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Florida Sinkholes and Grout Injection Stabilization

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Florida Sinkholes and Grout Injection Stabilization

Abstract

Florida has a major problem when it comes to sinkholes. These sinkholes can become very hazardous to people, homes, and to the landscape as a whole. Florida sits on a carbonate platform which is highly indicative of sinkholes. There are three main types of sinkholes which occur in Florida: dissolution, cover subsidence, and cover collapse. I will compare these types of sinkholes to the underlying formation beneath Florida to see if there is a connection between the types of sinkholes that occur. I will also create a 3D model of grout injection stabilization and calculate its volume to compare to the actual volume placed under the house. This information will help inform and bring attention to the problem in Florida and in turn, may help alleviate the problem if we can understand what causes these sinkholes. The 3D model may help engineering companies become more efficient in predicting the projected amount of volume to stabilize a house that may be in danger.

Keywords

sinkholes, stabilization, carbonate

MOTIVATION

This problem is not only important for engineering, but also for science. I work for an engineering company and wanted to try and help make the projections for stabilization more accurate. The reason for choosing this project and working on helping to predict the amount of grout being pumped under a house, is that this is a major business in Florida. With all of the sinkhole stabilization occurring in Florida, many engineering companies could benefit from understanding a little more about what is occurring beneath the surface of these houses. Understanding what is occurring under these houses and how much grout is to be pumped to stabilize can also help science and the environment.

There are three main types of formations/areas that sinkholes can form. Area *I* is bare or thinly covered limestone. The area is generally shallow and broad, and sinkholes develop over time, and dissolution sinkholes dominate this area, but are very few in number. In area *II* the cover is 30 -200 feet thick and cover subsidence sinkholes dominate the area, but are few in number. The area is made up of incohesive and permeable sand. Sinkholes in this area are shallow, small in diameter and develop slowly. In area *III* the cover is 30-200 feet thick, and sinkholes occur in high number. This region consists of mostly cohesive clayey material that has very low permeability. Cover Collapse sinkholes dominate the area and occur in very high number throughout Florida. Area *IV* has a cover over 200 feet thick. Sinkholes occur in very low number in this area but are very large in diameter and deep. This area material consists of cohesive sediments interlaid with discontinuous carbonate beds. The reason I chose to map out each sinkhole in Florida and compare it to its underlying formation/area is that dissolution sinkholes are rare, and occur fewest in number over the state. Dissolution of our carbonate platform is very prevalent throughout the state, and the data will show this.

