NC 811 Annual Report – 2022

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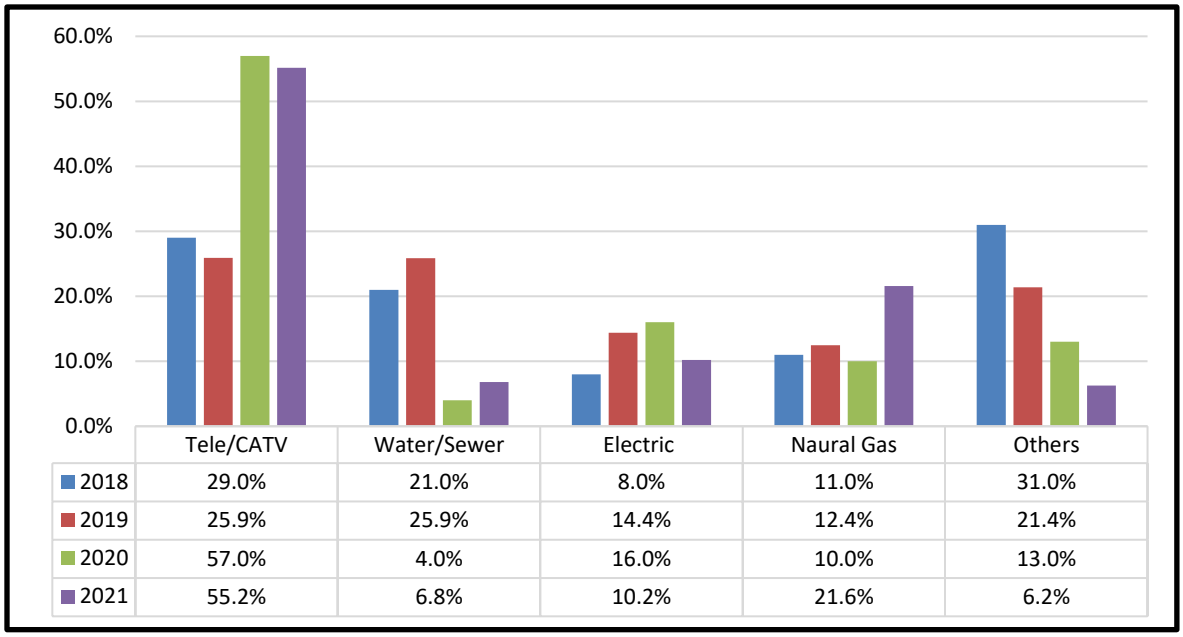
Number of Damages Reported in 2021

There were 16,214 estimated underground utility damages in the state of North Carolina in 2021, as has been reported by the Common Ground Alliance (CGA). Table 1 shows the number of damages between 2017 and 2021. It must be noted that the number of reported damages in 2021 was lower because a a large contributor to supplied data in previous years did not share 2021 damage reports. Overall, the number of damages is only an estimation based on the reported damages and does not represent the actual number of damages which is expected to be higher. Therefore, the information provided in this report should be looked at as information related to a sample, not the total number of damages.

Table 1. The Number of Reported Damages in North Carolina

Year	2021	2020	2019	2018	2017
NC 811	11,594	31,766	15,621	12,024	11,160
CGA	16,214	26,778	38,599	24,931	23,203

Figure 1 shows the percentage of damages per utility type between 2018 and 2021. Most of the damages in North Carolina occurred to telecommunication and cable TV subsurface utilities in the last two years. Al-Bayati and Panzer (2021) suggest a few unique factors that contribute to the damages of telecommunication and cable TV, including, shallow depth and their comparatively low-risk financial impact on the overall project. Furthermore, telecommunication and cable TV subsurface utilities are considered lower-risk damages than gas or electric. (Al-Bayati and Panzer, 2020). Low-risk damages have no potential high monetary impacts on construction projects' schedules and budgets unless damages occur to fiber-optic telecommunication lines.



	Tele/CATV	Water/Sewer	Electric	Naural Gas	Others
2018	29.0%	21.0%	8.0%	11.0%	31.0%
2019	25.9%	25.9%	14.4%	12.4%	21.4%
2020	57.0%	4.0%	16.0%	10.0%	13.0%
2021	55.2%	6.8%	10.2%	21.6%	6.2%

Fig. 1. Damage Proportion per Utility Type 2018 - 2021

An excavator is a person engaged in excavation or demolition. Several types of employers hire excavators to perform an excavation (e.g., contractors and utility owners). Within the CGA known data, professional contractors caused the most damage to underground utilities in 2021, accounting for 82.4% (13,305) of damages, followed by municipalities (5.14%, 830 damages). These rates are similar to those reported in previous years.

The service types are classified to transmission, distribution, and service lines. Transmission lines carry services such as electricity, clean water, and natural gas to distribution lines that carry services to customers through the service lines. Damages to transmission lines represent a small percentage of the overall damages reported, as can be seen in Figure 2. Transmission lines are deeper and better marked in Right of Way (ROW) with permanent above-ground marks.

Furthermore, transmission lines that are not in ROWs are usually along busy roads, not in neighborhoods. The Gas Transmission Integrity Management (GTIM) has required pipeline personnel to be present during excavation to satisfy the Pipeline and Hazardous Materials Safety

Administration (PHMSA). The higher risk of injury and the potential cost of disruption to the transmission lines make these utilities a higher priority to the owners.

The risk factor of these three affected services is inversely proportional to the percentages. The transmission category has the highest risk potential for injury or widespread outages. Therefore, the most significant emphasis from a safety perspective is placed on transmission (i.e., high-risk lines), even though the focus of damage prevention attempts to address all three types. For example, in April 2019, a natural gas service line was struck during a horizontal boring operation resulting om two fatalities, several injuries, and damaged and destroyed buildings in Durham, North Carolina.

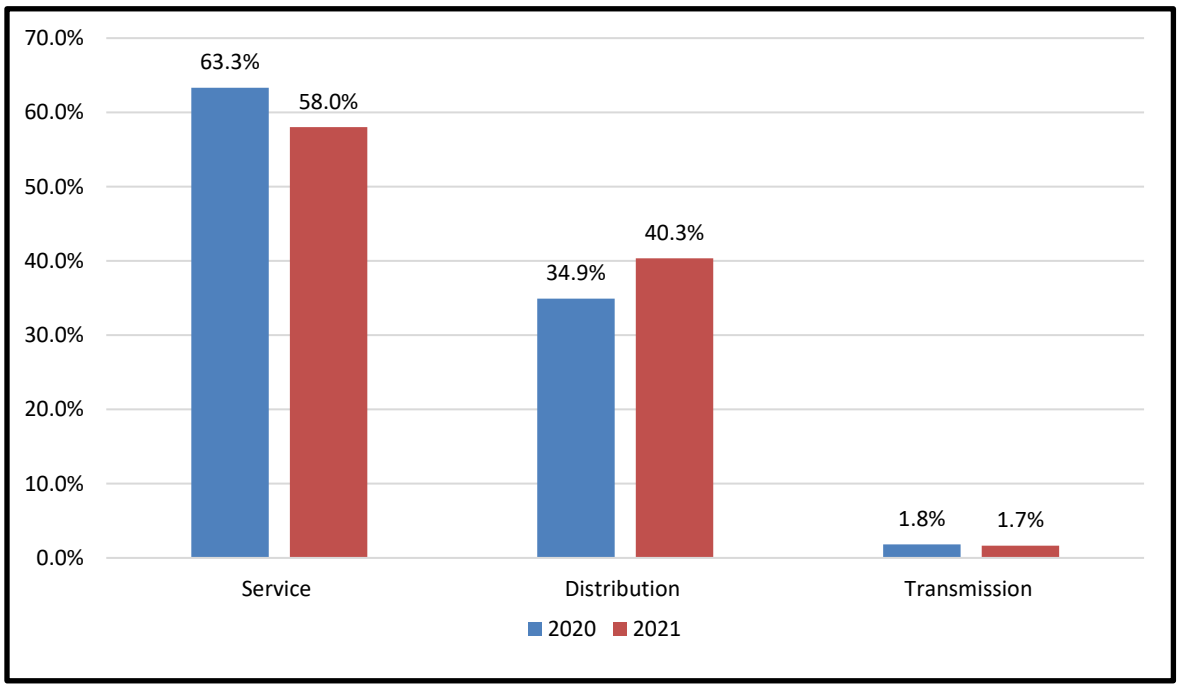


Fig. 2. The Affected Service

Locate Request Trends

NC 811 was created to ensure that all active underground utilities are marked before the excavation starts, and this process can only begin when excavators notify NC 811. The 2021 dataset shows that 2,558 (15.8%) damages were not associated with a locate request within reported causes. This percentage is lower than those found in 2020 (19.8%; 6,296 damages), 2019 (22.8%; 3,561 damages), 2018 (20%; 2,408 damages), 2017 (19.4%; 2,169 damages), and 2016 (21.56 %; 3,271 damages).

Like the previous reports, the firms that did not place a locate request mainly perform landscaping, water, and sewer works projects. Accordingly, this finding highlights specific sectors that NC 811 needs to target through educational and outreach efforts.

The examination of no locate requests indicates that most of the cases occurred in Mecklenburg County (22.8%), followed by Wake County (9.8%), Guilford County (5.24%), Buncombe County (3.8%), Iredell County (3.17%), and Durham County (3.13%). Comparing these percentages with previous years' shares shows an overall increase in no locate requests in Buncombe and Iredell; these two counties were not within the top four in the previous years, see Table 2.

Table 2. Locate Request Trends by Major County between 2016 and 2021

County	Mecklenburg	Wake	Durham	Guilford
2021	22.8%	9.8	3.1%	5.3%
2020	19.8%	17.38%	4.67%	4.49%
2019	33.4%	7.2%	2.4%	13.5%
2018	25.40%	9.96%	3.70%	8.68%
2017	23.10%	17.38%	5.53%	4.52%
2016	28.12%	18.52%	6.14%	4.49%

Damages per County

More than 49% of reported damages occurred in Mecklenburg County (19.3%), followed by Wake County (15.2%), Cumberland County (5.5%), Guilford County (5.1%), and Durham County (4.27). When comparing 2021 percentages, a consistent trend is identified, see Table 3. There is some expectation that these counites would have the highest occurrences of damages as most work is taking place in these locations. However, Cumberland County is among the top five counties for the first time, which requires further investigation and monitoring.

Table 3. Damages Percentages by Top Counties

County	Mecklenburg	Wake	Durham	Guilford
2021	19.3%	15.2%	4.27%	5.14%
2020	23.03%	17.5%	4.49%	4.94%
2019	21.79%	15.45%	5.19%	7.26%
2018	21.94%	16.32%	5.14%	5.82%
2017	26.09%	19.87%	5.39%	4.36%
2016	33.35%	21.46%	6.62%	3.96%

Damages per Work Performed

This section investigates damages per work type to reveal whether a type of work contributes more than others to underground utility damages. The results suggest that most of the damages, within known data, occurred while conducting tele/CATV work, followed by water/sewer work, electrical, and natural gas, see Figure 3. Figure 4 shows damage percentages per work performed between 2018 and 2021.

