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A Global Data Set of Soil Particle Size Properties

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Abstract

A standardized global data set of soil horizon thicknesses and textures (particle size distributions) has been compiled from the FAO/UNESCO Soil Map of the World, Vols. 2-10 (1971-81). This data set will be used by the improved ground hydrology parameterization (Abramopoulos *et al.*, 1988) designed for the GISS GCM (Goddard Institute for Space Studies General Circulation Model) Model III. The data set specifies the top and bottom depths and the percent abundance of sand, silt, and clay of individual soil horizons in each of the 106 soil types cataloged for nine continental divisions. When combined with the World Soil Data File (Zobler, 1986), the result is a global data set of variations in physical properties throughout the soil profile. These properties are important in the determination of water storage in individual soil horizons and exchange of water with the lower atmosphere. The incorporation of this data set into the GISS GCM should improve model performance by including more realistic variability in land-surface properties.

Introduction

As land-surface parameterizations in GCMs become more sophisticated, more detailed types of soil data are needed. Realistic models of water movement in the soil layer (e.g. Abramopoulos *et al.*, 1988) require information on variability of physical properties, including differences in the texture of soil horizons and thickness of these different horizons. In the global application of such land-surface parameterizations, the addition of geographic variability in the physical properties of soils, at the very least among the different continents, provides a more accurate description of surface characteristics that influence water movement in the soil profile.

In the modified bucket parameterizations used in the GISS GCM Model II, soil water capacities are calculated as a function of vegetation type (Hansen *et al.*, 1983). More recently, global data sets of available soil water have been compiled using textural information from the upper 30 cm of the soil profile to assign water-holding attributes to the entire soil profile (Bouwman *et al.*, 1991) or the root zone (Henderson-Sellars *et al.*, 1986). In these studies, surficial physical properties are assumed representative of the entire soil profile and then estimates of soil water-holding capacity are assigned as a function of soil type and surficial texture for use in bucket-model calculations. In most soils, the textural class of the underlying horizons are significantly different from the surface texture due to pedogenic processes including degradation, aggradation, or translocation of materials within the soil profile (Buol *et al.*, 1973). The bucket-model approach, however, is not appropriate when calculating water storage and movement throughout the complete soil profile as a function of hydraulic conductivity and matric potential. Furthermore, in a bucket model, infiltration can only be crudely estimated as a function of empirically determined parameters. These parameters, in turn, may unrealistically partition water at the atmosphere/soil interface into water lost as surface runoff versus water stored in the soil.

We have generated a standardized global data set of physical soil properties consisting of soil horizon textures and thicknesses for 106 soil types based on information published by FAO/UNESCO (1971-81). The soil horizons are differentiated over the nine major continental divisions. This data set can be combined with Zobler's (1986; Figure 1) World Soil Data File to generate a global data set of physical properties that maybe used in simulating water movement in GCMs.

The following report explains the decision-making process that went into compiling a standardized data set of texture and associated depth information, the organization of the data set, and some of its strengths and weaknesses. We then compare three estimates for the potential storage of water in soil calculated using our data set with the field capacities used in the GISS GCM Model II. The three estimates are: 1) potential storage of water in the soil profile, 2) potential storage of water in the root zone, and 3) potential storage of water derived from soil texture.

As investigators compiling a data set of physical soil properties to be used as prescribed surface characteristics in a GCM, we recognize that realistic values of available soil water can only be estimated as a combined function of climate, soil, and vegetation. Such research, though on-going, is beyond the scope of this report.

Data and Methods

The depth and textural (relative percent sand [2-0.05 mm], silt [0.05-0.002 mm], clay [<0.002 mm]) data for 106 soil types were taken from the Morphological, Chemical and Physical Properties Appendices in each of the nine volumes of the FAO-UNESCO Soil Map of the World (1971-81). These appendices listed data for selected soil profiles considered typical for each continental division. For some of the continental divisions the textural and depth data were not available for all of the soil types mapped by Zobler (1986). In other cases, the data were inconsistent or missing for one or more horizons of a soil type.

We elected to include information from the A-, E-, B-, and C-horizons in our data set in recognition that these horizons contribute to the storage and movement of water within the soil profile. We did not include data from the litter (O-) horizon, from bedrock, or from parent material. We used data from the more complete description or the description with greater geographic coverage for those soil types with multiple descriptions of physical properties within a single continent.

Decision Rules

A set of decision rules was adopted to standardize the data set, to check the data for errors and to correct them, and to fill in missing data. Table 1 summarizes the adjustments that were made to data.

1) Values were not included from horizons where the sum of percent sand, silt, and clay values was less than 50 or greater than 150 (presumably the result of either measurement or tabulation errors).

2) A default basal depth of 3.6 meters was used when no bottom depth was specified for a soil profile. The default depth of 3.6 meters was selected to allow realistic simulation of dynamic hydrology.

3) An average depth was calculated in cases when a depth range was given or the top and bottom depths of contiguous horizons were not the same. Depths reported in inches were converted to metric.

4) To use the particle size information for calculation of hydraulic conductivity and matric potential, the percent sand, silt, and clay data had to sum to 100 percent. To normalize the data to sum to 100 percent, we adjusted the percent clay values, rather than renormalizing all three size classes, because of the greater potential error in the measurement of the clay size class. As long as the summed percent ranged between 80 and 120 percent, the appropriate amount was subtracted/added from the clay fraction. In one case, when the summed percent was more than 120 percent or less than 80 percent, however, the qualitative descriptions of the soil horizons were used as guidelines to determine the proportions of each size class.

5) Interpolation of values as the average of data from bracketing horizons was used to fill in missing data for individual horizons. We elected to be conservative and presuppose continuity of trends within the soil profile rather than prescribe data on the basis of qualitative descriptions. We recognize that assigning values to a B-horizon as the intermediate properties of A- and C-horizons is not representative of many soils but we believe that this is more favorable to defining values arbitrarily.

5a) When qualitative descriptions suggested that adjacent horizons were very similar (e.g., similar horizon nomenclature: Bg1, Bg2, Bg3, ...), data from the adjacent horizon were substituted for the missing data.

6) Extrapolation of values assuming a linear rate of change was used to replace missing values in either the uppermost or lowermost horizon. Once again this is a conservative choice because we assumed continuity of trends between adjacent soil horizons.

7) Adjustments/Corrections were made for obvious tabulation errors and large discrepancies between the qualitative descriptions and percent sand, silt, and clay values. For many of the North Central Asia soils and a few soils from the other continental divisions, the particle size analyses were reported in nonstandard international particle size ranges. These data were converted to standard size ranges (sand > 0.05 mm; silt 0.05-0.002 mm; clay < 0.002 mm) by assuming uniform distributions within each reported size range and partitioning the data proportionally.

Missing Data

A number of soil types from each continent were completely missing data. To fill in the textural or depth data for these cases, we substituted data using the same soil type from a different continental division. The substitution order for each continent was made recognizing similarities in geology and modern climates. Table 2a lists the hierarchy used to substitute data from a different continent. When data for a soil type were absent from all the continents, data were substituted from an adjacent soil type with similar descriptive characteristics. Table 2b lists these soil types and their replacement soil types. Lithosols were assigned a total thickness of 10 cm and the particle size distributions of the C-horizon of a Eutric Regosol. Rankers were assigned a total thickness of 25 cm and the particle size distributions of the A-horizon of a Humic Cambisol. Histosols by definition are organic material and cannot be described in terms of relative percentage of sand, silt, and clay particle sizes. We assigned Histosols an average thickness of 360 cm and arbitrary distribution of particle sizes summing to 100 percent but not used in any subsequent calculations.

The frequency of occurrence of each of the 106 soil types for each of the nine continental divisions and missing data substitutions are listed in Table 3. In most cases, the potential error associated with substituting data for soil types with missing information is not large. The frequency of occurrence for these soils in Zobler's World Soil Data File rarely exceeds 50 1x1 grid cells, excluding Lithosols, Rankers, and Histosols. The most abundant soil type substituted for was Haplic Yermosol, with 615 1x1 grid cells. Among the continental divisions, the absence of soil properties data was most widespread for Mexico/Central America followed by North-Central Asia. We did not substitute data for the missing values of two minor soil types, Ferric Podzol and Gelic Planosol, since these were not present in the Zobler World Soil Data File.

Soil Profile Thickness

Maximum soil depths in the data set are shown in Table 5 and Figure 2. In many cases, the soil profile thicknesses represent minimum possible values because profile descriptions do not always extend to subsurface bedrock. The soil thicknesses range from 10 cm for Lithosol to 800 cm for Distric Nitosol in Africa. The spatial distribution of soil profile thickness can be summarized as thickest in the well-developed soils of tropical low latitudes and thinnest in the poorly developed soils of high latitudes. The soil profiles are thin in mountainous regions such as the Himalayas and Andes and are thick in mid-latitude peatlands such as those found in northern Europe and North America.

Potential Water Storage Calculations

Using the data set, we have calculated three different estimates of potential storage of water in soil. These estimates can be used as proxies for the amount of water in the soil layer available to plants for evaporation. They were all estimated as the sum of the amount of water in a soil column with a 1x1 cm cross section.

1) An estimate of potential storage of water in the soil profile was calculated. The relative saturation capacities for the different particle-size classes and for peat (Histosols) listed in Table 4a.

2) An estimate of potential storage of water in the root zone was also calculated. The root-zone thickness was derived using a) information from the simplified 8-type version of the Matthews (1983) 22-type global vegetation data set (Matthews, 1984; Hansen *et al.*, 1983) and b) estimates of maximum root-zone thicknesses for these eight types (Table 4b; Rosenzweig, *unpub.*). When the soil profile thickness is larger than the maximum root-zone thickness, root-zone thickness is limiting.

3) The potential storage of water derived from soil texture was calculated as a function of the textural class (Table 4c) of each horizon within the soil profile. The textural class of each horizon was estimated from the relative amounts of sand, silt, and clay.

These estimates of potential storage of water in soil are compared with the global distribution of the vegetation-dependent water-holding capacity prescribed for the GISS GCM Model II (see Table 6 in Hansen *et al.*, 1983). The water-holding capacities in Model II range from 20 mm for desert vegetation to 650 for cm rainforest vegetation. The spatial patterns of this estimate closely correspond to the mapped patterns in Matthews (1983) 22-type global vegetation data set. Low values are concentrated in subtropical and polar desert regions, whereas high values are associated with low latitude rainforests.

Derived Properties

Potential Storage of Water in the Soil Profile

The potential storage of water at 100 percent saturation represents the maximum amount of water that the soil profile can possibly hold (Table 6; Figure 3a). The values for potential storage of water for the entire soil profile range from 42 mm for Lithosol to 4432 mm for Distric Nitosol. The geographic distribution of this estimate shows that areas of high values closely correspond to areas of thick soil profiles with high clay content resulting from greater soil development; likewise, the areas of low values are associated with thin soil profiles with low clay content.

Distinct features include low values for high latitude Lithosols in northeastern Asia, northern North America, mountainous regions, and central desert areas. Large values are located along the equator in South America, Africa, and south Asia, and in midlatitude peatlands of northern Europe and

North America. The major desert regions are not resolved with this estimate because of the relatively large soil horizon thicknesses, underscoring that potential storage of water in the soil profile is the maximum amount of water that can be stored throughout the soil profile. Overall, the potential storage of water in the entire soil profile over estimates the amount of soil water available for evapotranspiration. Soils are rarely completely saturated throughout the profile.

Potential Storage of Water in the Root Zone

The potential storage of water in the root zone is shown in Figure 3b. This measure indirectly includes climate information as a function of the vegetation data because vegetation coverage and associated root-zone thickness reflect climatic moisture gradients. For example, maximum rooting depths in desert regions are determined by water supply. The values of the potential storage of water in the root zone range from less than 2 mm for desert type vegetation associated with Lithosols, Arenosols, and Xerosols to as large as 1700 mm for Woodland, Evergreen, and Deciduous vegetation associated with Histosols.