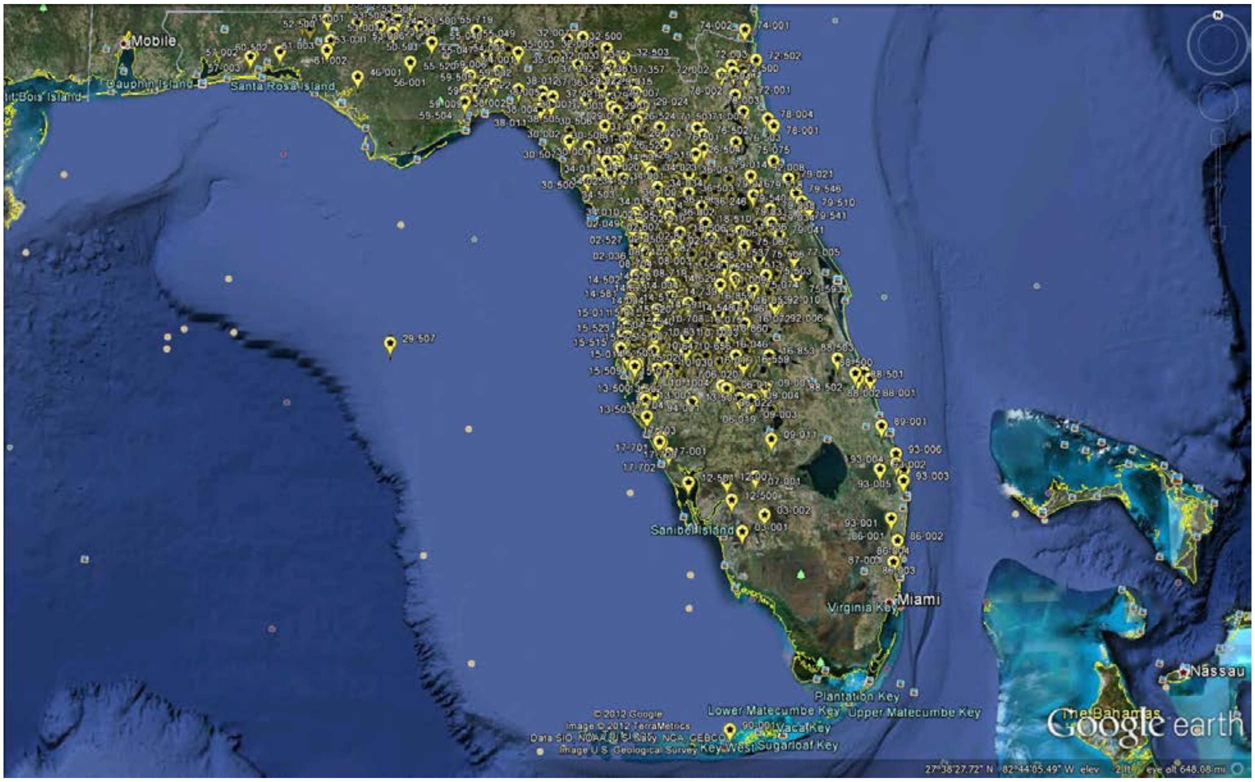

Figure 1

Google Earth image: Subsistence Incident Report locations

Florida Geological Survey (Florida Department of Environmental Protection)

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MATHEMATICAL DESCRIPTION AND SOLUTION APPROACH

Since we are using two planes to fit the data, we solve the equation:

$$z = ax + by + c \tag{1}$$

where x, y, and z are variables and a, b, and c are constants. To find the volume of grout to be placed in the 3D model we used the least regression squares technique to formulate our approach. Using that technique equation (1) becomes:

$$z = 0.0172249x - 0.273674y - 60.8454. \tag{2}$$

which will give a solid image. I used 4 rectangles to calculate the volume projected through the model. The calculation used to get the volume was achieved by the formula

$$v = ½(x_0 - x_1)\,(y_0 - y_1)\,(2c + ax_0 + ax_1 + by_0 + by_1) \tag{3}$$

The summation of each of these rectangles gives the projected volume. Wolfram Mathematica was used to project the models and help come up with the integration formula to sum up the rectangles.