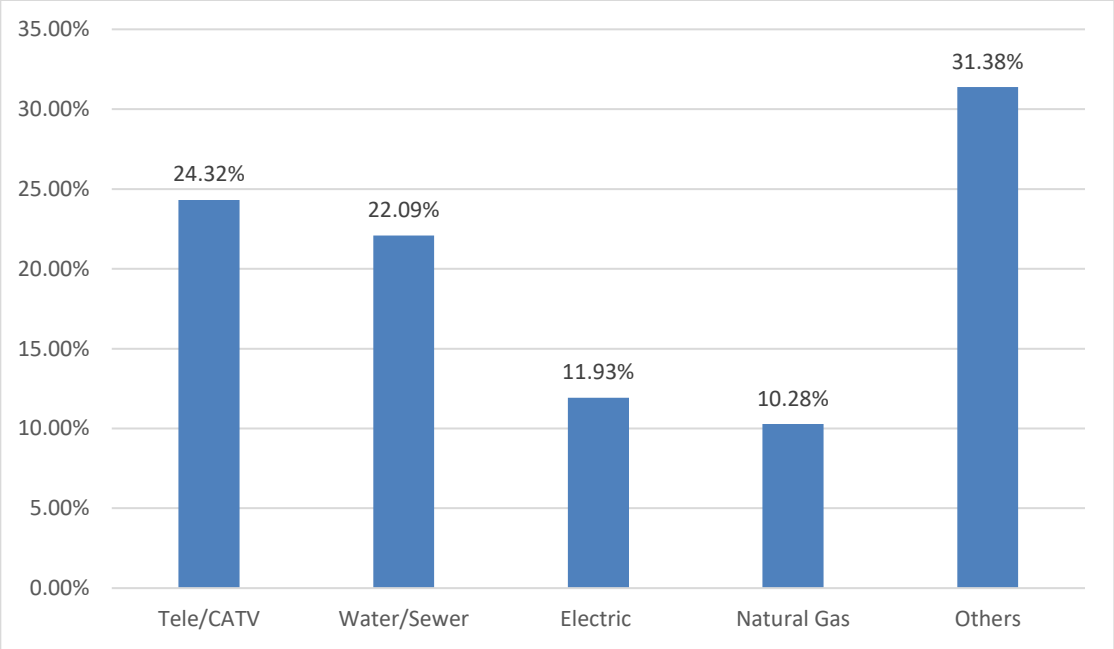


Fig. 3. Damages per Work Performed 2021

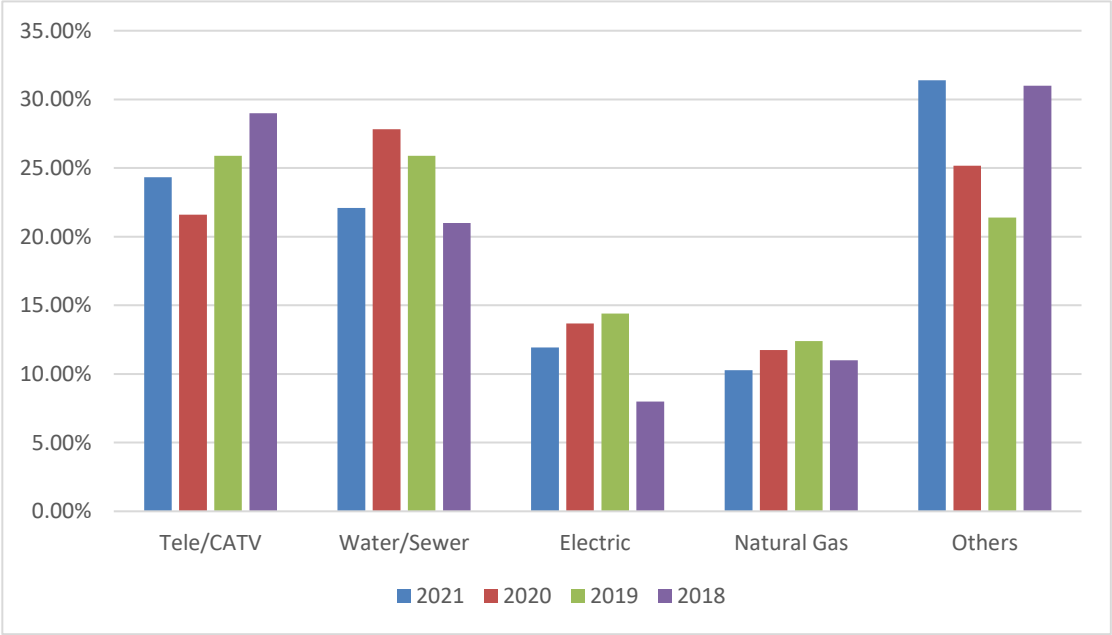


Fig. 4. Damages per Work Performed 2018- 2021

Positive Response Trends

Tickets are created after each notification received by the NC 811 notification center from an excavator. NC 811 transmits the received ticket to each member (i.e., utility owner/operator) that may have a conflict with the excavation. Several transmissions are typically associated with each ticket; roughly an 5.4:1 ratio of transmissions to tickets. There were 2,332,458 tickets and 13,189,250 transmissions in the state of North Carolina in 2021 (2,146,810 tickets and 12,421,473 transmissions in 2020). Out of the 100 counties in North Carolina, 48.5% of the 2021 transmissions were placed in the following counties: Mecklenburg (2,372,069), Wake (2,276,759), Guilford (692,714), Durham (636,255), and Forsyth (430,253). Figure 5 shows the proportion of transmissions in these counties between 2018 and 2021.

Positive responses are a requirement under the law and a method for the members of NC 811 to provide information to excavators regarding their tickets. The most frequent positive responses during 2021 were Code 10 (41.06%), followed by Code 20 (34.01%), Code 30 (8.41%), Code 999 (7.85%), Code 60 (3.48%), and Code 80 (2.69%), see Table 4. The data indicate that 55.4% of positive responses required four days or more to deliver the positive response, see Figure 6.

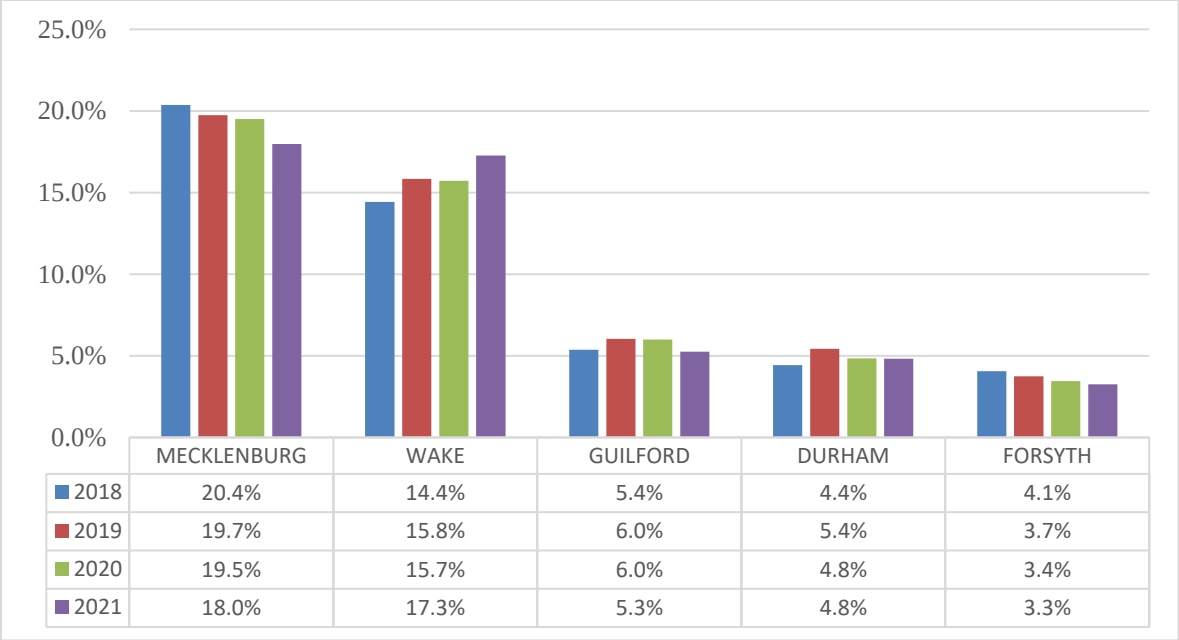
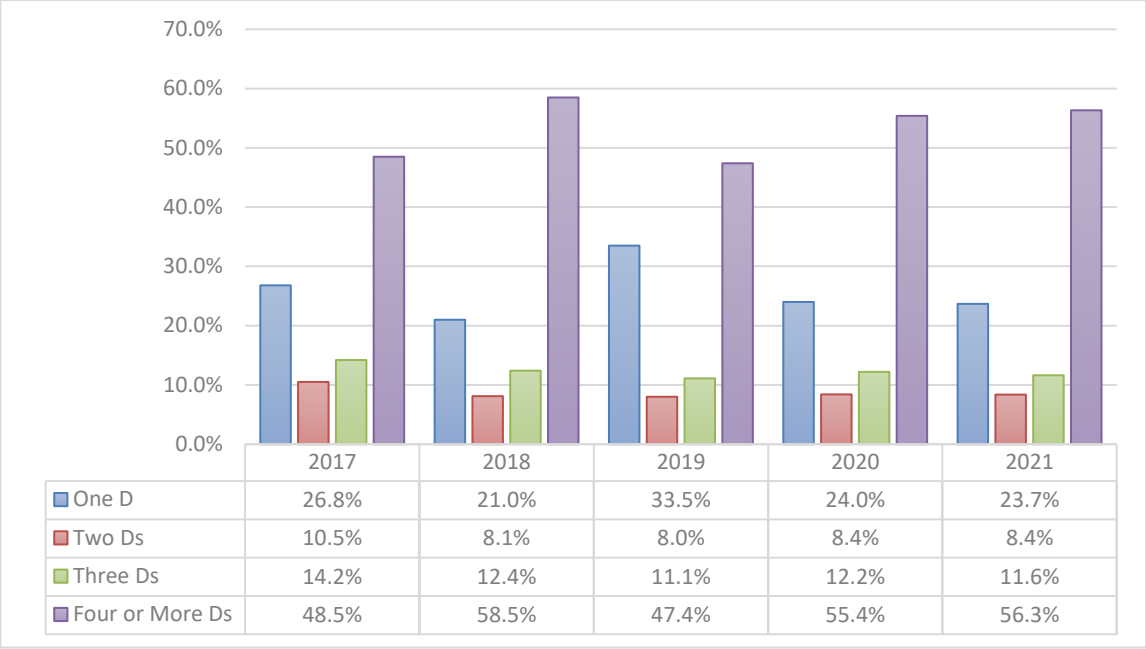


Fig. 5. Transmission Proportions Comparison 2018- 2021

Table 4. The Most Frequent Codes in 2018 - 2021

Code	Number (%) 2018	2019	2020	2021	Code Meaning
10	5,429,760 (39.7%)	6,318,607 (40.3%)	5,849,385 (42.3%)	6,056,978 (41.06%)	No conflict: the utility is outside of the stated work area.
20	4,547,857 (33.2%)	5,001,258 (31.9%)	4,812,998 (34.8%)	5,017,426 (34.01%)	Marked
60	856,923 (6.27%)	223,167 (1.4%)	945,636 (6.8%)	513,447 (3.48%)	The locator and excavator agreed and documented the marking schedule.
999	1,003,417 (7.34%)	1,616,907 (10.3%)	897,957 (6.5%)	1,158,315 (7.85%)	Member has not responded by the required time.
30	1,143,720 (8.36%)	1,843,619 (11.8%)	685,087 (5.0%)	1,240,435 (8.41%)	Not complete.
80	336,570 (2.46%)	334,547 (2.1%)	307,100 (2.2%)	396660 (2.69%)	Member's master contractor is responsible for locating facilities.



