SECTION III
Geo-Engineering Aspects

General - The alignment of this project follows the centerline of an existing county road between Stations 42/00 and 85/00, where it starts a curve to the south of east which stops at about Station 93/00, then is on tangent to about Station 275/00 where it curves north to about Station 335/00, then it parallels a township road with the centerline about 50 feet south of an existing road to the end of the project. It parallels K-16 from Station 312/75 to the end of the project. The county road on the west of the project has cuts that expose the Tawanda limestone, Holmesville shale and the upper part of the Fort Riley limestone.

Cut Section from Station 57/00 to Station 58/00

Rockfailure

A cut on the right of the existing road exposes the weathered base of the Tawanda limestone, the Holmesville shale and the uppermost Fort Riley limestone. The lower Holmesville shale and the upper Fort Riley limestone are exposed in the left bank slope.

The mantle of silty clay and limestone fragments should have a backslope of 2:1 or flatter.

The Tawanda limestone on the right has weathered to form numerous vertical and horizontal joints, therefore, a backslope of 1:1 is suggested. The upper Holmesville shale is weathered and should be placed on a slope of 2:1 to prevent undershifting of the Tawanda limestone. The limestone-siltstone base of the Holmesville shale will be satisfactory with a slope of 1:1. The lower shale of this unit where weathered should be 2:1 and unweathered will be satisfactory on a 1:1 slope.

Only the upper part of the Fort Riley limestone will be cut. Backslopes of 1:1 are recommended for the weathered part. Slopes of 2:1 will be satisfactory on the unweathered part.

Recommendation
The Tawanda limestone in this location will be rock excavation.
The Holmsville shale above the siltstone is highly weathered and will be common excavation. The siltstone and thin limestone above and below will be rock excavation except where weathered. The shale below the siltstone will be common excavation. The lower 2 to 3 feet of the Holmsville shale is very lily and will be rock excavation, except near its outcrop where it has weathered to common.

The unweathered upper part of the Fort Riley limestone will be rock excavation. Weathering to a depth of two to three feet can be expected where there is no Holmsville shale overlying the Fort Riley limestone.

Cut Section from Station 51+40 to Station 66+40

Backslope

From two to four feet of the Kawaida limestone and upper part of the Holmsville shale are exposed in the right backslope of the existing road. The slope of the land drops rapidly to the left and only mantle is exposed.

The mantle is very thin and should have a slope of 2:1 or flatter.

The Kawaida limestone is highly jointed and should be on a slope of 1:1 to prevent fallout.

The upper Holmsville shale is weathered and has underlain the Kawaida limestone. A slope of 2:1 is advisable to prevent undermining. Should the siltstone-limestone core be cut, a backslope of 1:1 would be satisfactory.

Excavation

The Kawaida limestone will be rock excavation.

The upper part of the Holmsville shale is weathered and will be common excavation. The limestone-siltstone core will be rock where covered by overlying shale but will be weathered to common to a depth of about two feet if no cover is present, such as at the ends of the cut. About three feet of the shale under the limestone-siltstone, if cut, will be common excavation. The remaining lower portion of the Holmsville shale and the Fort Riley limestone, if encountered, would be rock excavation.

Cut Section from Station 60+40 to Station 69+40

Backslope

Cutting through this hill will encounter a silty clay mantle, weathered Sage
shale, Towanda limestone and possibly the upper Holmeville shale. The mantle of reddish brown silty clay varies in thickness from less than one foot to ten feet. A backslope of 2½:1 or flatter is recommended to prevent surface wash and slumping.

The upper part of the Towanda limestone is shaly and would be satisfactory on a slope of 2½:1. The lower six to eight feet in thicker beds and would be satisfactory with a slope of 1:1.

Cutting into the upper part of the Holmeville shale is anticipated and because of its weathered condition, should have a backslope of 2:1 to protect against undercutting.

Excavation

The Towanda limestone will be rock excavation.

The Holmeville shale cut in the hill will all be loose excavation, providing the grade line stays above the limestone-siltstone zone of this unit.