For the most part, the mapped pattern of this measure resembles the Matthews (1983) 22-type global vegetation data set. Low values associated with major desert areas are well defined in north Africa and central Asia. The low values farther north correspond to high latitude Lithosols. High values in the moderate-to-high latitudes are often associated with forested, deep organic-rich soils. The low values in tropical rainforest areas of northeastern South America and west-central Africa derive from the moderately shallow maximum rooting depth used for rain forest vegetation.

Potential Storage of Water Derived from Soil Texture

A commonly used estimate of the amount of soil moisture available for evapotranspiration is calculated as a function of texture (Table 7; Figure 3c). This estimate is defined as the amount of water released between *in situ* field capacity and the soil wilting point (usually measured as the difference in water content at soil matric potentials of -0.03 MPa and -0.15 MPa; Soil Science Society of America, 1987). The values for potential storage of water derived from soil texture range from 17 mm for Lithosol to 2160 mm for Histosols. In general, the geographic distribution of this estimate shows that areas of high values also correspond to areas of organic soils or thick soil profiles with high clay content resulting from greater soil development.

Comparisons with the GISS GCM Model II Water-Holding Capacities

Spatial variation in the Model II water-holding capacities (Figure 3d), though consistently lower, resembles the estimate of potential storage of water in the root zone (Figure 3b). The similarities in geographic variability result from both the Model II and the root-zone estimates being derived from Matthews (1983) vegetation data set. The maximum possible water-holding capacity used in Model II of the GISS GCM (650 cm) is significantly smaller than the maximum possible values for either of our three estimates of potential storage of water in soil (1700-4432 cm). The mapped values of water-holding capacities used in Model II are concentrated at the low end of the scale and show much broader and smoother patterns of spatial variability than the three estimates we calculated.

Discussion

The task of generalizing soil properties for GCMs requires transforming very heterogeneous high resolution data into representative homogeneous information at a much lower resolution. Variability in soil physical properties (e.g. texture and thickness) is scale-dependent. While there remains a great deal of variability at the subcontinental scale not captured in our data set, we believe characterizing these properties at the continental scale is a necessary first step to improve current specifications of soil in GCMs.

A number of less-than-satisfactory GCM results have been attributed to inadequate ground hydrology parameterizations and the values used for soil water-holding capacity (Rind, 1988; Rind *et al.*, 1990; Delworth and Manabe, 1988; Kellogg and Zhao, 1988). For example, Rind (1988) has suggested that primitive ground hydrology parameterizations in the GISS GCM have resulted in "too much soil moisture and rainfall" for Canada and the northern USA. The data set we have compiled will be used in an updated version of the improved ground hydrology parameterization that is being incorporated into the current version of the NASA/GISS GCM (Abramopoulos *et al.*, 1988). We expect that GISS GCM experiments using the new ground hydrology scheme and the more realistic soil characteristics from our data set will provide insights into climate model sensitivity to energy/moisture fluxes between the land and atmosphere and lead to improved model performance.

Examination of the differences among our three potential storage of water in soil estimates demonstrates the problems that one may encounter portraying soil moisture as a static, empirically-derived estimate. Soil moisture is an extremely interactive measure reflecting the collective influence of climate, soil properties, and vegetation. Focusing on our results for northern Africa helps to illustrate this point. When the entire soil profile is considered as a possible reservoir, the soil profile has a relatively large storage capacity. In contrast, when only the maximum rooting depth is considered as a possible reservoir, the soil profile has an extremely small storage capacity. The soil texture-based water-storage estimate represents an intermediate alternative with moderately low storage capacity. The GISS Model II water-holding capacities for the region, also derived from vegetation data, are similar to the values based upon rooting depth. Under current dry conditions, the very small capacity seems intuitively more correct; however, if climate change resulted in regionally wetter conditions, the intermediate or the large capacity would be more appropriate.

In addition to describing our data set of physical property of soils, we have presented estimates for soil moisture as the potential storage of water in the soil profile, the potential storage of water in the root zone, and the potential storage of water derived from soil texture. Nevertheless, we feel it is important to caution that realistic estimates of soil moisture can only be calculated using an interactive climate forcing of moisture supply and demand.

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Appendix 1: Description of the Computer Files

The particle size data set has been archived at the National Space Science Data Center, NASA/Goddard Space Flight Center, Greenbelt, MD 20771. The data has been stored in free format as four 106x10x15 dimensioned real*4 arrays: depth, sand, silt, and clay. The first dimension (106) corresponds to the sequence number of the soil types in Zobler's (1986) World Soil Data File. The second dimension (10) corresponds to the volume numbers of the nine major continental divisions in the FAO/UNESCO Soil Map of the World, Vols. 2-10 (1971-81). The third dimension (15) corresponds to the individual horizons with data for each soil type from the Morphological, Chemical and Physical Properties Appendix in each of the nine volumes of the FAO/UNESCO Soil Map of the World (1971-81). The data in the sand, silt, and clay arrays are stored as proportional values for each soil horizon. The arbitrary particle size distribution summing to 100 percent included for Histosols (entries 61-63 in the first dimension of each array) should not be used. Instead, values reflecting the physical properties of organic soils and appropriate for specific research objectives should be inserted.

The data in the depth array are scaled in meters with the first value being 0 m depth for each soil type and the subsequent values the contact depths of contiguous horizons. By definition, the depth array contains one extra value for the third dimension corresponding to the bottom depth of the lowest horizon for each soil type. Within the data set, no soil type had more than 14 soil horizons. In cases when the number of horizons in a soil type was less than 14, we used -1.0 values to flag the end of the record for each soil type. For example, a soil type with 10 horizons has 10 data entries in the sand, silt, and clay arrays, 11 data entries for the depth array, and -1.0 values for entries 11 - 15 in each array (entries 12 - 15 for the depth array).

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Figure Captions

Figure 1. Global distribution of 26 major soil units mapped by Zobler (1986).

Figure 2. Global distribution of soil profile thickness based on maximum soil depth of each soil type.

Figure 3. Global distribution of *a*- the potential storage of water in the soil profile, *b*- the potential storage of water in the root zone, *c*- the potential storage of water derived from soil texture, and *d*- water-holding capacity prescribed for the GISS GCM Model II.

Table 1. Key punching corrections/modifications to each soil type by continent.

Soil Num.	Soil Code	Soil Name	North America	Mexico/ Central America	South America	Europe	Africa	South-Central Asia	North-Central Asia	South-east Asia	Australia /South Asia
1	AF	Ferric Acrisol					2,4			1,3,4,5	2
2	AG	Gleyic Acrisol					4,6				5
3	AH	Humic Acrisol		1,4						1,2,4	6,7
4	AO	Orthic Acrisol			1,2,4		4,5		1,2	1,2,3,4	
5	AP	Plinthic Acrisol					4,6		2	4	
6	BC	Chromic Cambisol		1			4,6		2,3,6,7		6
7	BD	Dystric Cambisol	1			1,3			1		5
8	BE	Eutric Cambisol	1			3,4	4,5			2	5
9	BF	Ferralic Cambisol					5		1	4	1
10	BG	Gleyic Cambisol				2	4		1		
11	BH	Humic Cambisol					2	5	1		5
12	BK	Calcic Cambisol				2,4	4				1
13	BV	Vertic Cambisol		4		3,4					
14	BX	Gelic Cambisol	4						4,6,7		
15	CG	Glossic Chernozem									
16	CH	Haplic Chernozem	2			4,7			1		
17	CK	Calcic Chernozem	2			1			1		
18	CL	Luvic Chernozem	2,4								
19	DD	Dystric Podzoluvisol			1,2,3,4						
20	DE	Eutric Podzoluvisol				1,4,7			1,7		
21	DG	Gleyic Podzoluvisol				4			1		
22	E	Rendzina	1	1		3,4					1
23	FA	Acric Ferralsol			5						1,5
24	FH	Humic Ferralsol			1		2,4,6				1
25	FO	Orthic Ferralsol			1,4		4			1	4
26	FP	Plinthic Ferralsol		1			4				
27	FR	Rhodic Ferralsol					2,4,6			2	1
28	FX	Xanthic Ferralsol			1		1				
29	GC	Calcaric Gleysol							4,6,7		
30	GD	Dystric Gleysol				2	4		1		
31	GE	Eutric Gleysol	1,6			2,4	2	5	1	1	
32	GH	Humic Gleysol				1,2,6					2,5,6
33	GM	Mollic Gleysol	2,4						1		
34	GP	Plinthic Gleysol									

37	HG	Gleyic Phaeozem				2					5,6
38	HH	Haplic Phaeozem		2,6	2						1
39	HL	Luvic Phaeozem			2	5					
40	I	Lithosol									
41	JC	Calcaric Fluvisol	6			4	4		1,4,7	4	
42	JD	Dystric Fluvisol	2								
43	JE	Eutric Fluvisol	1			1,2,4		1,4,7			6
44	JT	Thionic Fluvisol			1,4,6		4			1	
45	KH	Haplic Kastanozem	2						1,2,4,6,7		
46	KK	Calcic Kastanozem	6	1		5	4				
47	KL	Luvic Kastanozem	2,4			5,7			4,7		
48	LA	Albic Luvisol	1,5,6								
49	LC	Chromic Luvisol		1		1,4	4,6	1,4,7			
50	LF	Ferric Luvisol					2,4,6				
51	LG	Gleyic Luvisol		1		1					4
52	LK	Calcic Luvisol				2,4,5					4
53	LO	Orthic Luvisol				2					5
54	LP	Plinthic Luvisol					2,4,6				
55	LV	Vertic Luvisol									
56	MG	Gleyic Greyzem									
57	MO	Orthic Greyzem	2			1,4,7					
58	ND	Dystric Nitosol		1			4,6			4	1
59	NE	Eutric Nitosol		1			4			7	
60	NH	Humic Nitosol									
61	OD	Dystric Histosol	1		1	1		1	1		1
62	OE	Eutric Histosol	1			1					
63	OX	Gelic Histosol	1								
64	PF	Ferric Podzol									
65	PG	Gleyic Podzol	1			1,2,3,4					
66	PH	Humic Podzol				2,3,6			1,4,7	1,4	
67	PL	Leptic Podzol				1,6					
68	PO	Orthic Podzol	1			1,2,3,5				3,4	
69	PP	Placic Podzol				2,3,5,6					1,2,5,6
70	QA	Albic Arenosol									4,5
71	QC	Cambic Arenosol				4	4				
72	QF	Ferralic Arenosol					1				
73	QL	Luvic Arenosol					4,6				
74	RC	Calcaric Regosol									1,2
75	RD	Dystric Regosol									
76	RE	Eutric Regosol	1		2		4				

79	SM	Mollic Solonetz	2,3,4		6				2,4		
80	SO	Orthic Solonetz				4,7	4	2,7	1		4,5
81	TH	Humic Andosol			2,6	1			1	4	5,6
82	TM	Mollic Andosol		1						2,4	1
83	TO	Ochric Andosol				4					2,6
84	TV	Vitric Andosol			2	1					
85	U	Ranker									
86	VC	Chromic Vertisol				4	3	7		1	5
87	VP	Pellic Vertisol		1		4		7		4	4,5,6
88	WD	Dystric Planosol									
89	WE	Eutric Planosol		1			4				5
90	WH	Humic Planosol									
91	WM	Mollic Planosol									
92	WS	Solodic Planosol			2,4		4,5				
93	WX	Gelic Planosol									
94	XH	Haplic Xerosol						4,6	4,7		
95	XK	Calcic Xerosol	4			4	4				
96	XL	Luvic Xerosol		1					1		
97	XY	Gypsic Xerosol					4				
98	YH	Haplic Yermosol						6	1		
99	YK	Calcic Yermosol					4		1,2,4,5,7		
100	YL	Luvic Yermosol		1							5
101	YT	Takyric Yermosol							1		
102	YY	Gypsic Yermosol						6			
103	ZG	Gleyic Solonchak					1,4,6		1		
104	ZM	Mollic Solonchak							4,7		
105	ZO	Orthic Solonchak				2			2,7		
106	ZT	Takyric Solonchak					4		7		

KEY

1	one or more horizon in soil profile deleted
2	default depth for bottom of profile set to 3.6 meters
3	depth data for one or more horizons in profile corrected/adjusted
4	clay particle size data for one or more horizons in profile normalized to sum to 100 percent
5	particle size data for one or more horizons in profile interpolated
6	particle size data for one or more horizons in profile extrapolated
7	particle size data for one or more horizon in profile corrected/adjusted

Table 2a. Hierarchy for substituting for missing data using information from a different continent.

