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Part VI

LAND RECLAMATION AND REHABILITATION

A Review of Some Aspects of Soil Reclamation in Iraq

J. S. Dougrameji, K. I. Musleh and A. B. Hana

INTRODUCTION

Historically, the Lower Mesopotamian plain had to cope with serious problems of waterlogging and salinization. It is, therefore, not surprising that the oldest form of reclamation practice in the world is ascribed to the Sumerians. As early as 3000 B.C., they reclaimed land from marshes of the delta plain by bordering tracts of land with low dams and draining them. As the productivity of agricultural land started declining, land use practice shifted to a system of fallowing the land in rotation. This practice is still prevalent and represents an age-long struggle against the problem of waterlogging and salinization. The system was effective for cultivating salt affected soils. However, it did not prove successful to cure the lands. Thus, over time the Mesopotamian plain gradually transformed into a salt plain.

PREPROJECT REQUIREMENTS

Some theoretical and practical considerations that should enter the process of project planning as prerequisites are listed below:

(i) Soil survey on the type, concentration and distribution (vertically as well as horizontally) of salinity, ESP, CEC, gypsum and pH.

(ii) Soil structure, pore size distribution i.e. effective porosity and aggregate size and stability.

(iii) Texture and thickness of each soil layer and sequence of texture stratification.

(iv) Infiltration rate of the main soil units.

(v) Hydraulic conductivity of different soil layers and moisture characteristics.

(vi) Depth, quality, dynamics and fluctuation of water table.

(vii) Geomorphology, relief and drainage outlets and detailed topographic map.

(viii) Quantity and quality of irrigation water and its source.

(ix) Climatic conditions, including evaporation, rainfall, temperature and relative humidity.

DESIGN AND EXECUTION REQUIREMENTS

There are several aspects which should be evaluated before deciding upon a reclamation programme. Some of the most important ones are listed below:

(i) Extent of levelling required.
(ii) Volume of water required for leaching and irrigation network specifications.
(iii) Specifications of the drainage system as to depth and distances between the drains.
(iv) Volume of drainage water discharged.
(v) Time required for reclamation.

LEACHING AND CROPPING REQUIREMENTS

In the total scheme of reclamation, leaching and crops to be grown play an important role. For these factors, requirements are:

(i) Levelling.
(ii) Reduction of salt content in the root zone to a level of tolerance by the crops.
(iii) Reduction of exchangeable sodium below 10 percent.
(iv) Lowering of water table below critical level to prevent secondary resalinization.
(v) Demineralization of the ground water to a minimum concentration.
(vi) Selection of suitable crop rotations and management practices.
(vii) Monitoring the changes in hydro-physical, chemical and fertility status of the soil.

TESTING OF DRAIN PERFORMANCE

Too often, test drain lines are installed that are only visually inspected once or twice during the first year after installation. If some water is flowing from the pipes, it is concluded that the drain lines perform well. But, such testing does not meet normal standards of objectivity and scientific analysis. Such conclusions on performance based on the outflow alone, without relating it to soil and ground water conditions, may lead to disappointment. The methods and procedures of testing should be such that they permit an objective and scientific analysis of the information collected.

Assuming adequate flow capacity of the drain line, its performance is governed by the water inlet openings in or between drain pipes and the hydraulic properties of the envelope material and the backfill. These two factors are partly interdependent and are, in turn, influenced by such conditions as:

(i) Distribution and thickness of the envelope.
(ii) Stability of backfill.
(iii) Water table elevation, soil moisture and weather conditions during pipelaying.
(iv) Trench width, and
(v) Chemical deposits at or near water inlet openings of the pipes.

Smooth plastic pipes are a practical compromise between the desirable area of opening, on the one hand, and the requirements of pipe strength and low prices, on the other hand. Corrugated pipes usually have much better provision for water entry. The stability of backfill is important for its hydraulic properties. It is often adversely affected by conditions of wet weather and high water table during pipelaying. The trench width affects the backfill and the envelope and therefore their transmissivity. In addition, water inlet openings and pores in envelopes being clogged by physical factors, there are chemical compounds that contribute to the problem. These are normally iron, iron-sulphur and manganese compounds. Clogging results from oxidation of soluble iron in poorly drained soil when exposed to air on contact with the drain and from precipitation of insoluble compounds.

