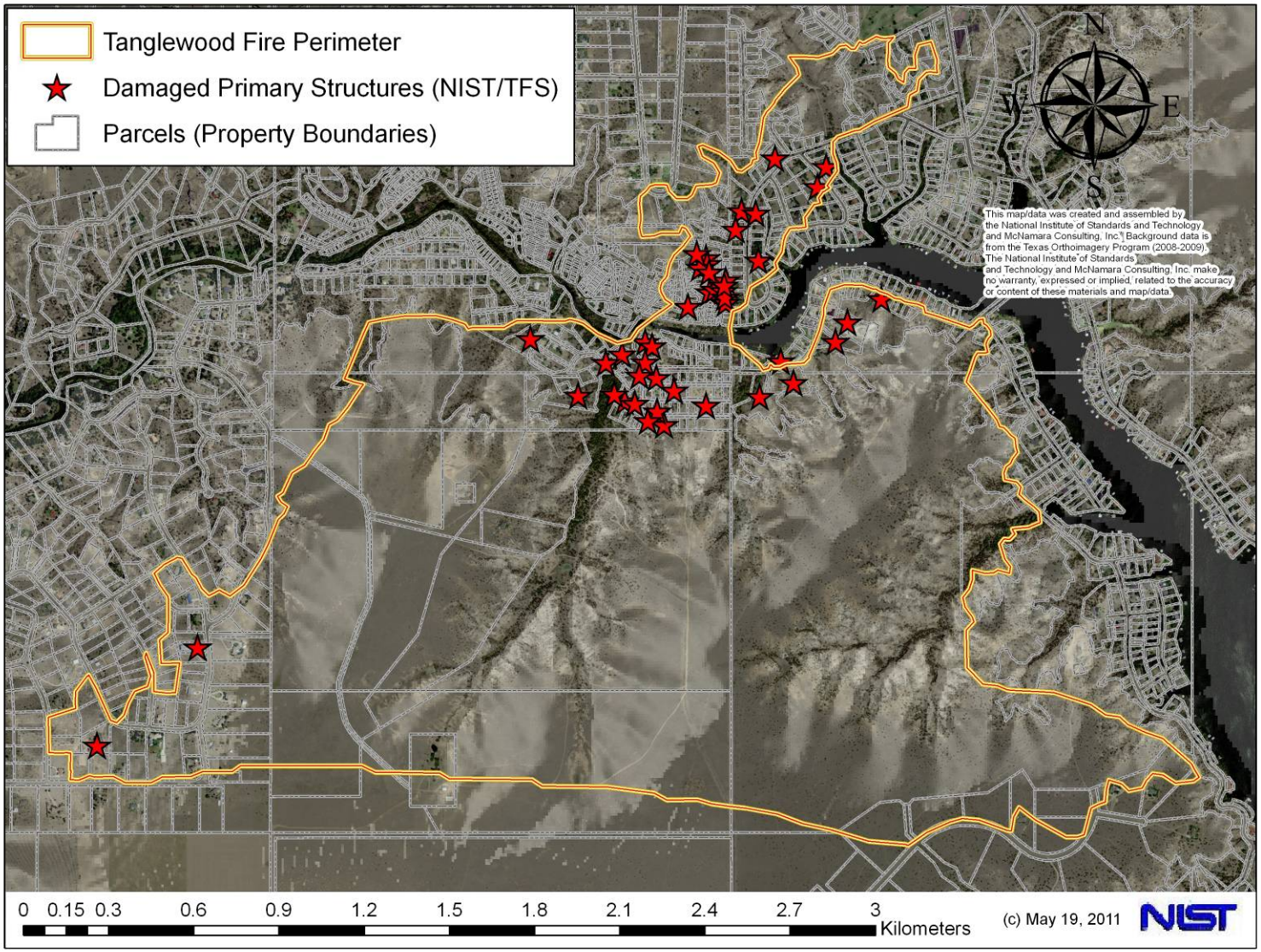


Figure 3 Tanglewood Fire perimeter portraying damage/destruction to primary structures.

3. Weather Synopsis

The following weather summary for the February 27, 2011 wildfires was provided by the National Weather Service's (NWS) Amarillo Office.[5]

> "A surface low pressure system strengthened and moved east-southeast across the northern portion of the Panhandle Region on February 27th. At the same time, an upper level low moved northeast across southeast Colorado and southwest Kansas. A strong thermal ridge set up across the Texas Panhandle by mid-day and slowly shifted east by the evening hours. As a result, strong southwest winds brought very dry and warm air into the area during the afternoon hours. The rapid heating at the surface under sunny skies allowed very strong winds at higher levels in the atmosphere east of the upper level low to mix down to the surface, producing widespread high winds, extremely critical fire weather conditions, and blowing dust across the Texas Panhandle. [See Figure 4.] Sustained winds between 40 and 45 mph (65 and 73 km/h), with gusts as high as 70 mph (113 km/h), were reported all across the Texas Panhandle. As a result, blowing dust developed with visibilities dropping below one mile several times. Relative humidity values dropped well below 10% across the entire Panhandle Region and combine this with the high winds across the area, extremely critical fire weather conditions developed [Figure 5]. A Red Flag Warning, High Wind Warning, and Blowing Dust Advisory were all in effect for all of the Texas Panhandle and southern Oklahoma on February 27th, 2011 [Figure 6]. A cold front pushed through the area after sunset shifting wind directions and increasing relative humidity values behind the front, thus decreasing the fire threat.
>
> During the fires, NWS Amarillo utilized numerous weather instrumentation sources including satellite data, the KAMA (Amarillo International Airport) radar, and several observations from across the area. However, surface observations are scarce across the different elevations in terrain over the Panhandle Region including off the Caprock and in the Palo Dura Canyon State Park. Surface winds can vary significantly in small changes in elevation so having additional observational equipment in numerous locations in the bottom of the canyon and along the creek beds would not only significantly help NWS forecasters, but also help local fire officials understand the potential behavior of the fire. Additional Remote Automated Weather Stations (RAWS) or West Texas MesoNet stations would be extremely helpful in cases of wildfires in these areas."

Specific weather information for the Tanglewood Complex fire.

At the time the Tanglewood Complex fire was reported (13:44 Eastern Standard Time) on February 27, 2011, the Amarillo International Airport local Remote Automated Weather Station (RAWS- KAMA) located 16 miles northeast of the fire, reported winds at 41 mph sustained and gusts of 60 mph out of the southwest. The Lake Tanglewood WAIS log[6], located at the entrance to Tanglewood subdivision, reported average winds of 31 mph out of the southwest at the same time.

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[5] Krissy Scotten, NWS Amarillo Office, email communication, March 28, 2011.

[6] Weather data from KVII television station, Amarillo, TX.

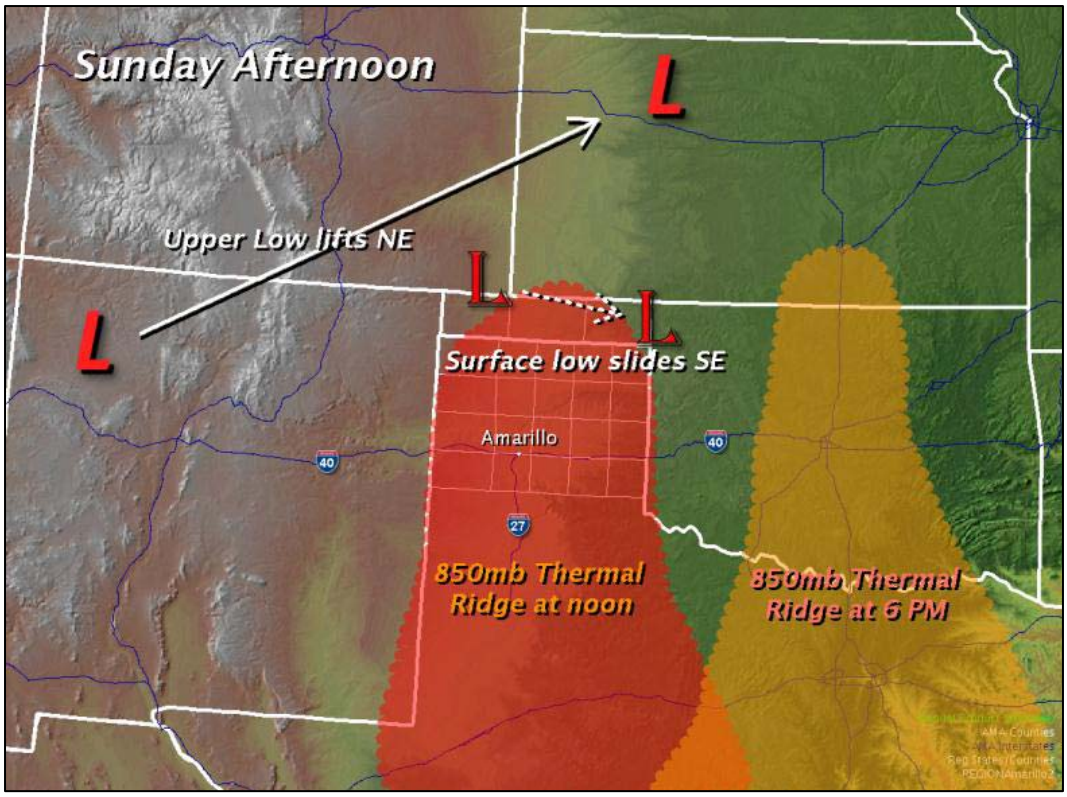


Figure 4 The Storm Prediction Center day one weather outlook for February 27th, 2011.

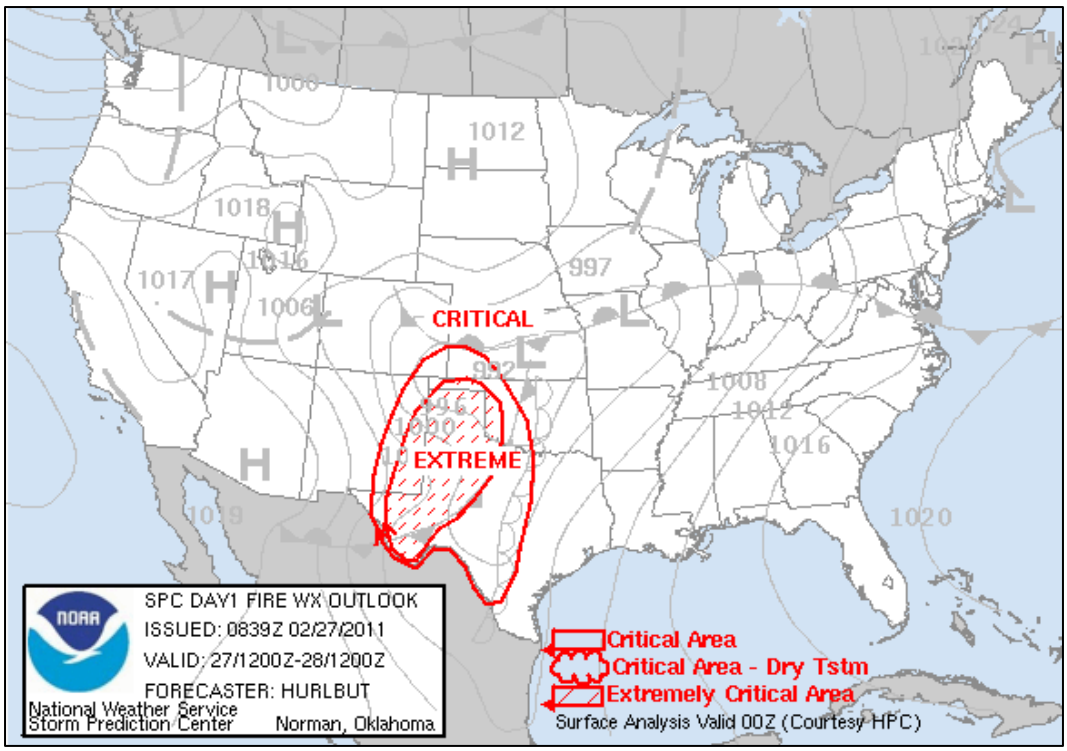


Figure 5. The weather set-up across the Texas Panhandle on February 27, 2011.

