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PRELIMINARY

SALT LAKE COUNTY DIVISION OF
WATER QUALITY AND WATER POLLUTION CONTROL

POLLUTION MITIGATION IN EMIGRATION CANYON

by

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ABSTRACT

A study of water pollution in Emigration Creek, Utah was undertaken to better understand the causes of the pollution and the possible mitigation measures. At the present time, Emigration Creek is suffering from bacterial, organic matter, suspended solids and nutrient (nitrates and phosphates) pollution. A computer simulation model was used to relate pollution generation, pollution transport and pollution survival to stream conditions.

Under the contract the canyon was divided into sixteen sections and the modelled coliform bacteria concentrations were calibrated against three (April 78, June 78, Aug. 80) observed coliform concentration profiles. Results from the simulation model showed about 87% of the stream coliform pollution load to be generated by people and domestic animals with about 5% coming from underground disposal systems. Total suspended solids were found to originate mainly from dirt roads, trails and construction sites.

The most effective mitigation measures were found to be domestic animal control and the provision of a buffer zone along the stream. It is recommended that a creek cleanup be performed and that a streamwater use regulation system be established along with better controls on off-road vehicle use and construction practices. A general citizen and landowner awareness and participation program on water pollution prevention is also suggested for Emigration Canyon.

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INTRODUCTION

Background:

Emigration Canyon's proximity to Salt Lake Valley and its natural and rural appearance make it a target for development pressures. It is therefore, not suprising that a controversy has developed over a proposed annexation of Emigration Canyon (or part of it) to Salt Lake City and the possible extension of municipal services.

Lack of culinary water, adequate fire protection, storm-water provisions, and a sewer are existing constraints on developments in Emigration Canyon. High costs and environmental consideration are the main reasons why such facilities have not yet been constructed.

Emigration Creek is one of two major Wasatch streams whose water is not presently used for culinary purposes by Salt Lake City (Mill Creek is the other). Due to pollution by people, animals, septic tanks, holding tanks, etc. in the Canyon, the streamwater and some of the well waters are presently not suitable as culinary water. In 1978, the Utah Water Pollution Committee specifically designated Emigration Creek, from Hogle Zoo to its headwater, as a class 3A stream to which its anti-degradation policy pertains. Salt Lake County has recommended that the stream be classified as Class 2B (protected for in-stream recreational use and aesthetics).

Specific concerns exist today regarding the possible drying up of Emigration Creek due to the interception of inflows and diversion of streamflows as well as possible further degradation of stream quality (specifically bacterial and suspended solids concentrations). The present streamflow at the mouth of the Canyon is typically only 1-2 cu. ft. per sec. in the early fall with a total coliform concentration of about 3400 MF/100 ml.

The existing appearance of Emigration Creek is quite varied. The upper reaches of the Creek are relatively rocky and undisturbed (except through water pollution causes and effects in Emigration Canyon. Specifically the investigation will define present non-point pollution source impacts of coliform bacteria and suspended solids and project potential developmental-related non-point pollution source impacts. This includes the proposal of an implementation strategy which insures, to the greatest extent possible, the restoration of pristine water quality conditions in Emigration Creek.

The scope and work plan of the study encompasses:

1. Incorporate 1978/1979 NPS inventory into overall assessment.
2. Devise an enforcement and implementation strategy to address existing NPS problems.
3. Calibrate University of Utah simulation model factors based on Emigration Canyon data compilation, utilizing assistance from the Division of Water Quality.
4. Model the effects of alternative types and levels of development within the Canyon.
5. Evaluate most effective controls of performance standards for mitigation of these impacts.
6. Devise implementation strategy for application of performance standards.

PAST AND EXISTING CANYON CONDITIONS

Physical Canyon Data:

Emigration Canyon is a relatively steep-walled canyon running approximately north-east to south-west and terminating on the north-east side of Salt Lake City. Consolidated crystalline rocks, shales, sandstones, limestones and volcanic rocks (Precambrian to Tertiary age) of low porosity make up the Canyon with sand and silty alluvial soils along the streams. Hydraulic conductivity (a measure of water transmissivity) of channel fill near the mouth of Emigration Canyon has been estimated to be 17 ft. per day (Utah Dept. of Natural Resources, 1971). Vegetation consists of cottonwoods and willows in stream bottoms, grasses and scrub oaks on hillsides and aspens at higher elevations.

The drainage area of Emigration Creek is about 18 sq. miles with elevations ranging from 4900 to 8950 feet. Stream length is about 10 miles with an average stream slope of approximately 0.044. Average annual precipitation is about 29 inches ranging from 20 inches near the Canyon mouth to 40 inches at the higher elevations (Utah Dept. of Nat. Resources, 1971). The largest 24-hour precipitation recorded at Mountain Dell Reservoir (adjacent drainage area, elevation 5420 feet) in 58 years of record keeping was 2.42 inches in September 1927 (U.S. Weather Bureau).

Streamflow at the mouth of the Canyon varies from next to nothing during very dry periods to a snowmelt flood of 156 cu. ft. per sec. measured on 26 April 1952. Average annual streamflow at the Canyon mouth is 6.3 cu. ft. per sec. (1930-75 record). The estimated 100-year flood based on frequency analysis of past floods is about 150 cu. ft. per sec. (Rollins, Brown and Gunnel, 1979). Records indicate that snowmelt floods are larger than cloudburst floods for drainage areas such as Emigration Canyon. Stauffer (1979) has estimated that a cloudburst flood as high as 160 cu. ft. per sec. may result from less than one square mile of future urbanized areas in Emigration Canyon.

A comparison of streamflow records from the Burr Fork gaging station (near the S-curve in the road at the foot of Little Mtn.) with a 5.9 sq. mile drainage area and the Hogle Zoo gaging station with an 18 sq. mile drainage area shows the upper part of Emigration Canyon to yield proportionally the largest flow of water. Records indicate that the lower gaging station on the average yields only about 60% higher flood flows than the Burr Fork gaging station. This phenomenon may be partly due to man-made diversions of water but during times of flood is most likely caused by non-uniform precipitation patterns, non-uniform snowmelt conditions and/or increased infiltration of water into groundwater aquifers in the lower part of the Canyon.

Traffic in Emigration Canyon has been increasing steadily at about a 3% rate per year. The average annual daily traffic (AADT) in 1979 was 2200 vehicles at the Canyon mouth. The AADT count on the road to Pinecrest (Burr FK.) was 860 in 1979. A questionnaire and door-to-door survey in the fall of 1980 yielded estimates of 263 houses, 674 residents, 508 automobiles, 127 dogs, 86 cats, 5 horses, 111 chickens, 18 duck, 1 goat and 1 cow living in Emigration Canyon. The survey also estimated that 214 wells and 27 springs for purposes of providing culinary water, 175 septic tanks and drainage fields and 110 holding tanks or vaults exist in the Canyon.

The reader is referred to Tables 1 and 2 for further physical data on Emigration Canyon.

Table 1. Annual Variations in Traffic, Flow and Water Quality in Emigration Canyon

Year	Avg. Annual Flow at Canyon Mouth (cfs)	Flow in Sept. at Canyon Mouth (cfs)	Avg. Annual Coliform Concen. at Canyon Mouth* (MPN/100 ml)	Max Monthly Coliform Concen. at Canyon Mouth* (MPN/100 ml)	Avg. Annual Coliform Load at Canyon Mouth* (billions/day)	Avg. Annual Traffic at Canyon Mouth (AADT)
1950	8.9	1.8				
1951	6.6	1.2				
1952	15.6	3.1				
1953	8.3	3.1				
1954	1.8	0.3				
1955	2.4	0.5				
1956	3.1	0.6				
1957	6.2	2.1				
1958	9.0	1.8				
1959	2.3	0.5				
1960	2.9	0.4				
1961	0.3	0.2				
1962	3.7	0.3				
1963	2.6	0.3				
1964	7.4	1.4				
1965	11.2	4.5				1370
1966	4.9	1.7				1215
1967	4.5	1.1				1340
1968	6.3	2.6	5400	14,300(Sep)	863	1430
1969	12.9	3.8	4410	13,700(Jul)	1008	1460
1970	5.9	1.9	2740	7,580(Jul)	374	1490
1971	10.9	2.6	1940	3,060(Sep)	395	1650
1972	9.9	2.2	1830	12,600(Sep)	194	1730
1973	7.6	2.9	2990	11,500(Sep)	402	1800
1974	13.5	1.9	830	3,990(Jul)	440	1850
1975	16.0	7.2	1000	3,030(Mar)	640	1850
1976	4.9	1.1	640	---		--
1977	1.1	0.6	930	2,250(Mar)		1980
1978	9.7	2.1		5,400(Aug)		2095
1979	4.1	0.6		2,400(Jun)		2200
Avg.	6.3 (1930-75)	1.8 (1930-75)				

* Multiple tube fermentation analysis (MPN) used prior to 1974 and membrane filter analysis (MF) after 1974.

Data from Wilhelm (1974), Hydroscience (1976), Sherwood (1980), and Jester (1980).