	2017	2018	2019	2020	2021
One D	26.8%	21.0%	33.5%	24.0%	23.7%
Two Ds	10.5%	8.1%	8.0%	8.4%	8.4%
Three Ds	14.2%	12.4%	11.1%	12.2%	11.6%
Four or More Ds	48.5%	58.5%	47.4%	55.4%	56.3%

Fig. 6. The Number of Days Needed for a Positive Response

Three-Hour Notice (3Hr) and Code 999

According to the damage prevention act in the state of North Carolina, utility owners must mark their utilities within three business days (BDs). Excavators shall place a three-hour notice (3Hr notice) when utility owners fail to mark their utilities within three BDs or if there is evidence of an unmarked facility after the 3BD [87–122, (C) (2)]. Code 999 is assigned to a ticket when utility owners do not respond within the required time. In 2021, 45.3% (i.e., 5,977,797) of transmissions were placed in Mecklenburg, Wake, Guilford, and Durham. The percentages of the 3Hr notices and Code 999 in these counties represent 51.4% and 46.4% of the total count, respectively.

Comparing the overall number of 3Hr and 999 Codes in these counties indicates that the 3Hr notice has not been fully utilized over the years. For example, the number of 999 Codes in Mecklenburg was 236,522, whereas the number of 3Hr notices was only 19,488, which may suggest failure to utilize the 3Hr notice and/or invalid use of Code 999, see Table 5. Thus, educational and outreach efforts should clearly explain the importance of utilizing the 3Hr notice.

Table 5. The Number of 3Hr Notices and Code 999

County	2018		2019		2020		2021	
	3Hr	Code 999	3Hr	Code 999	3Hr	Code 999	3Hr	Code 999
Mecklenburg	15,761	235,065	20,906	322,987	16,702	189,787	19,488	236,522
Wake	9,720	158,161	18,777	290,714	13,992	208,085	19,508	244,752
Guilford	2,193	39,807	4,570	57,046	2,391	16,326	3,146	19,503
Durham	2,767	69,056	5,323	120,266	3,186	16,862	4,395	36,479

Follow-up Survey 2022

The 2022 follow-up survey to assess the experiences of NC 811 customers was administered in May 2022. The survey targets callers who contacted NC 811 between January and March 2022; 38,954 individuals placed a total of 132,851 tickets during this period. This year's follow-up survey adopted a stratified random sample, a form of random sampling applied in each of a set of separate groups formed from all individuals who placed a ticket with NC 811. That is, a small, random portion of each particular group was selected, ensuring that each member of the said group had an equal probability of being chosen. A probability sample allows for the generalization of the findings because it reflects the characteristics of the targeted population. The stratified sample was selected to avoid skewing results since the dataset includes non-professional excavators such as homeowners. Accordingly, the sample consists of three categories: professional excavators (contractors), homeowners, and others (i.e., cities, counties, utility owners, A/E firms, and others).

The primary purpose of stratification is to control subgroup sample sizes. Proportional allocation, which involves applying the same sampling rate to all strata, is employed to assess the experiences of the subgroups and the population. The overall sample size, based on a 95% confidence level and a 5% margin of error, is 381. The sample size of each group was calculated using question 1. However, high non-response rates are prevalent in survey research studies, often compromising the reliability and validity of survey study findings. For example, a response rate of 30% means the study suffers from a non-response bias of 70%. The prior follow-up surveys noted response rates of 5% among homeowners and 2.5% among contractors. Thus, the probability sample was increased by 20 times for homeowners and other groups and 40 times for the contractor group to avoid non-response errors. Table 6 shows the calculated sample sizes for each group and

adjusted sample sizes for each group. The modified sample sizes were randomly drawn from the total population of each group. Responses were received from 534 individuals, 40.8% of whom were first-time users of the NC 811 system. Figure 7 shows the number of participants in the NC 811 follow-up surveys, including the 2022 survey. Most of the participants were homeowners (251; 47%), followed by contractors (164; 30.7%) and others (119; 22.3%). Most homeowners were first-time callers, whereas most contractors had called NC 811 many times per year. Figure 8 illustrates the method used by participants to place a locate ticket. Calling NC 811 via phone was the most frequently used method reported by the study sample, which is similar to what was reported in previous years.

$$n_x = Y(n|N) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where: n_x = The sample size of each group

Y = The population of each group

n = the overall sample size (i.e., 381)

N = the population size (i.e., 38,954)

Table 6. Sample Size Calculation

Group	Population Size	Calculated Sample Size (%)	Received Surveys
Homeowners	18,711	183	251
Contractors	14,567	143	164
Others	5,676	56	119
Total	38,954	382	534

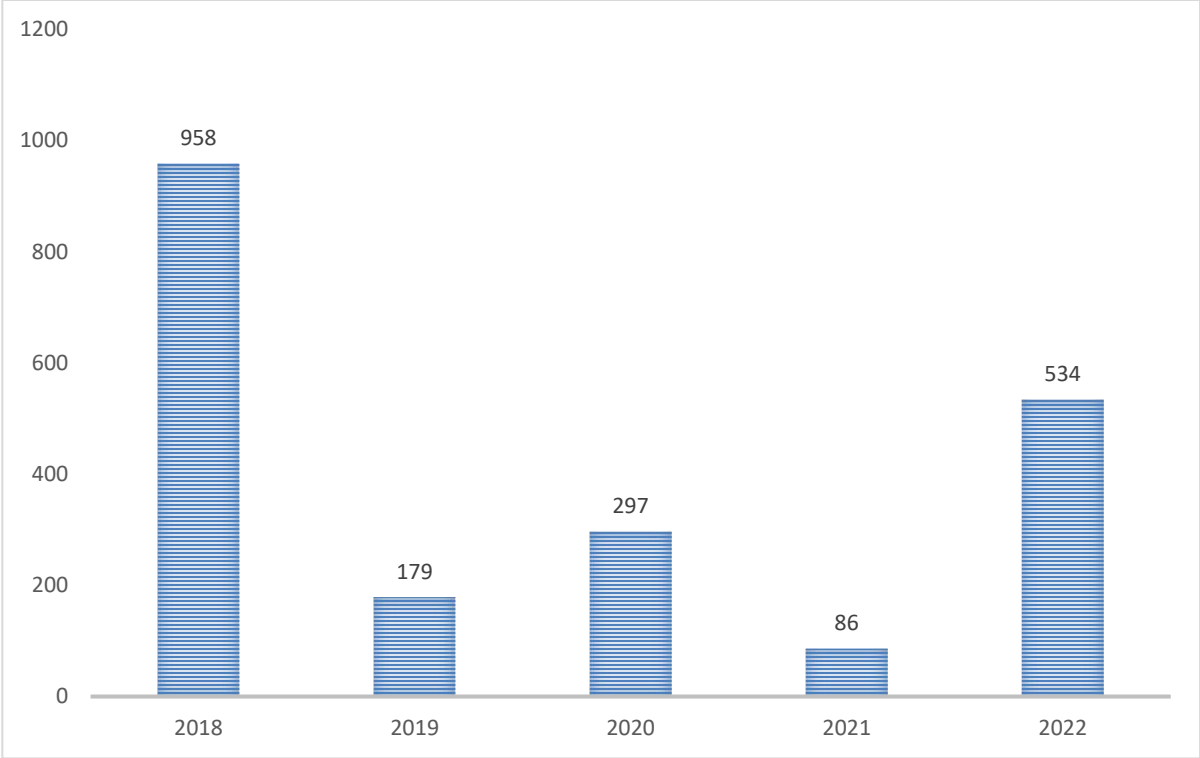


Fig. 7. The Sample Size Over the Last 5 Years

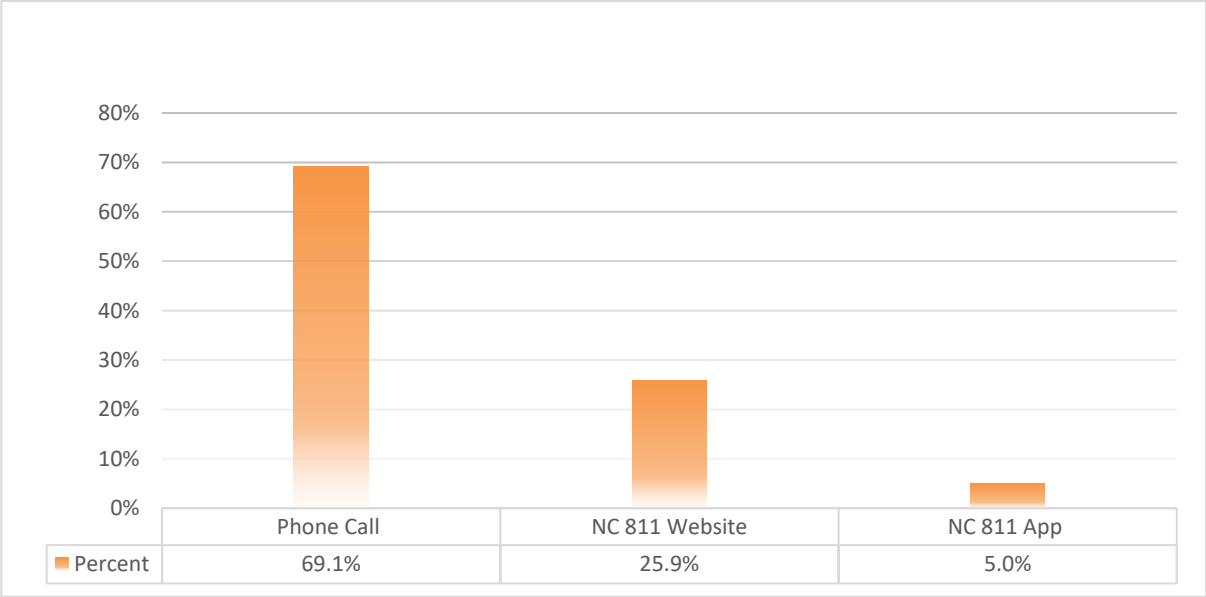


Fig. 8. NC 811 Contact Methods – 2021

Participants were asked about the ease of placing a locate ticket through NC 811. The collected data suggests that 96.1% of participants believed it was easy to place a locate ticket, and this percentage was 94.2% in 2021 and 96.1% in 2020. Table 7 lists a sample of reasons why 5.8% of the study sample believed it was not easy to place a locate ticket.

Table 7. Sample of Participant Feedback – Ticket Information

• The website is somewhat confusing. Too many choices. Make it clearer for the homeowner.
• I placed it on your website but had to follow up by calling.
• I usually place survey-related tickets in Virginia, but occasionally have to place them in NC as well. In VA, I can place single site tickets online for surveying, and they will locate any survey ticket within three business days. However, with NC there is no survey option online, so I have to call no matter what, and it takes 14 business days which is not ideal.
• Staff does not seem able to problem solve to get the correct result. Rigidly follow the script.

Locate Accuracy

The locate accuracy provided by NC 811 seemed to satisfy the individuals who participated in the study; 90.4% of them stated that the locate marks were accurate, representing a noticeable improvement from the previous year. This percentage was 82.6% in 2021, 82.1% in 2020, 83.8% in 2019, and 87.9% in 2018. The accuracy rates among the study groups are presented in Figure 9. The perceived accuracy rate score is the lowest among contractors. Looking closer at the contractor subgroup reveals that commercial contractors are the least satisfied with the accuracy of locates,

which could be explained by the fact that NC 811 members are not required to locate utilities on private lots, see Figure 10. Al-Bayati and Panzer (2021) suggest several causes of inaccurate locates based on locators' and excavators' observations and comments, such as workforce shortages, broken tracer wires, and inaccurate maps. See Table 8 for more details about the identified causes and their rankings. Participants from contractors and other subgroups who indicated that they received an inaccurate locate (n = 51) were asked about the inaccurate utility type. Most participants (23; 45.1%) suggested that tele/TV locates were inaccurate, followed by electrical locates (14; 27.5%), gas locates (9; 17.6%), and water and sewer locates (5; 9.8%).