North America	Mexico/ Central America	South America	Europe	Africa	South Central Asia	North Central Asia	Southeast Asia	Australia /Southern Asia
Mexico/CA	S America	Mexico/CA	NC Asia	S America	SE Asia	Europe	SC Asia	SE Asia
Europe	N America	Africa	N America	SC Asia	NC Asia	SC Asia	NC Asia	Africa
NC Asia	Africa	N America	SC Asia	Europe	Africa	SE Asia	Austr/Asia	S America
S America	SC Asia	Austr/Asia	Africa	Austr/Asia	Europe	N America	Africa	SC Asia
Africa	SE Asia	SE Asia	Mexico CA	Mexico CA	Austr/Asia	Austr/Asia	N America	N America
Austr/Asia	Europe	SC Asia	Austr/Asia	SE Asia	Mexico CA	S America	Mexico CA	Mexico CA
SC Asia	Austr/Asia	Europe	S. America	N America	N America	Africa	Europe	Europe
SE Asia	NC Asia	NC Asia	SE Asia	NC Asia	S America	Mexico CA	S America	NC Asia

Table 2b. Substitutions for missing data using other data from adjacent soil type.

Missing Data Soil Types	Replacement Soil Types
1- Direct Substitutions	
Glossic Chernozem (CG)	Haplic Kastanozem (KH)
Plinthic Gleysol (GP)	Plinthic Acrisol (AP)
Gelic Gleysol (GX)	Gelic Regosol (RX)
Vertic Luvisol (LV)	Chromic Luvisol (LC)
Gelic Greyzem (MG)	Orthic Greyzem (MO)
Humic Nitosol (NH)	Eutric Nitosol (NE)
Dystric Planosol (WD)	Eutric Planosol (WE)
Humic Planosol (WS)	Solodic Planosol (WS)
Takytic Yermosol (YT)	Takytic Solonchak (ZT)
Gelic Solonchak (ZG)	Mollic Solonchak (ZM)
2- Special substitution for Europe	
Gelic Solonchak (ZG)	Eutric Gleysol (GE)
3- Substitution of selected horizon of soil type	
Lithosol (i)	10 cm thick C-Horizon of Eutric Regosol
Ranker (U)	25 cm thick A-Horizon of Humic Cambisol
Histosols (OD,OE,OX)	360 cm thick 100% peat layer

Table 3. Summary of frequency of occurence of each soil type in Zobler World Soil File with numeric and letter codes in parentheses flagging the type of missing data substitution.

Soil Num.	Soil Code	Soil Name	North America	Mexico/ Central America	South America	Europe	Africa	South-Central Asia	North-Central Asia	South-east Asia	Australia /South Asia
1	AF	Ferric Acrisol	26	1(2)			49	1(9)		65	
2	AG	Gleyic Acrisol	12	1(2)	1(6)					13	9
3	AH	Humic Acrisol	6	10						17	2
4	AO	Orthic Acrisol	82	12(4)	113	7(2)	20	12(9)	9(9)	246	7
5	AP	Plinthic Acrisol	6(6)	1(6)	52(6)		5	2(9)		2	
6	BC	Chromic Cambisol		9(6)		13(8)	24	1(8)	15	9(8)	4
7	BD	Dystric Cambisol	86(5)	8(7)	16(10)	80	9(7)	16	27(5)	23(7)	16
8	BE	Eutric Cambisol	116(5)	7(6)	10(6)	69	20	36	14(5)	3	3
9	BF	Ferralic Cambisol					11	1(9)		6	1(9)
10	BG	Gleyic Cambisol				3			18(5)	1(6)	
11	BH	Humic Cambisol	7(4)		11	10(7)	7	4		14(7)	2
12	BK	Calcic Cambisol	1(5)	5(6)	2(6)	54	6	1	15(5)	2	
13	BV	Vertic Cambisol		2		9	4(5)	5(5)			
14	BX	Gelic Cambisol	11						450		
15	CG	Glossic Chernozem							8(KH)		
16	CH	Haplic Chernozem	30			73			58(5)		
17	CK	Calcic Chernozem	4			10			27(5)		
18	CL	Luvic Chernozem	15			41			29(5)		
19	DD	Dystric Podzoluvisol				49			60(5)		
20	DE	Eutric Podzoluvisol	8			159			69(5)		
21	DG	Gleyic Podzoluvisol				4			40(5)		
22	E	Rendzina	3	13(2)		25	4(5)			4(2)	
23	FA	Acric Ferralsol		1(4)	56						
24	FH	Humic Ferralsol			14(6)		1			8(6)	
25	FO	Orthic Ferralsol			204		208			3	
26	FP	Plinthic Ferralsol					29				2(6)
27	FR	Rhodic Ferralsol			19		30	1(9)		3	9(9)
28	FX	Xanthic Ferralsol			231		93			1(6)	3(6)
29	GC	Calcaric Gleysol		1(8)				2(8)	9	4(8)	
30	GD	Dystric Gleysol	139(5)	1(4)	39	4	6	1(6)	39(5)	1(6)	
31	GE	Eutric Gleysol	30	2(4)	5	14	22	9	10(5)	42	
32	GH	Humic Gleysol	1			4	9(4)		10(5)	4(10)	
33	GM	Mollic Gleysol	7	2(2)	6(2)	14(2)	2(2)		43(2)	5(2)	

36	HC	Calcaric Phaeozem				5					
37	HG	Gleyic Phaeozem	6			2			4(5)		
38	HH	Haplic Phaeozem	25		16	2		1(5)	17(5)		1(4)
39	HL	Luvic Phaeozem	43		37	1					1(4)
40	I	Lithosol	296	19	164	108	317	242	1373	108	52
41	JC	Calcaric Fluvisol	4	1(2)		11	17	10	14	4	
42	JD	Dystric Fluvisol			1(2)		3(2)		33(2)	11(2)	
43	JE	Eutric Fluvisol	14(3)		39(3)	14	26(7)	7	34(5)	13(7)	
44	JT	Thionic Fluvisol					7			2	
45	KH	Haplic Kastanozem	54	11(4)	32	62(8)			99		
46	KK	Calcic Kastanozem	2	3		8	1				
47	KL	Luvic Kastanozem	123	17(2)	20(2)	12			110		
48	LA	Albic Luvisol	149			1(2)					
49	LC	Chromic Luvisol	27	11(2)	42(6)	29	40	44	1(5)	11(7)	19
50	LF	Ferric Luvisol		3(4)	47	1(6)	145	19(9)		2	4
51	LG	Gleyic Luvisol	4	1(2)		43	13(5)		21(5)	1	
52	LK	Calcic Luvisol	13(5)				7				38
53	LO	Orthic Luvisol	48	12(2)	7(2)	86	4(5)	12(9)	3(5)	6	2
54	LP	Plinthic Luvisol			5(6)		14				
55	LV	Vertic Luvisol				1(LC)				1(7LC)	
56	MG	Gleyic Greyzem							15(5MO)		
57	MO	Orthic Greyzem	5			6			12(5)		
58	ND	Dystric Nitosol		5(4)	11		49	10		15	5(9)
59	NE	Eutric Nitosol		5(4)	9		32	15(9)		2	4(9)
60	NH	Humic Nitosol					11(NE)			1(NE)	
61	OD	Dystric Histosol	53			33		1	77	16	
62	OE	Eutric Histosol	7		3		1		39	11	
63	OX	Gelic Histosol	95			6			7		
64	PF	Ferric Podzol									
65	PG	Gleyic Podzol	8			46			21(5)	1(2)	
66	PH	Humic Podzol			3	10	2(4)		18	3	4(9)
67	PL	Leptic Podzol	8			15					
68	PO	Orthic Podzol	331			250			9(5)	1	5(9)
69	PP	Placic Podzol				2					
70	QA	Albic Arenosol					9(4)	2(10)		2(10)	4
71	QC	Cambic Arenosol				2	201	63	5(5)	1	4(9)
72	QF	Ferralic Arenosol			61		82				113
73	QL	Luvic Arenosol				1	70				
74	RC	Calcaric Regosol	40	3(2)		11(2)	49(7)	68	3(7)		
75	RD	Dystric Regosol	3		3(2)		13(2)		2(2)		56(2)

78	SG	Gleyic Solonetz							1(5)		
79	SM	Mollic Solonetz	10		12	1(8)			12		
80	SO	Orthic Solonetz	2		1(6)	13	11		11(5)		36
81	TH	Humic Andosol			15	1				2	1
82	TM	Mollic Andosol		1(9)	2(9)	1(9)	3(9)			3	
83	TO	Ochric Andosol					1(5)		23(5)	6(10)	1
84	TV	Vitric Andosol	21(3)	17	4	5			4(5)	1(10)	4
85	U	Ranker			2	2					
86	VC	Chromic Vertisol	1		2	1	49	47			77
87	VP	Pellic Vertisol	7	14(4)	12	7	30	9		9	8
88	WD	Dystric Planosol				1(WE)					
89	WE	Eutric Planosol	6(5)	1(4)	34	2	9		4(5)		1
90	WH	Humic Planosol									1(WS)
91	WM	Mollic Planosol			15						
92	WS	Solodic Planosol		1(4)			12				42
93	WX	Gelic Planosol									
94	XH	Haplic Xerosol	4(8)	1(4)	33	22(8)	43(4)	7	13		
95	XK	Calcic Xerosol	3	7(2)	12(6)	43	68	5(6)	30(5)		74
96	XL	Luvic Xerosol	21	5(2)		14(2)	1(2)		81(2)		
97	XY	Gypsic Xerosol				3(6)	3				
98	YH	Haplic Yermosol	13(10)	13(7)	34(10)	2(7)	385(7)	42	168(7)		38
99	YK	Calcic Yermosol	9	1(2)		27(8)	102	123	33		
100	YL	Luvic Yermosol	61	10(2)	56(2)			14(10)			86
101	YT	Takyric Yermosol							18(YK)		
102	YY	Gypsic Yermosol				11(7)	28(7)	7	19(7)		
103	ZG	Gleyic Solonchak			8(6YK)	2(GE)	2(YK)	5(YK)	6(YK)	2(7YK)	
104	ZM	Mollic Solonchak							6		
105	ZO	Orthic Solonchak			3(2)	9	8(5)	32(8)	36		3(2)
106	ZT	Takyric Solonchak				1(8)					2(6)

Key to substitution codes

2 North America
3 Mexico/Central America
4 South America
5 Europe
6 Africa
7 South Central Asia
8 North Central Asia
9 Southeast Asia
10 Australia/South Asia

Two letter codes refer to Column 2 within table

Table 4a. Maximum relative saturation for different soil classes.

Sand	0.394	(Zobler, unpub.)
Silt	0.537	(Zobler, unpub.)
Clay	0.577	(Zobler, unpub.)
Peat	0.85	(Webb, 1990)

Table 4b. Maximum rooting depth (m) of eight major vegetation types (Rosenzweig, *unpub.*).

