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STRUCTURAL SPECIFICATIONS AND CONSTRUCTION OF A CANAL SYSTEM FOR GRAVITY IRRIGATION

By:

W. R. Gwinn, T. K. Gates, Abdel Raouf Hassan,

Esmat Wafik and E. Nielsen

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EWUP PROJECT TECHNICAL REPORT NO. 51

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ABSTRACT

A water delivery system in Middle Egypt was renovated to provide controlled gravity flow for more efficient distribution and use of irrigation water. After thorough planning and design, structural specifications were prepared for watercourse renovation, hydraulic control structures, internal access roads, and land leveling. Contracts were awarded and construction was initiated. The effort to perform extensive renovation of a water delivery system at the farm level required an experimental approach to develop the best methods for quality construction with the least disruption to farming practices and irrigation schedules. A summary of the specifications, the contracts and costs, the construction procedures, and recommendations for future work were prepared.

ملخـــــــــص

لقد تم تجديد احدى شبكات توزيـــع مياه الرى فى مصر الوسطى بمـــا يوفر التحكم فى الرى بالراحة بهدف الوصول الى اعلى كفاءة فى استخدام وتوزيع مياه الرى . وبعد التخطيط الهندسى الدقيق ، تم عمل مواصفـــات انشائية لتجديد المجارى المائية ونقط التحكم الهيدروليكية والطـــرق الداخلية وتسوية الأراضى . وقد تم بالفعل توقيع العقود وبدأ تنفيـــذ الانشاءات . أما على المستوى الحقلى فقد وجد أن عملية التجديد هـــذه تتطلب تجربة افضل الطرق لاقامة الانشاءات مع اقل تدخل فى نظم الزراعـــة والرى السائدة . ويعرض البحث ملخصا للمواصفات والعقود والتكاليـــف ومراحل الانشاءات والتوصيات لمرحلة العمل المقبلة .

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STRUCTURAL SPECIFICATIONS AND CONSTRUCTION OF A CANAL SYSTEM FOR GRAVITY IRRIGATION

By
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Esmat Wafik, and Erwin Nielsen

Introduction

The Abyuha region is located approximately 17 km south of El-Minya in Middle Egypt. The region's source of irrigation water is the Ibrahimiya canal, the longest and largest canal in Egypt. Here, the Egypt Water Use and Management Project (EWUP) undertook the renovation of the Abyuha distributary canal system that serves approximately 1200 *feddans* of cultivate land (Figure 1). The objectives of the renovation were:

1) Distribute adequate flow rates under force of gravity for efficient irrigation and eliminate the need for lifting water;

2) Improve control of water delivery for irrigation scheduling among farmers and for reduced water losses to the drains; and

3) Facilitate farm mechanization by increasing the length of field strips and providing farm roads for internal access.

System Planning and Design

The system renovation planning was an interdisciplinary research effort to provide good irrigation practices for the site. The hydraulic design for the Abyuha system is only briefly discussed in this report. A more detailed discussion of the hydraulic design using a computer model is given in Gates et al (1984a).

A series of farmer interviews were launched by the senior EWUP sociologists together with the EWUP-Abyuha field team in May, 1979. Many of the farmers commented on unfavorable conditions of the private *mesqas* (farm channels). Weeds in the *mesqas* sometimes prevented water from reaching the mid and far reaches of the *mesqas* with sufficient quantity or head to provide good irrigation. Others claimed the slope of the *mesqas* favored those at the lower end who could take water by gravity any time they want it while those at the head must wait. The low head required inefficient lifting to provide the flow of water to the field. This was necessary in the *mesqas* located on the lower half of the canal. Inadequate control of flow at the inlets and outlets of the *mesqas* resulted in excessive flow to the drains and shortage of water along the lower end of the canal.

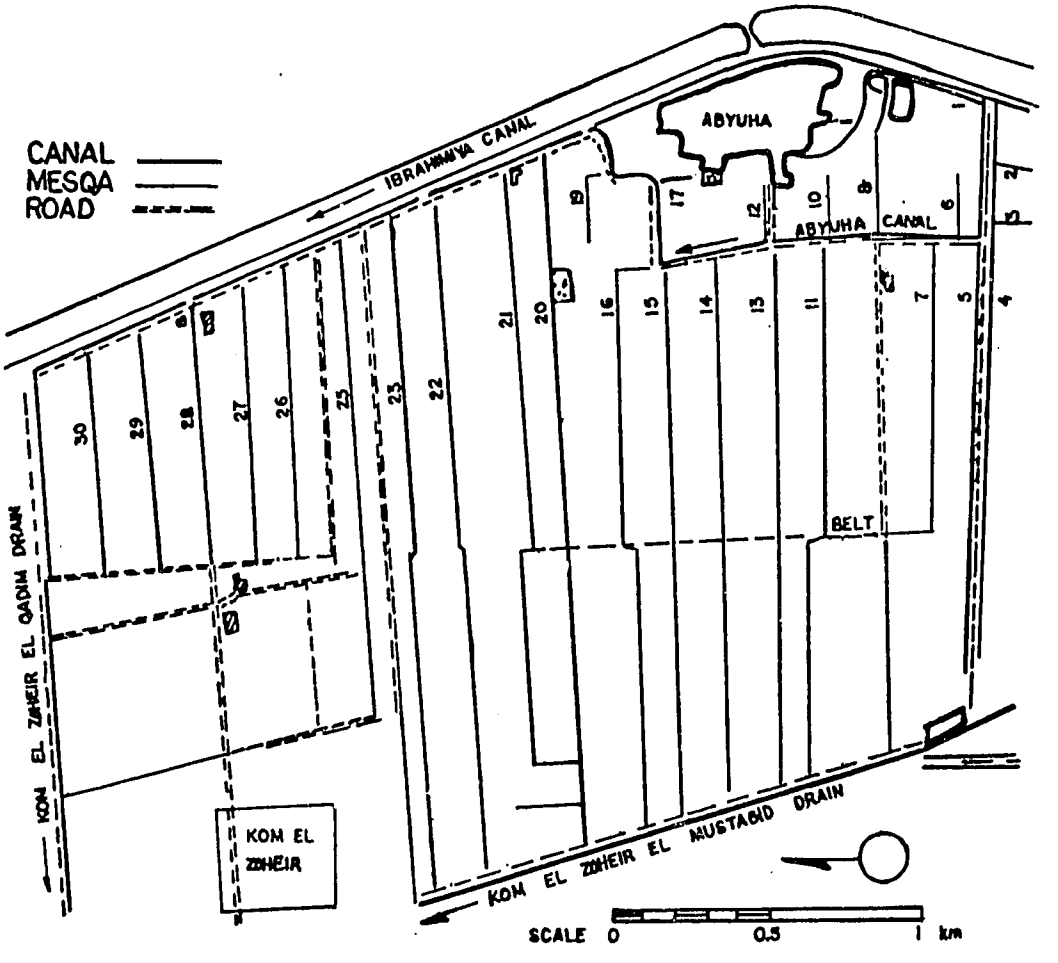


Figure 1. Abyuha EWUP Field Site Near El-Minya, Egypt.

Small flow rates at the field turnouts were a major problem with the system. A study of the water levels in the Ibrahimiya canal showed that head needed for adequate flow rates would be available during most of the year if the banks of the Abyuha canal were raised, the channels were improved, control gates and adequately sized *mesqa* inlet pipes were installed, and a flow rotation system among the *mesqas* was followed.

The flow of water in open channels is controlled by friction or energy loss which resists the pull of gravity. The criteria for design is the shape and size of channel for the desired flow rate, available energy slope and the design roughness coefficient, n. The value of n will depend on the expected level of maintenance of the channel. A Manning n value of 0.04 was selected for design. Also, a good maintenance condition with n = 0.03 and poor maintenance condition with n = 0.06 in the canal and n = 0.08 in the *mesqas* were studied for their effects on the system. Design slopes for channels are dependent on the following factors:

1) The required flow rate and water surface elevation to adequately irrigate each field,
2) The elevation of the water supply source,
3) The channel layout and the topography around the channels,
4) Head losses in the system, and
5) Limiting velocities in the channels.

These factors were considered in the design of the new system.

The required water surface elevation for a field of berseem (clover) was determined to be 12 cm above the ground surface. This was chosen as the minimum depth required to adequately irrigate each field. The elevation of the Ibrahimiya controls the water supply source. This varied from a maximum in August (elevation 41.5 m) to a minimum in December (elevation 40.8 m). For purpose of design, it was assumed that the levels in the Ibrahimiya canal would remain at last as high as those recorded in 1980.

The channel layout remained approximately the same with only minor changes to provide better alignment and to stay within established boundaries.

The soils in the Abyuha area are classified as vertisols or hydrated clay soils. Infiltration over an extended period of time is greatly reduced and approaches zero because of soil swelling. Therefore, lined ditches were not required to reduce seepage losses. For unlined channels in clay soils it has been suggested that the maximum flow velocity be limited to 1.14 m/s and the side slope, Z, be between 1 and 1.5 (Chow, 1959). A Z value of 1 was chosen for both the canal and *mesqas*. The maximum flow velocity was not a limiting factor in the design because of the low slopes used in the canal and *mesqas*.

The areas of each crop at Abyuha were measured during the period of 1980 through 1982 (Helal, et al, 1984) and these areas multiplied by the depth of water requirement to determine the volume of water needed for crop consumptive use for each month. The maximum volumes of consumptive use determined for each month were used for the design. Added to these volumes were estimated volumes of water required for land preparation (planting irrigations). Dividing the sum by the overall efficiency of the system (estimated as 0.63, the product of a conveyance efficiency of 0.90 and application efficiency of 0.70) provided the estimate of the water volume to be diverted into the Abyuha canal each month.

The average required flow rate into the Abyuha canal was calculated by dividing the monthly volume by the flow duration during the month and increasing the result by 10% to compensate for time losses expected from changing irrigation rotations along the canal and *mesqas*. An earlier study indicated that an acceptable system would be flow every day for 12 hours (daytime). For the Abyuha canal the required flow rates ranged from 250 liters per second in October to 1500 liters per second in July.

In order to have flow rates large enough for good irrigation application efficiency, the flow in the distributary canal was to be diverted to successive groups of *mesqas*, each group receiving water in turn. If the average total flow rate was small the number of *mesqas* in the group was to be small. For example, in October a flow of about 250 liters per second was to be diverted to *mesqas* serving one-fifth of the area. Each *mesqa* in the group was to receive five times its aliquot flow rate for one-fifth of the time. In July, when the flow rate was to be about 1500 liters per second, the *mesqas* were to be divided into two groups for receiving flow. For other months the rotations were set to meet the need.

Structural Specifications

Watercourses

A mathematical system model was employed to determine the hydraulic parameters for the canal and each of the *mesqas*. Details of the model and its use in the design are covered in Gates, et al (1984a). Structural specifications for the watercourses were based upon hydraulic design, professional standards for watercourse construction and local customs and preferences.

Abyuha Canal: The bottom of the canal at the entrance was set at elevation 39.9 m and at the exit was set at 39.5 with a constant slope of 0.0001. The side slope was 1 to 1 with a bottom width of 3 m from 0.0 km to 2.260 km, 2 m from 2.260 km to 3.200 km, and 1.5 m from 3.200 km to 4.080 km (end of the canal). The banks were 1.6 m to 1.7 m above the canal bottom. The canal contained five bends and four bridges that were part of the original canal. The plan and cross-sections of the canal are given in Appendix A.

Pitching (grouted rip-rap) was used along the slopes of the bends and on sections requiring earth fill to prevent widening of the canal. A typical pitching cross-section for one side is shown in Figure 2. The stone used for pitching should be dense and hard enough to withstand exposure to air and water and should be well graded with a minimum diameter of 10 cm. Table 1 lists the location and volume of pitching used in the canal. The stone that was to be was reasonably well graded in size and hand placed to produce a relatively smooth surface with the joints grouted at the surface.

The specified width of banks for the canal varied along its length. In all cases the bank width was great enough to prevent seepage to the agricultural land following the Ministry of Irrigation practice of assuming a 1 (vertical) to 7 (horizontal) slope of the seepage line in silty clay soils. A road of 4.0 m width was specified along the left bank. The road formed the left bank until station 0.400 km. At this point the top width of the left bank beside the canal was reduced to 1.0 m and the road followed beside at a lower elevation. The top width of the right bank was specified as 2.0 m to about station 2.000 km. From this station to the end of the canal the right bank was formed by the west bank of the road along the Ibrahimiya canal.

Mesqas: The design bottom width was 35 cm and the side slope was 1 to 1 for all *mesqas*. The bottom slope varied from 0.0002 to 0.0004. Design depths varied from 51 cm to 126 cm. The freeboard height of banks was 20 cm. The bank top width was 60 cm with an outside slope of 1.5 to 1. These dimensions are given in Table 2 and illustrated in Figure 3. The *mesqas* were to retain their existing layout with only slight straightening. This was because any significant change would result in some farmers losing land while others gained land.

Hydraulic Structures

The specifications for internal hydraulic structures were determined with the assistance of the mathematical system model. A design objective was to minimize the number of structures because of the low available head.

Headworks: The entrance to the Abyuha canal remained the same with the exception of changing the headgate. The original headgate consisted of stop logs in an arch-type masonry bridge shown in Figure 4. These stop logs leaked and a complete closure was not possible. They were to be replaced with a Fahmi Henein sluice gate to allow a complete closure as well as a regulated control of the flow to the canal. The sluice gate was to be calibrated and equipped with upstream and downstream water level recorders for flow measurement.

Table 1. Abyuha Canal Pitching (grouted rip-rap)

Table 1. Abyuha Canal Pitching (grouted rip-rap).			
Beginning Sta.* (km)	Ending Sta. (km)	Length (m)	Volume (m^3)
0.000 L	0.040 L	40	62.38
0.040 L	0.130 L	90	148.72
0.290 L	0.341 L	51	87.21
0.405 L	0.481 L	76	127.68
0.450 R	0.485 R	35	58.80
0.725 L	0.769 L	44	85.24
0.8685 R	0.887 R	18.5	31.45
0.911 L	0.927 L	16	27.36
0.960 R	0.976 R	16	27.36
1.050 L	1.092 L	42	71.82
1.050 R	1.092 R	42	71.82
1.420 L	1.487 L	67	113.90
1.463 R	1.525 R	62	107.10
1.545 R	1.563 R	18	30.60
1.577 R	1.588 R	11	18.70
1.610 R	1.642 R	32	54.40
1.613 L	1.623 L	10	17.00
1.630 L	1.638 L	8	13.68
1.663 L	1.696 L	33	56.10
1.663 R	1.703 R	40	68.00
1.818 L	1.885 L	67	114.57
1.937 L	1.981 L	44	81.40
1.937 R	2.008 R	71	115.49
2.153 L	2.186 L	33	43.04
2.322 L	2.334 L	12	21.82
2.537 L	2.5635 L	26.5	43.07
3.506 L	3.561 L	55	83.98
TOTAL		1060.0	1782.69

* L indicates left side and R indicates right side

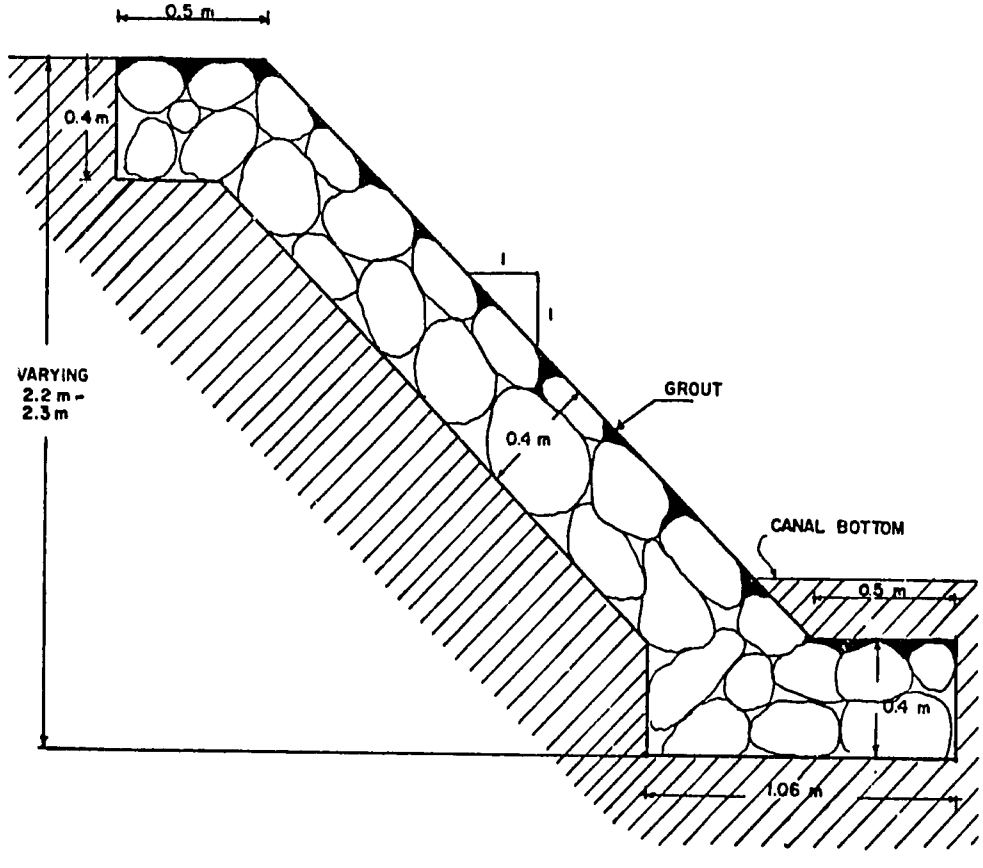


Figure 2. Typical Pitching Cross-Section

Table 2. Summary of Channel Design Parameters for Mesqas on Abyuha Canal.