Hydrology

A test hole 10 feet left of Station 78/60 penetrated the Towanda limestone and into the upper Holmeville shale. Free water was encountered at a 12 feet (127.1) and after standing, the water level was 15 feet (123.1). The water apparently is moving from right to left with the slope of the topography through joints in the Towanda limestone. The only evidence of water movement other than this hole, is the clayey nature of the limestone near the surface. If the grade line approaches an elevation of 1230 feet near Station 78/60, subdrains should be considered.

Cut Section from Station 85/00 to Station 100/00

Backslopes

The Towanda limestone, Holmeville shale and the foot Riley limestone will be cut in this hill. The mantle on the crest of the hill is thin and thickness to about 3 feet at Station 95/00. The mantle consists of silty clay and should be satisfactory on a 2½:1 slope.

The Towanda limestone from Station 85/00 to Station 94/65 will be thin bedded and should have a backslope of 2½:1 or flatter while the lower six feet of the unit will be satisfactory with a slope of 1:1, because this zone is composed of thicker beds.

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The Holmesville shale immediately under the Concordia limestone is highly weathered and to prevent undermining should be piled on a slope of 1:1. The silicate zone of the Holmesville shale will be resistant and a slope of 1:1 should be satisfactory. The shale below the silicate is less resistant to weathering and a slope of 1:2 is recommended. The lower three feet of the Holmesville shale is leg and should be satisfactory on a slope of 1:1.

The upper part of the Fort Riley limestone is cherty and will require a backslope of 1:1 to 1:2. The "riock" zone may be as much as eight feet thick and will stand on a vertical slope. Overburden may be a problem at this location. The natural joints from blocks four to five feet square and may range in thickness from eight-tenths to three feet. The leg shale below the "riock" should have a slope of 1:1 to prevent undermining.

The Chico shale in this location, is fairly fresh and should be satisfactory on a 1:1 slope.

Excavation

The Concordia limestone, where unweathered, will be rock excavation. A few tenths of a foot of clay formed by weathering may be found on top of the unweathered material.

The upper 12 to 13 feet of Holmesville shale will be common excavation. The silicate zone will be rock excavation while the green weathered shale below will be common excavation. The lower three to four feet of this unit will be rock excavation except where weathered near its surface.

The Fort Riley limestone will be rock excavation except for the thin weathered zone in the vicinity of Station 99/40.

The Chico shale will be rock excavation, as are by the grade line, except for the weathered zone of about two feet thick exposed below Station 100/40.

Hydrology

A test hole drilled 50 feet leaf of Station 99/40 unweathered free water at -7 feet when drilled. After standing five hours, the water level rose to -5-1/2 feet. This hole was later deepened and the water level after standing about four hours was at -8 feet, which indicates the Holmesville shale below the table.
stone scars. The water conditions of this cut should be observed when opened
and the decision upon the necessity of an underdrain be made at that time. The
higher water levels are probably a result of heavy rainfall and probably will be
handled by ditch construction.

Cut Section from Station 107+75 to Station 110+75

Backslopes

The Tamaqua limestone, Holmeville shale, Fort Riley limestone, Chico shale,
Florence limestone and Blue Springs shale will be cut through this section. These
strata is mostly silty clay and averages about two feet thick. Where encountered,
backslopes of 2:1 are recommended.

The Tamaqua limestone will be cut from Station 116+60 to about Station
125+00. The lower six to eight feet will be satisfactory with slopes of 1:1
while the upper part should be no steeper than 1:1. A maximum thickness of
four feet will be cut from Station 131+60 to Station 138+75 where the limestone
has weathered into thin blocks. A slope of 1:1 is recommended for this location.

The Holmeville shale cut from Station 116+40 to Station 125+65 will be
classified as before; that is, the upper 12 to 15 feet of weathered shale should
be placed on a slope of 2:1, the siltstone zone on 1:1, the shale below on 2:1
and the clay shale at the base on a slope of 1:1. The Holmeville shale cut
from Station 135+75 to 125+75 will find the upper shale thinned to 10 to 15
feet and weathered so a slope of 2:1 is suggested. The siltstone zone and under-
lying unweathered shale will be satisfactory on a slope of 1:1.

