Wildfire Evacuation Route Planning

Bobcat Wildfire Consultants

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Client: Austin Fire Department – Wildfire Division

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Abstract

Our project focused on wildfire evacuation route planning for high risk communities in Travis County, Texas. We were provided three shapefiles from the Austin Fire Department Wildfire Division that included ingress and egress points, Temporary Assembly Point (TAP) locations, and community polygons identified as wildfire prone. Our team, Bobcat Wildfire Consultants, expanded and modified these datasets and ran a series of network analyses using ArcGIS Pro to create four evacuation routes for each at risk community: two based on distance and two based on time. These routes support both residents evacuating a fire zone and first responders trying to reach those communities. During our analysis, we discovered major challenges related to data volume and ArcGIS credit and token limitations, which temporarily halted our progress. We also found that certain areas in Northwest and Southwest Travis County, such as near Jonestown and Spicewood, face significantly longer drive times to reach TAPs, sometimes over 25 minutes, due to terrain and limited access. Additionally, our team identified several Wildland Urban Interface zones where residential development is directly next to fire prone vegetation, which complicates evacuation planning and response. We proposed new TAP locations in underserved regions and categorized them based on parking capacity, enhancing the evacuation framework. Ultimately, our project produced a geodatabase and detailed community maps that strengthen public safety planning, improve emergency response strategies, and help mitigate wildfire risks throughout the greater Austin area.

Introduction

The city of Austin has experienced some of the fastest population growth in the United States in recent years. This has resulted in mass suburban developments throughout the greater Austin metropolitan area. The Austin Fire Department (AFD) Wildfire Division has utilized Geographic Information Systems (GIS) regularly as a visual aid for emergency responses.

When evacuating residents from wildfires, they direct them to large lots where they can gather for first responders to assess their status and safety, as well as direct them to further accommodations such as shelters. In their geo-database, these areas are referred to as *Temporary Assembly Points* (TAPs).

Our team was recruited by the wildfire division to assist in their digitization of new developments. There are many new at-risk communities, and our focus was specifically on those with limited ingress and egress (entrances and exits). In a wildfire scenario, limited in/egress would result in traffic bottlenecking as residents attempt to escape in their vehicles simultaneously. By using GIS to generate evacuation routes, we created multiple alternate escape routes for each community to help distribute evacuating residents in a way that prevents bottlenecking. Therefore, this project leverages the Austin Fire Department's Wildfire Division's GIS database by identifying and adding new at-risk community polygons, new points of in/egress, new TAPs, and optimized evacuation routes. Our updates will result in a more comprehensive assessment of at-risk communities and TAP locations, as well as newly updated evacuation routes.

Our evacuation route-analysis for the greater Austin metropolitan area focuses specifically on in/egress for vehicles escaping a wildfire. The network will help ensure that evacuees can be prepared to follow optimized evacuation routes to designated TAPs. These areas allow emergency respondents to identify residents and ensure their safety and move them to a more secure shelter. TAPs are typically spacious areas that residents of focus are familiar with, such as schools, stadiums, parks, etc., with a vast amount of parking spaces categorized in specific tiers that can hold a certain number of evacuees while they are accounted for by local fire and police departments.

Once TAPS are identified and added, a network/route analysis will be conducted connecting primary and alternate routes from these communities that are faced with limited/ingress to their closet TAP. The goal is for evacuees to be able to reach the closet TAP to them as quickly as possible. Not only does this help with evacuees, but also first responders and local fire departments in the evacuation process by providing them with prepared and informed real-time data. With evacuees and fire departments having pre-planned knowledge on where to go in an emergency event such as a wildfire, this will limit chaos and confusion from both parties

Problem Statement

Evacuating during a wildfire requires fast and informed decision making. In many areas of Travis County, certain residential communities face serious risks because they only have one or two access roads. These areas are known to have limited ingress and egress, which becomes a major issue during emergencies. If too many residents attempt to flee at once, traffic congestion builds rapidly, creating bottlenecks that trap people in dangerous conditions. This not only delays evacuees but also slows down fire departments and emergency vehicles trying to reach those who need help. Many of these neighborhoods are located in rough terrain with few road connections, making emergency response even more difficult.

Because of this, communities with limited access are a top priority for evacuation planning. Our team worked to address this issue by designing a GIS based evacuation framework that helps streamline routes and improve readiness. We used shapefiles of communities, TAP locations, and key access points provided by the Austin Fire Department to map out the safest and most efficient escape routes. Each community was given a total of four options: two based on shortest driving distance and two based on fastest travel time. This gives residents more flexibility when evacuating and helps emergency teams choose the best way to enter a fire affected area.

Network analysis tools allowed us to model different traffic scenarios based on factors like population size and potential for congestion. These models helped us understand how people might leave an area during an emergency and what conditions could slow them down. Knowing this in advance is crucial because wildfire behavior can change in minutes. Real time planning during an active fire is rarely practical, so preparing beforehand gives everyone a better chance to act quickly and safely.