Table 2. Use and Water Quality Data in Emigration Canyon

Section No.	Station Identif.	Stream Length (mi)	Drainage Area (mi²)	ADT-miles (1979)	People/ Animals (1980)	Houses/ Tanks (1980)	Construction and Road Area (ft²)	Coliforms —— (Apr. 78)		Coliform —— (Jun. 78)		Coliform —— (Aug. 80)		Susp. Solids (Aug. 80) (mg/ℓ)
								Concent. (MF/100 ml)	Load (billions/day)	Concent. (MF/100 ml)	Load (billions/day)	Concent. (MF/100 ml)	Load (billions/day)	
1	Hogle Zoo	0.5	0.25	1120	0	0	62,000					7200	423	14
2		0.1	0.24	310	0	0	54,000	378	242	1230	347	1470	86	6
3	Monum.	0.7	0.35	1560	0	0	17,000	379	240	1420	376	2320	113	7
4	1480 SL	0.6	0.81	990	122/29	40/43	222,000	450	275	1620	417	3310	154	8
5	1720 SL	0.6	0.67	1520	49/3	16/15	104,000	464	281	1420	354	3080	143	11
6	C. Kost.	0.9	1.70	1730	10/-	110.3	117,000	387	231	1340	331	2740	128	13
7	3100 EC	0.6	2.46	1490	142/56	42/43	352,000	408	241	1750	424	4220	186	11
8	3492 EC	0.7	1.42	1460	19/1	8/7	106,000	495	288	1730	410	4170	174	7
9	3690 EC	0.4	0.45	890	40/32	14/13	109,000	721	412	1750	408	4380	172	6
10	3990 EC	0.3	1.38	620	53/5	24/19	171,000	247	140	544	125	2450	96	6
11	4800 EC	0.3	1.71	820	80/16	28/23	165,000	293	164	488	111	4740	186	6
12	5220 EC	0.4	0.36	3200	43/3	18/9	158,000	283	157	392	88	1700	67	2
13	5602 EC	0.6	0.64	1820	54/5	20/19	216,000	302	166	404	91	1700	67	2
14	S-Curve	0.6	0.88	440	10/1	6/5	257,000	205	112	50	11	1310	51	3
15	Burr Fk.	2.3	2.12	730	49/22	42/23	296,000	276	62	29	2.7	756	13	5
16	Kilyon	0.4	2.95	3	3/1	4/3	67,000	24	7.6	30	3.8	681	15	8
Total		9.6	18.4		674/174	263/222	2,473,000							

Coliform data from Salt Lake City and County Health Dept.

Each coliform concentration is the geometric mean of 21 measurements in Apr. 78 and Jun. 78 and 7 measurements in Aug. 80.

Water Quality Data:

Table 3 gives an overview of the water quality of Emigration Creek near the Canyon mouth and a comparison with the relevant Utah Water Quality Standards. Emigration Creek waters can be seen to be relatively high in organic matter (BOD), in bacteria (coliforms), in suspended solids, and in nutrients (nitrates and phosphates). The sources of these pollutants are human and animal wastes as well as runoff from disturbed, developed and cultivated areas.

The background bacteria count in a stream such as Emigration Creek has been found to be 10-20 coliforms per 100 ml (Paschal, 1978). The average value of 163,000 for coliform bacteria in Table 3 seems high (Hogle Zoo may be the reason). Other data (from Table 1 and 2) indicate that a range of 1000-20,000 MPN/100 ml is more typical for total coliforms in Emigration Creek near the Canyon mouth.

Care should be taken when interpreting coliform data since the analysis method was changed from a multiple tube fermentation technique (MPN) to a membrane filter technique (MF) in 1974. Data from the two techniques should not be compared as to absolute values since the membrane filter method generally produces lower counts than the multiple tube fermentation method. When analyzing coliform data one should also be aware that rather large deviations may occur almost inexplicably in small samples.

Table 1 contains coliform data for Emigration Creek at the Canyon mouth for 1968-79. It appears that little or no correlation exists between coliform counts and traffic counts. Furthermore, the maximum monthly coliform levels seem to have decreased somewhat during this period. Coliform loads are calculated as follows:

$$(\text{Coliform Load}) = 24.5 \cdot 10^6 \, (\text{Coliform Concent.})(\text{Flow})$$

Table 3.

Comparison of Water Quality in Emigration Creek with Utah Water Quality Standards

		Utah Water Quality Std.	
Water Quality Characteristic	Emigration Creek at Canyon Mouth*	Recreation & Aesthetics Class 2B Water**	Aquatic & Wildlife Class 3A Water***
Temperature (°C)	5-20		20 max.
pH (units)	7.5-8.8	6.5-9.0	6.5-9.0
Dissolved Oxygen (mg/l)	8.7 avg.	5.5 min.	6.0 min.
Biochemical Oxygen Demand (mg/l)	10.4 avg.	5 max.	5 max.
Tot. Coliform Bacteria (MPN/100 ml).	163,000 avg.	5000 max.	
Total Dissolved Solids (mg/l)	692 avg.		
Turbidity	39.0 JTU	10 NTU (inc.)	10 NTU (inc.)
Oil and Grease (mg/l)	8.6		
Nitrate (as N) (mg/l)	7.0 avg.	4 max.	4 max.
Phosphate (as P) (mg/l)	0.5 avg.	.05 max.	.05 max.
Sulfate (SO) (mg/l)	122		
Chloride (Cl) (mg/l)	107		
Fluoride (F) (µg/l)	26		
Arsenic (As) (µg/l)	0.3		
Barium (Ba) (µg/l)	2.2		
Cadmium (Cd) (µg/l)	0.1		0.4 max.
Chromium (Cr) (µg/l)	0.2		100 max.
Copper (Cu) (µg/l)	0.4		10 max.
Iron (Fe) (µg/l)	96		1000 max.
Lead (Pb) (µg/l)	0.7		50 max.
Manganese (Mn) (µg/l)	1.3		
Selenium (Se) (µg/l)	0.9		50 max.
Silver (Ag) (µg/l)	0.4		10 max.
Zinc (Zn) (µg/l)	1.5		50 max.

*Data from; "Utah Lake - Jordan River Hydrologic Basins Water Quality Management Planning Study," Vol. II, Appendix. Templeton, Linke and Alsup & Engineering-Science, Inc., Salt Lake City, UT, June 1975.

**Recreation and Aesthetics Uses; Class 2B: Protected for boating, water skiing and similar uses, excluding recreational bathing (swimming).

***Aquatic and Wildlife Uses; Class 3A: Protection and propagation of desired cold water species of fish and other cold water aquatic wildlife, including the necessary organisms in their food chains.

in which coliform load is in nos. per day, coliform concentration is in nos. per 100 ml, and flow is in cu. ft. per sec. For suspended solids the same procedure yields:

(Suspended Load) = 5.39 (Suspended Concent.)(Flow)

in which suspended solids load is in lbs. per day, suspended solids concentration is in mg. per liter, and flow is in cu. ft. per sec.

The annual variations in coliform concentrations at the Canyon mouth and at Burr Fork are shown in Figure 1. Not surprisingly the highest concentrations occur in July-August when dilution water (flow) is scarce and the lowest concentrations in early part of the winter. Since flow and coliform concentrations are multiplied to produce coliform loads it is not necessary that maximum load and concentration coincide. The large amount of noise in the data can be blamed on the "randomness" of coliform bacteria. Coliform bacteria are generally produced in human and animal intestinal systems and seem to have their own rules and preferences as to travelling in groups and surviving in snow, water and soils.

Table 2 contains three coliform profiles within Emigration Canyon (Apr. 78, June 78 and August 80). The three profiles show the major share of the pollution load entering the stream in sections 9, 10 and 11 or approximately between stream miles 3.9 and 5.5 upstream of the Canyon mouth. Relatively small amounts of coliforms seem to be entering the stream in the lower part of the Canyon. Coliform concentrations can be seen to be a maximum in August, while coliform loads are a maximum in June. Figure 2 is a graphical representation of the three coliform concentration profiles in Table 2.

Hydroscience (1976) reports the results of a total and fecal coliform survey run in Emigration Creek in June 1972. The coliform profiles were very similar to those shown in Figure 2 and Hydroscience reported:

* Pollution appears to be related to the heavy residential use and the poor disposal of sanitary waste and household waste.