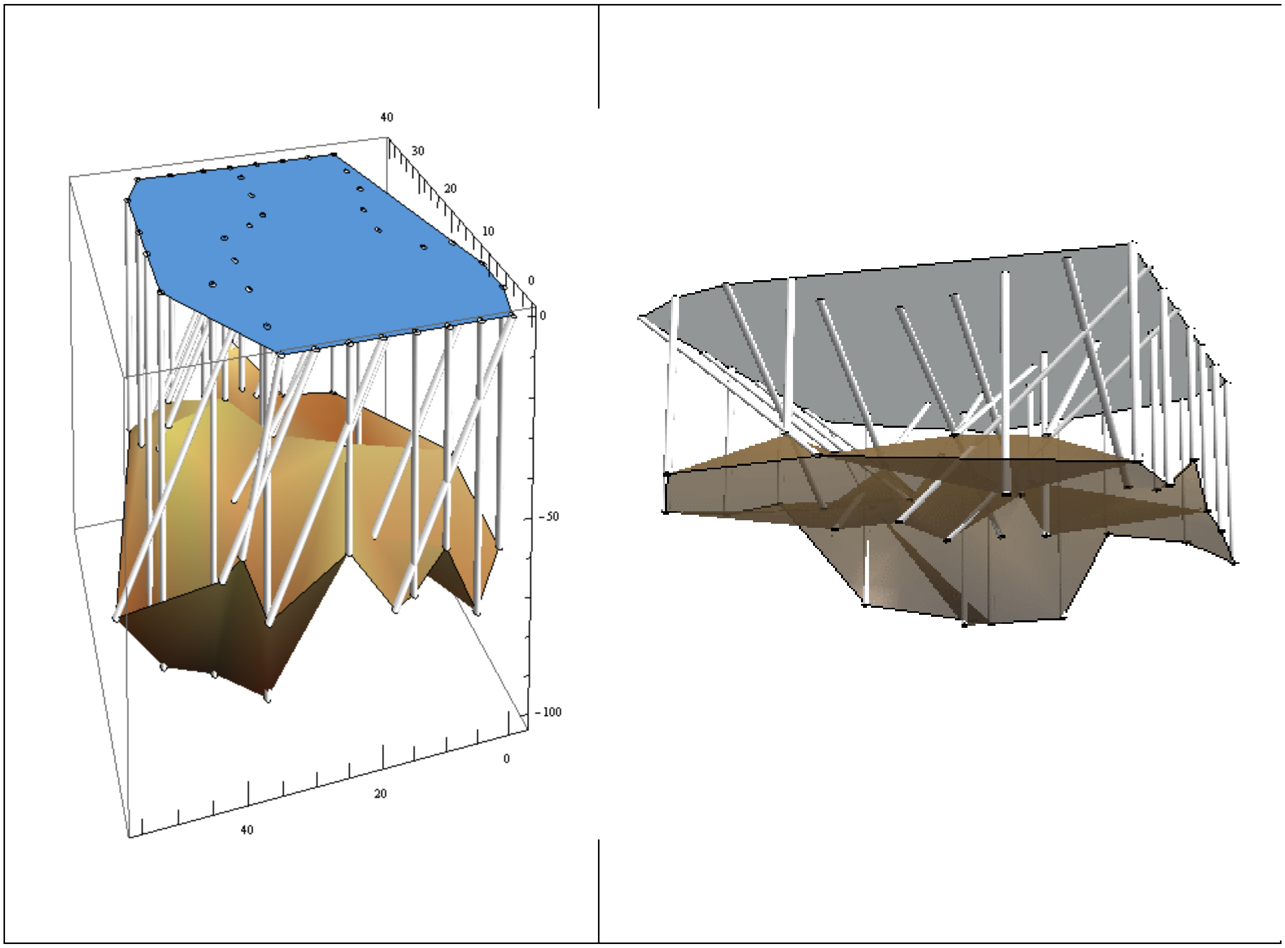

Figure 2

3D model of grout injection stabilization

Discussion

The results were stunning in both aspects of the research project. The spreadsheet below shows all the counties in Florida, the number of sinkholes in each county and in what formation/area these sinkholes are first created. The results contradict what I found in my original research which showed that the majority of sinkholes should occur in area *III* and the least should occur in area *I*. From the spreadsheet we see that there is a total of 3427 sinkholes throughout the state of Florida. In area *III* there are 15 counties represented and they contain about 52% of the sinkholes in Florida. Where the data shows a contradicting report is in area *I*, where sinkholes are supposed to be rare. The data shows 16 counties within area *I* and this area contains 34% of the sinkholes in Florida. This is far more than rare. This area holds the second highest percentage of sinkholes in Florida, showing that dissolution sinkholes develop and occur much more than previously thought.

The results found for the projected grout through the 3D model were very similar to what was actually put into the ground. I thought the volumes would be off by more than 10% because there is so much dissolution occurring in the limestone. The model gave a projected amount of 98,452.39 cubic feet. The amount of grout actually put into the ground is 90,612 cubic feet. In actuality the results showed that the projected model and the exact amount of grout put into this house only varied by 7.96%. With the accuracy of this model it can now be used to help other engineering companies more accurately project the amount of volume of grout that will be pumped under a house. If this model can be implemented through all engineering companies and can continue being developed it can possibly benefit people around the world.

Conclusion and Recommendations

Throughout the research we showed that dissolution sinkholes which occur in limestone are more frequent than originally thought. This idea contradicts the original research stating that these are the rarest among all sinkholes in Florida. What can be done to further this research is to break some of the counties into different areas. If these areas can be accurately divided and counted this could make the results a little more accurate. The results are close enough to where certain points can be adjusted and the model can be made even more accurate. The way this model can be made more accurate is by showing how much grout was injected in each point and the consistency of the material at that exact point. Showing how much grout is injected at each point can show a pattern of how much grout will take at a certain soil consistency. All in all the information provided can be used to help further our abilities in engineering and in helping the environment.

