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Documenting the current pollution patterns on the Cathedral of Learning

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Documenting the Current Pollution Patterns on the Cathedral of Learning

Eric Dieckman, Curt Doernberg, Theresa Knaebel, Grace Liu,
Geoffrey Milanovich, Melissa Sikes, Kathleen Yen, Aaron Young

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Abstract

During the summer of 1994, as part of the Careers in Science and Applied Technology (CAST) program, seven high school students and an elementary school teacher worked together to document the current pollution patterns on the Cathedral of Learning on the University of Pittsburgh campus. This report presents the results of their research in which they used surveying, sketching and photography to document the pollution patterns They also recorded their data in an AutoCAD model of the Cathedral. This project was part of a larger study being done for the National Park Service on Acid Deposition on Limestone Buildings. The project was also sponsored by the Engineering Design Research Center under the Green Design initiative.

Front Row: Sabeena Jindal, Grace Liu, Kathleen Yen. Back Row: Bridget Caster, Curt Doernberg, Susan linger, Eric Dicckinnn. Aaron Young, Geoffrey Milanovich, Theresa Knaebel, Kenon Tutcin, Melissa Sikes.

1. Introduction

Many monuments that Americans associate with the history of this country are constructed of limestone. Over time the deposition of pollutants on these historic buildings and monuments results in aesthetic problems and creates structural damage. The National Park Service (NPS), a division of the Department of the Interior, is responsible for the maintenance of monuments and historic buildings. Therefore, they are very interested in the dynamics that cause the soiling and deterioration of these structures.

For this reason the NPS, with funds obtained from the Department of the Interior, awarded money to the Civil Engineering Department at CMU to study acid deposition on limestone buildings.

The project began in 1987 to study pollutants on the monuments at the Gettysburg **battle** field. This study was mostly focused on the chemical reaction that causes physical damage to the limestone. More information was needed to discover how the pollutants were deposited and how certain changes in conditions affected the problem.

It was decided that the Cathedral of Learning would be a useful structure to study the problems for these reasons:

1. It is a limestone building (the material that many monuments are made of).
2. The entire building is made of the same type of limestone from the same quarry so the chemical composition of the stone is the same throughout the building.
3. There is an abundance of traffic around the building, providing a source of pollution.
4. There has been heavy industrial pollution in the area.

This paper will provide an explanation of how pollution deposits on the building, how the pollution is measured and what we did to map the patterns of pollution.

2. Acid Deposition

The main factor that is causing the pollution on the Cathedral of Learning is acid deposition. Acid deposition is the transfer of acid onto a surface. There are two types of acid deposition: wet deposition and dry deposition. Wet deposition is the process of substances falling on a surface in the presence of precipitation. A well-known example of wet deposition is acid rain. The **Cathedral** of Learning Project does not concentrate on wet deposition. It is centered on dry deposition.

Dry acid deposition is the process of dry substances falling on a surface. Reactions occur in the presence of a monolayer of moisture, such as dew, but in the absence of precipitation. **Dry** deposition is occurring on the outer walls of Cathedral of Learning and is causing the black **pollution** on the **cathedral.**

The deposition is occurring on the cathedral through a series of reactions. The **overall** reaction involved is:

$$CaCO_3 + SO_2 \longrightarrow CaSO_4 \text{ and other products}$$

[aqueous conditions]

CaCCh (calcium carbonate) is limestone, and the walls of the Cathedral of Learning are **made** of limestone that is from a quarry in Indiana. This limestone is characteristic of having low amounts of iron. It is important to know specifically the origin of the limestone and the characteristics of it because these factors affect the overall deposition of the pollution.

SO_2 is sulfur dioxide, a gas released into the atmosphere by the burning of fossil fuels. Calcium carbonate and sulfur dioxide need a precise amount of moisture and heat for the reactions to take place. The reactions occur in dry weather but only under aqueous conditions. The aqueous conditions may be provided from dew or from moisture from one monolayer of water, meaning one molecule thick of H_2O, is on the surface of the limestone, sulfur dioxide is drawn into the porous limestone. Sulfur dioxide usually bounces off surfaces, but the moist limestone causes the sulfur dioxide to stick to it. The calcium carbonate and the sulfur dioxide react to form calcium sulfate (CaSO^), which is commonly called gypsum.

Gypsum occupies more volume than calcium carbonate. So, as gypsum replaces calcium carbonate, it causes cracks in the limestone walls. Gypsum is also very water soluble, therefore when it rains the calcium sulfate gets washed away, leaving many empty pits in the limestone. These pits are relatively tiny compared to the whole limestone structure.

Carbon particles from the atmosphere, which also normally bounce off surfaces, fill these pits. Carbon particles are extremely small. They are one micron thick, which is one millionth of a meter. Carbon particles are easily deposited into the cracks by the wind. The carbon particles react with the limestone, and these two substances bind together. The equations for these reactions are not yet known.

Carbon is the black pollution that is filling the many tiny pits in the limestone, and so the general effect is a blackened building. Water cannot easily wash away the carbon. The carbon also cannot be scraped off readily, since it is bound to the limestone and is not just on the surface of the limestone.

3. Experimental Equipment

An essential element in measuring the pollution on the limestone was the equipment located on the Cathedral of Learning. This is an area of the Acid Deposition Project that we did not directly work with, however the data provided from these experiments was an essential portion of the project as a whole. The information gained for this portion of the paper was acquired through interviews with Dr. Cliff Davidson, Dr. Susan Finger, and Mike Lutz and also from the progress report prepared for the National Parks Service in May of 1993 entitled Influence of Atmospheric Pollutant Concentrations and Deposition Rates on Soiling of Limestone Building Surfaces.

There are three primary sampling sites located on the Cathedral of Learning. These sampling sites are located on the 41st floor (roof) and the ledges of the 16th and 5th floors. The data collected at these sampling sites is determined through direct measurement. The results from the experiments are then collected and stored in dataloggers which are connected to a central computer. With these dataloggers, researchers have easy access to the data collected by the experiments.

The experiments performed can be split up into three broad categories of measurements. These are: measurements of atmospheric properties, measurements of pollutants, and measurements of surface properties.

Measurement of atmospheric properties consists of five subcategories. These are wind speed/wind direction, air temperature, relative humidity, solar radiation, and atmospheric stability.

Wind speed and wind direction are sampled at two different sites on the building, the 41st floor (roof) and the 5th floor. The location on the 41st floor provides the wind speed/wind direction sensors access to free stream wind conditions. The other sensor located on the 5th floor is a three-dimensional wind speed sensor. Because of the wind eddies often found on the lower regions of the Cathedral of Learning, it is necessary to have a wind speed and a wind direction sensor that has the capability of splitting the wind into three vectors.

Air temperature is measured by resistance sensors. One is permanently assigned to the 5th floor and the 16th floor. The results from the resistance sensors are compared to the surface temperature results to help assess the effect temperature has on deposition.

Relative humidity is measured by the use of humidistats. The results collected are used in correlation with surface moisture sensors to determine the rates of condensation and evaporation of moisture on **the** Cathedral of Learning's surface.

Solar radiation is measured by the use of silicon solar cells located on the 5th and **the** 16th floors. Results gathered here are also correlated with the data gathered from surface moisture to *s^sess* the effect that solar radiation has on the evaporation of moisture from the Cathedral of **Learning's** surface.

The last subcategory is atmospheric stability. Atmospheric stability is characterized **by vertical** temperature profiles in which solar radiation and wind speed serve as **the** x-axis, and height on **the** Cathedral of Learning serves as the y-axis. By graphing these functions the stability of the atmosphere can be easily determined, therefore allowing conclusions to be formulated on **the way** in which particles will deposit upon the Cathedral of Learning.

The measurement of pollutants is the next major category of experiments performed on **the** Cathedral of Learning. The two subcategories in which pollutants can be measured **are airborne** concentrations and deposition flux.

Airborne concentrations pertains to the amount of carbon, and sulfur dioxide **particles that** are present in the airspace surrounding the Cathedral of Learning. The airborne concentrations are measured on a time averaged basis using pre-fired quartz-fiber filters that are placed about six inches above the Cathedral of Learning's surface. These pre-fired quartz-fiber filters are then sent to the Desert Research Institute in Reno, Nevada where the data is analyzed.

Deposition flux is the rate at which carbon and sulfur dioxide particles are actually depositing upon the Cathedral of Learning's surface. The carbon and sulfiir dioxide particles are brought to the Cathedral of Learning's surface by wind eddies and gravity. These particles will only stick to the limestone if there is a layer of moisture present on the surface. If the surface is dry, the particles will bounce off of the surface much like a rubber bouncing ball would bounce off of a wall. For this reason deposition flux is measured by greased Teflon sheets. The results gained from this experiment are then used to determine the rate at which the particles are deposited onto the surface of the Cathedral of Learning.

The last major category of experiments performed on the Cathedral of Learning is the measurement of surface properties. The measurements of surface properties can be split up into two separate subcategories, surface moisture and surface temperature.

Surface moisture is a critical variable in determining how much damage can occur to the Cathedral of Learning. Carbon particles and sulfur dioxide particles need to have moisture present on the surface in order to chemically combine with the limestone. Therefore, the measurements taken by moisture sensors becomes very important, however the moisture sensors presently being used are extremely inaccurate. For instance, if the moisture sensors were to measure the amount of dew present on the surface of the Cathedral of Learning, there would be about a 57% error.

Surface temperature is the last subcategory dealing with the measurements of surface properties. Surface temperature is measured by thermisters and T-type thermocouples. The data gained here is often used in correlation with air temperature, solar radiation, and wind speed to assess the rate of evaporation and condensation of moisture upon the Cathedral of Learning.

This data gained from the equipment located on the Cathedral of Learning will allow the National Parks Service to make assessments on what type of action, if any, needs to be done in order to assure that the Cathedral of Learning will not suffer any damages in the future.

4. Surveying

Though the chemistry and equipment involved in measuring the pollution was important to our group, we were primarily interested in finding a method to document the pollution patterns on the building. While searching for a method to accomplish this goal, we were introduced to the technology of surveying. Once we had mastered the techniques involved in surveying, we decided that it would be a good resource to help create our pollution map.

Surveying involves using an instrument, known as a transit, a set distance from the object being surveyed. In this case, that object was the Cathedral of Learning. Once the transit was set up and leveled, a reference point was found upon the building, with the aid of a large ruler, known as a Philadelphia rod. With this reference point, and the transit, we were able to determine the location of any point on the building.

When we began looking at the Cathedral, we noticed that most of the pollution patterns were geometric—triangles, rectangles, squares, or any combination of the three. So when we began surveying, we took the vertices of these geometric shapes to form a polygon that enclosed the pollution. All of these points were recorded in our logbook in the form of two angles; the angle of elevation, which is vertical, and the angle of azimuth, which is horizontal.

