The Pennsylvania Department of
Environmental Protection

PITTSTON CITY POTENTIAL MINE SUBSIDENCE STUDY

LUZERNE COUNTY, PENNSYLVANIA

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LUZERNE COUNTY, PENNSYLVANIA

PREPARED BY

COMMONWEALTH OF PENNSYLVANIA

DEPARTMENT OF ENVIRONMENTAL PROTECTION

BUREAU OF ABANDONED MINE RECLAMATION

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A. EXECUTIVE SUMMARY

On August 28, 2006, at a meeting concerning mine-related and sewer line-related *subsidence*[1] problems in the city of Pittston, The Bureau of Abandoned Mine Reclamation (BAMR), Department of Environmental Protection (DEP), was asked to perform a study to identify those areas of the City of Pittston that exhibit a high potential for subsidence events and to provide recommendations on what steps should be taken to address the subsidence prone areas.

Certainly any area within the Wyoming Valley where coal has been extracted by underground *mining* methods has the potential for subsidence. Factors such as the type and depth of unconsolidated soil and overburden, rock, thickness and number of *coal seams*, the width and spacing of coal pillars, the depth and thickness of the rock interval between the various mined seams, underground water flow, infiltration of surface water and fluctuations in the *mine pool* all must be considered when trying to evaluate an area's subsidence potential.

Portions of the City of Pittston, particularly the Mill Street area, have been plagued by the collapse of the voids left as a result of past underground mining of the various coal seams underlying the City. Since 1942, BAMR has investigated 149 mine-related subsidences in the city.

These collapses manifest themselves at the surface in any number of ways, from shallow depressions in lawns or roadways to openings in the ground of varying diameter and depth. These larger surface expressions present a hazard to residents and cause damage to roadways, sidewalks, utilities, swimming pools, small out buildings such as garages or sheds, and even to the foundations of the principal structures on the property, such as homes or businesses.

[1] See Appendix 1 for a definition of this and other technical terms used throughout the report.

Residents of the community are aware of the potential for damage due to subsidence events as reflected by the fact that as of July 3, 2008, there were 473 active mine subsidence insurance policies in the City of Pittston administered by the Mine Subsidence Insurance Board through DEP.

This study encompasses the entire area bounded by the Pittston City limits. However, particular attention was paid to populated areas.

The city of Pittston is underlain by eight (8) coal veins. As the depth from the surface to a particular coal seam increases, the likelihood of a collapse in the abandoned mine workings propagating to the surface and causing a problem decreases. For this reason, the study concentrated on the three upper veins, the Checker, Pittston and Top Marcy veins.

A major source of information for the study was the mine maps of these seams, their relationship with the surface, the slope of the seam, and other information on them. The Federal Office of Surface Mining (OSM) maintains a map repository in Wilkes-Barre that contains most of the available mine maps for the Anthracite Region.

Other data evaluated for the project was the previously mentioned subsidence investigations, drill logs from the various state and federal drilling projects in Pittston, construction project reports from the numerous localized emergency stabilization projects the Office of Surface Mining has conducted and from the two large subsidence control projects in Pittston that the Department did in 1977 and 1985. (Total cost of $6.3 million).

In addition to these data, information was gleaned from the results of the Light Detection and Ranging (LIDAR) project conducted by the Department of Conservation and Natural Resources in 2006, which focused on mapping 21 southeastern PA counties and Luzerne County using laser mapping technology. A review of the LIDAR map for the City of

Pittston revealed contour depressions indicative of surface subsidence, and helped delineate the risk areas.

The purpose of this study was to identify areas within the City of Pittston that exhibit a high potential for subsidence. A Potential Subsidence Risk Area is a rather broad term that describes any area within the Anthracite Coal Fields that has been deep mined, and not day-lighted by surface mining. Both the area covered by the City of Pittston - 1.7 square miles - and more generally the full area of 484 square miles encompassing the anthracite region are within the Potential Subsidence Risk Area. Subsidence problems occur most often if the conditions involve very shallow mining of a thick vein of coal, little or no rock cover and a very cohesionless soil, such as sand, separating the mining from the surface.