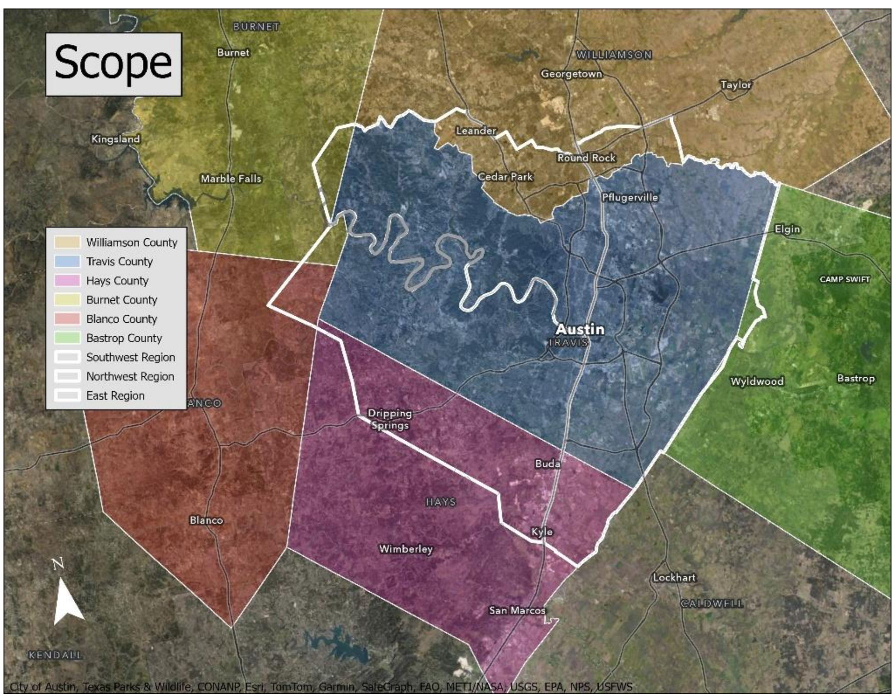
Although there is no way to completely eliminate confusion or panic in a crisis, clear and accessible evacuation routes can make a major difference. When communities are prepared and fire departments already have accurate maps and staging points, the entire evacuation process becomes faster and more effective. This level of preparation helps reduce property loss and saves lives when disaster strikes.

Scope

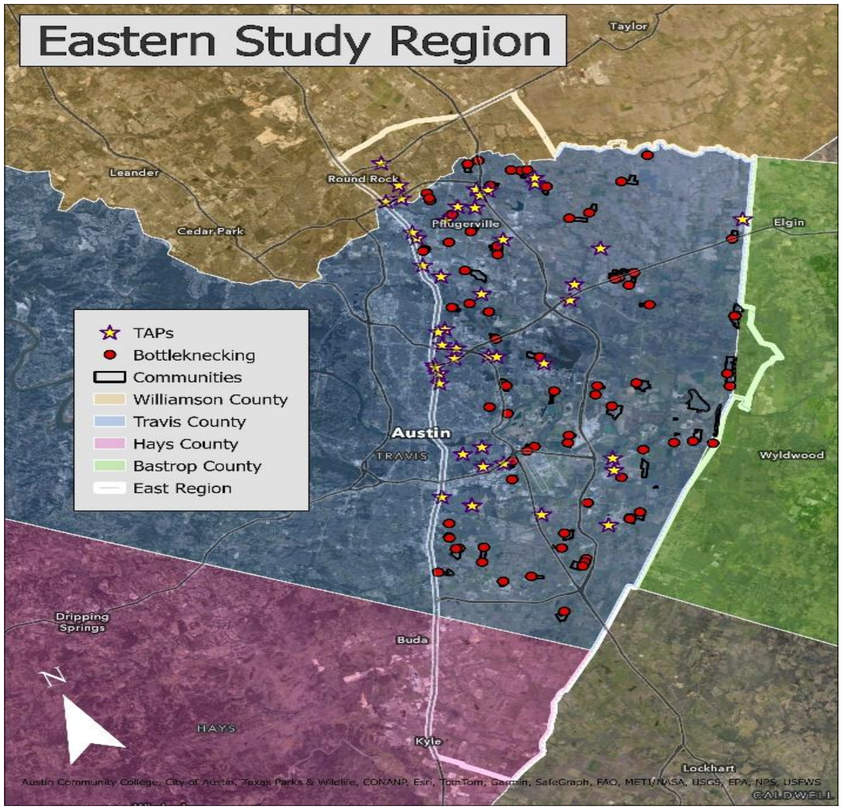
The original scope of this project was focused solely on Travis County, Texas. However, as we began designing routes from high-risk communities to nearby TAPs, we found that limiting the analysis strictly to Travis County boundaries would negatively impact route options for many neighborhoods. Some communities, especially those near the edges of the county, required access to TAPs located just outside Travis County. For this reason, we expanded our scope to include small portions of neighboring counties: Williamson, Bastrop, Blanco, Burnet, and Hays.

Additionally, while our full-scale network analysis covered the entire Travis County region, we also produced detailed small-scale maps for two specific high-risk neighborhoods—Steiner Ranch and West Lake Hills. These neighborhoods were selected due to their complex terrain, limited access, and the presence of many WUI zones, making them ideal for deeper analysis and map creation.