GROUND WATER FLOW INTO DRAIN PIPES

There are a number of equations based on steady state and non-steady state flow conditions that describe the flow of ground water into parallel drain lines. They are based on simplified alternate field conditions and related assumptions such as:

(i) The soil profile is homogeneous, having the same hydraulic properties in any part of the flow regions.
(ii) The soil profile is not homogeneous but is considered to consist of two or three distinctly different layers.
(iii) The area immediately surrounding the drain, especially the lower part of the trench, is homogeneous and has water transmitting properties not different from those of adjacent undisturbed soil, and
(iv) The drain is a so-called ideal drain, i.e., the water can enter the pipe without resistance at any point of its circumference (meaning, the pipe wall is as permeable as the surrounding soil).

In reality, soils are often heterogeneous, particularly in flat alluvial plains, and boundaires between layers are not always sharp. In the lower part of the trench, one usually finds cover material over the drain or envelope material around it and the backfill. The permeability of each one may be high and remain so for many years or for certain reasons decline soon after installation. Criteria for entrance resistance depend on normal discharge rates under prevailing hydrologic and cropping conditions, depth of drains and water table depth and its fluctuations. As a general rule the following criteria are recommended:

Head loss fraction	Drain line performance
smaller than 0.2	good
0.2 to 0.4	moderate
0.4 to 0.6	poor
larger than 0.6	very poor

Under irrigation conditions of arid zones (drain depth of 1.8 m, drain spacing of 50 m and water table one to two days after irrigation at 1.0 m with discharge rate of 4 mm per day), the corresponding values for entrance resistance are as under:

Entrance resistance r_e (days/m)	Entrance head loss (m)	Drain line performance
Smaller than 0.75	Smaller than 0.15	good
0.75 to 1.50	0.15 to 0.30	moderate
1.50 to 2.25	0.30 to 0.45	poor
Larger than 2.25	Larger than 0.45	very poor

SOIL FACTORS INFLUENCING DRAINAGE

The soil quality is a dominating factor in drain performance because the drain itself is passive and can only add resistance, but does nothing to encourage the water to flow towards it. This means that, given optimal drain performance, the water flow is controlled by soil factors as discussed below:

Infiltration rate of surface soil. The value is important to drainage if it is so low as to cause a perched water table or ponded water on the surface.

Uniformity of the soil. A fairly high degree of soil uniformity is desirable. Complete uniformity will normally be unlikely. It is difficult to define acceptable variability in finite terms. This varies for different soil properties. However, the surface topography should be particularly uniform as should be the depth to impermeable layers. Normally, the hydraulic conductivity of the soil would show a fairly large variability. A range of factor 10 from the highest to lowest value is common. Sites with a systematic variation should be avoided, unless this can be taken care of in the design. The initial evaluation of uniformity can be made by trial pits and auger borings.

Depth of different layers. The depth of the various soil layers can be determined through the tests mentioned above. Their efficacy will depend on the depth and hydraulic conductivity of the soil because the tests listed here are based on drainage theories which assume radial flow in the vicinity of the drain. If any layer has a hydraulic conductivity value of less than one-tenth of that of the layer above, it (the lower layer) may be considered as impermeable. It is particularly important for easy theoretical evaluation that there be no such impermeable layer down to 0.5 metre below drain depth. Even at this level it will affect the radial flow. Ideally the impermeable layer should be at least one-eighth of the drain spacing below drain depth. A good site for drain testing should have a uniform soil down to at least four metres over the whole area.

Hydraulic conductivity. Hydraulic conductivity is the most important property in drainage. Lower hydraulic conductivity value, all other factors remaining the same, means high water table at midspacing. Likewise, lower hydraulic conductivity value would mean greater head at entry. An ideal site would have a deep uniform soil with a hydraulic conductivity of more than 1 m/d. A value of 0.2 m/d should be considered as the minimum.

Soil stability to water. A soil relatively unstable to water will tend to slake when wet, i.e., the soil tends to run together and lose its structure. The collapse of the structure causes a loss of larger pores and lower hydraulic conductivity. Stability to water is particularly important in surface soils and in the trench zone soon after backfilling. Slaking in the latter area can ruin the drainage system.

Particle size distribution. The mechanical composition or particle size will determine whether or not a filter is needed. The composition of subsoils at drain depth is most important from this point of view.