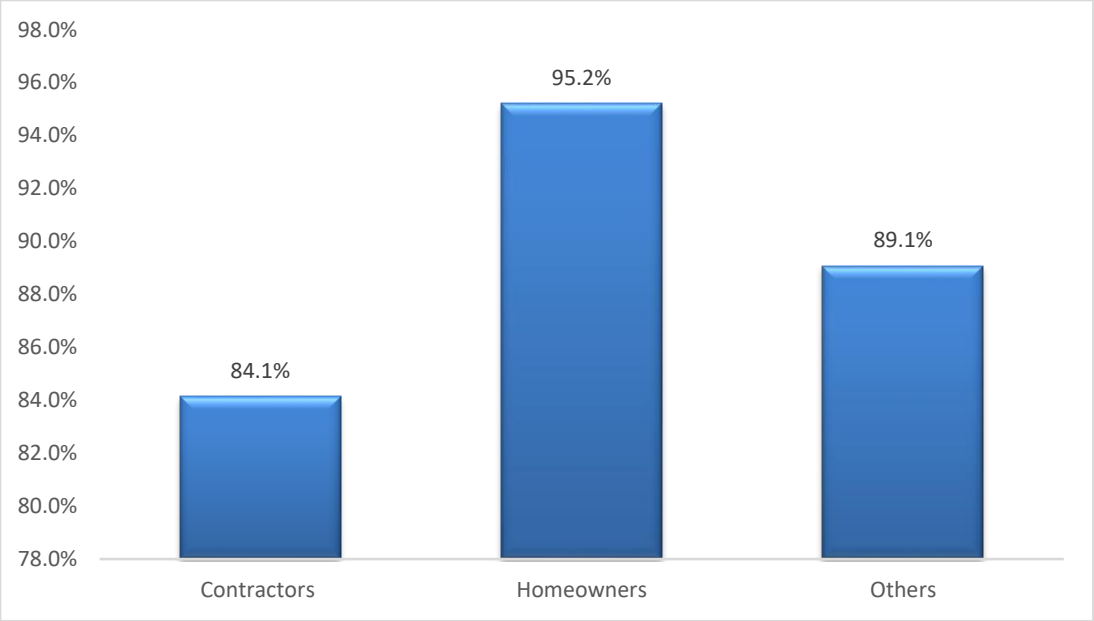


Fig. 9. The Accuracy Rate by Study Group

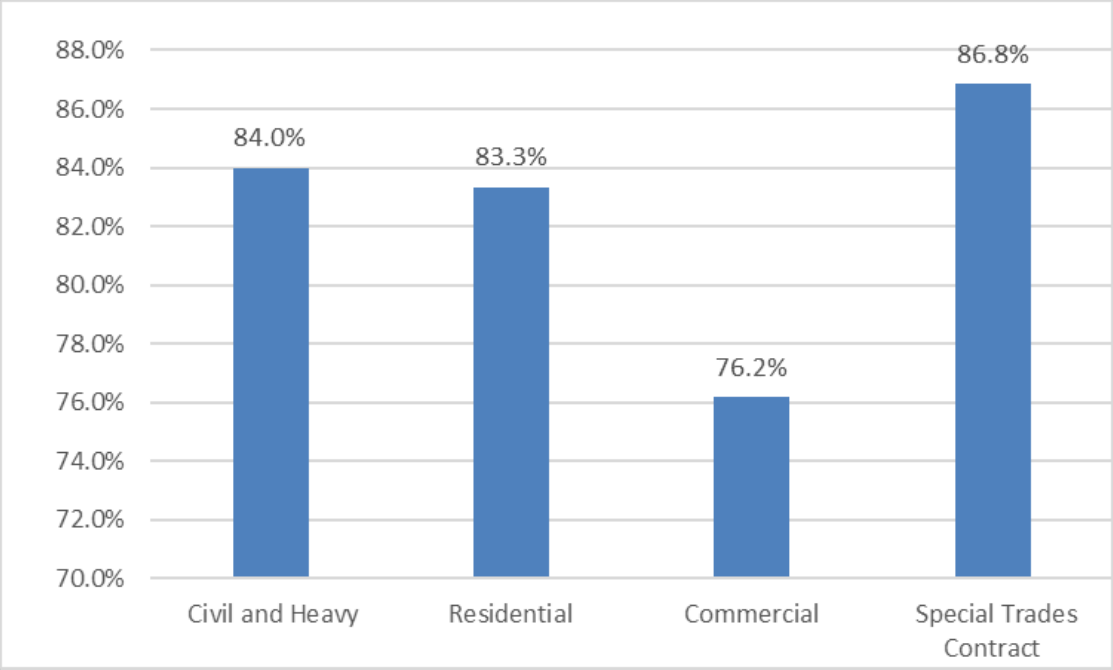


Fig. 10. The Accuracy Rates within the Contractor Subgroup

Table 8. Statistical Ranking of Inaccurate Locate Causes		
Excavator*	Locators**	Cause
1	1	Locators rushing due to workforce shortages
4	2	Broken tracer wires
2		Inaccurate maps
1	3	Insufficient locator training
4		Utility location obscured due to material interference
4		Utility location obscured due to vegetation
3	4	The utility installed with unmarked looped lines
N/A		Locating equipment limitations

*Al-Bayati and Panzer 2019; ** Al-Bayati and Panzer 2020

Unmarked Utilities

Unmarked utilities could be a result of the following:

- An abandoned utility,
- A utility owner not being a member of NC 811,
- Inaccurate as-built maps that indicate no utilities exist within the proposed excavation area,
- Utility owner/operator fails to respond to locate ticket, or
- Excavators start excavation before receiving a positive response.

Contractors and Other groups were asked if they had encountered an unmarked utility. The data indicates that 92 (33.8%) experienced an unmarked utility. Participants were also asked if damage occurred during the excavation. Sixty-one participants (22.4%) stated that they had encountered utility damage during the excavation. The damage rate seems higher among participants who encounter an unmarked utility. Accordingly, the odds ratio of encountering damage where there is an unmarked utility was calculated based on the data presented in Table 9. The results suggest that the odds ratio of damage where there is an unmarked utility is 71.67 larger (95% confidence interval [CI]: 24.4 to 210.3) than on excavation sites where all utilities are marked. This would mean that excavations with unmarked underground utilities are 71.67 times more likely to encounter damage than excavations where underground utilities are all marked. The 95% CI of 24.4 to 210.3 means that we can be 95% confident that the true odds ratio lies somewhere between 24.4 and 210.3. A 95% CI that does not eclipse 1.0 would commonly be interpreted as statistically significant.

Two follow-up questions were asked to capture damage report practices. The data suggest that 85.2% of participants who encountered damage reported it to the utility owners, whereas only 62.3% reported it to NC 811.

Table 9. Damage Versus Unmarked Utilities Crosstabulation

		Damage occurs		Total
		Yes	No	
Unmarked Utility	Yes	57	35	92
	No	4	176	180
Total		61	211	272

Locate Time

The legally required timeframe to locate underground utilities is three business days in North Carolina. The collected data suggest that utility locators could not complete 37.9% of locate requests within the legally required timeframe in 2022, see Figure 11. This percentage is higher than the percentages found in the 2021 follow-up survey, which was 25.5%. Excavators must give a 3-hour notice when locators fail to mark their utilities within the legally required timeframe [NC Gen Stat §87-122, (C) (2)].

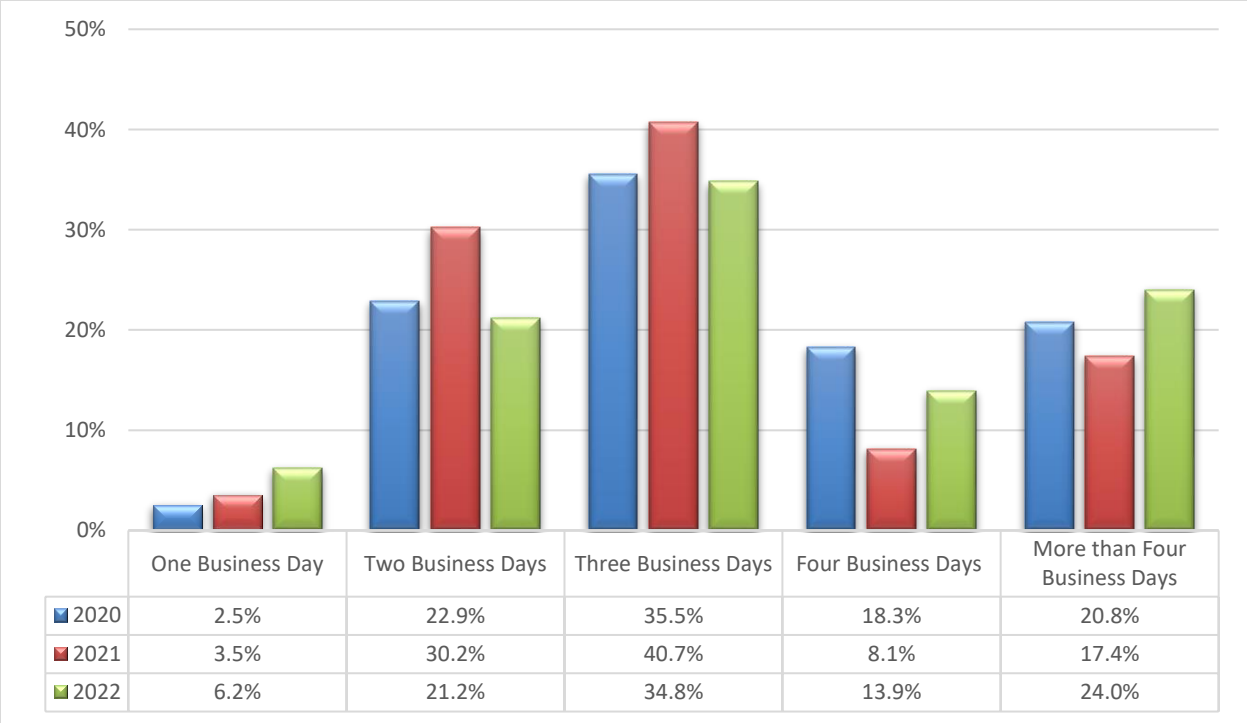


Fig. 11. Number of Days Needed to Locate Underground Utilities

Al-Bayati and Panzer (2021) suggest several causes for late locates, including workforce shortages, inaccurate maps, use of the wrong ticket type by excavators or designers, absence of white lining, and improper update tickets. According to the locators who participated in Al-Bayati and Panzer's (2021) study, workforce shortages were the greatest contributor to late locates, followed by inaccurate maps and the use of normal locate tickets for design/survey work. The legally required timeframe to respond to a design/survey ticket is ten business days instead of three full business days. In addition, the response to a design/survey ticket could be a physical locate, the provision of maps, or access to the maps provided by the utility. Designers often desire a physical locate, which is not guaranteed with a design/survey request, or they do not want to wait ten days to get a response. This inappropriate utilization of 811 tickets places an unnecessary burden on locators.

Locators also reported white lining as a major challenge that increases the required time to complete a locate. White lining is vital to define the excavated area and facilitates accurate locates of utilities within an acceptable timeframe. In North Carolina, the law requires excavators to place white lining around the proposed excavation area when the area cannot be adequately described in the ticket. The follow-up survey results suggest that 28.4% of homeowners who participated in the study are unaware of white lining and its meaning, see Figure 12.