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References

Florida Department of Environmental Protection. 2014. 2014 <http://www.dep.state.fl.us/geology/gisdatamaps/SIRs_database.htm>.

Sinclair, William, C and J.W. Stewart. Sinkhole Type, Development, and Distribution in Florida. Tallahasee: Bureau of Geology, 1985.

APPENDICES

County	Square miles	#of sinkholes	Sinkhole/square mile	Acreage/sqaure mile	Sinkholes/Acre Squaremile
Alachula	875.02	59	0.06742703	560012.8	0.000105355
Baker	585.23	0	0	374547.2	0
Bay	758.46	1	0.001318461	485414.4	2.0601E-06
Bradford	293.96	0	0	188134.4	0
Brevard	1015.66	0	0	650022.4	0
Broward	1209.79	4	0.003306359	774265.6	5.16619E-06
Calhoun	567.33	0	0	363091.2	0
Charlotte	680.28	1	0.001469983	435379.2	2.29685E-06
Citrus	581.7	358	0.615437511	372288	0.000961621
Clay	604.36	3	0.004963929	386790.4	7.75614E-06
Collier	1998.32	2	0.001000841	1278924.8	1.56381E-06
Columbia	797.57	31	0.038868062	510444.8	6.07313E-05
DeSoto	637.06	0	0	407718.4	0
Dixie	705.05	13	0.018438409	451232	2.881E-05
Duval	762.19	8	0.010496071	487801.6	1.64001E-05
Escambia	656.46	0	0	420134.4	0
Flagler	484.46	0	0	310054.4	0
Franklin	534.73	0	0	342227.2	0
Gadsden	516.33	2	0.003873492	330451.2	6.05233E-06
Gilchrist	349.68	46	0.131548845	223795.2	0.000205545
Glades	806.01	0	0	515846.4	0
Gulf	564.01	0	0	360966.4	0
Hamilton	513.79	13	0.025302166	328825.6	3.95346E-05
Hardee	637.78	22	0.034494653	408179.2	5.38979E-05
Hendry	1152.75	1	0.000867491	737760	1.35545E-06
Hernando	472.54	273	0.57772887	302425.6	0.000902701
Highlands	1016.62	11	0.010820169	650636.8	1.69065E-05
Hillsborough	1020.21	522	0.511659364	652934.4	0.000799468
Holmes	478.78	3	0.006265926	306419.2	9.79051E-06
Indian River	502.87	6	0.011931513	321836.8	1.8643E-05
Jackson	917.76	20	0.02179219	587366.4	3.40503E-05
Jefferson	598.1	3	0.005015884	382784	7.83732E-06