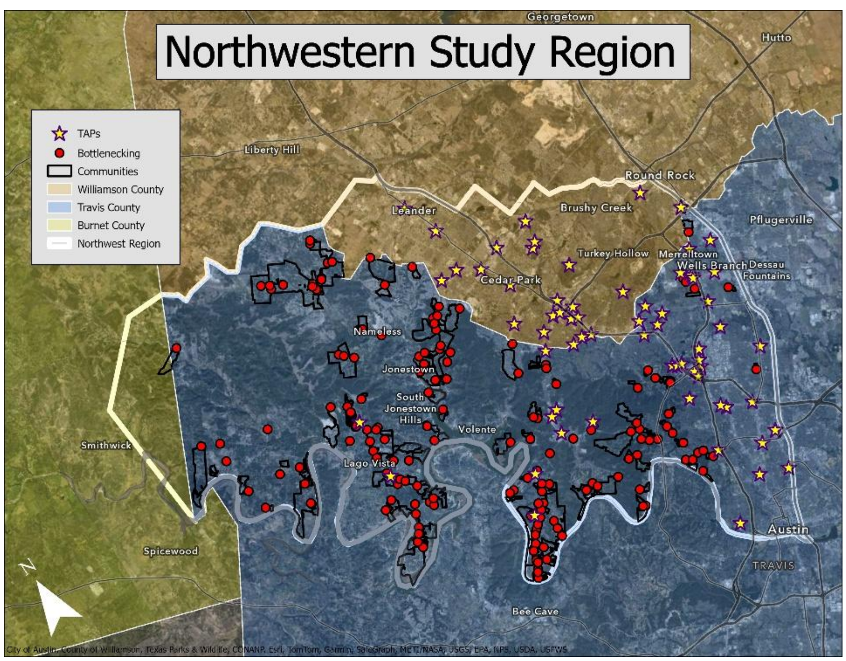
Our analysis was vehicle-focused, meaning all routes were designed assuming evacuation would be done by car. Pedestrian-based evacuation was outside the scope of this project. All work was completed between January and April 2025 as part of our GIS Consulting Practicum at Texas State University. The final deliverables include community evacuation maps, a geodatabase of routes, and a final report documenting our process and findings.



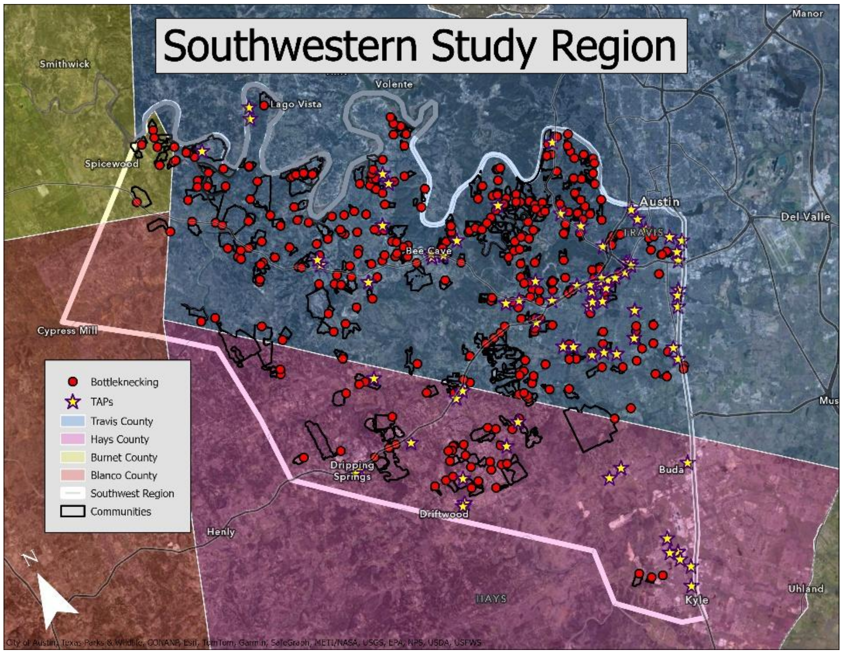
(Figure 1: Travis County study area w/ other counties attached)



(Figure 2: Eastern Study region w/ additional counties)



(Figure 3: Northwestern Study region w/ additional counties)



(Figure 4: Southwestern Study region w/ additional counties)

Data

Our project relied on a combination of client-provided shapefiles, public open data, and custom data created by our team. The Austin Fire Department Wildfire Division gave us four core datasets: community polygons with limited ingress and egress, Temporary Assembly Points (TAPs), in/egress points likely to bottleneck during a wildfire, and fire station locations. These layers were our starting point for identifying high-risk areas and planning evacuation routes.

To strengthen our foundation, we pulled additional spatial data from the TxDOT Open Data Portal and the Travis County Open Data platform. From these sources, we obtained current road networks, address points, and updated county boundary files. These were essential for validating and improving the accuracy of the older data we received.

After organizing our workspace into three zones (Northwest, East, and Southwest Travis County) we created multiple new layers. This included entirely new at-risk community polygons, digitized manually by our team based on aerial imagery and housing density. New in/egress points were added where road layouts showed a clear bottleneck that was not captured in the original dataset. Our boundary shapefiles ensured each team member stayed within their assigned zone, preventing overlap and data conflicts.