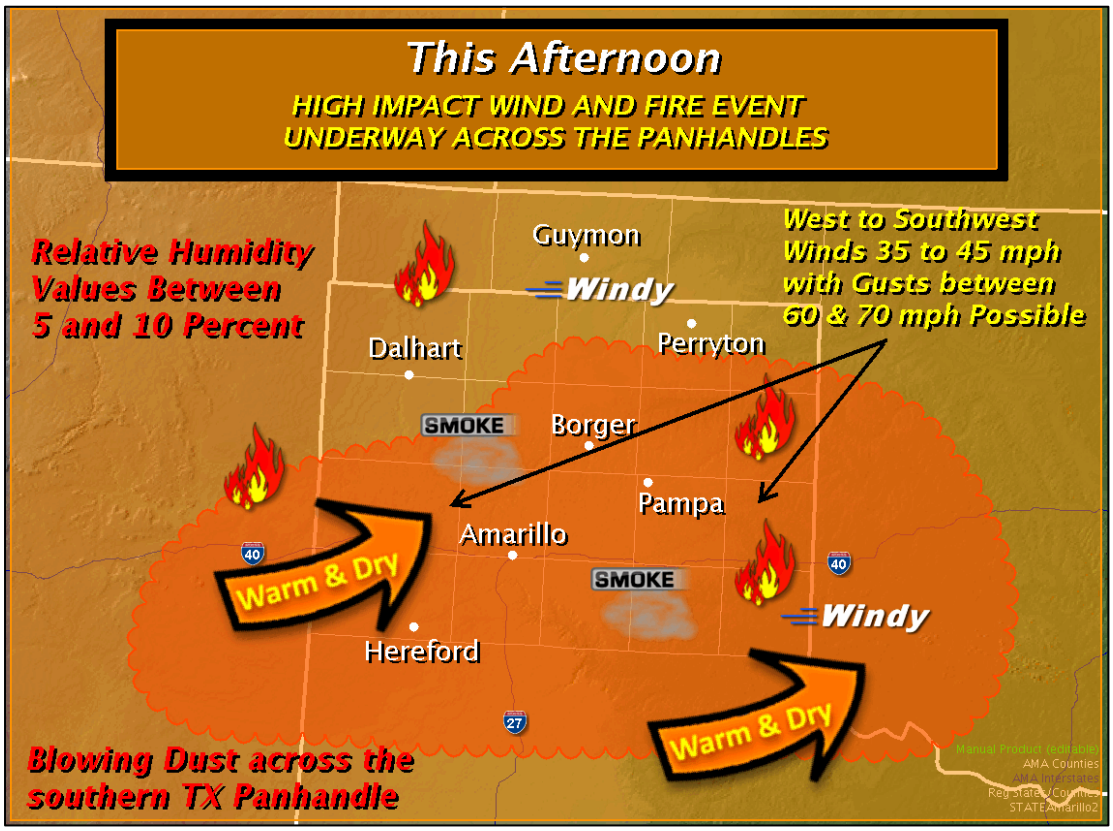


Figure 6. NWS Amarillo Graphicast© depicting the extremely critical fire weather conditions on February 27, 2011.

4. WUI Data Collection Background

NIST has developed a two tiered approach to enable the collection of reliable post WUI fire data. The first tier, called WUI 1, is used to collect widespread data across the entire fire perimeter, while the second tier, WUI 2, focuses on specific communities of interest. By collecting and analyzing data from disparate WUI fire affected communities across the United States, key vulnerabilities and common attributes in WUI fires might be identified.

In anticipation of a severe fire season NIST and the Texas Forest Service (TFS) worked together in October 2010 to train TFS personnel in the NIST WUI data collection methodology. The NIST hardware was pre-staged in Texas and several field training exercises were conducted to develop and maintain data collection proficiency.

WUI 1: single form data collection

The WUI 1 data collection methodology consists of a single page data collection form (see Appendix B). Needed hardware include a camera and a GPS unit. The single page form is filled out for all structures within the fire perimeter, not just the structures that were damaged or destroyed, enabling the collection of critical baseline information. This is a critical component of the methodology as it enables a valid assessment of the vulnerabilities of structures in the WUI.

The WUI 1 data collection methodology was tested at the Willow Creek fire. While the methodology was successfully tested, limited resources prevented the completion of that data collection effort. Recommendations for improvements to the WUI 1 data collection methodology can be found in the Appendix of this report.

WUI 2: GIS based data collection including timeline reconstruction

The WUI 2 data collection method is based on the Geographic Information System (GIS). Figure 7 provides an overview of the NIST WUI 2 Post-Fire Incident Assessment procedures. The figure illustrates how all the pre-fire and post-fire data fit together from the parcel all the way to the community levels. The WUI 2 assessment is assembled through a combination of field/office data collection and production activities.
The methodology is designed around a parcel-centric data collection and storage architecture. Tablet PCs are loaded with high-resolution imagery and parcel information prior to field use. At the end of each day, the parcel-centric structure and landscaping attributes are uploaded into the WUI 2 data base. Quality Assurance/Quality Control (QA/QC) checks are then performed overnight and new parcel data is readied for field use for the next day.

Timeline reconstruction is a critical part of the WUI 2 data collection methodology. This is accomplished primarily by technical discussions with first responders and collection of timeline information such as radio logs and time-stamped images or video. Extensive defensive actions were taken by local and non-local fire departments. The actions will be documented in the full technical report of the Tanglewood Complex Fire. Figure 8 provides a graphical representation of the information collected through property data

collections. Figure 9 is a photograph of a data taker using a tablet PC while inspecting a fire damaged structure.

The Amarillo NIST/TFS Deployment Team

A review of deployment and study procedures and data collection protocols can be found in Appendix A. Alexander Maranghides was the NIST Reconnaissance Leader and Karen Ridenour was the TFS Strike Team Leader. Glenn Forney (NIST) provided data handling support while Derek McNamara (McNamara Consulting) and Jason Trook (Coeur D'Alene Tribe) provided NIST GIS support and quality control/quality assurance. The TFS WUI 2 field data collectors were Landon Temple, Sean Rissel, Wade Powell, Dwight Dold, and April Phillips. Karen Stafford (TFS) conducted both WUI 2 and WUI 1 data collection and Justice Jones (TFS) conducted exclusively WUI 1.

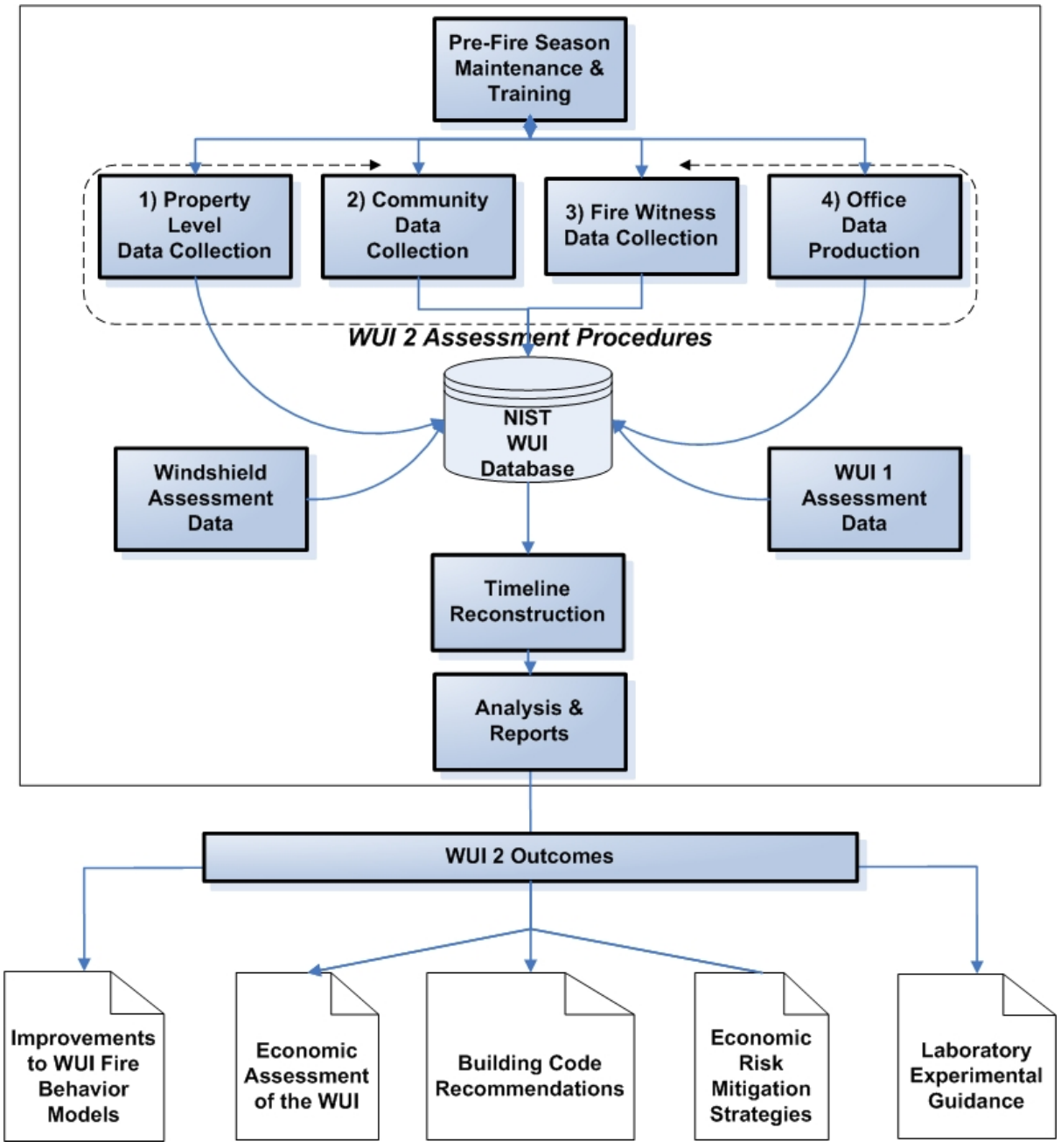


Figure 7 Overview of WUI 2 assessment procedures with anticipated outcomes.