By the end of the three weeks we worked on the project, we were able to document all the pollution on three sides of the Cathedral with the use of surveying. The Bigelow side, the Bellefield side, and the Fifth Avenue side. We could not survey the Forbes side due to the many obstructions, such as trees, as well as The Carnegie Museum and Library. Figure 1 shows the transit set up on the Bellefield side.

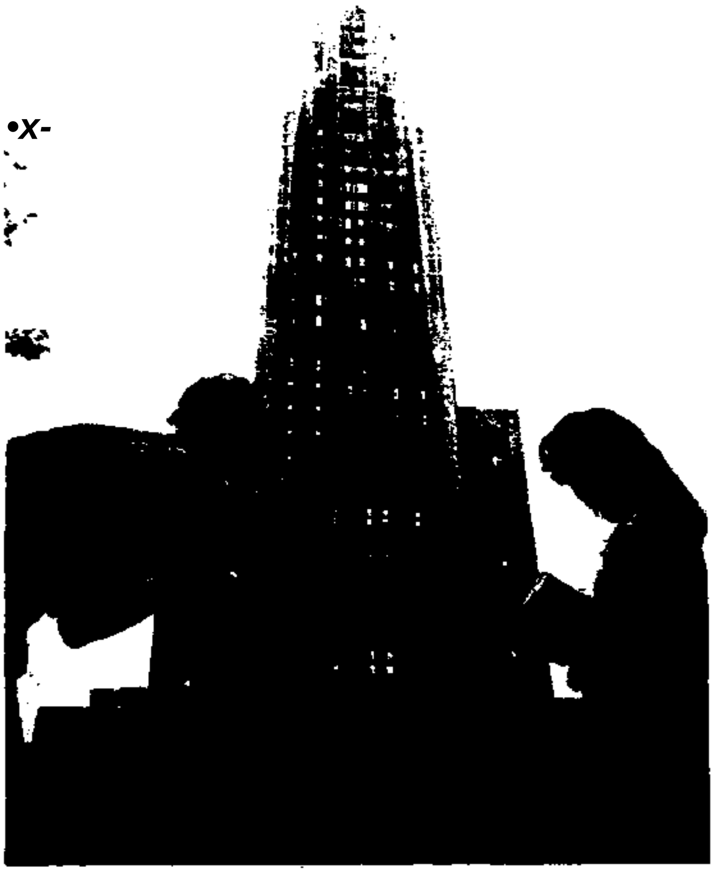

Figure 1: Erik Deickman and Melissa Sikes Surveying the Pollution Patterns on the Bellefield Portal

During our experience surveying the Cathedral of Learning we encountered many problems. One such problem was the lack of a model study to which we could compare our results. We had no idea whether the pollution had grown or receded, because no other group had surveyed the pollution on the Cathedral of Learning. Another problem was conveying the location of pollution on the building from the surveyor to the record keeper. However, this problem was eventually solved with the aid of several small sketches of the building we had. We decided to grid the drawings into a coordinate system similar to ones found on a map. The surveyor could then state his coordinates, and the recorder would know his exact location. Some of the sketches are included in Appendix 1. Other minor problems included the bright sunlight, the heat, and the accuracy of the instrument, but overall our work with surveying was a great success.

The results of our work turned out to be highly successful. We learned to survey, we documented the pollution on the Cathedral, and we recorded our data for use as a model study in the future.

5. AutoCAD

After surveying all of the pollution, the next step was to put the results into AutoCAD. AutoCAD is a three-dimensional modeling program and ran on an IBM 486-66 computer. A model of the Cathedral has already been built using AutoCAD, but it is an extremely large file and is cumbersome to use.

We began putting the windows on the AutoCAD model and mapping the pollution. The windows on the building were difficult to draw for several reasons. First, there were already hundreds of lines on the building, each representing one of the different faces of the buildings, and adding the windows made the model even more confusing. Also, because window locations are not necessarily the same on the blueprint as on the building, it was difficult to ensure accuracy, unless we were somehow able to move the computer close to the building and compare the building with the model. Whether the windows are needed on the model was another question to be asked. The trade-off of accuracy of the model versus size and speed of the model must be weighed.

Mapping the pollution presents other problems. The data from the surveying involves one length and two angles, the azimuth and elevation. This data must then be converted into three spatial coordinates, x, y, and z. The conversion from surveyor's units to three-dimensional coordinates is illustrated in Figure 2. During the CAST program, a computer program was written that does this conversion. After getting the three coordinates, they must be mapped into AutoCAD, which only gives two coordinates to represent the mouse cursor's position. By putting the origin of the coordinate system in a different place, say on the face of the building, it was possible to map the pollution. The only setback is the speed of the model. It would be possible to put the pollution on a less complicated model, but whether this would provide as complete a picture as the largest model must be considered.

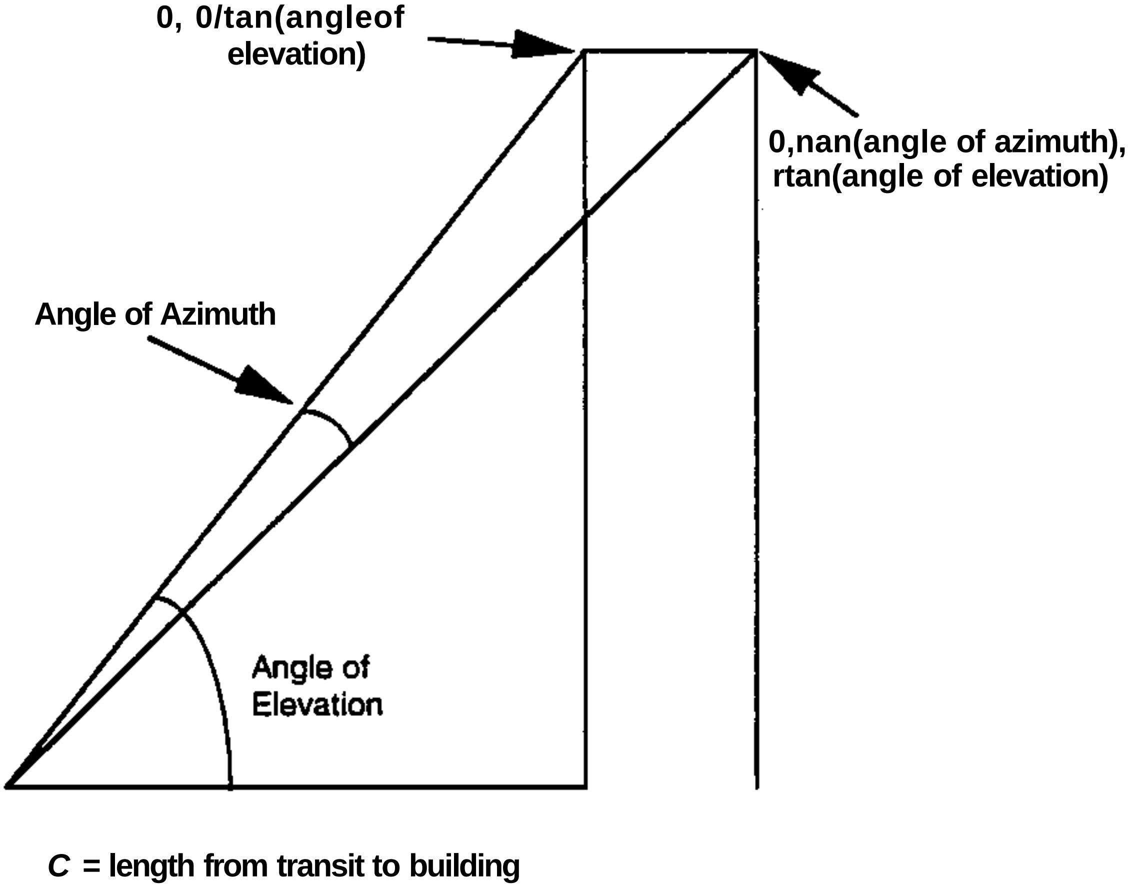

Figure 2. Converting from Surveyor's units to X, Y, Z coordinates

Eventually, a complete map of the pollution will be placed on the AutoCAD model. As of today, the windows are less important than the pollution, but may be necessary for future studies. Because the surveying, photography, and sketching were the main focuses of the project, the AutoCAD received less attention and time than the other parts of the study. But because researchers now know the problems with mapping the pollution, and because a computer program was developed to convert the different coordinate systems, future work will be much easier.

In the future, the model may play an important part in the research. If other scientists wish to model the rain or wind patterns around the building, they may be able to use the AutoCAD model in their program instead of having to redraw the entire model. Also, the model could be used in an education aspect. If the Pittsburgh Historical Society or the National Parks Service wished to raise money for cleaning, they may consider putting a computer in the Cathedral with the model on it and show the pollution and ways to reduce future pollution and remove the current carbon.

6. Photography and Sketching

Photography and sketching were alternate methods used to map the pollution existing on the Cathedral of Learning. Our goal in utilizing them was, again, to accurately map the large scale pollution patterns currently existing on the building. The data could also be used to compare the patterns on the various sides of the building since some of the sides are significantly more polluted than others. Since we did not have any other data with which to compare our findings, another goal was to have concrete data for those who may work on this project in future years.

Photography had previously been abandoned as a method of mapping the pollution because it was difficult to see the pollution patterns on the photographs. However, with the help of a professional photographer, we were able to obtain a high contrast between the polluted and clean areas. First, we looked for existing photographs in the Pittsburgh Historical Society, the archives at the Carnegie Museum, the bookstores located at the Cathedral of Learning, and at the gift shops in the Pittsburgh area. Unfortunately, none of these places proved to have useful photographs. However, we serendipitously came upon postcards of the Cathedral of Learning and after some examination, we realized that the photographer lived in the Pittsburgh area.

After getting in contact with the photographer, we were able to obtain twenty-one slides of the building, of which we made one eight by ten print. Most of the slides were from various years, which was evident because of the cleanliness of the Carnegie Museum, which was pitch black in one slide and white in another. Although we only made one print due to the time and budget of our project, the slides proved to be a good source of information and one that could be used for future projects.

We were also able to develop some of the pictures we took in the given six week period. Through the help of the developers at the Photography and Graphic Services Department of Mellon Institute, we were able to get a clean distinction between the areas of pollution in all the shots. This aided us in our project since it showed that our results were not final until the developing stage was complete. For example, Gary Thomas from Photography and Graphic Services returned two contact sheets for one roll of film. On one sheet, all of the lighter pictures came out, while all the darker pictures came out on the second contact sheet. While this was good, in the sense that it allowed for us to have a higher contrast in the pictures, it also required that we use this lab for developing prints, rather than a less expensive one.

In order to take the pictures, we were required to locate photography equipment, locations from which to take the photos, and film and developing at relatively low costs. The equipment presented some problems because we had to make use of what we could get. Therefore, we used a telephoto lens that was not compatible with our camera. The problem was remedied through finding the f-stop on the normal lens, and quickly changing to the telephoto lens and adjusting it the settings of the normal lens. While this helped in terms of determining the light meter setting, it presented a problem with focusing the image since focus can not be determined numerically the way the f-stop can be determined.