Chemical properties. The main chemical properties of drainage interest are the pH, the sulphate content (because of its effect on concrete pipes) and the soil cation exchange characteristics, especially the exchangeable sodium percentage. The cation exchange condition can affect the stability of the soil.

Filter material. A safe guideline is that the hydraulic conductivity of the surround should be at least ten times as high as that of the soil. The basic requirement of a filter material is adequate hydraulic conductivity. The material should not be larger than 50 mm diameter because of the risk of pipe damage during placing. No more than 10 percent should be below 250 micron, because the finer material will clog the opening of the drain pipes. For the same reason, care should be taken to avoid incorporation of top soil material during the process of drain installation.

ASPECTS OF DRAINAGE AND RECLAMATION IN IRAQ

Physiography and Soil

The Plain is part of an old geosyncline which in historical times was submerged by the sea. Sedimentation established an alluvial plain and a landscape of meandering rivers developed. Hence, the soils were mainly from river sediment and the original landscape consisted primarily of river levees and basins situated two to three metres low. Nearer the sea the levees became less pronounced and smaller. The thickness of the alluvial deposits is not exactly known. Generaly, from some tens of metres in the northern part, it becomes deeper near Basrah. The alluvial deposits overlie older formations, including Bakhtiari and Lower-Fars formations which contain saline layers.

Climate

The climate did not change substantially after man's occupation of the Plain. It is classified as subdesertic with a mean annual rainfall decreasing towards south, from 151 mm in Baghdad to 121 mm in Diwaniyah and 140 mm in Basrah. Both the high summer temperatures (33 to 44oC) and the low relative humidity values (23 to 32 percent) result in high evaporation, averaging 200 cm per annum for lake evaporation.

Hydrology

The hydrological conditions of the Plain are governed by the Euphrates and Tigris rivers through their natural flows and the volume of water allocated under irrigation systems and water management practices followed. The Mesopotamian plain with its very gradual southward slope is intersected by marshes, waterlogged areas and numerous working or abandoned water courses of varying sizes. The whole configuration of the plain suggests that natural drainage conditions are poor. The capillary rise from the shallow ground water plays an important role in the ground water behaviour, which needs to be researched. Both the Euphrates and Tigris rivers recharge the ground water in the delta. Seepage from rivers predominates throughout the year with possible exception of the Diyala river which also acts as a drain. The contour lines of the water table more or less follow the topographical contour lines and consequently the water table gradient becomes very moderate, less than the critical gradient required for extensive ground water flow. The only areas with some natural drainage are the higher situated river levees which are small, elongated strips along the rivers. At present, the water table in the major part of the plain is within 3 metres depth from the surface. Where it was deeper, it was built up to within this depth, due to intensive irrigation over the past five to ten years. The water table is not constant throughout the year. It is at its maximum in April-May, coinciding with the highest river discharge, and at its minimum in October-November, coinciding with the lowest discharge. This sinesoidal effect is partly inherited and is partly a result of the prevailing environmental conditions in the Plain.

Hydraulic Conductivity

The alluvial plain sediment deposits have a complex pattern that suggests a wide variation in hydraulic conductivity. In general, the hydraulic conductivity values range from 0.1 to 3 m/day indicating moderate permeability. An inventory of hydraulic conductivity measurements of the upper 5 metres of the soils was made for project areas (Table 1). From the data, the following general conclusions can be drawn:

(i) The permeability values vary widely both with location and depth, but in general the permeability increases with depth.

(ii) The Euphrates sediments seem to be more permeable than the Tigris sediments and

(iii) Towards the south the permeability does not decrease with the change in the soil texture as is generally expected.

In order to make reliable estimates of hydraulic conductivity, an adequate number of permeability tests should be made - one test per 10 hectares on the average. Although this observation density may not have been fulfilled for the project areas, it is believed the permeability values adopted for calculations were in the right range.