BAMR drew on its past experience in dealing with subsidence events, conducting exploratory drilling and implementing subsidence projects to develop criteria to determine which areas of Pittston were **High Risk Areas.** These were defined as areas in which the mined *coal vein outcrops* near the surface or the rock strata are comparatively thin in relation to the *wash* and depth of the vein. For the purposes of this study, a high-risk area was defined as any area where the top of the first underlying mined coal vein has 35 feet or less of total cover and has 15 feet or less of rock. The boundaries of the High-risk Areas were further defined by the other data sources. There are 24 areas in Pittston City defined as such, totaling 130 acres, or 12% of the city's area.

The study provides recommendations on the priority that should be given to these identified areas for further investigation to determine justification of the need for additional action in the form of subsidence control projects.

It is the conclusion of the study that the area bounded by Church, Butler, Hunter and Center Streets, hereafter known as the Mill Street Area (Area 1C), be the first portion of the City considered for further remedial action. Other areas that warrant further investigative efforts are as follows:

- The area bounded by Nafus, Vine, Pine and LaGrange Streets (Areas 14P, 21M and 22M).
- The area bounded by River, Garfield, Elizabeth and East Streets (Areas 12BC and 13BC).
- The area bounded by South Main, Pine, La Grange and Charles Streets (Area 15P).
- The area bounded by Pine, Curran, Market and Vine Streets (Areas 23M and 24M).

The remaining areas meeting the definition of a high-risk area are either outside developed commercial or residential areas or have not exhibited a pattern of mine-related problems at this time. The inclusion of these into the high-risk category should serve as a cautionary note for anyone considering future development in these areas. However, no other action is recommended at this time for those areas.

The recommendation for a Mill Street Area Project.

1. Public Meetings.
2. Geophysical Study.
3. Easements.
4. Drilling.
5. Borehole camera investigation.
6. Specs and Contract for subsidence control project – phases?
7. Learn from what we do.
8. Time Frame – project ready for funding in 2-3 years.

B. INTRODUCTION

Following a series of private and public meetings with Congressman Paul E. Kanjorski and others, it was decided that the Bureau of Abandoned Mine Reclamation, Department of Environmental Protection would conduct a study of the entire City of Pittston in regards to the subsidence potential due to the abandoned underground coal mines beneath the City. The following are acronyms that will be used throughout the report:

BAMR - Bureau of Abandoned Mine Reclamation

DEP - Department of Environmental Protection, Commonwealth of Pennsylvania

OSM - Office of Surface Mining Reclamation and Enforcement United States Department of the Interior

1. Purpose

The purpose of the study was to identify those areas of the City of Pittston that might exhibit a high potential for subsidence events and to make suggestions or recommendations on how to best mitigate those problems.

Portions of the City of Pittston, particularly the Mill Street area, have been plagued by the collapse of the voids left as a result of past underground mining of the various coal seams underlying the City. The collapses manifest themselves at the surface in any number of ways, from shallow depressions in lawns or roadways to openings in the ground of varying diameter and depth. These larger surface expressions present a hazard to residents and cause damage to roadways, sidewalks, utilities, swimming pools, small outbuildings such as garages or sheds, and even to the foundations of the principal structures on the property, such as homes or businesses. The subsidences often result in cracks in the structure foundation that in turn allow water or mine gases to enter the structure, compromising the integrity of the structure and endangering the occupants. Residents of the community are aware of the potential for damage due to subsidence events as reflected by the fact that as of July 3, 2008, there were 473 active mine subsidence insurance policies in the City of Pittston administered by the Mine Subsidence Insurance Board through DEP. This figure represents only about 12% of the residential and commercial units in the City, which means the vast majority of the properties are not covered in the event of a mine subsidence.

In order to prevent or minimize these subsidence events, it is necessary to fill the underground void spaces created by the removal of the coal. This can be accomplished by employing several proven methods that will be discussed later in this report.