Desert	0.005
Tundra	0.1
Grassland	1.1
Shrub	1.5
Woodland	2.0
Deciduous	2.0
Evergreen	2.0
Rainforest	0.8

Table 4c. Relative amount of available water for different soil textures (Petersen *et al.*, 1968)

Sand	0.04
Loamy Sand	0.08
Sandy Loam, Sandy Clay Loam, Clay Loam, Sandy Clay, Silty Clay, Clay	0.14
Silty Clay Loam, Loam	0.17
Silt Loam, Silt	0.20
Organic Soil	0.60

Table 5. Soil thickness for 106 soil types, 9 continents (cm)

Soil Num.	Soil Code	Soil Name	North America	Mexico/ Central America	South America	Europe	Africa	South-Central Asia	North-Central Asia	South-east Asia	Australia /South Asia
1	AF	Ferric Acrisol	61	61	360	61	360	210	210	210	360
2	AG	Gleyic Acrisol	119	119	150	119	150	90	90	90	150
3	AH	Humic Acrisol	86	190	190	86	180	360	360	360	180
4	AO	Orthic Acrisol	142	250	250	142	183	360	360	360	90
5	AP	Plinthic Acrisol	120	120	120	120	120	360	360	360	360
6	BC	Chromic Cambisol	360	132	132	360	132	360	360	360	137
7	BD	Dystric Cambisol	115	182	66	115	182	182	115	182	66
8	BE	Eutric Cambisol	125	150	150	125	150	137	125	360	120
9	BF	Ferralic Cambisol	235	235	235	235	235	138	138	138	138
10	BG	Gleyic Cambisol	360	150	150	360	150	150	360	150	150
11	BH	Humic Cambisol	300	300	300	137	360	137	137	137	107
12	BK	Calcic Cambisol	360	70	70	360	70	55	360	150	150
13	BV	Vertic Cambisol	130	130	130	151	151	151	151	130	130
14	BX	Gelic Cambisol	98	98	98	80	98	80	80	80	98
15	CG	Glossic Chernozem	360	80	80	360	80	360	360	360	76
16	CH	Haplic Chernozem	360	360	360	160	160	160	160	360	360
17	CK	Calcic Chernozem	360	360	360	108	108	108	108	360	360
18	CL	Luvic Chernozem	360	360	360	200	200	200	200	360	360
19	DD	Dystric Podzoluvisol	360	360	360	360	360	360	360	360	360
20	DE	Eutric Podzoluvisol	152	152	152	205	205	205	205	152	152
21	DG	Gleyic Podzoluvisol	150	150	150	150	150	150	150	150	150
22	E	Rendzina	61	61	61	55	55	55	55	61	61
23	FA	Acric Ferralsol	460	460	460	150	460	200	200	200	150
24	FH	Humic Ferralsol	360	360	360	360	360	360	360	360	360
25	FO	Orthic Ferralsol	270	270	270	400	400	140	140	140	122
26	FP	Plinthic Ferralsol	258	258	258	258	258	258	258	258	258
27	FR	Rhodic Ferralsol	130	130	130	360	360	360	360	360	360
28	FX	Xanthic Ferralsol	250	250	250	150	150	150	250	150	150
29	GC	Calcaric Gleysol	100	100	100	100	100	100	100	100	100
30	GD	Dystric Gleysol	360	130	130	360	180	180	360	180	180
31	GE	Eutric Gleysol	107	150	150	360	360	138	360	120	120
32	GH	Humic Gleysol	127	125	125	360	125	360	360	360	360
33	GM	Mollic Gleysol	360	360	360	360	360	360	360	360	360
34	GP	Plinthic Gleysol	120	120	120	120	120	122	122	122	122

37	HG	Gleyic Phaeozem	206	206	206	360	360	360	360	122	122
38	HH	Haplic Phaeozem	196	360	360	250	360	250	250	196	360
39	HL	Luvic Phaeozem	178	360	360	205	360	205	205	178	360
40	I	Lithosol	10	10	10	10	10	10	10	10	10
41	JC	Calcaric Fluvisol	152	152	140	120	140	162	100	100	100
42	JD	Dystric Fluvisol	360	360	360	360	360	360	360	360	360
43	JE	Eutric Fluvisol	200	200	200	360	120	120	360	120	140
44	JT	Thionic Fluvisol	150	150	150	120	120	190	190	190	190
45	KH	Haplic Kastanozem	360	80	80	360	80	360	360	360	76
46	KK	Calcic Kastanozem	353	55	55	180	170	170	180	170	170
47	KL	Luvic Kastanozem	360	360	360	170	170	135	135	135	360
48	LA	Albic Luvisol	118	118	118	118	118	118	118	118	118
49	LC	Chromic Luvisol	124	124	193	150	193	183	150	183	75
50	LF	Ferric Luvisol	209	209	209	360	360	200	200	200	183
51	LG	Gleyic Luvisol	185	185	185	122	122	105	122	105	76
52	LK	Calcic Luvisol	360	180	180	360	180	130	360	130	175
53	LO	Orthic Luvisol	168	168	168	360	360	105	360	105	104
54	LP	Plinthic Luvisol	360	360	360	360	360	120	120	120	120
55	LV	Vertic Luvisol	124	124	193	150	193	183	150	183	75
56	MG	Gleyic Greyzem	360	360	360	190	190	190	190	360	360
57	MO	Orthic Greyzem	360	360	360	190	190	190	190	360	360
58	ND	Dystric Nitosol	190	190	190	155	800	155	155	100	100
59	NE	Eutric Nitosol	250	250	250	246	246	150	150	150	150
60	NH	Humic Nitosol	250	250	250	246	246	150	150	150	150
61	OD	Dystric Histosol	360	360	360	360	360	360	360	360	360
62	OE	Eutric Histosol	360	360	360	360	360	360	360	360	360
63	OX	Gelic Histosol	360	360	360	360	360	360	360	360	360
64	PF	Ferric Podzol									
65	PG	Gleyic Podzol	107	107	107	360	360	360	360	107	107
66	PH	Humic Podzol	360	195	195	360	195	60	102	60	60
67	PL	Leptic Podzol	102	102	102	65	65	65	65	102	102
68	PO	Orthic Podzol	302	302	302	360	360	200	360	200	200
69	PP	Placic Podzol	360	360	360	360	360	360	360	360	360
70	QA	Albic Arenosol	120	120	120	700	120	700	700	700	700
71	QC	Cambic Arenosol	360	200	200	360	200	148	360	120	120
72	QF	Ferralic Arenosol	600	600	600	200	200	200	110	110	110
73	QL	Luvic Arenosol	160	150	150	160	150	150	160	150	150
74	RC	Calcaric Regosol	122	122	122	122	150	150	150	150	150
75	RD	Dystric Regosol	122	122	122	122	122	122	122	122	122
76	RE	Eutric Regosol	360	360	360	175	175	175	150	150	150

79	SM	Mollic Solonetz	360	150	150	190	150	190	190	190	150
80	SO	Orthic Solonetz	104	104	100	170	100	360	170	360	135
81	TH	Humic Andosol	110	360	360	110	360	150	110	150	360
82	TM	Mollic Andosol	360	360	360	360	360	360	360	360	360
83	TO	Ochric Andosol	130	130	360	130	130	130	130	360	360
84	TV	Vitric Andosol	175	175	360	150	360	150	150	122	122
85	U	Ranker	25	25	25	25	25	25	25	25	25
86	VC	Chromic Vertisol	124	142	142	150	250	183	150	183	180
87	VP	Pellic Vertisol	244	170	170	210	100	132	210	220	229
88	WD	Dystric Planosol	200	150	150	200	127	127	200	70	70
89	WE	Eutric Planosol	200	150	150	200	127	127	200	70	70
90	WH	Humic Planosol	360	360	360	180	180	180	107	107	107
91	WM	Mollic Planosol	125	125	125	125	125	125	125	125	125
92	WS	Solodic Planosol	360	360	360	180	180	180	107	107	107
93	WX	Gelic Planosol									
94	XH	Haplic Xerosol	360	180	180	360	180	152	360	152	180
95	XK	Calcic Xerosol	157	157	75	100	75	75	100	152	152
96	XL	Luvic Xerosol	96	96	96	96	96	96	96	96	96
97	XY	Gypsic Xerosol	140	140	140	140	140	140	140	140	140
98	YH	Haplic Yermosol	48	140	48	140	140	140	140	140	48
99	YK	Calcic Yermosol	117	117	128	360	128	100	360	100	128
100	YL	Luvic Yermosol	168	168	168	168	178	178	168	178	178
101	YT	Takyric Yermosol	117	117	128	360	128	100	360	100	128
102	YY	Gypsic Yermosol	500	500	500	500	500	500	500	500	500
103	ZG	Gleyic Solonchak	117	117	128	360	128	100	360	100	128
104	ZM	Mollic Solonchak	150	150	150	150	150	150	150	150	150
105	ZO	Orthic Solonchak	102	102	102	360	360	360	360	360	102
106	ZT	Takyric Solonchak	300	99	99	300	99	300	300	300	99

Table 6. Potential storage of water in the soil profile for the 106 soil types, 9 continents (mm)

Soil Num.	Soil Code	Soil Name	North America	Mexico/ Central America	South America	Europe	Africa	South-Central Asia	North-Central Asia	South-east Asia	Australia /South Asia
1	AF	Ferric Acrisol	279	279	1917	279	1917	1001	1001	1001	1834
2	AG	Gleyic Acrisol	592	592	763	592	763	486	486	486	671
3	AH	Humic Acrisol	473	1074	1074	473	836	1879	1879	1879	836
4	AO	Orthic Acrisol	658	1130	1130	658	937	1846	1846	1846	393
5	AP	Plinthic Acrisol	581	581	581	581	581	1741	1741	1741	1741
6	BC	Chromic Cambisol	1698	680	680	1698	680	1698	1698	1698	737
7	BD	Dystric Cambisol	569	865	327	569	865	865	569	865	327
8	BE	Eutric Cambisol	685	764	764	685	764	595	685	1922	563
9	BF	Ferralic Cambisol	1096	1096	1096	1096	1096	722	722	722	722
10	BG	Gleyic Cambisol	1742	651	651	1742	651	651	1742	651	651
11	BH	Humic Cambisol	1368	1368	1368	573	1596	573	573	573	499
12	BK	Calcic Cambisol	1827	353	353	1827	353	296	1827	790	790
13	BV	Vertic Cambisol	679	679	679	835	835	835	835	679	679
14	BX	Gelic Cambisol	508	508	508	376	508	376	376	376	508
15	CG	Glossic Chernozem	1661	377	377	1888	377	1888	1888	1888	354
16	CH	Haplic Chernozem	1705	1705	1705	823	823	823	823	1705	1705
17	CK	Calcic Chernozem	1614	1614	1614	591	591	591	591	1614	1614
18	CL	Luvic Chernozem	1751	1751	1751	1110	1110	1110	1110	1751	1751
19	DD	Dystric Podzoluvisol	1945	1945	1945	1945	1945	1945	1945	1945	1945
20	DE	Eutric Podzoluvisol	737	737	737	1087	1087	1087	1087	737	737
21	DG	Gleyic Podzoluvisol	731	731	731	731	731	731	731	731	731
22	E	Rendzina	311	311	311	286	286	286	286	311	311
23	FA	Acric Ferralsol	2570	2570	2570	774	2570	1092	1092	1092	774
24	FH	Humic Ferralsol	1870	1870	1870	1870	1870	1870	1870	1870	1870
25	FO	Orthic Ferralsol	1530	1530	1530	1948	1948	655	655	655	681
26	FP	Plinthic Ferralsol	1311	1311	1311	1311	1311	1311	1311	1311	1311
27	FR	Rhodic Ferralsol	683	683	683	1884	1884	1945	1945	1945	1945
28	FX	Xanthic Ferralsol	1379	1379	1379	685	685	685	1379	685	685
29	GC	Calcaric Gleysol	553	553	553	553	553	553	553	553	553
30	GD	Dystric Gleysol	1718	662	662	1718	772	772	1718	772	772
31	GE	Eutric Gleysol	599	823	823	2014	1499	716	2014	671	671
32	GH	Humic Gleysol	511	677	677	1689	677	1689	1689	1722	1722
33	GM	Mollic Gleysol	2019	2019	2019	2019	2019	2019	2019	2019	2019
34	GP	Plinthic Gleysol	581	581	581	581	581	573	573	573	573

