ANALYSIS OF THE MANTI CANYON-COTTONWOOD LAND FLOW AND ITS POTENTIAL DOWNSTREAM IMPACTS

September 10, 1975

PREPARED BY THE FIELD INVESTIGATIVE TEAM
AS DIRECTED BY THE EXECUTIVE COMMITTEE

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<u>TEAM MEMBERS</u>

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I. INTRODUCTION

The Manti Canyon-Cottonwood Earth Flow, after remaining in an acquiescent state during the recent past, began accelerated movement in June of 1974. This movement is within Sections 13, 14, 23 and 24, T18S, R3E, SLM. Sanpete County. It is approximately 4,1/2 miles east of Manti City.

The earth flow is relatively large, 1,3/4 miles in length, 3/4 mile wide at the toe, reducing in width to approximately 150 yards at the head. The toe is in excess of 300 feet deep grading to depths of 50 to 100 feet through the main body and head of the slide. The slide has been estimated to contain an excess of 25 million cubic yards of earth material.

The surrounding area has long been relatively active seismically and landslides have been historically common. Earl Olson, U. S. Forest Service Geologist, and Bruce Kaliser, Utah State Geologist, have independently identified over 60 historic landslides in Manti Canyon.

The lower most portion of the toe is a deep channel cut by Manti Canyon creek. Vertical banks from 100 to 120 feet are present on both sides of the stream channel. The channel is naturally very narrow. At the water level it is normally between 10 and 12 feet wide.

At the present time the slide is moving into the streambed, reducing the width and depositing earth material into the stream. This action is occurring at various rates along the entire length of the toe. The west side of the toe is presently moving more rapidly than other areas. Since August 22, there has been lateral movement in excess of 60 feet. The central portions of the slide moved approximately 40 feet between July 28 and September 2, 1975. Slide monitoring indicates the speed of lateral movement is increasing daily.

Manti Canyon creek has an annual low flow of between 20 and 40 cubic feet/second (c.f.s.). During spring snowmelt, the average peak discharge approximates 400 c.f.s. The highest spring runoff load of Manti Canyon creek was recorded at 800 c.f.s. in 1952. There has been flood flows recorded as high as 1000 c.f.s.

On August 28, 1975, the Executive Committee (see Appendix I) composed a "Charter For Field Study Team" (see Appendix II). In this Charter a Field Investigative Team was named and charged with the following basic responsibilities:

(1) Identify and quantify impacts to natural and man-made features that may occur as a result of the slide.

(2) Identify and present feasible alternatives to alleviate such impacts.

(3) Make team recommendations, cost and time frame estimates of the most feasible courses of action to pursue.

The Field Team was composed of Federal, State and local personnel derived from various fields of expertise. These personnel are as shown on the title page of this report.

The Field Team considered immediate (0-6 months), and long-term alternatives. Dynamic properties of the landslide, absolute values, physical possibilities, ie. earth movement, slide lubrication, shear surfaces, hydraulics, sesimic influences, etc. are all unknowns. This makes the feasibility of long-term solutions highly questionable. Because of this lack of data, this team addressed themselves to the immediate alternatives.

II. SITUATION STATEMENT

The Manti Canyon-Cottonwood Earth Flow is moving very rapidly. Much of the shear strength of the slide material is gone and its own mass is the major restraining element. The stream bed at the toe of the slide has been moved north at least 10 feet. There are places the channel has been restricted from a normal 10-12 feet to as little as 3 feet in width. There are three locations on the west end of the toe that are continually dumping earth material into the stream. The stream channel on the west end has been raised over 20 feet since the first of September. It has been raised in excess of 10 feet on the east end since the same date. Some water is being pooled by the raised stream bed. This action indicates slide activity below the stream bed to an unknown depth. The underground activity is also creating a disturbance on the north side of the channel. The north side is the toe of an ancient landslide originating high on the divide between Ephraim and Manti Canyons. The disturbance is evidenced by cracking along the steep north face of the channel. There has been some material from the north face that has entered the stream and much more ready to fall.

Several short-term blockages of the stream have already occurred. Present stream flow and downstream channel conditions have been adequate to remove the blockage material and transport the impounded water. However, there is a high probability that longer duration blockages will occur within the next few days. Temporary high flows may result from instant failures of these blockages. Such releases, added to existing stream flow, transporting excessive quantities of debris could exceed the transportation capability of Manti City's irrigation and flood channel system.

The possibility for a larger, instantaneous failure of the earth flow material is imminent now and increasing daily.

III. POTENTIAL SITUATION

The team considered a large number of combinations of possible occurrences due to movement of the landslide. Specifics of actual phenomena relating to earth movements, water flow, sediment deposition, and related physical parameters were not theoretically approached. Rather, the circumstances created from integrated reactions of these parameters were analyzed in respect to alternative proposals which possibly could minimize damages from downstream flooding. The alternatives and impacts, assuming some type of slide movement, have been displayed in Table 1. Considerations have been given to three stream flow rates and related to 5 locations beginning at the site of the slide and ending atthe flood plain on the outskirts of Manti City. These same alternatives were analyzed and used as a basis for recommendations or remedial action. Information contained in Table I may be supplemented with reaction times and potential flood flows related to various size blockages as shown in appendices III and IV.

The data in Table I is listed under two major categories. The first (I) catagory considered is a fast moving landslide with a a large quantity of material deposited in the channel. The second (II) category is a fast moving landslide with somewhat smaller amount of materials deposited in the stream channel. Under the conditions described for both categories, rates of erosion and failure are variable. They range from impoundment, rapid erosion, and immediate failure; to impoundment, prolonged erosion and delayed failure.

The subheadings are self explanatory. The relationships between the advantages and disadvantages of alternatives and the impacts merits further explanation as follows: Impacts. The impacts considered here are the effects on the physical environment throughout the area of concern resulting from two sizes of slide masses entering the stream. The impacts are considered only if no remedial action is taken.

Table II displays alternatives, their advantages and disadvantages, for actions which could be initiated prior to stream blockage by the slide.

Table 1.

Category I. Fast Moving Landslide with Large Quantities of Materials Deposited in the Channel.

Area of Consideration and Flow Conditions	Impacts	Alternatives: Advantages	Alternatives: Disadvantages
A. Slide Area		Alternative No. 1 - Mechanical Removal of Blockage	
1. Flow less than 50 c.f.s.	1. Immediate blocking of the channel & immediate impoundment of water. See Appendix No. II for reaction times and Appendix No. III for potential flows related to depth of blockage.	1. Heavy equipment is available.	1. Limited access to site.
	2. High debris production.	2. Positive flow control can be maintained.	2. Hazard to operators.
	3. Impoundment of water.	3. Reduction of reservoir impoundment.	3. Reaction time limited.
		4. Moderate expense.	
		Alternate No. 2 - Blasting a channel Through the Slide to Keep Water Flowing.	
		1. Relatively low expense.	1. Chance of causing an additional landslide or accelerate movement of present slide.
		2. Reasonably fast action (Materials can be prestocked.)	2. Trained people may not be available.
		3. Limited people and equipment required.	3. Possibility of additional plugging the channel after blasting.