2. Objectives

The objective of this study was to first identify areas of the City of Pittston that might be particularly prone to subsidence. Certainly any area within the Wyoming Valley where coal had been extracted by underground mining methods has the potential for subsidence. Factors such as the type and depth of unconsolidated soil and overburden, rock, thickness and number of coal seams, the width and spacing of coal pillars, the depth and thickness of the rock interval between the various mined seams, underground water flow, infiltration of surface water and fluctuations in the mine pool all must be considered when trying to evaluate an area's subsidence potential.

The second objective after identifying areas of concern was to provide recommendations on what steps should be taken to address the subsidence prone areas.

3. The Community

The City of Pittston is located in Luzerne County, Pennsylvania about mid-way between Scranton and Wilkes-Barre (**FIGURE NO. 1**). The western edge of the City borders the Susquehanna River. The downtown area can be reached by taking either Exit 175A or B from Interstate 81 to Route 315 and then Oak Street (SR 2019). Follow Oak Street west to South Township Boulevard, also known as the Pittston Bypass. Turn right onto the Pittston Bypass and follow it to the first traffic signal, which is William Street (SR 0011). Turn left onto William Street and follow it to the downtown area at Main Street.

Named after the English statesman William Pitt, the City was founded in 1838 and was originally named Pittstown. The City is located at 41°19'26" N and 75°47'20" W. According to the United States Census Bureau, the City has a total area of 1.7 square miles. The population was 8,104 at the time of the 2000 census but a 2004 estimate indicates that the population has decreased to 7,753 people.

Like most communities in the Wyoming Valley, anthracite coal mining was an important industry in Pittston up until the time of the Knox Mine Disaster in nearby Port Griffith, Jenkins Township. This event essentially shut down the mining industry in Northeastern Pennsylvania in 1959. Twelve miners were killed immediately when the mine roof collapsed allowing water from the Susquehanna River to enter the coal mine. Sixty-two other miners working at the time of the collapse were able to escape.

It became economically unfeasible for the various coal companies to pump out the water that accumulated in the mine workings. As pumping was discontinued and the mine workings abandoned, the void spaces left as a result of the mining gradually filled with water creating what is known as the mine pool. The elevation of any given mine pool is governed by the outfall point to the surface. This can be a mine opening of some type or as a result of the installation of a borehole to prevent the water from rising to an elevation that would affect residents whose basement elevation was lower than the mine pool elevation.

4. Study Area

The study area encompasses the entire area bounded by the Pittston City limits as shown on **FIGURE NO. 1**. However, particular attention was paid to populated areas.

5. Mining History

The discussion in this section contains terms commonly used in the mining industry. Before proceeding further, it may be helpful to those unfamiliar with mining terminology to review the definitions found in Appendix A. *These technical terms are italicized the first time each is used in this section.*

The Anthracite Coal Region includes the four anthracite fields in eastern Pennsylvania: the Northern, Eastern Middle, Western Middle and Southern **(FIGURE NO. 2).** Pittston is located in the Northern Anthracite Field.

The City of Pittston is underlain by eight (8) coal veins **(FIGURE NO. 3)**. They are, in order from top to bottom: Checker (included in this is the Bottom Checker, also known as a "split" vein), Pittston, Top Marcy, Marcy, Clark, Bottom Clark, Middle Red Ash and Bottom Red Ash. As the depth from the surface to a particular coal seam increases, the likelihood of a collapse in the abandoned mine workings propagating to the surface and causing a problem decreases. For this reason, the study focused on the three upper veins that are most problematic, those being the Checker, Pittston and Top Marcy veins. The orientation of the three veins varies from flat (horizontal) to a maximum inclination of 45° at the outcrops. The veins generally slope downward going from east to west. The average thickness of the Marcy vein is 7 feet, the Pittston vein, 6 feet and the Checker vein, 7 feet. The roof rock overlying the Pittston vein is slatestone, while the other two veins have a sandstone roof.