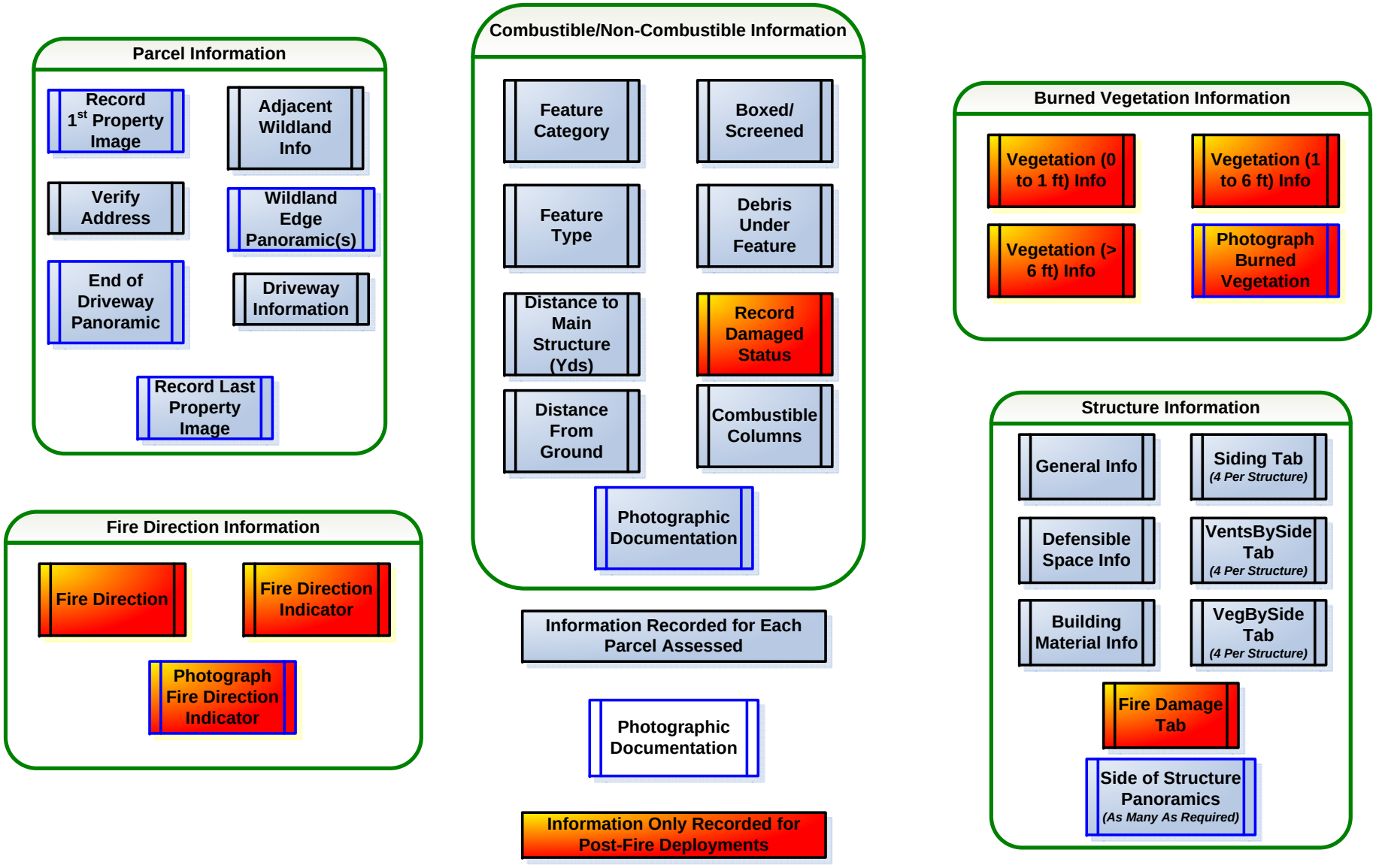


Figure 8 Graphical representation of data collected for NIST WUI assessment property data collections.



Figure 9 Tanglewood Complex Fire WUI 2 data collection using the tablet PC (NIST photo).

5. Interactions with State and Local Agencies

The agencies and organizations listed in this section provided critical information regarding the Amarillo Fires. Extensive coordination with these different agencies and organizations was necessary in order to capture the data during the initial reconnaissance. The parties coordinated their information collection through telephone conversations, email exchanges and in-person meetings. Twenty three different agencies and organizations were contacted during the initial reconnaissance deployment. The information that was collected is being used to develop the fire timeline for the Tanglewood Complex fire and to provide fire ignition information for the Willow Creek fire.

Agencies/Organizations:

- Amarillo 911 Center
- Amarillo Fire Department
- *Amarillo Globe News*
- Amarillo/Potter/Randal Emergency Operation Center
- Amarillo Tax Appraisal Office
- City of Amarillo
- Happy Volunteer Fire Department
- KVII-TV, Amarillo Texas, ABC Affiliate
- Lake Tanglewood Police Department
- National Weather Service
- Palisades VFD
- Pantex Fire Department

- Potter County Fire-Rescue
- Potter County Sheriff Office
- Randall County Fire Coordinator
- Randall County Fire Department
- Randall County Sheriff Office
- Tanglewood VFD
- Texas Department of Public Safety
- Texas Governor's Office
- Texas Small Business Administration
- Timber Creek VFD
- West Texas A&M University

6. NIST and Texas Forest Service Deployment Timeline

The Willow Creek and Tanglewood Complex fires started in the early afternoon hours of Sunday, February 27, 2011. The TFS Team Lead (Ridenour), who was out of state on leave, received information from TFS that structures had burned in the Amarillo area. This information was communicated to NIST at 20:00. The NIST GIS team initiated data collection in anticipation of a possible NIST deployment. TFS activated their WUI data collection team at 20:00 on February 27. On Monday, February 28, NIST made the decision to deploy personnel for an Initial Reconnaissance study at 14:28. On February 28, TFS personnel started mobilizing and part of the team arrived in Amarillo with the data collection kits while NIST personnel traveled to Texas. Table 1 describes the major events of the deployment timeline.

The data collection process assigned resources between the Tanglewood Complex and the Willow Creek fires. Based on initial reconnaissance and the available resources, it was decided to conduct WUI 2 at the Tanglewood Complex and WUI 1 at Willow Creek. The Willow Creek site lent itself to WUI 1 because it had a simple road network and well-defined community boundaries.

This WUI 1/WUI 2 assignment approach was maintained until the completion of the data collection on March 20, 2011. The number of field data collection teams available, ranging from two to four teams at any given time. Resources also were allocated to collect timeline and general incident particulars. Since the data collection resources permitted only one WUI 2 data collection effort, the primary effort was on the Tanglewood Complex fire.

The data collection and analysis processes were run continuously, 24 hour a day for 21 days. The daily safety brief was conducted at 07:00. The tablet PCs were subsequently loaded and field data collection was conducted during daylight hours. Post field work included data transfer and handling. Overnight work was conducted to check data into the database, check data out of the database, create field maps and perform a limited QA/QC.

Table 1 Fire deployment timeline.

Date and Time (mmddyy, hh:mm)	Event/Action
022711 15:00	TFS Team Leader informed of WUI structural loses
022711 20:00	TFS informs NIST of losses. Information gathered to determine appropriate NIST response and pre-deployment actions began in the event a decision is made to deploy a NIST team.
022711 20:00	TFS Team initiated deployment
022811	TFS Team mobilized – kits collected and team drives to Incident Command Post (ICP) (Merkel) to check in and proceeds to Amarillo
022811	NIST decision to conduct Initial Recon and travel to Dallas/Ft. Worth
030111	NIST Team travels to Merkel to check in, meet with TFS Team Lead (Ridenour) and proceeds to Amarillo
030111	TFS Field data collection initiated in Tanglewood and Willow Creek
030111 – 032011	Field data collection
032111	TFS Team demobilizes and drives to ICP (Merkel).

7. Data Collected using WUI 2

The immediate post-fire field deployment focused on property level and fire witness data collection. Due to time constraints community field data collection activities (refer to Figure 8) have not been conducted to date. The information pertaining to a community data collection relates to transportation networks, utilities, water supply, first responder distance and vegetation present in the community and can be collected after the incident. Fire witness data collection/discussions were conducted with homeowners and first responders. These discussions will be ongoing throughout the Tanglewood Complex fire analysis. Office data reduction has begun and will also be ongoing through the Tanglewood fire analysis. The remainder of this section focuses on the information collected through property data collections.

Property data collection began by defining areas for each WUI Assessment Team to assess. Data collection areas are defined at the parcel level[g] with each Team being provided a group of parcels to assess for the respective data collection day. Each property level assessment begins by recording the first image taken on the property, typically of the electronic parcel form containing the parcel identifier and address. Burned vegetation, fire direction[h], combustible and non-combustibles features, structure type, defensible space, building materials, fire damage, vegetation treatments, fire responder accessibility and photographic documentation are recorded for each property. Figure 10 shows the area assessed, at a parcel level, for the property data collection activities. Efforts were focused on collecting information on residential properties that experienced fire. It is believed each property containing a structure and experiencing fire was assessed during the Tanglewood deployment. Parcels containing structures and no evidence of fire may be assessed at a later date.

The parcels containing vegetation that burned, shown in Figure 10, were broken into 272 polygons. The vegetation polygons may overlap as the data was collected in layers. It is estimated that while 385 acres were delineated, when the polygon overlaps are considered, the actual area is reduced to about 336 acres. Tables 2 through 5 summarize the field observations. These observations are preliminary and may be updated as the analysis continues. Note that estimates of combustible/non-combustible features and structures were edited significantly after returning from the field based on pre and post-fire aerial imagery, information obtained from the Potter-Randal Appraisal District, information obtained from the City of Amarillo and NIST/TFS recorded ground images. Fire direction and burned vegetation data have not been analyzed to date.

Figures 11 through 16 show locations and the extent of fire, including direction observations, delineated burned vegetation, primary and secondary structures, combustible features and non-combustible features assessed by the NIST/TFS Team. Initial information on defended properties is identified in Figure 16. This information may be modified as the current information is analyzed and more data are collected.

The wildland vegetation on the plateau in the area of the Tanglewood Complex fire is primarily *Bouteloua dactyloides*, commonly known as Buffalograss or Buffalo Grass, a prairie grass native to North America. The Buffalo Grass was commonly used as an ornamental grass for landscaping. The analysis of the wildland fuels associated with the Tanglewood Complex fire will be part of the detailed technical report.

[g] Parcels range in size from a fraction of an acre to many acres.

[h] Fire Direction can be obtained by many different field indicators such as needle freeze – the process of leafs or needles loosing their moisture and "freezing" in the downwind direction.