Table 1. Continued

Area of Consideration and Flow Conditions	Impacts	Alternatives: Advantages	Alternatives: Disadvantages
		Alternate No. 3 - Install a Siphon Across the Channel Plug.	
		1. Provide control of flow.	1. High cost.
		2. Reduction of reservoir impoundment.	2. Long time to install.
			3. Materials availability.
			4. Equipment availability.
			5. May be covered by additional slideing.
			6. Basic logistics will be a problem.
		Alternate No. 4 - Install Bypass Around Slide Area.	
		1. Control of flow.	1. Limited time.
		2. Reduction of impoundment.	2. Will require construction in the north slide and would interfere with existing road and city waterline.
			3. Damage to road could occur.
			4. Damage to pipeline could occur.
			5. May saturate and activate the old north slide.

Table 1. Continued

Area of Consideration and Flow Conditions	Impacts	Alternatives: Advantages	Alternatives: Disadvantages
		Alternative No. 5 - No Action	
		1. No expenditure of funds or manpower.	1. No control of flow. 2. Danger to downstream values.
		Alternative No. 6 - Install Flood Warning System and Initiate Emergency Plans.	
		1. System can be installed quickly. 2. Inexpensive to community. 3. Alerts community to danger.	1. Does not physically protect any structure. 2. Does not control flow. 3. Would still require a field check to determine nature of emergency.
		Alternative No. 1 - Mechanical Removal of Blockage	
2. Flow 50 c.f.s. to 1000 c.f.s.	1. Immediate blocking of the channel & immediate impoundment of water. See Appendix No. II for reaction times and Appendix No. III for potential flows related to depth of blockage. 2. High debris production. 3. Impoundment of water behind plug will be much more rapid and will increase danger and decrease response time.	Advantages and disadvantages are the same as alternate no. I of Section A-1 above, however, the reaction time is reduced so drastically that the alternative is rendered unfeasible.	

Table I. Continued

Area of Consideration and Flow Conditions	Impacts	Alternatives: Advantages	Alternatives: Disadvantages
		<u>Alternative No. 2 - Blasting a Channel Through the Slide to Keep Water Flowing.</u>	
		Advantages and disadvantages are the same as alternate No. 2 of Section A-1, however, the reaction time is reduced considerably.	
		<u>Alternative No. 3 - Install a Siphon Across the Channel Plug.</u>	
		Advantages and disadvantages are the same as alternative No. 3 of Section A-1, however, the reaction time is reduced considerably and it would require larger size or quantity of siphons to handle increased flows.	
		<u>Alternative No. 4 - Install Bypass Around Slide Area.</u>	
		Advantages and disadvantages are the same as alternative No. 4 of Section A-1, however, the reaction time is reduced considerably.	
		<u>Alternative No. 5 - No Action.</u>	
		Advantages and disadvantages are the same as alternative No. 5 of Section A-1.	
		<u>Alternative No. 6 - Install Flood Warning System and Initiate Emergency Plans.</u>	
		1. System can be installed quickly.	1. Does not physically protect any structure.
		2. Inexpensive to the community.	2. Does not control flow.
		3. Alerts community to danger.	3. Would still require a field check to determine nature of emergency.

Table I. Continued

Area of Consideration and Flow Conditions	Impacts	Alternatives: Advantages	Alternatives: Disadvantages
3. Flow above 1000 c.f.s.	1. Immediate blocking of the channel & immediate impoundment of water. See Appendix No. II for reaction times and Appendix No. III for potential flows related to depth of blockage. 2. High debris production. 3. Impoundment of water. 4. Impoundment of water behind plug will be very rapid. Very little response time will be available.	Alternative No. 1 - Mechanical Removal of Blockage Advantages and disadvantages are the same as alternative No. 1 under Section A-1 and 2, however, reaction time is reduced to the point that this alternative is not viable. Alternative No. 2 - Blasting a Channel Through the Slide to Keep Water Flowing. Advantages and disadvantages are the same, reaction time reduced to the point that this alternative is not viable. Alternative No. 3 - Install a Siphon Across the Channel Plug. Not a viable solution because of reduced response time. Alternative No. 4 - Install Bypass Around Slide Area. Not a viable solution because of reduced response time. Alternative No. 5 - No Action. This is the only viable solution under these extreme high flows. Emergency safety measures must be initiated.	

Table 1. Continued.

Area of Consideration and Flow Conditions	Impacts	Alternatives	
		Advantages	Disadvantages
B. Channel			
		Alternative No. 1 - No Action.	
1. Flow less than 50 c.f.s.	1. Some sedimentation.	1. No expense.	1. No change to normal conditions.
	2. Lower peak flows for longer duration.		
	3. Little effect on man-made structures.		
	4. Most mineral debris remaining in slide area.		
		Alternative No. 2 - Clearing and Snagging.	
		Not considered as necessary for passage of low flows. Advantages and disadvantages not discussed.	
2. Flow 50 c.f.s. to 1000 c.f.s.	1. High debris production.	Alternative No. 1 - No Action.	
	2. Possible large surges of flow.	1. No expense.	1. Existing channel capacity is inadequate.
	3. High channel erosion.		
	4. Possible damage to man-made structures.	Alternative No. 2 - Clearing and Snagging.	
	5. Sedimentation of irrigation channels.	1. Improve channel capacity.	1. High cost.
		2. Reduce downstream debris deposition.	2. Time consuming.
	6. Generate sediment and debris which may fill debris basins.	3. Reduce downstream debris damage.	
	7. Possible road damage.		

Table 1. Continued.

Area of Consideration and Flow Conditions	Impacts	Alternatives: Advantages	Alternatives: Disadvantages
3. Flow greater than 1000 c.f.s.	1. Excessive debris production.	Alternative No. 1 - No Action.	
	2. Possible large surges of flow.	1. No expense.	1. Reduced channel capacity because of large amounts of debris and high liklihood for debris damage
	3. Extreme channel erosion.		2. High cost downstream during post flow debris removal.
	4. Damage to man-made structures.	Alternative No. 2 - Clearing and Snagging.	
	5. Covering of irrigation channels with sediment.	1. Improve channel capacity.	1. High cost.
	6. Fill debris basins.	2. Reduce downstream debris deposition.	2. Time consuming.
	7. Road damage will occur.	3. Reduce downstream debris damage.	

Table I. Continued

Area of Consideration and Flow Conditions	Impacts	Alternatives	
		Advantages	Disadvantages
C. Debris Basins			
1. Flow less than 50 c.f.s.	1. Some sedimentation.	Alternative No 1. - No Action.	
	2. Little effect on debris basin dams.	1. No expense.	1. None.
		Alternative No. 2 - Clean Out Debris Basin and Remove Vegetation.	
		1. Effective debris control.	1. Expense of cleaning and disposition of material.
		2. Furnish construction fill material	2. Annual maintenance.
			3. Public safety hazard.
2. Flow 50 c.f.s. to 1000 c.f.s.	1. Possible damage to debris basin.	Alternative No. 1 - No Action.	
	2. Sedimentation of irrigation and flood channels.	1. No expense	1. Debris and sediment will continue on through the drainage system.
	3. Possible road damage.		
	4. Debris basin will begin to fill with bedload and settleable suspended material.		2. Greater debris deposition and damage downstream.
	5. Life of debris basin decreased.		3. Will not attenuate peak flows.

Table I. Continued.