37	HG	Gleyic Phaeozem	1126	1126	1126	1969	1969	1969	1969	670	670
38	HH	Haplic Phaeozem	1065	1841	1698	1192	1698	1192	1192	1065	1698
39	HL	Luvic Phaeozem	968	1770	1770	1115	1770	1115	1115	968	1770
40	I	Lithosol	42	42	42	42	42	42	42	42	42
41	JC	Calcaric Fluvisol	718	718	665	519	665	829	546	513	513
42	JD	Dystric Fluvisol	1903	1903	1903	1903	1903	1903	1903	1903	1903
43	JE	Eutric Fluvisol	1008	1008	1008	1609	585	585	1609	585	765
44	JT	Thionic Fluvisol	828	828	828	649	649	1037	1037	1037	1037
45	KH	Haplic Kastanozem	1661	377	377	1888	377	1888	1888	1888	354
46	KK	Calcic Kastanozem	1907	269	269	974	870	870	974	870	870
47	KL	Luvic Kastanozem	1851	1851	1851	912	912	733	733	733	1851
48	LA	Albic Luvisol	575	575	575	575	575	575	575	575	575
49	LC	Chromic Luvisol	558	558	917	743	917	864	743	864	420
50	LF	Ferric Luvisol	895	895	895	1770	1770	1078	1078	1078	928
51	LG	Gleyic Luvisol	907	907	907	649	649	564	649	564	378
52	LK	Calcic Luvisol	1704	839	839	1704	839	639	1704	639	904
53	LO	Orthic Luvisol	910	910	910	1940	1940	480	1940	480	449
54	LP	Plinthic Luvisol	1781	1781	1781	1781	1781	542	542	542	542
55	LV	Vertic Luvisol	558	558	917	743	917	864	743	864	420
56	MG	Gleyic Greyzem	1928	1928	1928	1036	1036	1036	1036	1928	1928
57	MO	Orthic Greyzem	1928	1928	1928	1036	1036	1036	1036	1928	1928
58	ND	Dystric Nitosol	1038	1038	1038	795	4432	795	795	496	496
59	NE	Eutric Nitosol	1352	1352	1352	1211	1211	729	729	729	729
60	NH	Humic Nitosol	1352	1352	1352	1211	1211	729	729	729	729
61	OD	Dystric Histosol	3060	3060	3060	3060	3060	3060	3060	3060	3060
62	OE	Eutric Histosol	3060	3060	3060	3060	3060	3060	3060	3060	3060
63	OX	Gelic Histosol	3060	3060	3060	3060	3060	3060	3060	3060	3060
64	PF	Ferric Podzol									
65	PG	Gleyic Podzol	429	429	429	1443	1443	1443	1443	429	429
66	PH	Humic Podzol	1468	774	774	1468	774	258	436	258	258
67	PL	Leptic Podzol	467	467	467	308	308	308	308	467	467
68	PO	Orthic Podzol	1199	1199	1199	1521	1521	798	1521	798	798
69	PP	Placic Podzol	1603	1603	1807	1603	1603	1603	1603	1807	1807
70	QA	Albic Arenosol	477	477	477	3273	477	3273	3273	3273	3273
71	QC	Cambic Arenosol	1633	815	815	1633	815	612	1633	502	502
72	QF	Ferralic Arenosol	2563	2563	2563	853	853	853	470	470	470
73	QL	Luvic Arenosol	674	626	626	674	626	626	674	626	626
74	RC	Calcaric Regosol	653	653	653	653	616	616	616	616	616
75	RD	Dystric Regosol	490	490	490	490	490	490	490	490	490
76	RE	Eutric Regosol	1529	1529	1529	700	700	700	649	649	649

79	SM	Mollic Solonetz	2017	690	690	936	690	936	936	936	690
80	SO	Orthic Solonetz	501	501	463	881	463	1726	881	1726	628
81	TH	Humic Andosol	532	1877	1877	532	1877	693	532	693	1536
82	TM	Mollic Andosol	1897	1897	1897	1897	1897	1897	1897	1897	1897
83	TO	Ochric Andosol	674	674	1605	674	674	674	674	1605	1605
84	TV	Vitric Andosol	851	851	1506	717	1506	717	717	523	523
85	U	Ranker	116	116	116	116	116	116	116	116	116
86	VC	Chromic Vertisol	673	717	717	762	1285	952	762	952	973
87	VP	Pellic Vertisol	1298	866	866	1159	552	650	1159	1230	1260
88	WD	Dystric Planosol	1070	730	730	1070	588	588	1070	305	305
89	WE	Eutric Planosol	1070	730	730	1070	588	588	1070	305	305
90	WH	Humic Planosol	1663	1663	1663	840	840	840	552	552	552
91	WM	Mollic Planosol	631	631	631	631	631	631	631	631	631
92	WS	Solodic Planosol	1663	1663	1663	840	840	840	552	552	552
93	WX	Gelic Planosol									
94	XH	Haplic Xerosol	1813	787	787	1813	787	807	1813	807	787
95	XK	Calcic Xerosol	782	782	347	535	347	347	535	656	656
96	XL	Luvic Xerosol	466	466	466	466	466	466	466	466	466
97	XY	Gypsic Xerosol	580	580	580	580	580	580	580	580	580
98	YH	Haplic Yermosol	209	746	209	746	746	746	746	746	209
99	YK	Calcic Yermosol	508	508	609	1657	609	465	1657	465	609
100	YL	Luvic Yermosol	731	731	731	731	851	851	731	851	851
101	YT	Takyric Yermosol	508	508	609	1657	609	465	1657	465	609
102	YY	Gypsic Yermosol	2402	2402	2402	2402	2402	2402	2402	2402	2402
103	ZG	Gleyic Solonchak	508	508	609	2014	609	465	1657	465	609
104	ZM	Mollic Solonchak	819	819	819	819	819	819	819	819	819
105	ZO	Orthic Solonchak	472	472	472	1907	1907	1927	1927	1927	472
106	ZT	Takyric Solonchak	1601	543	543	1601	543	1601	1601	1601	543

Table 7. Potential storage of water derived from soil texture for the 106 soil types, 9 continents (mm)

Soil Num.	Soil Code	Soil Name	North America	Mexico/ Central America	South America	Europe	Africa	South-Central Asia	North-Central Asia	South-east Asia	Australia /South Asia
1	AF	Ferric Acrisol	104	104	612	104	612	357	357	357	612
2	AG	Gleyic Acrisol	203	203	255	203	255	153	153	153	255
3	AH	Humic Acrisol	147	323	323	147	306	612	612	612	306
4	AO	Orthic Acrisol	242	425	425	242	311	612	612	612	153
5	AP	Plinthic Acrisol	204	204	204	204	204	612	612	612	612
6	BC	Chromic Cambisol	612	224	224	612	224	612	612	612	233
7	BD	Dystric Cambisol	195	309	112	195	309	309	195	309	112
8	BE	Eutric Cambisol	212	255	255	212	255	233	212	612	204
9	BF	Ferralic Cambisol	399	399	399	399	399	235	235	235	235
10	BG	Gleyic Cambisol	612	255	255	612	255	255	612	255	255
11	BH	Humic Cambisol	510	510	510	233	612	233	233	233	182
12	BK	Calcic Cambisol	612	119	119	612	119	93	612	255	255
13	BV	Vertic Cambisol	221	221	221	258	258	258	258	221	221
14	BX	Gelic Cambisol	166	166	166	136	166	136	136	136	166
15	CG	Glossic Chernozem	612	136	136	612	136	612	612	612	129
16	CH	Haplic Chernozem	612	612	612	272	272	272	272	612	612
17	CK	Calcic Chernozem	612	612	612	184	184	184	184	612	612
18	CL	Luvic Chernozem	612	612	612	340	340	340	340	612	612
19	DD	Dystric Podzoluvisol	612	612	612	612	612	612	612	612	612
20	DE	Eutric Podzoluvisol	259	259	259	348	348	348	348	259	259
21	DG	Gleyic Podzoluvisol	255	255	255	255	255	255	255	255	255
22	E	Rendzina	104	104	104	93	93	93	93	104	104
23	FA	Acric Ferralsol	782	782	782	255	782	340	340	340	255
24	FH	Humic Ferralsol	612	612	612	612	612	612	612	612	612
25	FO	Orthic Ferralsol	442	442	442	680	680	238	238	238	207
26	FP	Plinthic Ferralsol	439	439	439	439	439	439	439	439	439
27	FR	Rhodic Ferralsol	221	221	221	612	612	612	612	612	612
28	FX	Xanthic Ferralsol	425	425	425	253	253	253	425	253	253
29	GC	Calcaric Gleysol	170	170	170	170	170	170	170	170	170
30	GD	Dystric Gleysol	612	221	221	612	306	306	612	306	306
31	GE	Eutric Gleysol	181	255	255	612	612	235	612	204	204
32	GH	Humic Gleysol	216	212	212	612	212	612	612	612	612
33	GM	Mollic Gleysol	612	612	612	612	612	612	612	612	612
34	GP	Plinthic Gleysol	204	204	204	204	204	612	612	612	612

37	HG	Gleyic Phaeozem	350	350	350	612	612	612	612	207	207
38	HH	Haplic Phaeozem	333	612	612	425	612	425	425	333	612
39	HL	Luvic Phaeozem	302	612	612	348	612	348	348	302	612
40	I	Lithosol	17	17	17	17	17	17	17	17	17
41	JC	Calcaric Fluvisol	259	259	238	204	238	275	170	170	170
42	JD	Dystric Fluvisol	612	612	612	612	612	612	612	612	612
43	JE	Eutric Fluvisol	340	340	340	612	204	204	612	204	238
44	JT	Thionic Fluvisol	255	255	255	204	204	323	323	323	323
45	KH	Haplic Kastanozem	612	136	136	612	136	612	612	612	129
46	KK	Calcic Kastanozem	600	93	93	306	289	289	306	289	289
47	KL	Luvic Kastanozem	612	612	612	289	289	229	229	229	612
48	LA	Albic Luvisol	201	201	201	201	201	201	201	201	201
49	LC	Chromic Luvisol	212	212	328	255	328	311	255	311	127
50	LF	Ferric Luvisol	355	355	355	612	612	340	340	340	311
51	LG	Gleyic Luvisol	315	315	315	207	207	178	207	178	129
52	LK	Calcic Luvisol	612	306	306	612	306	221	612	221	297
53	LO	Orthic Luvisol	285	285	285	612	612	178	612	178	177
54	LP	Plinthic Luvisol	612	612	612	612	612	204	204	204	204
55	LV	Vertic Luvisol	212	212	328	255	328	311	255	311	127
56	MG	Gleyic Greyzem	612	612	612	323	323	323	323	612	612
57	MO	Orthic Greyzem	612	612	612	323	323	323	323	612	612
58	ND	Dystric Nitosol	323	323	323	263	1360	263	263	170	170
59	NE	Eutric Nitosol	425	425	425	418	418	255	255	255	255
60	NH	Humic Nitosol	425	425	425	418	418	255	255	255	255
61	OD	Dystric Histosol	2160	2160	2160	2160	2160	2160	2160	2160	216
62	OE	Eutric Histosol	2160	2160	2160	2160	2160	2160	2160	2160	216
63	OX	Gelic Histosol	2160	2160	2160	2160	2160	2160	2160	2160	216
64	PF	Ferric Podzol0									
65	PG	Gleyic Podzol	181	181	181	612	612	612	612	181	181
66	PH	Humic Podzol	612	331	331	612	331	102	150	102	102
67	PL	Leptic Podzol	173	173	173	110	110	110	110	173	173
68	PO	Orthic Podzol	514	514	514	612	612	340	612	340	340
69	PP	Placic Podzol	612	612	612	612	612	612	612	612	612
70	QA	Albic Arenosol	204	204	204	1190	204	1190	1190	1190	119
71	QC	Cambic Arenosol	612	340	340	612	340	252	612	204	204
72	QF	Ferralic Arenosol	1020	1020	1020	340	340	340	187	187	187
73	QL	Luvic Arenosol	272	255	255	272	255	255	272	255	255
74	RC	Calcaric Regosol	207	207	207	207	255	255	255	255	255
75	RD	Dystric Regosol	207	207	207	207	207	207	207	207	207
76	RE	Eutric Regosol	612	612	612	297	297	297	255	255	255