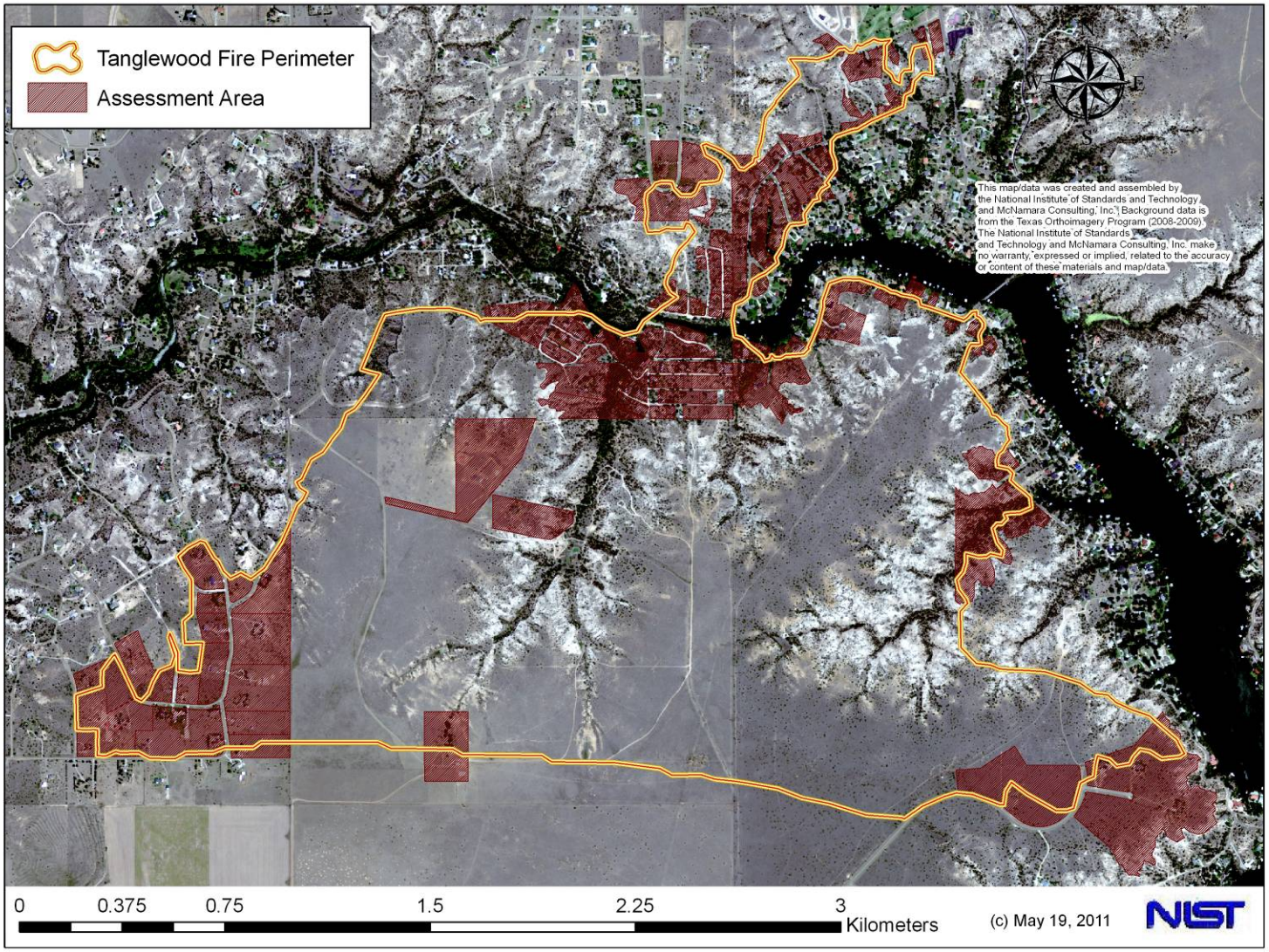


Figure 10 NIST/TFS Tanglewood deployment property assessment area.

Table 2 NIST/TFS recorded fire direction observations.

Fire Direction Type	Number of Observations Recorded
Flame Spread (Needle Freeze)	18
Flame Spread (Scorching)	154
Fire Jump (Embers)	88
Radiant Heat	9

Table 3 NIST/TFS assessed structures.

Structure Type	Number Assessed
Single Family Residences	150
Guest Homes	3
Mobile Homes	15
Accessory Structures	223
Car Ports	19

Table 4 NIST/TFS assessed combustible features[i].

Type	Number Assessed	Type	Number Assessed	Type	Number Assessed
Decks	62	**Utilities**	1	**Furniture**	620
Pergolas /Gazebos	24	**HVAC**	19	**Vehicle**	121
Kennels	15	**Corrals**	2	**Plastic Pools**	2
Fences[j]	161	**Lawn Mowers**	43	**Planters**	46
Retaining Walls	140	**Brush Piles**	17	**Wagons**	7
Patios	49	**Grills (no gas)**	46	**Mailbox**	1
Propane Tanks	37	**Boats**	38	**Dog Houses**	5
Playground Equipments	67	**Trailers**	79	**Lawn Art**	207
Hot Tubs	11	**Grouped Tires**	12	**Docks**	3
Stairs	36	**Wheelbarrows**	9	**Gas Cans**	4
Building Materials	107	**Trash Piles**	16	**Oil Containers**	2
Dustbins	51	**Work Benches**	5	**Grouped Railroad Ties**	23
Bird Feeders	2	**Door Mats**	2	**Grouped Landscape Timbers**	24
Stock Feeds	4	**Bridges**	5	**Campers**	15
Firewood Piles	79	**Trash Containers**	3	**Other Combustibles**	97

[i] Additional combustibles were captured in the ground images and have not been mapped to date.
[2] Single connected fences and retaining walls were sometimes recorded as multiple points.

Table 5 NIST/TFS assessed non-combustible features[k].

Type	Number Assessed	Type	Number Assessed
Deck	1	**Pools**	4
Pergolas /Gazebos	2	**Planters**	1
Kennels	4	**Communication Towers**	7
Fences[l]	57	**Camper**	1
Retaining Walls	35	**Corral**	1
Patios	19	**Scrap Metal**	3
Propane Tanks	37	**Boats**	3
Playground Equipments	7	**Grills (no gas)**	6
Hot Tubs	1	**Barrel**	1
Stairs	17	**HVAC**	2
Other Non-Combustibles	44	**Machinery**	1
Lawn Art	24	**Building Material**	27
Lawn Furniture	27	**Bridge**	1

[k] Additional non-combustibles were captured in the ground images and have not been mapped to date.
[l] Single connected fences and retaining walls were sometimes recorded as multiple points.

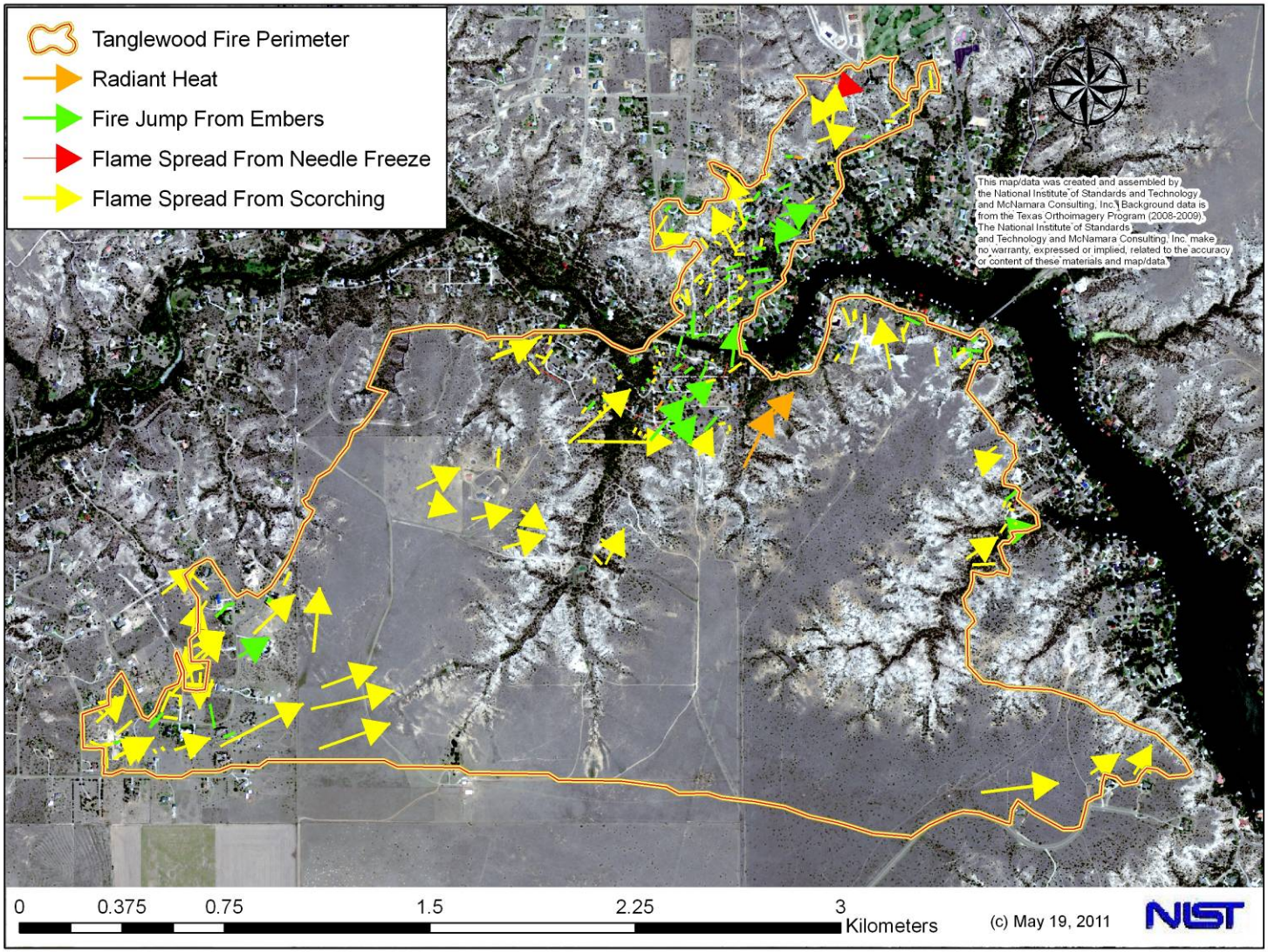


Figure 11 NIST/TFS fire direction observations.