Area of Consideration and Flow Conditions	Impacts	Alternatives: Advantages	Alternatives: Disadvantages
		Alternative No. 2 - Clean Out Debris Basin and Remove Vegetation.	
		1. Effective debris control.	1. Expense of cleaning and disposition of material.
		2. Furnish construction fill material.	2. Annual maintenance.
		3. Peak flows will be attenuated.	3. Public safety hazard.
3. Flow greater than 1000 c.f.s.	1. Possible debris basin dam failure.	**Alternative No. 1 - No Action.**	
	2. Possible mud flow from material within debris basin should dam fail.	1. No expense.	1. Spillway may plug easier.
	3. Time of basin filling will be substantially decreased.		2. Debris and sediment will continue on through drainage system.
	4. Possible plugging of spillway with vegetative debris.		3. Will not attenuate peak flows.

Table I. Continued.

Area of Consideration and Flow Conditions	Impacts	Alternatives: Advantages	Alternatives: Disadvantages
		Alternative No. 2 - Clean Out Debris Basin and Remove Vegetation.	
		1. Effective debris control.	1. Expense of cleaning.
		2. Furnish construction fill material.	2. Annual maintenance.
		3. Flood flow will be attenuated.	3. Public safety hazard.
			4. Possible dam failure.
			5. Inadequate for flows 1000 c.f.s. or greater.

Table I. Continued.

Area of Consideration and Flow Conditions	Impacts	Alternatives	
		Advantages	Disadvantages
D. Channel Below Debris Basin to and Including Diversion Structure		**Alternative No. 1 - No Action**	
1. Flow less than 50 c.f.s.	1. Some debris catch. 2. Some sedimentation. 3. Low effect on structure. 4. Flow can be handled without danger or damage.	1. No expense or effort.	1. Inefficient operation of the water distribution system
		Alternative No. 2 - Upgrade Diversion Structure and Clean Channel.	
		1. Increase efficiency of water control throughout the downstream system. 2. Moderate expense.	1. Some expense.

Table 1. Continued.

Area of Consideration and Flow Conditions	Impacts	Alternatives: Advantages	Alternatives: Disadvantages
2. Flow 50 c.f.s. to 1000 c.f.s.	1. Moderate debris catch.	Alternative No. 1 - No Action.	
	2. Moderate sedimentation.	1. No expense or effort.	1. Inefficient operation of system.
	3. Moderate channel erosion.		2. Increased chance of damage to structures.
	4. Possible damage to diversion structures and lower power house.		3. Loss of control for water regulation.
	5. Chance of overtopping banks and flooding.		4. Danger to operator.
		Alternative No. 2 - Upgrade Diversion Structure and Clean Channel.	
		1. Increased efficiency of system.	1. Some expense involved.
		2. Relieve chance of damage to channel and structure.	2. Structure will still be somewhat inefficient and not completely adequate under high flow conditions.
		3. Relieve danger to operator.	
		4. Moderate expense.	

Table 1. Continued.

Area of Consideration and Flow Conditions	Impacts	Alternatives: Advantages	Alternatives: Disadvantages
		Alternative No. 3 - Replace Diversion Structure and Clean Channel.	
		1. Provide positive control of water. 2. Increased efficiency of system. 3. Relieve chance of damage to channel and structure.	1. Complete engineering analysis and design of entire system should be completed to include high flow requirements. 2. Local reaction concerning use of land, water rights, etc. may arise. 3. Higher costs.
3. Flow above 1000 c.f.s.	1. Heavy debris catch. 2. Heavy sedimentation. 3. Extreme channel erosion. 4. Probable damage to structures. 5. Definite flooding and overtopping of channel and structure. 6. Danger to human and animal life.	Alternative No. 1 - No Action. 1. No monetary expense or effort.	1. Inefficient operation of system. 2. Damage to structure. 3. Danger to human and animal life. 4. Danger to operator. 5. Some expense for damages incurred.

Table 1. Continued.

Area of Consideration and Flow Conditions	Impacts	Alternatives: Advantages	Alternatives: Disadvantages
		Alternative No. 2 - Upgrade Diversion Structure and Clean Channel.	
		1. Increase efficiency of system.	1. Moderate expense for materials and labor.
		2. Provide additional protection for operator.	2. Structure and channel will still be inadequate to handle this much flow.
		3. Provide additional protection to structure.	
		Alternative No. 3 - Replace Diversion Structure and Clean Channel.	
		1. Provide positive control of water.	1. Complete engineering analysis and design of entire system should be completed to include high flow requirements.
		2. Increased efficiency of system.	2. Local reaction concerning use of land, water rights, etc. may arise
		3. Relieve chance of damage to channel and structure.	3. Higher costs

Table 1. Continued.

Area of Consideration and Flow Conditions	Impacts	Alternatives: Advantages	Alternatives: Disadvantages
E. Area Below Diversion Structure. (Manti City and Adjacent Flood Plain)			
1. Flow less than 50 c.f.s.	1. Small amounts of debris. 2. Small quantity of water. 3. Some siltation. 4. Normal operation. 5. No danger to structures or life.	Alternative No. 1 - No Action. 1. No expense or effort.	 1. Continued degradation of water distribution and irrigation systems
		Alternative No. 2 - Clean and Repair Existing System. 1. Improved efficiency of system.	 1. Some expense involved.
2. Flow 50 c.f.s. to 1000 c.f.s.	1. Moderate amounts of debris. 2. Moderate amounts of water. 3. Moderate siltation and sedimentation. 4. Some damage to bridges and structures. 5. Flooding in low areas along water channels.	Alternative No. 1 - No Action. 1. No initial expense or effort.	 1. Continual degradation of the system. 2. Danger of damage to structures will continue to be present. 3. Serious flooding in low areas along water channels. 4. Expense for damages incurred.

Table 1. Continued.

Area of Consideration and Flow Conditions	Impacts	Alternatives	
		Advantages	**Disadvantages**
		Alternative No. 2 - Clean and Repair Existing System	
		1. Improved efficiency of system.	1. Some cost and effort required.
		2. Prevent flooding along channels.	2. Continual maintenance required.
		3. Capability exists for the City distribution system to handle this flow if existing channels are cleaned and repaired.	
3. Flow above 1000 c.f.s.	1. Heavy amounts of debris.	**Alternative No. 1 - No Action.**	
	2. Heavy sedimentation of channels.	1. No initial expense.	1. Excessive degradation of the system.
	3. Sedimentation and rocks deposition outside of channels.		2. Extreme danger of damage to bridges and structures will continue to be present.
	4. Excessive damage to bridges and structures.		3. No protection against and serious flooding throughout flood plain.
	5. Widespread flooding throughout flood plain.		4. Danger to life and property will remain present.
	6. Danger to human and animal life especially near the mouth of the canyon.		

Table 1. Continued.

Area of Consideration and Flow Conditions	Impacts	Alternatives: Advantages	Alternatives: Disadvantages
		Alternative No. 2 - Clean and Repair Existing System and Update Emergency Prepardness Plan.	
		1. Reduce the amount of flooding.	1. Some expense and effort required.
		2. Reduce the dangers to life and property.	

Table 1. Continued

Category II. Fast Moving Landslide with Small Quantities of Materials Deposited in the Stream Channel.