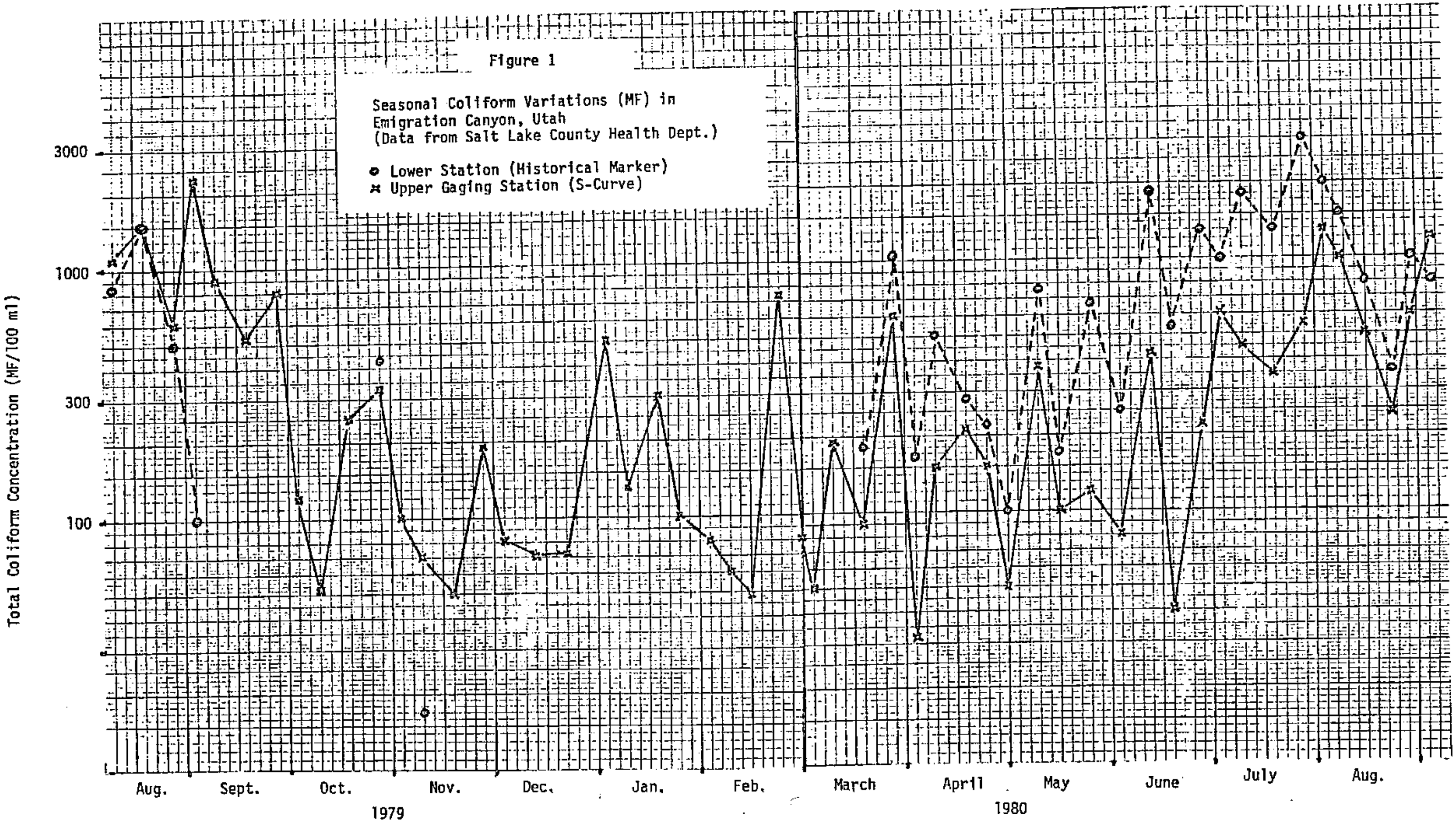

Figure 1

Seasonal Coliform Variations (MF) in
Emigration Canyon, Utah
(Data from Salt Lake County Health Dept.)

- ● Lower Station (Historical Marker)
- ¤ Upper Gaging Station (S-Curve)

the developments at Burr Fork) with local intake structures (for withdrawing stream water) a fairly common sight. Above Camp Kostopulos, the Creek flows through a meadow of alluvial silt deposits and tends to become turbid and murky. In the lower reaches the streambed is sometimes clogged with branches, construction materials, tires, plastic bottles, etc. About one mile upstream from the Canyon mouth, a spring on the south side of the Canyon (Emigration Tunnel) produces a flow of about 2.5 cu. ft. per sec. Most of this water is diverted by the Salt Lake City Water Department for use at Hogle Zoo or the Bonneville golf course. Emigration creek has been incorporated into a fishpond, several irrigation systems and gardens, and a couple of farmyards along its course. Clearly the developments in Emigration Canyon have already affected the streamflow and degraded the water quality in the Creek.

Historically, Emigration Canyon has seen fur trappers, the Donner Party (1846), the Mormon pioneers (1847), gold diggers, and a few enterprising and hardy developers. In 1852 a franchise on the timber in the canyon was granted and a sawmill was built at the base of Big Mountain. In 1907 a railroad was built to Pinecrest Inn for purposes of transporting sandstone and limestone quarried in the Canyon to the Salt Lake Valley. Pinecrest Inn with accomodations to sleep 60 people was closed in 1917 when the railroad, which ran only in the summer, was dismantled.

Sheep and cattle were grazed in Emigration Canyon during the first half of the twentieth century, but only a few rugged residents lived in the Canyon. In 1950 there were approximately 200 permanent residents. A 1980 questionnaire and canvassing produced an estimate of 675 permanent residents. Except for a couple of restaurants, little commercial activity exists in the Canyon today.

Purpose and Scope:

The purpose of this study is to investigate the relationships between

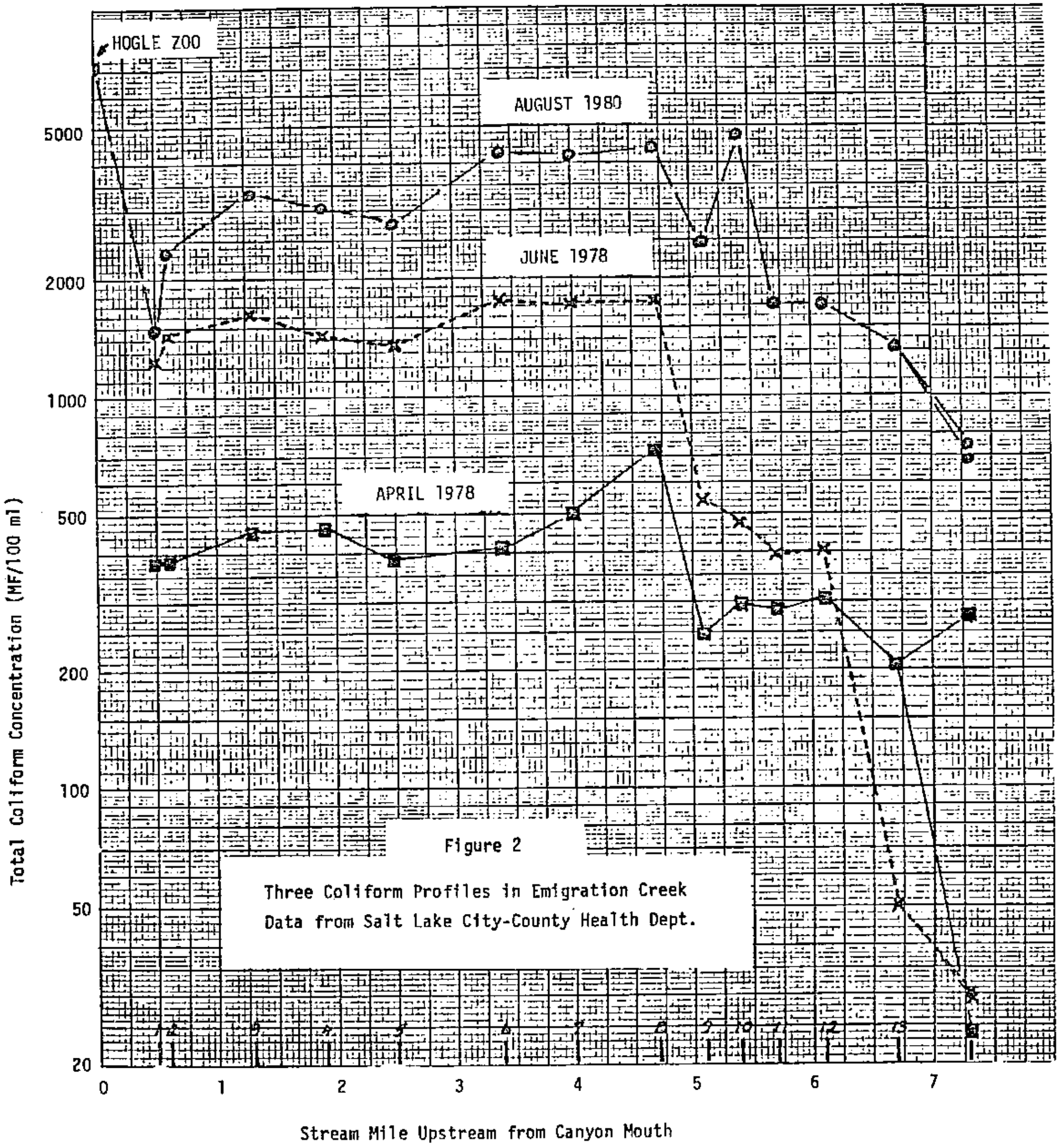

Figure 2

Three Coliform Profiles in Emigration Creek
Data from Salt Lake City-County Health Dept.

- At present monthly average coliform concentrations can be expected to range in the canyon from 1000 to 7000 MPN/100 ml., averaging 2900.
- Coliform concentrations are slightly affected by variations in annual flow.
- A large amount of fecal coliforms enter Emigration Creek between Kelvin Grove and Lost Camp, probably from inadequate septic facilities in this narrow reach of the stream. (Between upstream miles of 3.6 and 5.5.)
- Unit annual coliform loads for Emigration Canyon with septic tanks on steep slopes near the stream bank is, perhaps, 80 MPN/100 ml cabin/mile; i.e., on the average, the coliform concentration of Emigration Creek is increased by 80 MPN/100 ml by each cabin per mile of creek.

The same sixteen stations were used for total suspended solid (TSS) sampling as for coliform bacteria data collection. The samples were taken during a moderate rainstorm. It had been raining intermittently for approximately two days prior to sample collection. The conditions were indicative of a prolonged wet weather state rather than a single event storm.

In addition to the sixteen original sampling sites, four tributaries which flow into Emigration Creek were tested. They are: Brigham Fork (below Crompton's Cafe), Freeze Creek (below Brigham Fork), Pioneer Fork (Acorn Hills Subdivision site), and Strong/Bayliss Fork (across from Camp Kostopolus). These four tributaries contribute what is thought to be a significant sediment load to Emigration Creek.

Table 4 contains TSS, flow, and velocity data for Emigration Creek for two storms in May 1981. The May 16th storm was used in TSS modelling on the computer.

In November 1970 Templeton, Linke and Alsup, Consulting Engineers in Salt Lake City, produced a feasibility report for a water distribution system in Emigration Canyon for the Emigration Improvement District. The report states among other things that:

* 800 permanent residents live in Emigration Canyon.