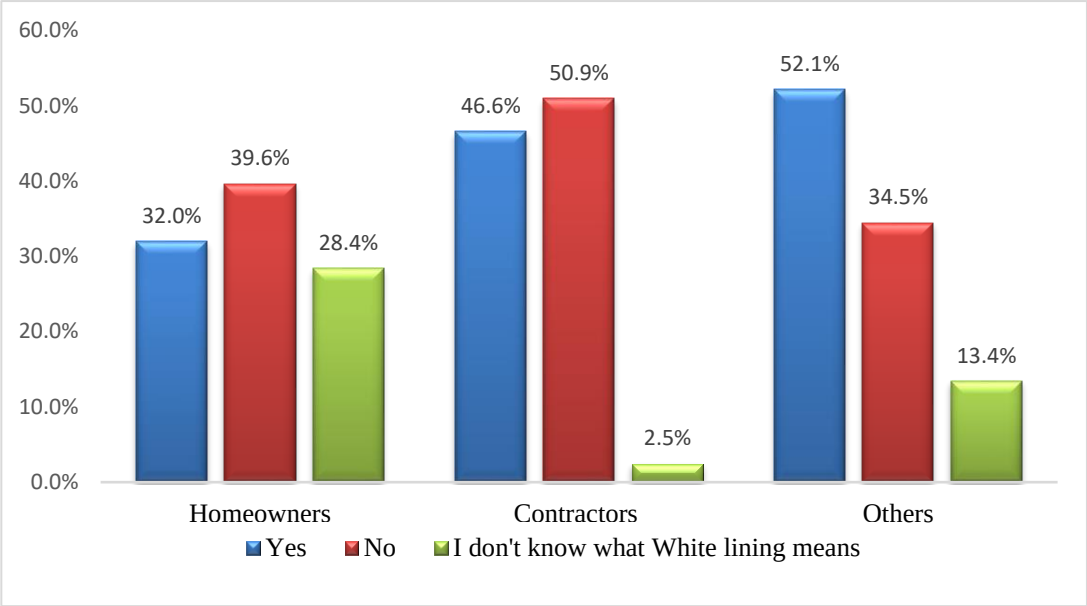


Fig. 12. White Lining Utilization

The other interesting finding is that a high proportion of contractors are not utilizing white lining despite its importance in reducing locate time and improving overall accuracy. A closer look at the contractors' subgroups indicates that a higher proportion of special trade contractors (60%) are not utilizing white lining, followed by commercial building construction contractors (47.6%), residential building construction contractors (45.2%), and civil and heavy construction contractors (36%).

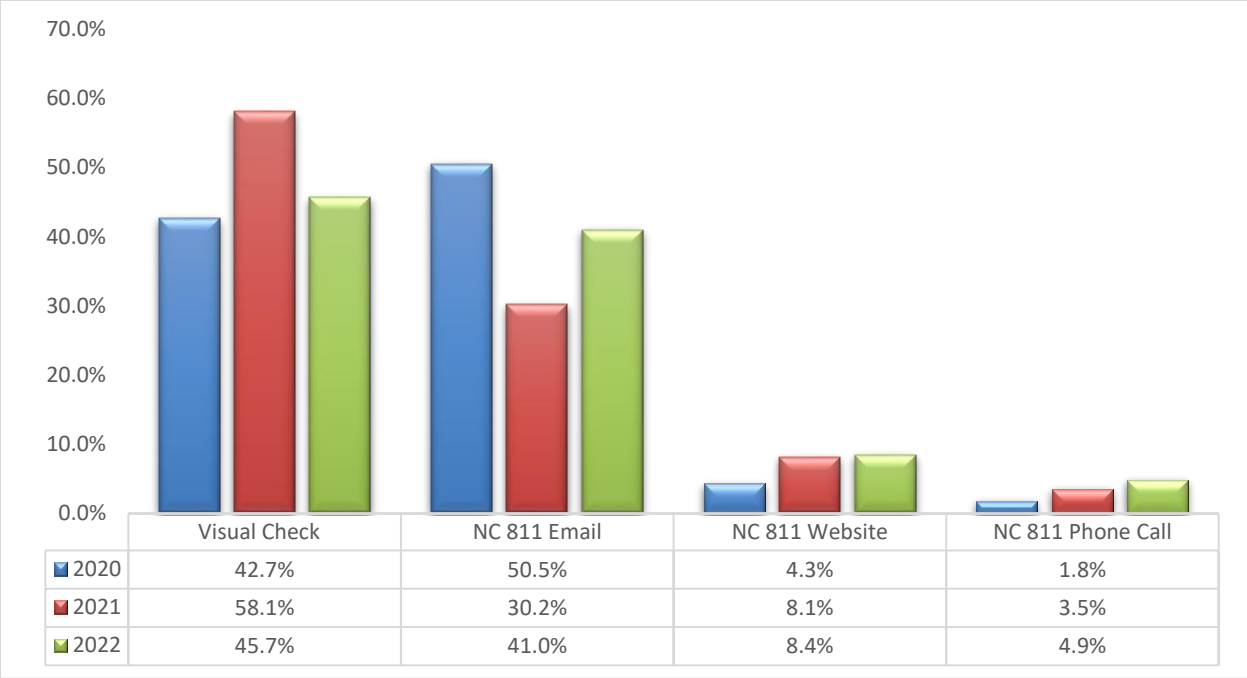
The lack of white lining and inappropriate use of locate tickets create system noise, which causes a compounding effect that leads to many undesirable scenarios, as suggested by Al-Bayati and Panzer (2021). For example:

- When excavators believe they will not receive a response in the required timeframe, they may place locate tickets weeks in advance, hoping to obtain marks when they are planning to dig.
- Excavators may lose confidence that the locates will be completed on time. In this case, the

excavator may place a series of tickets with the hope that some of the work will be located on time, and those will be the jobs they move the crews to work on.

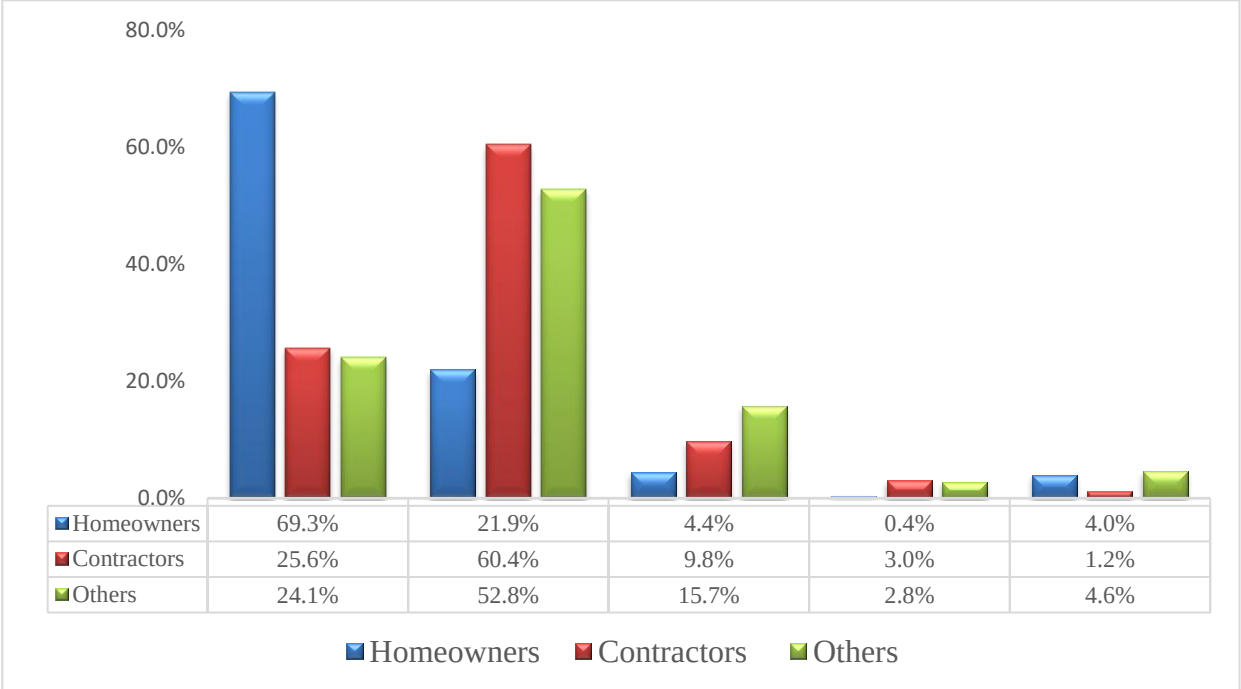
Positive Response Verification

Article §87-122. (a) (2) of the Damage Prevention Act in North Carolina requires excavators to ensure that all underground utilities have been marked (i.e., positive response) by checking with NC 811 via phone, email, or through NC 811's website. However, the results indicate that 45.7% of participants only visually checked the excavation areas to verify the status of their locate request. Figure 13 suggests that the issue of using an inappropriate method to check for a positive response has been reported frequently from 2020 to 2022. Checking the excavation area alone is not sufficient to verify a positive response. Thus, increasing efforts to educate excavators about the correct methods for verifying a positive response is crucial. It is essential to reach out to homeowners because a high proportion of them (almost 70%) indicated that they check the proposed area visually to verify the positive response, see Figure 14. NC 811 has produced an educational video about the correct method to verify positive responses. ***This video should be distributed via email or text message after a locate ticket is placed to ensure excavators know how to verify positive responses correctly. The video can be found here: https://www.youtube.com/watch?v=ujKnBWcKmfw***



	Visual Check	NC 811 Email	NC 811 Website	NC 811 Phone Call
2020	42.7%	50.5%	4.3%	1.8%
2021	58.1%	30.2%	8.1%	3.5%
2022	45.7%	41.0%	8.4%	4.9%

Fig.13. Positive Response Verification Methods



Homeowners	69.3%	21.9%	4.4%	0.4%	4.0%
Contractors	25.6%	60.4%	9.8%	3.0%	1.2%
Others	24.1%	52.8%	15.7%	2.8%	4.6%

Fig.14. Positive Response Verification Methods by Survey Subgroup

The Quality of Services

This section assesses the perceptions of the study sample about the following items using a 1 to 10 scale: the professionalism of NC 811, the overall process of NC 811, the accuracy and completion time of locate requests, and the professionalism of locators. Similar to those found in previous years, the results suggest that NC 811 professionalism scored higher than other aspects, followed by NC 811 overall process, with average scores of 8.9 and 8.4, respectively. The scores of locater professionalism and locate accuracy seem to have improved over the last few years; see Figure 15. However, the completion time score is still lagging compared to other measured aspects, with an average score of 7.4. This low score is expected due to the high percentage of late locates, as reported earlier in this document. A one-way ANOVA test was conducted to assess for statistically significant differences between the five aspects. The ANOVA result indicates a statistically significant difference between the five aspects of services ($F = 27.147$, $df = 4, 2665$, $p < 0.001$). This means that there is less than a 0.005 chance that the difference in scores could be attributed to random effects. This also means that at least one of the aspects is statistically significantly different from the others. Tukey's honestly significant difference (HSD) tests were conducted to determine the source of variation to evaluate the pairwise differences between the measured aspects. The results reveal that NC 811 professionalism scored higher than other aspects to a statistically significant degree, and completion time scored the lowest among the aspects to a statistically significant degree. Table 10 illustrates the groups that were found to be significantly different ($p < 0.05$). Finally, the collected data suggests that the customers of NC 811 from all sup-groups are most satisfied with NC 811's professionalism and its overall process, see Figure 16. Completion time scored the lowest (6.5) based on contractors' experiences, which is an expected result.