Mesqa No.	Discharge Q (l/sec)	Length (m)	Bottom Slope (m/m)	Design Depth (cm)	Bottom Elevation at End (m)
1	30	550	0.0004	82	40.20
3	30	180	0.0002	80	40.10
4	225	1400	0.0002	109	39.65
5	175	1400	0.0002	101	39.67
6	30	200	0.0002	88	40.12
7	225	875	0.0003	102	39.77
8	40	255	0.0003	82	40.13
10	30	1550	0.0003	57	40.29
11	276	182	0.0002	112	39.34
12	30	275	0.0002	57	40.36
13	140	1640	0.0003	88	39.52
14	300	1650	0.0003	115	39.27
15	150	1650	0.0003	90	39.48
16	250	1850	0.0003	108	39.38
17	30	110	0.0002	51	40.44
19	30	260	0.0003	59	40.28
20	200	2110	0.0003	118	39.27
21	156	1895	0.0003	105	39.42
22	286	2085	0.0003	126	39.10
23	192	2080	0.0003	116	39.16
25	80	985	0.0003	103	39.68
26	100	850	0.0002	80	40.07
27	104	802	0.0003	102	39.77
28	72	780	0.0003	96	39.94
29	72	670	0.0003	93	39.85
30	88	600	0.0002	94	39.86

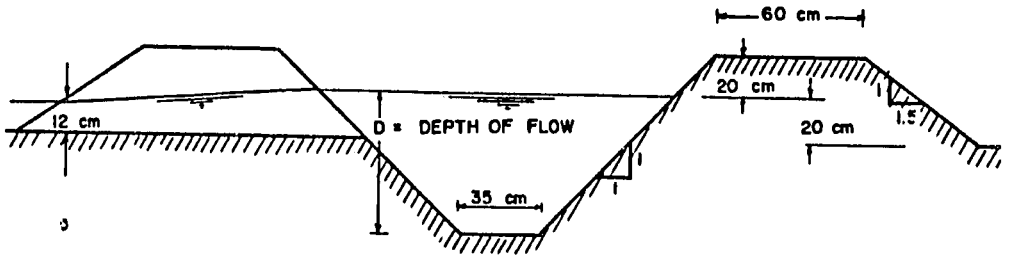


Figure 3. Mesqa Design Cross Section.

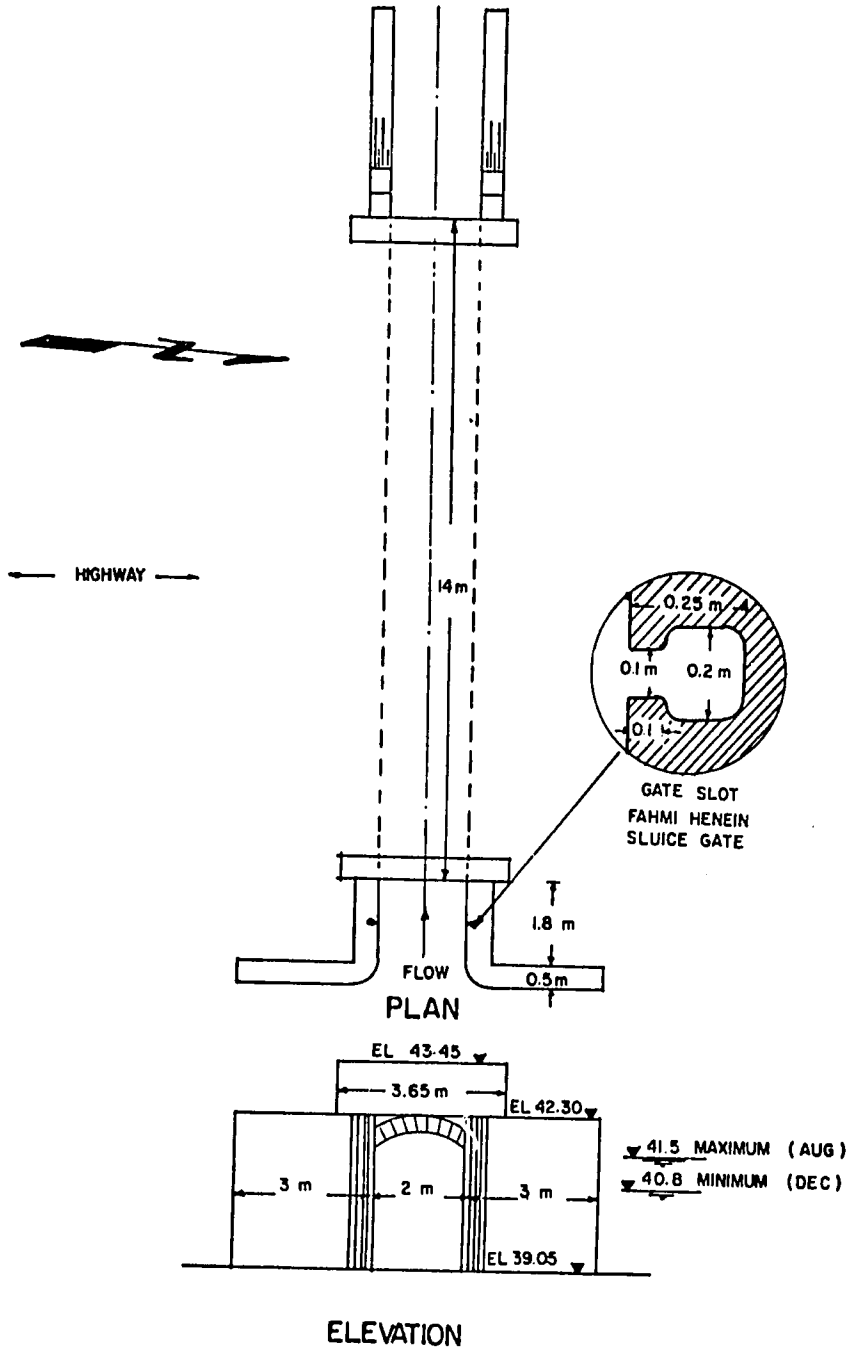


Figure 4. Arch-Type Masonry Bridge Inlet to Abyuha Canal.

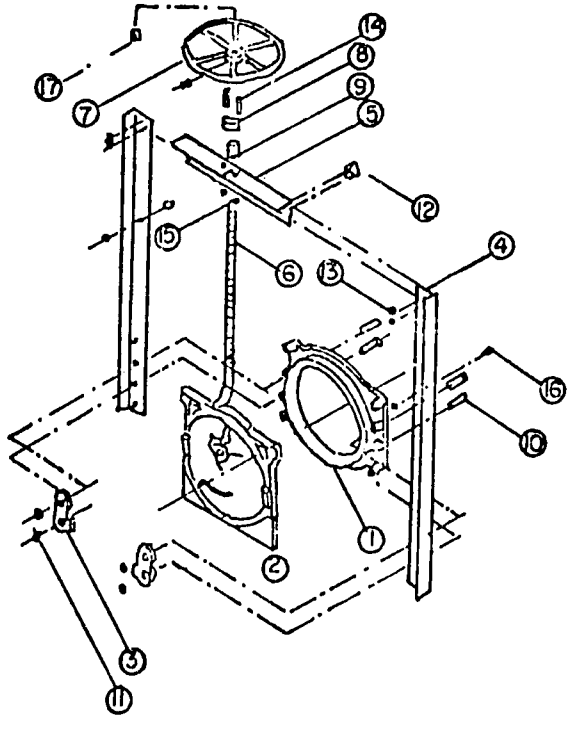
The flow from the canal to the *mesqas* and to direct irrigation turnouts was designed to be controlled with a square-bottom metergate (Figure 5) patterned after Waterman Industries Inc. Model CL-10. Such gates need to have a minimal leakage when closed, minimal obstruction when open, be easy to open and close, and simple to construct and install. These gates were to be mounted on a masonry wall and flush with concrete pipes that convey the flow under the canal bank road. The gate sizes were limited to four sizes to minimize the cost of manufacturing. The manufacturing of these gates represented a new industry in Egypt. The gate sizes and the pipe dimensions are given in Table 3.

Check Structures: The *mesqas* at Abyuha required check structures for controlling water surface levels to provide adequate gravity flow through field turnouts. Check structures were located so that 20 cm head would be available for irrigation at any point downstream of the last open check structure on the *mesqa* without causing the water surface to rise higher than 10 cm below the bank top elevation at any point. Thus, starting from the downstream end of the *mesqa* a check was to be constructed at approximately every 10 cm rise in land elevation upstream.

Three types of check structures were prepared for use on the *mesqas*: ordinary masonry check walls with gates, bridge checks with gates, and outlet check structures to be installed at the ends of the *mesqas*. Sketches of the ordinary check walls and bridge checks with pertinent dimensions are shown in Figures 6 and 7. The location type, and dimensions of ordinary check walls and bridge checks are given in Tables 4 and 5 for each *mesqa*. Outlet check structures are described below.

Outlet Check Structures: In addition to controlling water level the outlet check structure has two other purposes: (1) provide a drain for the channel at the end of irrigation, and (2) provide an emergency spillway in case all the turnouts are closed and the entrance flow is not shut off. Flow over a weir using part of the freeboard head was to be used for emergency spillage. These structures were needed for the canal and the *mesqas*.

The outlet of the Abyuha canal was to the Kom El-Zoheir El-Qadim drain. A pipe outlet structure was needed to provide flow under the road that paralleled the canal. The control on the drain was an arch-type bridge located 1920 m downstream of the canal outlet. The flow under this bridge was assumed to be at critical depth. Water surface elevations were computed for each 200 m using a standard-step method and field survey of the cross-sections for the peak design discharge of 1.5 m^3/s. The lush grass (80-60 cm in length) in the drain was assumed to have a B class retardance (Palmer, 1947). The resulting water surface elevation for the drain at the outlet of Abyuha canal was 40.25 m. The design water level for the canal



1. FRAME
2. COVER
3. WEDGE (R&L)
4. GUIDE RAIL (R&L)
5. HEAD RAIL
6. STEM
7. HANDWHEEL
8. THRUST COLLAR
9. LIFT NUT
10. WEDGE BOLT
11. WEDGE NUT
12. FRAME BOLT
13. FRAME NUT
14. COLLAR BOLT
15. COLLAR NUT
16. STOP BOLT & NUT
17. LIMIT NUT

Figure 5. Head Gate for *Mesqa*.

Table 3. Summary of Mesqa and Turnout Sizes for Abyuha Canal.

Mesqa No.	Turnout No.	Abyuha Canal Sta.* (km)	Area Served (*fed*)	Gate Size (cm)	Pipe ID (cm)	Pipe Length (m)
1		0.000 R	10.0	30	20	6
	Ganabiya	0.000 L		50		
2		0.150 L	3.0	30		
3		0.402 L	5.0			
4		0.402 L	90.0	75	30(2)	6(2)
5		0.430 L	50.0	65	45	14
6		0.450 R	6.0	30	20	4
7		0.526 L	90.7	50	35(2)	7(2)
8		0.770 R	15.0	30	20	4
11		0.920 L	83.0	75	70	8
10		0.940 R	8.0	30	20	4
12		1.095 R	12.0	30	20	5
13		1.095 L	58.0	50	50	7
14		1.260 L	62.7	65	65	8
	1	1.265 R	2.5	30	20	
15		1.423 L	64.1	50	50	8
16		1.444 L	68.2	65	65	7
	2	1.470 R	2.3	30	20	
	3	1.564 R	3.5	30	20	
	4	1.564 L	5.0	30	20	
	5	1.600 R	2.8	30	20	
	6	1.642 L	2.5	30	20	
17		1.700 R	7.0	30	25	6
	7	1.716 R	2.3	30	20	
19		1.850 L	10.0	30	20	9
	8	1.880 R	2.0	30	20	
	9	1.880 L	2.5	30	20	
20		2.177 L	84.5	65	70	8
21		2.330 L	65.1	50	40	9
22		2.545 L	118.0	65	65	[illegible]
23		2.756 L	65.0	75	70	8
25		2.950 L	49.4	30	30	7
26		3.173 L	39.7	50	35	9
27		3.337 L	30.3	50	35	7
28		3.523 L	28.2	30	30	7
29		3.734 L	28.6	50	40	9
30		3.918 L	36.5	30	30	7

* L indicates the left side and R indicates the right side.

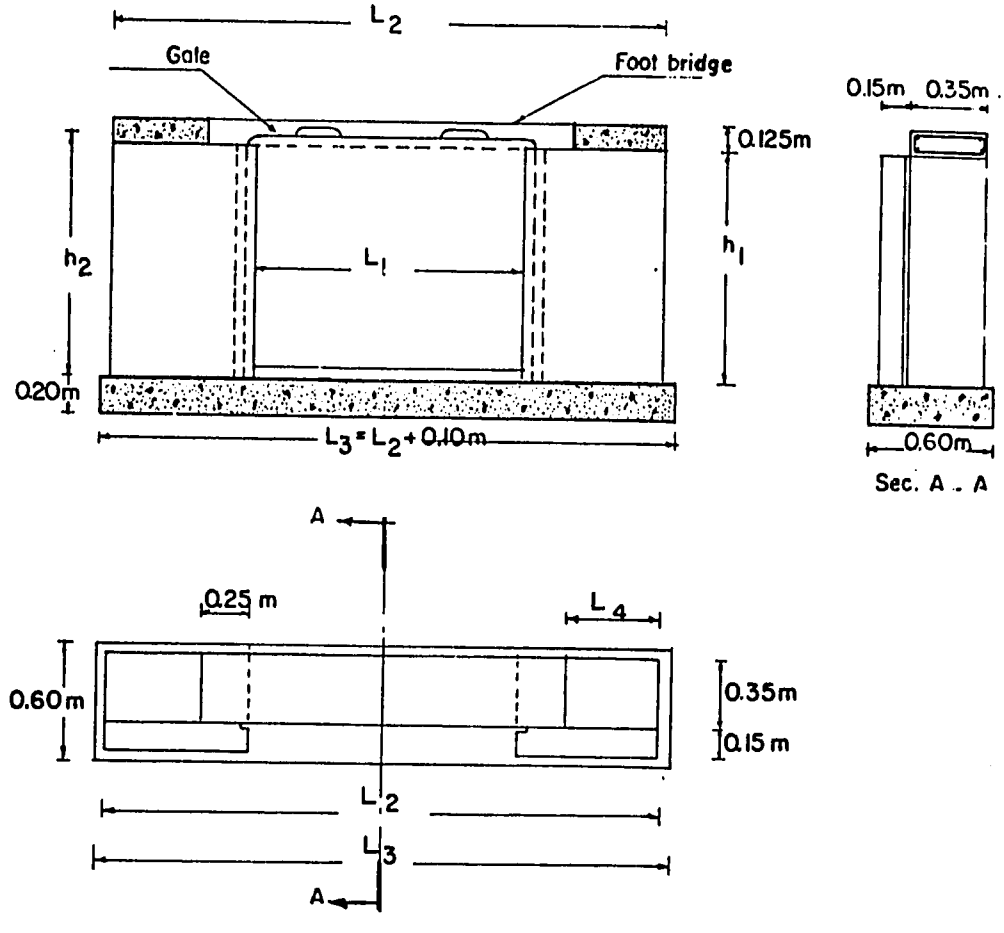


Figure 6. Ordinary Masonry Wall Check Structure with Gate for Mesqas (See Table 4 for Dimensions).