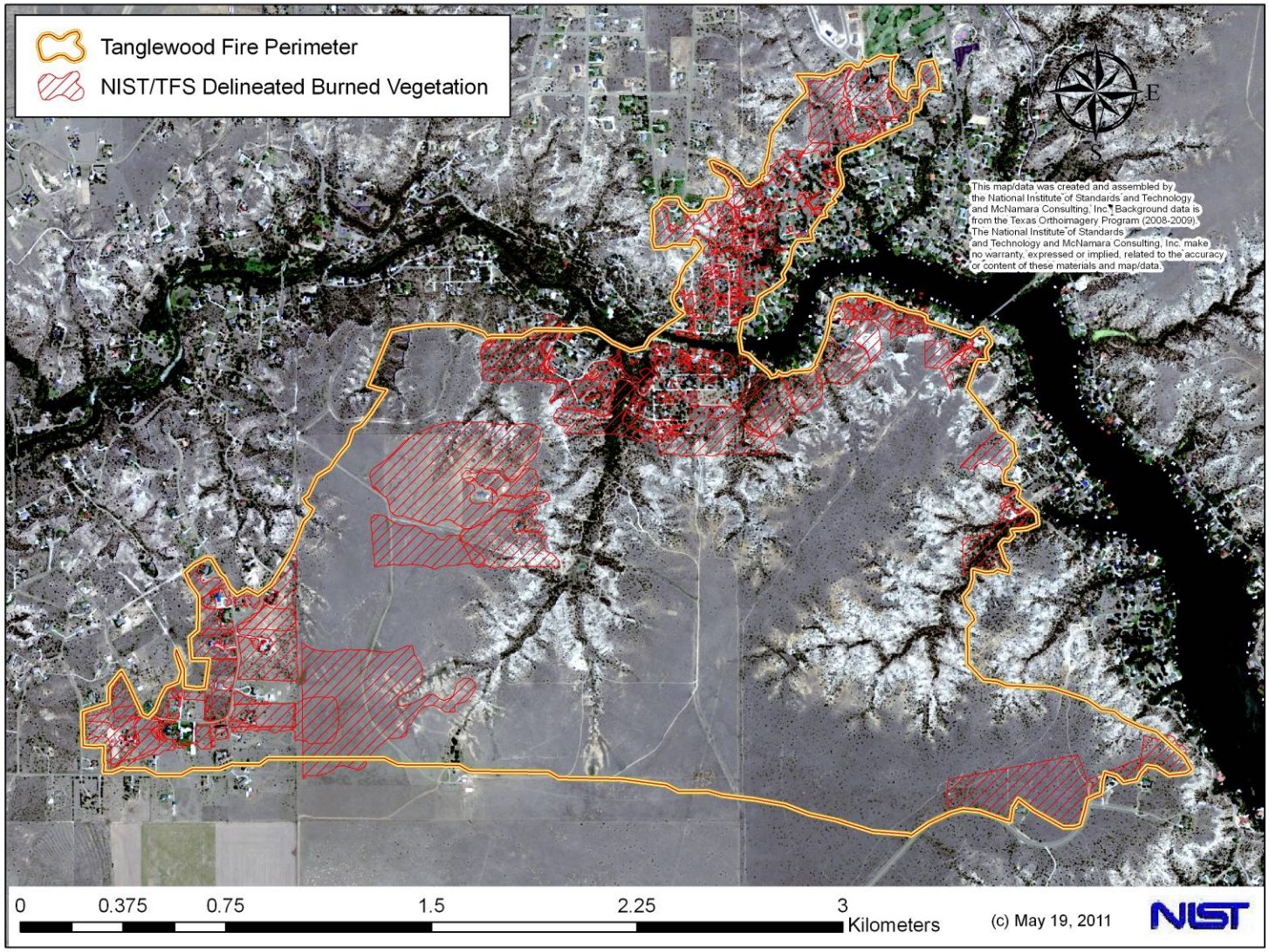


Figure 12 NIST/TFS burned vegetation observations.

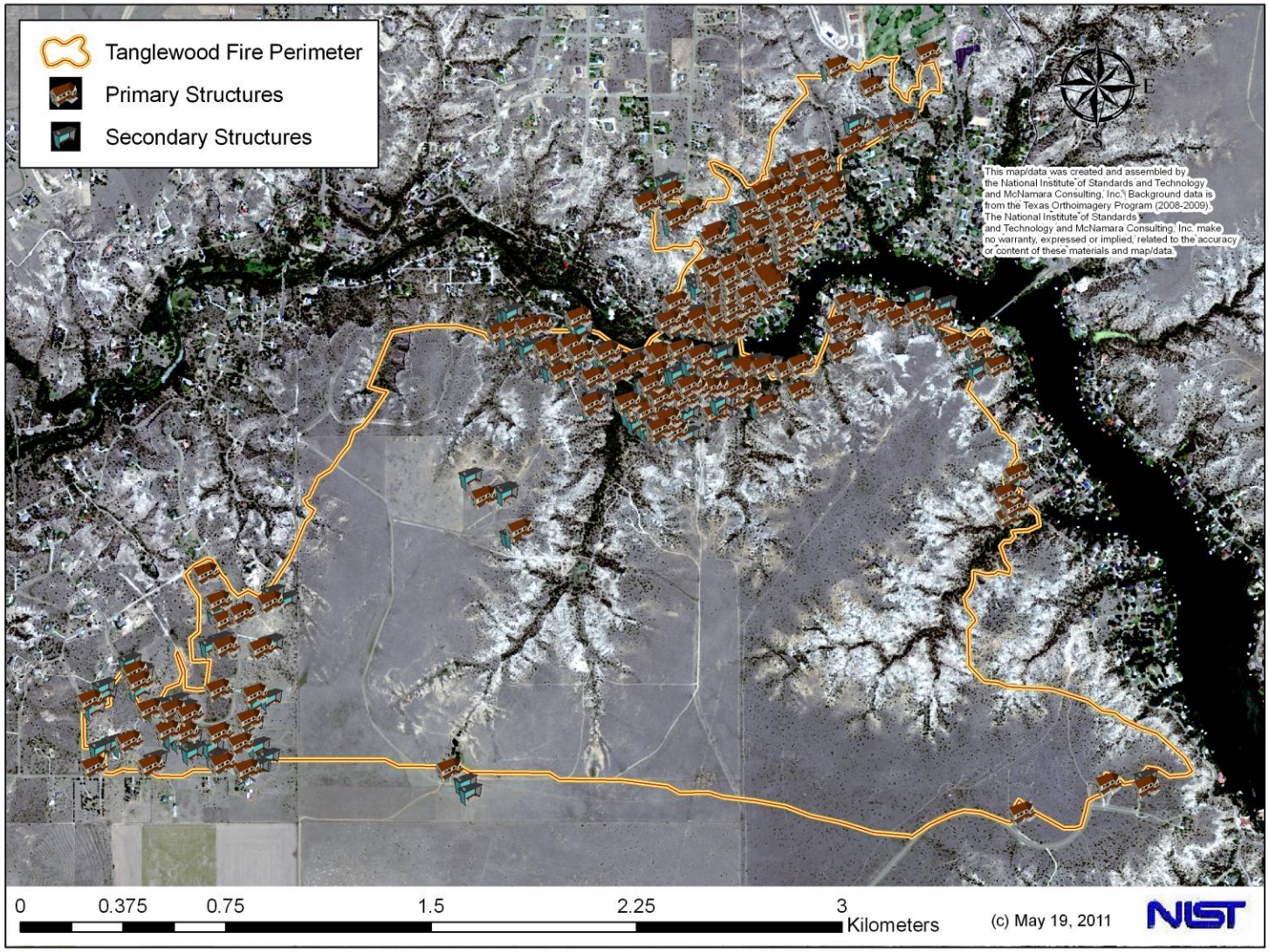


Figure 13 NIST/TFS assessed primary and secondary structures.

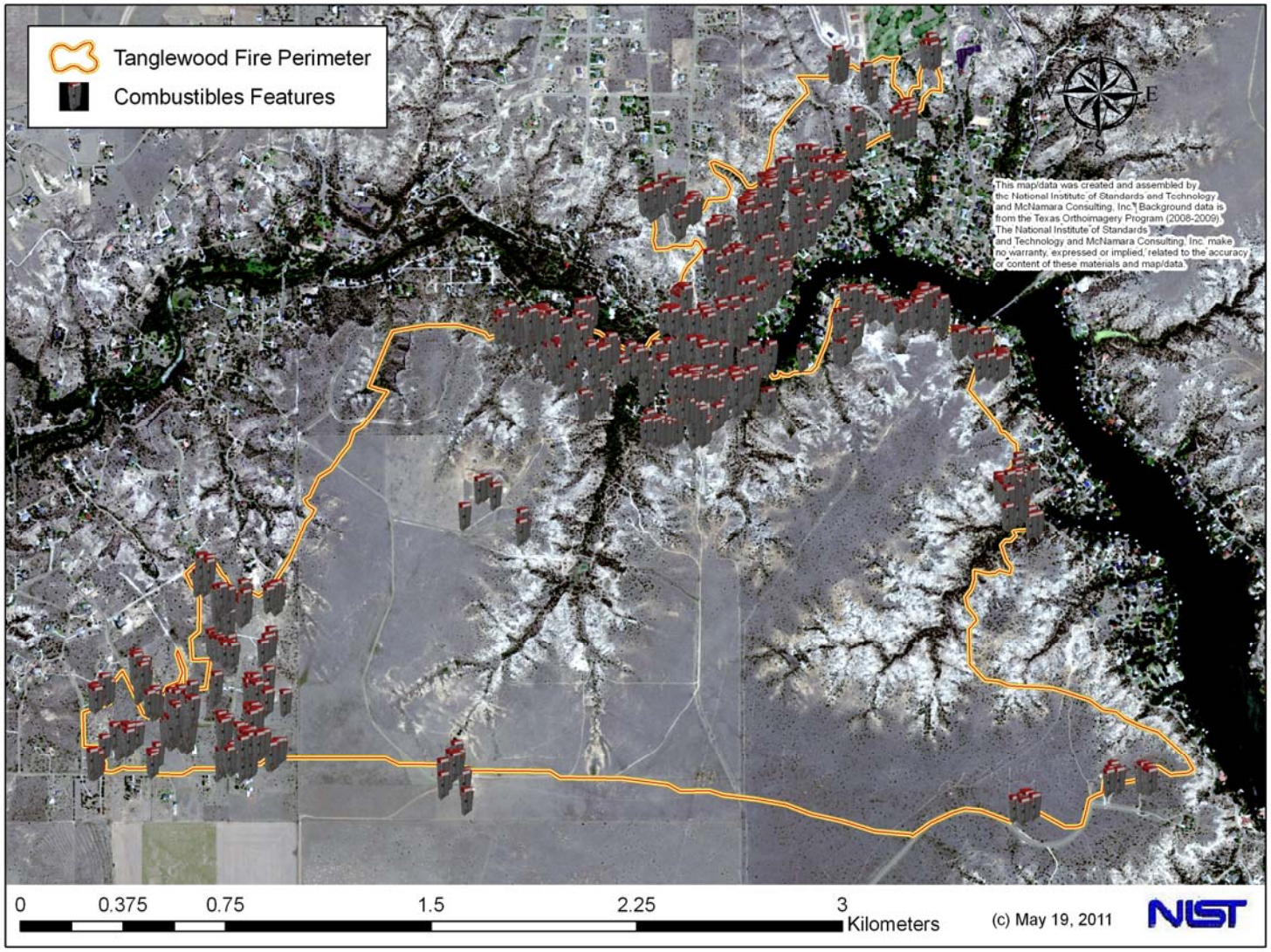


Figure 14 NIST/TFS assessed combustible features.