Most of the Pittston area was deep mined by the Pennsylvania Coal Company's No. 9 Colliery. A small area in the northeast corner of Pittston was mined by the Pennsylvania Coal Company's Seneca Colliery. The Ewen Colliery was located in the southwestern end of Pittston, known as South Pittston and the Butler Colliery affected a small area near the top of William and Butler Streets. The method of underground mining was known as the *room*-and-*pillar* method. This method involved driving *gangways* into the face of the coal. *Chambers* or "headings" were then driven perpendicular to the gangway, separated by relatively uniform distances based on the depth of the vein. The chambers were driven into the coal at roughly the same distance at which point a cross-cut would be made between the chambers. This effectively formed a pillar of coal whose purpose was to provide support to the rock roof. In this fashion, the mining advanced through the coal seam in this rectangular pattern, creating a system of rooms and pillars. This was commonly known as first mining.

The geometry of the mining was affected by the slope and thickness of the coal being mined **(FIGURE NO. 4)**. Second mining consisted of "shaving" the pillar, decreasing its size or sometimes even driving a chamber through the pillar, splitting it in half. Third or retreat mining, also known as *robbing*, removed the pillars in their entirety, with subsequent collapse of the void space once this support was removed. This work was dangerous to say the least. All three types of mining techniques were performed to some degree in these top three veins. Vertical wood props and horizontal cross pieces were used in areas where the roof rock was not competent enough to support itself. **FIGURE NOS. 5A and 5B** are photographs taken of typical underground mine workings showing the pillars of coal, wooden props and roof fall material littering the floor of the chamber. **FIGURE NOS. 5C and 5D** are photographs that depict how the surface may be affected by a typical mine-related subsidence. Over the years, the wooden props have deteriorated to the point where they provide little or no roof support. The wooden props were never meant to nor could they ever bear the entire weight of the material above the mine working, rather, they were utilized to shore up loose or crumbling sections of the roof rock. However, as the roof rock spalls off due to the enormous pressure from above it, this type of collapse can slowly propagate toward the surface where it manifests itself as a shallow depression or outright opening in the ground surface.

Oftentimes, rather than hauling rock removed as part of the mining process to the surface, the mine workers would stow the rock in chambers that would no longer be worked. Material was also placed in chambers where the surface stability was threatened by the mining. **FIGURE NO. 4** denotes these various features.

Mining followed the coal seam until the coal vein thinned out, was structurally absent or the roof rock became so fractious or non-existent that further removal of the coal was not possible without risking a collapse. Frequently the seam of coal was pursued until it *daylighted* itself at or near the surface. Over time, in places where there was no longer any roof rock support, the wash material remaining would collapse into the void created by the mining all the way to the surface and become what is known as a cropfall. Mining was sometimes conducted at such shallow depths that people would report hearing the miners as they worked under their homes. It is not uncommon to this day for people excavating for an in-ground swimming pool or building foundation to intercept abandoned underground mine voids.

In order to conduct the mining, it was often necessary for the various mining companies to employ pumps to remove accumulated water from the underground workings. Sometimes the mining company was able to dig a rock *tunnel* that would allow water to leave the mine workings by gravity alone. This was the case in Pittston with the Butler Mine Tunnel (noted as Pittston Water Tunnel on mine maps). Once mining and pumping ceased, the voids created by the removal of the coal filled with water. Surface water enters the mine voids through cracks or fissures in the rock, subsidences or other types of openings between the mine voids and the surface. The mine water pool is a huge underground reservoir, with both an inflow and outflow of water. The elevation of any individual mine pool fluctuates depending on the time of the year and rainfall events. The normal water elevation in a mine pool is governed by the elevation at which the collected water is able to drain from the underground and by the rate at which it is able to drain. Again, this could be through abandoned openings or a *borehole* drilled expressly for the purpose of draining the mine pool. The Old Forge Borehole, located in the borough of Old forge, is an example of a borehole drilled to discharge mine water directly into the Lackawanna River. It is a major source of pollution in the form of *acid mine drainage.*

6. Drilling Projects

Over the years, a number of drilling projects were conducted in Pittston to gather information concerning the condition of the underground mine workings. The location of the boreholes were based on subsidence potential using the available mine maps and subsidence events. The goal of drilling is to intercept void spaces in the abandoned underground mine workings.