The Fort Riley limestone should be placed on three different angles of
slope. That part above the "rimrock", if present, will stand on slopes of 1:1.
This zone is weathered near its outcrop so should be on a slope of 1:1. The
"rimrock" zone will stand vertically but oversteepening should be anticipated. This
zone ranges from two to seven feet on weathered surfaces but in fresh cuts
probably averages about seven feet. The zone below the "rimrock" weathered shale
so should be placed on a slope of 1:1 to prevent undermining of the "rimrock".

The Chico shale is weathered to a depth of two feet in the vicinity of
Station 125+60 to Station 133+00 and near Station 141+00. These weathered areas
should have back slopes of 1:1 and where weathered, 1:2 should be satisfactory.

The Florence limestones will be unexcavated where cut between Station 130/60 and Station 140/60 and an overall slope of 1:1 is recommended.

The Elms Springs shale may possibly be cut in the vicinity of Station 110/60. A slope of 1:1 is recommended for this unit.

The cut section from Station 133/60 to Station 138/60 may be as much as 30 or 50 feet. Bold construction to use an embankment area should be considered in this location if steeper slopes than those that are suggested are used.

Excavation

The Tresenda limestones from Station 116/60 to Station 122/60 will be rock excavation. A maximum thickness of about 3 feet is expected in the vicinity of Station 120/60. Only four feet of this formation remains coping the hill from Station 137/60 to Station 138/60.

The Holmeville shale from Station 116/60 to Station 125/60 will be classed as follows: The upper 12 to 14 feet and weathered zone of the silstones will be common excavation, the silstones zone of two and one-half to three feet will be rock excavation, about three feet of shale below the silstones will be common excavation and the lower one and one-half to two feet will be rock excavation, except near its outcrop where it has weathered to common excavation. From Station 136/50 to Station 139/50 the shale in the upper Holmeville shale is about 16 feet thick and will all be common excavation. The silstones zone is about two feet thick and will be rock except for the very outer part of the zone that has weathered to common excavation. The shale below the silstones that will be common excavation is about two and one-half feet thick and the lower portion of this unit will be rock excavation.

The Fort Riley limestones will be rock excavation except where it is not overlain by the Holmeville shale where weathering to a depth of three to four feet has formed a ten clay that will be common excavation. Overburden should be anticipated in the Fort Riley limestones because of the large blocks of the "wastrock" formed by jointing.
The Overo shale is exposed only between Station 131/80 and Station 133/80 and on the west face of the large hill near Station 145/00 where weathering has progressed to a depth of one to two feet and excavation will be common. All other Overo shale cut will be rock excavation.

The Florence limestone will all be rock excavation. The face of the hill from Station 141/00 to 141/75 will be covered with one to two feet of mantle consisting of clay and limestone-chert fragments.

Any Elmo Springs shale cut will be rock excavation except on the face of the hill where it has weathered to a depth of 7 to 8 feet.

Hydrology

The only free water found in this cut section during the field investigation appeared to be coming from the joints of the Tormanda limestone and in the siltstone zone of the Holmesville shale. Should the grade line cut the base of the Tormanda limestone or the limestone-siltstone zone of the Holmesville shale, subdrains should be considered.

On Sections from Station 136/50 to Station 206/80

The Fort Riley limestone, Overo shale, Florence limestone, Elmo Springs shale, Kimsey limestone, Wymore shale and Schroer limestone will be encountered through this location. The mantle overlying these bedrock units is very thin and consists of silty clay with limestone and chert fragments with one exception. This exception is between Station 206/00 and 209/30 where a mini-blown silty clay that varies from 3.0 feet to 9.0 feet overlies the Florence limestone.

Backspans

A slope of 2:1 or flatter is suggested for the mantle.

The lower portion of the Fort Riley limestone will be encountered between Station 219/50 and Station 225/00. The small amount of shaly limestone that overlies the "rimrock" of the Fort Riley should be placed on a 1:1 or flatter slope. The "rimrock" is vertically jointed and will tend to be excavated in large blocks leaving a vertical slope. It has slumped down over the lower shaly limestone zone of this member along its outcropping edge. It has also settled down in place between Station 222/40 and 225/00. Some overbreakings can be expected from this
none and care should be taken to remove any loose blocks from the backslope. A 1:1 slope is suggested for the shaly limestone that underlies the "rimrock".