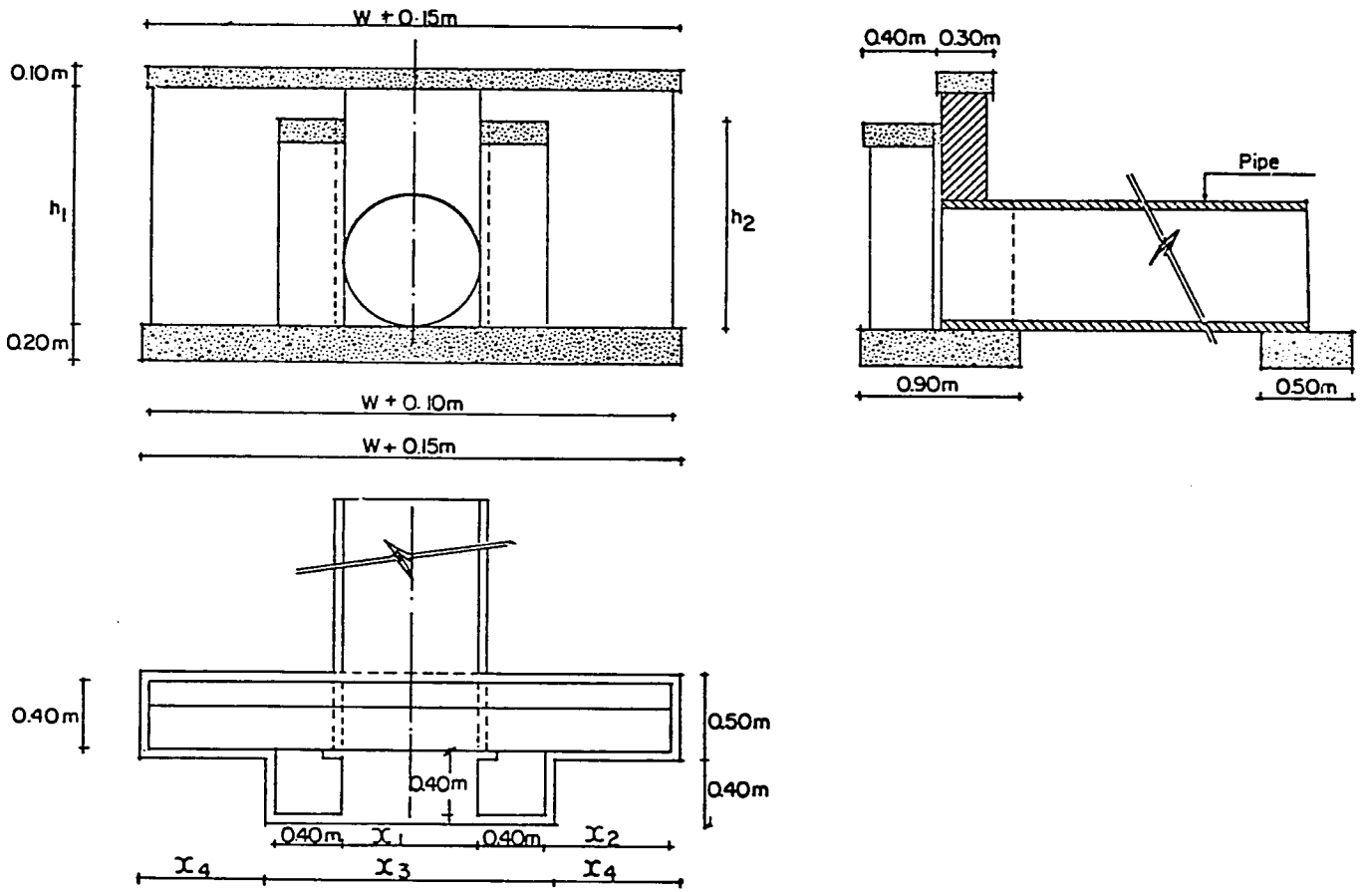


Figure 7. Bridge Check Structure.

was 41.00 m. Thus, with no submergence of the weir, the available head for pipe flow was 0.75 m. The required pipe diameter was 0.85 m using the following dimensions: pipe length = 9 m, pipe roughness = 0.003 m, kinematic viscosity = 1 x 10^{-6} m^2/s, discharge = 1.5 m^3/s, entrance loss coefficient K_1 = 0.8, and exit loss coefficient K_2 = 1.0. The length of weir, L, was determined using the following equation:

$$L = Q/[1.79 + 0.509 \, Log_{10} \, (H/T_c)] \, H^{1.5} \qquad (1)$$

Table 4. Dimensions for Ordinary Masonry Wall Check Structures in *Mesqas* (see Figure 6)

Mesqa No.	Dimensions (cm)				
	h(1)	h(2)	L(1)	L(3)	L(4)
1	72	77		200	
4	99	104	75	255	70.0
5	91	96	55	240	72.5
7	92	97	75	240	62.5
11A	102	107	70	260	75.0
11B	102	107	70	260	75.0
13	78	83	65	215	55.0
14	105	110	55	265	85.0
15	80	85	70	215	52.5
16	98	103	65	255	75.0
20	108	113	65	275	85.0
21	95	100	65	245	70.0
22	116	121	75	290	87.5
23	106	111	55	270	87.5
25	93	98	55	245	75.0
27	92	97	35	240	82.5
28	78	83	35	230	77.5
29	84	89	40	225	72.5
30	84	89	50	225	67.5

Table 5. Dimensions for bridge check structures (see Figure 7).

Mesqa Number	Dimensions (m)						
	W	h_1	h_2	x_1	x_2	x_3	x_4
1	1.99	0.82	0.46	0.40	0.45	1.30	0.55
4	2.53	1.17	0.63	1.00	0.41	1.90	0.51
5	2.37	1.02	0.56	0.80	0.44	1.70	0.54
7	2.39	1.03	0.57	1.00	0.35	1.90	0.45
11	2.58	1.12	0.61	1.00	0.44	1.90	0.54
13	2.11	0.88	0.50	0.85	0.28	1.75	0.38
14	2.65	1.15	0.63	0.90	0.53	1.80	0.63
15	2.16	0.90	0.51	0.90	0.28	1.80	0.38
16	2.51	1.08	0.60	0.90	0.45	1.80	0.56
20	2.71	1.18	0.65	1.00	0.51	1.90	0.61
21	2.46	1.05	0.58	0.90	0.43	1.80	0.53
22	2.87	1.26	0.68	1.00	0.59	1.90	0.69
23	2.68	1.16	0.63	0.90	0.54	1.80	0.64
25	2.41	1.03	0.57	0.80	0.46	1.70	0.56
27	2.38	1.03	0.57	0.55	0.57	1.45	0.67
28	2.27	0.96	0.53	0.55	0.51	1.45	0.61
29	2.21	0.93	0.52	0.55	0.48	1.45	0.58
30	2.23	0.94	0.52	0.55	0.49	1.45	0.59

Where

Q = discharge (m^3/s),
H = weir head (m), and
T_c = thickness of crest (m).

With T_c = 0.12 m and H = 0.2 m (freeboard head = 0.24), the computed L = 8.81 m. This equation applies to a quarter rounded crest with a radius of 0.5 T_c on the downstream side. Drainage of the canal was to be provided by the use of a circular concrete turnout or a slide gate. The final design is shown in Figure 8.

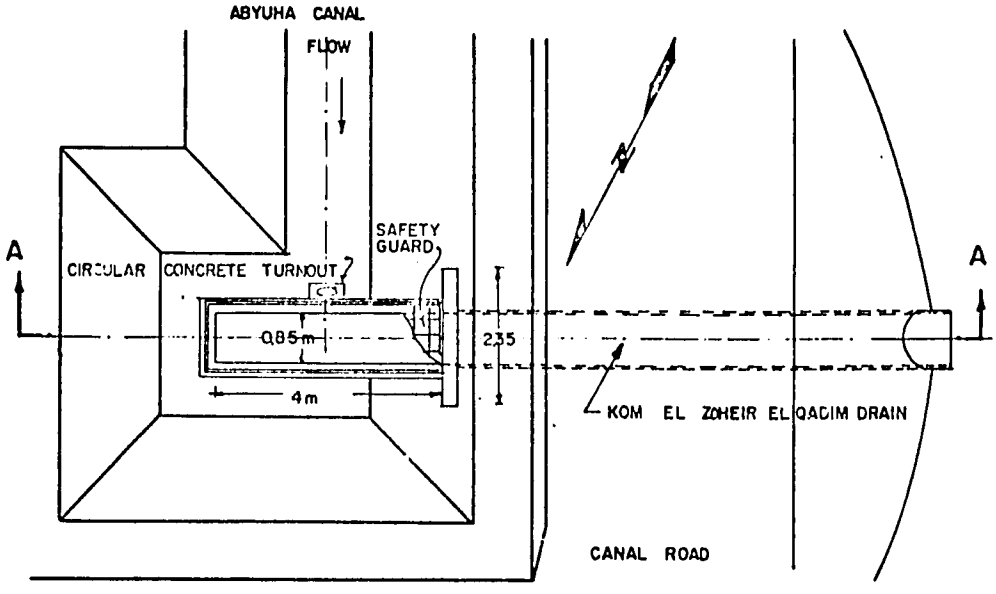
The outlet check structure to be used for the *mesqas* is shown in Figure 9. At the end of the *mesqas* that emptied into the Kom El-Zoheir El-Mustaged drain and private drain there was land available for a road. Therefore, a pipe outlet structure to pass the flow under the road was desirable. The pipe sizes were determined using the design discharges and field survey data on high water marks in the drain to determine the available head. The minimum weir lengths were computed using equation 1. The dimensions illustrated in Figure 9 are given in Table 6 for each *mesqa* with an outlet to a drain. *Mesqas* 1, 2, 3, 6, 8, 10, 12, 17, and 19 were to have a closed outlet because they did not drain (Figure 1).

Field Turnouts: Field turnouts are used to divert flow from the *mesqa* to the farm field. Several different types of field turnouts were to be installed for use on *mesqas* at Abyuha. These included ordinary bankcuts, poly vinyl chloride (PVC) pipes, reinforced concrete pipes and circular concrete turnouts.

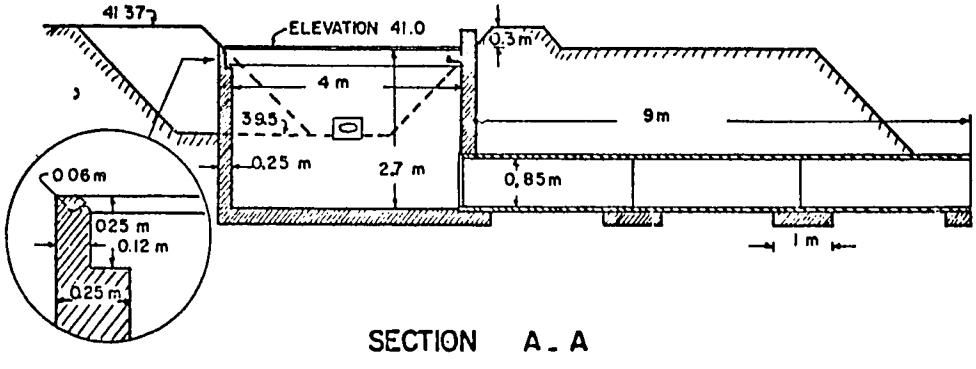
The bankcut is the common method used by farmers in the area. A small channel of about 20 to 30 cm width is dug through the bank with the bottom set at field level. After irrigation is complete, the bankcut is filled with mud. This method is effective, inexpensive, and requires very little head loss. However, with time it can cause erosion of banks.

As a relatively inexpensive alternative to bankcuts, PVC or reinforced concrete pipes were to be installed in selected *mesqas* at a spacing of about 50 m on each side. In contrast to reinforced concrete, PVC pipes are light in weight and easy to transport and install. It was determined that 20 cm diameter pipes would be adequate to pass the desired flow rates with little head loss. The pipes could be plugged with mud when not in use.

The circular concrete irrigation turnout developed in Pakistan (Trout, et al, 1981) was to be used on some *mesqas*. Molds and forms for these turnouts were fabricated in EWUP shops for a five-piece pre-cast culvert shown in Figure 10. The flow through this structure (diameter 28 cm) can be estimated using the following equation:



PLAN



SECTION A - A

Figure 8. Outlet Check Structure for Abyuha Canal.

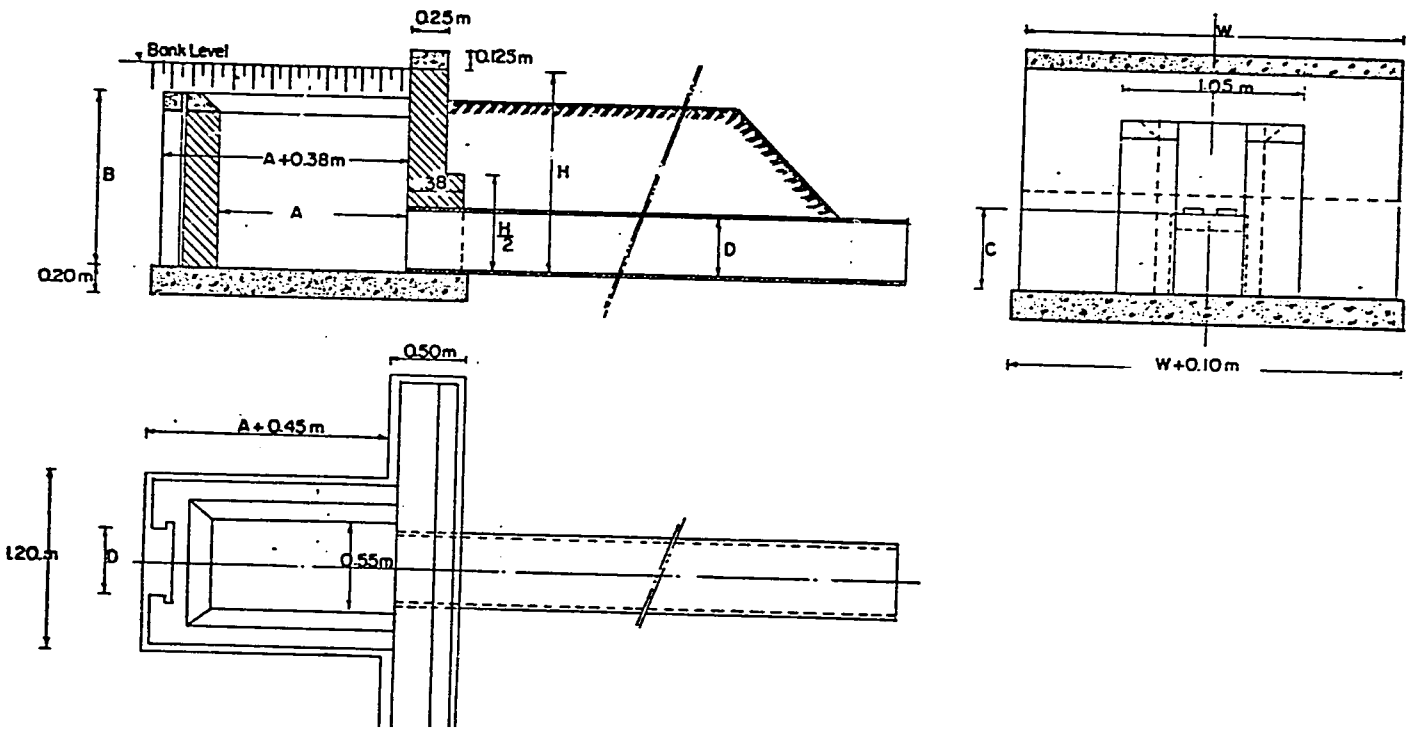


Figure 9. Outlet Check Structure for Mesqas (See Table 6)

Table 6. Dimensions for *Meaqa* Outlet Check Structures (see Figure 9)

Meaqa No.	Crest Elevation (m)	Dimensions (cm)					
		A	B	C	D	H	W
4	40.54	100	104	55	40	119	255
5	40.48	75	96	55	40	111	237
7	40.59	100	97	55	40	112	240
11A	40.26	50	107	55	40	122	260
11B	40.26	50	107	55	40	122	260
13	40.20	75	83	55	40	98	211
14	40.22	150	110	70	55	125	265
15	40.18	75	85	55	40	100	215
16	40.26	100	103	65	50	118	251
20	40.25	75	113	60	45	128	271
21	40.27	75	100	60	45	115	245
22	40.16	150	121	60	45	136	287
23	40.12	75	111	55	40	126	267
25	40.51	50	98	45	40	125	265
26	40.67	50	75	45	40	113	241
27	40.59	50	97	45	40	112	239
28	40.70	50	83	45	40	106	227
29	40.58	50	88	45	40	103	221
30	40.60	50	89	45	40	104	223

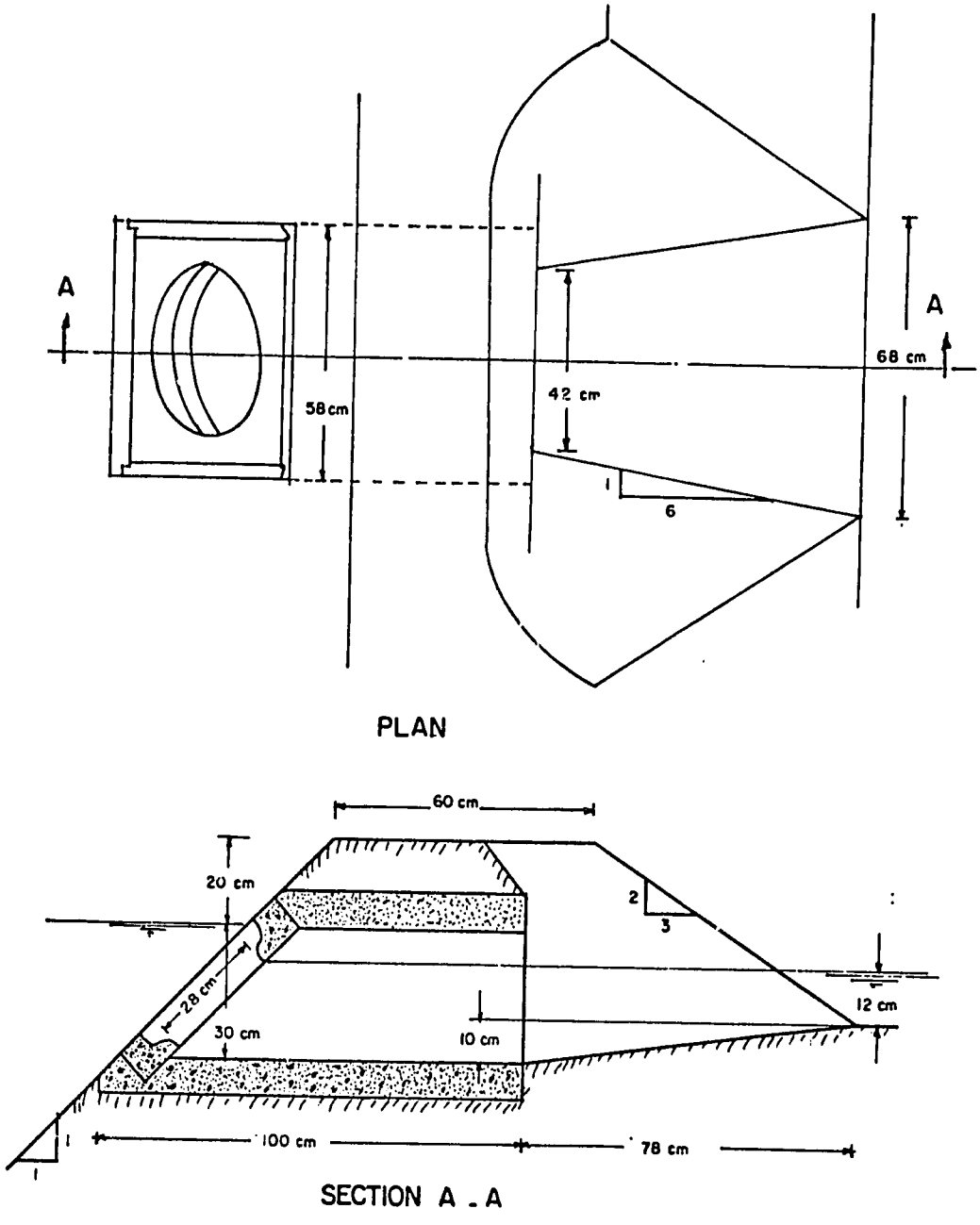


Figure 10. Circular Concrete Irrigation Turnout.