* Water within the Canyon when developed on an individual basis would be adequate for 800 to 1000 persons.

* Water within the Canyon if developed as a District would serve 3600 persons.

* If developed after annexation to Salt Lake City the Canyon water sources and additional water could be provided to serve the 11,000 estimated ultimate population.

* Analysis shows that 40% of the wells tested in Emigration Canyon have a coliform count in excess of established drinking water standards.

* Emigration Creek has a coliform count in excess of 5000 MPN/100 ml which is established as the limit for useable water within the State.

* All of the water in Emigration Creek has been appropriated.

* The most feasible plan would be to annex to Salt Lake City and to develop a water and sewer project capable of serving 900 connections initially and capable of extending mains and laterals to serve additional growth as it occurs.

TABLE 4, TSS, FLOW AND VELOCITY DATA IN EMIGRATION CREEK

	May 8, 1981 Storm				May 16, 1981 Storm			
Sect. No.	Q (cfs)	V (ft/sec)	Conc. (mg/1)	Load (1bs/day)	Q (cfs)	V (ft/sec)	Conc. (mg/1)	Load (1b/day)
1	4.2	.87	65	1500	8.8	1.12	260	1200
2	4.1	.84	120	2700	8.6	1.08	270	1200
3	3.9	.82	65	1400	7.5	1.02	270	1100
4	3.8	1.33	60	1200	7.1	1.64	240	9500
5	3.7	1.25	60	1200	6.8	1.54	230	8600
6	3.6	.87	90	1700	6.5	1.06	240	8400
6A	.07		1800	680	.01		230	12
7	3.55	.76	40	770	6.1	.91	250	8300
7A	.05		950	260	.01		3300	180
8	3.5	.57	30	570	5.7	.68	190	6000
9	3.5	.91	30	570	5.5	1.06	230	6900
10	3.5	1.04	20	380	5.3	1.2	240	6900
11	3.5	.91	20	380	5.1	1.04	340	9500
11B	.25		0	0	.5		160	430
11A	.25		5	6.7	.5		200	540
12	3.0	.50	10	160	3.9	.54	400	8400
13	3.0	.62	20	320	3.8	.67	420	8600
14	2.9	.92	0	0	3.7	1.0	440	8600
15	1.3	1.23	15	100	1.5	1.3	700	5600
16	1.5	.89	10	81	2.1	1.0	25	290

SIMULATION MODEL

General Structure:

For purposes of data resolution the Canyon is divided into sections, a section being the land area between two sampling stations. In Emigration Canyon, sixteen sampling stations on the Creek defined sixteen sections. For each section, a general simulation model, as shown in Figure 3, was devised. The model was designed to simulate the movement of constituents such as coliform bacteria and total suspended solids in Emigration Canyon.

Starting at the headwater and proceeding downstream, the computer (a UNIVAC 1160) calculated and summed the inputs and outputs for each section of the Creek. The program was written in BASIC language and is appended to this report.

Generation Factors:

Five relatively independent sources of coliform bacteria pollution were considered, namely:

* Background Load. This is the load which would be present were man and his developments not present. Paschal, Jr. (1978) studied bacterial background generation for the Wasatch Front and other locations and came up with the function: $27\ e^{-0.092(T-20)}$ in which T is the mean air temperature in degrees Celsius and the expression gives the numbers of coliform bacteria introduced to the stream per day per square foot of drainage area in the section. This expression shows that background generation goes up as the temperature goes down due to a smaller bacterial decay at low temperatures. The background generation is mainly from the presence of undomesticated animals and from natural rotting processes, a few of which may produce coliform bacteria.

* Disposal System Load. This is the load produced from drainage fields, leaky holding tanks, overflowing septic tanks, etc. The load is considered to be proportional to the number of disposal systems present in a section (see

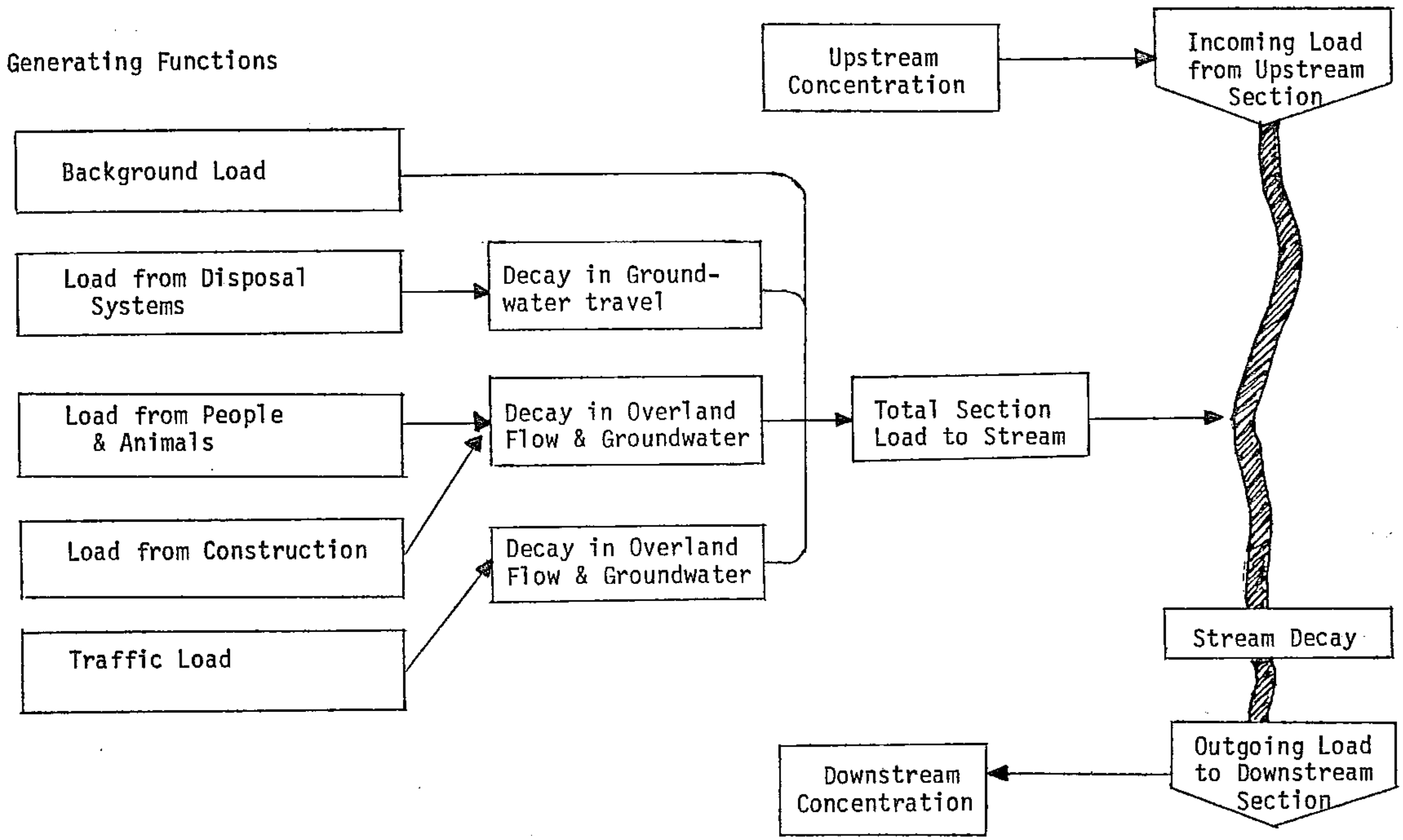

Figure 3. Simulation Model for Individual Section

Table 2). The pollution is considered to travel to the stream as groundwater flow. The actual generation factor is determined in the model calibration process.

* People and Animal Load. This is the pollution load deposited on the ground surface by people and animals. It is not only due to fecal matter, but also due to rotting processes such as organic matter decomposition caused by man. The load is considered to find its way into the stream via overland flow or groundwater flow, depending on the weather. The numbers and kinds of animals present are converted into equivalent people, the actual number of people added and the generation factor set proportional to this total number in the section. The actual generation factor is determined in the model calibration process.

* Traffic Load. This is the pollution load caused by traffic and the presence of automobiles, trucks, motorcycles, etc. The generation is proportional to the number of ADT-miles in a section, which is the resulting number when the average daily traffic (ADT) is multiplied by the number of road miles in the section (see Table 2). Since little apparent functionality between traffic and pollution is evident in Emigration Canyon, the generation factor of 2×10^6 coliforms per ADT-mile developed by Paschal in Little Cottonwood Canyon was used.

* Construction Load. This is the pollution load due to the construction of roads, houses and other facilities. The load is thought to come from general disturbance of the soil surface, which increases transport of soil and pollutants to the creek and from general deposition of pollutants in connection with construction. The generation is proportional to the square feet of developed area in each section. The coliform bacteria generation factor used is 120 per square foot of construction area per day (Paschal, 1978).

Three sources of total suspended solids were used in the simulation model. They are:

- * Construction and Dirt Road Load. The generation coefficient is multiplied by the area used for dirt roads and construction. The TSS generation coefficient is determined in the model calibration process.
- * People and Animal Load. The TSS generation coefficient is determined in the model calibration procedure.
- * Tributary Load. This is the TSS load which comes into the creek via side streams. The TSS concentration and flow of each tributary are measured and entered into the model directly. It is assumed that 100% of the tributary load reaches the main creek.