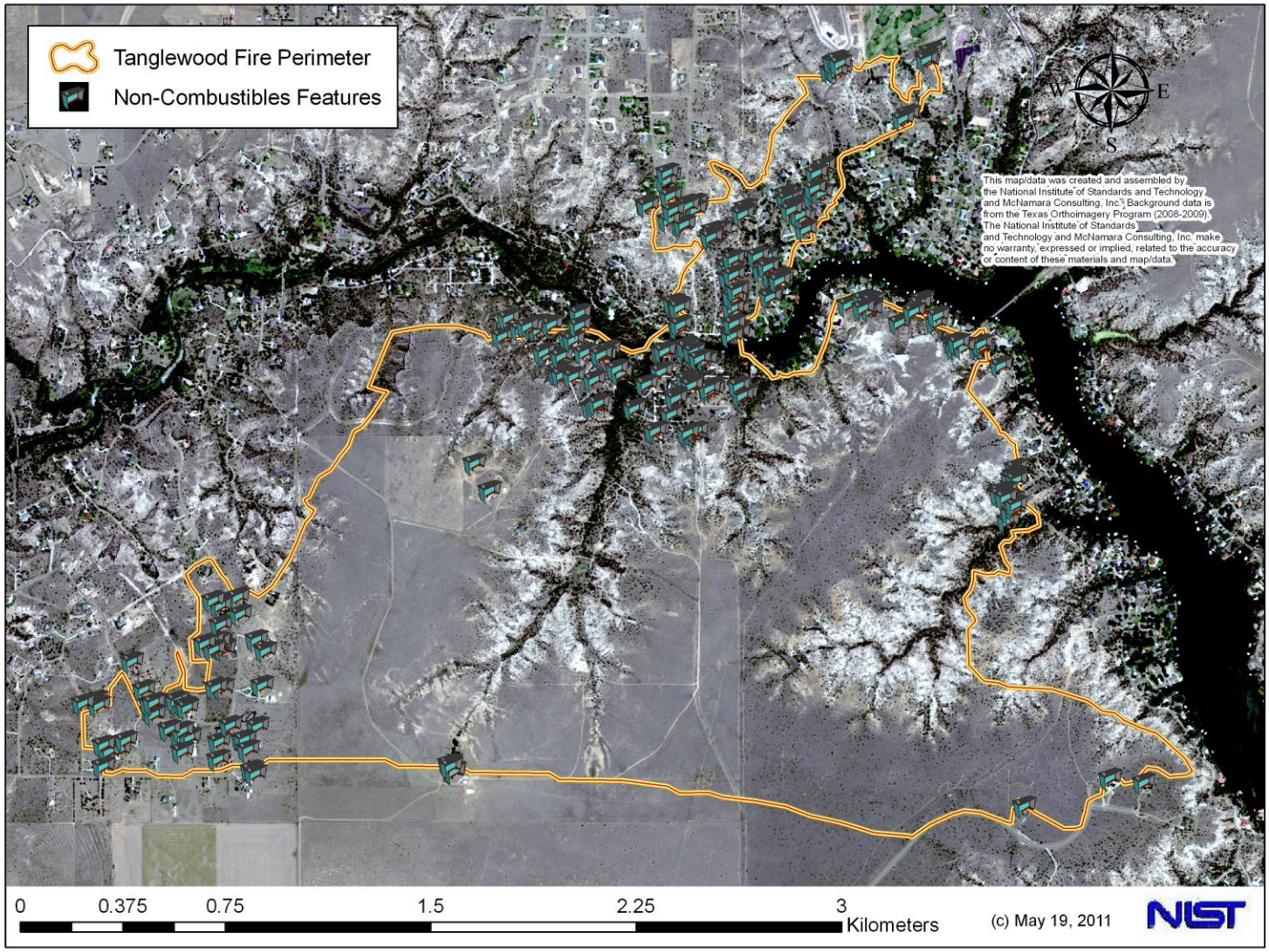


Figure 15 NIST/TFS assessed non-combustible features.

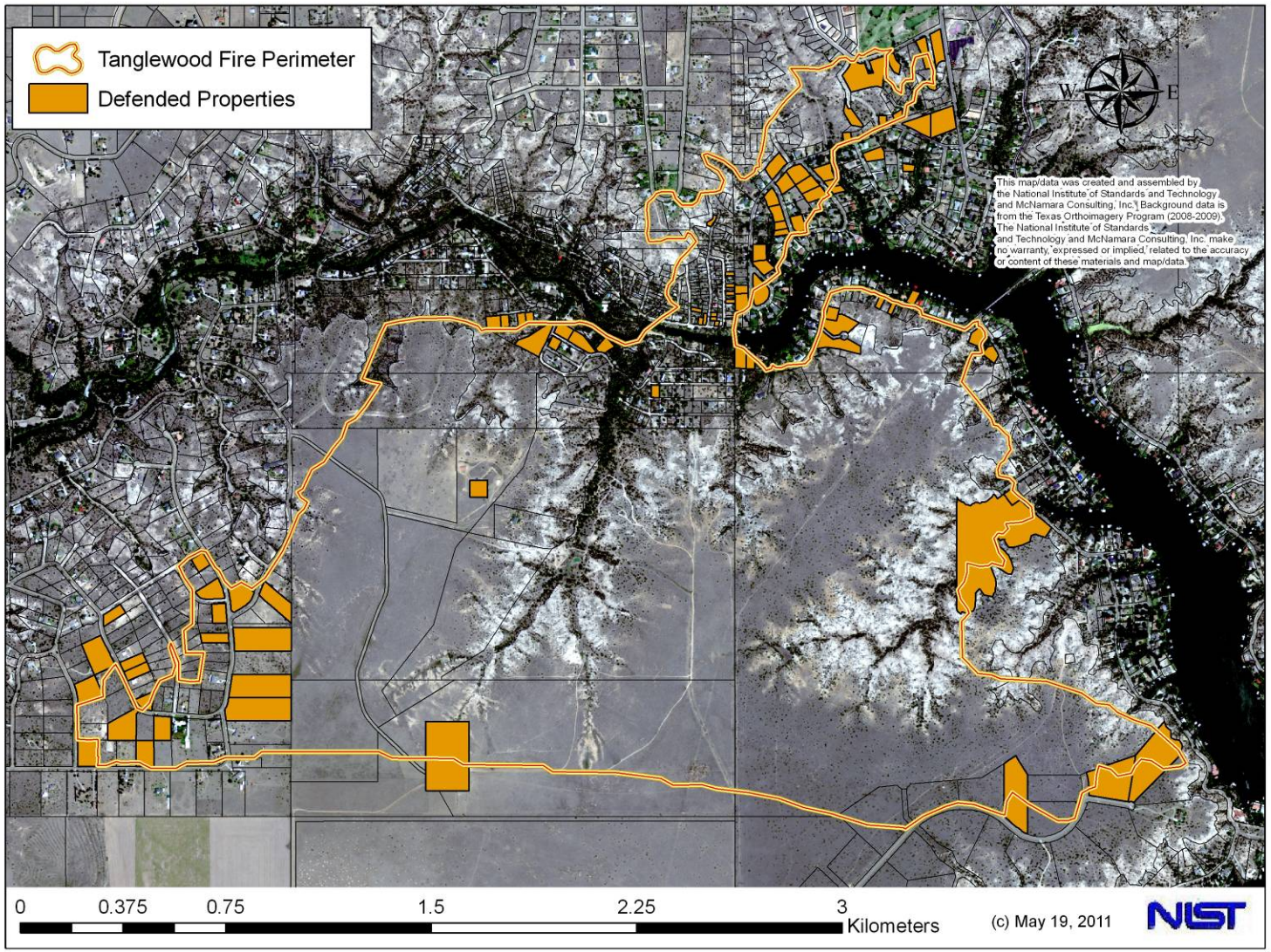


Figure 16 NIST/TFS identified defended properties.

8. Destroyed and Damaged Structures

Table 6 contains a list of identified damaged and destroyed primary structures from the Tanglewood Complex fire. The list was compiled from data collected by NIST/TFS, the City of Amarillo and the Texas Small Business Association. There are discrepancies between the various sources for a number of reasons:

- Different organizations use different definitions for "damaged" depending on the purpose of the assessment. The City of Amarillo and the Texas Small Business Administration (SBA) were primarily concerned with habitability of structures while NIST/TFS were interested in any fire related damage. Consequently, the NIST/TFS team identified a greater number of damaged structures.
- Different organizations use different definitions of primary structures. The City of Amarillo and the Texas SBA did not appear to consider secondary homes on a single lot as primary structures. The NIST/TFS allowed for multiple primary structures on a single lot if the structures all serve the same purpose (e.g. a main structure and a mobile home on a single lot that were both used as residences were both considered primary structures).
- Different databases used by the different organizations might portray addresses differently.
- Different data collection teams from the City of Amarillo and NIST/TFS interpreted the respective damage categories differently as the categories are not standardized.
- Different levels of rigor were applied to the different assessments. The NIST/TFS team spent 21 days on the deployment and more than 60 person-hours after the deployment, utilizing numerous data sources to clean up data and ensure all damaged/destroyed structures were delineated correctly. The City of Amarillo had significantly less time to conduct their assessment and it is believed the Texas SBA obtained their data largely from the City of Amarillo.

The use of pre and post-fire aerial imagery from the Environmental Systems Research Institute (ESRI 1995-2011) coupled with Potter-Randal County Assessor data was essential to mapping the correct number of secondary structures. This is likely the only feasible method for obtaining accurate counts of destroyed secondary structures, short of extensive discussions with homeowners, many of whom were no longer in the area since their homes had been damaged or destroyed.

Table 6 Destroyed and damaged primary structures.