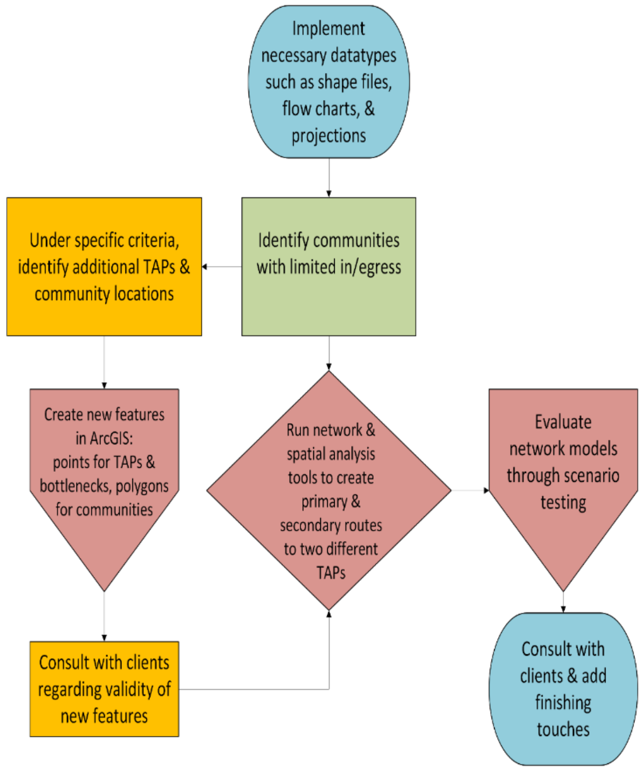
The TAP dataset required the most enhancement. Many areas lacked adequate TAP coverage, so we manually located and added new TAP candidates. We based our TAP selection on proximity to neighborhoods and the presence of large parking areas. TAPs were then categorized into three types based on parking capacity: Type 1 (500+ spaces), Type 2 (301–499), and Type 3 (0–300). We estimated capacity by creating a visual polygon representing 100 parking spots and moving it across the lot to reach a reasonable count. Each TAP was assigned a name, address, estimated capacity, and tier classification.

Our final geodatabase contained all original shapefiles, updated and expanded to reflect current development, plus new layers for communities, TAPs, in/egress points, boundaries, and evacuation routes. All data was cleaned, organized, and prepared for use in network analysis using ArcGIS Pro.

Data (shapefile)	**Description**	**Spatial Object**	**Status**	**Source**	**Unit**	**Year**
Limited In/Egress Communities	At Risk Communities	Polygon	available	Braniff Davis, Sr. Geospatial Analyst, Austin Fire Dept. Wildfire Division	US Foot	2022
Temporary Assembly Point (TAP) Locations	Gathering points post fire	Point	available	Braniff Davis, Sr. Geospatial Analyst, Austin Fire Dept. Wildfire Division	US Foot	2022
In/egress Points	Points where bottlenecking is likely to occur	Point	available	Braniff Davis, Sr. Geospatial Analyst, Austin Fire Dept. Wildfire Division	US Foot	2022
County Boundaries	Regional Boundaries for separation	Polygon	available	TxDOT Open Data Portal (Travis, Williamson, Bastrop, Blanco, Burnet, and Hays)	US Foot	2025
Addresses	Address points for at risk communities	Point	available	TxDOT Open Data Portal	US Foot	2025
New Limited In/egress Communities	Newly added at risk communities	Polygon	available	Bobcat Wildfire Consultants, Texas State University	US Foot	2025
New Temporary Assembly Point (TAP) Locations	Newly added gathering points	Points	available	Bobcat Wildfire Consultants, Texas State University	US Foot	2025
New In/egress Points	Newly added points where bottlenecking is likely to occur	Point	available	Bobcat Wildfire Consultants, Texas State University	US Foot	2025
Boundary Shapefiles	County borders & study area boundaries	Polygon	available	Bobcat Wildfire Consultants, Texas State University	US Foot	2025
Closest Facility Network Analysis	Escape routes (four routes total for each community)	Line	available	Bobcat Wildfire Consultants, Texas State University	US Foot	2025

(Table 1: Open-source data table with original and new shapefiles)

Data Visualization



(Figure 6: Flow chart representing data flow/process)

Methodology

GIS Data Preparation and Regional Division

Our project began by dividing the full study area into three separate regions: Northwest, East, and Southwest Travis County. Each team member was responsible for one region, and we created boundary shapefiles to define each workspace. This helped manage data edits, avoid overlap, and kept our geodatabase organized. Once regions were set, we began updating, editing, and digitizing shapefiles from the original datasets provided by the Austin Fire Department Wildfire Division. New communities, in and egress points, TAPs, and road connections were created manually where needed. This preparation phase laid the foundation for the spatial analysis that followed.

Identifying At Risk Communities

To determine which communities were most vulnerable during a wildfire evacuation, we used a combination of visual and automated methods. The density-based clustering tool in ArcGIS helped us quickly identify address clusters with twenty or more structures. While this tool was helpful for an initial visual scan, it lacked precision in many areas, especially where housing was irregularly spaced or road networks were difficult to read. For these cases, we manually examined aerial imagery and the surrounding road layers. Some team members improved their visual workflow by adjusting road symbology, such as increasing line thickness and contrast, which made bottlenecks and dead ends easier to spot. This method allowed us to identify neighborhoods with limited road access and potential for severe bottlenecking.

Once at-risk communities were identified, we digitized new polygons for each one, using visual boundaries that aligned with terrain, development edges, and road connections. These community polygons served as the anchor points for our in and egress locations and later, our network analysis.