79	SM	Mollic Solonetz	612	255	255	323	255	323	323	323	255
80	SO	Orthic Solonetz	177	177	170	289	170	612	289	612	229
81	TH	Humic Andosol	187	612	612	187	612	255	187	255	612
82	TM	Mollic Andosol	612	612	612	612	612	612	612	612	612
83	TO	Ochric Andosol	221	221	612	221	221	221	221	612	612
84	TV	Vitric Andosol	178	178	612	255	612	255	255	207	207
85	U	Ranker	43	43	43	43	43	43	43	43	43
86	VC	Chromic Vertisol	212	241	241	255	425	311	255	311	306
87	VP	Pellic Vertisol	414	289	289	357	170	224	357	374	389
88	WD	Dystric Planosol	340	255	255	340	216	216	340	119	119
89	WE	Eutric Planosol	340	255	255	340	216	216	340	119	119
90	WH	Humic Planosol	612	612	612	306	306	306	182	182	182
91	WM	Mollic Planosol	212	212	212	212	212	212	212	212	212
92	WS	Solodic Planosol	612	612	612	306	306	306	182	182	182
93	WX	Gelic Planosol									
94	XH	Haplic Xerosol	612	306	306	612	306	258	612	258	306
95	XK	Calcic Xerosol	268	268	127	170	127	127	170	258	258
96	XL	Luvic Xerosol	164	164	164	164	164	164	164	164	164
97	XY	Gypsic Xerosol	238	238	238	238	238	238	238	238	238
98	YH	Haplic Yermosol	82	238	82	238	238	238	238	238	82
99	YK	Calcic Yermosol	199	199	218	612	218	119	612	119	218
100	YL	Luvic Yermosol	285	285	285	285	303	303	285	303	303
101	YT	Takyric Yermosol	199	199	218	612	218	119	612	119	218
102	YY	Gypsic Yermosol	850	850	850	850	850	850	850	850	850
103	ZG	Gleyic Solonchak	199	199	218	612	218	119	612	119	218
104	ZM	Mollic Solonchak	255	255	255	255	255	255	255	255	255
105	ZO	Orthic Solonchak	173	173	173	612	612	612	612	612	173
106	ZT	Takyric Solonchak	510	168	168	510	168	510	510	510	168

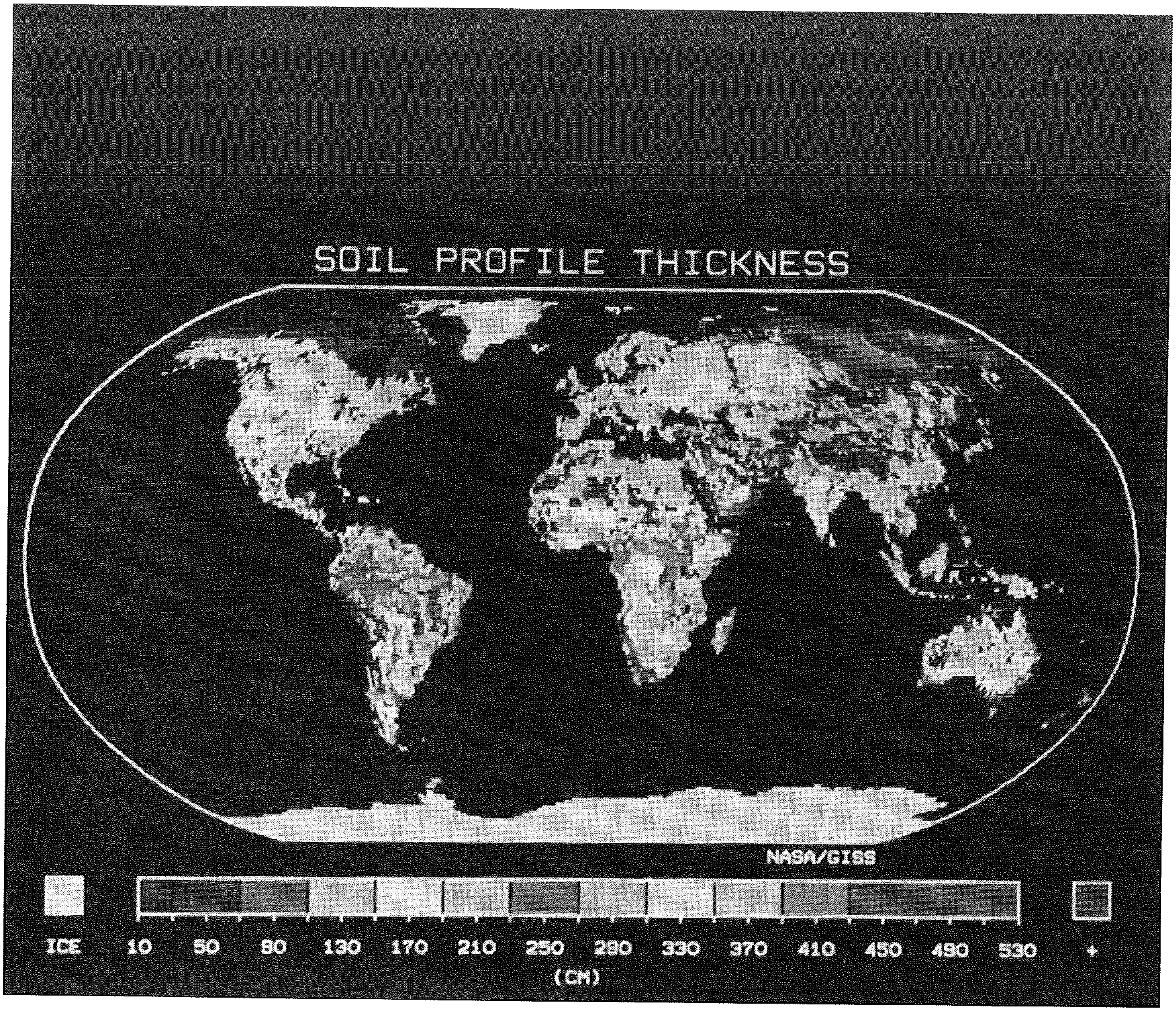


Figure 1. Soil Profile Thickness.