We also encountered difficulties in finding points from which to take the photographs since there were many trees, vines and other obstructions in front of the building. For example, the enlarged slide has a statue in front of the building, blocking some of the pollution patterns. Although none of our photographs have statues obstructing the view, we do have a lot of trees and vines and even cars blocking off areas of the building. The ledges on the building also affect the view of the polluted areas. Taking pictures from the bottom of the building might block three stories of the building due to the angle of the photograph as well as having a tapered off effect at the top of the building. Although the width of the building does not decrease, it will appear that way on the photos and thus distort the view of the photographs. Therefore, we were required to climb up on top of various building to try to get different views unobtainable from the ground.

Many other obstacles also stood in the way of photographing the pollution patterns. The lack of a wide angle lens forced us to take a number of pictures to map one side of the building. For example, one might take a photograph of the top two-thirds of the building and then take another picture of the bottom two-thirds of the building. The lack of a wide angle lens also led toward more distortion at the top of the building. Another area of concern was the sun and the shadows created by the building. It was necessary to be able to determine between the shadow and the pollution that was located on the surface area. Therefore, it was important to buy high resolution film which would create a higher contrast between the polluted and non-polluted areas. It was also important to visit the Cathedral of Learning at various times of the day and under various cloud conditions to see what effect they might have on the resulting photos.

Difficulties were also encountered when we tried to sketch the pollution. An easily overlooked problem is that the sketch is a two-dimensional representation of the Cathedral while the building is three-dimensional. Therefore the pollution located on the ins and outs of the building could not be mapped, since the drawing was a frontal view. The drawings had been previously created from the blue prints of the building, but unfortunately the blue prints were as designed and not as built. Since the blue prints are only necessary as a guide to constructing the building, it was not necessary to fix the sketches after the building had been built. This created a big problem since the structure and the drawing of the Cathedral did not match up and therefore, it was necessary to make an "intelligent guess" as to where the actual pollution should be placed on the drawing. As with the photographs, those of us who worked on the sketching section of the project had to work around the obstructions located around the building. However, when one moved to work his or her way around the building, the pollution patterns would seem to change. For example, from face on, I may not see pollution on the top third of the building, but if I move two feet one way, I may now be able to see the pollution located on the building. The sketching aspects of the project also allowed for human interpretation of where the pollution was located and where it wasn't. The pollution changes in color from black to light gray but on the drawings it was shaded black only and interpretations as to where it ended was left up to the artist. A final hindrance was the weather system created around the building. Since the area around the building was very windy and we were merely sketching on the ground, the paper kept on flying around and often we were forced to chase various pieces of our equipment.

7. Conclusions

As with all research projects, the Cathedral of Learning project was force to deal with its share of problems, but despite all the difficulties, there were a lot of positive outcomes as well. First of all, we were able to find old photographs to compare to the present photographs and determine the extent of change in large scale pollution patterns. We found that the pollution patterns on the eight by ten print of the slide were the same as those found on the five by seven pictures we had taken during the six week period. This brought back a method that had previously been abandoned. Our photographs were now there as a comparison point for future study on acid deposition on the Cathedral of Learning. We now had the photographs of the various pieces of the Cathedral to correct the sketches, especially the top third of the building, for a more accurate record of the pollution. Another outcome was an accurate representation of the pollution located on the Forbes side of the Cathedral, which is important since it is the side that the surveyors were unable to record and it currently is the dirtiest side of the building. The sketching also resulted in a pollution map of all four sides of the Cathedral of Learning, which could be used for future comparisons.

Surveying, photography, and sketching each had some problems and some advantages. The surveying in combination with AutoCAD is good for turning observations into hard data, such as finding the ratio of polluted to non-polluted limestone, or comparing pollution with air flow or sunlight. The photography and sketching would be better for overall analysis, such as the relation between positions of overhangs and positions of pollution or to see how pollution changes over time.

We tried to record large scale patterns, not every detail, because time and equipment did not permit the comprehensive analysis that the Cathedral of Learning requires. There seemed to be a consistency between the data obtained through the three different methods, probably because these methods were used on a large scale. On a smaller scale, surveying would probably give the best results because it can be easily done in parts, as opposed to photography and sketching which lose accuracy when done in sections.

We also compared photographs from ten years ago with photographs from today. One important piece of information we found from this comparison was that the pollution patterns on the Forbes side have not changed much over the last ten years. This would lead to the conclusion that

mapping the change in pollution over time would be a very long term project because it takes a long time for noticeable change to occur.

Working with the Engineering Design Research Center (EDRC), we were introduced to the research project of Acid Deposition on Limestone Buildings at the Cathedral of Learning. With the cooperation of college students, professors, and professionals, we learned about the different aspects of research. As a part of our study, we participated in the research. For our segment of the research, we decided to map the pollution of the Cathedral of Learning using three different methods: photography, sketching, and surveying.

Mapping on a large scale was successfully completed on all four sides of the Cathedral of Learning. Through surveying, the sides of Bigelow Avenue, Bellefield Avenue, and Fifth Avenue were completely mapped by data points. Through AutoCAD, these points will later be place into the computer and sketched onto the AutoCAD drawing of the Cathedral. By sketching, all four sides of the building, including Forbes Avenue, were recorded on to paper drawings. Photography recorded the pollution patterns of the most polluted side of the Cathedral, Forbes Avenue.

When the EDRC presents their recommendations of preserving the Cathedral of Learning, they will emphasize the method of protection. The EDRC already has an idea for preservation that the National Park Service has used successfully before. The plan is to limit the amount of traffic around the Cathedral of Learning. This could be achieved by not allowing cars to drive on the streets which face the dirtiest sides of the building. That would be the avenues of Forbes and Bellefield. The National Park Service used this plan with the Lincoln Memorial. Cars used to be able to drive all around the Memorial, but now half of the circle has been closed. The front half of the circle (the half facing the entrance of the Memorial) was closed because the pollution from buses and cars was soiling the Memorial. So far, limiting the traffic around the Memorial has been successful in keeping it clean. Because of this example and others, the EDRC believes that protection is the best solution.

If the protection plan is put into effect our mappings could be used in follow up research. A few years after the traffic controls are put in, the pollution should begin to disintegrate. The effectiveness of this plan will be able to be determined by comparing the amounts of pollution on the building to the mappings that we made as a part of our research. The photos that we took will also be available to compare with the side of the Cathedral facing Forbes Avenue. Hopeftilly, our research will provide much assistance to future researchers in years to come.