TABLE 1 Permeability of the Soil as Related to the Depth below Surface, Selected Locations in Iraq

Location		Percentage of observation at 2 levels and five depths					Number of observations
		1m	2m	3m	4m	5m	
Lower Diyala	(1)	29	49	56	61	63	137
	(2)	29	36	36	40	42	
Middle Tigris	(1)	-	91	63	58	48	130
	(2)	-	55	33	30	26	
Middle Tigris	(1)	-	56	77	77	74	127
	(2)	-	44	58	47	39	
Gharraf East	(1)	87	75	73	76	73	588
	(2)	68	56	54	53	50	
Hilla-Diwaniya	(1)	29	61	78	86	89	1 762
	(2)	9	32	54	63	67	
Rumaitha	(1)	-	96	94	96	96	511
	(2)	-	83	81	83	83	

Note: (1): at 2 m/day
(2): at 1 m/day
1m ... 5m: are five soil depths.

Salinity

Through time the Plain developed into a marine delta in which salts were deposited both under the influence of rivers and the sea invasion. The geological build-up with its salt containing strata of the Pliocene and Miocene age developed saline ground waters. With the intensification of irrigation, the water table rose to within the critical depth for salinization (+ 350 cm). The salt was transported to the surface through capillary action and residual salinity was transformed into actual salinity. The salinity of the soil has been mapped at the project and

country level. It is estimated that 80 percent of the soils in the Plain are to some degree affected by salinity. The central part of the Plain can be classified as of the sulphate-chloride type. In the south choride-type salinity dominates. Although river waters do not contain high salt concentration, the salinity gradually increases towards the south. The Tigris water near Baghdad and the Euphrates near Falluja have salinity values ranging from 300 to 500 ppm. At their confluence near Garmat Ali, salinity values increase to over 600 ppm.

TABLE 2 Summary of Surface Water Analysis during Normal Flow of Tigris and Euphrates Rivers

River	Location	EC x 10^6 (micromhos/cm)	SAR	Salinity class	Sodicity class	pH
Tigris	Mosul	404	0.3	C2	S1	7.2
	Amarah	650	-	-	S1	-
	Qurna	-	1.5	C3	S1	8.5
Euphrates	Al-Kaim	575	0.9	C2	S1	7.2
	Qurna	960	2.2	C3	S1	8.6
Diyala	Ba'qouba	730	1.2	C2	S1	7.3
	Baghdad	1 050	1.8	C3	S1	7.9
Shatt	Qurna	900	2.0	C3	S1	7.5
Al-Arab	Fao	2 800	7.0	C3	S2	8.5

The chemical distribution of the cations and anions suggests that in all the rivers calcium and bicarbonate are the most predominant salts. One-third to one-half of total salts are mainly calcium carbonate and, occasionally, some magnesium carbonate and gypsum. These are, however, responsible for a decrease in the salinity of the rivers by a factor approaching one-third to one-half of its quantity. Precipitation of these salts indicated that the change in the SAR was almost within the same class of the sodium hazard mentioned above. Calculations suggested no positive residual sodium carbonate. The water of the rivers is very hard; the total hardness exceeds 200 ppm. It needs softening treatment for public use. Salt water intrusion from the Gulf is evident. Over the years a gradual rise in salinity has been noticed. The salts balance of the Plain shows that a major part of the salts carried to the Plain accumulates on the land and only 20 percent of it escapes beyond Basrah.

Drainage

Problems of waterlogging and salinity can best be solved by control and often lowering of the ground water table, subsequent desalinization and proper crop management. It is well-known that certain drainage projects failed to show results. This was not merely due to inexperience with the execution of the projects which resulted into improper layout and maintenance of irrigation and drainage systems consequently leading to resalinization.

The selection of the criteria for drainage designs were sometimes too optimistic and would not control salinity as envisaged. Some drainage criteria used for pilot projects are presented in Table 3 and criteria applied for a number of project areas given in Table 4. Over time, the drainage criterion was amended in a way that a deeper dewatering zone and a greater discharge rate were adopted. The drainage

TABLE 3 Drainage Criteria used for Drain Space Calculations in some Pilot Projects in the Lower Mesopotamian Plain

Location	Year of Design	Drainage criterion discharge (mm/day)	Water table (m)
Dujailah Pilot project	1954	1.0	0.60
Abu-Ghraib Farm	1958	1.0	1.00
Suwaira Governmental Farm	1967	2.0	1.50
Lower Khalis Pilot project	1970	3.5	1.30

TABLE 4 Drainage Criteria used for Drain Space Calculations in some Project Areas in the Lower Mesopotamian Plain