Transport and Survival Rates:

The pollution constituents decay with time in travelling from their point of deposition to the stream or in the stream. Four different survival rates were used for coliform bacteria for four different travelling modes. They are survival rate in the stream, disposal system groundwater survival rate, combined overland and groundwater rates for people, animals and construction deposits, and a combined survival rate for traffic pollution.

The general form for the survival rates is (e^{-kt}), where k is the decay rate (per day) and t is the travel time (in days) of the pollution constituent.

The decay rate for coliform bacteria is dependent on the media host as well as the temperature of the media. After Thomann (1972), Fair, Geyer and Okun (1968), and Paschal (1978), the following two equations were used for determination of coliform decay rates:

In soils: $k = 0.85\ e^{-0.092(14-T)}$

In water: $k = 2.5\ e^{-0.092(20-T)}$

in which T is the temperature of the media in degrees Celsius.

The travel time is determined from (L/V), where L is the distance (in feet) the pollution must travel and V is the pollution velocity (in feet per day). For stream survival, L is the section stream length (see Table 2). V is one-half the average stream velocity in the section. (To account for bacterial retardation due to adhesion and interference from the bottom one-half the stream velocity is used for shallow streams.) In general, the section stream survival rates for coliform bacteria are very high (85-99%) due to the short stream travel times. For groundwater survival, L is the distance of the disposal system from the Creek and V is the groundwater velocity as determined from Darcy's Law:

$$V = KS$$

in which K is the hydraulic conductivity of the soil used as 17 ft/day, and S is the slope of the groundwater table (see Table 5).

The groundwater travel times can be seen to be quite long, and the coliform survival rates quite low except for the traffic load in section 13, where the S-curve places the road in close proximity to the Creek.

For overland flow survival, L is the distance of the highway or dwelling from the Creek and V is the overland flow velocity as determined from Izzard's formula:

$$t = \frac{L}{V} = \frac{41\ b\ L^{1/3}}{i^{2/3}}$$

$$b = \frac{0.0007\ i + C}{S^{1/3}}$$

Table 5. Constituent Transport Times and Coliform Survival Rates for Stream Transport and Groundwater Transport in August 1980. (Hydraulic Conductivity = 17 ft./day)

Section No.	Stream Transport					Groundwater Transport					Groundwater Survival			
							Houses		Traffic					
	Stream Vel. (ft/sec)	Travel Time (min)	Stream Temp (°C)	Decay Rate (per day)	Survival Rate	Slope	Length (ft)	Time (days)	Length (ft)	Time (days)	Temp (°C)	Decay Rate	Survival Rates (Houses)	Survival Rates (Traffic)
1	0.72	59	12	1.20	.95	0.11	---	---	250	133	23	1.95	---	0
2	0.70	13			.99	0.24	---	---	94	23			---	0
3	0.65	95			.93	0.49	---	---	63	7.6			---	0
4	1.05	50			.96	0.28	39	8.2	81	17			.003	0
5	1.0	53			.96	0.28	31	6.5	94	20			.010	0
6	0.70	113			.91	0.14	300	12.6	156	66			0	0
7	0.60	88			.93	0.17	40	14	231	80			0	0
8	0.45	137			.90	0.26	21	4.8	113	26			.035	0
9	0.70	50			.96	0.16	34	13	113	42			0	0
10	0.80	33			.97	0.14	29	12	106	45			0	0
11	0.70	38			.97	0.22	38	10	125	33			.001	0
12	0.40	88			.93	0.22	26	7.0	81	22			.007	.001
13	0.50	106			.92	0.32	28	5.1	19	3.5			.026	.363
14	0.75	70			.94	0.14	28	12	44	18			0	.030
15	1.0	202			.85	0.31	28	5.3	75	14			.023	0
16	0.75	47			.96	0.09	15	9.8	50	33			.001	.004
Total		1,242			.34									

in which C is the retardance coefficient used as 0.04, S is the land slope of the section, i is the rainfall intensity used as 0.125 inches per hour, and t is the overland section travel time in minutes. From Table 6, the overland transport times can be seen to be a matter of minutes as compared to days for the groundwater transport times in Table 5. The August overland coliform survival rates are quite high (0.89-0.97), indicating that during summer rainstorms 89%-97% of the coliform pollutants are flushed into the Creek.

During a time period of a month, it is assumed that surface depositions of pollutants may be moved partly by overland flow andpartly by groundwater flow. An examination of rainstorms which occurred at Mountain Dell Reservoir during the sampling months was carried out in order to come up with a method for assessing a combined survival rate for the coliform load deposited by people, animals, construction and traffic. The data and estimates of the effective duration of overland flow are shown in Table 7. The effective duration of overland flow (in days) was arrived at from the expression:

$$\frac{\text{Rainfall Duration (hrs)}}{24} + \frac{\text{No. of Rainstorms}}{2}$$

in which the first term is the actual rainfall duration and the second term is an estimate of a flushing period assuming that the 50% coliform survival rate is about half a day (0.36 days for $k = 1.9$ in $c = c_0 e^{-kt}$).

Table 6 gives values for combined coliform survival rates assuming the overland survival rate to be in effect during the effective duration of overland flow and the groundwater survival rate in effect the rest of the days during the month. The combined coliform survival rates in Table 6 can be seen to vary between 6.2% and 10% for coliforms deposited near the houses and between 6.4% and 41% for highway and traffic coliforms in June, 1978.

Table 6. Constituent Transport Times and Coliform Survival Rates for Overland Flow and Combined Flow in Aug. 1980 ($i = 0.125$ in/hr, $C = 0.04$).

			Overland Transport				Overland Coliform Survival				Combined Coliform Survival		
Section No.	Land Slope	b Value (Izzard)	Houses		Traffic		Temp °C	Decay Rate (per day)	Survival Rates (Houses)	Survival Rates (Traffic)	Overland Flow (days)	Survival Houses	Survival Traffic
			Length (ft)	Time	Length (ft)	Time							
1	0.23	.065	---	---	250	68	17	1.9	---	.91	2.1	---	.064
2	0.24	.064	---	---	94	48			---	.94		---	.066
3	0.26	.063	---	---	63	41			---	.95		---	.066
4	0.29	.060	39	34	81	43			.96	.94		.070	.066
5	0.29	.060	31	31	94	45			.96	.94		.076	.066
6	0.13	.079	300	87	156	70			.89	.91		.062	.064
7	0.21	.067	40	38	231	68			.95	.91		.067	.064
8	0.29	.060	21	27	113	48			.96	.94		.100	.066
9	0.37	.056	34	30	113	44			.96	.94		.067	.066
10	0.26	.063	29	32	106	49			.96	.94		.067	.066
11	0.14	.077	38	42	125	63			.95	.92		.067	.064
12	0.48	.051	26	25	81	36			.97	.95		.074	.068
13	0.78	.043	28	21	19	19			.97	.98		.092	.406
14	0.52	.050	28	25	44	29			.97	.96		.068	.095
15	0.34	.057	28	28	75	40			.96	.95		.089	.066
16	0.38	.055	15	22	50	33			.97	.96		.069	.071

Table 7. Rainstorm Data from Mountain Dell Reservoir and Effective Duration of Overland Flow

	Total Rainfall (inches)	Hours of Rainfall	Rainfall Intensity (in/hr)	No. of Rainstorms	Effective Duration of Overland Flow (days)*
April 1978	5.42	43	0.126	14	11.6 (6.8)
June 1978	0.30	3	0.10	2	1.3 (3.4)
August 1980	1.00	-	-	7	3.8 (2.1)

---

* The numbers in parentheses are calculated using rainfall data for the fifteen days preceding the days of sampling.

Similar transport and survival rate calculations to those shown in Tables 5 and 6 were made for April 1978 and June 1978 using different stream velocities, temperatures, and effective overland flow durations.

The sediment survival rate through each section of the stream is modelled according to an exponential decay, where k is the erosion or deposition rate per minute and t is the travel time in minutes. The travel time is determined in the same manner for TSS as for coliform modelling. The TSS sediment survival rates are quite high (90%+) due to short stream travel times.

The decay rate is determined by using the general formula: $g_2=g_1e^{-kt}$; where g_2 is the TSS load at the Hogle Zoo sampling station in lb/day, g_1 is the TSS load at Burr Fork sampling station in lb/day, and t is the travel time in minutes between the two stations. The equation is solved for k, which gave .00054 min.^{-1}, a representative decay rate for the entire canyon.

Table 8 gives stream travel times and sediment section survival rates for each section:

TABLE 8

Section No.	Decay Rate Min.^{-1}	Travel Time Min.	TSS Survival e^{-kt}
1	.00054	39.3	.98
2		8.1	99
3		60.4	.97
4		32.2	.98
5		34.3	.98
6		74.7	.96
7		58.0	.97
8		90.6	.95
9		33.2	.98
10		22.0	.99
11		25.4	.99
12		65.2	.96
13		78.8	.96
14		52.8	.97
15		156	.92
16		35.2	.98

Model Calibration:

Three coliform profiles (April 1978, June 1978 and August 1980) with sixteen sampling stations on each profile were used to calibrate the model. The factors which ended up being determined or adjusted by the calibration process were:

* Background generation of $27e^{-.092(T-20)}$. This factor was used and resulted in model stream coliform concentrations of about 20 MF/100 ml when all other generation factors were set to zero.

* A disposal system generation factor of $8 \cdot 10^9$ coliforms/tank/day. This factor was found to give the truest to observed concentration profiles in the Canyon for April, June and August conditions.

* A people and animal generation factor of $2 \cdot 10^9$ coliforms per people equivalent per day. This factor was found to give the best total levels of coliform pollution when compared with the observed levels in April, June, and August.