The process of choosing a location to drill a borehole starts with an examination of the mine maps for the area. Ideally, the borehole is located such that it can intercept an open area, such as a chamber or gangway in one or more of the underlying, mined coal seams. Once a location is selected, a site visit will determine if the borehole can be physically drilled at that particular location. The ideal spot may be occupied by a structure or a utility. A rotary drill rig has a tower that is stored in the horizontal position when traveling from site to site. Once at the location of the proposed borehole, this tower must be raised to a vertical position. The top of the drilling rig tower or derrick is about 30 feet in the air, so any overhead wires or tree limbs pose a problem. Beneath the surface are possibly electric, water, gas, sanitary sewer, storm sewer or other conduits. A conflict with any one of these existing services could render the proposed site unusable.

Access to an area could be a problem. Before working on private property, the Department must first obtain an easement, also known as a right of way agreement, from the affected property owners(s). An easement is a written document, signed and notarized by both parties that sets forth the conditions under which the work will be done. However, because of easement and space issues, most drilling takes place within the public right of way. Plans to drill on residential properties present a variety of challenges. Beside the main structure on a lot, a homeowner may have constructed a garage or other outbuildings, erected fences or a swimming pool, all of which serve to limit where a borehole can be located. Boreholes are drilled using either core or rotary methods from the surface through the various underground strata and mine workings. A core drill has the capability of retrieving a sample of the strata being drilled so that it may be examined later by a geologist. The cores are removed in sections and stored in specially constructed wooden boxes so that it is possible for a person to physically view the materials the drill passed through all the way from the surface until the boring was discontinued. Thus, if the boring penetrated a coal pillar, it then becomes possible to know the exact depth that the coal exists below the surface, the thickness of the coal seam and the type of rock strata above and below the coal seam. It is also possible to see the orientation of the rock strata in relation to the horizontal and to examine the rock cores to determine the type of rock and whether or not there are any weak areas or cracks. If necessary, the rock core could also be tested to determine its strength. Core drilling is limited as to the diameter of the hole that can be drilled.

A rotary drill is able to gather much the same information with a larger hole diameter but is unable to retrieve an intact core specimen of material to examine. The larger diameter allows this type of borehole to be used to inject *flush material* underground to fill the void spaces and provide surface support. These boreholes can also provide a means to lower a remote camera to examine the underground conditions. The rotary drill uses a cutting head mounted to a hollow steel shaft. As the hole is drilled deeper, additional sections of steel shaft can be added. The cutting head contains diamond cutting edges that allow it to cut and grind away at any rock encountered by the drilling process. In order to keep the borehole cleared of material while it is being drilled, compressed air or water is forced down through the hollow steel drill shafts and the air then forces the cuttings back to the surface, where they are kept clear of the borehole by the drill operator's assistant. These cuttings are examined and give a good indication of the type of material the drill is going through.

The drill is capable of exerting a downforce on the steel shafts, in much the same way as one would use a power drill and bit to form holes in wood. The drill operator can get an indication of the general competency of the rock being drilled by the amount of downpressure required to advance the drill bit and by how quickly the drill bit is able to pass through the various strata. If an opening is encountered, the drill operator has the capability of allowing the steel shaft to slowly pass through the opening and measuring the distance the steel shafts descends in order to determine the height of the opening. All of the information collected by the driller is committed to a drill log for future use. A copy of a typical Drillers Report is presented as **FIGURE NO. 6**. The Report lists the location of the borehole and the date it was drilled. The types and depths of the various strata encountered are noted. From this log one can see that the drill passed through 16 feet of wash (soil) material and then through 20 feet of rock before encountering an 8 feet high void with 2 feet of loose broken material along the roof of the opening. The location of the drilling and depth of the void from the surface indicates that the drill intercepted the Checker vein at this point. The drill continued beyond the top vein through 65 feet of rock at which point the Pittston vein was intersected. The void space consists of loose rock at the roof level, 4 feet of open void and 4 feet of loose broken material on the floor of the mine. This loose broken material on the floor could represent roof rock that has detached itself and collapsed onto the floor of the mine. The drilling continued through another 34 feet of rock before encountering an opening 7 feet high with 6 feet of loose broken material on the floor of the mine. Given the depth from the surface, this vein was identified as being the Marcy vein. The drilling continued for an additional 2 feet into the floor of the vein to "prove out" the borehole. The driller's log or borehole log, as it is also known, provides a snapshot of what the strata looks like at this particular borehole location. The rock interval between each coal seam and the depths to the floor of each vein can be compared to other boreholes to evaluate the accuracy of the mine maps. The information on the log can also be used to estimate the work quantities needed for drilling other boreholes and estimating how much material may be needed to fill the voids. A steel casing pipe is installed in the borehole to keep the hole from collapsing and a threaded cap is welded to the top of the casing at the surface. This threaded cap allows access for monitoring purposes and possible future use as an injection site for flush material.