Acknowledgments

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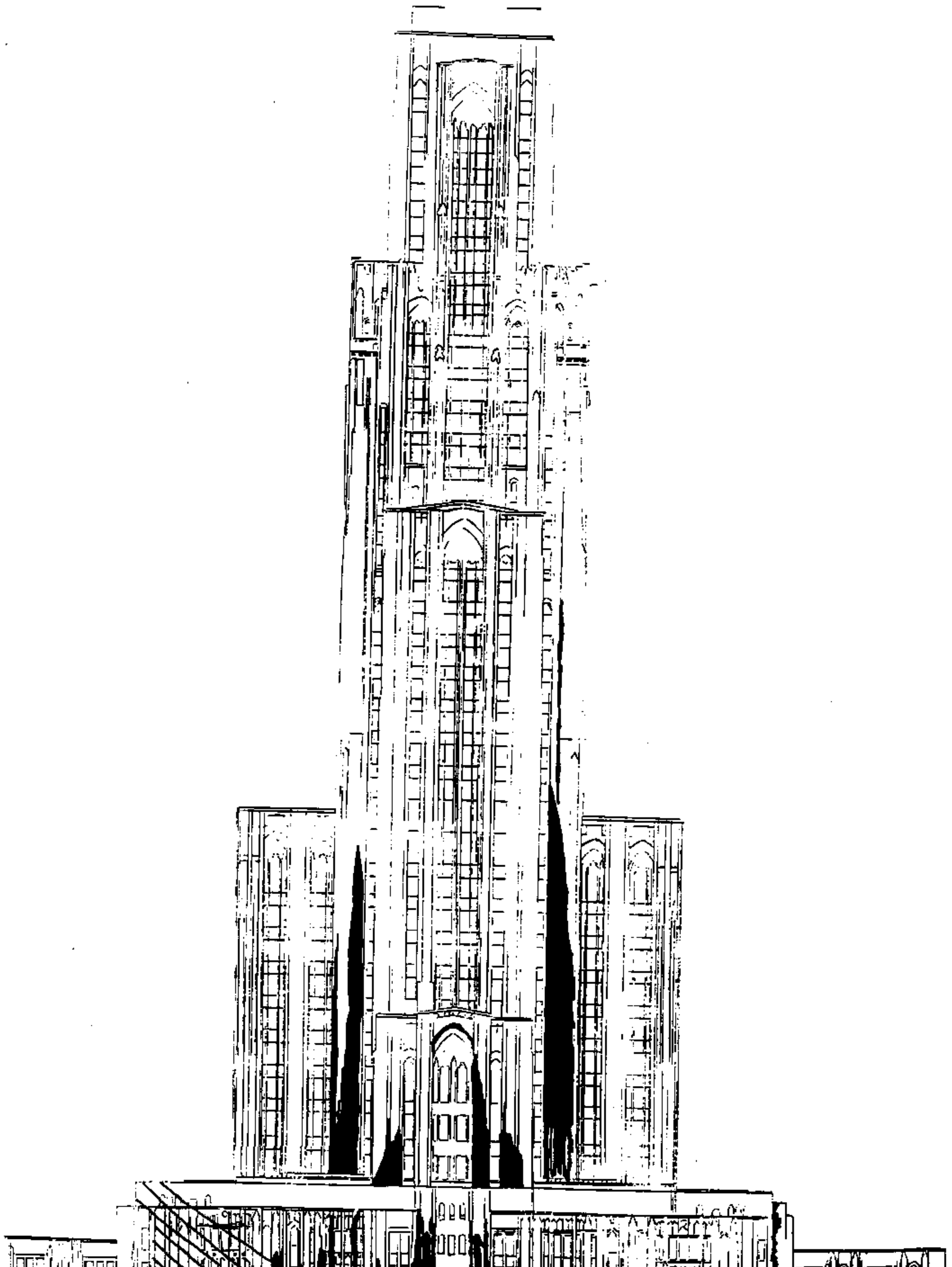
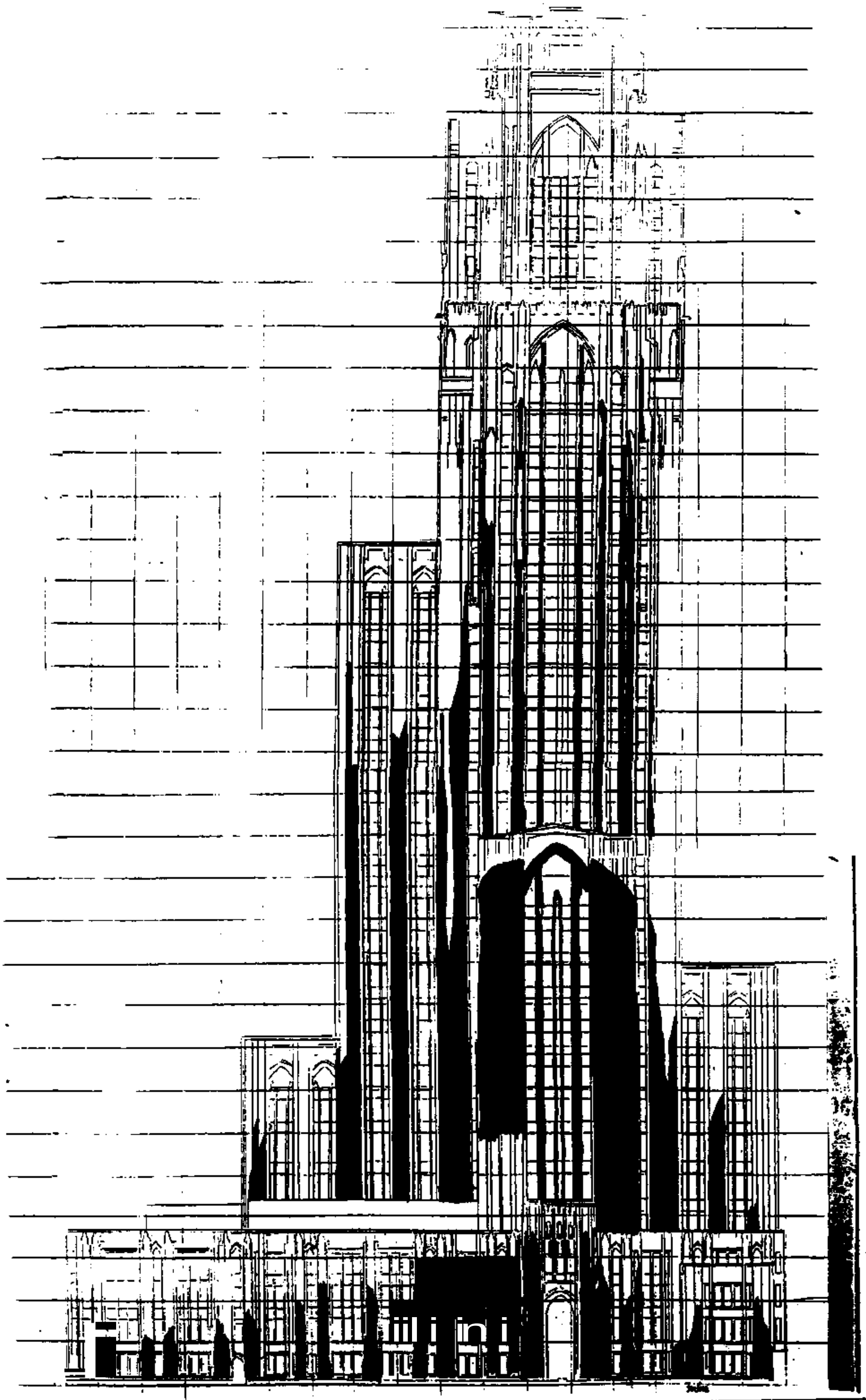
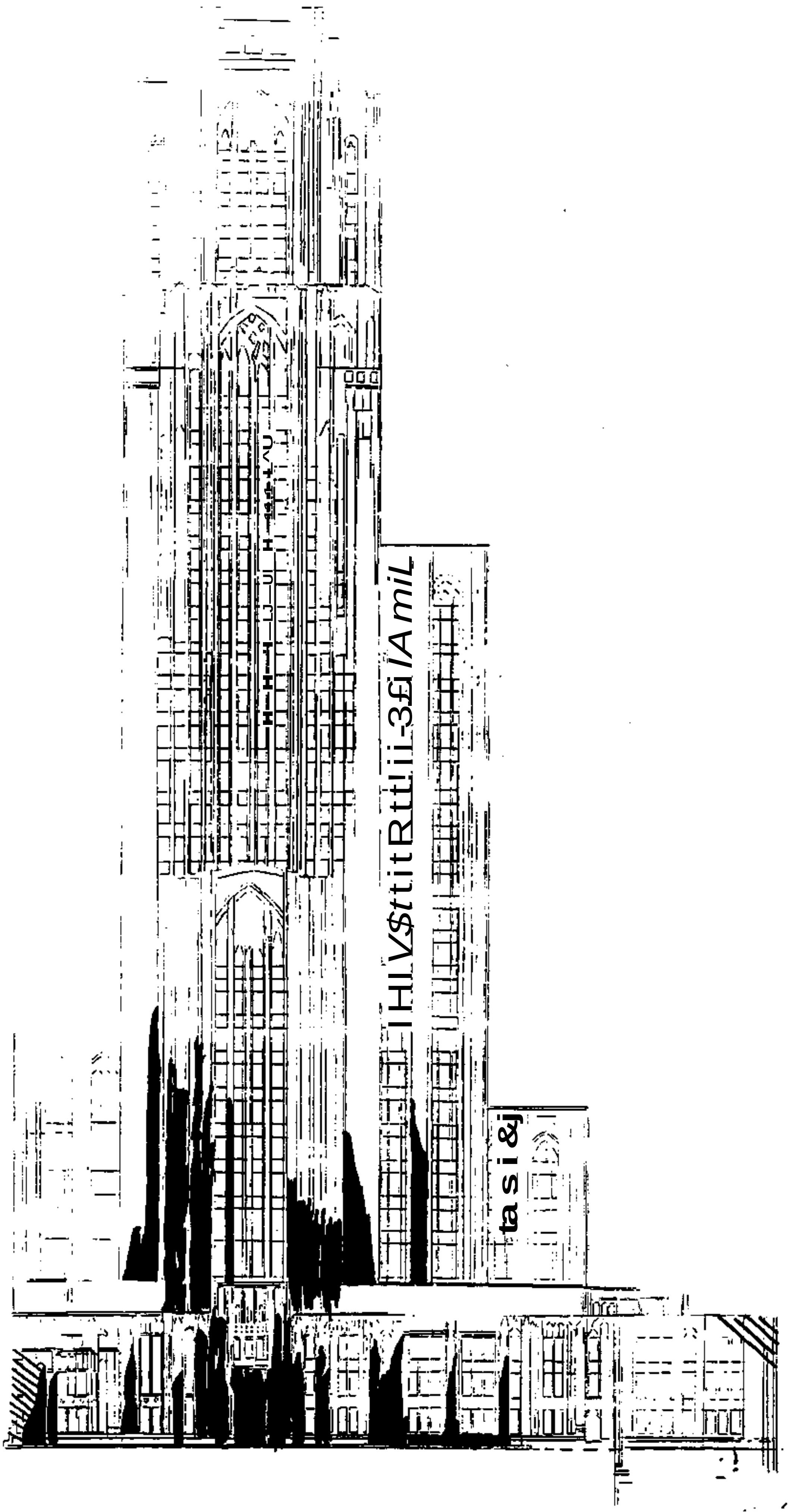
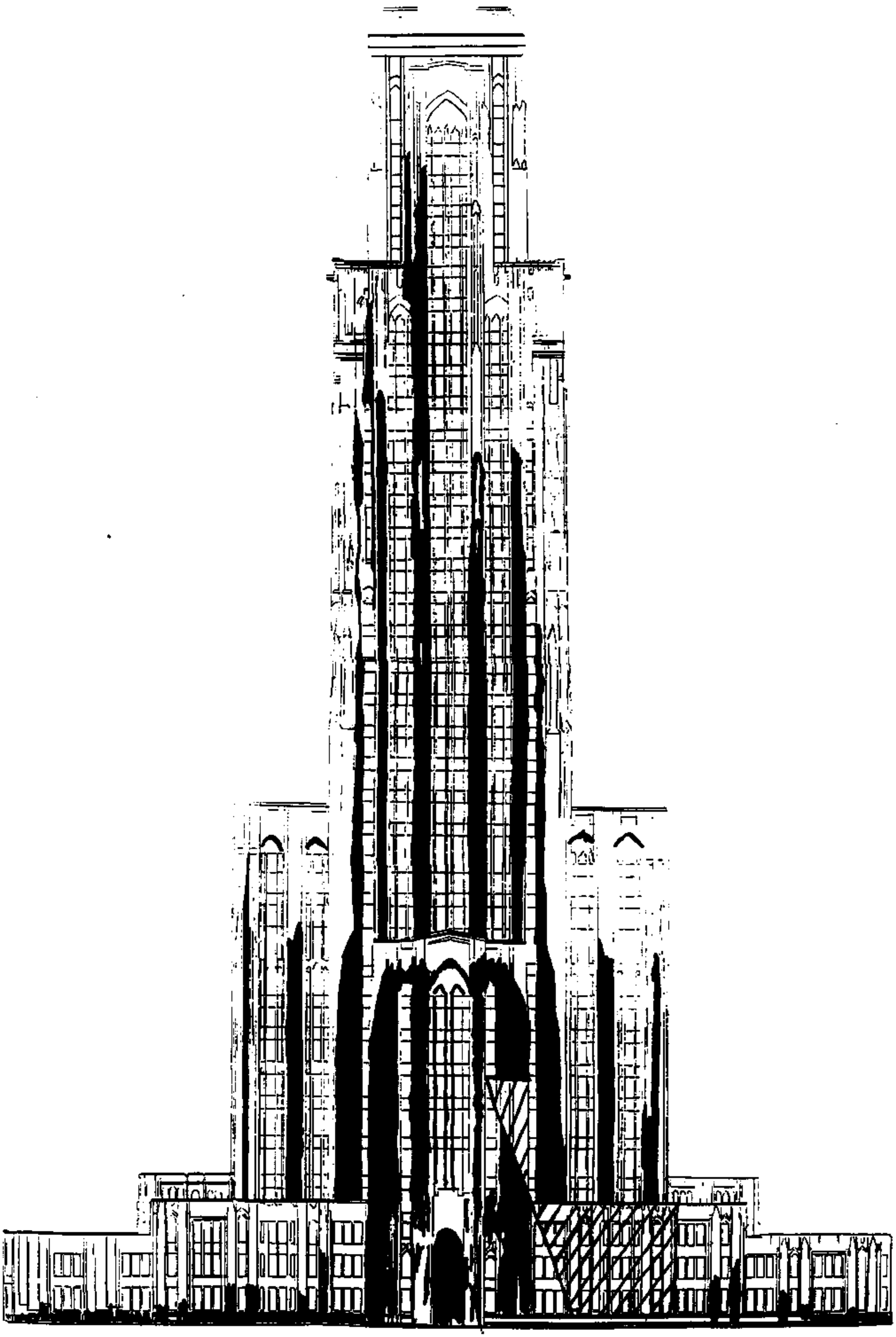
For organizing the 1994 CAST program, we would like to thank Dr. Alfred Bortz. Both Gary Thomas aand Jeff Macklin from the Carnegie Mellon Research Institute Photography and Graphics Service were very helpful. Gary Thomas took special care in developing our photographs of the Cathedral. Jeff Macklin photographed us while working and is to thank for most of the pictures in our report. The other pictures of the Cathedral came from slides loaned to us from J.B. Jeffers and Company. Bridget Caster, Sabeena Jindal, and Kenon Tutein assisted us with our research of the Cathedral of Learning. Prof. Cliff Davidson and Larry Cartwright from Civil Engineering helped us to understand the history of this research project, and provided us with the knowledge to complete our project. We would also like to thank various people throughout the EDRC including Tara Taylor and Sylvia Walters. Most of all we would like to thank Dr. Susan Finger for her leadership in our research. Allowing us to plan our own day on our own and having us figure it all out for ourselves really gave us a taste of the real world and what engineering is all about. Without her none of this work would have been possible.