Table 7. Summary of Construction Costs for System Renovation at Abyuha.

Item	LE	LE/*feddan*
Water Delivery System		
Abyuha Canal	161500	147
Mesqas	51660	47
Subtotal	213160	194
Roads	7000	6
Land Leveling	33000	30
Total	253160	230

$$Q = 19 (h)^{(} \quad (2)$$

Where

Q = discharg(

h = differential head (cm)

With a differential head of 8 cm, the estimated flow is 54 *l*/s. This flow is shown graphically in Section A-A of Figure 10. With the tapering exit, the water surface will remain level with the field water surface.

Roads

Land area for perimeter roads is provided by government controlled areas along distributary canals and collecter drains. The road of 4 m width along the Abyuha canal was to be built within this government right of way.

To make the farms accessible to farm machinery and vehicles for transporting goods and produce. a long range plan was formulated for constructing internal access roads. After land leveling and watercourse improvement, *mesqas* 9, 13, 15, 24, 28, and 30 were to be eliminated and replaced by access roads. Farms affected by the elimination of *mesqas* would be irrigated by an adjacent *mesqa*. Roads were also to be constructed between the remaining *mesqas* by widening the existing border dykes at the ends of farms.

The roads were to be constructed of compacted soil at a height of 20 cm above the farm fields to make them usable during periods of irrigation.

Land Layout

The use of machinery to perform farming operations requires that fields be large enough to allow equipment to be easily maneuvered. Consequently, the small (typically 10 m by 10 m) basins traditionally used in Egypt are not easily adapted to mechanized farming. In Abyuha work was done with farmers to promote the use of larger field sizes by introducing systems of long (150 m - 200 m) level basin and long level furrow irrigation. In addition to facilitating the use of machinery in the field. the long border and long furrow layout, in conjunction with the larger flow rates provided by the improved gravity system. would allow irrigation of the entire field length from only one *mesqa*. This would allow *mesqas* at the opposite end of the fields to be replaced with roads.

The introduction of long level border and level furrow irrigation requires land leveling to insure uniform spreading and efficient application of water. In Abyuha plans were made to level farmer's fields to zero grade with a tolerance of $\pm$ 3 cm with no reverse slope. This leveling would be performed in coordination with the channel renovation work during the

periods between harvesting and planting. A thin layer of soil would be moved from the fields by land plane or bulldozer for use in filling the old *mesqas*. The land leveling operation would then be performed using tractors, scrapers, and land planes controlled either manually or by laser sending unit. Most farmers in Abyuha agreed to allow limited crossing of land ownership boundaries in the performance of earth moving and leveling, thus allowing easier movement of machinery in the field.

Contracting

Adly Youssef Darwish and Partners of El-Minya was awarded the contract for renovation of the Abyuha canal in April, 1982 and commenced work in May, 1982. The contractor was losing money near the end of the job and consequently did not finish the construction. He was paid according to the amount of work completed. A summary of the contract items is given in Table B1 of Appendix B.

The contract to manufacture the *mesqa* headgates was awarded to Mohamed Mohamed Abdel Aziz in Zagazig. The building of the headgates for the *mesqas* required new casting and molds. The delivery of the gates was delayed due to the tooling up process required. The costs of the headgates are given in Table B2 of Appendix B. The headgates were installed by EWUP.

The contract for renovation of the *mesqas* was awarded in March, 1983 to the Egyptian Company for Irrigation, Drainage, and Civil Constructions in Asyut. The company began work in May, 1983. A summary of the contract items is given in Table B3 of Appendix B.

Land leveling and construction of internal access roads in the region was conducted by EWUP with the assistance of the Egypt Agricultural Mechanization Project (EAMP). The total cost of land leveling was estimated to be about LE 33,000. For road construction the estimated cost was LE 7000.

A summary of construction costs for the system renovation at Abyuha is given in Table 7. Renovation of the water delivery system alone cost about LE 213,160, or LE 194/*feddan*. The total construction cost, including road construction and land leveling, was about LE 253,160 or LE 230/*feddan*. Planning and design costs were not included in the calculations.

Construction Procedures

Construction at Abyuha was to consist of renovating watercourses, installing structures, building roads and leveling land according to approved plans and specifications. The actual procedures that were followed in the field

along with the problems that were encountered are summarized below. The contractor's practices are reviewed and contrasted with recommended procedures.

Watercourse Renovation

Abuyha Canal: Prior to beginning the earthwork on the Abyuha canal a baseline was located beside the canal by a field survey and was marked with stakes. This baseline served as a reference datum for locating the design canal centerline and cross sections.

The contractor started the work on the canal by removing the existing cutthroat flume and pitching along the old side slopes. He then began transferring fill soil to the site for use in raising the banks. This soil was taken from the Moheet drain located approximately 5.5 km from the work site. Initially, two trucks of 10 m^3 and 7 m^3 capacity were used to transport the soil. Since these trucks were not adequate for transporting the soil quickly enough, the contractor rented about fifteen tractors with wagons, each wagon having a capacity of about 3 m^3. The contractor did not adequately supervise the quantity of soil delivered by these wagons. Consequently, it was not discovered until late in the construction period that the wagon loads were delivering only 2 to 2.5 m^3 per load rather than the contracted amount of 3 m^3. This was one of the causes for the contractor running out of funds before completion of the contract.

The earthwork on the canal had to be performed during the off periods of the water delivery rotation. Thus, only short segments of the canal could be renovated at a time. At the beginning of an off period laborers would construct an earth dam at the downstream reach of the segment to be worked on. They would then remove the water from the canal manually using *tambours* and buckets.

Cut and fill to design cross section was performed entirely by hand labor utilizing 50 to 80 laborers at a time. Cuts in the heavy clay soil at the site resulted in stable side slopes. A major problem encountered in the construction, however, was the poor compaction of earth fill in the channel section and on the banks. Compaction of the banks is very important to reduce seepage. Akram and Kemper (1979) reported that the compaction pressure should exceed 2 kg/cm^2 with the soil moisture near field capacity and the thickness of each layer less than 10 cm. Though the contract clearly stated that the fill was to be compacted to a specified density at a particular moisture content, the contractor could not supply the equipment or the expertise to meet the specifications. Initially, he attempted to fill and compact the soil in thick layers using large tractor equipment to roll over the soil. After being informed that this procedure was unsatisfactory, he obtained a small sheepfoot roller and began compacting the

banks in smaller layers after spraying with water. There was little control, however, on the amount of water applied, the thickness of the compacted layers or the load applied. No testing was performed to verify the final compacted density. The poor compaction of fill in the channel section resulted in the use of additional pitching to stabilize the side slope.

White limestone was transferred to the site for use in pitching the side slopes constructed from fill and those located on bends in the canal. A small amount of old pitching was removed in realigning the canal.

The stone from these sites was transferred to be used for pitching in new locations. Three to four laborers were used to install pitching at a given location. Each laborer installed 7 to 10 m^3 of pitching per day.

Due to financial mismanagement and penalties for delaying the work the company did not complete the specifications of the contract. Transfer, filling, and compaction of soil for the banks remains uncompleted at limited sites along the canal. The plan is that EWUP will complete this work with the remaining contract funds.

Mesqas: Generally, contractors in Egypt do not have experience with reconstructing watercourses in irrigated lands; rather, they are accustomed to construction and maintenance of large canals within government right-of-ways. In Abyuha, construction problems occcurred when the contractor's work on the *mesqas* had to be coordinated with the breaks between crop and irrigation rotations. The Project had to work closely with the farmers and the contractor to determine the best procedures for accomplishing the *mesqa* renovation.

The procedures adopted for renovating the *mesqas* were very similar to those described by Trout and Kemper (1980). They are summarized as follows:

1. A baseline was established beside the *mesqa* by a field survey and marked with stakes. This baseline served as a reference datum for the location of the design *mesqa* centerline and cross sections.

2. Excess water was removed from the old *mesqa*. It was found that leaving 10 to 20 cm depth of water in the bottom of the *mesqas* provided moisture that aided in the compaction of the dry soil that was used to fill the old cross section.

3. Laborers manually removed the grass and weeds from the cross section and banks of the old *mesqa*.

On the first few *mesqas* that the contractor worked on, the banks of the old *mesqa* along with the weeds were completely removed by the blade of the bulldozer. However, it was later decided in consultation with the farmers to leave the old banks in place and remove as much of the weeds as possible. Farmers felt that the old banks would provide added protection against seepage when the water level in the new *mesqa* would be raised.

4. Soil for fill was collected from the surface layer (approximately 3 to 4 cm depth) of the land adjacent to the *mesqa* on both sides. Initially, chisel plows were used to break up the surface layer. Bulldozers and land planes then were used for moving the soil to beside the *mesqa*. Afterwards, the land was leveled with conventional or laser guided equipment.

   In the first stage of the work the soil for fill was obtained by excavating small "borrow ditches" (approximately 25 cm deep and 50 cm wide) beside the old *mesqa*. The advantage of this technique is that it allows construction to take place while crops are still in the field. The borrow ditches could then be filled by the farmer during the period between harvest and planting. However, it was found that upon using the *mesqa* for irrigation the borrow ditches would fill with water. The water would stand in the field for several days causing damage to adjacent crops. Thus, this method was abandoned and soil for fill was obtained from the entire field surface during the periods between harvest and planting.

5. The old cross section was filled with soil to land level. The fill in the old cross section could not easily be compacted in layers with the equipment used by the contractor. The sheepfoot roller was too wide for most of the *mesqas* at the site. Also, since the tracks of the bulldozer were more narrow than the *mesqa* top width, the bulldozer could not be supported by the firm banks of the old *mesqa* for easily pulling the sheepfoot roller in the old section. Thus, compaction with the roller was not begun until the fill approached the level of the land.

6. A pad of soil was built up to the design bank elevation. This was accomplished by successively filling and compacting layers of approximately 20 to 25 cm thickness. A water tank with sprayer was pulled along the pad with a tractor to apply moisture to each layer before compaction. A chisel plow was then used to mix the soil and distribute the moisture. After spraying a second time, compaction was carried out by means of a sheepfoot roller pulled by a tractor. No measurements of compaction density were made but compaction appeared adeqaute.

7. The centerline and topwidth boundaries of the *mesqa* were marked on the compacted pad and the design cross section was excavated. This was done manually using approximately 30 laborers at a time. Each laborer excavated about 5 m^3 per six hour work day. The excavated soil was deposited beside the *mesqas* for later redistribution on the fields by the farmers.

8. The banks were shaped manually to their design dimensions.

Plans were made to line *mesqa* 13 with plain concrete cast in place or with stone and mortar. This work had not yet been initiated at the time of this report.

Hydraulic Structures Installation

Abyuha Canal: Reinforced concrete pipes for outlets to *mesqas* were transferred to the site on flatbed trucks. Many of the pipes were allowed to fall to the ground while being removed from the trucks. This resulted in considerable damage to several of the pipes which consequently were rejected. Upon careful inspection of the remaining pipes it was found that the inside surfaces were very rough and the actual inside diameters were 10 to 20% smaller than the specified nominal inside diameters. This was brought to the attention of the contractor who agreed to incease by 5 cm the nominal diameter of the pipes to be delivered and installed.

Pipes for outlets to *mesqas* were installed at the design elevation by laying them on small concrete blocks on subgrade as a supporting foundation. Concrete with small aggregates was used for sealing of pipe joints. A masonry headwall was constructed around the entrance to each pipe outlet to support the headgate. Concrete and mortar were mixed by hand on the ground, a procedure which often results in a poor quality mixture.

The manufacture of the gates for the outlets to the *mesqas* required tooling up and a new set of foundry molds and castings. Problems were discovered which required changes in the design and the manufacturing process. Consequently, delivery and installation of the headgates was delayed. In the meantime, the new pipe outlets had been installed. With no gates for control, the flow to some *mesqas* was excessive and was deficient to others. Temporary gates or obstructions in the pipes were required to obtain flow control until headgate installation was completed. After installation, the headgates appeared tight and easy to operate.

The new headgate on the Abyuha canal was installed by the Ministry of Irrigation during the canal closure period of January, 1983. The gate was not properly installed to insure a tight seal against the sill and

along the sides. Consequently, some leakage occurred under and along the sides of the gates. In the closure period of January, 1984 EWUP raised the sill of the gate to eliminate the leakage under the gate. Plans have been made to correct the small amount of leakage that still occurs along the sides.

At the time this report was prepared, the outlet check structure on the Abyuha canal had not yet been constructed.

Mesqas: Check wall structures, outlet check structures, and bridge check structures for the *mesqas* were built of masonry and concrete according to specifications. Concrete and mortar were mixed by hand on the ground. Iron gates as specificed for flow control on these structures were manufactured, delivered, and installed by the contractor.

At the time of preparation of this report, reinforced concerete pipe of 20 cm inside diameter had been delivered by the contractor and installed for field turnouts at selected locations on *mesqas*. Installation of additional turnouts remained to be completed.

Road Building

Mesqas 9 and 24 were completely filled with soil and replaced with farm access roads. A road was also constructed between *mesqas* 25 and 26 on the boundary separating the ends of the farms. Replacement of *mesqas* 13, 15, 28, and 30 with roads was postponed pending full agreement by farmers. Filling, wetting, compacting by sheepfoot roller, and smoothing was accomplished to construct the roads at a height of approximately 20 to 25 cm above the land elevation.

Land Leveling

Leveling of farms in the Abyuha area was accomplished by two methods: (1) by the use of conventional land planes and scrapers pulled by tractors and (2) by the use of tractors and scrapers controlled by a laser transmitter.

The first leveling in the area was performed by EWUP using the conventional procedure. Grid surveys were made of the farms to be leveled and the amount and location of required cut and fill to bring the land to zero grade were determined. Scrapers and/or land planes were then used to move the soil. Afterwards, another survey was made to check that the elevations were within a $\pm$ 2 cm tolerance. This process was repeated until a satisfactory leveling operation was completed. Final smoothing then was accomplished with the land plane.

Laser leveling was performed on the largest part of the area with the equipment and assistance of EAMP. A laser transmitter was mounted on a tripod in the center of the area to be leveled. The laser beam was emitted from a revolving head on the top of the transmitter. After completing an initial field survey, several tractors with scrapers were controlled by the laser for leveling.

A receiver mounted on the scraper automatically operated the hydraulic system to control the blade at the desired final field elevation. No field smoothing was required.

Carrying out the land leveling in coordination with the movement of soil from the fields for use in reconstructing the *mesqas* required precise timing and good management. Good communication and cooperation with farmers was essential to performing the work with the least interruption to other farming activities and in a manner that was acceptable to the farmers.

Summary

The Abyuha distributary canal system serving 1200 *feddans* in Middle Egypt was renovated to provide controlled gravity surface flow for more efficient distribution and use of irrigation water. The renovation was carried out to improve the distribution of flow, eliminate the need for lifting water, allow improved on-farm irrigation, facilitate farm mechanization, and reduce water loss to the drains.

Structural specifications are given for watercourse renovation, headworks, check structures, fields turnouts, roads, and land leveling. Planning and design of the system is briefly discussed along with brief description of contractural agreements. The construction process is described and evaluated with recommendations for improvements in future systems.

Recommendations

The renovation of the Abyuha system was experimental in that new approaches and methods for planning, design, and construction were developed and tested. The effort to perform extensive renovation of a water delivery system at the farm level required a trial and error approach to develop the best methods for quality construction with the least disruption to farming practices and irrigation schedules. Several general recommendations can be made.

Interviews with farmers should be conducted to find out their concerns and seek their cooperation in improving the system. Farmers will have more pride and be more likely to maintain the system if they are involved in the decision making process during the planning stage and while construction is being carried out.

In preparing the construction schedule, close consideration must be given to coordinating the schedule with farming practices, irrigation schedules, and availability of constructions materials and equipment. The schedule should be made very clear to the contractor before beginning the work in the field. The construction schedule will depend on the ability of the contractor and the amount of equipment used. The past performance of a contractor in following schedules should be considered in accepting bids for construction.