Table 10. Quality Classifications Based on the ANOVA Test

Group #	Aspect	Score Average
1	NC 811 Professionalism	8.9
2	NC Overall Process	8.4
	Locater Professionalism	8.3
	Locate Accuracy	8.2
3	Completion Time	7.3

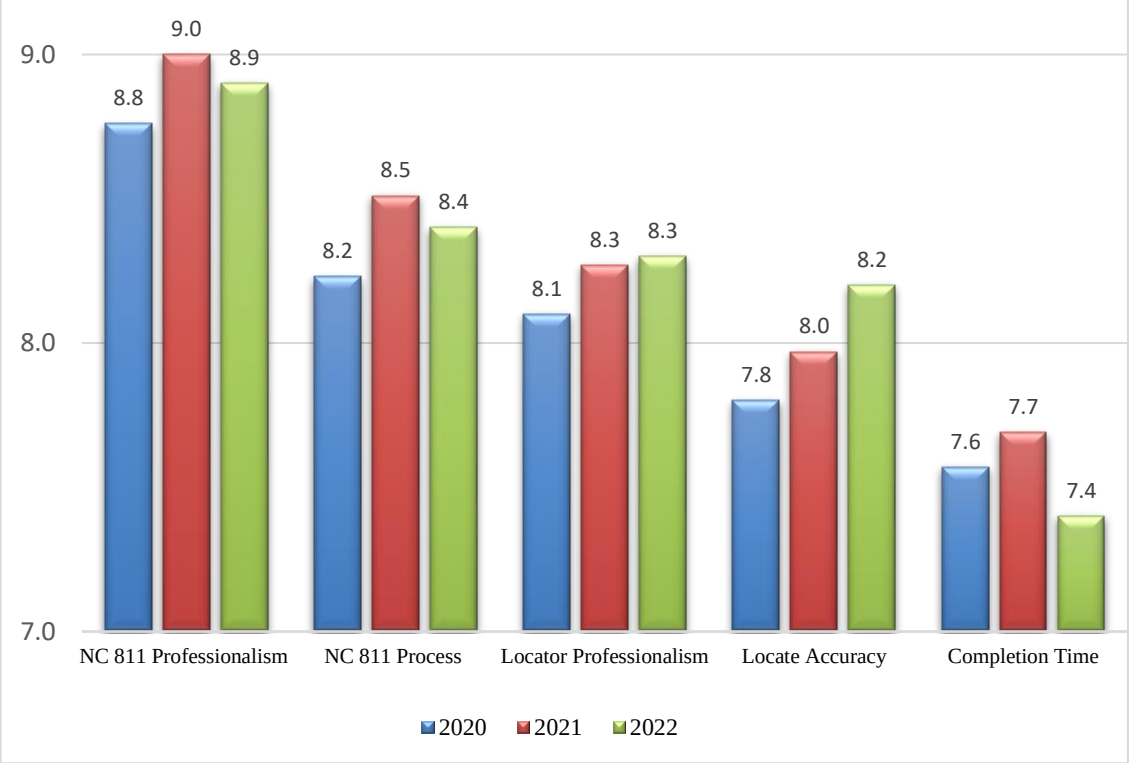


Fig. 15. Quality of Service Provided by NC 811 and Locators

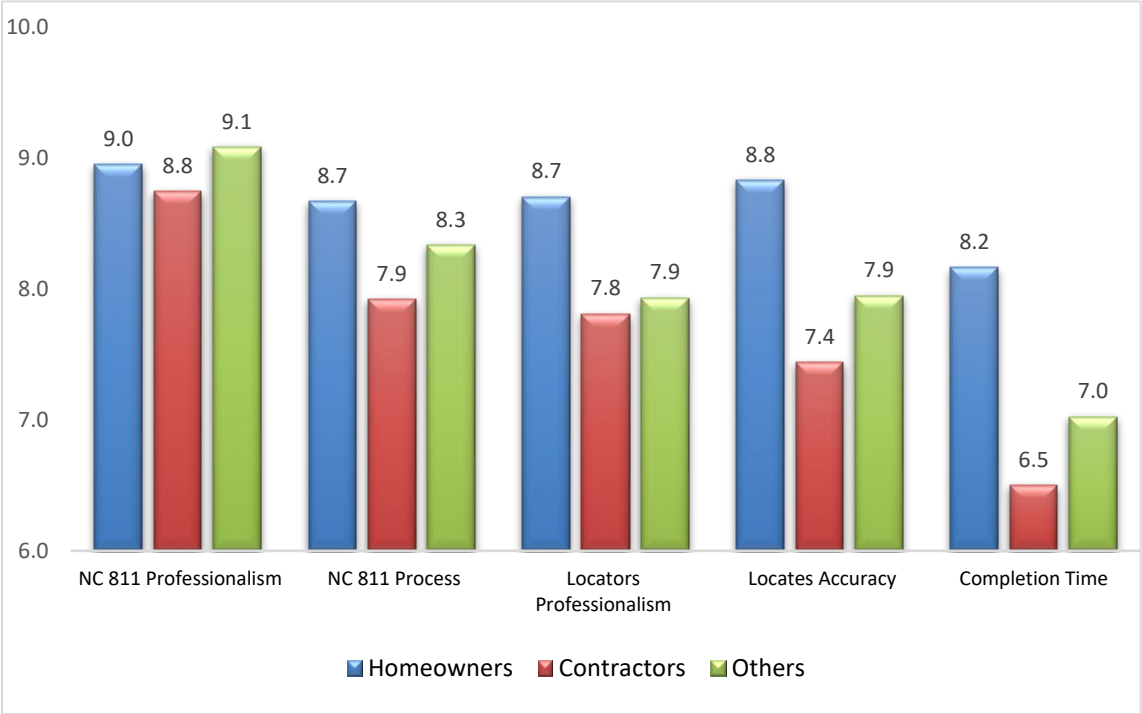
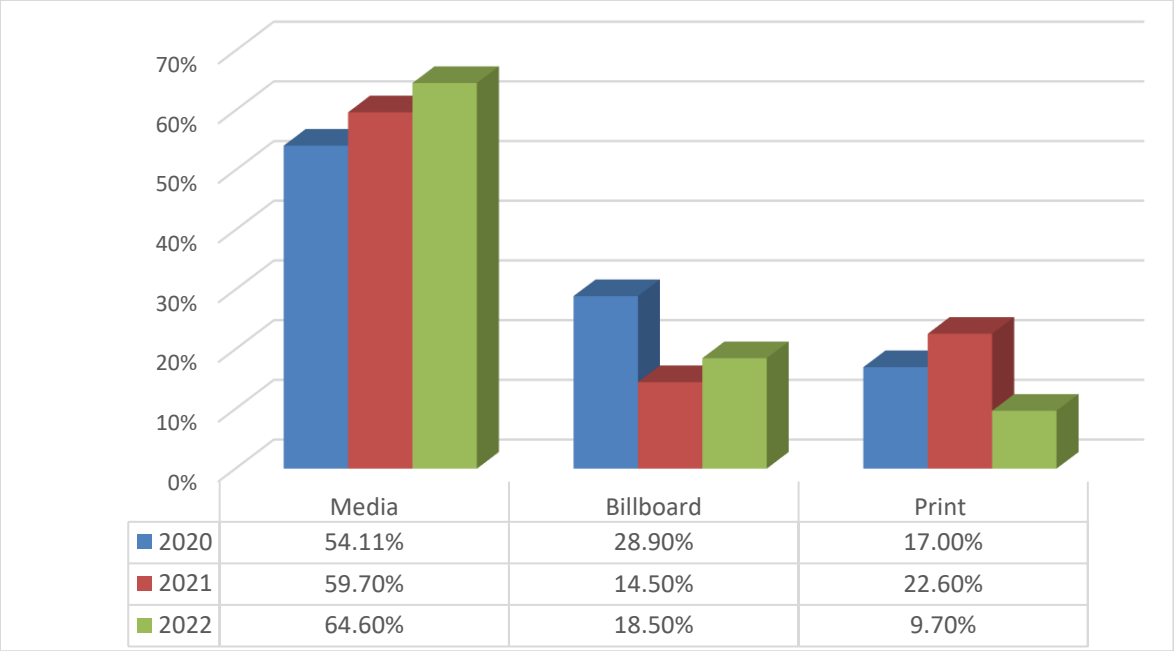


Fig. 16. Quality of Services by Subgroups

NC 811 Outreach Efforts

North Carolina 811 works hard to educate the citizens of North Carolina about its services. These education efforts come in different formats, such as billboard, TV, and radio advertisements. Of the 2021 follow-up survey participants, 78.8% indicated that they had seen an NC 811 advertisement. Figure 11 illustrates the frequency of advertising methods that were seen according to participants' feedback. According to this feedback, media (e.g., television, radio, and internet advertisements) represents the most effective method of advertising, accounting for 64.6% (n = 272) of responses, followed by billboard (18.5%), print (i.e., in magazines, phonebooks, and utility bills) (9.7%), and other (7.1%) advertisements, see Figure 17. Clearly, the overall findings suggest that media advertisements continue to gain ground over the years, and this finding should contribute to shaping future advertising funds allocated by NC 811.



	Media	Billboard	Print
2020	54.11%	28.90%	17.00%
2021	59.70%	14.50%	22.60%
2022	64.60%	18.50%	9.70%

Fig. 17. Effectiveness of Advertising Methods

Subsurface Utility Engineering (SUE)

This is a new section of the NC 811 follow-up survey created due to the increased utilization and importance of SUE, which is a standardized process introduced by the American Society of Civil Engineers (ASCE) in 2002. SUE practice is different than the one-call practice in many aspects. The main difference is that SUE aims to collect reliable information about active, abandoned, and unknown utilities, whereas the one call center only provides information about active public utilities (Al-Bayati and Panzer 2021). The other significant difference is that SUE requires a registered professional (e.g., engineer or surveyor) to determine the quality level of utility information based on the means and methods used and to affix their stamp on the plans that depict the SUE quality level. Finally, SUE is not free, while one-call service is free. NC citizens need to be aware of these differences as well as the existence of SUE so they can choose the most efficient method to use based on site conditions and project complexity.

A large proportion of the study sample (420; 78.7%) is unaware of SUE. This proportion is very concerning, especially given that 62% (i.e., 102) of contractors are unaware of SUE, see Figure 18. Further questions were asked about SUE; however, homeowners were excluded from them. Participants were asked if they hired a private locating firm to locate private utilities. The responses indicate that only 16.6% (i.e., 47) of participants hire private locating firms. Those who hired private locating firms were asked if they require SUE practice; only 31.9% (i.e., 15) indicated that they do. Again, there is a clear lack of awareness of SUE practice within the industry. This conclusion should be reviewed considering the participants' characteristics. Most participants are smaller construction firms; 47% (i.e., 133) of them work for firms with less than ten employees, and 31.4% (i.e., 89) of them work for firms that hire between 10 and 50 employees.