Area of Consideration and Flow Conditions	Impacts	Alternatives	
		Advantages	Disadvantages
A. Slide Area			
1. Flow less than 50 c.f.s.	1. Moderate damming. (Less than 5 minute blockages.) 2. Amounts of slide material distributed throughout the system. 3. Natural channel erosion occurring.	Flows of 50 c.f.s. and less will not impound enough water during the short term small size blockages to cause any flood hazard concern. Therefore no alternatives were evaluated.	
2. Flow 50 c.f.s. to 1000 c.f.s.	1. High quantities of slide material distributed throughout the drainage system. 2. No damming. 3. Moderate increases in channel erosion rates.	Damming will not be a concern. Only small blockages will occur. Flows in excess of 50 c.f.s. will remove the material. Therefore, alternatives were not evaluated.	
3. Flow greater than 1000 c.f.s.	1. Excessive distribution of slide material throughout the system. 2. Accelerated channel scour.	The alternate proposed was to install a flash flood alarm system immediately downstream and initiate emergency plans for the community of Manti.	
		1. System can be installed quickly. 2. Inexpensive to community. 3. Alerts community to danger.	1. Does not physically protect any structures. 2. Does not control flow. 3. Response time is near one hour.

In looking at the remaining physical components of the area, i.e. channel, debris basin, diversion structures and Manti City and Flood Plain under the constraints of Category II conditions, it became apparent to the team that the impacts and alternative courses of action were the same as those presented for the Category I conditions. To avoid repetition, the reader can consider the impacts and alternatives presented under Category I the same for the remaining Category II physical components.

Table 2.

Pre-Slide Alternatives

Technique	Advantage	Disadvantage
A. Provide a toe drain and subsurface water course along the existing channel.		
1. Rock Drain (French drain) The base of the drain is three stones high, each stone being of 15 cubic yard minimum size. The next layer is comprised of 5 to 15 cubic yard size rock. The upper 5 feet, 5 cubic yard material graded to 12" maximum size. The structure would be approximately 20 feet high, the full width of creek.	Maintain stream flow and and eliminate impoundment of water.	1. Time excessive. 2. Cost excessive. 3. Unknown if voids will pass 400 c.f.s. flow. 4. Shear on east flank could close structure. 5. Sedimentation of megavoids would stop the flow. 6. No bottom preparation possible therefore setteling likely.
2. Tetrapoids A tetrapoid is a concrete structure designed to reduce erosion yet allow the flow of water around it. A layer of graded rock varying from 10 cu. yd. in size to 12" in diameter would provide a filter over the tetrapoids.	Maintain stream flow and eliminate impoundment of water.	1. Tetrapoids available in California only. 2. Transport to site at very high cost. 3. Time of construction excessive. 4. Unknown if voids would fill and flow cease. 5. Rotational flow may raise structure above effective level.

Table 2. Continued.

Technique	Advantage	Disadvantage
B. Divert water out of Manti drainage above the slide by tunneling through the mountains, either north or south to an adjacent drainage.	Transfer waters to non-peopled site.	1. Extreme cost. 2. Extremely long time of construction. 3. Reduces quantity of water available below landslide for power generation and irrigation purposes. 4. Increase flow in adjacent drainage and create accelerated erosion conditions.
C. Place reinforced concrete pipe in the bottom of the channel below toe of slide.	Maintain stream flow	1. Doubtful if available pipe would be strong enough to withstand pressure. 2. Stream bed upthrust would offset alignment and break pipe. 3. Hazard to men and equipment during placement.
D. Stop slide movement.		
1. Electrostatic precipitation of moisture. Electrod plates would be placed in the slide to precipitate the moisture. Water would have to be pumped away from the electrode plates.	Stop the landslide.	1. Would require large quantities of electricity. 2. Pumps and collection structures would have to be installed. 3. Yearly operation cost extreme. 4. High initial cost for installation would require drilling multiple wells at very high costs.

Table 2. Continued.

Technique	Advantage	Disadvantage
2. Freezing with liquid nitrogen or refridgerant would require drilling many wells and pumping the material into the slide.	Stop the landslide.	1. Would have to drill many well at high cost. 2. Cost for the amount of refrigerant or nitrogen needed is extreme. 3. Availability of enough liquid nitrogen or refrigerant is questionable.
3. Grout with cement or other material would require the drilling of many holes and pumping grout into the slide.	Stop the landslide.	1. Grouting generally ineffective in unconsolidated masses. 2. High cost of grouting. 3. The large quantity of cement needed may not be available. 4. The number of holes that would have to be drilled would make costs extreme. 5. Grouting would seal in the water and aggrevate the slide.

Table 2. Continued

Technique	Advantage	Disadvantage
E. Maintain landslide mass blockage as a permanent dam.	Would create a recreation facility. Control stream discharge.	1. Inundate existing road. 2. Water in such a reservoir may saturate north slide material and smaller slides to the east and start additional slide movement. 3. Slide materials provide poor foundation conditions for a dam and reservoir. 4. Could not control seepage without high cost. 5. System would be structurally unsound. 6. Would require the design and building of a spillway.
F. Divert the creek from the existing channel to a new course across the north slide. A controlled diversion works will be required for all projects listed below: 1. Tunnel Concrete and steel lined tunnel in north slide material. 2. Pipe Concrete pipe. 3. Open concrete canal.	Maintain stream flow. Control stream flow. Eliminate impoundment of water.	1. High construction cost. 2. Long design and construction time required. 3. Detailed site investigation would be required. 4. Foundation poor. 5. Would interfer with existing roads and city culinary water pipeline.

Table 2. Continued.

Technique	Advantage	Disadvantage
G. Initiate immediate slide closure of Manti creek under low flow conditions to eliminate the supposition of other natural closure possibilities.		
1. Use of explosives.to instantaneously accelerate slide movement. The charges would be set in slide mass in such a manner that upon detonation the toe of the slide would move instantly across the channel of Manti creek.	1. Ability to control slide at our convenience. 2. Removes immediate threat of random closure of Manti creek. 3. Reduces flood threat. 4. Fast action. 5. Moderate cost. 6. Control of channel debris. 7. Control of channel closure to coincide with the low stream flow.	1. May not be a permanent solution. 2. May trigger other slides. 3. May accelerate movement of the remainder of the existing slide. 4. No certainty of success. 5. Storage facilities for explosives are very limited. 6. May produce large bedload with next spring flow.
2. Use heavy construction equipment to close the Manti Creek channel with available materials.		1. Construction operations hazardous to equipment and operators. 2. May produce large bedload with next spring flow. 3. Temporary solution as spring flow may leave same condition as present.

Table 2. Continued.

Technique	Advantage	Disadvantage
H. Deep well injection.		
Dispose of the water in the channel of Manti creek by subsurface disposal of it down specially constructed well.	Removes the stream from the influence of the slide.	1. Would have legal ramifications related to water rights. 2. Would eliminate water for irrigation and power generation. 3. Hydrogeological uncertainties - offer no assurance that subsurface disposal is possible or where the diverted water would again surface.
I. Employment of mobile crane.		
Mobile crane is to be kept in operation to move slide material and debris to keep water flowing in the channel.	The channel would be kept open. The equipment is available.	1. Constant duty required. 2. High cost of equipment rental and operation. 3. Slide may move faster than the equipment could keep it open. 4. Limited area for equipment to work in. 5. Hazardous for night work.

Table 2. Continued.