TAP Location Selection and Classification

Finding effective TAP locations required manual inspection of satellite imagery. We searched for large open areas such as school parking lots, strip malls, or religious facilities with ample space for vehicles. We avoided locations close to vegetation, steep terrain, or dense development. Safety, space, and accessibility were our top criteria. Once a site was selected, we estimated its parking capacity using a visual counting method. We created a reference polygon that covered approximately one hundred parking spaces and moved it across the site in sections to estimate the total. TAPs were then categorized into three types:

- Type 1: 500 or more parking spaces
- Type 2: 301 to 499 parking spaces
- Type 3: 0 to 300 parking spaces

We often added notes in the TAP record that explained whether adjacent lots or neighboring facilities could be used to expand capacity if needed. In some cases, we considered an entire block of different parking lots, such as a church next to a shopping strip, as a single TAP location due to their proximity and combined parking space.

Network Analysis Tool Selection and Testing

One of the most important phases of the project was determining the best GIS tool to run our evacuation route analysis. Initially, we tried Route Analysis, Origin Destination Cost Matrix, and Service Area tools. However, none of these allowed us to input both TAPs and in and egress points as separate shapefiles while outputting multiple distinct routes from a single point.

After testing and comparing several options, we selected the Closest Facility tool. This tool allowed us to use in and egress points as incidents and TAPs as facilities. It calculated the best routes based on either distance or time, depending on how the tool was configured. This gave us the flexibility to create four total routes for each community:

- Two routes based on shortest distance
- Two routes based on fastest drive time

Each in and egress point was connected to two TAPs for redundancy, so that communities had both a primary and secondary escape plan along with two alternate options.

Symbology and Map Design

While the Closest Facility tool gave us the routes we needed, symbolizing the output presented a challenge. ArcGIS Pro does not let users assign different colors to individual routes within the same layer if they are generated from a single analysis. Because of this, both routes from one analysis (for example, shortest distance) had to share the same color, making it hard to visually separate the primary from the alternate.

Our workaround was to run two separate Closest Facility analyses, one using distance, the other using time, and assign each a distinct color. We then created maps that included both layers, allowing users to at least distinguish between distance based and time-based routes. We applied this method to all of Travis County and produced large scale maps for two specific communities: Steiner Ranch and West Lake Hills. These maps displayed every route, TAP, and boundary for easy reference by our client and emergency planners.

Analysis Evaluation and Variable Testing

Throughout the project, we tested different variables within the Closest Facility tool. We compared time versus distance settings to see which produced more efficient and realistic routes. We experimented with assigning different numbers of facilities per incident and toggling directionality settings on roads to see how routes were affected. These tests helped us better understand how ArcGIS interprets real world traffic patterns and let us fine tune our final product.

Evaluation of Planning Questions

Which Communities face the greatest evacuation challenges based on current TAP locations?

Communities along the Balcones Escarpment and western edge of Travis County are among the most vulnerable. The Hill Country terrain, presence of dense Ashe Juniper vegetation, and narrow, two-lane county roads make these areas extremely difficult to evacuate quickly. Many of these communities have only one or two exits, and the TAPs that serve them are often located miles away, increasing drive time and bottleneck risk. West Lake Hills, Steiner Ranch, and neighborhoods near the wildlife refuge west of Jonestown are prime examples. These areas not only face geographic isolation but are also surrounded by fuel heavy vegetation that increases fire intensity and spreads. Because the road networks in these zones are sparse and winding, it places even more stress on the need for fast, well-planned evacuation. If TAPs are not located within close proximity or if congestion builds too quickly, entire neighborhoods could become trapped or delayed during a critical window of time.

Where should new TAPs be placed to reduce travel times for high-risk communities?

New TAPs should be placed in cleared, flat, open areas far from dense vegetation. Parking lots of large public buildings, shopping centers, and open sports complexes are ideal. However, finding suitable space becomes more difficult as you move westward into private ranch land, preserves, and federal land like the Balcones Canyonlands National Wildlife Refuge. These restrictions limit our ability to improve TAP coverage in the most isolated regions. Still, we identified several feasible spots closer to the county edge to help reduce travel times from the most isolated neighborhoods.

Can communities reach their designated TAP within a reasonable drive time threshold?

Yes. Our network analysis showed that most communities can reach at least one TAP within 5 to 15 minutes. The fastest route was just under 2 minutes, while the longest route, for more rural, isolated neighborhoods, was around 23 minutes. On average, driving times were within an acceptable threshold. The system was designed to prioritize speed of access and flexibility, allowing each community four routes that account for distance and time.

How well do current TAPs meet capacity needs based on their designated type of classification?

TAPs are generally well matched to the communities they serve. The tier system helps allocate evacuees efficiently, and notes were added to many TAP records identifying nearby lots that could serve as overflow space. There is room for improvement, especially in isolated zones, and we identified opportunities to add new TAPs across all three tiers. Our additions were distributed evenly, including high-capacity lots and smaller, more localized spaces. In several cases, we grouped adjacent properties like a strip mall and a church to form a larger, combined TAP area capable of supporting more evacuees during an emergency.