Location	Year of Design	Cropping intensity (gross area)		Drainage criterion	
		Winter	Summer	Discharge	Water table below surface
		(percentage)		(m/day)	(m)
Greater Mussayeb project	1953	75	60	0.4	1.00
Lower Diyala project	1954	67	42	0.8	1.00
Hilla-Diwaniyah project	1959	80	18	1.8	1.50
Amara project	1965	75	28	1.0	1.00
East-Gharraf project	1967	60	40	2.2	1.50
Ramadi project	1968	100	40	2.5	1.25-1.50
Radwaniyah project	1970	50	15	2.5	1.00
Dalmej project	1974				
Greater Mussayeb	1973	125-170		1.85-3.2	0.9 -1.5

systems gradually became deeper, from 1.5 to over 2.0 m, and closer spaced, from average values of 300-1 000 m to 100-200 m. Dependence on the cropping intensity became very significant. This was because of (i) insufficient or incomplete information, (ii) uncontrolled irrigation practices and the tendency to systematically overirrigate, which resulted in high percolation losses, (iii) improper maintenance of drainage systems, (iv) capillary rise of the highly saline ground water which was underestimated and (v) the capillary rise of saline ground water during summer fallow, which was not taken into account in the determination of leaching requirements. It is, therefore, logical that over the years the drainage criterion was adjusted, i.e., more precautions were taken to minimize the salinization hazard.

The natural boundary of the flow system can be considered as one-fourth to one-sixth of the drain spacing. This implies that conditions and permeability of the subsoil should be known to greater depth (10-50 m) in order to obtain the most appropriate drain spacing. Sufficient information on this aspect is normally not available. There is, therefore, a need to carry out some pumping tests to determine exact values for various project areas. In general, a transmissivity (kd) value of 15-20 m^2/day seems to be a reasonable estimate for the central part of the lain, although higher values may occur where pleistocene sandy strata underly the recent alluvium.

Reclamation

Chemical analyses show that a major part of salt affected soils in the plain can be classified as saline/alkali, with rare occurence of saline or alkali soils. Most studies have indicated that leaching does not constitute a major problem. It depends upon soil structure, texture, porosity, salt composition of irrigation water and soil, efficiency of irrigation networks, methods of leaching and leaching time. Leaching curves were established for various soils depicting the relationship between the depth of leaching water application and decrease in soil salinity. All curves show a positive relationship. The data in Table 5 give leaching requirements for soils of different textures and salinity levels in Wahda, Khalis and Abu-Ghraib areas. It was noticed that sabakh soils were easiest to be leached, followed by the dry and puffed solonchake and takyr-like solonchaks, which are encountered in depression areas.

TABLE 5 Net Leaching Requirements for One Metre of Soil Depth for Soils of Different Textures and Salinity Levels in Iraq

(thousand cubic metres per ha.)

Salinity level (mmhos/cm)	Heavy textured clay soils, homogeneous with poor drainability	Medium textured soils and stratified with medium drainability	Light loamy textured soils and stratified with good drainability
4-8	1.5 - 5.4	1.3 - 4.4	0.8 - 2.8
8-16	5.4 - 7.65	4.4 - 6.2	2.8 - 4.0
16-32	7.65 - 11.5	6.2 - 9.3	4.0 - 6.0
32-64	11.5 - 15.5	9.3 - 12.4	6.0 - 7.95

The salinity-stricken depression areas are composed of heavy textured soils and are characterized by low intake rates and low permeability values in the upper soil layers which restrict proper water percolation and salt movement. After rain-showers in winter, depressed areas are flooded and standing water would disappear only by evaporation. Special agricultural practices such as subsoiling, and deep-ploughing should be followed to improve the physical condition and related drainability of these soils. Moreover, provision for surface drainage should be included in the system. The highest river discharge occurs in winter and spring during which evaporation is lowest. This period is, therefore, most suitable for leaching.

Cropping

Continuous sedimentation, salt deposits in soil, saline ground water and resalinization make agriculture a difficult task in the plain. Intensity of cropping can be, therefore, increased only gradually and an overall maximum intensity of 120 to 130 percent should be a reasonable target. Only on better lands, i.e., on the level soils, higher intensities may be aimed at. The process of reclamation will have to encompass changes in the cropping pattern, which would involve changes in acreage under existing crops and introduction of new crops. The following aspects should be considered for achieving high cropping intensities:

(i) That there is overlap in growing seasons for certain crops, like cotton and wheat, if sown in succession.