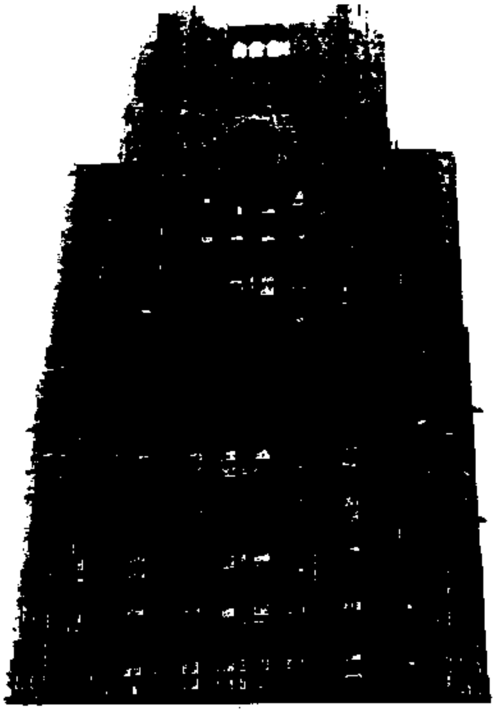
Appendix 1: Sketches and Photographs

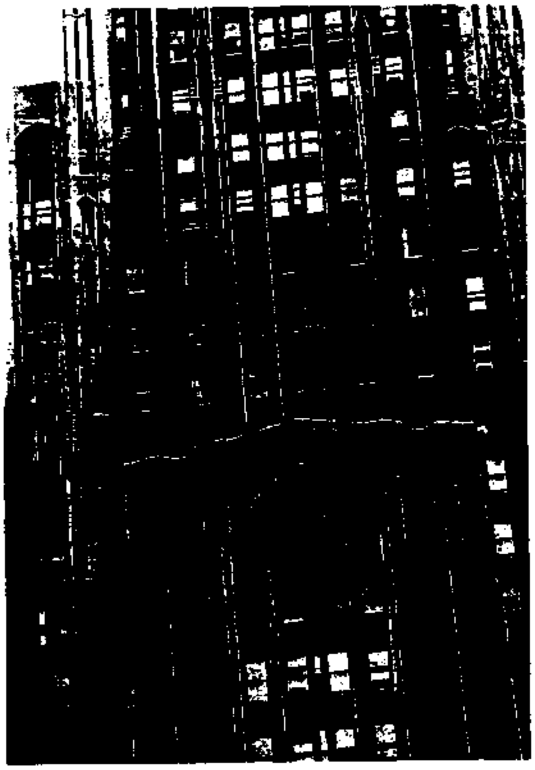

BIGELOW

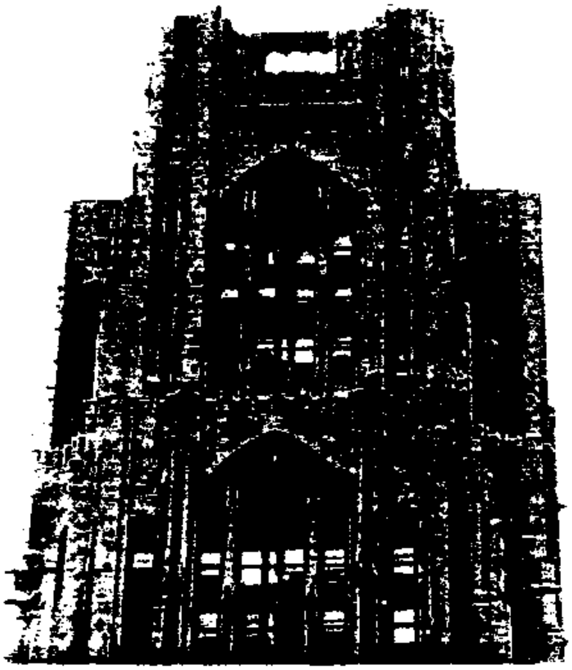


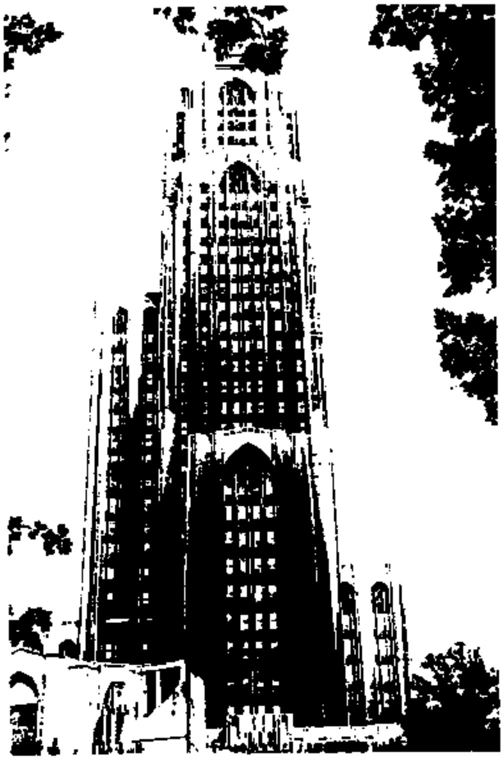


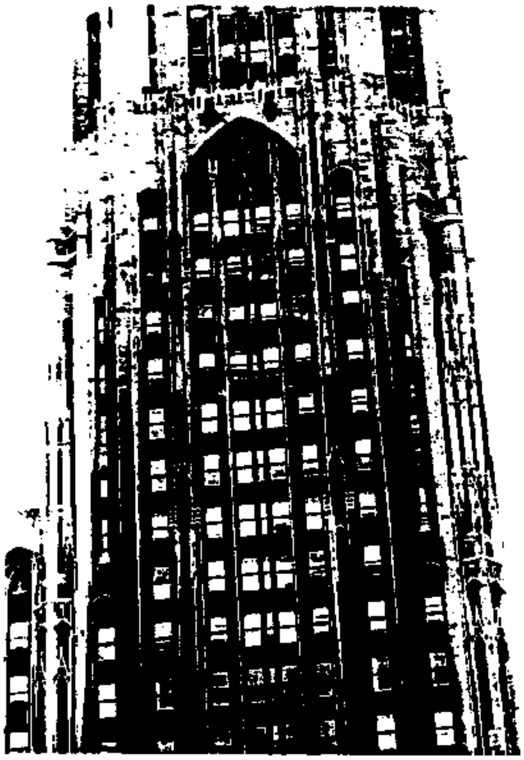


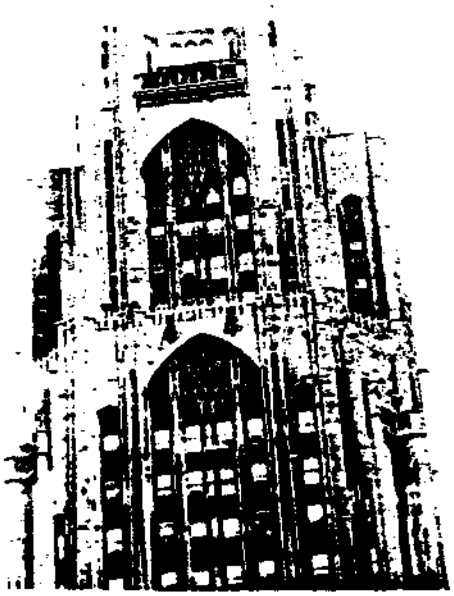












Appendix 2: Surveying Log Book

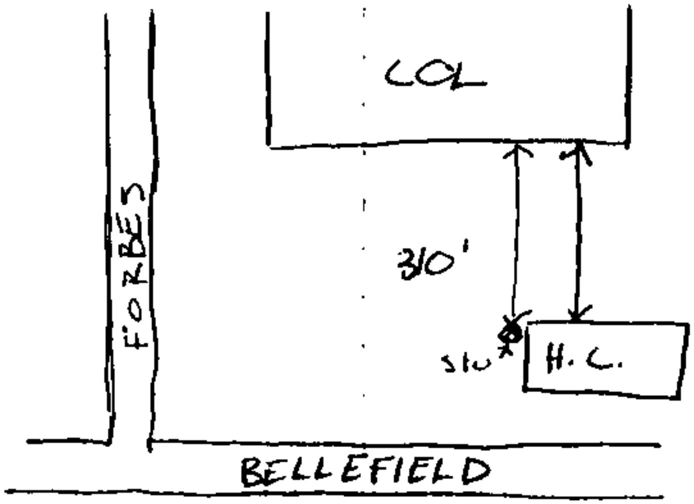
NATIONAL
41
FIELD/TRANSIT BOOK

Property of CAST Program (EDRC):
Melissa Sikes, Kathleen Yen
Address Susan Finger, TERRI KNAEBEL
Curt Dornberg, Kevin Tutein
Telephone LARRY CARTWRIGHT
SABEENA JINDAL
BRIDGET OSTER
Aaron J. Young
Grace S Hu
Eric Dieckman

This Book is manufactured of a High Grade 50% Rag Paper having a Water Resisting Surface, and is sewed with Nylon Waterproof Thread.

7-6

Distance from east side of COL to Heinz Chapel 310 feet.