The review and approval of plans and specifications for construction should be done by a professional other than the one preparing the plans. Any recommended changes should be made before the final specifications are prepared. Changes in contracts during the construction process are difficult and costly.

Additional research should be conducted to determine the most effective and efficient procedures to follow in renovation of *mesqas*. The procedures described in this report were found to be adequate for the given site conditions. It was found that the use of heavy field equipment for clearing, filling, and compaction is feasible and efficient. However, experimentation with other types of equipment and techniques under varying field conditions is needed before firm recommendations can be made for widespread applications in Egypt.

Contractors, who are expected to implement improvements of water delivery systems at the farm level, should be provided training. At Abyuha contractors repeatedly failed to assemble necessary resources, follow specifications and complete work according to schedule. Problems with farmers occurred when work had to be coordinated with farming practices and irrigation schedules. Farmers were disturbed when contractors did not follow previously agreed upon construction schedules. They were also concerned about seepage from channel banks caused by improper compaction. Improvement of contractor capability is vital to any program for widespread improvement of water delivery systems.

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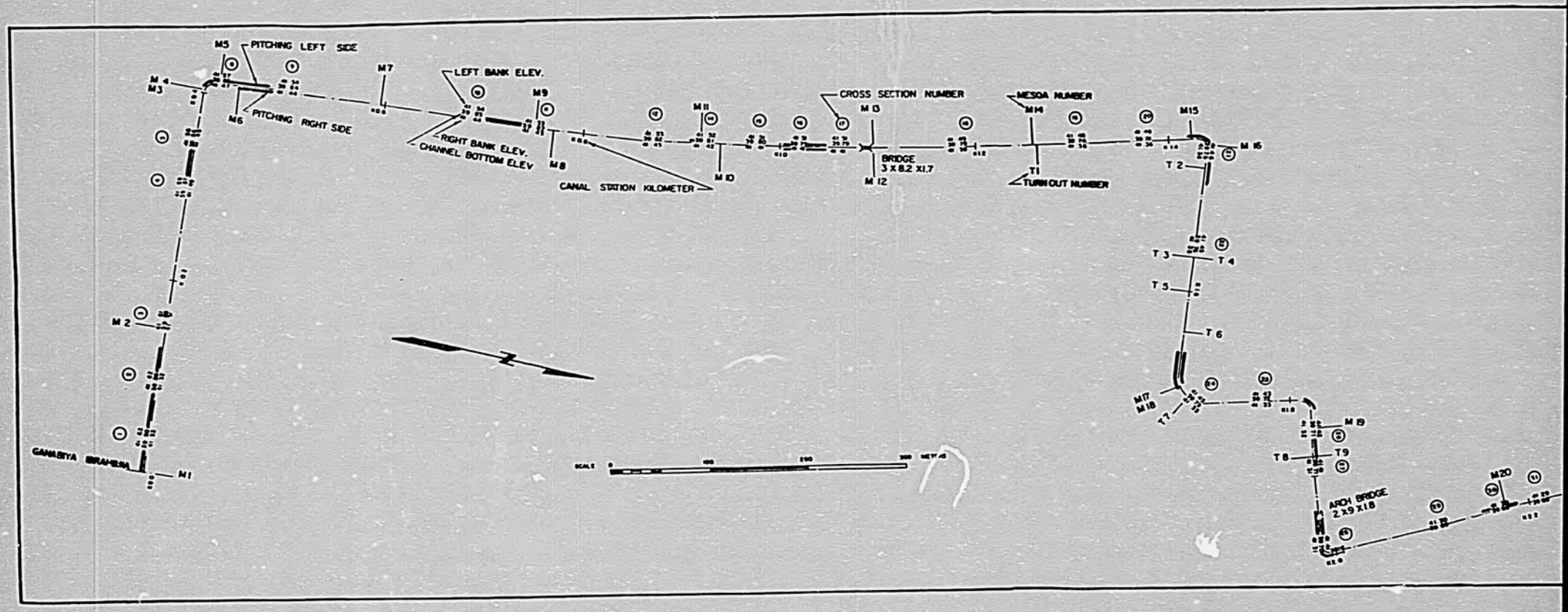
APPENDICES

Appendix A

Abyuha Canal Layout and Cross-Sections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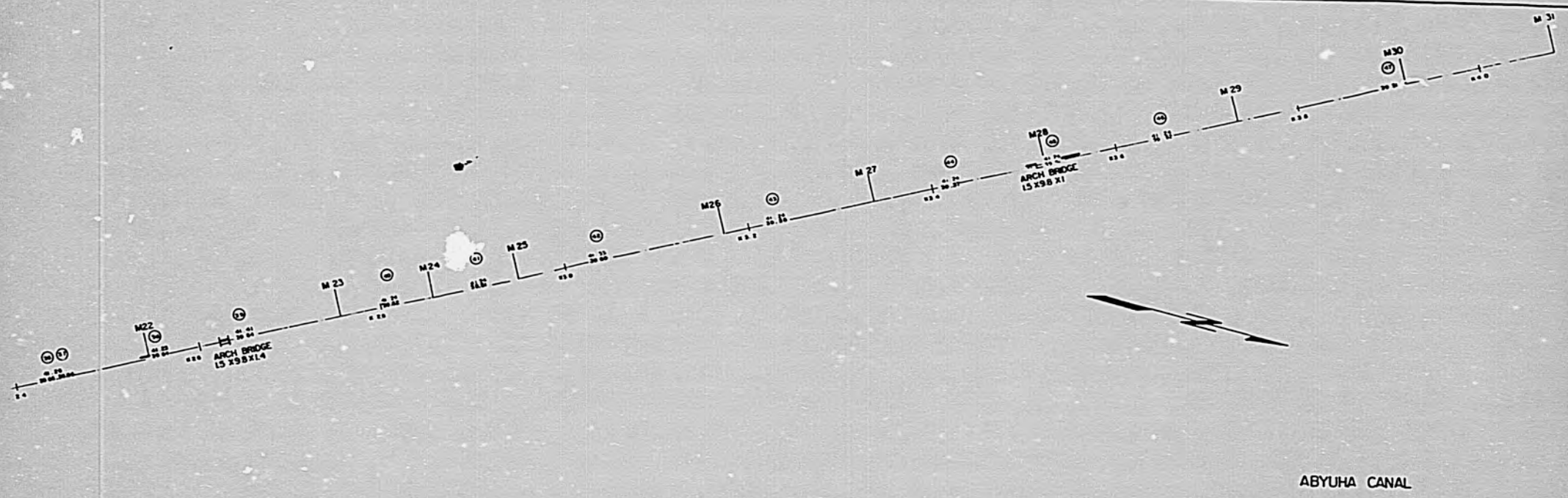
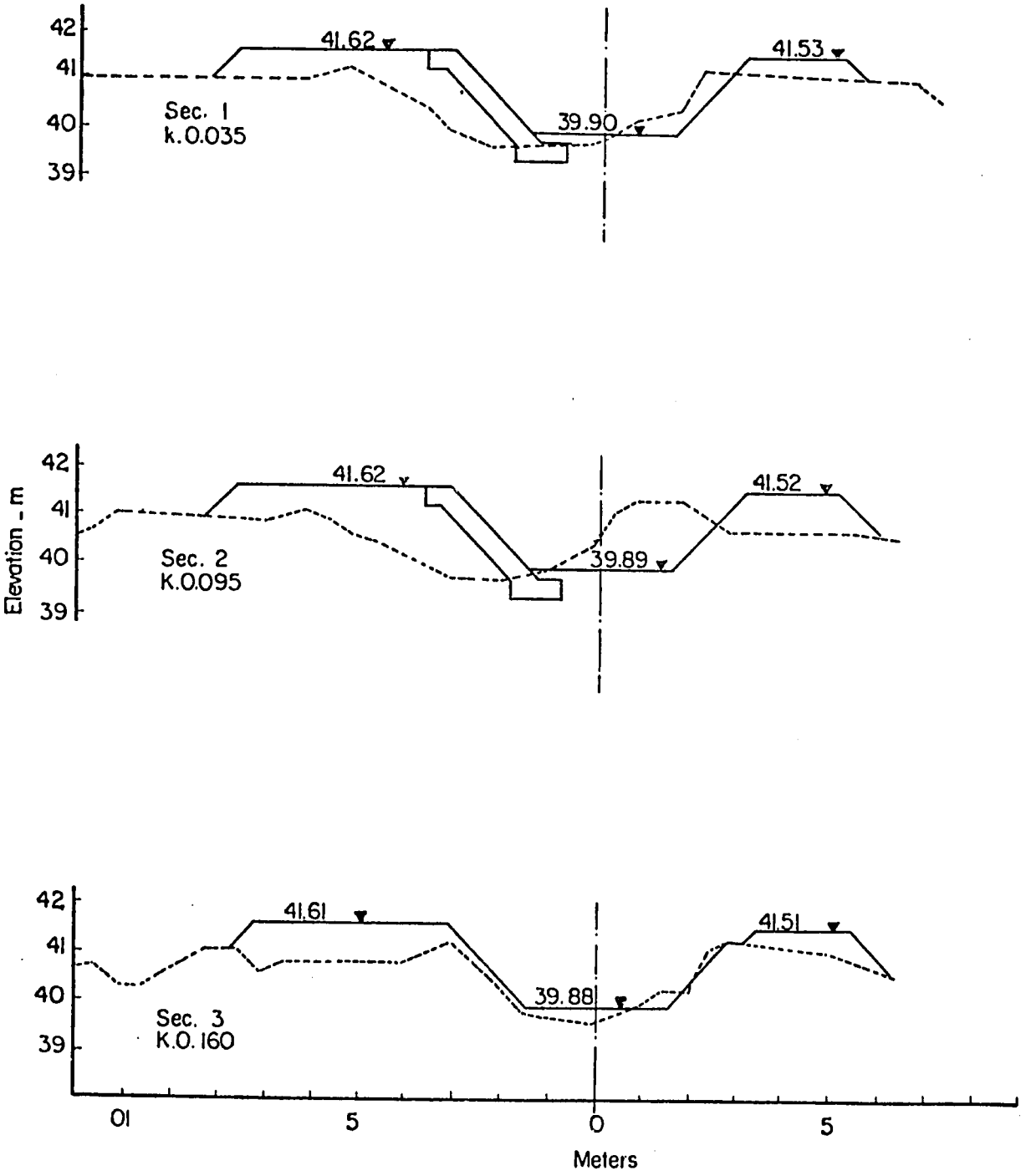
PITCHING LEFT SIDE
M4
M3
M6
PITCHING RIGHT SIDE
M7
LEFT BANK ELEV.
M9
RIGHT BANK ELEV.
CHANNEL BOTTOM ELEV
M8
CANAL STATION KILOMETER
M11
M10
CROSS SECTION NUMBER
M13
BRIDGE
3 X 8.2 X1.7
M12
MESOA NUMBER
M14
T1
TURNOUT NUMBER
M15
M16
T2
T3
T4
T5
T6
M17
M18
T7
M19
T8
T9
ARCH BRIDGE
2 X 9 X 1.8
M20
M2
GANABIYA BRAHEMA
M1
SCALE
0
100
200
300
METRES