Included in the Appendix of this report is a compact disk that contains the Drillers Reports for the following projects conducted in Pittston:

Project ID	Description	Completion date
ASP 17 FE 40:6	Drilling & Casing Exploratory Boreholes, Abandoned No. 9 Colliery, Oregon and Welch Hill Areas of Pittston	February 22, 1974
ASP 17	Filling Mine Voids Abandoned No. 9 and Ewen Colliers Oregon and Welch Hill Sections City of Pittston	November 30, 1977
SL 470-101.5	Drilling Exploratory Boreholes, Pittston	September 24, 1979
OSM 40(807-83)101.5	Pittston and Duryea Core Boring	August 20, 1985
OSM 40(511-83)101.1	Subsidence Control Project, Pittston 2 – Phase 1 Flushing	January 14, 1986
OSM PA(813)101.5, WS# 3	William Street, Pittston	June 4, 1986
SP 3525402002, OSM PA(819)108.5, WS#2, OSM 40(3031)101.5	Rotary Drilling Exploratory Investigation, Pittston	August 30, 2005
PA No. 9 Colliery Logs	Dated 1910 to 1943	

7. Subsidence Control Projects

a. Gravity and Pressure Flushing Methods

The Department has conducted two large subsidence control projects in Pittston. In addition, the Office of Surface Mining has conducted numerous localized emergency stabilization projects. In the Anthracite Region, the most commonly used method of filling underground mine voids over large areas is by injecting a slurry consisting of water and a graded granular material through boreholes using either gravity or pressure.

Contract No. ASP 17 was completed by the Department on November 30, 1977. A total of 642,075 tons of material was injected into the Checker, Pittston and Marcy veins in an area generally bounded by the Susquehanna River, Dock, Charles, Vine, Nafus and West Streets. The project limits are shown on **FIGURE NO. 7**. The cost of the project was $2,019,783.75.

Contract No. OSM 40(511-83)101.1, was completed by DEP on January 14, 1986. A total of 849,811 tons of material was injected into the Checker, Pittston and Marcy veins in an area generally bounded by North Main, Lambert, Division, Hunter and Butler Streets. The project limits are shown on **FIGURE NO. 7**. The cost of this project was $4,266,324.85. The material was injected through boreholes previously drilled under Contract No. SL 470-101.5 augmented by additional boreholes drilled as part of Contract No. OSM 40(511-83)101.1.