Technique	Advantage	Disadvantage
J. No Action.	No costs incurred. Slide(s) may erode rapidly enough to create a sufficient channel for natural flows.	1. No assurance of flood control. 2. May affect community psychologically. 3. Requires continuous alert to emergency plan. 4. No plan of action would be available in the event of channel closure.

IV. RECOMMENDATIONS AND ESTIMATED COSTS

The team felt the most immediate action that should be initiated for the security of the City of Manti was the installation of an early warning system. Such a system would allow time for emergency action in the city if an immediate hazard developed. Two devices are recommended, a high water alarm at the USGS gaging station and a low water alarm immediately downstream from the western most toe of the slide. The units which are recommended for installation are the Flash Flood Alarm Systems of the National Weather Service (NWS). The units would be operational two weeks after the NWS received a request for installation. The estimated cost for the operational system would be $8,000.00. Roughly 75 percent of the cost would be borne by the NWS.

Other courses of action recommended by the team are best addressed by speaking to various components of the overall slide threat. The problem area was divided into five physical sections as follows:

A. At the slide itself.

B. The channel from the slide downstream to the debris basins.

C. The debris basins.

D. The diversion structure.

E. Manti City and Flood Plain.

The recommendations pertaining to each physical component are discussed independently in the following text.

AT THE SLIDE

It was determined the most feasible action to be recommended for the slide would be to pre-empt natural flow closure of the channel by forcing an immediate closure. Closure at this point in time would allow manipulation of the stream system under low flow conditions and eliminate the guess work in trying to surmise the type of closure natural sliding would create. Of the alternatives evaluated for channel closure, two viable methods were identified: mechanical equipment and use of explosives.

Mechanical equipment closure was identified as being preferential to explosives in that the placement of fill and channel manipulation would be more controlled. The use of explosives would be a two phase operation. The first phase would be detonations to accelerate movement of the toe into the channel. The second phase would be smaller detonations to open a channel through the fill material. Some mechanical equipment would have to be on hand to insure the channel remained open. The use of explosives, though more expedient and less costly, has undefined ramifications that would place such action in an experimental category. The estimated cost for mechanical equipment closure is $40,000.00, requiring 400 hours for completion. The cost for use of explosives ranges between $7,000 and $12,000. Variables such as type of explosive required, number of charge holes to be drilled and so on account for the range in cost. The time required for blasting closure was estimated to be four days of preparation and immediate closure.

It is recommended that slide monitoring be continued until such time as the existing slide no longer presents a threat to the city of Manti. Monitoring should also be initiated on the old north slide to determine if it is moving. Such a determination would provide direction to formulation of viable long term alternatives. It would also give insight to the potential of further aggrevation of the existing channel from the north. Present monitoring should be coordinated under the control of one agency.

It is recommended that seismic traverses of the existing slide be initiated. Such traverses would provide needed information to improve prediction of slide movement. As the slide movement and potential movement is better understood a clearer picture of viable long term alternatives is possible.

It is recommended that precipitation stations be established at the Cottonwood site and Burnt Hill Flat. Such information would provide hydrologic analysis to forecast runoff and document climatic trends that may cause changes in slide movement. This should be a cooperative effort between the U. S. Forest Service and the National Weather Service. The radar information base of climatic system movements, over Manti which may affect slide movement, should be called into the city of Manti as they are identified. Such warnings would indicate a need for close local surveillance of the slide. This should be coordinated between the NWS and the City of Manti.

It is recommended that the NWS mobile Fire Weather Forecast unit be available in June to provide on-the-spot forecasting. June was determined to be the critical month for summer storms in the slide area. On-the-spot forecasts would provide immediate information of pending hazardous conditions to the City of Manti.

IN CHANNEL

The 4, 1/2 miles of channel between the slide and the City of Manti is a cobble bottom system with unstable banks. Flood plain width varies from 40 feet in restrictions to several hundred feet in the lower areas. The slope ranges from 3 to 10 percent, averaging around 7 percent. The average yearly peaks have historically been around 400 c.f.s. The flood channel has overgrown islands, trees and log jams throughout. It is recommended that channel clearing and snagging operations be conducted from the slide to the debris basins. The resultant channel should have a capacity of 1000 c.f.s. This operation includes the removal of down+dead debris, live vegetation, trees and unnecessary or abandoned channel improvements. Key structures adjacent to or in the channel and road prisms near the channel should be protected. Channel realignment will be required on a limited scale to accomplish the structural protection and limit the amount of live vegetation removal. Cross sectioning of the channel should be initiated to determine the width of clearing needed. The costs have been estimated at $12,000 per mile of channel and requiring about one month to complete.

DEBRIS BASINS

There are two debris basins on the Manti creek system. Both are located on Forest Service land near the mouth of the canyon. The upstream basin is the larger, appearing to have a surface area of approximately 3 acres. The downstream basin appears to be 1/2 acre in size. Both basins are full and overgrown with vegetation. There is approximately 1 acre of vegetation on the lower basin. The dam on the larger, upper basin is a rock masonary structure in good condition. The dam on the lower structure is hand placed rock with no masonary.

It is recommended that both basins be cleared of vegetation and cleaned of rock and sand. The larger dam should be cleared to an average depth of 10 feet. It should be 400 feet long, 300 feet wide at the dam and 200 feet wide at the upstream end, see Appendix V. This configuration will approximate 40,000 cubic yards capacity. No attempt was made to determine design size based on bedload transport as physical limitation presupposes a structure much larger than that mentioned. The smaller lower basin should be cleared to a capacity of 7500 cubic yards. Dimensions will be a function of available area. The bottom material is not substantial enough in either basin to support a catepillar tractor in the center. Cats may be able to work the perimeters but a dragline/cat operation is recommended. The cost for the upper basin approximates $114,000 and 400 hours of time. The cost for the lower basin approximates

$20,500 and 75 hours of time. The road access to the lower basin is presently across the face of the dam creating a depression. This depression will have to be filled to bring the dam to full capacity. The lower powerhouse should be sand bagged 3 bags high. The channel between the two debris basins and below the lower basin to the diversion structure should be cleared and snagged to a 1000 c.f.s. capacity. The cost for the channel clearing approximates $2500.00 and will take 3 days.

DIVERSION STRUCTURE

The channel immediately upstream from the diversion structure has a capacity of 1800 c.f.s. The right bank (looking upstream) is constructed of wood plank and the left bank is a grouted rock wall. Two channels result from the diversion structure, a flood channel which flows northwest through the southwest portion of town and City Creek which flows directly through the center of town. The City Creek control structure needs to be replaced. It is recommended that a new gate, 4 ft. by 12 ft. be installed. The gate should be capable of being raised and lowered by manual operation. The gate installation is estimated to cost $1,200 and requires one week to install once on hand.

MANTI CITY AND FLOOD PLAIN

The two channels through the City approximate cross sectioned areas of 20 to 25 square feet, see Appendix VI. The City Creek channel is lined with grouted rock for approximately 2/3 of its length. The flood channel is rocked only where it goes under main streets. They are high velocity channels. The City Creek channel was flowing in the neighborhood of 8 to 10 feet per second when observed with a 16 c.f.s. flow. Flood velocities may approximate 10 to 15 feet per second. City Creek enters an aqueduct that flows below the business section of town. There are numerous large and small bridge crossings that have the potential to collect debris at high flows.