366


M22
ARCH BRIDGE
1.5 X 9.8 X 1.4
M 23
M24
M 25
M26
M 27
M28
ARCH BRIDGE
1.5 X 9.8 X 1
M 29
M30
M 31
ABYUHA CANAL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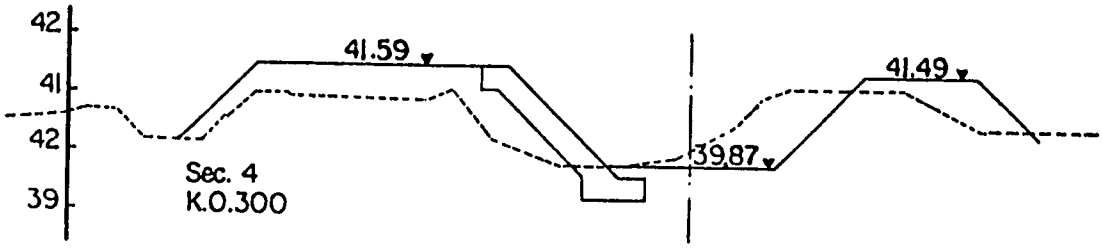
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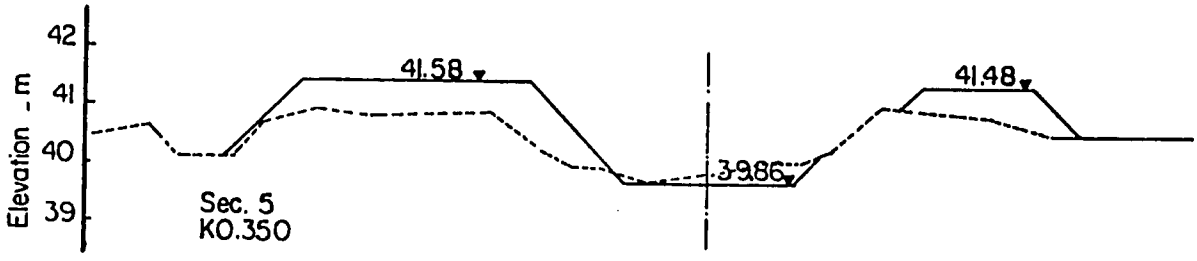
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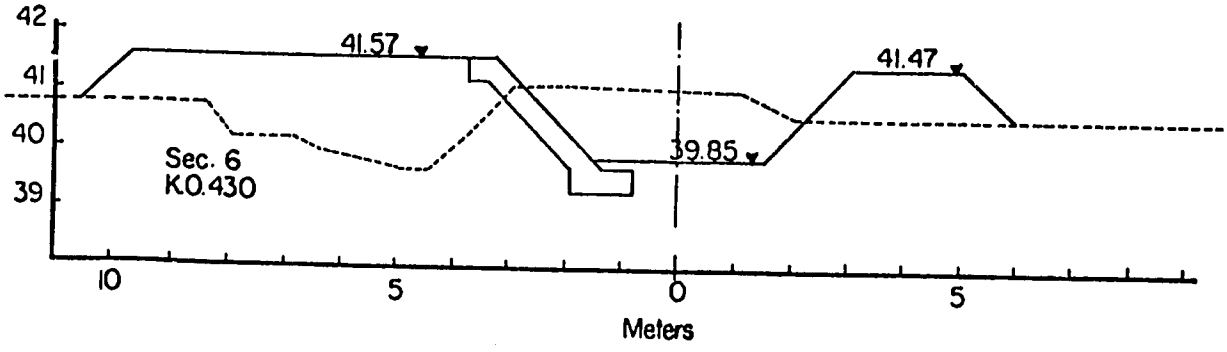
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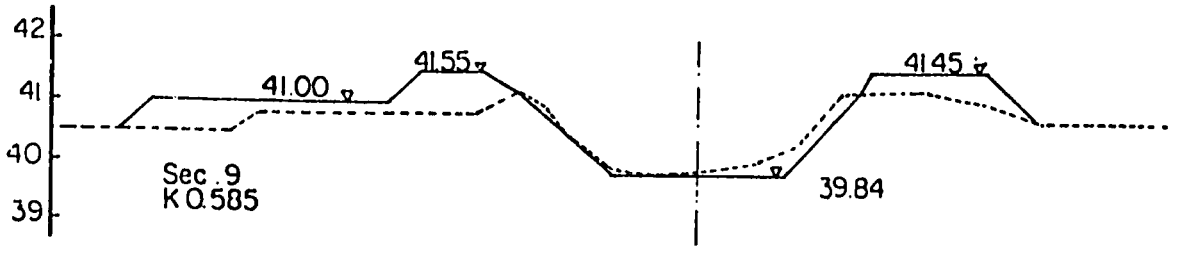
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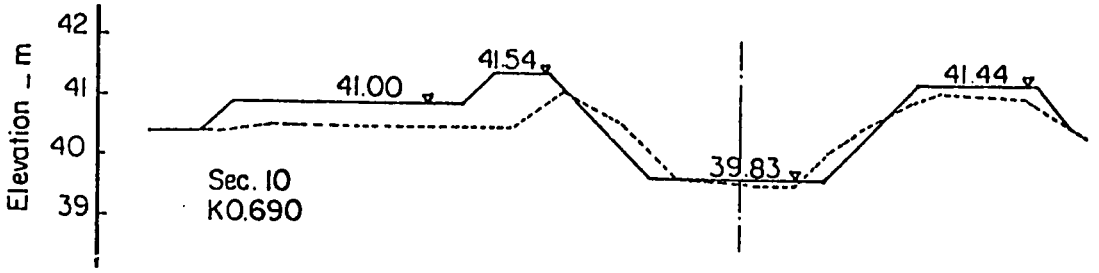
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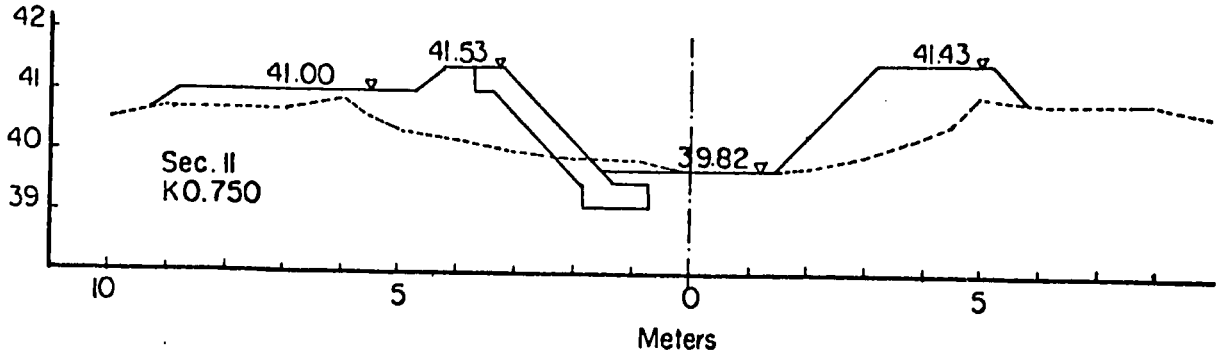
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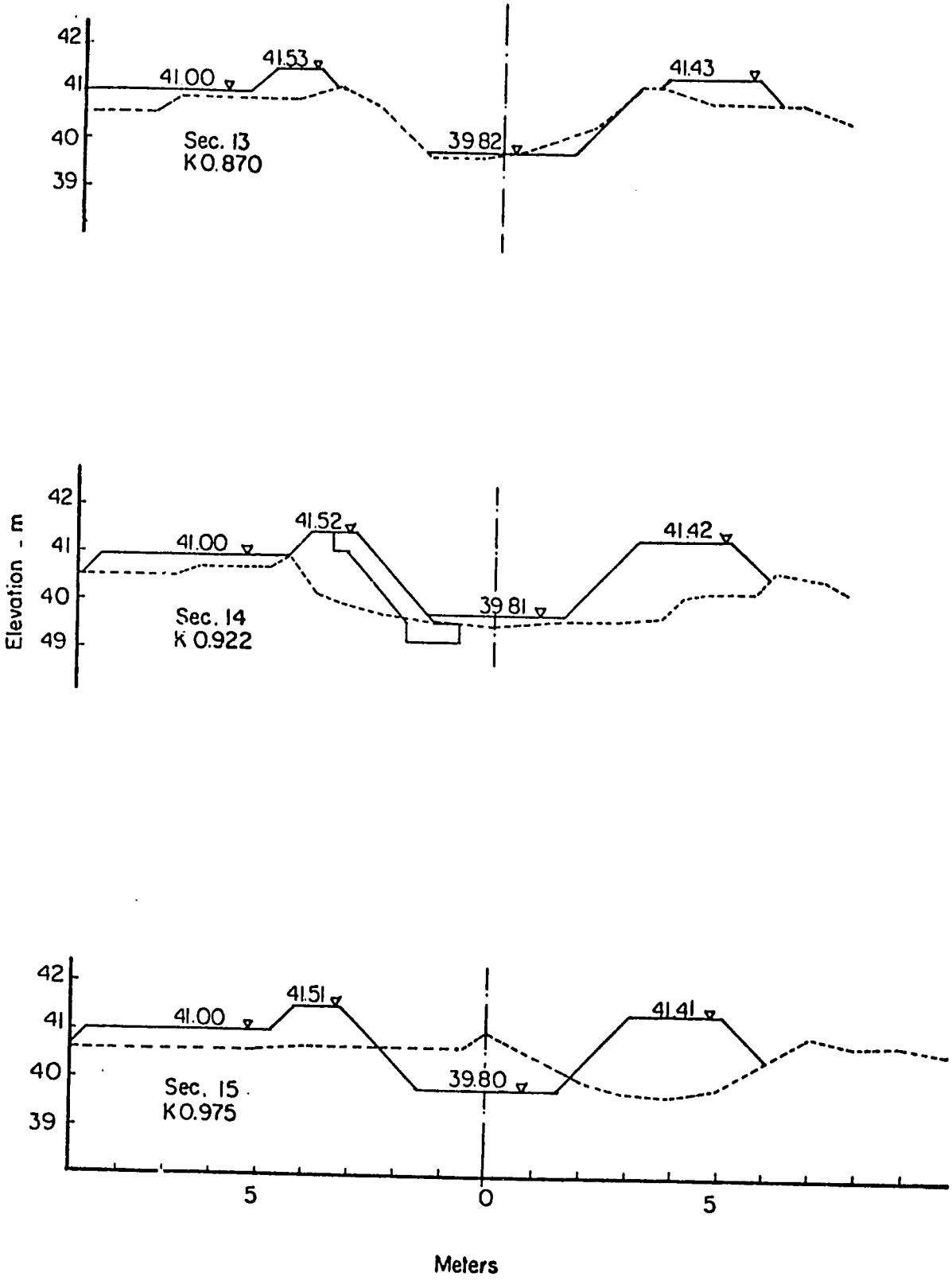
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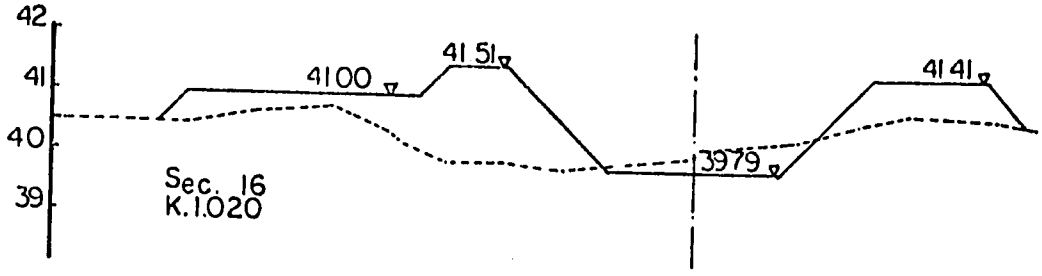
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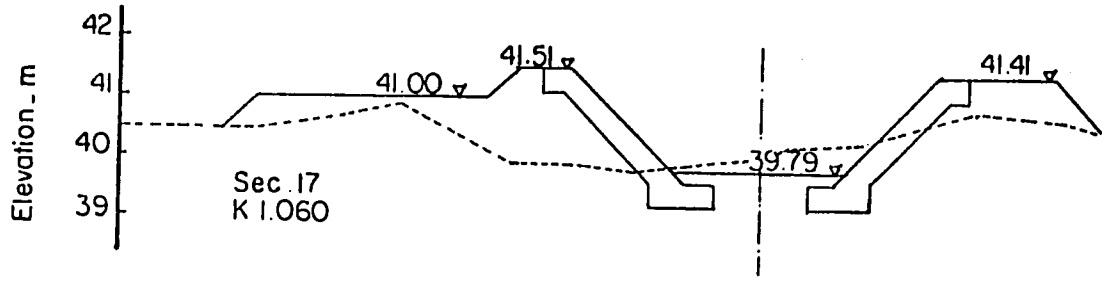
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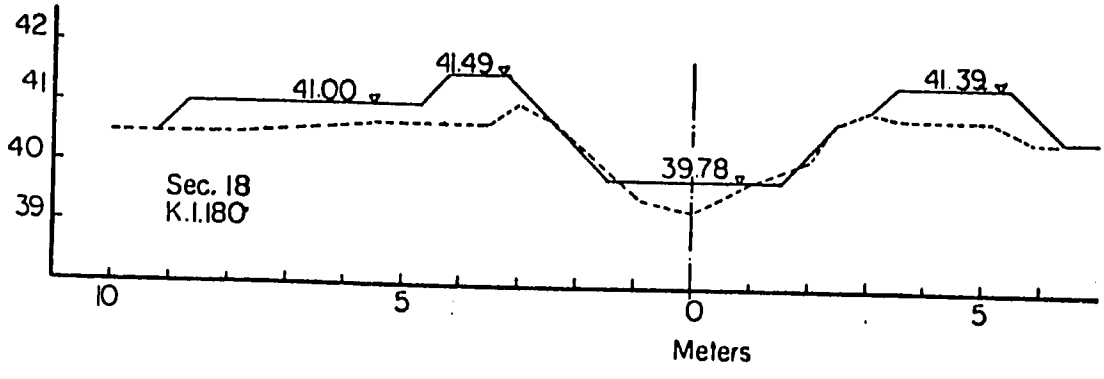
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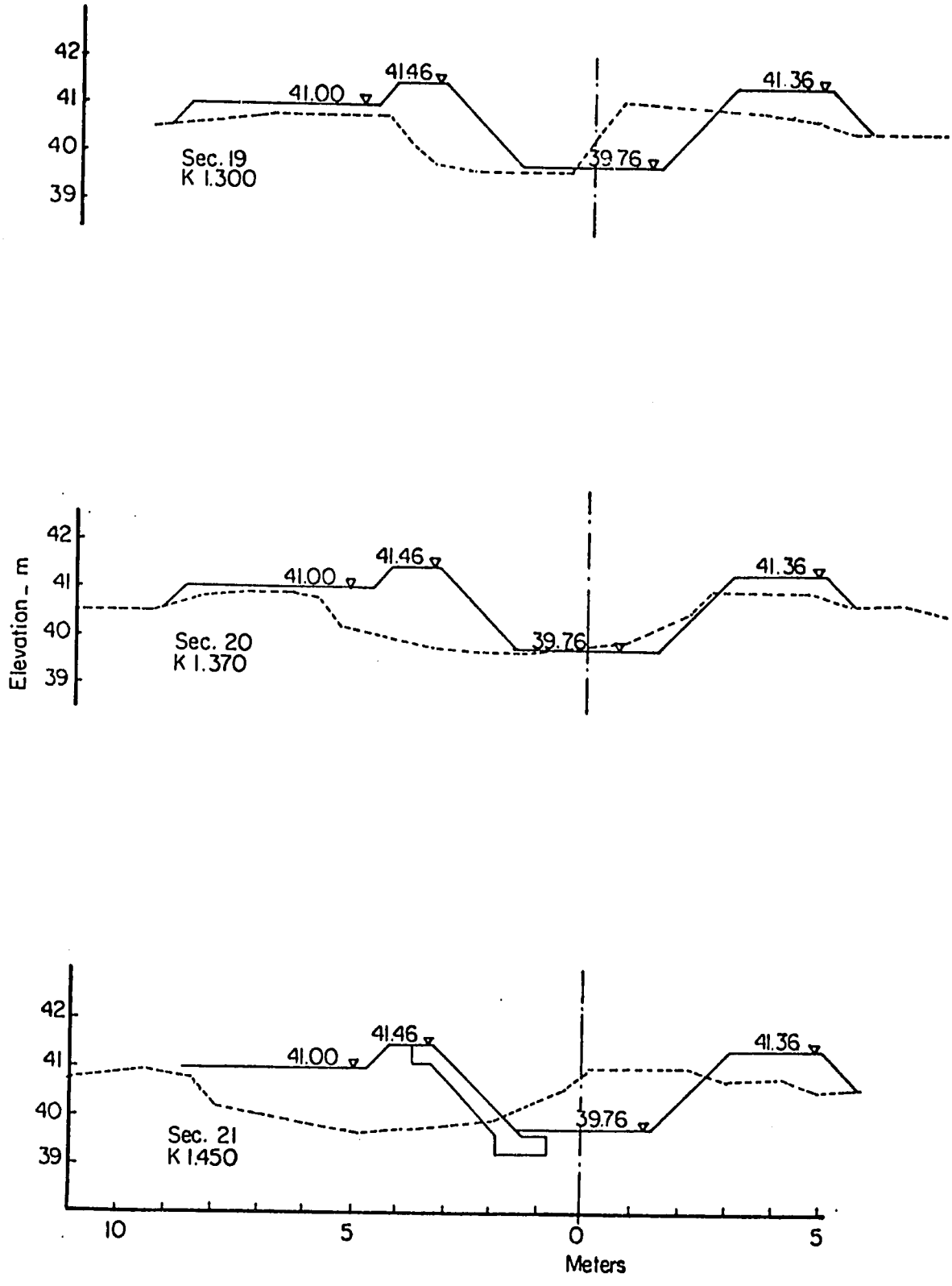
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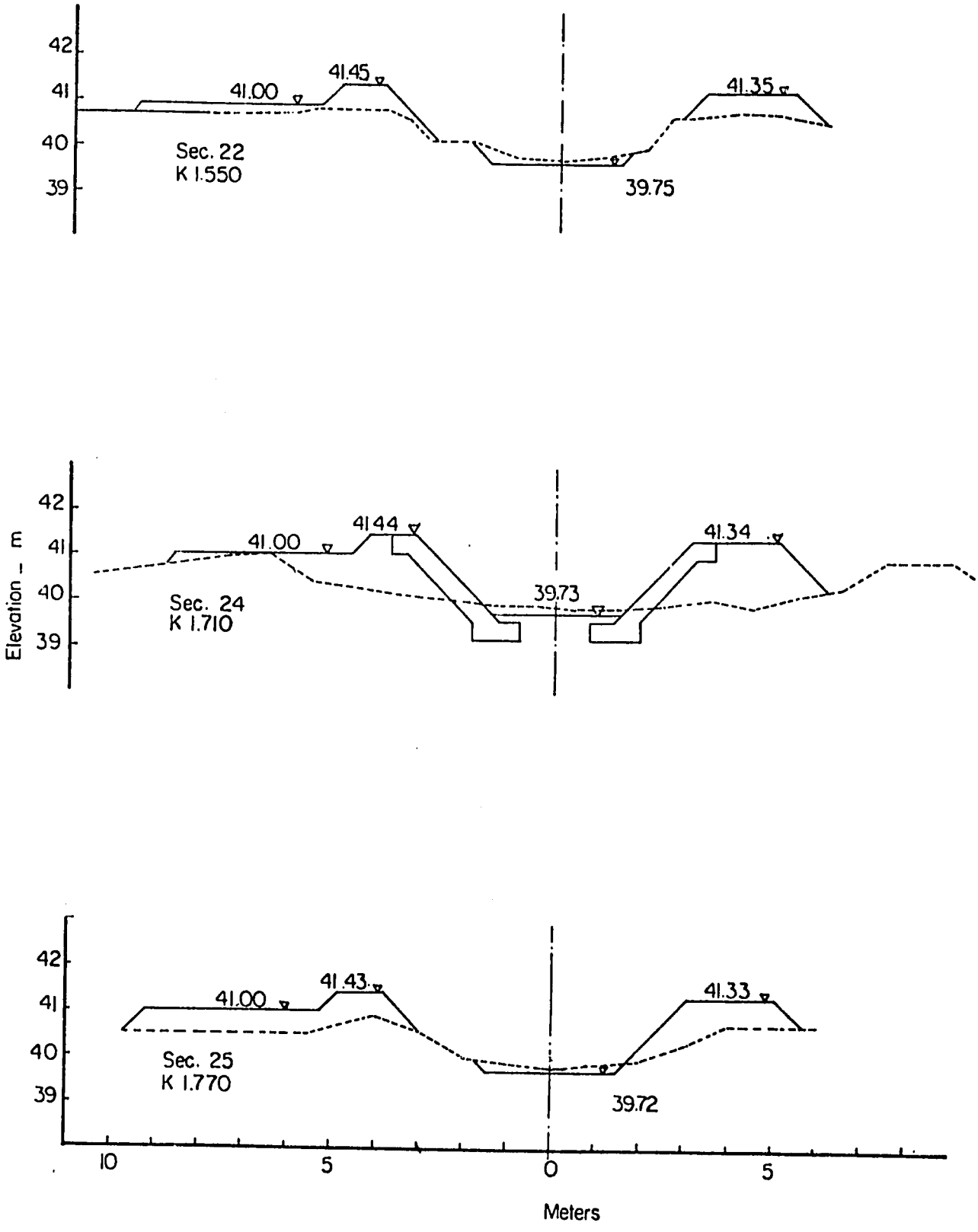