Address	NIST/TFS	City of Amarillo	Texas SBA
100 Colony Rd	Destroyed Single Family (SF)	Destroyed SF	Not in List
102 Gary Dr	Destroyed Mobile Home (MH)	Destroyed MH	Destroyed MH
102 Port-o-Call Dr	Destroyed SF	Destroyed SF	Destroyed SF
102 S Shore Dr	Destroyed SF	Destroyed SF	Destroyed SF
106 Gary Dr	Destroyed SF	Destroyed SF	Destroyed SF
110 S Shore Dr	Destroyed SF	Destroyed SF	Destroyed SF
111 Gary Dr	Destroyed SF	Destroyed SF	Destroyed SF
112 Exmoor Rd	Destroyed SF	Destroyed SF	Destroyed SF
113 Janet Dr	Destroyed SF	Destroyed SF	Destroyed SF
565 Canyon Creek Dr	Destroyed Guest Home (GH)	Destroyed GH	Not on List
118 Bayshore Dr	Destroyed SF	Destroyed SF	Destroyed SF
119 Bayshore Dr	Destroyed SF	Destroyed SF	Destroyed SF
120 Russel Dr	Destroyed SF	Destroyed SF	Not on List
120 Saint Andrews Rd	Destroyed SF	Destroyed SF	Destroyed SF
122 Exmoor Rd	Destroyed SF	Destroyed SF	Destroyed SF
125 Exmoor Rd	Destroyed SF	Destroyed SF	Destroyed SF
126 Exmoor Rd	Destroyed SF	Destroyed SF	Destroyed SF
128 Exmoor Rd	Destroyed MH	Not on List	Not on List
130 Exmoor Rd	Destroyed MH	Destroyed MH	Destroyed SF
130 Saint Andrews Rd	Destroyed SF	Destroyed SF	Destroyed SF
131 Saint Andrews Rd	Destroyed	3 Destroyed SF[m]	Destroyed SF
134 Saint Andrews Rd	Destroyed MH	Destroyed MH	Destroyed MH
135 Saint Andrews Rd	Destroyed MH	Not on List	Not on List
136 S Shore Dr	Destroyed SF	Destroyed SF	Destroyed SF
144 Bayshore Dr	Destroyed SF	Destroyed SF	Destroyed SF
338 Cactus Dr	Destroyed SF	Not on List	Destroyed SF
465 Casino Dr	Destroyed SF	Destroyed SF	Destroyed SF
506 Casino Dr	Destroyed SF	Destroyed SF	Destroyed SF
507 Casino Dr	Destroyed SF	Destroyed SF	Destroyed SF
513 Casino Dr	Destroyed SF	Destroyed MH	Destroyed MH

[m] It is believed this is a data entry error. Only one structure should be reported.

Table 6 (continued) Destroyed and damaged primary structures.

Address	NIST/TFS	City of Amarillo	Texas SBA
519 Casino Dr	Destroyed MH	Not on List	Not on List
519 Casino Dr	Destroyed SF	Not on List	Not on List
55 Jamie Ln	Destroyed SF	Not on List	Not on List
65 Jamie Ln	Destroyed SF	2 Destroyed SF	Destroyed SF
75 Shannon Dr	Destroyed SF	Destroyed SF	Destroyed SF
113 Jamie Ln	Not on List	Not on List	Destroyed SF
1 Canyon Cir[n]	Damaged (Minor)	Not on List	Not on List[o]
105 Port-o-Call Dr	Damaged (Minor)	Damaged (In Comments)	Not on List
124 Saint Andrews Rd[p]	Damaged (Minor)	Not on List	Not on List
4 Canyon Cir	Damaged (Minor)	Not on List	Not on List
400 Casino Dr	Damaged (Minor)	Damaged (Affected)[q]	Not on List
475 Casino Dr	Damaged (Minor)	Not on List	Not on List
102 Gary Dr	Damaged (Minor)	Damaged (Affected)	Not on List
114 Bayshore Dr	Damaged (Major)	Damaged (Major)	Not on List
411 Roberts Dr	Damaged (Major)	Damaged (Minor)	Not on List
140 Bayshore Dr[r]	Damaged (Major)	Not on List	Not on List
100 Camino Alto	Not on List	Damaged (Affected)[s]	Not on List
100 Janet Dr	Not on List	Damaged (Affected)	Not on List
146 Port-o-Call Dr	Not on List	Damaged (Affected)	Not on List
TOTAL DESTROYED	35	32	28
TOTAL DAMAGED	10	8	N/A

[n] The damage to this structure has not been confirmed and might be a field data entry error.
[o] The SBA appeared to only record destroyed primary structures.
[p] The damage to this structure has not been confirmed and might be a field data entry error.
[q] Some damage on structure
[r] The damage to this structure has not been confirmed and might be a field data entry error.
[s] City of Amarillo listed as damage to primary structure but NIST/TFS assessment only show damage to secondary structure.

9. Preliminary findings

The following preliminary findings relate to the two specific objectives of the initial reconnaissance:

Likely technical factors responsible for the damage, failure, and/or successful performance of buildings and/or infrastructure in the aftermath of the Amarillo fires

- Extreme weather, in the form of severe wind and very low humidity, resulted in very rapid fire spread.
- Buffalo grass, even when mowed carried fire on residential yards and in the wild.
- Statewide pre-deployment of fire fighting resources using the Texas Intrastate Fire Mutual Aid System (TIFMAS) was effective in rapidly getting resources to the fires.
- Extensive defensive actions were identified in the Tanglewood Complex fire. The defensive actions will be factored in the evaluation of the response of structures to the WUI fire in the detailed technical report.
- Certain foundation constructions (pier and beam) as well as modular/mobile homes may exhibit certain ignition vulnerabilities.
- Pre-fire and post-fire aerial imagery, particularly oblique imagery such as that found on Microsoft™ Bing Maps, was found to be essential for efficient and accurate delineation of the total number of damaged/destroyed structures.
- The local wind direction and speed and the topography had a significant impact on fire behavior; however, limited weather observation equipment was located in the bottom of the canyon and along the creek beds.

Specific improvements to standards, codes, and practices as well as any further research and other appropriate actions based on study findings

- The multijurisdictional aspects of this event posed a significant challenge to the accurate documentation of the damage and performance of the buildings.
- In the absence of a national standardized data collection framework, the NIST-developed WUI 1 and WUI 2 systems enabled the documentation and analysis of structural loses from the Amarillo WUI fire.
- Collecting data from undamaged as well as from the damaged/destroyed structures provided for meaningful assessment of the data.
- There is no scale to characterize the severity of WUI events, like the scales used to rate tornadoes, hurricanes or earthquakes.
- Additional weather observational equipment in numerous locations in the bottom of the canyon and along the creek beds would significantly help NWS forecasters, and also help local fire officials understand the potential behavior of the fire. Additional Remote Automated Weather Stations (RAWS) or West Texas MesoNet stations would be extremely helpful in cases of wildfires in these areas.[t]

[t] From NWS Amarillo Office, email communication, March 28, 2011.

10. Recommendations related to improving national standards, codes and practices, and future research

There are currently several codes and standards documents that can be used to guide construction at the WUI. At the national level these include the ICC International Wildland-Urban Interface Code®, and the NFPA Forest and Rural Fire Protection Committee. At the state level there are several documents tied to specific legislation such as the California Building Code (CBC) Chapter 7A specifically addressing construction at the WUI. NIST WUI research is being incorporated in both national and state standards and codes documents as well as in guides for best practices.

One critical challenge associated with the WUI community resilience is the lack of reliable data on what is burning and what is surviving WUI fires. The collection of data in a standardized method using a technically sound methodology is a critical first step in determining key structure survivability vulnerabilities. Identifying structure survivability vulnerabilities enables the formulation of targeted solutions that, when implemented, will improve structure survivability and community resilience to WUI fires. The following recommendations are designed to improve community resilience to WUI fires.

Recommendations for codes and standards improvements

- Create an exposure scale for WUI fires. This classification scale in concept may be similar to the ones used for tornadoes, hurricanes or earthquakes. This scale will be used to drive construction and hazard reduction in the WUI built environment.
- Conduct WUI data collection in a standardized fashion. The NIST WUI 1 data collection methodology is an example of a standardized data collection form that can be used for rapid post-WUI fire assessments.
- Collect data from all structures within the fireline, not only on what has been damaged and destroyed, in order to better understand structural performance. Data should also be collected from structures exposed to fire-spotting that occurs outside the fireline.
- Form an incident-centric repository to capture WUI incident data. This effort should be coordinated through the NIST Disaster and Failure Studies Program.

Recommendations for Further Research

Further research is required to develop predictive tools for WUI fire behavior. Specific recommendations are to:

- Conduct a detailed analysis of structure ignitions for the Tanglewood Complex Fire and document in a final report by May 2012.
- Conduct a series of prescribed burns in *Bouteloua dactyloides*, commonly known as Buffalograss or Buffalo Grass, for variable wind speeds and fuel loadings.
- Characterize wind in complex topographies such as canyons. Topography can locally increase wind velocity and dramatically affect fire behavior.
- Determine the ignition vulnerabilities of pier and beam foundation construction.
- Determine the ignition vulnerabilities of mobile homes.

- Compare the use of remote sensing data and the use of ground assessments to determine where and what kinds of remote sensing data can be used to improve efficiencies of ground data collection operations.
- Determine ignition vulnerabilities of structures from adjacent combustibles, specifically fences and decks.

The WUI data collection methodology can be enhanced by incorporating the following recommendations:

- The entire data collection team should be in the field. While the remote location of the GIS team was necessary due to budget constraints, data transfer and QA/QC efficiency would be improved by having the entire team on site. Loss of Internet capabilities during deployment highlighted this vulnerability
- In the WUI 2 system, provide a parcel linking feature to the field data collector. The Texas deployment highlighted this issue since in many instances structures straddled more than one parcel. The parcel liking feature will enable data collectors to easily link parcels that are part of one residence.
- Provide a fence line tracing tool in WUI 2 data collection interface. This is important in order to properly document the spatial relationship of this type of combustible to its surroundings.
- In the WUI 2 software/hardware system, all features should have associated images.
- In the WUI 2 system, locations of panoramic image sequences should be recorded in the field.
- The WUI 2 Assessment Principal Investigators (PI) should work with the TFS damage inspectors review the data and determine which building and parcel attributes were interpreted correctly and which were not.
- Post-fire aerial imagery should be obtained, as practical, for WUI 1 and WUI 2 assessments.

11. Acknowledgments

The authors would like to acknowledge the contributions of the institutions and organizations listed in Section 6. The authors would like to acknowledge the contributions of the Mayors and Home Owners Associations of the Timber Creek, Palisades and Tanglewood communities, as well as the numerous homeowners that provided critical information on both the Willow Creek and the Tanglewood Complex fires. Lastly, the authors would like to acknowledge the contributions of Bruce Woods from the TFS for enabling his deployment and Wanda Duffin and Eric Letvin from NIST for facilitating the deployment logistics.

Appendix A – Review of Deployment and Study Procedures and Data Collection Protocols

The following is a summary of the "lessons learned" from the joint NIST/TFS field deployment.

Successes

- The deployment model was successful and the coupling between Federal, state and local agencies worked very well.
- Fewer than 48 hours elapsed from fire initiation to WUI 2 data collection initiation.
- Two tiered data collection methodology was successfully field tested. Both the WUI 1 and the WUI 2 methods proved workable. Improvements have been listed in section 12.
- The WUI 2 Assessment System functioned with only minor errors that were corrected during the deployment.
- SOPs worked as designed. Morning safety briefs were provided at the hotel since the ICP was located 260 miles (420 km) away in Merkel, TX.