The Ozark shale is a very limy recipient member. A slope of 1:1 or flatter for common excavation and 1:2 or flatter for rock excavation will stand satisfactorily.

An overall slope of 1:1 will stand satisfactorily for the cherty Florence limestone member.

A slope of 1:1 or flatter for rock excavation and 1:2 or flatter for common excavation is suggested for the Blue Springs shale. These slopes will protect against spalling and undercutting of the overlying Florence limestone.

A slope of 1:1 is suggested for the limestone zone in the Kimsey member. The shale zone should be placed on a 1:1 or flatter for rock excavation and 1:2 or flatter for common excavation.

A slope of 1:1 or flatter for rock excavation and 1:2 or flatter for common excavation is suggested for the Wynne shale.

The upper limestone zone of the Schuyler limestone will tend to stand on a vertical slope. The underlying shale zone, No. 51 in the generalized section, should be placed on a slope of 1:1 or flatter for rock excavation and 1:2 or flatter for common excavation to protect against undercutting. The remaining zones of the Schuyler limestone will stand satisfactorily on a 1:1 slope.

Excavation

The lower portion of the Fort Riley limestone is rock excavation except for the shaly limestone that overlies the "rimrock". This zone has weathered to common excavation to a depth of approximately one foot.

The Ozark shale is rock excavation except where it is weathered. It has weathered to a depth of approximately one foot along its outer edges.

The Florence limestone is rock excavation.

The Blue Springs shale is rock excavation except where it is weathered. Its depth of weathering varies from 3.0 to 10.0 feet.

The limestone zones of the Kimsey limestone member are rock excavation. The shale zone is rock excavation where it is not weathered. Its weathering depth
The Wynaar shale is rock excavation where it is not weathered. The weathering depth will be about 7 feet.

The Schuyer limestone member is rock excavation with the exception of its upper shale zone which has weathered to common excavation unless it is overlain by the complete upper limestone zone of the Schuyer and 1 foot of the Wynaar shale.

*Hydrology*

There are four zones through this location that are known ground water carriers, throughout the State. They are the base of the Florence limestone, a maroon limestone zone in the Blue Springs shale and the upper and lower limestone zones of the Kinney limestone member. There were positive indications that any of these zones were carrying ground water at this particular location; however, it is possible that one or all of these zones are carrying ground water back in the hill where they will be cut by the grade line. It is suggested that they be checked after excavation to determine if subsurface water would be desirable.

*Seep Location*

At Station 216'/73, 42 feet left, there is ground water seeping out of the limestone fragments along the mantle-bedrock contact in a valley. It is thought that this water movement originates from the base of the Florence limestone.

*Cut Section From Station 226'/50 to Station 241'/92*

The Topeka limestone, Holmeville shale, Fort Riley limestone, Chote shale and possibly a small amount of Florence limestone will be encountered in this cut. The bedrock is overlain by a very thin mantle covering.

*Bedrock Slope*

A slope of 2:1 or flatter is suggested for the mantle.

The Topeka limestone capping the hill and has a well-developed joint pattern.

A slope of 4:1 or flatter is suggested for this limestone.

The complete Holmeville shale has weathered to common excavation here. It has quite a lot of ground water moving through it. A slope of 2:1 is suggested for the Holmeville shale.

A slope of 4:1 for rock excavation and 1:1 or flatter for common excavation.
is suggested for the shaly limestone zone of the Fort Riley limestone member. The "rimrock" contains vertical joints and will tend to stand on a vertical slope. Some overwearing can be expected in the "rimrock".

A slope of $\frac{1}{2}:1$ is suggested for the Cenozoic shale member.

A slope of $\frac{1}{4}:1$ is suggested for the Florence limestone.

**Holmesville**

The Towanda limestone is rock excavation except where it is badly weathered. There are a few locations over the top of this hill where excessive weathering has taken place. The depth of weathering varies from a few tenths of a foot to an average of nearly 3 feet at Station 239/00.

The entire Holmesville shale has weathered to common excavation in this hill. This excessive weathering is caused by ground water movement.

The Fort Riley limestone is rock excavation except where badly weathered. The upper shaly limestone zone of this member has weathered to common excavation to a depth of from 3 to 4 feet along its outer edges.