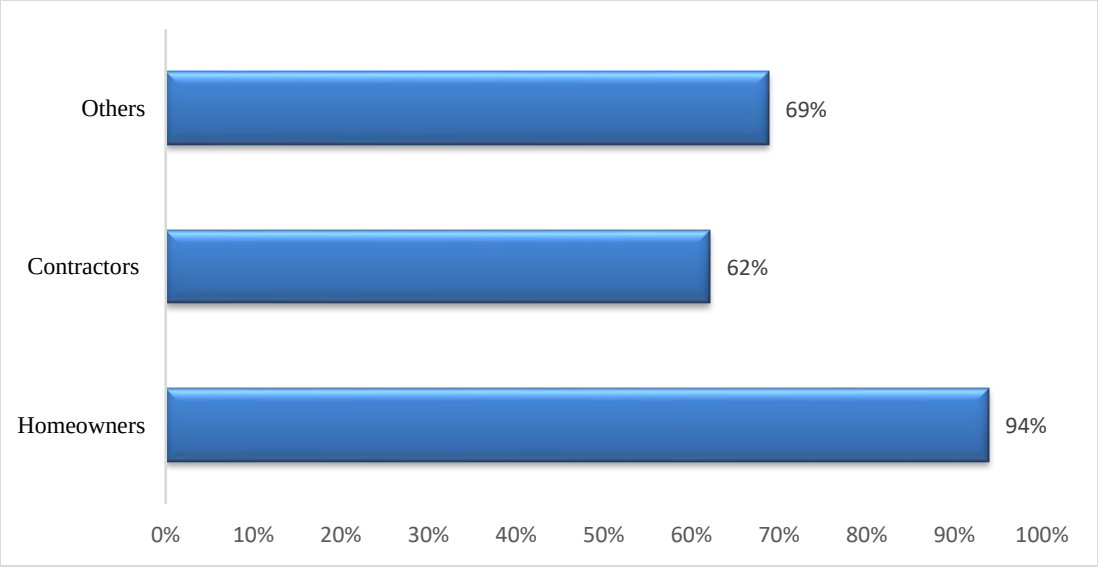


Fig. 18. SUE Lack of Awareness

Survey Key Findings

1. NC 811 consumers who placed a ticket with NC 811 during the first three months of 2022 were satisfied with the following:
    a. The ease of placing a ticket with NC 811; 96.1% of survey participants reported that this process was easy.
    b. The locate accuracy; 90.4% of survey participants reported accurate finds. This indicates an improvement in locate accuracy; it is the highest satisfaction rate since 2018. The locate accuracy rate within the commercial contractor group scored the lowest, which could be because damage prevention law does not require utility owners to locate their utilities on private lots.
2. 33.8% of participants from the contractor group and other categories encountered an unmarked utility. The odds ratio calculation indicates a 71.67 larger probability of damage to an underground utility when there is an unmarked utility. This significant probability should be carefully addressed to reduce damages to underground utilities.
3. 37.9% of locate tickets were not cleared within the legally required timeframe in North Carolina (i.e., 3 business days). One of the contributing factors to this issue is the excavator failure to use white lining. This study suggests that a high proportion of homeowners do not deliver or are unaware of white lining, and a high proportion of contractors do not provide it even though they know its meaning.
4. A high proportion of NC 811 callers (i.e., 45.7%) still use a non-valid method, visual inspection of the proposed excavation area, to verify a positive response.
5. NC 811 professionalism scored the highest (score average: 8.9) among the aspects measured to assess service quality. The locate time scored the lowest (score average: 7.3).
6. Media advertisements continue to gain ground over the years in comparison to billboard

and print advertisements.

7. Awareness of Subsurface Utility Engineering (SUE) practice is lacking, even though it was introduced to the industry in 2002.

Every year, millions of tickets are placed through the notification system to locate underground utilities before excavation starts. This study aims to identify and quantify gas damage risks associated with notification tickets. Accordingly, the study explores the Gas damage ticket characteristics to determine their association with damages to underground gas utilities. The damage data between 2017 and 2021 were collected from North Carolina's notification system (NC 811). The results suggest that telecommunication, water, and sewer work contribute the most to natural gas damage. As for excavation tools/techniques, backhoe and trackhoe use led to more than 50% of damages between 2017 and 2021. Finally, works on landowner easement and city street rights-of-way experienced significantly greater damages. The findings indicate the feasibility of creating a model that quantifies the collective risk associated with notification tickets to assign a damage risk level. The study findings will contribute to better risk management among damage prevention stakeholders.

Introduction

Underground facilities such as power, communication, water, and gas lines have become increasingly complex and congested. Numerous factors may contribute to underground utility damages. Most underground utilities are fragile and are easily damaged by excavation or even by locating methods intended to prevent damage, such as using hand tools to uncover underground utilities. The notification system was created to aid damage prevention by serving as a communication channel between excavators and utility operators/owners. The system starts with a ticket placed by excavators before excavation begins.

This study explores reported characteristics of natural gas damage to identify the features that are often associated with damages. Accordingly, 3294 damages that occurred between 2017 and 2021 were assessed. Figure 19 shows the number of assessed damages per year. While there

are more reported damages per year, these are the only data points where all explored characteristics (i.e., Right of Way [ROW] types, type of work, and excavation tool/technique) were reported.

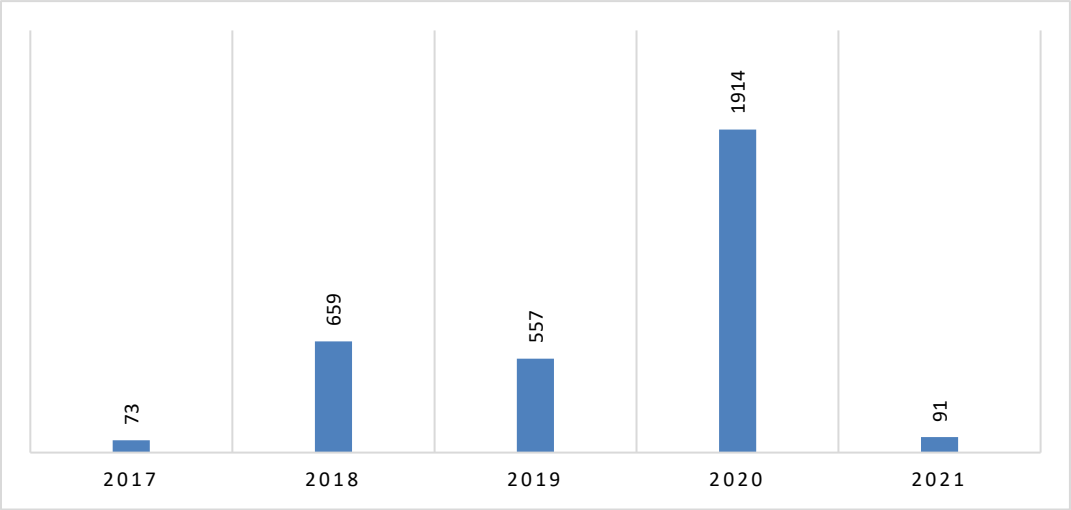


Fig. 19. The number of gas damages per year within the Study Sample

Most of the damages within the study sample occurred to service lines (2629; 79.8%) and distribution lines (650; 20%). A utility pipeline can be classified into a transmission, distribution, or service line. Transmission lines carry products such as clean water and natural gas to distribution lines that deliver the product to customers through service lines. Damages to transmission lines represent a small percentage of overall damages. Transmission lines are deeper and better marked in ROW with permanent above-ground marks.

Furthermore, transmission lines not in private ROWs are usually along busy roads, not in neighborhoods. Gas Transmission Integrity Management (GTIM) has required pipeline personnel to be present during excavation to satisfy the Pipeline and Hazardous Materials Safety Administration (PHMSA). The higher risk of injury and the potential cost of disruption to the transmission lines make these utilities a higher priority to the owners.

Damage Ticket Characteristics

Right of Way (ROW), performed work, and excavation tool/technique are the main characteristics that will be explored to achieve the study objective. The following subsections discuss each of these characteristics:

Right of Way (ROW)

ROW refers to the situation in which, although a parcel of land has an owner, some other party has a legal right to take over that land (Francis, 2009). The ROW types within NC 811 data include the following:

- Private ROW: An easement allows utility operators to place their facilities through private property in a specific location. There are two main types of private ROW:
    - Landowner
    - Business
- Federal Land
- Public ROW
    - City Street
    - County Road
    - State Highway

Figure 20 shows the frequency of gas facility damages per ROW type. Most of the damages occurred in Landowner ROW and Public–City Street ROW. Within the study sample, Public – City Road ROW was associated with 49.3% of damages that occurred between 2017 and 2021, followed by Private – Landowner ROW (47.2%). The damages in landowner ROW increased in 2020 and 2021, which could be a result of the COVID-19 pandemic. The pandemic led to more home renovation projects due to the stay-at-home order.

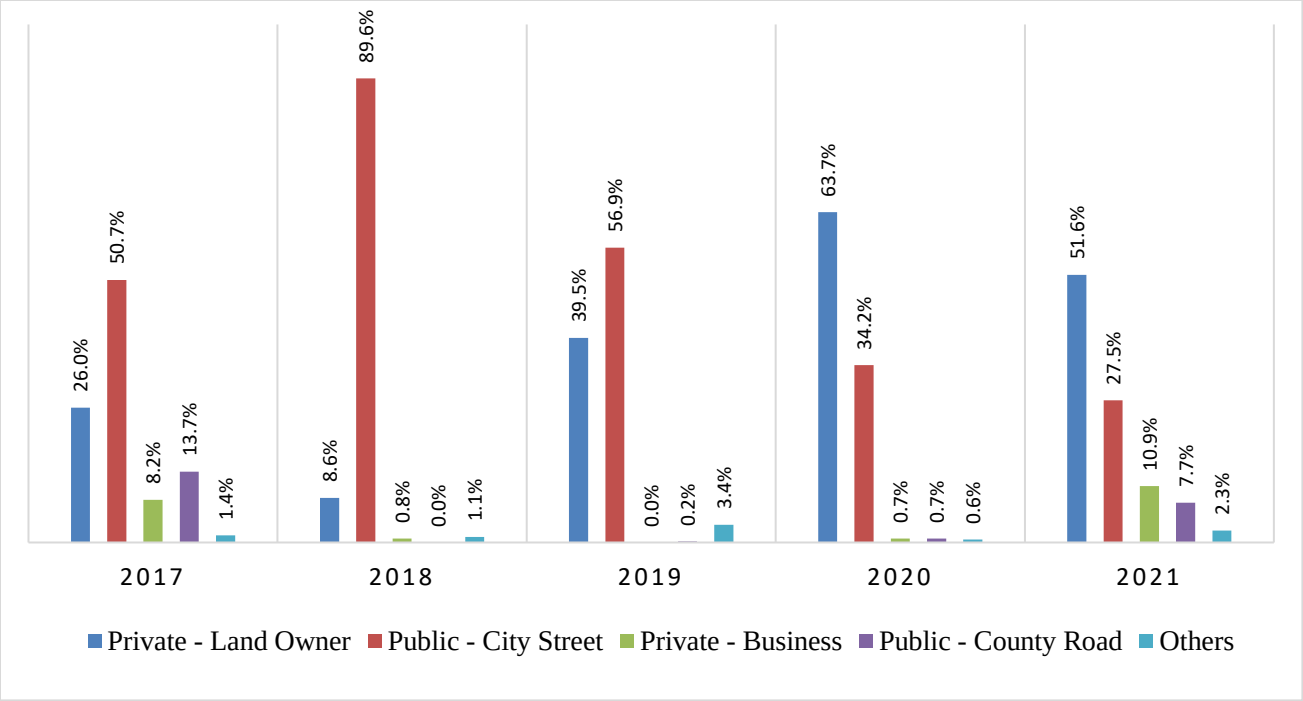


Fig. 10. The percentage of damage per ROW type (2017-2021)

Excavation Tool/Technique

There are nine excavation tools/techniques associated with the damages within the study sample, such as probing devices, trencher, and grader. Figure 21 shows the reported tools/techniques associated with more than 5% of damages within the study sample. Using a backhoe/trackhoe is associated with the most damage over the study period. It must be noted that using a backhoe/trackhoe should not be an issue if the utilities within the proposed excavation area have been visually located. Most notification system laws require excavators to hand expose utilities before utilizing power equipment to excavate. Thus, it is anticipated that these cases are more likely to have occurred when no hand tools were used to uncover underground utilities.

On the other hand, the high number of incidents associated with hand tool use is concerning, as using non-powered equipment should be associated with a lower number of damages. One potential explanation is that the reported information is not accurate, since some excavators may not want to report that they used powered equipment instead of using a hand tool to expose utilities.