FIGURE NO. 8 depicts the installation of a typical injection or monitoring borehole. Beginning at the surface, the driller bores down through the wash material and four feet into the bedrock. The drill steel and cutting head are withdrawn from the hole and a grout mix is poured into the borehole. A steel casing pipe, called the surface casing, is inserted into the hole and bedded in the grout mixture at the bottom of the hole. The grout is forced up into the casing but also outside the casing to form a tight seal between the casing and the rock. The grout is allowed to set at least 24 hours before drilling resumes. The purpose of this casing is to prevent the loose wash material from collapsing and blocking the borehole. Using a smaller cutting head, the driller proceeds to drill through the layer of grout in the bottom of the borehole and continues down through the rock, eventually intersecting the various coal veins. Ideally the borehole will intersect an opening in the mined out area, although sometimes the borehole instead encounters a pillar of coal that remains in place. Nevertheless, a borehole that hits a coal pillar, also known as a "solid" hole, provides information that can be useful, such as the exact distance from the surface to the bottom of the coal seam and the exact thickness of the coal seam. If the drilling encounters one or more openings, the driller replaces the cutting head with a larger diameter "bit" that will ream out the borehole to a point about 10 feet above the lower-most opening. A smaller casing is inserted into the borehole, through the surface casing and allowed to rest on the small ledge created by the two different size bits. A standard steel casing pipe is generally 20 feet in length, so successive pieces of casing pipe are welded together and lowered into the hole until the hole is cased from the surface to 10 feet above the lowest opening. This casing is called the injection casing. A plate is welded to the top of the surface and injection casings to seal the borehole. A threaded sleeve is inserted with a plug that will allow access for monitoring purposes.

When a borehole is used for injection purposes, the plate is removed from the top of the borehole casing and either a metal hopper is set directly over the borehole for gravity *flushing* or a delivery pipeline is welded directly to the borehole casing for pressure flushing. If multiple seams are being flushed from the same borehole, the bottom-most vein is filled to refusal at which point the delivery pipe is disconnected and the injection casing is pulled up the borehole until it is at the top of the next vein. This process is repeated until all of the seams intersected by that particular borehole are filled to refusal. The inspector is able to track the spread of the injected material underground by dropping a measuring tape in adjacent boreholes to check for material migration. The inspector can then use the information obtained through this monitoring, in conjunction with the amount of material injected into each particular vein, the results of the drilling and an examination of the mine maps to estimate the extent of the underground voids filled as a result of the flushing. Additional boreholes can be drilled to verify the extent of the filling if necessary.

FIGURE NO. 9A is a list of all the boreholes that were used to inject material underground during the construction of Contract No. ASP 17. The figure also notes the amount of material that was injected in each vein opening. While there is some data in the records indicating that boreholes were monitored to track the flow of flush material, the record is not detailed enough to definitively identify which openings in what veins may have been filled from adjacent injection boreholes. **FIGURE NO. 9B** depicts the location of the boreholes proposed for use in the flushing project. Additional boreholes were drilled during the course of the project but are not listed on the drawing. The description on the Drillers Report of where the additional boreholes were drilled does not provide information that is specific enough to accurately locate the boreholes on the drawing.

FIGURE NO. 9C is a list of all the boreholes that were used during the construction of Contract No. OSM 40(511-83)101.1. The table also notes the amount of material that was injected in each borehole. **FIGURE NOS. 9D and 9E** depict the location of the boreholes used in the flushing project. A combination of both gravity and pressure flushing techniques were used. If the information obtained through the drilling of the boreholes indicated that there was an opening or even loose broken material at the vein location, an attempt was made to inject material. Water alone was first introduced into the borehole to determine if there was enough of an opening to allow the water to flow freely. Despite the fact that the borehole information may have indicated some type of opening or loose material, there were often times when the borehole would not even accept the introduction of water. If the borehole would accept water without exceeding a pre-determined pressure, as indicated by a gauge at the top of the borehole, the crushed material would be added to the water and injected until the borehole became blocked or reached a predetermined pressure. It was necessary to limit the pressure used based on the amount of rock interval between the vein being flushed and the surface. Under pressure conditions, it is possible to force the slurry mixture back to the surface, causing property damage.

FIGURE NO. 10 is a graphical representation on how flushing was conducted. When using the gravity method, the contractor would erect a steel hopper over the borehole to be used for injection. Dry, screened material would be deposited into the hopper from dump trucks. A stream of water would be directed into the material, in effect washing (flushing) it down the borehole, by gravity, until the borehole becomes plugged and will not accept any more material. This process is repeated for each borehole. The gravity method is used where there is little or no rock cover and there is a concern that any pressure used to inject the material could create a problem at the surface. This method is very dependent on how open the void space is underground and how easily the material can travel underground. Boreholes must be spaced relatively closely together in order for this method to be effective.