* A multiplication factor of five to be applied to the animals in the Canyon to produce the equivalent surface coliform pollution of people. Using a factor of five seemed to produce a truer fit to observed fluctuations than

Canyon to produce the equivalent surface coliform pollution of people. Using a factor of five seemed to produce a truer fit to observed fluctuations than

the other multiplication factors tried. That the factor is as high as five can perhaps be best explained by the fact that animals tend to deposit their feces outside and often in close proximity to the Creek.

* An overland flow duration based on the rainfall duration and frequency observed during the fifteen days preceding the sampling period (see Table 6). This procedure was adopted when it produced an adjustment of the three monthly coliform levels which agreed better with the observed levels than did the overland flow durations based on the monthly data.

Initially a linear programming technique was used to arrive at the best fit generation factors. The technique showed that the generation of coliforms from traffic and construction was quite inconsequential in Emigration Canyon. As a result of this observation the generation factors for traffic and construction were kept at the values proposed by Paschal (1978).

Difficulty was encountered when trying to model the coliform peaks observed in Section 9 for all three months and in Section 11 in August. It was concluded that either a potent farmyard or one or more leaky disposal systems is the cause of the high pollution level in this part of the Creek, and that the model is not up to simulating this phenomenon without further investigation.

For the month of August the observed coliform levels show a sharper decrease near the mouth of the Canyon than the simulated values do (see Table 7). It is just possible that recharging of groundwater aquifers in this reach may also drain off some of the coliforms which the model seems to indicate should be there. This discrepancy near the Canyon mouth is not nearly so evident for the months of April and June when the streamflow is high.

For total suspended solids, the model was calibrated using the May 16th storm data profile. The coefficients which were determined in the calibration procedure are:

* A construction and dirt road coefficient of .015 lb/ft^2/day.

* A people and animal coefficient of .0001 lb/person/day.

A linear regression program was used to determine these coefficients.

MODELLING RESULTS

Existing Sources of Pollution:

Since August is the month which generally gives the highest coliform concentrations, it was chosen as the month to display calculated transport times, survival rates (Tables 5 and 6) and calculated loads and concentrations (Table 9). Actually June is the month which gave the best agreement with the observed and calculated coliform concentrations with a correlation coefficient of 0.89. The calculated coliform concentrations for the month of

Table 9. Calculated and Measured Coliform Loads and Concentrations in Emigration Canyon, August 1980.

Section No.	Coliform Stream Loads (per day)					Total Stream Load x10^9	Coliform Concentrations	
	Background x10^9	People & Animals x10^9	Disposal Systems x10^9	Traffic x10^9	Construct. x10^6		Model MF/100 ml	Measured MF/100 ml
1	0.25	0	0	0.14	0	150	2600	7200*
2	0.24	0	0	0.04	0	160	2700	1470
3	0.35	0	0	0.21	0	160	3300	2320
4	0.80	37	1.0	0.13	1.9	170	3700	3310
5	0.66	9.8	1.2	0.20	0.95	140	3000	3080
6	1.7	1.2	0	0.22	0.87	130	2900	2740
7	2.4	56	0.02	0.19	2.8	140	3200	4220
8	1.4	.48	1.9	0.19	1.3	95	2300	4170
9	0.45	27	0.02	0.12	0.88	97	2500	4380
10	1.4	11	0.03	0.08	1.4	73	1900	2450
11	1.7	21	0.14	0.11	1.3	64	1600	4740
12	0.36	8.6	0.53	0.43	1.4	43	1100	1700
13	0.63	15	4.0	1.5	2.4	36	900	1700
14	0.87	2.0	0.01	0.08	2.1	18	500	1310
15	2.1	10	2.2	0.10	3.2	13	700	756
16	2.9	1.1	0.02	0	0.55	4	200	681
Total	18.2	214	11.1	3.7	21.1		r = 0.59	
%	7.4	87	4.5	1.5	---			

* High concentration probably due to Hogle Zoo influence (not modelled).

April gave a correlation coefficient of 0.60 and for August of 0.59 when compared with the measured concentrations. Considering the randomness of coliform bacteria data and uncertainties in other parameters (rainfalls, decay rates, hydraulic conductivity, use data, etc.) these correlation coefficients seem reasonable. The modelled coliform loads in August (shown in Table 9) gave a correlation coefficient of 0.65 when compared with the ones derived from observed flows and concentrations.

Table 9 shows the sources of the modelled coliform pollution in August for each section. The major share of the coliform load (87%) can be seen to be caused by the surface load due to the presence of people and animals. Indications are that animals are a major culprit.

Background is a distant second with a 7.4% contribution and disposal systems third with 4.5% of the total coliform load. When a higher coliform generation factor was used for the disposal systems in the Canyon, a poorer compliance to the observed coliform profiles resulted. The same happened when a higher hydraulic conductivity was used.

The loads can be seen to vary widely from section to section. Most of the people and animal load originates in Section 7, while both disposal and traffic contribute strongly in Section 13 (the S-curve section) where the road and disposal systems are close to the Creek. Most of the background coliform load comes from the three largest sections.

Considering the complexities of the generation, transport and decay phenomena, the simulation model does a fairly good job of copying the three observed coliform profiles. It should be kept in mind that the results are intended to be indications rather than slide-rule accuracy predictions.

In general, the model seems to underestimate the coliform concentrations in Section 16 (Kilyon Canyon) and Sections 11 and 9. It also seems to overestimate the coliform concentrations in Section 15 (Burr Fork) and near the mouth of the Canyon. Perhaps the underestimation of the pollution loads near the mouth of the Canyon is due to infiltration of pollutants into groundwater aquifiers. Flow considerations indicate that such outflows may exist.

The modelled TSS loads for the May 16th storm (shown in Table 10) gave a correlation coefficient of .73. The trends of TSS loading are followed fairly well by the computer model. The largest variations occur in sections 15 (Burr Fork), 14 (S-curve), and 8 (3492 EC). Section 8 is overestimated by the model and the others are slightly underestimated.

Impacts of Development Alternatives:

With the computer model calibrated to simulate existing conditions it is possible to alter the inputs, transports or survival rates to simulate hypothetical conditions. For the model to be valid under such hypothetical conditions it is necessary that the basic simulation construction still apply. This may mean for example, that extreme flooding or dry-weather conditions should not be run in the model without modifications.

Keeping this limitation in mind the following hypothetical alternatives, thought to be representative of possible future conditions, were analyzed for bacterial pollution (coliforms) using the model:

A. August 1980 conditions, but with an installed sewer exporting the pollution from all disposal systems.

B. August 1980 conditions, but with all animals removed except cats and dogs.

C. August 1980 conditions, but with all animals removed except cats and dogs and with an installed sewer (combination of alternatives A and B).

D. August 1980 conditions, but with twice the nos. of people, animals, disposal systems, traffic and construction.

TABLE 10. CALCULATED AND MEASURED TSS LOADS AND CONCENTRATIONS

Section	TSS Loads (lb/day)		TSS Conc. (mg/l)	
	Model	Measured	Model	Measured
1	11000	12000	230	260
2	11000	12000	230	270
3	11000	11000	260	270
4	11000	9500	280	240
5	10000	8600	280	230
6	9900	8400	280	240
7	10000	8200	300	250
8	9100	6100	290	190
9	9000	6900	300	230
10	8600	6900	300	240
11	8000	9500	290	340
12	6800	8400	320	400
13	5900	8600	290	420
14	3700	8600	180	440
15	1400	5600	171	700
16	370	280	30	25

r = .73

E. August 1980 conditions, but with twice the nos. of people, animals, disposal systems, traffic and construction and with an installed sewer (combination of Alternatives A and D).

F. August 1980 conditions, but with twice the nos. of people, animals, disposal systems, traffic and construction and with all development removed an additional 100 feet away from the Creek.

G. August 1980 conditions, but with an effective duration of overland flow of 5.0 days (increased flushing of pollutants).

The simulated results for stream coliform concentrations for Alternatives A-G and the present August 1980 conditions are shown in Table 11. The sewer alternatives (A & E) can be seen to reduce the mean stream coliform concentrations by 140 and 220 MF/100 ml respectively. Removing all domestic animals except dogs and cats can be seen to reduce the mean August stream coliform concentration by about 440 MF/100 ml for a 27% decrease.

A general doubling of all coliform pollution loads can be seen to increase the mean August stream coliform concentration from 1650 to 2980 MF/100 ml, for an 81% increase. Adding a 100 foot buffer zone (increasing pollution travel by 100 feet) can be seen to drop the mean August stream concentration from 2980 to 2460 MF/100 ml for a 17% decrease.

Alternative G, although not a development alternative, illustrates how a few days of rain in August readily flushes pollutants into the stream. Changing the effective overland flow duration from 2.1 days to 5.0 days (holding other quantities fixed) can be seen to double the August coliform stream concentrations.