The Cenozoic shale is rock excavation except where weathered. It has weathered to a depth of approximately 1 foot along its outer edges.

The Florence limestone is rock excavation.

**Hydrology**

The Towanda limestone has a small amount of ground water moving along its base. This water will probably be cut off by the ditches.

The lower portion of the Holmesville shale, units No. 8, 9, 10, 11 and 12, are weathered and have a fairly high moisture content. There are several water-carrying zones within these units. If the proposed grade line cuts across this portion of the Holmesville, it is probable that subdrainage will be desirable.

Ground water was found moving through and along the top of the Fort Riley limestone in this cut section. It is probable that subdrainage will be desirable for this limestone member depending upon the final grade.

**Spring Location**

At Station 239/00, 50 feet right, there is a seasonal spring location. The ground water is moving out from the base of the Towanda limestone. A large
share of this ground water moves from the gully through the sand and comes out at Station 225/90, 150 feet right, in a step area.

Sedg Location

At Station 231/40, 73 feet left, there is seepage in a gully. This seepage carries on down the gully to the left. There is water standing in pot holes down this gully from which cattle drink. The ground water is coming out of the center portion of the Holmesville shale.

Cut Section from Station 235/00 to Station 277/00

Backslopes

The mantle in this cut will vary from a featheredge to about five feet thick and is largely clay. Backslopes of 2:1 are recommended.

The Tonawa limestone ranges in thickness from 4 to 18 feet in this area.

The upper 10 to 12 feet is shaly and thin beded so should have backslopes of 2:1.

The lower 4 to 6 feet will be satisfactory with slopes of 3:1.

The Holmesville shale that is likely to be cut in this area is weathered shale and a backslope of 2:1 is recommended. The lower Holmesville shale may be cut from Station 272/40 to Station 275/00 where it has weathered and backslopes of 2:1 are recommended.

Excavation

The Tonawa limestone will be rock excavation below the weathered contact.

The Holmesville shale has weathered and will be common excavation.

Hydrology

Seepage 150 feet right of Station 245/00 from the Fort Riley limestone is supplying water to three small pools. The area should be outside the construction limits with the present grade line.

A well equipped with a windmill 250 feet left of Station 269/00 has a top hole altitude about equal to the top of the Fort Riley limestone.

Special Situation - Spring Location

Spring 50 Feet Right of Station 288/57

The spring that is 60 feet right of Station 280/57 may be covered by fill across the creek valley. This spring is the main source of water in this pasture.
spring supplies a small pond (See Figure 1) formed by dumping at the fence line.

The water issues from a joint in the Florence limestone and apparently moves from the southwest as indicated by water levels in test holes in the vicinity.

The landowner is very much concerned and has expressed a desire that this spring be saved.

Cut Section from Station 283/00 to Station 291/00

Backslope

Backslopes on the mantle and weathered Fort Riley limestone should be no steeper than 2:1.

The lower five feet of the "riasock" will stand vertically but the limestone above the "riasock" should have slopes of 1:1. The weathered "riasock" is only about two feet thick, but in fresh cuts will average about five feet. The Fort Riley limestone below the "riasock" is shaly and should have a slope of 1:1 to prevent undercutting.

Excavation

The Fort Riley limestone, except where weathered, will be rock excavation. Overbreakage in the "riasock" should be anticipated. The blocks in this area are not as large as over the rest of the project.

Hydrology

Seepage from the lower Fort Riley limestone was noted during the investigation after a period of prolonged precipitation in the vicinity of 20 feet right of Station 283/00. The right ditch should intercept this seasonal ground water movement.

Cut Section from Station 294/00 to Station 281/00 (End of Project)

Backslope

Mantle of glacial till will be the only material encountered in cutting in this vicinity. The nature of the material suggest backslopes of 1:1 or flatter.

Excavation

All excavation will be common.

Hydrology

The only water encountered in this vicinity appears to be at the contact of the weathered Fort Riley limestone and overlying glacial till. The depth to water is great enough to not be of any consequence.

A well was noted about 400 feet right of Station 300/75 but measuring was impossible. Water is probably being produced from the contact zone of the glacial till with the weathered surface of the Fort Riley limestone in this well. Water encountered and found acceptable to well and stable in place for the well in this area.