When the rock cover is deemed sufficient, pressure may be utilized to force the material to spread further in the underground mine voids. In this method, a centralized hopper is used to accept the prepared material. A constant stream of water is introduced into the hopper to produce a slurry that is then pumped under pressure through a steel pipeline to the borehole being flushed. The pipeline is welded to the casing pipe previously installed in the borehole during the drilling process.

A pressure gauge is installed on the pipe at the top of the borehole to monitor the amount of pressure at the injection site. Under ideal conditions, the gauge may register a negative pressure, or vacuum, because the slurry is able to move quickly down the borehole and into the void spaces unimpeded. When the slurry mixture reaches the mine void, the heavier particles begin dropping out and depositing on the floor of the void. The water continues to transport the finer materials farther from the injection point with particles that drop out becoming finer and finer until only the smallest of particles remaining in suspension. As the void space fills in the vicinity of the injection hole, the space between the material and the roof of the opening gets smaller. Thus, for the same volume of slurry to pass through this space, the velocity of the slurry increases, resulting in the flush material being carried further and further from the injection site. With an increase of velocity also comes an increase in pressure as the pump attempts to push the slurry further and further away, until eventually the pressure reaches a point where injection is halted so as to prevent any problems to the equipment or at the surface.

It is possible to estimate the area being filled through an examination of the available mine maps to determine the percentage of coal extraction, the data collected through the drilling process and the amount of material injected through the borehole. Surrounding boreholes can be monitored by sounding them with a weighted tape and thus track the spread of the material. Often, the voids encountered by adjacent boreholes are filled from the injection borehole. Under good conditions, the material transported by the slurry can spread several hundred feet from the injection site.

The process continues from borehole to borehole until no more material can be injected. While this process yields good results, there is no guarantee that 100% of the void spaces have been filled since the extent of the backfilling cannot be physically seen. Material may be prevented from entering areas that have become isolated due to cave-ins blocking the gangways or entrances to chambers. The only methods to ensure complete backfilling of the voids are by "daylighting" the mine workings, which means excavating down to the elevation of the mine workings and then backfilling from that point back to the surface or by "controlled flushing", which requires workers to enter the abandoned underground mine workings and directing the flow of the pumped slurry underground through a piping system to each and every gangway and chamber, thus increasing the efficiency of filling the voids. This type of flushing has not been performed for over 30 years due to the inherent risks to workers and would not be considered as a viable option in this area.

b. Other Flushing Methods

Other methods used to inject material into the underground mine voids have consisted of using a commercial concrete pump that is connected to the top of previously drilled core holes or boreholes to pump material underground. The material varies according to the given situation, but the materials pumped have consisted of commercially available concrete mixes of various compressive strengths, grout mixes made up of water, cement and fine aggregate (sand), concrete or grout mixes containing other additives to control the time it takes for the mixture to set underground, a mixture of water, flyash and fine aggregate and several other variations. Utilizing a concrete pump is generally confined to small areas due to cost issues. It is primarily the method used by OSM for their emergency projects as noted below.

8. *OSM Emergency Projects*

The United States Department of the Interior, Office of Surface Mining has conducted a number of emergency projects in the City of Pittston. These projects tend to be site specific, addressing a particular mine-related problem that has manifested itself on a commercial or residential property. These projects tend to concentrate on mitigating the immediate problem, such as a subsidence in the yard area around a residential structure or sometimes even in the structure itself, and are not meant to be preventative and address entire neighborhoods. **FIGURE NO. 11**, OSM Emergency Projects Location Map depicts the location of the projects performed by OSM in the Pittston area along with a brief description of the work performed. A more detailed report of what each individual project entailed can be obtained by contacting the Office of Surface Mining, Anthracite Branch, at the Stegmaier Building, 7 N. Wilkes-Barre Blvd., Ste. 308, Wilkes-Barre, PA 18702-5293, Telephone 570-830-1400.