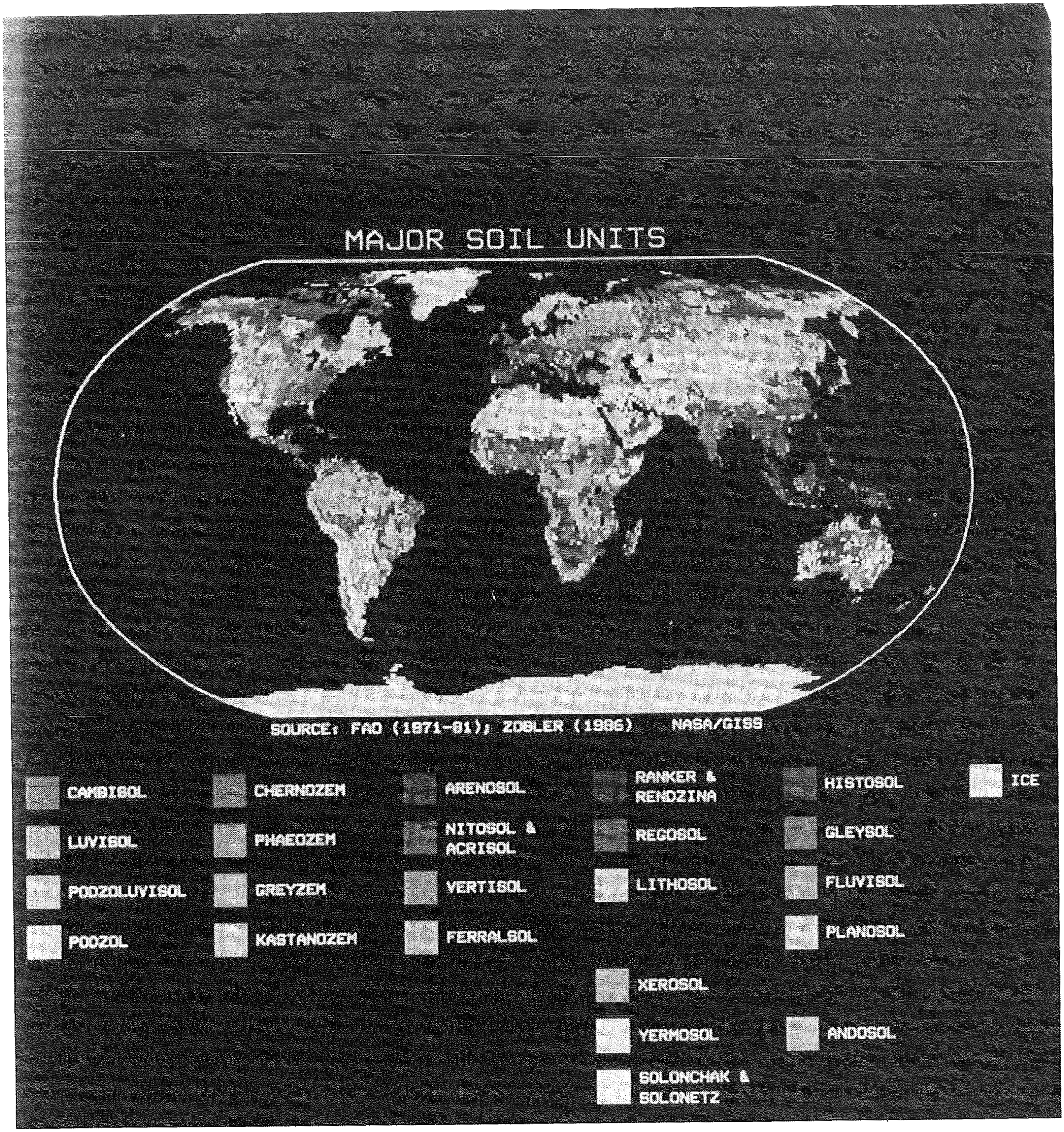


Figure 2. Major Soil Units

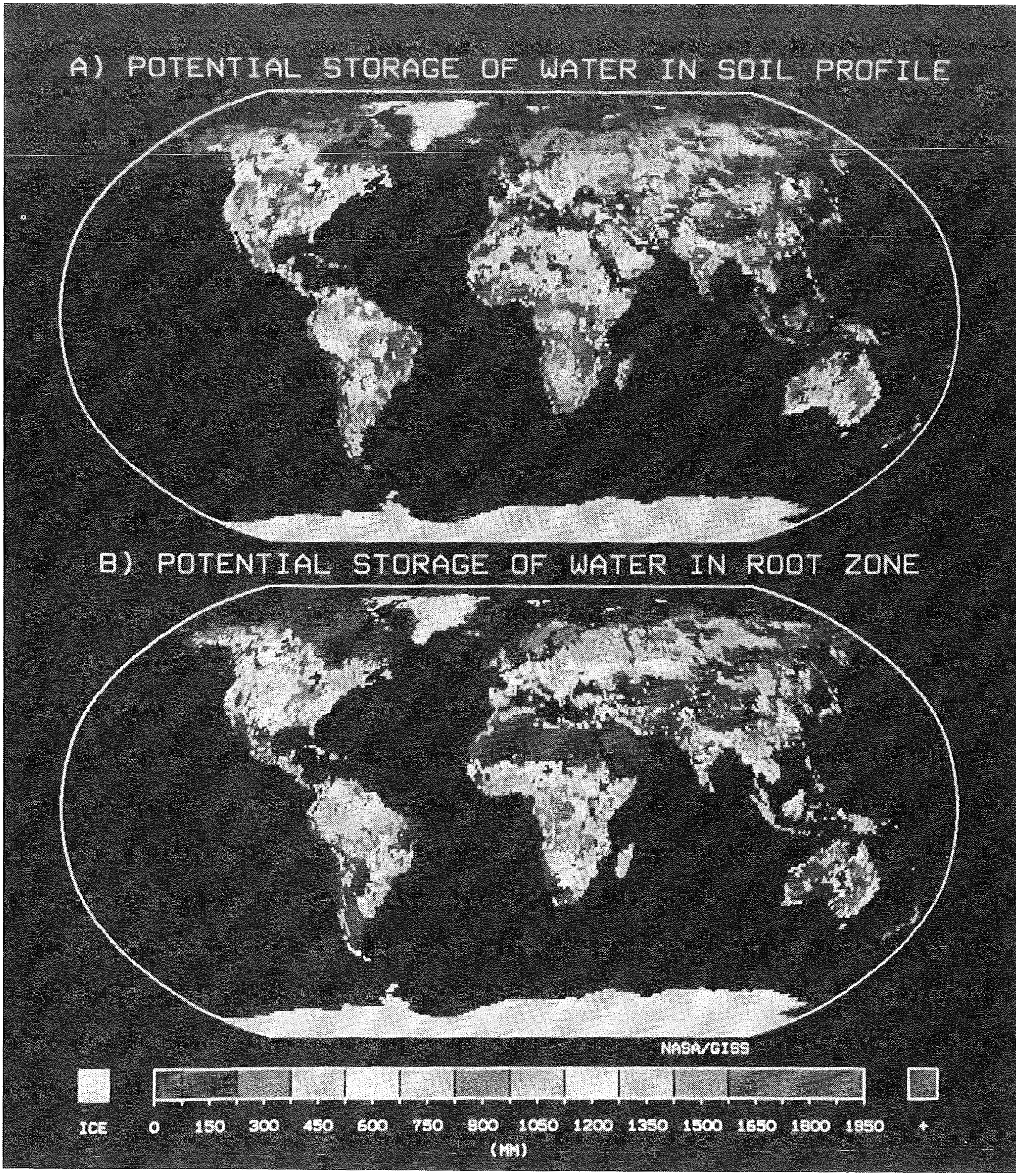
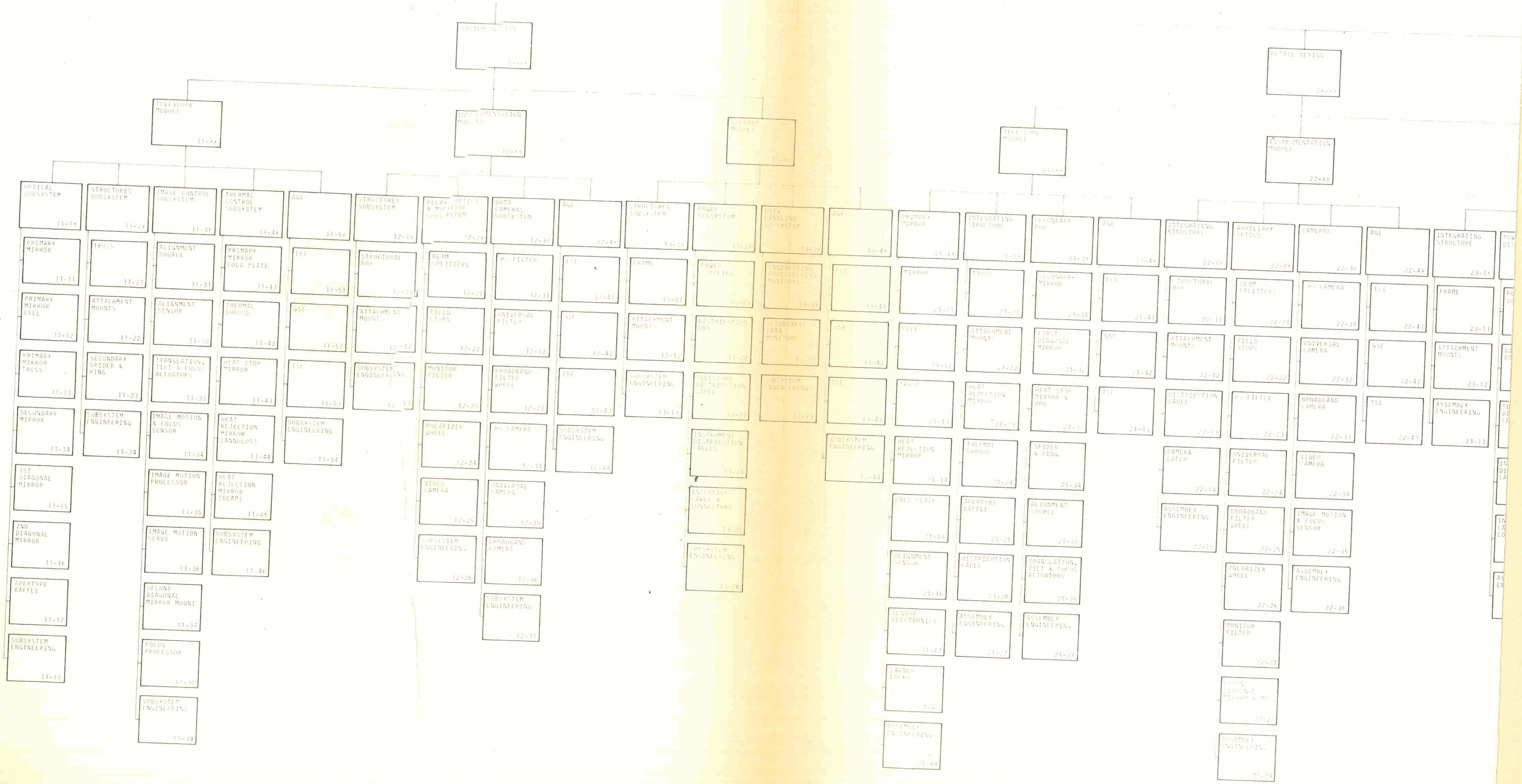


Figure 3a and 3b.

FOLDOUT FRAME 1

FOLDOUT FRAME 2



FOLDOUT FRAME 3

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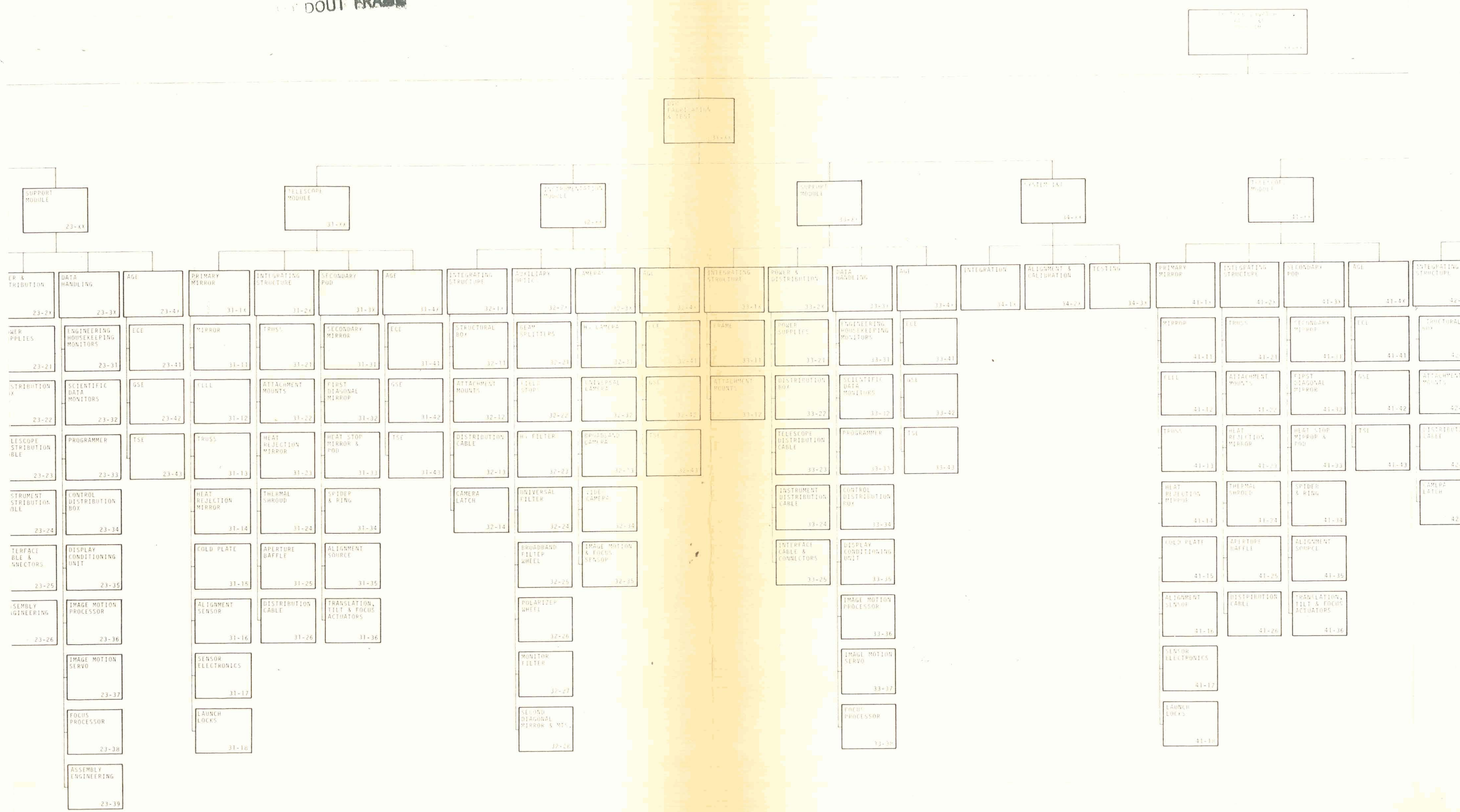
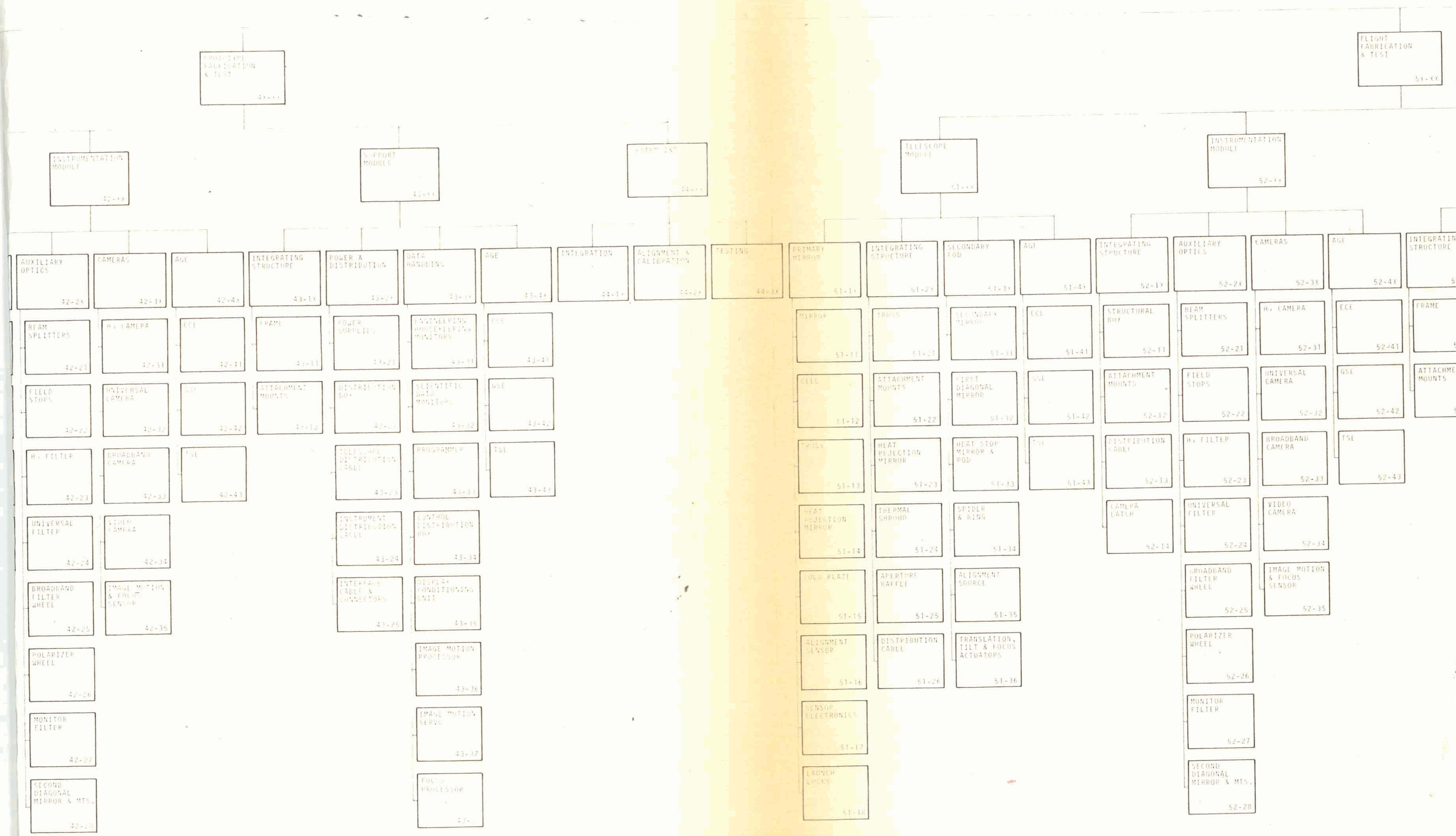
FOLDOUT FRAME 4