Marter (⊗) located ~~south~~ east of COL and south of chapel (near front steps)

Surveying to test the accuracy of charting the pollution patterns on the COL. Today we are surveying the portal entrance on the east side (including the main two sets of windows)

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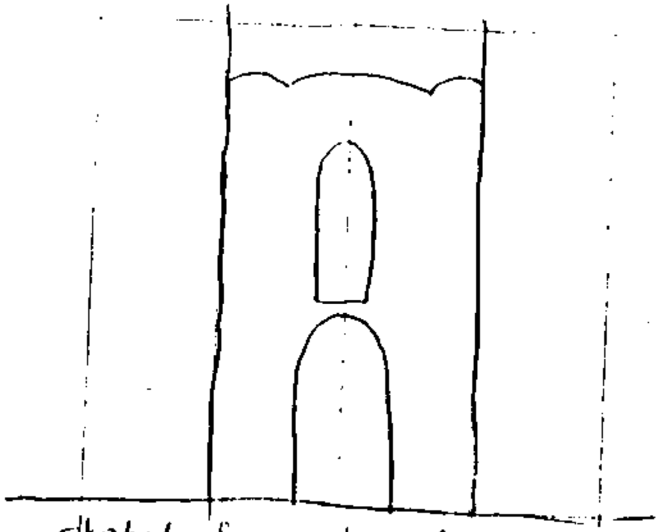
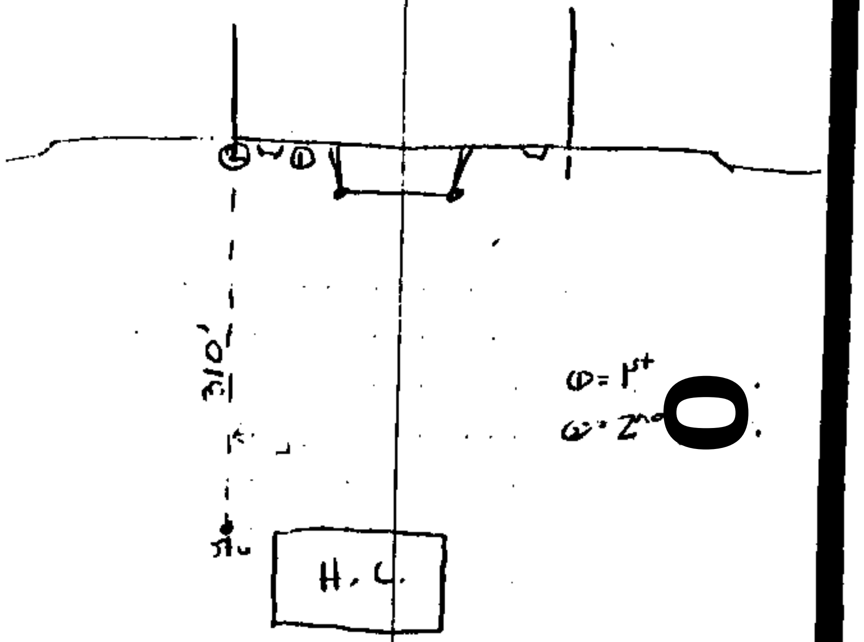
meas.
meas.



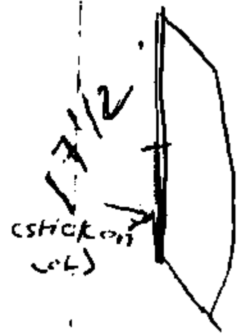
Sketch of east portal entrance of COL.

First measurement was less effective then if measurement is made on edge. If set on edge and made zero, then the azmuth and vertical angles can be found. In the second meas. the BMZ is the same but scope changes azmuth.

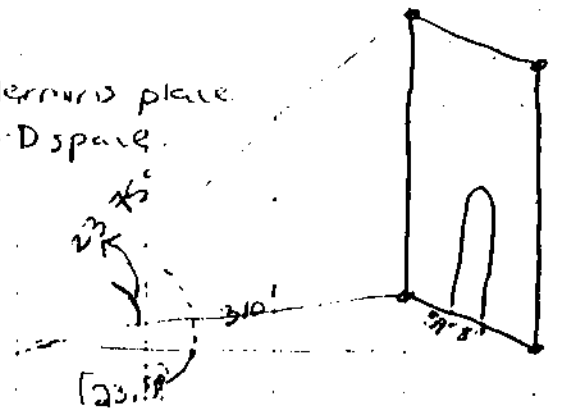


The surveying is to also test the ability of measuring a building of such large height and complexity.

Ex [illegible]
BM2 - 17½ in.
H of I - 52 in.



Determine place
in 3-D space.



3-D view

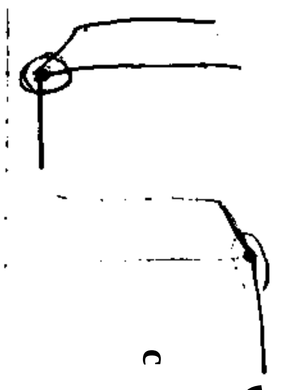
[redacted]

upper left hand cor 7
Angle of height up 2 . 5°
Azmuth unchanged : . 10
read to of portal side.

upper right hand corner:
Angle of height up: 23 0

Dis between of the two corners:
5 ' 8"

pt. meas. at
(trim)



appr
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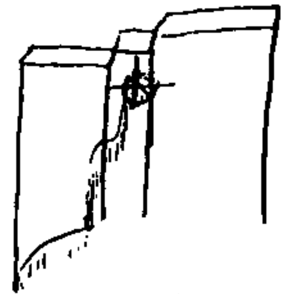
the
is lsted



ledge of left hand
portal entrance

elevation of ⊕ 23°
azmuth 1° 30min.

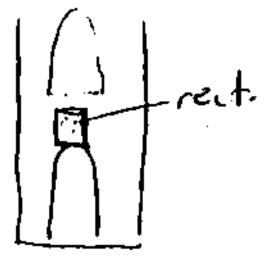
⊕ point of pollution ending

7-19-94

H of I - 56½ in
BM2 - 25in (2' 1")
Distance from Stew to COL - 36'

Pollution: black - polluted
white/non-black - clean

Surveying at Stew.
Sketching East Portal Entrance
Grid - 6n
Btm, Rt - 6°15' El - 9°
(Reference point)
(edge of rectangle above door)



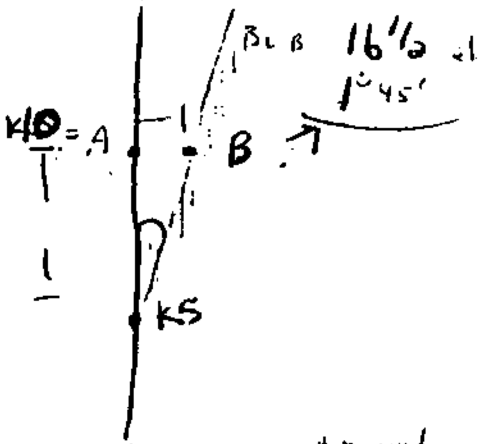
Grid 5 K/L (mainly L)
El. 7½° 15mins. p Lt
azmuth

7/ 04

H of I - 55¼"
BM2 - 2½" 1'½"
Surv g at St

5) angles of the slants.

Grid - K5 - 9° elevation 2° 5'
K10 - 16½ elevation
~~2° 5'~~ 2°15'



All degrees are left of the transit

K11 - 19½ elevation
1°15'

* on the left edge of middle section
limiting angle/slope of pollution.

L 12 1st point
elevation to the R
P 12 2nd point
elevation, 0° to the R
2 points at the top
rtal entrance, e
h edge. These two
ll us the approx. ation
pollution. The pollution is
between the points but they
p the same height.

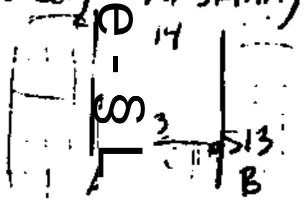
26½° elevation, 11° 15' to R
26½° elevation, 10° to R

* Rt. of center
piece (same as
last, but opp side)

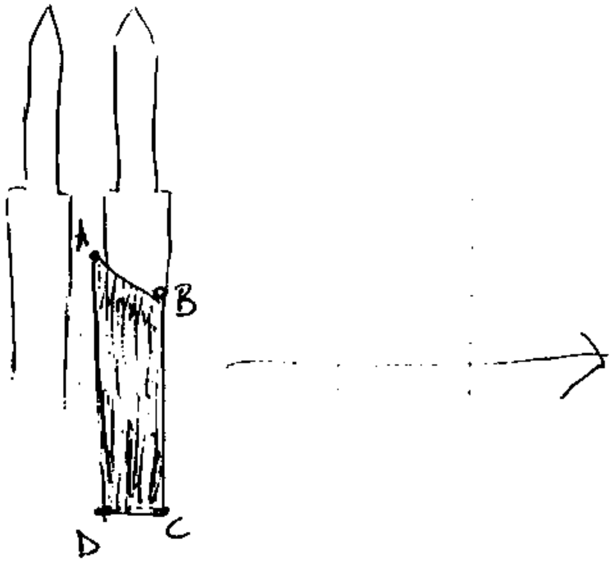
* Lt. sec

S/12 (at top)

top Lt. S14 · 2
(skinny pl. at top) 12
A S13 18.5°
(Big midd > section)
B S13 (edge) Rt skinny



* Rt. sect. between windows
same as last but opp side

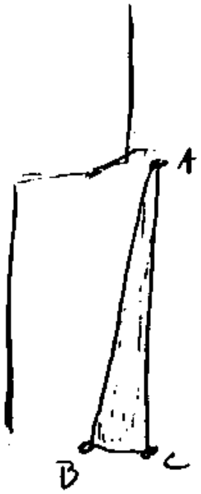


7-21-94

HofI 61"
BM2-1'4¾" (16¾")
Surveying at Stew

Grid [illegible] H11-elevation 18°
[illegible] (A) 6° 45' to L
H11[illegible]- [illegible]elevation 15°
(B) 6°15' to L
elevation 11°
H6 (C) 6°15' to L
elevation 11°
H6 (D) 6°30' to L

*Left edge of building, just below spires



L33 Elevation 46°
(top) (A) 0° [illegible]5' to R
(B) L 29 Elevation 43°
(lower left corner) 0° 15' to L
(C) L29 elevation 43°
(lower Rt corner) 15' to R
* Left edge of middle (main section), below large ledge

P29 elevation 43°
(top left corner) 8°45' to R
P29 elevation
(top rt corner) elevation 43°
9° to R

★ R. side of main building, in between first 2 sets of windows.