Results

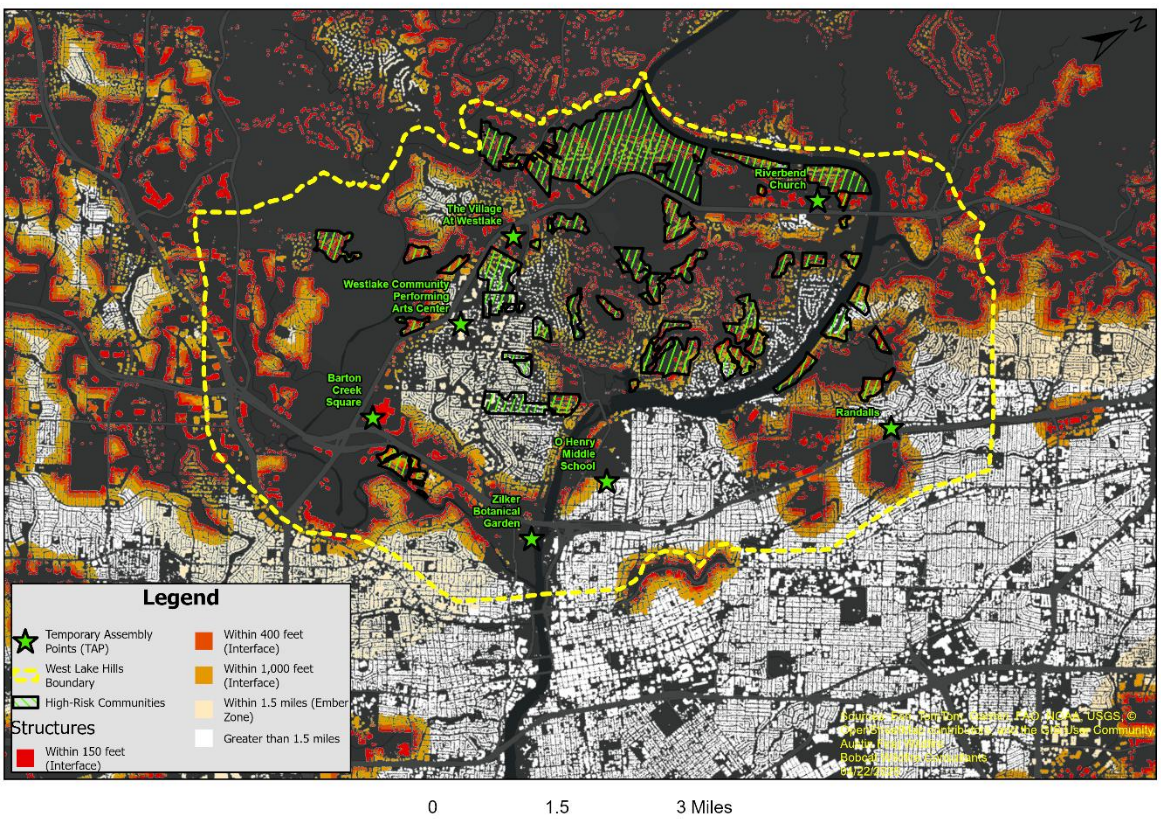
The final result of our analysis is a fully integrated and mapped evacuation system for wildfire emergencies in Travis County. Each at risk community was given four unique vehicle-based routes to safe zones, connecting in and egress points to designated TAP locations. These routes include a combination of shortest drive time, shortest distance options, and changes to facility variables, giving residents flexibility during evacuation and giving first responders multiple paths to reach those communities.

We discovered multiple communities that had serious evacuation concerns. In addition to long drive times, many of these communities were accessible only by narrow two lane roads. In places like West Lake Hills and Jonestown, we saw terrain related barriers and steep elevation changes that created winding roadways and choke points. Some neighborhoods were so isolated that TAP coverage required extension into neighboring counties to find adequate space.

We created dozens of new TAPs to close these gaps. TAP locations were identified manually and confirmed with aerial imagery. Using parking space estimates, we categorized each TAP into one of three capacity tiers and created attribute records for each one with address, classification, and notes about overflow space. In several areas, TAP clusters emerged naturally where schools, supermarkets, strip malls and stadiums were located near large shopping centers and other public places, giving us opportunities to combine them into super TAPs.

To enhance our understanding of high-risk areas, we used a Wildland Urban Interface (WUI) shapefile to evaluate the relationship between developed communities and unoccupied, fire prone land. This layer was especially useful in our West Lake Hills analysis. The WUI shapefile included color coded distance values showing the proximity of development to wildland areas: red indicated areas within 150 feet, orange for 400 feet, dark yellow for 1000 feet, light yellow for 1.5 miles, and white for areas greater than 1.5 miles away. Mapping these values gave us clear insight into where fire spread is most likely to reach neighborhoods. This added context to our route planning and TAP positioning by emphasizing which communities are at risk due to their interface with vegetation, terrain, and slope.