It is recommended that the channels be cleared of all obstructions and dike identifiable low spots to assure maximum capacity. The channels should be cleared from the diversion structure all the way to the end of the channels, not just through town. Failure to clear the entire length may result in debris and sediment on farm fields. Fences, old tires, boards, over-hanging limbs, sediment and logs are examples of the type of debris needing removal. The physical structures coincidental with the channel systems, i.e., bridges, aqueduct, irrigation ditches, etc. need to be inspected and repaired where necessary to assure stability. Clearing of City Creek for sure and possibly the flood way will have to be done by hand labor. It is recommended that this be accomplished by the City and/or County. No time or cost estimates were made, as public response to the clearing is unknown.

General Recommendation

An Emergency Plan of Action should be developed by the City of Manti through coordination efforts of the County Emergency Services Director. This plan should include actions to be taken when notification of immediate imminent flooding has been received. Personnel to be contacted should be identified and ensuing responsibilities given. Warning actions pertaining to notification of citizens, road closures, transportation, rations and communications should be included.

To realize the greatest benefit from initial flood damage prevention actions, the team felt corrective measures should first be directed at remedying unsatisfactory conditions closest to the City. That is to say, before any action is taken at the slide all downstream measures should be completed, first in town, second at the diversion structure, third at the debris basins, and fourth in the stream channel. Such a sequence of action will buy the most protection for the City over the next six-month period.

All cost estimates are based on the assumption that the work is to be contracted. A rough breakdown of the cost estimates is available at the Sanpete Ranger District.

CONCLUSION

Based on advantages and disadvantages of alternatives considered, filling the stream channel in advance of the slide appears most feasible. Because of the experimental status and unknown affects of explosives, the mechanical method has been recommended. This recommendation is not made as a long-time solution, only as an immediate and short-term measure.

It must be understood that the study team has analyzed impacts and minimizing alternatives for a water flow compatible with Manti City's irrigation and flood channel system. This has been determined to be 1000 c.f.s. Flows in excess of this will threaten life and create property damage. To cope with this situation, the team recommends an emergency plan be developed by the Utah State Office of Emergency Services.

APPENDIX

EXECUTIVE COMMITTEE--MANTI SLIDE PROBLEM

August 28, 1975

	Title, Address, and Telephone
1. Wes Carlson, Chairman	Director, Soil & Water Management U. S. Forest Service 324-25th Street Ogden, Utah 84401 801/399-6561
2. Paul Koenig, Cochairman	Search and Rescue/Disaster Assistance Utah State Office of Emergency Services P. O. Box 8100 Salt Lake City, Utah 84108 801/533-5271
3. Lee J. McQuivey	Engineering Division Representative Utah & Upper Colorado Sacramento District, Corps of Engineers 135 South State, Room 342 Salt Lake City, Utah 84111 801/524-4264
4. John H. Schmidt	Assistant State Conservationist USDA Soil Conservation Service Room 4012, Federal Building Salt Lake City, Utah 84111 801/524-5051
5. Bruce Kaliser	Geologist Utah Geological Survey University of Utah Campus Salt Lake City, Utah 84412 801/581-6831
6. Col. T. Ray Kingston	Military Support Section Utah National Guard P. O. Box 8000 Salt Lake City, Utah 84108 801/533-5474
7. Ned Madsen	San Pete County Commissioner Manti, Utah 801/835-2141 Home--801/835-4612
Advisor on Federal Assistance William H. Traugh	Federal Disaster Assistance Administration Suite 1140, Lincoln Tower 1860 Lincoln Street Denver, Colorado 80203 303/837-2891

MANTI CANYON LAND FLOW

Charter for Field Study Team
Developed by the Executive Committee

August 28, 1975

Because of a major landslide in Manti Canyon, there eixsts a threat to life and property in the area of the slide and for a distance of several miles downstream. Manti City, located at the mouth of the canyon, is in a position to receive the greatest damage.

The City of Manti and Sanpete County, Utah, have very little expertise in the area of flood management or control. Therefore, they have requested assistance to determine the best means of planning for potential disaster and handling flood flows which may occur. Governor Rampton has declared an emergency situation and requested Federal help.

After a field review of the situation on the ground August 27 by a joint State-Federal group, it was decided that two teams were needed:

1. A State-Federal executive committee to assemble information, organize field investigative teams, disseminate information, and coordinate activities related to the Manti problem. This group consists of:

   Wes Carlson, U. S. Forest Service, Cochairman
   Paul Koenig, Utah Office of Emergency Services, Cochairman

   Lee J. McQuivey, Corps of Engineers
   John H. Schmidt, Soil Conservation Service
   Bruce Kaliser, Utah Geological Survey
   Dana Peck, Utah Office of Emergency Services
   Col. T. Ray Kingston, Utah National Guard

   It is agreed that inquiries and news releases should be handled through the cochairmen.

2. A field investigative team composed of appropriate expertise to project potential effects of the slide and develop alternative solutions for handling or correcting the attendant problems. Members of this team are:

Member	Agency	Discipline
Don Garrett	Corps of Engineers	Civil Engineer (Civil Hydraulics, Emergency Planning)
Phil Coombs	Soil Conservation Service	Engineer (Debris Basins, Structures)

Earl Olson	Forest Service	Environmental Geologist
John Riley	Forest Service	Engineer (Ditches, Canals, and Reservoirs)
John Rector	Forest Service	Hydrologist
Bruce Kaliser	Utah Geological Survey	Geologist
Russ Bateman	Utah Office of Emergency Services	Emergency Planner
Paul Koenig (or alternate)	Utah Office of Emergency Services	Emergency Planner

Richard Allred, District Forest Ranger, Ephraim, Utah, will serve as coordinator for the field team. He will handle field logistics, organize the plan of attack for the field investigation, and direct preparation of the team's report. He should request additional expertise through the cochairmen if such a need is identified.

THE PROBLEM

1. Current Situation

As of August 21, 1975, the 1-3/4 mile long Cottonwood Creek land flow slide is on nearly a 1/2-mile front. It is constricting the creek slightly and is moving at a rate of 9 inches a day. The toe of the slide is extremely steep from the historic action of the creek eroding through debris from the previous north and south paleo slides. Slopes into the creek from the slide toe are 70 to 80 percent and from 80 to 100 feet tall.

As the slide moves forward, rocks, soil, and vegetation are falling into the creek. At the present rate of advance, this debris is washed downstream. However, due to the plasticity of the slide and the sandy nature of the slide (similar to the Gros Ventre slide), the slide could either continue to move forward slowly or suddenly release. A sudden release or, eventually, the creep will dam Manti Creek for a time. In a sudden slide situation, it is expected the creek will saturate the flow debris and cause a sudden flush of water and sediment down Manti Creek possibly flooding two-thirds of Manti City. If the blocking debris does not release, water will eventually find a way around the slide and erode a new creek bed.

On August 21, 1975, Manti Creek was flowing 21 cubic feet/second of water and is at or near its low yearly flow, except for increases due to intense summer storms. It is, therefore, imperative that immediate action be taken to handle the present flow of water down Manti Creek, as well as any anticipated high flow which could reach volumes of 800 cubic feet/second or more, to prevent a disastrous flood into Manti City.