(top Rt) elevation 43°
L29 2°30' to R
(top left) elevation 43°
L29 2° 15'

★ Same as last but on left side of main building

7-22-94

~~[illegible]~~ Surveying on Bigelow
301 feet from CCL to transit

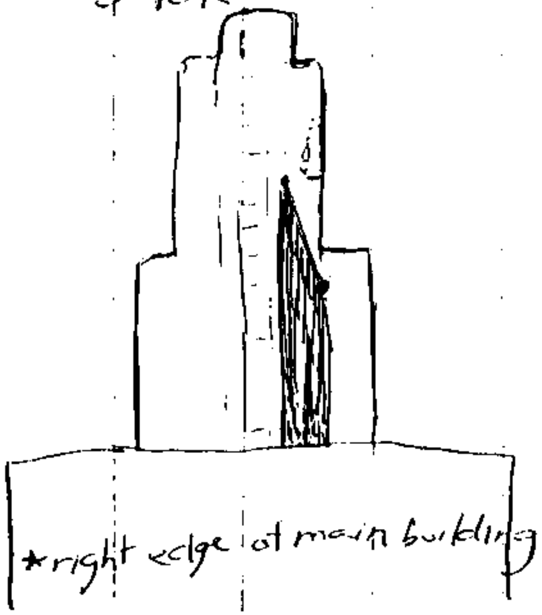
Marker lo[illegible] of CCL and east of Pitt [illegible] (left of entrance)

BM 2 - 8' 3 1/4"
Ht of I - 60 1/2"

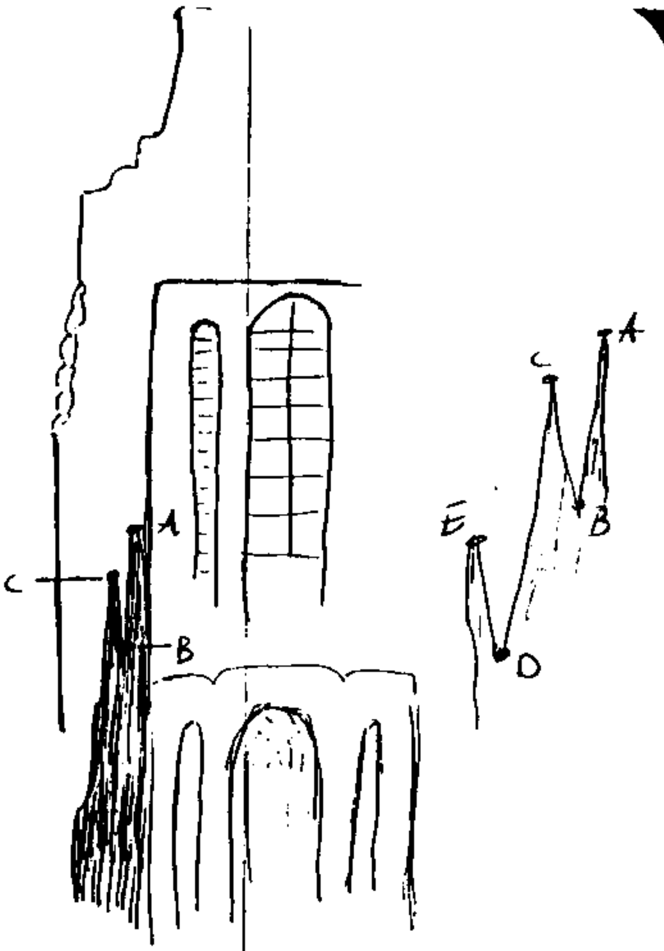
[illegible] R6-R20 - on the right side of the main [illegible]lding

R11 (right uppermost pt. - all black)
G elevation 3°
F 4°45' to R

F19 (top pt. at which it tapers off)
27½° ~~28°~~ elevation
3° to R



L19
~~[illegible]~~ (top point of the tallest streak of pollution)
(A) 22° elevation
5°30' to L

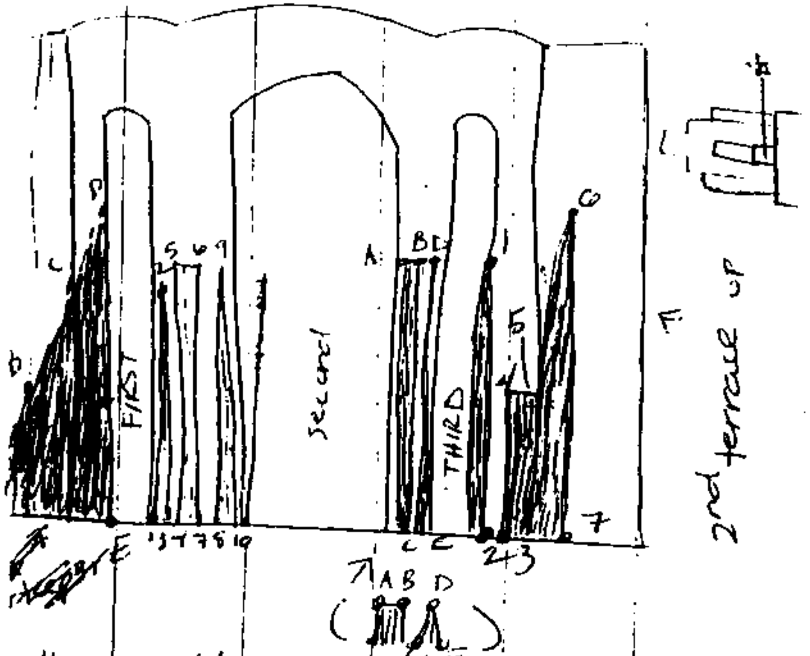


(B) 17° elevation
5°45' to L

(C) 18° elevation
6°15' to L

(D) 11° elevation
6°30' to L

(E) 13½° elevation
6° 30' to L
* Rt. edge of main building



bottom left corner)
A) elevation 9° 30'
5° 45' to L

(B) 11° elevation
5° to L

(C) 13° 15' elevation
4° 30' L

(D) 12° 30' elevation
4° L

(E) 9° 30' elevation
4° L (bottom rt. corner

* Left of 1st window

(1) Bottom 10° 30' elevation
3° 30' to L

(2) top 13° elevation
3° 30' to L

(3) bottom 10° 30' elevation
3° 15' to L

(4) bottom 10° 30' elevation
3° 10' to L

(5) top 13° 15' elevation
3° 10' to L

(6) top 13° 15' elevation
2° 45' to L

(7) bottom 10° 15' elevation
2° 45' to L

(8) bottom 10° 15' elevation
2° 15' to L

(9) top 14° elevation
2°35'

(10) bottom 10° 15' elevation
2° [illegible] to L

* be[illegible] 1st & 2nd windows

(11 left) 14° elevation
A 0° azimuth

(1[illegible] [illegible]) 13.8° elevation
0.5° to R (30')

(bo[illegible]) 10.8° elevation
30' to R
13.8° elevation
45' to R

([illegible] R) 12° elevation
45' to [illegible]
seen 2nd [illegible] windows

(1) top right 1[illegible] elevation
12
1° [illegible]' to [illegible]

(2) Bottom 14° elevation
1°15' to R

(3) bottom 10° elevation
1°45' to R

(4) top L 13° elevation
1°45' to R

(5) top R 13° elevation
2° to R

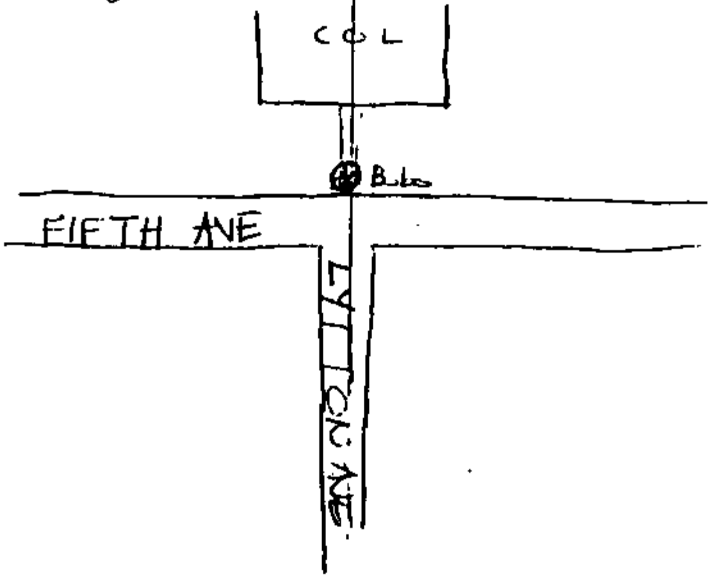
(6 [illegible]) 14.8° elevation
2°15' to R

(7) bottom R* 10° elevation
2[illegible]' to R

* Right of 3rd window

7/26/94

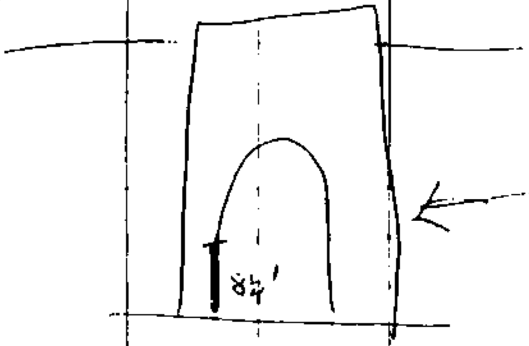
Surveying at Fifth Ave. (BoBo)



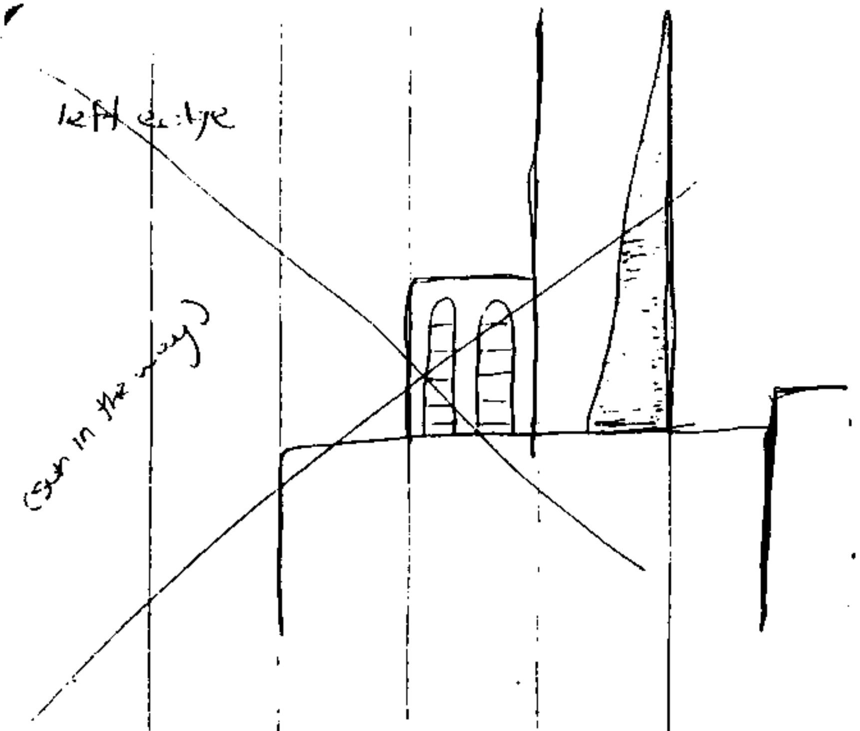
Distance from marker to COL - 178'

Hot I - 61.5"
BM2 - ~~8.25ft~~ [illegible] 8.25"