Problem areas and solutions

- Data transfer to the remote GIS team was hindered by the transfer of large files and loss of internet connection (system was down in part of Amarillo). Future deployments should have the GIS team on site. This will expedite the QAQC and limit time constraints associated with synchronizing data.
- In several instances combustible/non-combustible features were recorded but later could not be confirmed because there were no associated images. Additionally, recorded damage to certain structures could not be confirmed due to lack of photographic documentation. All features collected should have associated images. All damaged status records should have images of the damage associated with the respective damage record.
- Many combustible/non-combustible features were recorded in the images and not documented in the GIS database. Crews should be trained to record all combustible/non-combustible features.
- Sometimes the contents of structures (e.g. lawn mowers, machinery, etc.) were recorded and sometimes they were not. SOPs will be modified to always record the contents of structures in order to assess the ignitability of the contents.
- Often times it appeared that fire direction was recorded as an interpretation and not as evidence from an actual fire direction indicator. While it is fine to get an interpretation of fire direction from the Damage Inspectors, these should be differentiated from solid evidence of fire direction from scorching, needle freeze, radiant heat and fire jump from embers. Inclusion of a point fire direction feature that has a field for direction (0 to 359 degrees) might help differentiate different types of observed fire direction.

- Damage Inspectors had difficulty delineating burned vegetation. Crews should receive additional training in the art and science of digitizing features from aerial imagery. The burned vegetation data should also be simplified and post-fire aerial imagery should be obtained, as practical for post-fire deployments.
- SOPs will be modified to ensure that, at the beginning of any WUI 2 assessment, all team members together with the PIs, assess one property together to ensure data are collected consistently. Additional SOP modification will include periodic assessment of certain properties with Damage Inspectors to ensure the data collection consistency is being maintained throughout the deployment.
- All Damage Inspectors should have experience collecting data for research purposes. Research training will enhance the collectors understanding of the scope of the WUI research and how the data is being used to develop solutions.
- There was confusion as to whom was responsible for obtaining base data (such as parcel/aerial imagery and fire perimeter layers) necessary for the deployment. This responsibility should be assigned to a single team member. If joint deployments involving multiple organizations are conducted in the future a quality assurance project plan should be developed to identify who is responsible for which activities. The SOPs will be updated to reflect the assignment of responsibilities.
- Streamlined decision making procedures will better ensure timely deployment commitments and uninterrupted field data collection.

Appendix B– NIST WUI 1 Form

Insert Logo Here

County/City Name: _____
Department/District: _____

DAMAGE ASSESSMENT REPORT

1	Event Type:	☐ Fire	☐ Flood	☐ Wind	☐ Earthquake	☐ Other: _____
	Incident Name: _____			Recording Date: ____/____/_____		Time Recorded: _____
	Recording Team: _____	Phone/Cell: _____		Camera Name: _____		Photo Number(s): _____
	GPS Name: _____	GPS Position: ____ _____ ; -____ . _____				Way Point # _____
		Latitude		Longitude		
2	SITE INFORMATION					
	Street Number	Street Name				Unit No.
	City or Community			State		Zip
	Property Owner Last Name (if known):			Parcel ID		
3	PRIMARY STRUCTURE	☐ RESIDENTIAL	☐ COMMERCIAL	*Please Check Only Once*		
	Residential Type:	☐ Fixed	☐ RV/Travel Trailer	☐ Mobile Home		
	Extent of Damage:	☐ Minor	☐ Major	☐ Destroyed	☐ No Damage	☐ N/D
	Estimated Value of Structure: $_____					
	Exterior Material: (CHECK PRIMARY 2 TYPES)	☐ Metal	☐ Wood	☐ Stucco	☐ Brick	☐ Aluminum
		☐ Cement	☐ Vinyl	☐ Other	☐ N/D	☐ N/A
	Roof Type: (CHECK PRIMARY TYPE)	☐ Flat Tile	☐ Spanish Tile	☐ Wood	☐ Metal	☐ Asphalt
		☐ Other	☐ N/D	☐ N/A		
	Roof Vents: (CHECK PRIMARY TYPE)	☐ Flat	☐ Gable	☐ Eave Block	☐ Soffit Strip	☐ Dormer
		☐ Other	☐ N/D	☐ N/A		
	Edge Protection: (CHECK PRIMARY TYPE)	☐ None	☐ Mortar	☐ Bird Stops	☐ Metal	☐ Other
		☐ N/D	☐ N/A			
	Eave Construction: (CHECK PRIMARY TYPE)	☐ Cement Fiber	☐ Stucco	☐ Light Timber	☐ Heavy Timber	☐ Other
		☐ N/D	☐ N/A			
	Window Frame Type: (CHECK PRIMARY TYPE)	☐ Metal	☐ Wood	☐ Vinyl	☐ Other	☐ N/D
		☐ N/A				
	Foundation:	☐ Exposed Combustible	☐ Non-Combustible	☐ N/D		
	Topography:	☐ Flat	☐ Hill/Midslope	☐ Canyon Bottom	☐ Ridge Top	☐ N/D
		☐ N/A				
	Veg. Clearance:	☐ 0-30'	☐ 30-60'	☐ 60-100'	☐ 100-200'	☐ >200'
	Size of Primary Structure: _____ sq. ft			Number of Stories: _____ (IF UNKNOWN WRITE "NK")		
	Structure Ignition Category	☐ A - Uninterrupted	☐ B - Embers on Vegetation	☐ C - Embers on Structure	☐ N/D	
4	AFFECTED SECONDARY NON-RESIDENTIAL STRUCTURES (OVER 120 SQ. FT.)					
	Count of Damaged Structures:	____ Minor	____ Major	____ Destroyed	____ No Damage	____ N/D
	Cumulative Size of Affected Secondary Structures: _____ sq. ft.			(TOTAL SIZE OF ALL DAMAGED SECONDARY STRUCTURES COMBINED)		
5	VEHICLES					
	Number of Vehicles Destroyed: _____		Number of Vehicles Damaged: _____		☐ No Damage	
6	NOTES - OTHER DAMAGE NOT LISTED ABOVE:					
7	STATE COMPLIANCE	☐ YES	☐ NO	☐ N/A	COUNTY/DISTRICT CODE COMPLIANCE	☐ YES ☐ NO ☐ N/A
8	ESTIMATED VALUE OF DAMAGE/DESTROYED: $_____					
9	LOCAL DATA: If additional information is required for local departments complete on separate form and attach to this document.					

Use these instructions as a guide for completing wildfire damage assessments

Section 1. Incident & Field Collector Information
Record the event type, incident name (e.g., Witch), date, time recorded (military time), recording team, phone/cell information, camera name, and photo numbers. Please take a photo documenting the property address, and a representative photo(s) of the primary structure. If a GPS is being used, please record the GPS unit, lat/long coordinates, and waypoint number.

Section 2. Site Information
Please complete address information. If information is unknown or uncertain use 'N/D' (not determined). If values do not apply for a particular attribute use 'N/A'.

Section 3. Primary Structure Damage
Primary status for a structure is based on the use. You may encounter a situation where a detached garage or other secondary structure is significantly larger than the dwelling. Remember, the use determines whether a structure is primary or secondary, not the relative size, location on the property or appearance. Any parcel, residential or commercial, can have more than one primary structure. This situation will occur in apartments/condominiums, trailer parks, agriculture parcels and other situations for residential areas or for commercial parcels with multiple buildings used for similar purposes. These situations require completing a separate form for each primary structure found on the parcel. Secondary structures can be associated with the closest primary structure or all grouped with one structure and should only be recorded in one of the forms.

RESIDENTIAL TYPE: If primary type is residential check whether structure is fixed (e.g., house) or mobile (e.g., RV).
EXTENT OF DAMAGE: Determine the damage based upon the following criteria: **Minor** - localized combustion of an element on the exterior house that has **not spread** to other elements, or localized damage that requires rectification for normal house function, e.g. cracked or broken windows, burned window frame and eaves; **Major** - flames have entered the house and engulfed at least one room in the structure, or sufficient external combustion to compromise the structural integrity of the house; **Destroyed** - more than 50% of the floor area of the structure is burned and no longer habitable; **No Damage** - the structure has not been damaged
ESTIMATED VALUE OF STRUCTURE: Give an estimated dollar amount for the primary structure.
EXTERIOR MATERIAL: Determine the type of material that was used for the exterior wall finish. Check up to 2 primary types.
ROOF TYPE: Determine the roof material. Please check the primary type.
ROOF VENTS: Determine the roof vent type(s). Please check the primary type.
EDGE PROTECTION: Determine whether the roof edge had gaps and openings protected and if so indicate if mortar or bird stops were used. Please check the primary type.
EAVE CONSTRUCTION: Determine the eave construction. Please check the primary type.
WINDOW FRAME TYPE: Determine the window frame material. Please check the primary type.
WINDOW GLAZING: Determine if the windows are or were single or dual paned. Also if it appears the majority of the windows had tempered glass also check the "Tempered" box. Please check the primary type.
FOUNDATION: Determine if the structure foundation contains exposed combustible material.
TOPOGRAPHY: Determine the topography that best represents the parcel: **Flat** - house is situated on a 0-10% slope; **Hill/Midslope** - house is situated on the side of a hill with a >10% slope; **Canyon Bottom** - house is located at the bottom of a valley with steep sides; **Ridge Top** - the house is located on the crest of a ridge.
VEGETATION CLEARANCE: Determine the amount of vegetation clearance surrounding the primary structure.
SIZE OF PRIMARY STRUCTURE: Determine to the best of your ability the approximate square footage of the primary structure. It is understood that you may not be able to make an accurate determination. This is especially so when assessing a two-story structure, or a structure with a raised and stepped foundation or similar circumstances. This field is considered your best estimate only.
NUMBER OF STORIES: Determine to the best of your ability the number of above ground stories. If unknown write 'N/D'.
STRUCTURE IGNTION CATEGORY: A - Uninterrupted fire from the wildlands, **B** - Embers were involved in either igniting residential vegetation or directly igniting the structure, C - Structure ignition from embers, no damage to vegetation around structure, **N/D** - Not Determined

Section 4. Affected Secondary Structure Damage:
Secondary structures are those that are ancillary to the main building(s). Multiple residential dwellings on a single parcel would be recorded individually on a separate form. Secondary structures are associated with the closest building or one primary building. They are not to be duplicated with each form when a parcel contains multiple primary structures. However, only structures that would require a permit should be included in the assessment.
COUNT OF DAMAGED STRUCTURES: Count the number of secondary structures in damaged category. Refer to the definition in the primary structure for 'Extent of Damage'.
CUMULATIVE TOTAL SIZE OF AFFECTED ACCESSORY STRUCTURES: Please calculate and add together the square footages of all affected accessory structures and enter in this field.

Section 5. Vehicle Damage
NUMBER OF VEHICLES DESTROYED: Count only vehicles that were left with no part undamaged.
NUMBER OF VEHICLES DAMAGED: Count vehicles that received damage that will require repair to restore the vehicle to pre-disaster condition, even if the damage is minor.
Section 6. Notes & Other Damage & GPS Info: Briefly describe OTHER damage not listed in any of the sections above.
Section 7. State Compliance and County Code Compliance: Check if compliance is met.
Section 8. Estimated Value of Damaged/Destroyed: Total Value of damaged property documented on form.
Section 9. Local Data: Complete and attach document if additional local information is collected.

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