Several alternatives were run using the calibrated model to simulate hypothetical TSS conditions. The alternatives are:

A. May 16th storm conditions, but with double the square footage of dirt roads and construction sites.

Table 11. Stream Coliform Concentrations for Development Alternatives

Section No.	Aug. 1980 Conditions MF/100 ml	Alt. A MF/100 ml	Alt. B MF/100 ml	Alt. C MF/100 ml	Alt. D MF/100 ml	Alt. E MF/100 ml	Alt. F MF/100 ml	Alt. G MF/100 ml
1	2600	2500	1700	1600	5000	4800	4400	5500
2	2700	2600	1800	1700	5200	5000	4600	5800
3	3300	3100	2200	2000	6300	6000	5600	7000
4	3700	3500	2500	2300	7100	6800	6300	8000
5	3000	2900	2000	1900	5700	5500	5100	6400
6	2900	2800	1900	1800	5500	5300	4900	6100
7	3200	3100	2100	2000	6200	6000	5600	7000
8	2300	2100	1800	1600	4300	4000	3700	4700
9	2500	2300	1800	1700	4700	4500	4100	5200
10	1900	1700	1700	1600	3600	3300	2900	3800
11	1600	1500	1400	1300	3100	2800	2500	3200
12	1100	900	1000	900	2000	1800	1400	1900
13	900	800	800	700	1700	1400	1100	1600
14	500	400	400	300	800	700	600	790
15	700	600	600	500	1400	1100	900	1300
16	200	200	100	100	200	200	200	240
Geo. Mean	1650	1510	1210	1100	2980	2760	2460	3200

B. May 16th storm conditions, but with triple the square footage of dirt roads and construction.

C. May 16th storm conditions, but with twice the numbers of people and animals.

D. May 16th storm conditions with double the tributary TSS loads.

E. May 16th storm conditions with double the velocity in the main channel.

F. May 16th storm conditions with double the square footage of dirt roads and construction, double the tributary load, and double the stream velocity.

G. May 16th storm conditions with half the square footage of dirt road and construction sites to simulate a reduction of construction impact.

The TSS load results for alternatives A through G are shown in Table 12. It can be seen that any further increase in area devoted to dirt roads and construction (ie. Alts. A & B) sites will increase drastically the total suspended solids in the creek. Increased velocities due to heavier storms also raise TSS loads. A combination of double the dirt roads and construction sites, double velocities and double people and animals gives the highest TSS loads. Halving the area of land occupied by dirt roads and construction considerably alleviates TSS loading. These results show that area of dirt roads and construction is the main cause of TSS loading in Emigration Creek.

Doubling the number of people and animals in the canyon seems to have essentially no effect on the amount of total suspended solids in the creek.

TABLE 12. TSS LOADS FOR MODEL ALTERNATIVES

Section No.	May 16th Storm Cond. (lb/day)	Alt. A (lb/day)	Alt. B (lb/day)	Alt. C (lb/day)	Alt. D (lb/day)	Alt. E (lb/day)	Alt. F (lb/day)	Alt. G (lb/day)
1	11000	21000	31000	11000	12000	12000	25000	5900
2	11000	21000	31000	11000	12000	12000	24000	5900
3	11000	20000	30000	11000	12000	12000	24000	5800
4	11000	21000	31000	11000	12000	12000	24000	6000
5	10000	19000	28000	10000	11000	11000	23000	5600
6	9900	19000	28000	9900	11000	11000	22000	5400
7	10000	19000	28000	10000	11000	11000	22000	5500
8	9100	17000	25000	9100	9900	9800	20000	5000
9	9000	17000	25000	9000	10000	9600	19000	5000
10	8600	16000	24000	8600	9500	9100	18000	4800
11	8000	15000	22000	8000	9000	8400	17000	4500
12	6800	14000	20000	6800	6800	7200	14000	3400
13	5900	12000	18000	5900	6000	6200	12000	3000
14	3700	7300	11000	3700	3700	3800	7600	1800
15	1400	2800	4200	1400	1400	1500	2900	700
16	370	750	1100	370	370	380	760	190

CONCLUSIONS AND RECOMMENDATIONS

General Conclusions:

The following general conclusions are based on water quality and land use data collected, observations of Canyon conditions, model simulation results and evaluations of past studies in Emigration Canyon:

- * The water quality in Emigration Creek is variable but generally below the Utah Water Quality Standards for Recreation & Aesthetics Use (Class 2B) with respect to organic matter (BOD), bacteria, (total coliforms), and nutrient contents (nitrates and phosphates).
- * The quality of the water in Emigration Creek can be expected to further deteriorate if the present rate of development and sanitary practices continue. The simulation model indicates a possible 81% increase in stream coliform concentrations for a 100% population increase.
- * Natural conditions coupled with existing diversions of water from Emigration Creek may bring late summer conditions of little or no flow and high bacterial stream concentrations in the lower half of the Canyon.
- * The messy and constricted streambed conditions which exist, expecially in the lower half of the Canyon, may essentially dam the creek during floods and bring torrential and damaging floods.

- The use of Emigration Creek water for irrigation, in gardens, in fishponds and in farmyards is affecting streamflow and degrading the stream quality.

- The numbers of domestic animals (dogs, cats, chickens, ducks, horses, cows, etc.) present in the Canyon and their close proximity to the Creek are seriously affecting the bacterial quality of Emigration Creek. The simulation model indicates that a reduction in the numbers of domestic animals can aid in reducing bacterial stream pollution.

- A lower rate of bacterial loading to the stream than expected seems to take place in the first couple of stream miles upstream of the Canyon mouth. This may be due to good sanitary practices or perhaps infiltration to ground-water aquifers in the reach.

- Traffic (except in the S-curve section) and construction do not seem to contribute significantly to the bacterial stream loading at this time.

- The simulation model indicates that buffer zones along Emigration Creek can be helpful in detaining and decaying pollutants. A 100 foot wide buffer zone was found to reduce August stream coliform concentrations about 17%.

- The simulation model indicates that at this time a sewer in Emigration Canyon will not result in a significant coliform bacteria reduction in Emigration Creek. If all the residences were connected the model predicted an approximate

8% stream coliform concentration decrease for August conditions.

- * During rainy weather conditions considerable amounts (12,000 pounds per day on 16th of May, 1981) of suspended solids are transported out of Emigration Canyon by Emigration Creek.
- * Linear regression of measured total suspended solids concentration with use and development data indicates that dirt roads and construction sites generate most of the suspended solids found in the Emigration Creek during rainy weather.

Best Management Practices:

When attempting to mitigate water pollution in developed areas peoples knowledge and concern about pollution is a significant factor. Good hygiene, tidiness and care on the part of residents and visitors in Emigration Canyon can aid particularly in holding down bacterial pollution levels. A series of practices are available to individuals, the Emigration Improvement District and Salt Lake County planners which can help in abating pollution in Emigration Canyon:

- * A general cleanup is needed in many parts of the Canyon. Old cars, refuse, garbage, construction material, etc., need be removed. In particular the areas adjacent to the Creek and the streambed itself need be cleaned up. The streambed in the lower part of the Canyon is a hazard in times of floods. Sunlight should penetrate to stream and streambanks and vegetation should be maintained but controlled on streambanks.

- A minimum stream flow must be maintained in summer and fall to provide dilution water and prevent stagnant and septic pools from developing. This may mean restrictions on water withdrawals from the Creek and a general inspection of existing intake systems.

- As is, the stream is run through gardens, fishpools, and farmyards. Clearly these are activities which may interfere with the self-cleansing action of the stream and add organic matter, bacteria and nutrients. Such uses of the stream should be discontinued.

- The number of domestic animals allowed in the Canyon should be restricted and particular care need be exercised in keeping the animals away from streams.

- When fertilizers and pesticides are applied to lawns, trees, bushes and gardens special precautions must be taken to prevent residues from flushing into streams. Nutrients from fertilizers cause algal blooms and eutrophication in stream waters.

- Inspection of holding tanks and septic tanks should be carried out to locate leaky ones. This is particularly urgent in the reach between 3.0 and 5.5 miles upstream of the Canyon mouth.

- A required program for periodic emptying of holding tanks and septic tanks need be instigated.

- Buffer strips along Emigration Creek and its tributaries should be required and maintained to allow for better detention and decay of pollutants. Such strips will also serve to keep sources of pollution (people, animals, traffic, construction, etc.) away from streams.
- Roads, road cuts and developments should be so planned and designed that erosion during construction and operation does not occur into streams.
- Stormwater systems need be planned and designed for new developments to prevent discharge, floods and the flushing of soil and pollutants into nearby streams.
- Off-road vehicle traffic need be restricted. It should not be allowed where trails cross streambeds and cause erosion into streams or tributaries. Revegetation of some dirt roads, road cuts and trails should be considered.

Pollution Mitigation Implementation:

Continuing development in Emigration Canyon appears to be on a collision course with the anti-degradation clause in the Utah Water Quality Standards. To prevent further degradation of the water quality in Emigration Creek the developers, Canyon residents, Emigration Canyon Improvement District and Salt Lake County Division of Water Quality and Water Pollution Control need agree on a cooperative water pollution mitigation program and its mode of implementation.

It is recommended that Salt Lake County Division of Water Quality and Water Pollution Control propose water pollution mitigation measures regarding stormwater collection systems, water supply systems, road placement, buffer zones and general construction techniques in Emigration Canyon. Such measures should become part of a construction guidance program for Emigration Canyon in addition to the existing restrictions on holding tanks, septic tanks, etc.

It is also recommended that Emigration Canyon Improvement District be responsible for; (1) a general Emigration Creek cleanup, (2) establishment and enforcement of domestic animal regulations, (3) establishment and enforcement of streamwater use and withdrawal regulations, (4) establishment and enforcement of disposal system maintenance regulations, and (5) operation of a minimum streamflow program, (6) establishment of off-road vehicle regulations, and (7) construction guidelines for prevention of erosion.

In the end it is the Canyon residents, landowners and developers who must show the interest and be willing to pay for the efforts necessary to maintain a satisfactory Canyon environment. An awareness and participation program on water pollution need be organized for these citizen.