2. Slide Location and Geologic Description

The Cottonwood land flow slide is located partly in Sections 10, 11, 14, 15, 23, and 24, Township 18 South, Range 3 East, SLM. It is 1-3/4 miles long and extends from 7,160 feet elevation at its toe to 8,600 feet at the head. The slide toe is 4-3/4 miles from the limits of Manti City.

The Cottonwood Creek land flow slide originates from the north face of a gradually ascending flat ridge between Manti Canyon and Six Mile Canyon. This ridge extends westerly from the southern portion of the Wasatch Plateau. The slide first impacts Cottonwood Creek, a small tributary of Manti Creek and has now enlarged at the toe to encompass Manti Creek.

The slide is made up of rock units from Paleocene age Flagstaff Limestone. These are about 63 million years old. The limestone overlies a thick sequence of shale, mudstone, and sandstone beds called the North Horn Formation. This formation weathers to a silty clay and becomes plastic when moist. The North Horn is the most landslide prone formation in the State of Utah.

This slide has been moving off and on for several hundred years.

The present creek may be closed by the continuation of the slide. This will backup several acre feet of water and break the landslide dam and flood below.

EFFECT

The team is expected to:

1. Identify and quantify the impacts which could be expected from various actions of the slide and weather events (impoundment, flooding, mud-rock flow, etc.).

2. Attempt to define impacts in the canyon area (mostly National Forest) as well as downstream (flood plain below mouth of canyon).

3. Assess anticipated damages to natural features, residences, businesses, streets, roads, pipelines, powerlines, and other improvements.

ALTERNATIVE SOLUTIONS

The team will:

1. Display a list of alternatives, together with their positive and negative values.

2. Identify the relevant factors, including estimated costs, related to each alternative and express an analysis of feasibility for each.

3. Develop and display a joint recommendation for solution. This will include an estimated cost and realistic estimate of time required for accomplishment.

EXISTING INFORMATION

Each agency has background materials and information which can be utilized in the study. A few specific items include:

1. USGS quadrangle contour maps.

2. The Forest Service will have available two sets of aerial photo stereo coverage of the affected area.

3. The Manti-LaSal National Forest has prepared a draft disaster plan and recommendations for the affected area. Four copies will be available.

LOCAL TEAM

A group of local people was recently organized to address the problem of possible disaster resulting from the landslide. Included in the group are Mayor Frank Wanlass, County Commissioner Ned Madsen, and local representatives of State and Federal agencies. Team coordinator Dick Allred, can obtain any information which this group has assembled.

The field team should work through coordinator Allred to maintain close working relations at all times with the local group. The Mayor and Commissioner should be fully informed of progress.

TIME SCHEDULE

1. The field team will assemble at 1 p.m. in the District Forest Ranger's office at Ephraim, Utah, on Wednesday, September 3. A brief orientation session there will be immediately followed by moving into the field investigation.

2. It is anticipated that 2 to 3 days field time will be adequate. This phase should be completed by close of business on Friday, September 5.

3. The field team's report should be in the hands of the executive committee ahead of its next scheduled meeting in Salt Lake City on Friday, September 12.

APPENDIX III

Reaction Time Before Overflow in Hours

Blockage Height	Discharge 10	25	75	100	150	200	250	300	400	500	600	Backed up Ac. Ft.
10 foot	.530	.212	.071	.053	.035	.027	.021	.018	.013	.011	.009	0.44
20 foot	3.000	1.200	0.400	0.300	0.200	0.150	0.120	0.100	0.015	0.060	0.050	2.50
30 foot	8.540	3.420	1.140	0.854	0.570	0.427	0.342	0.285	0.214	0.171	0.142	7.06
40 foot	18.33	7.33	2.44	1.83	1.22	.92	.734	.611	.460	.368	.306	15.15
50 foot	33.53	13.41	4.71	3.36	2.24	1.68	1.34	1.121	0.841	0.673	0.560	27.71
60 foot	55.32	22.13	7.376	5.534	3.684	2.767	2.214	1.845	1.384	1.107	0.923	45.72
70 foot	84.84	33.94	11.31	8.49	5.65	4.24	3.39	2.83	2.123	1.698	1.415	70.12
80 foot	123	49	16.44	12.33	8.22	6.17	4.93	4.11	3.09	2.468	2.057	101.91

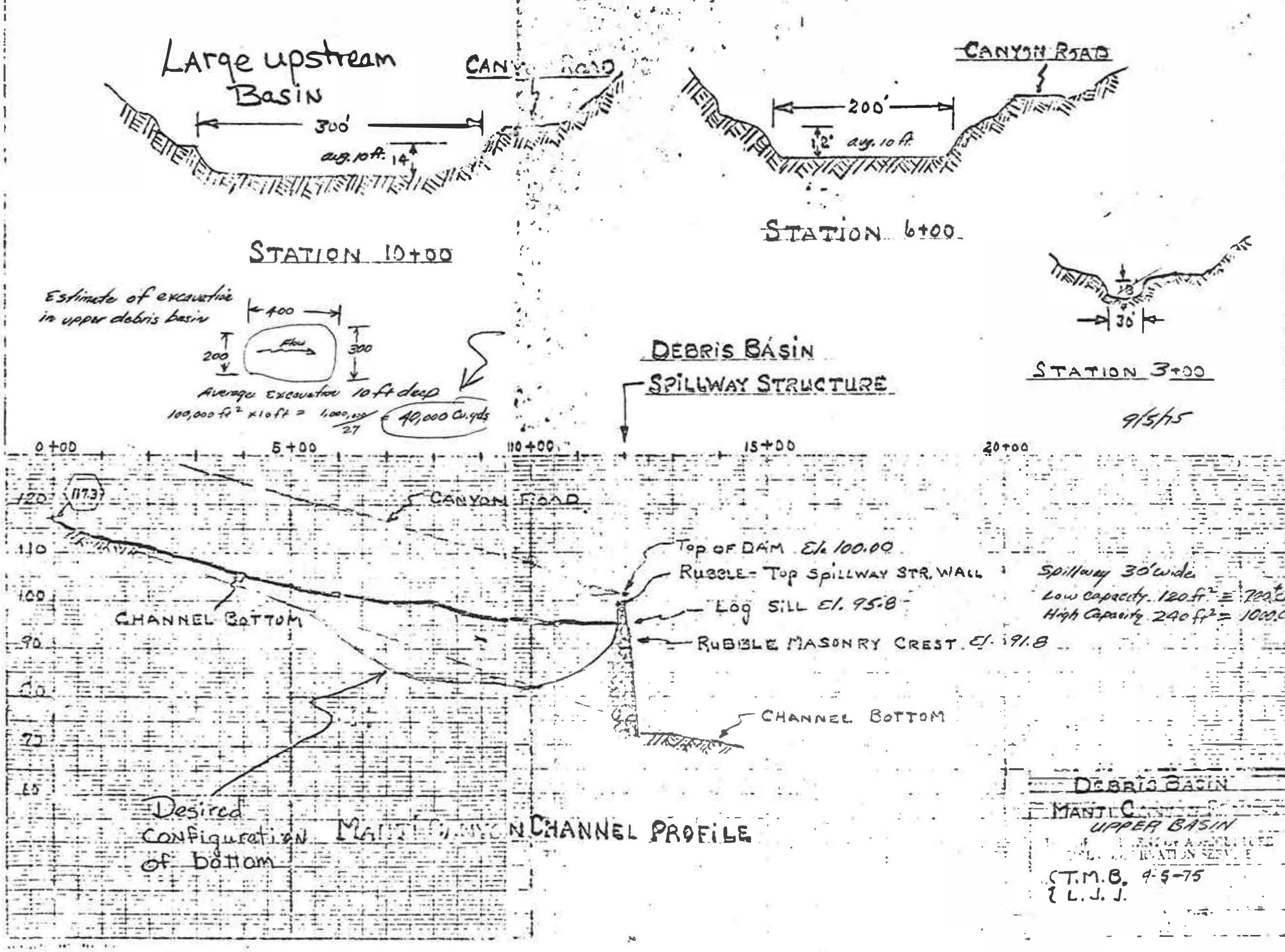
APPENDIX IV

Channel Blockage Height and Estimated Discharge Data for Various Times of Failure of Blockage