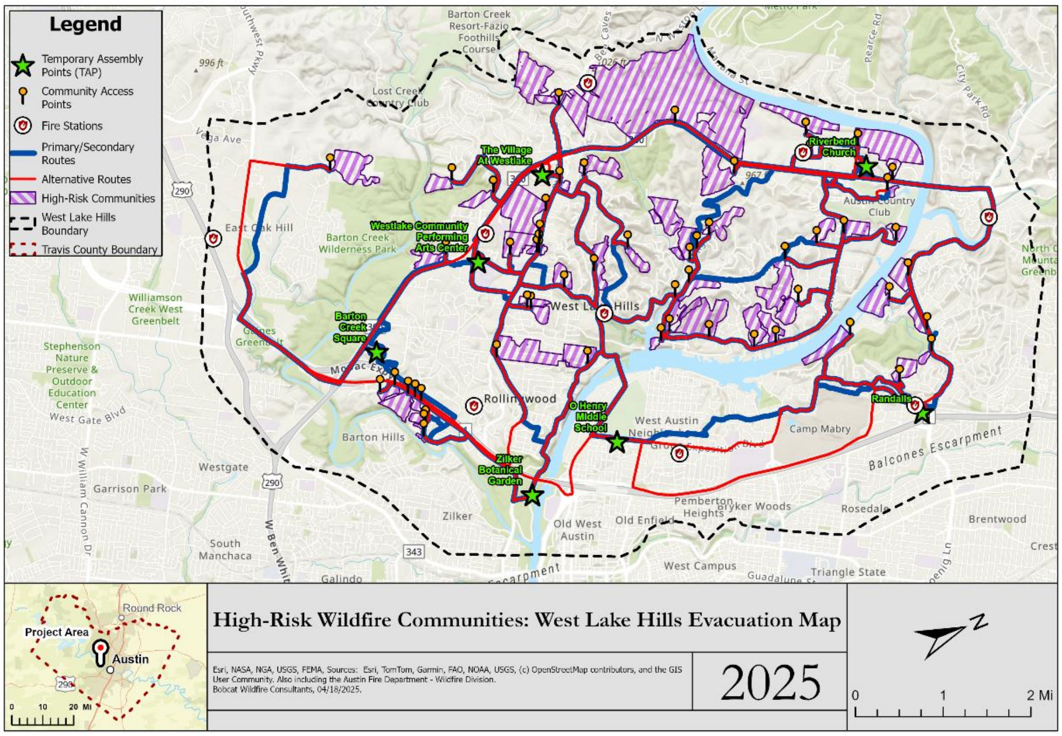
West Lake Hills Wildland Urban Interface (WUI)



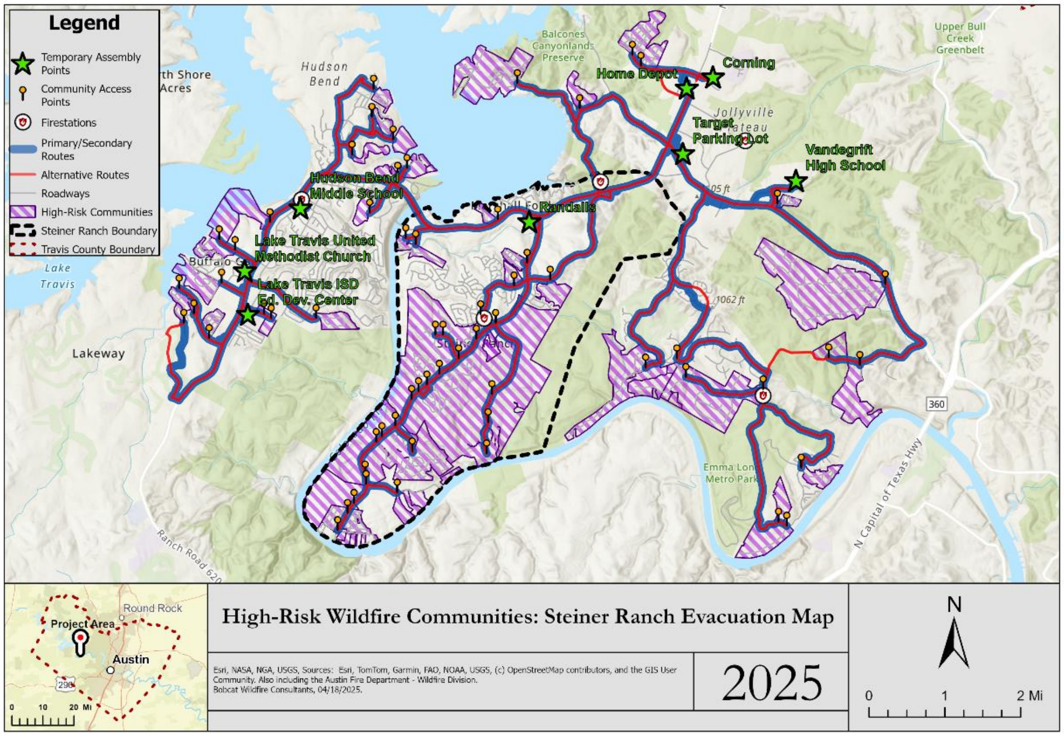
(Figure 7: WUI visual representation using West Lake Hills community)

We also delivered two large scale community maps. The West Lake Hills map and the Steiner Ranch map both show high resolution community outlines, roadways, in and egress points, TAP connections, and all four evacuation routes. These maps are designed for real world communication with planners and emergency managers. The West Lake Hills map and the Steiner Ranch map both show high resolution community outlines, roadways, in and egress points, TAP connections, and all four evacuation routes. These maps are designed for real world communication with planners and emergency managers.