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BASIC Computer Program

```
00 ∂ PROGRAM CANYON
1  ∂ WRITTEN BY MARY WEST
20 ∂ NOVEMBER 24, 1980
30 ∂
4  ∂ THIS PROGRAM SIMULATES THE COLIFORM LOAD IN
5  ∂ EMIGRATION CREEK.
60 ∂
70 PRINT 'THIS PROGRAM GIVES THE POLLUTION LOAD IN EMIGRATION'
8  PRINT 'CREEK.  INPUT DATA WHEN REQUESTED.'
9  PRINT
00 PRINT
1  ∂
2  ∂
30 ∂ ___VARIABLE, INDEX AND ARRAY IDENTIFICATION___
240 ∂
25 ∂
26 ∂ A(J)  NUMBER OF ADT-MILES IN EACH SECTION
270 ∂ B(J)  AREA OF SECTION IN SQU. FT. (BACKGROUND POLLUTION)
280 ∂ C  RETARDATION COEFFICIENT FOR OVERLAND SURVIVAL
29 ∂ C(1,J)  COMBINED SURVIVAL RATE (HOUSES TO CREEK)
30 ∂ C(2,J)  COMBINED SURVIVAL RATE (ROAD TO CREEK)
310 ∂ C1  HOUSING AND CONST. COEFF. (#/SQU.FT./DAY)
32 ∂ C2  PEOPLE AND ANIMAL COEFFICIENT (#/PERSON/DAY)
33 ∂ C3  TRAFFIC COEFFICIENT (#/ADT-MILE)
340 ∂ C4  SEPTIC TANK COEFFICIENT (#/SEPTIC TANK/DAY)
350 ∂ C5  BACKGROUND POLLUTION COEFFICIENT
36 ∂ D  DURATION OF RAINFALL FOR MONTH IN DAYS
37 ∂ D(J)  COLIFORM LOAD IN EACH SECTION (#/DAY)
380 ∂ E(J)  C1*H(J)*O(1,J)
390 ∂ F(J)  FRACTION OF COLIFORM LOAD IN EACH SECTION
40 ∂ G(1,J)  GROUNDWATER SURVIVAL (HOUSES TO CREEK)
41 ∂ G(2,J)  GROUNDWATER SURVIVAL (ROAD TO CREEK)
420 ∂ H(J)  AREA OCCUPIED BY HOUSING AND CONST. (SQU.FT.)
43 ∂ I  RAINFALL INTENSITY (IN./HR.)
44 ∂ J  SECTION NUMBER
450 ∂ K  PERMIABILITY COEFFICIENT (DAY*-1)  V=KS
460 ∂ K1  OVERLAND COEFFICIENT  K1=2.5EXP(-.092(20-T))
46 ∂ K(J)  FLOW IN CFS
47 ∂ L(1,J)  LENGTH FROM SEPTIC TANKS TO CREEK
480 ∂ L(2,J)  LENGTH FROM ROAD TO CREEK (FT.)
490 ∂ L(3,J)  STREAM LENGTH IN SECTION (MI.)
50 ∂ M(J)  C2*P(J)*O(1,J)
51 ∂ N(J)  C4*W(J)*G(1,J)
520 ∂ O(1,J)  OVERLAND SURVIVAL (HOUSES TO CREEK)
53 ∂ O(2,J)  OVERLAND SURVIVAL (ROAD TO CREEK)
55 ∂ P(J)  NUMBER OF PEOPLE AND ANIMALS
560 ∂ Q(J)  C3*A(J)*O(2,J)
570 ∂ R(J)  C5*B(J)
58 ∂ S(1,J)  GROUNDWATER SLOPE (HOUSES TO CREEK)
59 ∂ S(2,J)  OVERLAND SLOPE (ROAD AND HOUSES TO CREEK)
600 ∂ S(3,J)  STREAM SURVIVAL
61 ∂ T  AIR TEMP. IN DEGREES CELSIUS
62 ∂ T1  SOIL TEMP. IN DEGREES CELSIUS
630 ∂ T(1,J)  GROUND TEMP. IN DEGREES CELSIUS
640 ∂ T(2,J)  OVERLAND TIME (MIN) T=41B(L**2/3)/I**2/3)
65 ∂ T(3,J)  OVERLAND TIME (MIN) ROAD TO CREEK
66 ∂ T(4,J)  STREAM SURVIVAL TIME (MIN)
670 ∂ V(J)  VELOCITY OF STREAM (FT/SEC)
680 ∂ W(J)  NUMBER OF SEPTIC TANKS IN SECTION
69 ∂ Y(J)  LOAD DIFFERENCE
6 ∂ Z(J)  TOTAL LOAD TO THAT POINT
```

```
1280 FOR J=1 TO 16 LET T(1,J)=12
1290 PRINT
1291 PRINT 'INPUT THE STREAM VELOCITY (IN FT/SEC) FOR EACH SECTION'
1292 FOR J=1 TO 16
1293 PRINT J;'?'
1294 INPUT V(J)
1295 NEXT J
1300 FOR J=1 TO 16 READ V(J)
1310 DATA .75,.7,.65,1.05,1,.7,.6,.45
1311 DATA .7,.8,.7,.4,.5,.75,1,.75
1320 FOR J=1 TO 16 READ W(J)
1330 DATA 0,0,0,43,15.33,.33,43,7,13,18.7,23.3,9,19,5.33,12,2.7
1340 @
1350 @
1360 @___CALCULATION OF RESULTS___
1370 @
1380 @
1390 @ CALCULATE GROUNDWATER SURVIVAL FROM SEPTIC TANKS TO CREEK
1400 @
1410 FOR J=4 TO 16
1420 LET G(1,J)=EXP(-.85*L(1,J)/K/S(1,J)*EXP(-.092*(14-T(1,J))))
1430 NEXT J
1440 FOR J=1 TO 3 LET G(1,J)=0
1450 @
1460 @ CALCULATE OVERLAND FLOW SURVIVAL (HOUSES TO CREEK)
1470 @
1480 LET K1=2.5*EXP(-.092*(20-T))
1500 FOR J=4 TO 16
1510 LET T(2,J)=((41*(L(1,J)/S(2,J))**(1/3))/I**(2/3)*(.0007*I+C))/1440
1520 LET O(1,J)=EXP(-K1*T(2,J))
1530 NEXT J
1540 FOR J=1 TO 3 LET O(1,J)=0
1550 @
1560 @ CALCULATE COMBINED SURVIVAL RATE (HOUSES TO CREEK)
1570 @
1580 FOR J=1 TO 16
1590 LET C(1,J)=(D*O(1,J)+(30-D)*G(1,J))/30
1600 NEXT J
1610 @
1620 @ CALCULATE ROAD TO CREEK GROUNDWATER SURVIVAL
1630 @
1640 FOR J=1 TO 16
1650 LET G(2,J)=EXP(-.85*L(2,J)/K/S(2,J)*EXP(-.092*(14-T(1,J))))
1660 NEXT J
1670 @
1680 @ CALCULATE ROAD TO CREEK OVERLAND SURVIVAL
1690 @
1700 FOR J=1 TO 16
1710 LET T(3,J)=((41*(L(2,J)/S(2,J))**(1/3))/I**(2/3)*(.0007*I+C))/1440
1720 LET O(2,J)=EXP(-K1*T(3,J))
1730 NEXT J
1740 @
1750 @ CALCULATE ROAD TO CREEK COMBINED SURVIVAL RATE
1760 @
1770 FOR J=1 TO 16
1780 LET C(2,J)=(D*O(2,J)+(30-D)*G(2,J))/30
1790 NEXT J
1800 @
1810 @ CALCULATE STREAM SURVIVAL
1820 @
1830 FOR J=1 TO 16
1840 LET T(4,J)=L(3,J)*5280/V(J)/86400
1850 LET S(3,J)=EXP(-2.5*EXP(-.092*(20-T(1,J)))*T(4,J))
1860 NEXT J
```

PROGRAM

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00100 @ PROGRAM TSS
00110 @ WRITTEN BY MARY WEST
00120 @ JUNE 26, 1981
00130 @
00140 @ THIS PROGRAM GIVES SEDIMENT LOAD AND CONCENTRATION
00150 @ IN EMIGRATION CREEK.
00160 @
00170 PRINT
00180 PRINT
00190 @
00200 @
00210 @---VARIABLE, INDEX AND ARRAY IDENTIFICATION---
00220 @
00230 @
00240 @ C6  TSS CONSTRUCTION COEFFICIENT (LB/SQ FT/DAY)
00250 @ C7  TSS PEOPLE AND ANIMAL COEFFICIENT (LB/PERS/DAY)
00260 @ H(J)  AREA OCCUPIED BY CONST. AND DIRT ROADS (SQ FT)
00270 @ J INDEX
00280 @ K2 IN STREAM SEDIMENT RATE COEFFICIENT
00290 @ K(J) FLOW (CFS)
00300 @ L(3,J) STREAM LENGTH IN SECTION (MI.)
00310 @ M(1,J) SECTION LOAD (LB/DAY)
00320 @ M(2,J) TRIBUTARY LOAD (LB/DAY)
00330 @ P(J) NUMBER OF PEOPLE AND ANIMALS IN SECTION
00340 @ S(2,J) OVERLAND SLOPE
00350 @ S(4,J) STREAM SEDIMENTATION OR EROSION RATE
00360 @ T(4,J) STREAM SURVIVAL (MIN)
00370 @ V(J) VELOCITY (FT/SEC)
00380 @ Z(1,J) TOTAL TSS LOAD (LB/DAY)
00390 @
00400 @
00410 @DIMENSION ARRAYS
00420 @
00430 @
00440 DIM H(16),K(16),L(3,16),M(2,16),P(16)
00450 DIM S(4,16),T(4,16),V(16),Z(1,16)
00460 @
00470 @
```