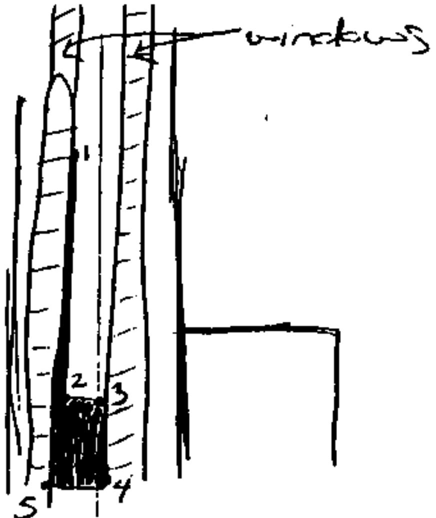
(pt. of ref. is located at the inside of the left edge of portal entrance)



I:



Gnd MIO
(right side
of COL)



1) elevation 22°
10° to R

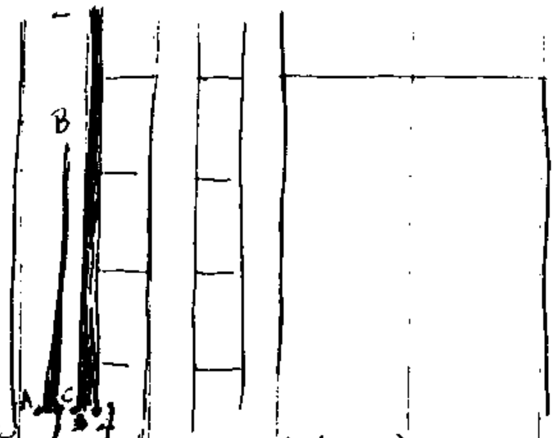
2) elevation 19° 30'
10° 45' to R

3) elevation 19°
11° 45' to R

4) elevation 14°
11° 45' to R

5) elevation 14°
10° 15' to R

(M7)



A) 14° elevation (bottom L)
8°45' to R

B) 17°30' elevation (top)
8°46' to R

1) 14° elevation (bot. R)
2) 8°48' to R

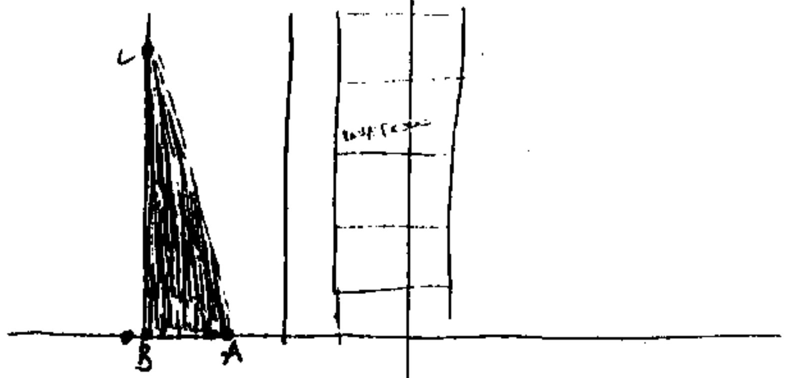
14° elevation (bottom L)
8° 50' to R

24° elevation (top L)
8°50' to R

3) 24° elevation (top R)
8°53' to R

4) 14° elevation (bottom R)
[illegible] 3 to R

(Grid L5-L12)



A (bot. R) 14.5° elevation
8° to [illegible] R

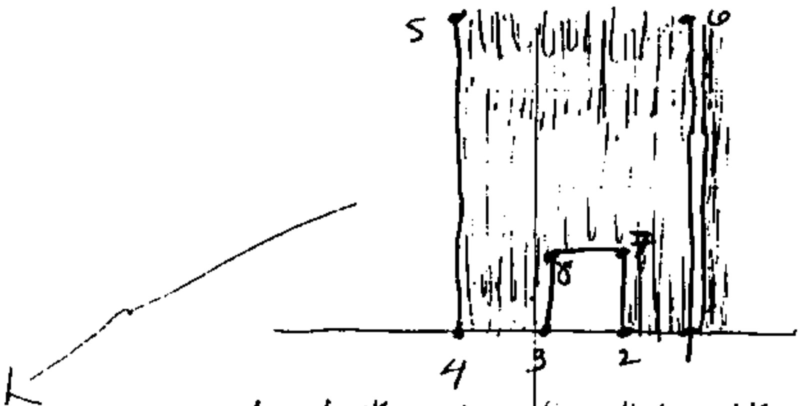
B (bot. L) 14.5° elevation
7°15' to R

C (top L) 24.75 elevation
7°15' to R

(J6-J10)

(Bot R) 14.5° elevation
7°15' to R

Back L)	14.5° ele 5°45' to R
(2) (Mid.	
(3) (Mid)	14.5° elevation 5° to R
(4)	14.5° elevation 4° to R 15'
1) (bot. far L)	
2) (5) B (top L)	21° elevation 3°45' to R
3) (6) (top R)	3° elevation 6°45' to R
1) (7) mid)	6° elevation 0°45' to R
2) (top mid)	10° elevation 5° to R



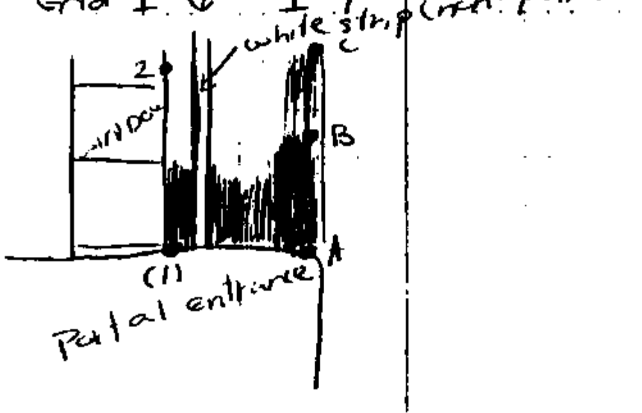
★ at the top of pollution there is no clear line across. The pattern is wavy.

7/27/94

Surveying at BaBa (5th Ave.)

H of I - 59 3/4"
BM2 - 8"

Grid I-6 - I-9



A) bottom right	17.5° elevation 5°30' to R	
B)	21° elevation 5°30' to R	(top of very dark)
C)	29° elevation 5°30' to R	(top of light pollution)

(whole strip)

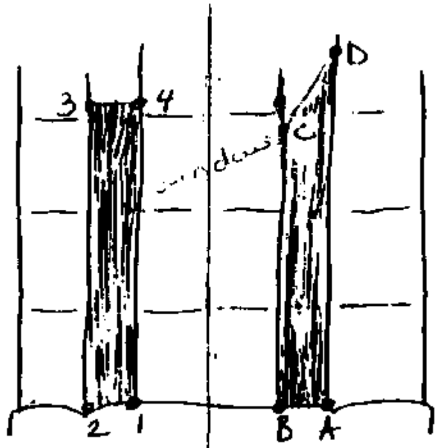
(1) 17.5° [illegible]
[illegible]' to R (c[illegible]ll [illegible] the [illegible]y straight up)

(2) 17.5° elevation (continues up)
4°30' to R

(no energy fr[illegible] h[illegible])

[illegible]) pt next to [illegible] (bottom [illegible])
17.5° elevation
4°15' to R

([illegible]) (top)
29° elevation
[illegible]30' to R



A) 12.25° elevation (bot. R)
3°15' to R

B) 1[illegible].25° elevation (bot. L)
2°45' to R

C) [illegible]6° elevation (top L)
2°30' [illegible]

D) 28° elevation (top R)
3° to R

1) [illegible].5° elevation (bot. R)
[illegible] to L

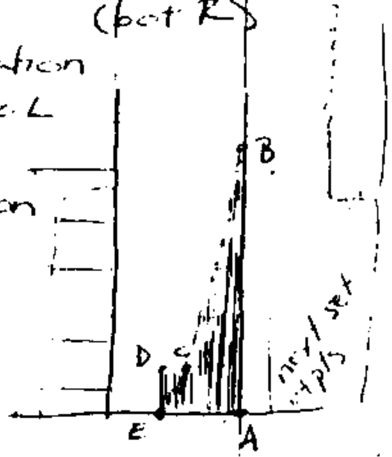
2) 11.5° elevation (bot. L)
0°45' to L

3) 28° elevation (top L)
0° 45' to L

1) 28° elevation (top R)
0° 30' to L

Grid (E6 – E13)

A) 15° elevation (bot R)
7° 15' to L

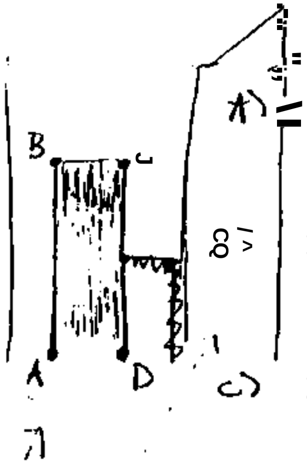


B) (top) 29° 30' elevation
7° 30' to L

) 12° elevation
7° 45' to L

) 12° elevation
8° 40' to L

) 15° elevation (bot L)
8° 40' to L

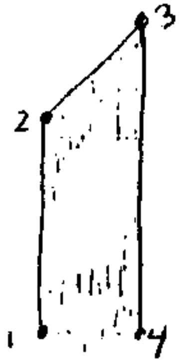


A) [illegible] (b of L)

B) elevation (top L)
to L

C) 26° el[illegible]n (top R)
6° 45' [illegible]

D) [illegible] elev[illegible] [illegible] R
6° [illegible]

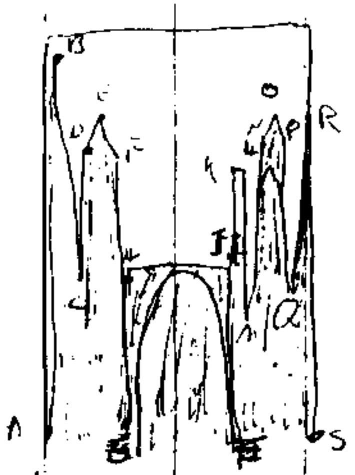


1) 15° ele[illegible] [illegible] of L)
4° 45' to [illegible]

2) elevation (top L
to L

3) 28° el
3° ~~45'~~
30'

Doorway (HS -III)
(15- I D)



A) 2° elevation
4° to L

B) 15° elevation
4°10' to L

C) 8° elevation
3° to L

D) 12°40' elevation
2°45' [illegible]

E) 13°[illegible]0' [illegible]

F) 12° ~~4~~ 40' [illegible]
[illegible]

G) [illegible]

H) 8° [illegible]
1°3[illegible] [illegible]

I) 8° elevation
3°~~55~~' to R

K) 14°45' elevation
2°55' to R

L) 14°45 elevation
2°55' to R

M) 8° elevation
3°15' to R

N) 12°40' elevation
3°[illegible]' to R

O) 13°30' elevation
3°50' to R

P) 12° 40' elevation
4°10' to R

Q) 9° elevation
4°[illegible]0' to R

R) 14°30' elevation
4°25' to R

S) [illegible]° 40' elevation to R
5° to R

Appendix 3: AutoCAD Model