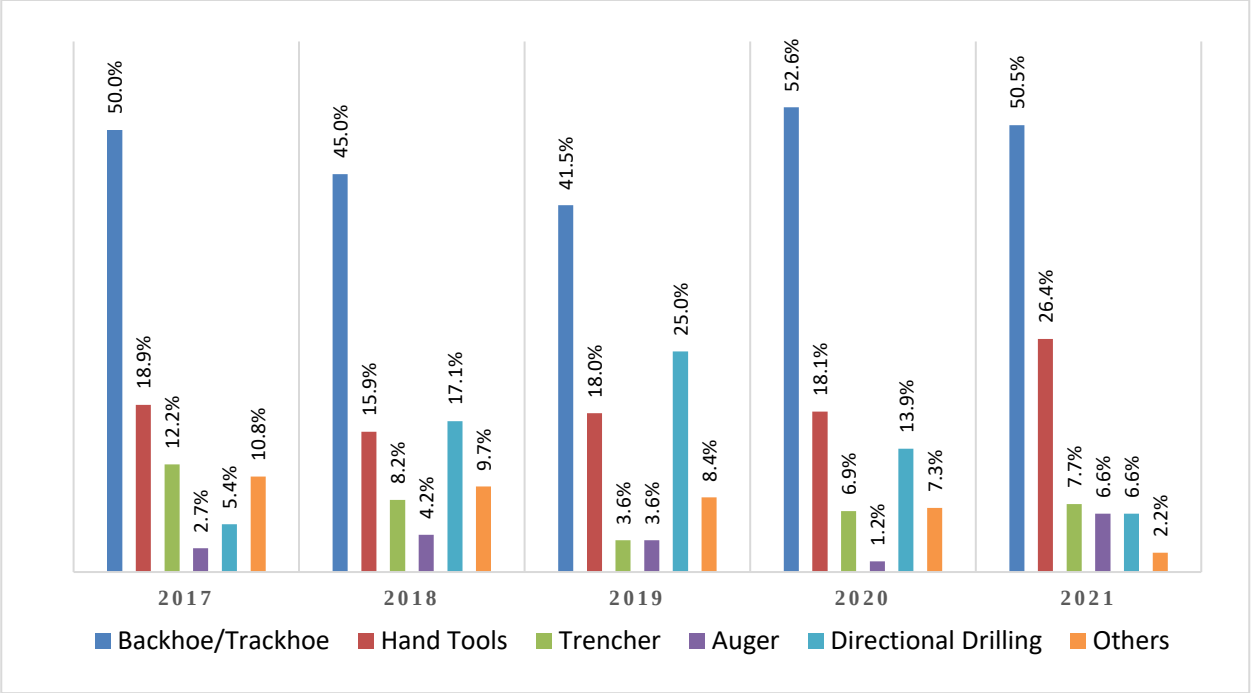


Fig. 21. The percentage of damage per excavation tool/ technique

Work Performed

The NC 811 damage tickets include information about the intended work. There are roughly 25 reported work types, such as streetlights, site development, surveying, and traffic signals. Figure 22 shows the damage frequencies per various work types associated with more than 5% of damages. Telecommunication work was associated with a high number of damages in 2018 and 2019. Within the study sample, Telecommunication work is associated with 25.6% of damages

that occurred between 2017 and 2021, followed by water (13.9%), sewer (12.6%), electrical (9.6%), and Landscaping (8.4%).

While it is understandable that water and sewer works may lead to gas line damages due to their depth, it is unclear why telecommunication has a high association. Thus, excavation tools/techniques used for telecommunication work were assessed. The assessment suggests that 92% (446) of horizontal directional drilling (HDD) were associated with telecommunication works, which explains the higher association between telecommunication work and gas line damages. HDD is an alternative to open trenching method for installing underground utilities. It requires an entry and exit pit which are often in an unpaved area. As a result, cutting pavement, traffic disruption, and restoration issues such as unsightly patches and uneven settlement are avoided. However, there is no visual verification of the HDD's drill path unless potholing is performed. As a result, there is high probability of damaging underground utilities while utilizing HDD.

As for sewer and water, the excavation techniques used are backhoe/trackhoe due to their depth. Practically, it is a challenge to use a different excavation method with sewer and water works due to their depth. Within the study sample, 28.7% of backhoe/trackhoe use was associated with sewer work, and 23% was associated with water work.

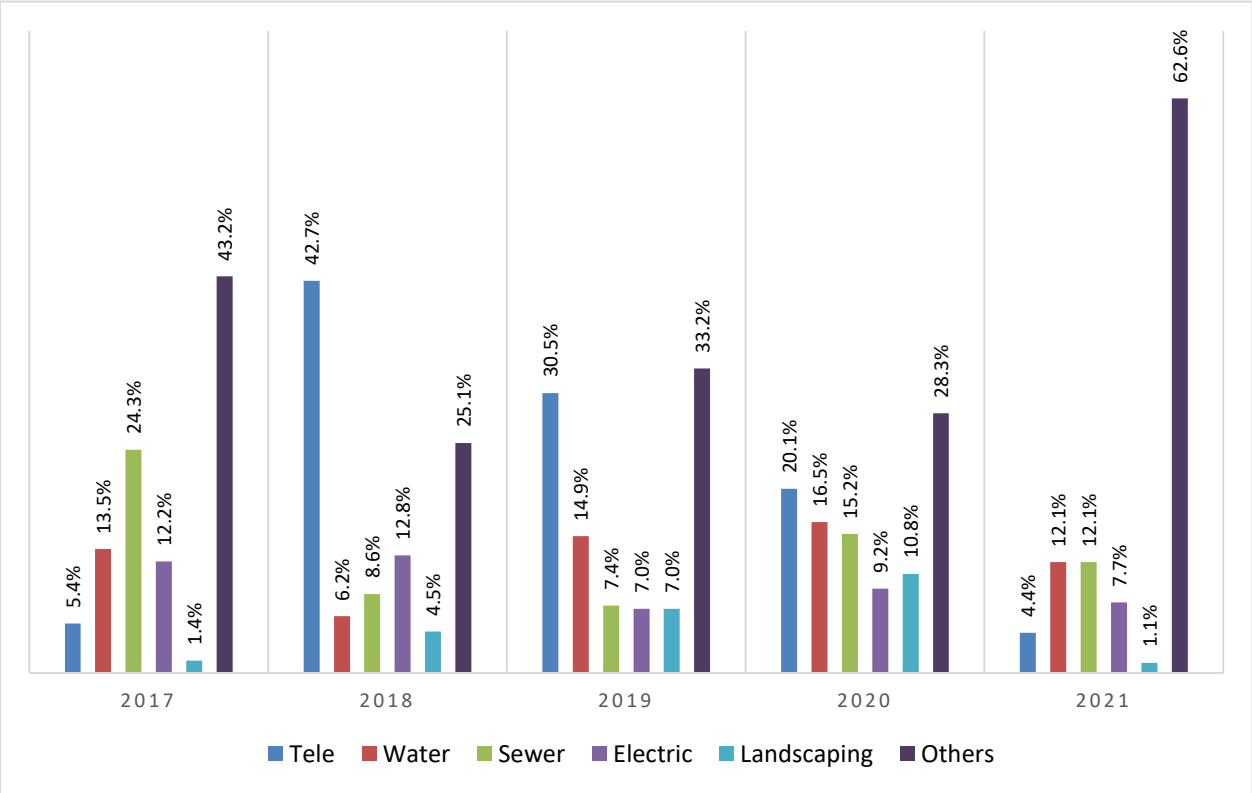


Fig. 22. The percentage of damage per work type

Discussion

Newton's third law states that for every action, there must be an equal and opposite reaction. When this same concept is applied to damage prevention, one may recognize that damage prevention efforts should equal the damage risk level. Assuming that every utility operator offers some damage risk mitigation, the mitigation ability should equal the risk level of the placed ticket. In theory, to reach equilibrium and make the risk system stable (i.e., damage free), the damage effort must meet or exceed the risk level.

Each notification ticket is associated with specific characteristics that may increase or decrease the probability of utility damage (i.e., damage risk level). Building a risk model based on the notification system's damage ticket characteristics is a promising innovative approach.

Strategies such as assigning an expert locator, allocating time or utilizing an advanced technique to accurately designate the underground facility, and communicating and working directly with the excavator could be used to address high-damage risk level tickets.

The study findings show a significant association between a few damage ticket characteristics and damages to gas facilities. This association could be used to create a damage risk matrix, which is vital to improve overall damage prevention since the current efforts are informal and variable, while the ticket risk level is not. Specifically, the findings suggest that excavations in city streets or landowner easements while performing work related to telecommunication (utilizing directional drilling), water, and sewer have a higher probability of damaging underground gas facilities.

To assess the feasibility of creating a risk matrix for gas tickets, a ticket risk matrix will be created based on the findings of this study. The matrix will be based on ROW, work to be performed, and excavating tool/technique. Each characteristic has been assigned a damage association number (i.e., an arbitrary value) between 1 and 5, where 5 is given to the characteristic with a high association and 1 to the characteristic with a low association. Table 11 shows a 5 X 7 damage risk matrix with scores 1-25, which can be classified into three risk categories: high, medium, and low. The risk categories with scores 1- 8 are regarded as low risk, 9-15 as medium risk, and 16-25 as high risk.

Table 11. A 6 X 7 Gas Damage Risk Matrix

ROW	Work Type						
	Tele (HDD)* (5)	Water (5)	Sewer (5)	Electric (3)	Landscaping (2)	Tele (Other) (1)	Others (1)
Others (1)	5	5	5	3	2	1	1
Public - State Highway (2)	10	10	10	6	4	2	2
Private - Business (3)	15	15	15	9	6	3	3
Public - County Road (3)	15	15	15	9	6	3	3
Public - City Street (5)	25	25	25	15	10	5	5
Private - Landowner (5)	25	25	25	15	10	5	5

*Horizontal Directional Drilling

This proposed risk matrix is only an explanatory tool; ongoing research into the development, refinement, and validation should be carried out. Specifically, the assigned association value must be built on an objective statistical model. Furthermore, additional research into the association of other ticket characteristics, such as geographic location, high-pressure facilities, and facilities that service critical entities, would be helpful in further refining the model.

Conclusion

There is no precise or wide-use mechanism for utility operators to formally allocate advance efforts to deal with high-level risk tickets. Most troubling, however, is that there is no guidance for utility operators with limited resources (e.g., workforce shortage and locating equipment limitations) to assign an objective risk level to notification tickets, and, consequently, allocate effective strategies to mitigate the identified risk. This study suggests that every notification ticket

is associated with specific risks and utility operators are capable of mitigating a portion of such risks. Once the cumulative risk for a ticket is assessed, utility operators can objectively and efficiently reduce the risk.

The main contribution of this study is highlighting the possibility of creating a successful damage risk matrix. However, it is believed that practical use of the ultimate outcome of this study will help improve the effectiveness of the overall damage prevention effort for a given ticket, guide resource allocation, and identify the level of intervention required.

North Carolina Damage Probability Study

NC 811 has been exploring ways to improve and monitor the normalization of damage statistics from year to year. It is critical to measure the state damage prevention performance with an indicator related to the number of damages. As discussed earlier, the number of damages is only an estimation based on the reported damages. The actual number of damages is expected to be higher.

Table 12. Number of Transmissions, Damages, and Damages/1000 Transmissions

Year	# of Transmissions	Reported Damages	Damages/1000 Transmissions
2013	7,664,152	6,048	7.89
2014	7,812,616	6,845	8.76
2015	7,810,046	8,492	10.87
2016	10,814,059	15,172	14.03
2017	8,098,230	11,160	13.78
2018	11,056,065	12,061	10.91
2019	12,418,911	15,621	12.58
2020	12,421,473	31,766	25.57
2021	13,189,250	11,594	8.79

This section compares the NC 811 performance based on reported damages to NC 811 and the actual number of transmissions between 2013 and 2021. The number of transmissions has been used because it reflects the subsurface utilities' density. Based on the information in Table 12, the average number of damages is 12.6 per 1000 transmissions, with a standard deviation of 5.4.

Accordingly, The expected number of damages with 95% confidence is 21.5 per 1000 transmissions (i.e., damage rate).

The estimated number of damages per 1000 transmissions was 25.57 in 2020, which is higher than those calculated for other years, see Table 12. Thus, increasing the damage rate by five is justifiable to create a reasonable benchmark. Accordingly, the benchmark value that should be used for evaluating the overall damage prevention effort is 26.5 damages per 1000 transmissions. This calculated benchmark should be monitored and improved over the coming years.