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Lafayette	543.41	6	0.011041387	347782.4	1.72522E-05
Lake	938.38	117	0.124682964	600563.2	0.000194817
Lee	784.51	3	0.003824043	502086.4	5.97507E-06
Leon	666.85	120	0.179950514	426784	0.000281173
Levy	1118.21	69	0.061705762	715654.4	9.64153E-05
Liberty	835.56	1	0.001196802	534758.4	1.87E-06
Madison	695.95	6	0.008621309	445408	1.34708E-05
Manatee	742.93	5	0.006730109	475475.2	1.05158E-05
Marion	1584.55	343	0.216465242	1014112	0.000338227
Martin	543.46	1	0.001840062	347814.4	2.8751E-06
Miami-Dade	1897.72	1	0.000526948	1214540.8	8.23356E-07
Monroe	983.28	1	0.001017004	629299.2	1.58907E-06
Nassau	648.64	2	0.003083374	415129.6	4.81777E-06
Okaloosa	930.25	2	0.00214996	595360	3.35931E-06
Okeechobee	768.91	0	0	492102.4	0
Orange	903.43	196	0.216950954	578195.2	0.000338986
Osceola	1327.45	12	0.009039889	849568	1.41248E-05
Palm Beach	1969.76	6	0.003046056	1260646.4	4.75946E-06
Pasco	746.89	258	0.345432393	478009.6	0.000539738
Pinellas	273.8	74	0.27027027	175232	0.000422297
Polk	1797.84	269	0.149623993	1150617.6	0.000233787
Putnam	727.62	4	0.005497375	465676.8	8.58965E-06
St Johns	600.66	4	0.006659341	384422.4	1.04052E-05
St Lucie	571.93	1	0.001748466	366035.2	2.73198E-06
Santa Rosa	1011.61	0	0	647430.4	0
Sarasota	555.87	6	0.010793891	355756.8	1.68655E-05
Seminole	309.22	131	0.423646595	197900.8	0.000661948
Sumter	546.93	24	0.043881301	350035.2	6.85645E-05
Suwannee	688.55	194	0.281751507	440672	0.000440237
Taylor	1043.31	20	0.019169758	667718.4	2.99527E-05
Union	243.56	0	0	155878.4	0
Volusia	1101.03	87	0.079016921	704659.2	0.000123464
Wakulla	606.42	56	0.092345239	388108.8	0.000144289
Walton	1037.63	3	0.002891204	664083.2	4.51751E-06
Washington	582.8	3	0.005147563	372992	8.04307E-06
Toals	53623.78	3427			

Area I	Area II	Area III	Area IV
Alachula	Broward	Clay	Bay
Citrus	Collier	Hamilton	Calhoun
Columbia	Hendry	Highlands	Charlotte
Dixie	Hernando	Hillsborough	Duval
Gilchrist	Indian River	Holmes	Esacambia
Jackson	Lee	Jefferson	Gadsden
Lafyette	Martin	Lake	Hardee
Levy	Osceola	Leon	Liberty
Madison	Palm Beach	Marion	Manatee
Dade	St Lucie	Orange	Nassau
Monroe		Pinellas	Okaloosa
Pasco		Polk	St Johns
Sumter		Putnam	Santa Rosa
Suwannee		Volusia	Sarasota
Taylor		Washington	Seminole
Wakulla			Walton

% Per Area	I	II	III	IV
	33.90721	9.016633	51.76539	5.310767

	Above Ground Points	Below Ground Points
1	(0,0,0)	(17.85,0,-66.65)
2	(5,-2,0)	(5,-2,-67)
3	(10,-2,0)	(10,15.85,-66.65)
4	(15,0,0)	(15,0,-57)
5	(15,5,0)	(15,18.2,-49.26)
6	(20,10,0)	(20,34.66,-67.66)
7	(25,10,0)	(25,26.04,-59.89)
8	(30,8,0)	(30,8,-80)
9	(35,8,0)	(35,25.08,-63.75)
10	(40,8,0)	(40,8,-75)
11	(40,13,0)	(18.78,13,-79.21)
12	(40,18,0)	(40,18,-73)
13	(40,23,0)	(19.04,23,-78.24)
14	(40,28,0)	(40,28,-53)

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15	(40,33,0)	(40,33,-69)
16	(40,39,0)	(40,39,-72)
17	(40,45,0)	(40,45,-81)
18	(35,48,0)	(35,48,-67)
19	(27,48,0)	(27,48,-59)
20	(22,48,0)	(22,48,-97)
21	(14,48,0)	(14,48,-97)
22	(14,40,0)	(14,40,-102)
23	(12,35,0)	(12,14.29,-77.27)
24	(5,35,0)	(5,35,-92)
25	(0,35,0)	(5.61,35,-45.66)
26	(0,30,0)	(13.46,30,-50.23)
27	(0,25,0)	(0,25,-50)
28	(0,20,0)	(16.56,20,-62.79)
29	(0,15,0)	(0,15,-64)
30	(0,10,0)	(13.97,10,-52.16)
31	(0,5,0)	(0,5,-72)
32	(18,35,0)	(18,24.13,-40.57)
33	(23,35,0)	(23,35,-44)
34	(25,30,0)	(25,10,-53,58)
35	(27,27,0)	(27,27,-77)
36	(32,27,0)	(32,11.99,-56.02)
37	(37,27,0)	(37,27,-64)