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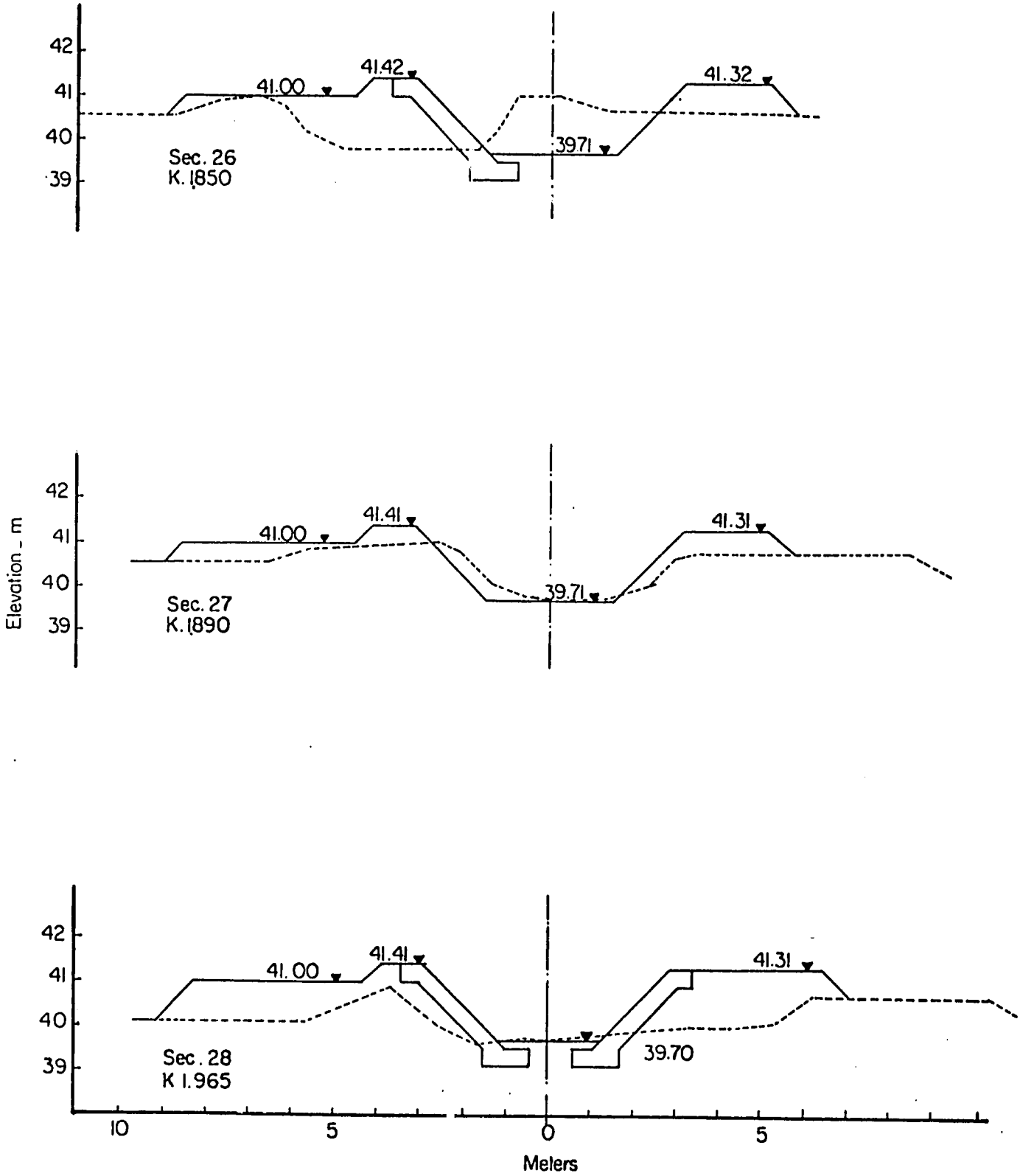
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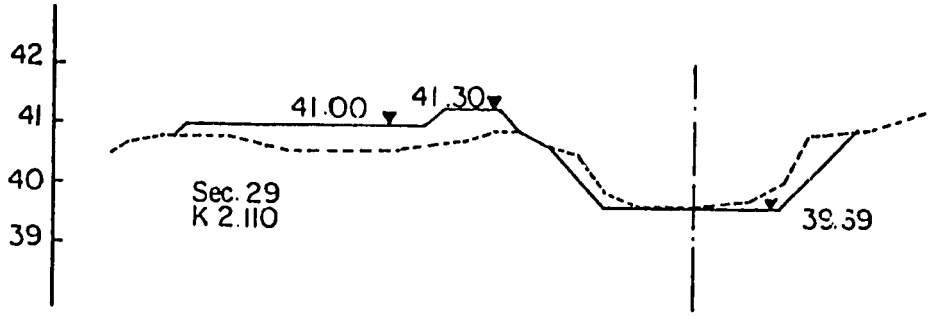
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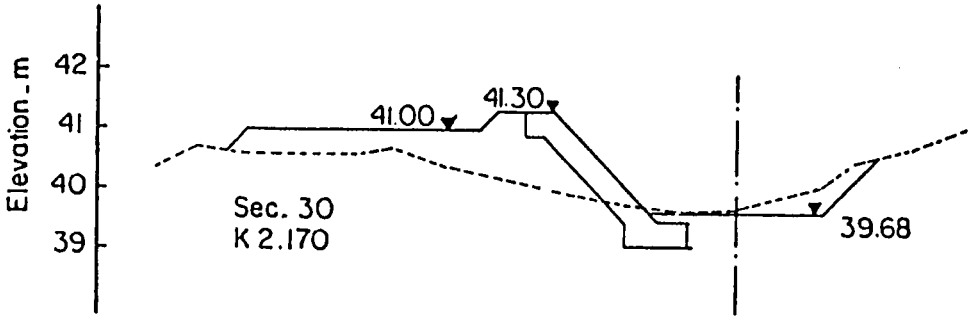
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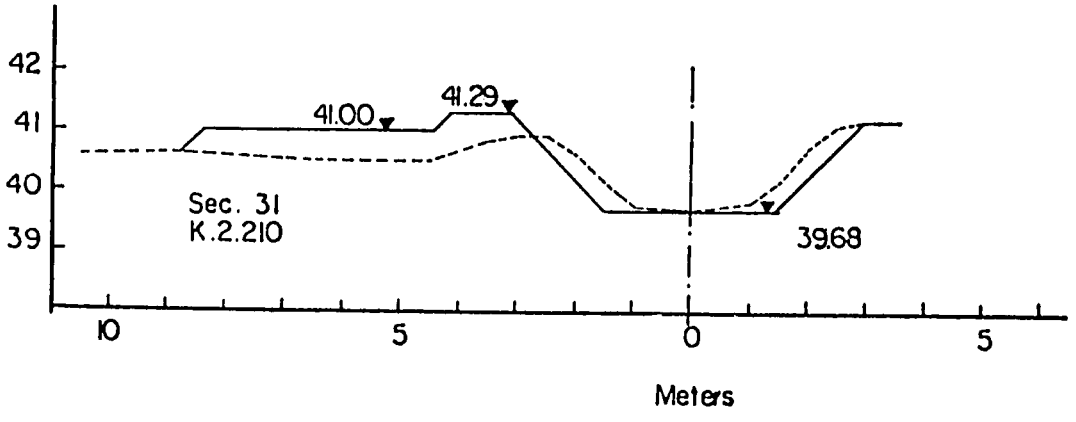
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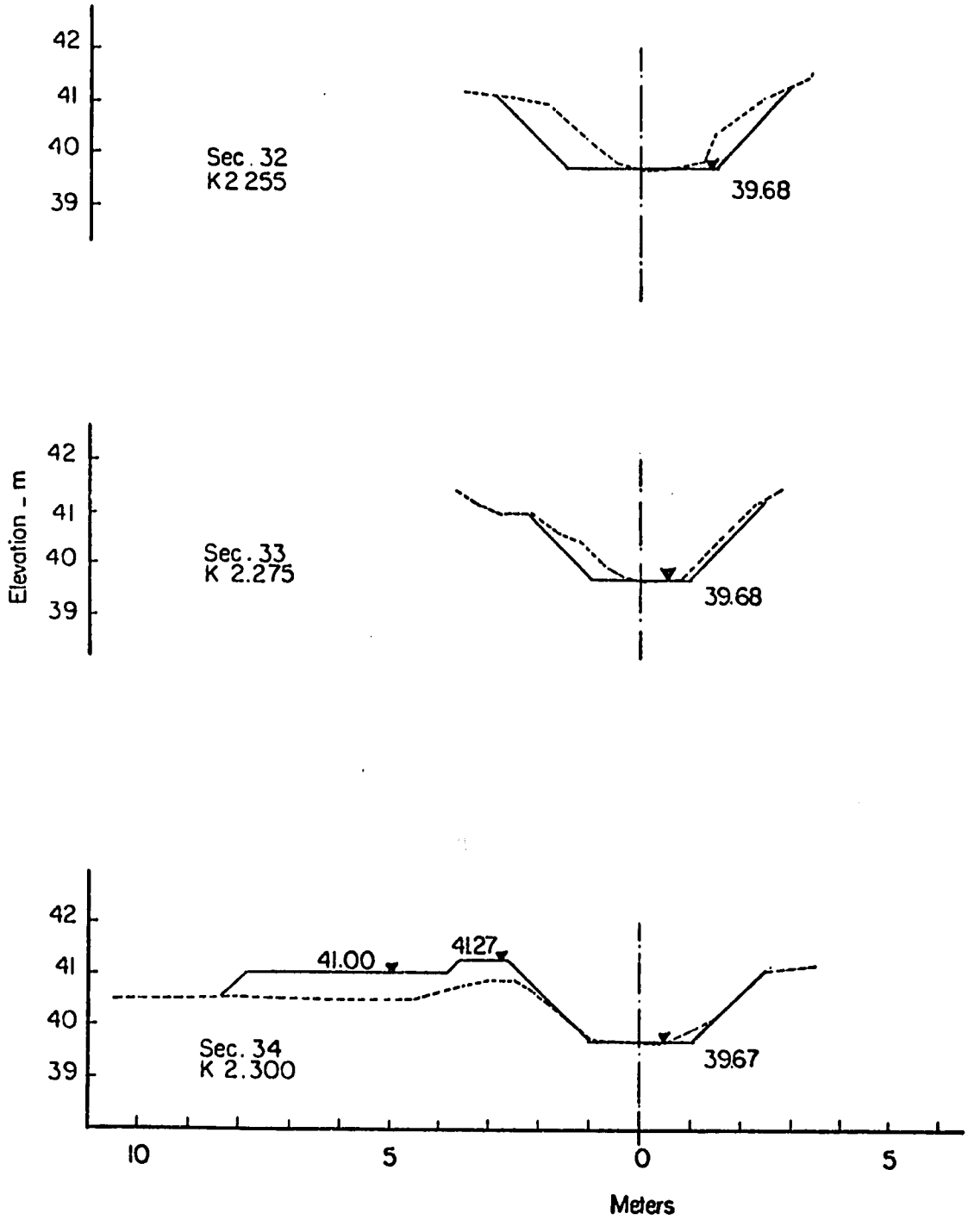
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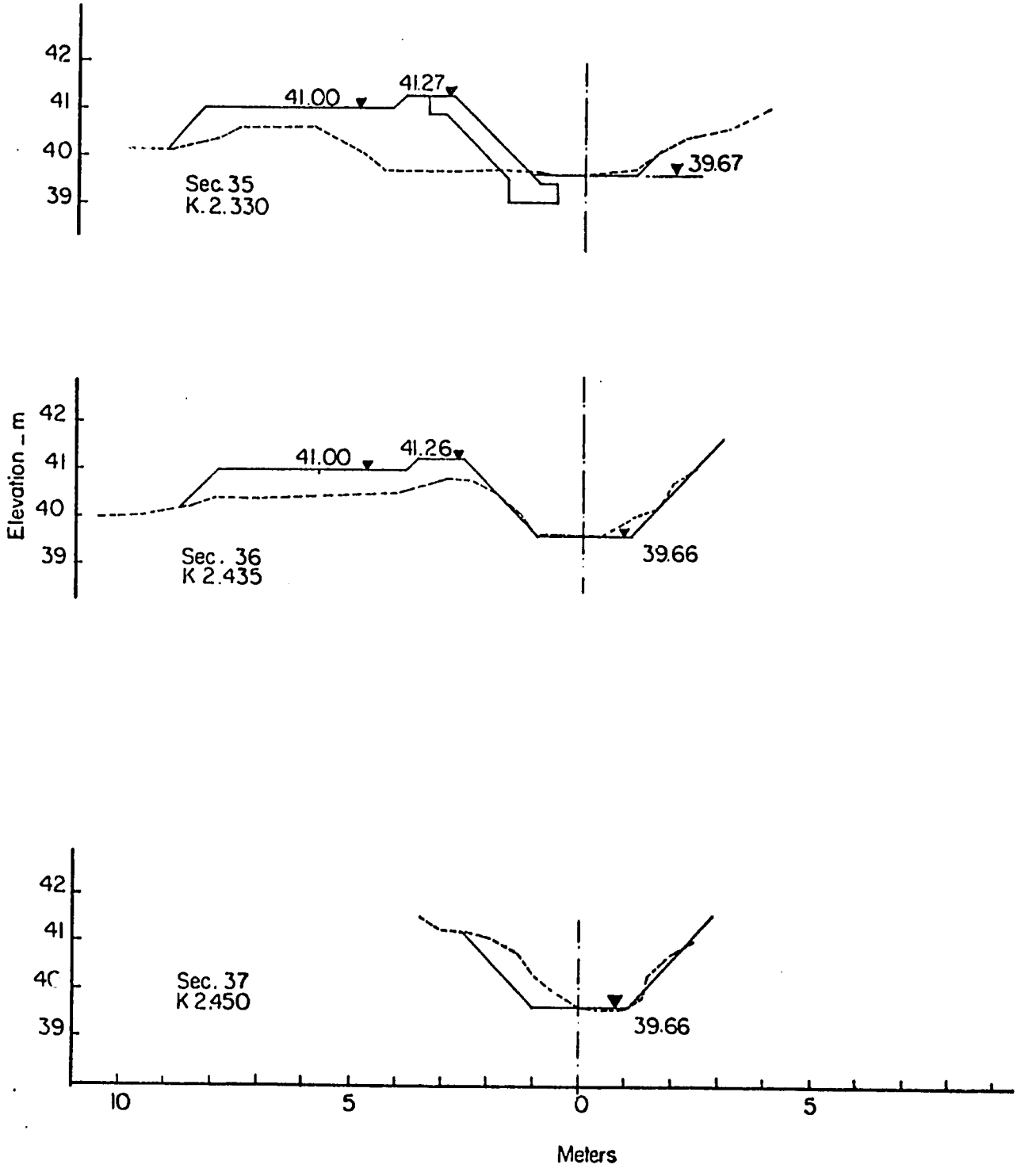
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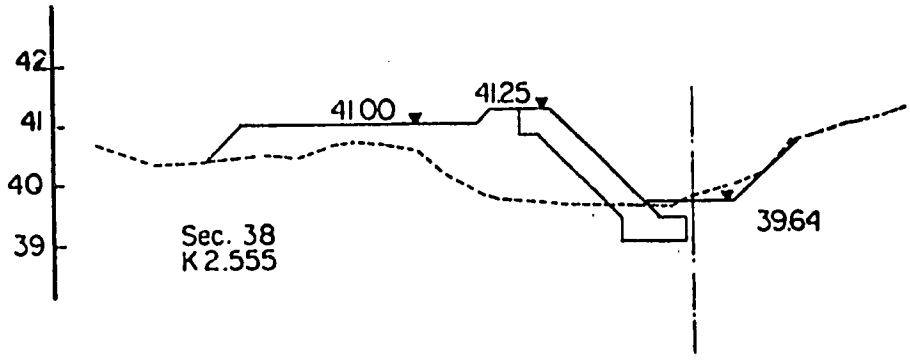
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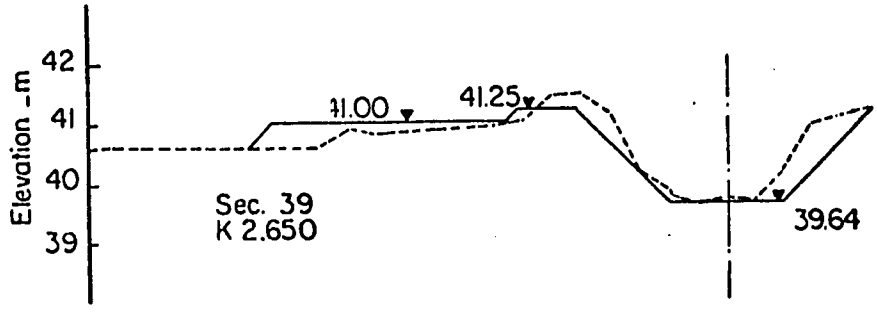
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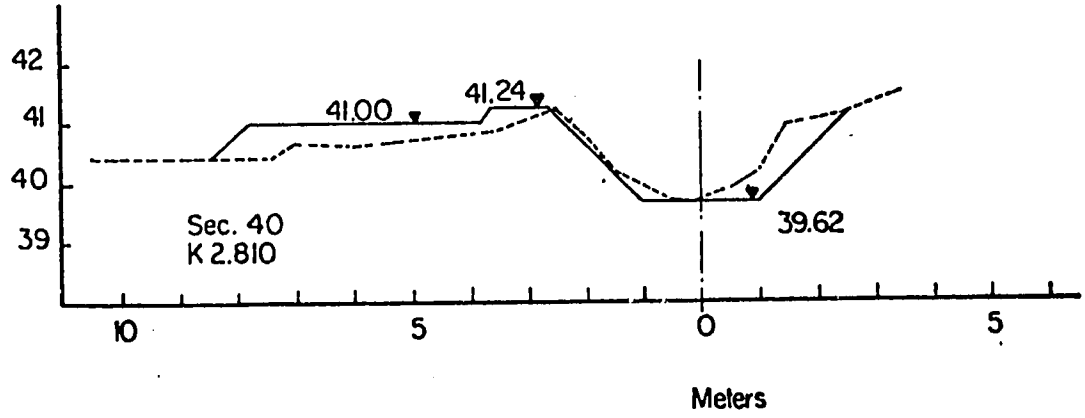
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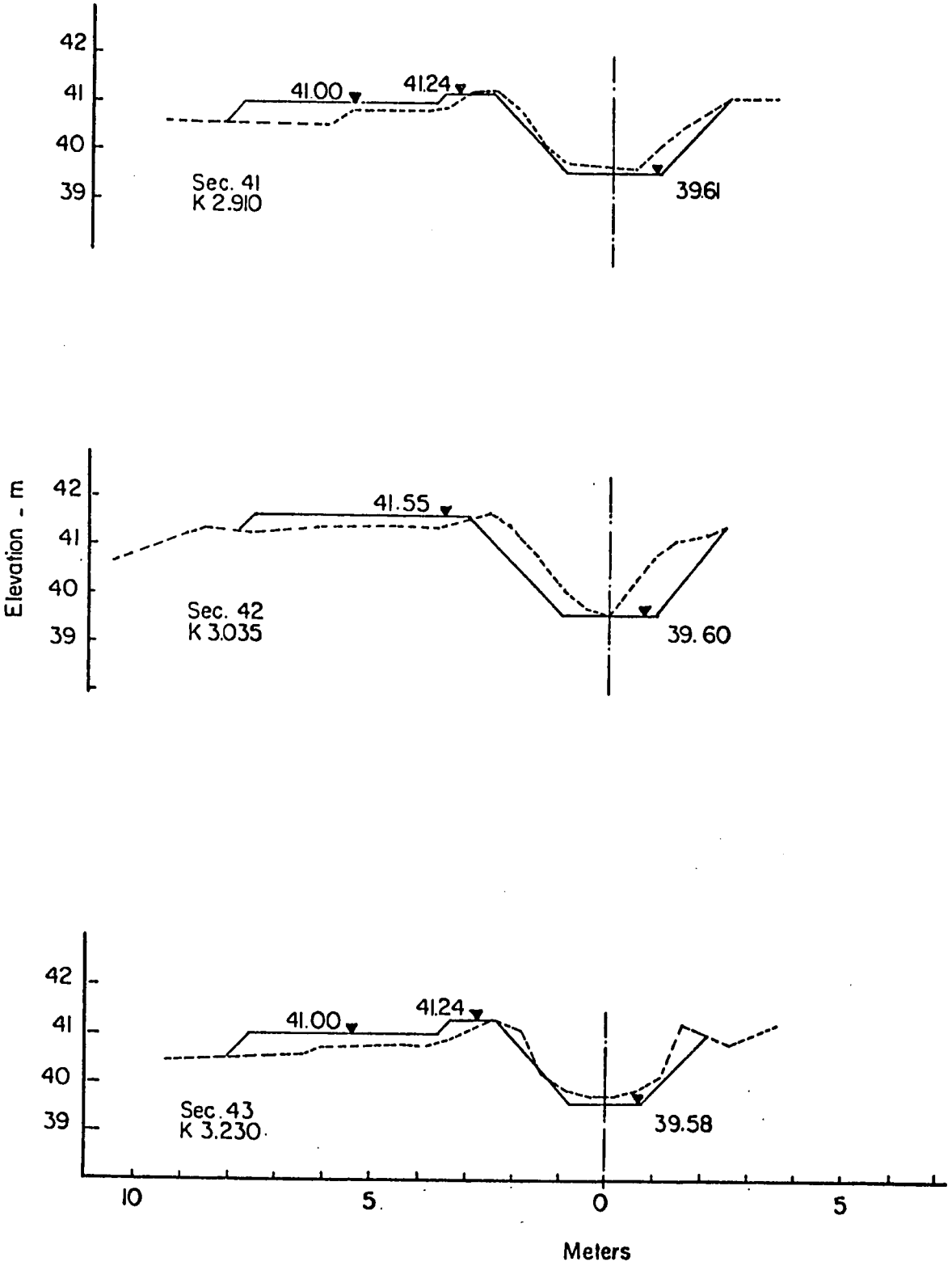
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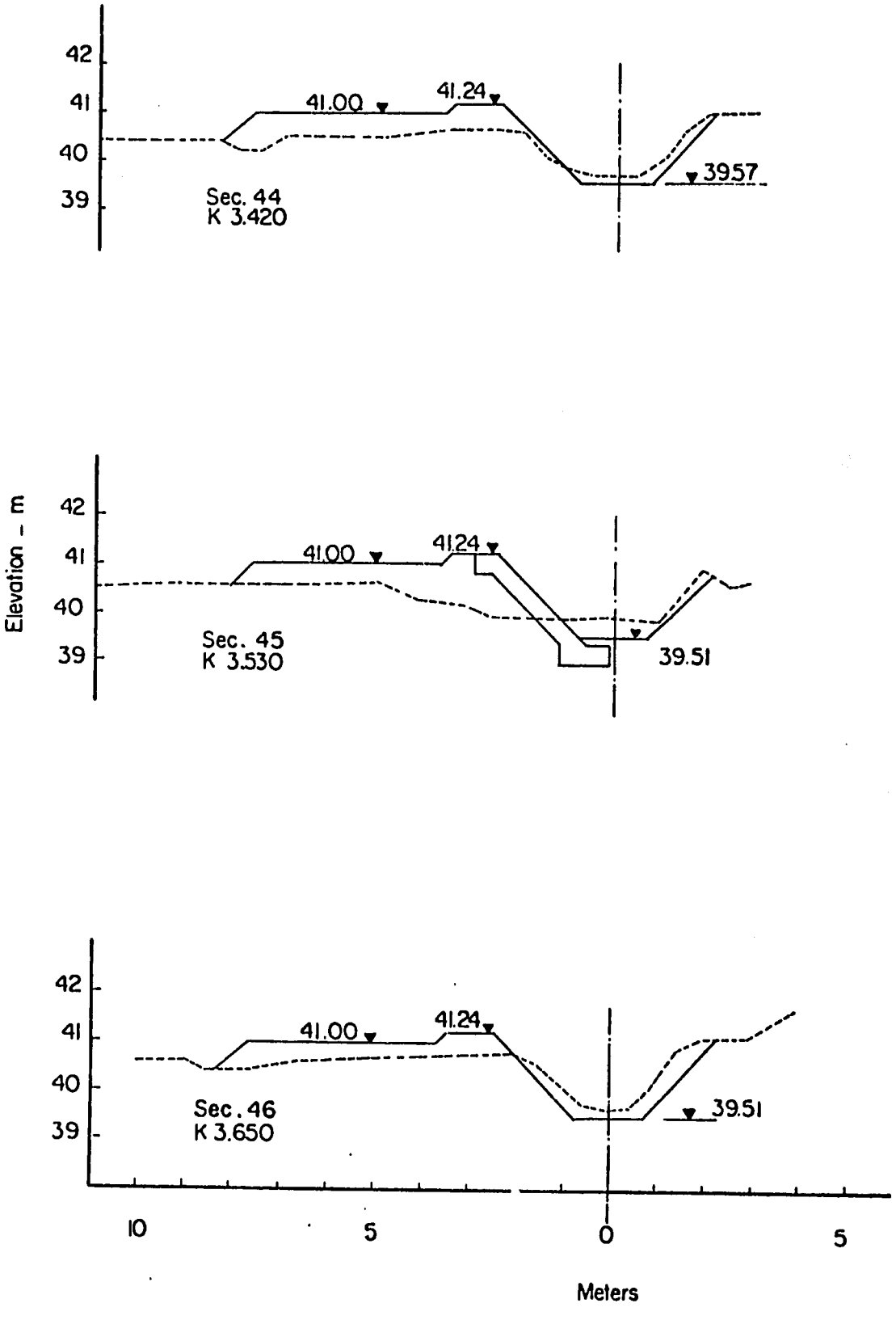
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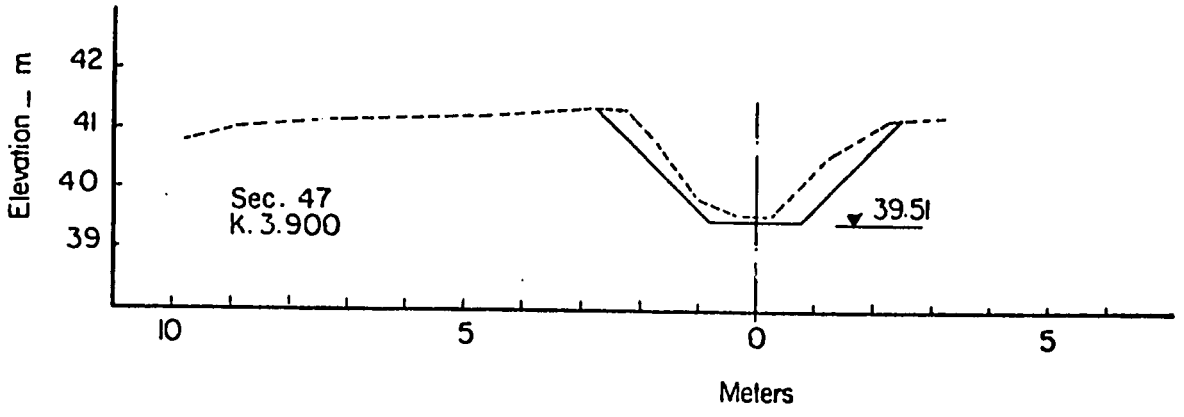
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Meters