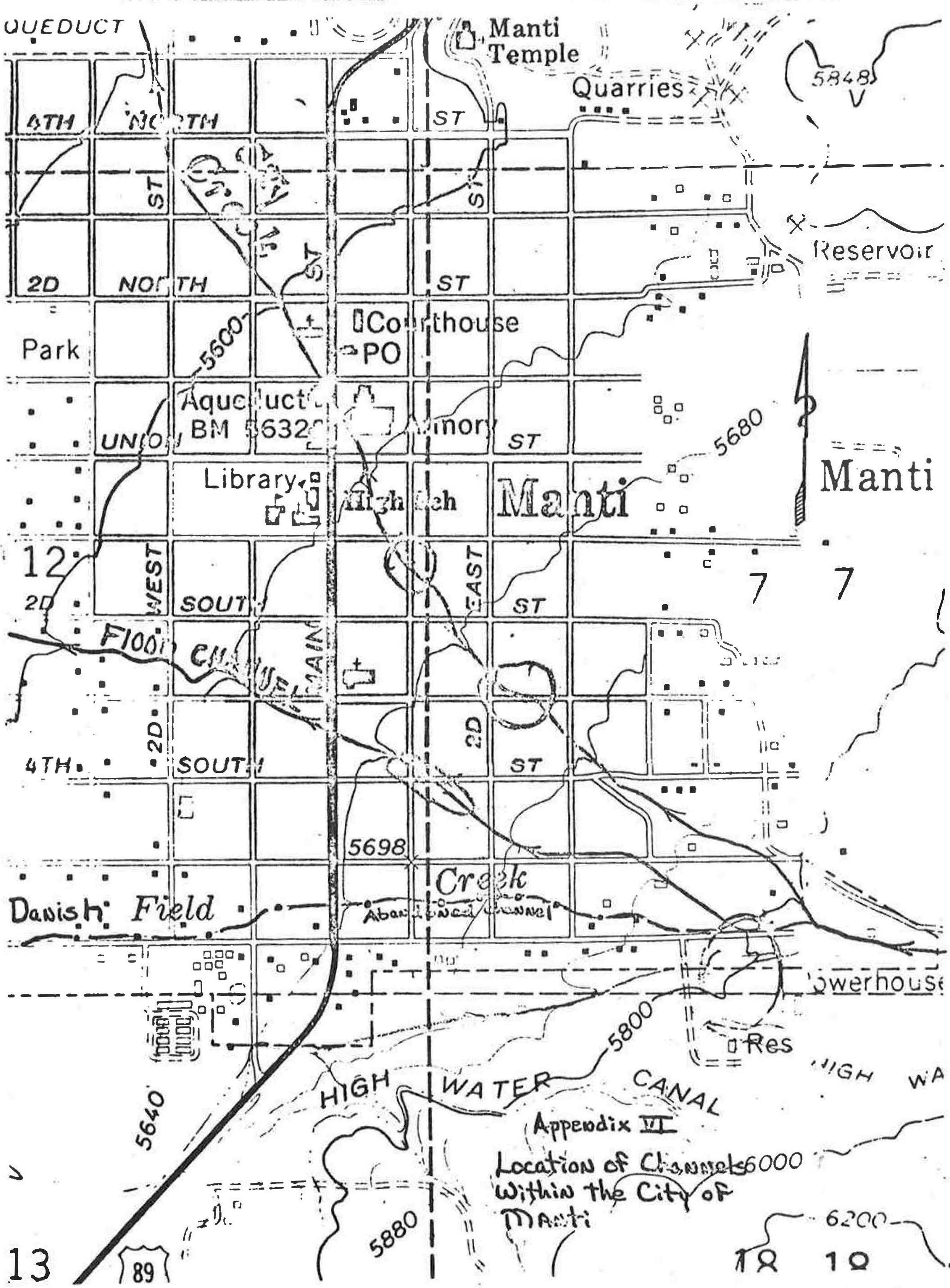
Blockage in Feet Height	Volume of Water Backing Up in Acre Feet	Peak Discharge			
		1 Hour Failure CFS	30 Minute Failure CFS	*5 Minute Failure CFS	*1 Minute Failure CFS
10	0.44	5	30	66	330
20	2.50	31	63	375	1,875
30	7.06	88	176	1,059	5,295
40	15.15	189	378	2,272	11,362
50	27.71	346	693	4,156	20,782
60	45.72	571	1,143	6,858	34,290
70	70.12	876	1,753	10,518	52,590
80	101.91	1,276	2,548	15,282	76,432

*Due to presence of large volumes of rock in slide and channel areas, a 5-minute or 1-minute failure of the slide blockage and complete drainage of backed-up water in these periods of time is quite improbable.

APPENDIX V



Large upstream Basin
300'
avg. 10 ft.
14
STATION 10+00
200'
avg. 10 ft
1.2'
CANYON ROAD
STATION 6+00
18
30'
STATION 3+00
9/5/75
Estimate of excavation in upper debris basin
400
200
300
Flow
Average excavation 10 ft deep
100,000 ft² x 10 ft = 1,000,000/27 = 40,000 Cu. yds
DEBRIS BASIN
SPILLWAY STRUCTURE
0+00
5+00
10+00
15+00
20+00
120
110
100
90
117.3
CANYON ROAD
CHANNEL BOTTOM
Top of DAM El. 100.00
RUBBLE - Top Spillway STR. WALL
Log SILL El. 95.8
RUBBLE MASONRY CREST El. 91.8
CHANNEL BOTTOM
Spillway 30' wide
Low capacity 120 ft² = 720± cfs
High Capacity 240 ft² = 1000 cfs
Desired Configuration of bottom
CHANNEL PROFILE
DEBRIS BASIN
UPPER BASIN
T.M.B. 9-5-75
L.J.J.



QUEDUCT
Manti Temple
Quarries
5848
Reservoir
4TH NORTH ST
2D NORTH ST
Park
Courthouse
PO
5600
Aqueduct
BM 5632
Armory
UNION ST
Library
High Sch
Manti
5680
12
7 7
WEST ST
EAST ST
MAIN ST
2D SOUTH ST
Flood Channel
4TH SOUTH ST
2D ST
5698
Creek
Danish Field
Abandoned Channel
Powerhouse
Res
5800
HIGH WATER CANAL
5640
5880
6000
6200
13
89
18
Appendix VI
Location of Channels Within the City of Manti