All route analysis layers, community features, TAPs, and supporting infrastructure were compiled into a single geodatabase with organized folders and naming conventions. This makes it easy to replicate the process or run new analyses later



(Figure 8: Route Analysis map of West Lake Hills, Austin TX and neighboring communities)



(Figure 9: Route Analysis map of Steiner Ranch, Austin TX and neighboring communities)

Discussion

While the analysis was successful, we ran into several issues that impacted our timeline and deliverables. The biggest barrier was token consumption. ArcGIS Pro requires service credits for running online network analysis tools, and with thousands of points and polygons in our dataset, we quickly exceeded the default credit limit. This caused a delay while we submitted a request to IT support for more tokens, which were eventually approved but not immediately. The downtime reduced our momentum and created a bottleneck at a critical time in the semester.

Symbology was another challenge. We wanted to show each of the four evacuation routes with different colors, but ArcGIS did not allow us to assign individual symbols to routes generated from a single Closest Facility layer. As a workaround, we ran two separate layers, one for distance and one for time, and assigned them contrasting colors. However, since each layer still generated two routes, this meant that the primary and secondary routes looked identical. It required explanation to differentiate them and could confuse users unfamiliar with the software. Despite this, all four routes still exist and are functional within the dataset.

We also explored how Wildland Urban Interfaces, or WUIs, influence evacuation planning. These are critical transition zones where development meets undeveloped vegetation. They play a major role in wildfire risk because they represent points of ignition and fast fire spread. By integrating the WUI shapefile into our analysis, we gained a better understanding of how close homes and infrastructure are to potential fire sources. This insight helped strengthen our route justification, especially in West Lake Hills where several neighborhoods are directly adjacent to high risk WUI zones.

Time allocation could have been improved. We spent a large portion of the project digitizing TAPs, community polygons, and in and egress points. While this was necessary, it left less time for advanced route testing and symbology experimentation. More time spent on fine tuning our outputs or running small batch analyses might have improved the final layout. Still, the end product met our goals and delivered the routes and maps the client needed.

Conclusion

Wildfires in Travis County pose a serious and recurring threat, especially for neighborhoods with limited road access and dense surrounding vegetation. Communities with only one or two exits are more likely to experience dangerous bottlenecks during an emergency, where just a few minutes can mean the difference between safety and catastrophe. The ability to pre-plan for evacuation is not just helpful, it is essential. Through the use of route and network analysis, first responders can identify the most efficient and reliable evacuation paths in advance, allowing for faster response and safer outcomes for everyone involved.

The pre-identification of TAPs and the development of evacuation routes tailored to time and distance improves the overall planning capabilities of emergency responders. By organizing data into a central geodatabase and delivering updated, field-ready maps, this report strengthens the ability of agencies to coordinate evacuations and assist vulnerable communities. The inclusion of Wildland Urban Interface analysis also enhances preparedness by clearly identifying neighborhoods where fire exposure risk is highest due to proximity to unoccupied vegetated land.

It is impossible to eliminate every source of chaos in a wildfire evacuation scenario, but clear planning and spatial insight drastically reduce confusion and improve coordination. The information presented in this report supports emergency preparedness, strengthens the capabilities of the Austin Fire Department Wildfire Division, and offers a replicable model for surrounding counties. With the right tools, accurate data, and proactive planning, public safety outcomes can be significantly improved when facing natural disasters. By building a geodatabase of TAPs, community polygons, and in and egress points, and by connecting them with logical and strategic route analysis, we created something that could genuinely help residents and first responders in a wildfire event.

We learned how to prioritize data processing, design around software limitations, and coordinate across multiple users. We encountered setbacks like token shortages and symbology issues, but we found workarounds and moved forward. The value of this project is not just in the maps but in the process of creating a resource that reflects how GIS can be applied in real world crisis planning.

If we had more time, we would have spent more of it refining the final visual product. We also would have explored adding risk layers like slopes or vegetation to increase the precision of our TAP assignments. The broader impact of this work is that it can serve as a model for other counties facing similar wildfire risks. It can also be scaled or updated as more TAPs are built or as the county grows.

Emergency preparation requires proactive tools, and this project showed how GIS can be one of the strongest tools available when it comes to protecting lives and helping people move to safety.

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Participation

<u>AJ (GIS Analysist)</u> - Summary, scope, little bit of lit review, budget, timetable, conclusion, references, (work edited by group members).

<u>Hank (GIS Analyst)</u> - Major editing overall, roughly half of the methodology including the flow chart, introduction, & expected results.

<u>Dawson (GIS Analyst/Project Manager)</u> - I created the team's name (with help from the team), proposal title (with help from the team), logo, and cover page. I also structured the table of contents and wrote the introduction while helping refine the summary and purpose. A significant portion of my work went into the literature review, while my team collaboratively gathered and formatted citations. Additionally, I created and revised the data table (master data list). In the methodology section, I contributed to the model design, data processing and analysis, and hypothesis and research questions. To complete the proposal, I refined the conclusion.

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This project aims to help these communities and local fire departments by conducting a network/route analysis from these limited ingress/egress communities to their closet TAP's (Temporary Assembly Point) where evacuees where will be accounted for and safe. By identifying and mapping TAPS', ranging from schools, malls, and churches with a vast amount of parking space, our goal is to provide transparent and accessible routes for evacuees and fire departments.

Several communities with a minimum of 20 or more structures in Travis County are faced with limited ingress/egress, which leads to the challenges of bottlenecking and congestion of cars trying to evacuate simultaneously.