(ii) Labour, mechanization and management constraints may make it not possible to have a variety of summer and winter crops grown in succession, and

(iii) High summer crop intensities will put high demand on the drainage system to control salinity, and high demand on irrigation water as well, see Table 6.

TABLE 6 Drain Spacings in Relation to Cropping Intensity for Some Soils in the Greater Mussayeb Project, Iraq

Cropping intensity	Drain spacing in metres	
	High levee soil	Basin soil
100% winter + 100% summer	65	50
100% winter + 75% summer	85	65
100% winter + 50% summer	115	85
100% winter + 25% summer	185	150

Social and Organizational Aspects

Social and organizational aspects play an important role in the process of land use planning. To make a land reclamation scheme a success, farmers must be provided with satisfactory living and working conditions. In 1951, the Miri-Sirf Land Development Law was passed giving the government the right to transfer ownership to the cultivators of flow irrigated farm units not exceeding 25 hectares. Under this law 6 250 hectares of land were distributed among settlers in farm units of 12.5 hectares in the Latifiyah project in 1952 and some 20 000 hectares in the Greater Mussayeb project in 1957 and 1958. This experiment did not prove successful as the farmers had to cope with serious problems of salinization, sedimentation and unreliable water supply. This encouraged subsistence farming and affected the rate of return adversely.

In 1958, an Agrarian Reform Law was passed by which the ownership was limited to a maximum of 250 hectares of irrigated lands. Under this law some 22 000 hectares were distributed in units of 16.5 hectares in the Greater Mussayeb project. This time cooperatives were set up, but proved not to be effective because the farmers were unable to maintain farm drainage and irrigation systems, to benefit from high quality seed and fertilizer and to make use of machinery services. The

Agrarian Reform Law of 1970 further reduced the maximum personal holding to 75 hectares for good quality land supplied with gravity irrigation. The area was to be reduced by half, if it was situated not far away from a marketing centre.

CONCLUSIONS

Experience has shown that there exists strong relationships among overirrigation, soil salinity, crop production and general welfare of the population in an irrigation project. Salinity reduces the productivity and forces the land to return to the traditional fallow system. Soils of the Mesopotamian plain are, however, such that soil productivity losses are not irreversible because practically all soil types can be more or less readily reclaimed. Yet, problems of soil fertility must still be solved after the process of reclamation is completed. Proper designing of an irrigation and drainage network requires a thorough understanding of physical and chemical properties of local soil types and water requirements of crops to be grown. In arid and semi-arid areas coordinated advanced research is of particularly great importance.

Concerning drainage, the experience acquired elsewhere on spacing of tiles and composition of thickness of drain envelopes may not be directly applicable to soils of arid and semi-arid regions. Different clay mineralogy and a generalized lack of organic water may considerably affect the soil structure. Further research is required on necessary conditions to operate best and economically drains in soils subject to low rainfall and high temperatures. Further research of direct relevance is the range of soil mechanics/soil physics matters on interactions between soil, water and implements. The problems are not unique to drainage but apply to cropping, levelling and similar tasks too. Perhaps the only difference is that drainage is more concerned with subsoils. A proper understanding of interactions would allow estimations of correct conditions for subsoiling at the dry end. Furthermore, swelling soils and textural stratification present a whole range of problems that need to be tackled. The importance of carrying out pilot projects before undertaking a full-scale project operation cannot be over-emphasized, whenever techniques introduced from elsewhere encounter differing local conditions.

Sociological problems are more difficult to solve. A system which relies upon combining of special managerial skills, organized administration, teams of engineers, researchers, economists, technicians and social workers and a farming population receptive to the new methods and advice, often demands a revolutionary change in life styles of technical personnel as well as the farmers. Beyond question, intensive cultivation of reclaimed areas requires continued education of the farmer. An extension service capable of explaining to the farmer, in his own language, the advantages of alternative methods of land use and training him in the use of equipment, seeds, fertilizers, pesticides, etc. is of particular importance. Efforts in these directions should be backed up by a satisfactory credit and marketing system. An in-depth study of social conditions and constraints related to the implementation of agricultural development and schemes in areas with predominantly traditional farming populations might contribute to solving a number of outstanding problems.