FOLDOUT FRAME 5

FOLDOUT FRAME 6



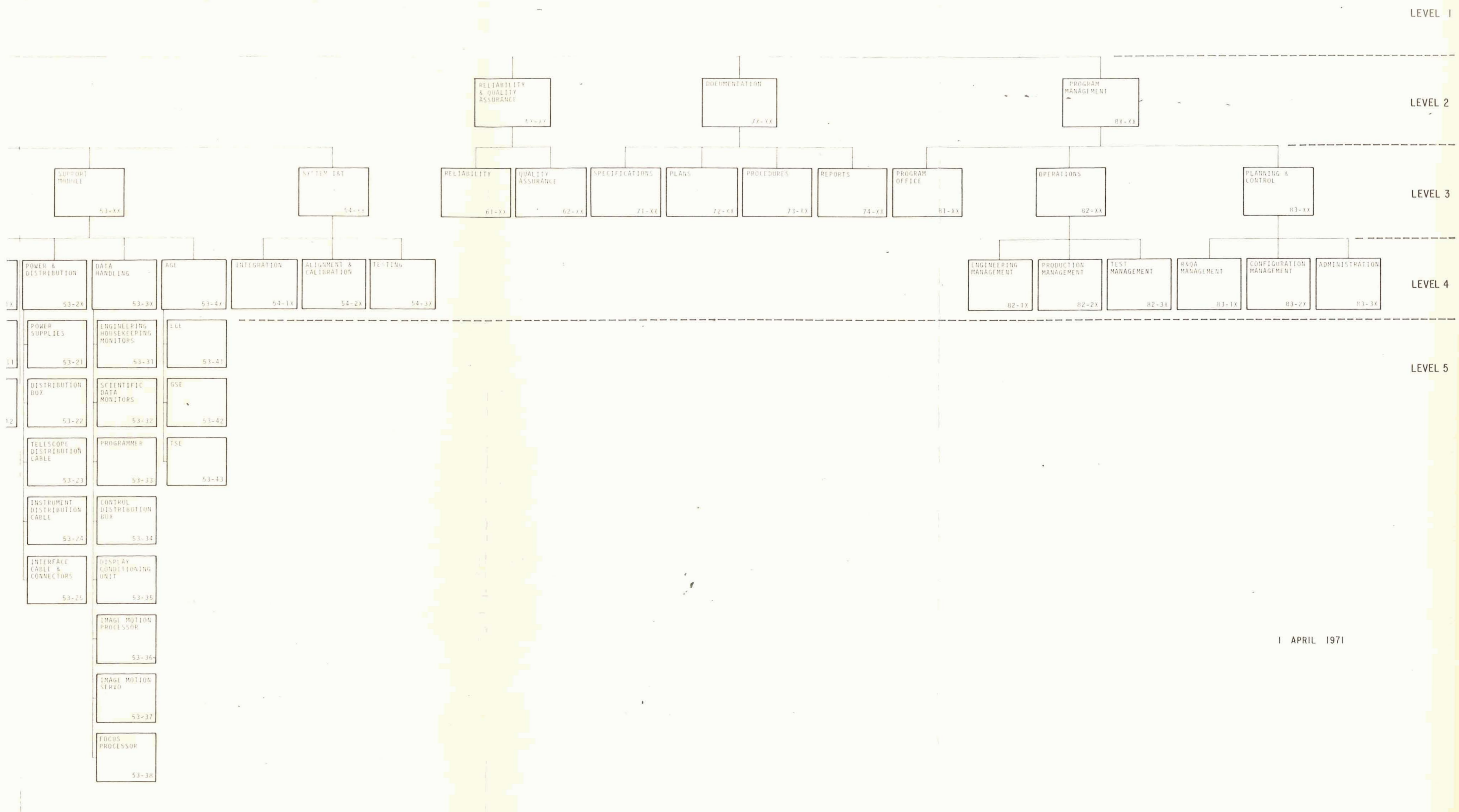


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Fig. 3-2 Photoheliograph Phase C and D Program Work Breakdown Structure

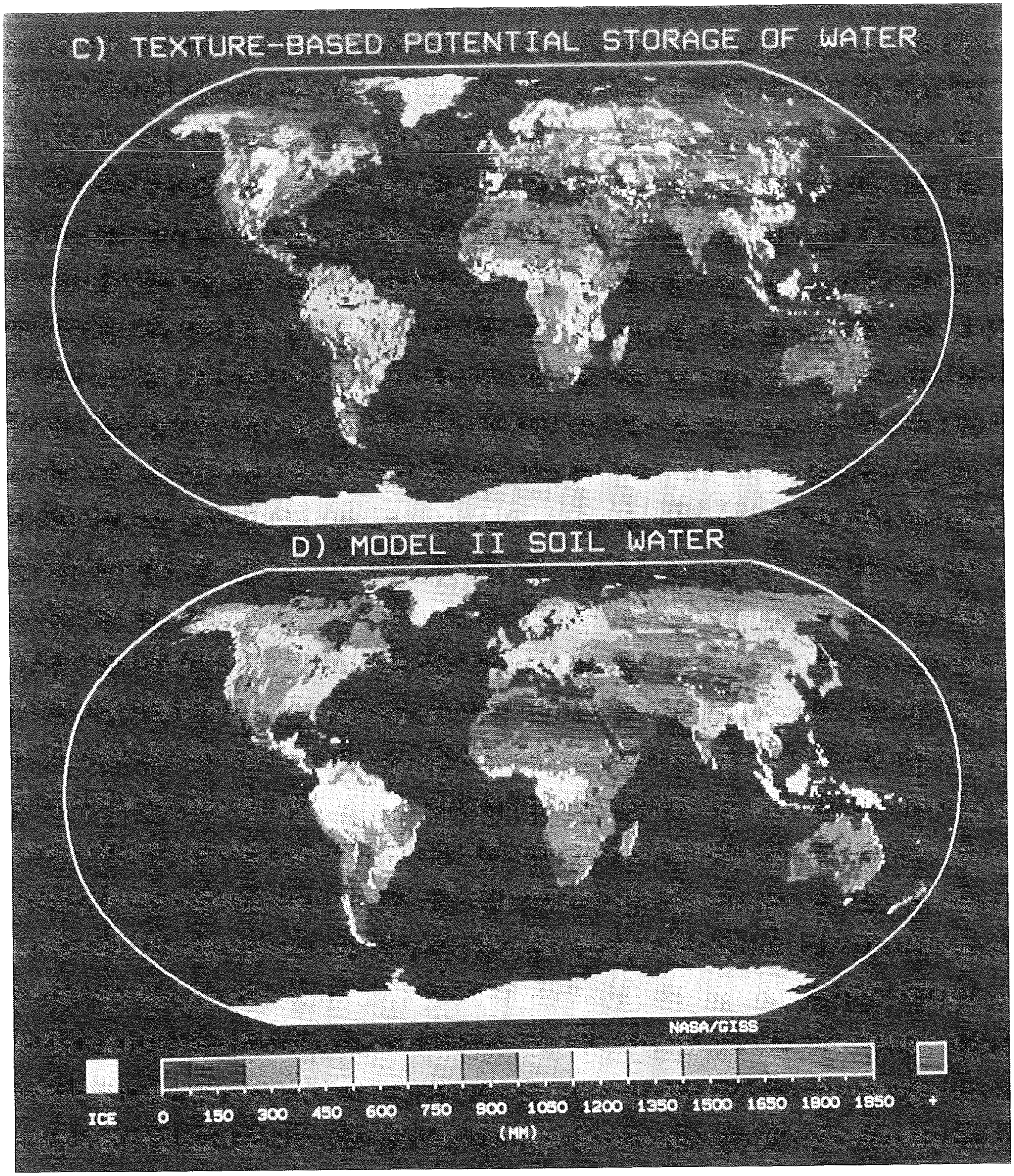

Figure 3c and 3d.

Report Documentation Page

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15. Supplementary Notes

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16. Abstract

A standardized global data set of soil horizon thicknesses and textures (particle size distributions) has been compiled from the FAO/UNESCO Soil Map of the World, Vols. 2-10 (1971-81). This data set will be used by the improved ground hydrology parameterization (Abramopoulos *et al.*, 1988) designed for the GISS GCM (Goddard Institute for Space Studies General Circulation Model) Model III. The data set specifies the top and bottom depths and the percent abundance of sand, silt, and clay of individual soil horizons in each of the 106 soil types cataloged for nine continental divisions. When combined with the World Soil Data File (Zobler, 1986), the result is a global data set of variations in physical properties throughout the soil profile. These properties are important in the determination of water storage in individual soil horizons and exchange of water with the lower atmosphere. The incorporation of this data set into the GISS GCM should improve model performance by including more realistic variability in land-surface properties.

17. Key Words (Suggested by Author(s)): global soil data set, particle size properties, potential water storage		18. Distribution Statement: Unclassified - Unlimited Subject Category 43	
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