Appendix B

Contracted Items and Costs

Table B1. Contracted and Actually Used Items for Abyuha Canal Renovation.

Item	Contracted Items			Items Actually Used	
	Quantity	Unit Cost (LE/Unit)	Total Cost (LE)	Quantity	Total Cost (LE)
Earth Cut	3000 m^3	0.70/m^3	2100.00	5378 m^3	3764.60
Transfer Soil	12000 m^3	2.50/m^3	30000.00	11895 m^3	29737.50
Stone Pitching					
Removal, reset	100 m^3	2.50/m^3	250.00	69 m^3	172.50
Transport, inside	300 m^3	2.00/m^3	600.00	130 m^3	260.00
Transport, outside	1200 m^3	8.00/m^3	9600.00	1396 m^3	11168.00
Installation, surface grout	1450 m^3	3.00/m^3	4350.00	1500 m^3	4500.00
Installation, complete grout	50 m^3	5.00/m^3	250.00	61 m^3	305.00
Removal of Flume	1	500/flume	500.00	1	500.00
Concrete Footings	65 m^3	40.00/m^3	2600.00	65 m^3	2600.00
Masonry Headwalls	70 m^3	50.00/m^3	3500.00	56 m^3	2800.00
Reinforced Concrete Pipe					
25 cm I.D.	70 m	10.00/m	750.00	105	1050.00
35 cm I.D.	40 m	15.00/m	600.00	47	705.00
45 cm I.D.	30 m	25.00/m	750.00	32	800.00
55 cm I.D.	30 m	35.00/m	1050.00	15	525.00
70 cm I.D.	25 m	35.00/m	875.00	46	1610.00
Transport and Installation	50	2.00/pipe	100.00	12	24.00
Subtotal			57875.00		60521.60
First Discount : 1%			-578.75		605.22
Subtotal			57296.25		59916.38
Second Discount: 10%			-5729.62		-5991.64
Subtotal			51566.63		53924.74
Penalties					-2265.25
Total			51566.63		51659.50

Table B2. Contracted Items for Manufacture of Headgates for Inlets to *Mesqas* on Abyuha Canal.

Gate Width (cm)	Contracted Items		
	Number	Unit Cost (LE)	Total Cost (LE)
30	25	130	3375
50	6	170	1020
65	5	175	875
75	3	185	555
Total			5825

Table B3. Contracted Items and Estimated Actually Used Items For Renovation of Mesqas on Abyuha Canal.

Item	Contracted Items			Estimated Items Actually used	
	Quantity	Unit Cost (LE/Unit)	Total Cost (LE)	Quantity	Total Cost (LE)
Earthwork	22700 m^3	2.50/m^3	56750.00	40700 m^3	101750.00
Reinforced Concrete Pipe					
Farm Turnouts (20 cm I.D.)	600 m	4.00/m	2400.00	900 m^3	3600.00
Farm Turnouts (20 cm I.D.)	600 m	5.00/m	3000.00	900 m^3	4500.00
Check Structures (10 to 25 cm I.D.)					
Delivered from outside	80 m	10.00/m	800.00	80 m	800.00
Transferred from EWUP Store	50 m	6.00/m	300.00	50 m	300.00
Check Structures (30 to 100 cm I.D.)					
Delivered from outside	80 m	30.00/m	2400.00	80 m	2400.00
Transferred from EWUP Store	50 m	10.00/m	500.00	50 m	500.00
Lining with Plain Concrete	750 m^3	40.00/m^3	30000.00	750 m^3	30000.00
Concrete for Foundations and Finishing	30 m^3	40.00/m^3	1200.00	45 m^3	1800.00
Masonry Construction for Check Sturctures	50 m^3	50.00/m^3	2500.00	105 m^3	5250.00
Manufacture and Delivery of Iron Gates for Checks	3000 kg	1.50/kg	4500.00	6000 kg	9000.00
Total			104350.00		159900.00

AMERICAN EQUIVALENTS OF EGYPTIAN ARABIC TERMS AND MEASURES COMMONLY USED IN IRRIGATION WORK

LAND AREA	IN SQ METERS	IN ACRES	IN FEDDANS	IN HECTARES
1 acre	4,046.856	1.000	0.963	0.405
1 feddan	4,200.833	1.038	1.000	0.420
1 hectare (ha)	10,000.000	2.471	2.380	1.000
1 sq. kilometer	100×10^4	247.105	238.048	100.000
1 sq. mile	259×10^6	640.000	616.400	259.000

WATER MEASUREMENTS	FEDDAN-CM	ACRE-FEET	ACRE-INCHES
1 billion m^3	23,809,000.000	810,710.000	
1,000 m^3	23.809	0.811	9.728
1,000 m^3 /Feddan (= 238 mm rainfall)	23.809	0.781	9.372
420 m^3 /Feddan (= 100 mm rainfall)	10.00	0.328	3.936

OTHER CONVERSION		METRIC	U.S.
1 ardab	=	198 liters	5.62 bushels
1 ardab/feddan	=		5.41 bushels/acre
1 kg/feddan	=		2.12 lb/acre
1 donkey load	=	100 kg	
1 camel load	=	250 kg	
1 donkey load of manure	=	0.1 m^3	
1 camel load of manure	=	0.25 m^3	

EGYPTIAN UNITS OF FIELD CROPS

CROP	EG. UNIT	IN KG	IN LBS	IN BUSHELS
Lentils	ardeb	160.0	352.42	5.87
Clover	ardeb	157.0	345.81	5.76
Broadbeans	ardeb	155.0	341.41	6.10
Wheat	ardeb	150.0	330.40	5.51
Maize, Sorghum	ardeb	140.0	308.37	5.51
Barley	ardeb	120.0	264.32	5.51
Cottonseed	ardeb	120.0	264.32	8.26
Sesame	ardeb	120.0	264.32	
Groundnut	ardeb	75.0	165.20	7.51
Rice	dariba	945.0	2081.50	46.26
Chick-peas	ardeb	150.0	330.40	
Lupine	ardeb	150.0	330.40	
Linseed	ardeb	122.0	268.72	
Fenugreek	ardeb	155.0	341.41	
Cotton (unginned)	metric qintar	157.5	346.92	
Cotton (lint or ginned)	metric qintar	50.0	110.13	

EGYPTIAN FARMING AND IRRIGATION TERMS

fara = branch
marwa = small distributer, irrigation ditch
masraf = field drain
mesqa = small canal feeding from 10 to 40 farms
qirat = cf. English "karat", A land measure of 1/24 feddan, 175.03 m^2
qaria = village
sahm = 1/24th of a qirat, 7.29 m^2
saqia = animal powered water wheel
sarf = drain (vb.), or drainage. See also masraf, (n.)

EGYPT WATER USE AND MANAGEMENT PROJECT

PROJECT TECHNICAL REPORTS

NO.	TITLE	AUTHOR
PTR#1	Problem Identification Report for Mansuriya Study Area, 10/77 to 10/78.	Egyptian and American Field Teams.
PTR#2	Preliminary Soil Survey Report for the Beni Magdul and El-Hammami Areas.	A. D. Dotzenko, M. Zanati, A. A. Abdel Wahed, & A. M. Keleg.
PTR#3	Preliminary Evaluation of Mansuriya Canal System, Giza Governorate, Egypt.	American and Egyptian Field Teams.
PTR#4	On-farm Irrigation Practices in Mansuriya District, Egypt.	M. El-Kady, W. Clyma & M. Abu-Zeid
PTR#5	Economic Costs of Water Shortage Along Branch Canals.	A. El Shinnawi M. Skold & M. Nasr
PTR#6	Problem Identification Report For Kafr El-Sheikh Study Area.	Egyptian and American Field Teams.
PTR#7	A Procedure for Evaluating the Cost of Lifting Water for Irrigation in Egypt.	H. Wahby, G. Quenemoen & M. Helal
PTR#8	Farm Record Summary and Analysis for Study Cases at Abu Raya and Mansuriya Sites, 1978/1979.	F. Abdel Al & M. Skold
PTR#9	Irrigation & Production of Rice in Abu Raya, Kafr El-Sheikh Governorate.	Kafr El-Sheikh Team as Compiled by T. W. Ley & R. L. Tinsley
PTR#10	Soil Fertility Survey in Kafr El-Sheikh, El Mansuriya and El-Minya Sites.	M. Zanati, P. N. Soltanpour, A.T.A. Mostafa, & A. Keleg.
PTR#11	Kafr El-Sheikh Farm Management Survey Crop Enterprise Budgets and Profitability Analysis.	M. Haider & F. Abdel Al
PTR#12	Use of Feasibility Studies and Evaluation of Irrigation Projects: Procedures for Analysing Alternative Water Distribution System In Egypt.	R. J. McConnen, F. Abdel Al, M. Skold, G. Ayad & E. Sorial

NO.	TITLE	AUTHOR
PTR#13	The Role of Rural Sociologists in an Interdisciplinary, Action-Orientated Project: An Egyptian Case Study.	J. Layton and M. Sallam
PTR#14	Administering an Interdisciplinary Project: Some Fundamental Assumptions Upon Which to Build.	J. B. Mayfield & M. Naguib
PTR#15	Village Bank Loans to Egyptian Farmers.	G. Ayad, M. Skold, & M. Quenemoen.
PTR#16A	Irrigation System Improvement By Simulation and Optimization: 1. Theory.	J. Mohan Reddy & W. Clyma
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