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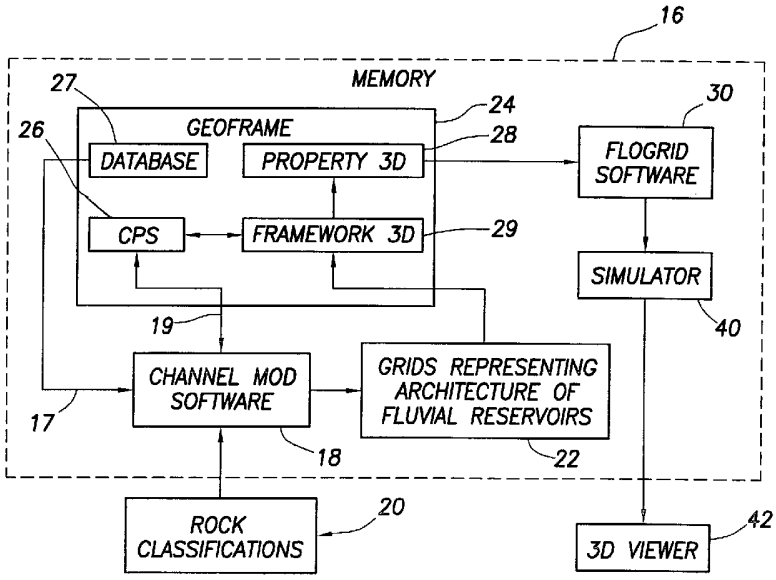
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(54) **Title:** METHOD AND PROGRAM STORAGE DEVICE FOR GENERATING GRIDS REPRESENTING THE ARCHITECTURE OF FLUVIAL RESERVOIRS



(57) **Abstract:** A method of generating a plurality of simulation results adapted for display on a display device including generating a plurality of model realizations of representing an architecture of a fluvial reservoir to a plurality of rock classifications (18, 20) and generating a plurality of grids (22) representing the architecture of the fluvial reservoir based on the plurality of model relaizations. A first software module (24) receives the plurality of grids (22) and generates 3D grids processed by a second software module (30) into gridded tops and bases of a plurality of valid channel realizations, with the 3D grids representing the plurality of grids modelling the architecture of the fluvial reservoir. The 3D grids are displayed using a 3D viewer (42).

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Method and Program Storage Device for Generating Grids Representing the Architecture of Fluvial Reservoirs

BACKGROUND OF THE INVENTION

The subject matter of the present invention relates to a method and program storage device for generating grids representing the architecture of fluvial reservoirs.

Shale or other fine grained rock in a reservoir represents a barrier to the flow of oil or gas in the reservoir because the shale or other fine grain rock will inhibit the flow of the oil or gas in the reservoir. On the other hand, sand in a reservoir does not represent a barrier because the sand will not inhibit the flow of the oil or gas in the reservoir. Therefore, in reservoir development, there is a concern regarding the three dimensional distribution in the reservoir of the shale or other fine grained rock because the shale and/or fine grain rock will impede the movement of fluids in the reservoir. As a result, in order to plan development of oil or gas from the reservoir, there is a need to predict the specific locations in the reservoir where the shale and/or fine grain rock exists.

Accordingly, when modeling a reservoir for development planning, there exists a need to predict the specific locations in the reservoir where the shale or fine grain rock is located.

SUMMARY OF THE INVENTION

A first aspect of the present invention includes a method of generating a plurality of simulation results adapted for display on a display device, comprising the steps of: (a) generating, responsive to a plurality of rock classifications, a plurality of model realizations representing an architecture of a fluvial reservoir; and (b) generating, responsive to the plurality of model realizations representing the architecture of the fluvial reservoir, a plurality of grids, the plurality of grids representing said simulation results adapted for display on the display device.

Another aspect of the present invention includes a program storage device readable by a machine, tangibly embodying a program of instructions executable by the machine, to perform method steps for generating a plurality of simulation results adapted for display on a display device, the method steps comprising: (a) generating, responsive to a plurality of rock classifications, a plurality of model realizations representing an architecture of a fluvial reservoir; and (b) generating, responsive to the plurality of model realizations representing the architecture of the fluvial reservoir, the plurality of grids, the plurality of grids representing said simulation results adapted for display on the display device.

Another aspect of the present invention includes a system adapted for generating a plurality of simulation results adapted for display on a display device, comprising: apparatus adapted for generating, responsive to a plurality of rock classifications, a plurality of model realizations representing an architecture of a fluvial reservoir; and apparatus adapted for generating, responsive to the plurality of model realizations representing the architecture of the fluvial reservoir, a plurality of grids, the plurality of grids representing said simulation results adapted for display on the display device.

Another aspect of the present invention includes a method of generating, responsive to a set of predefined channel belt margins, a plurality of model realizations representing an architecture of a fluvial reservoir, the channel belt margins being predefined in response to a set of rock classifications, comprising the steps of: generating a plurality of channel realizations in response to the predefined channel belt margins; rejecting invalid ones of the plurality of channel realizations thereby generating a plurality of valid channel realizations; and gridding tops and bases of the plurality of valid channel realizations, the plurality of model realizations being generated in response to the gridding of the tops and bases of the plurality of valid channel realizations.

Another aspect of the present invention includes a program storage device readable by a machine tangibly embodying a program of instructions executable by the machine to perform method steps for generating, responsive to a set of predefined channel belt margins, a plurality of model realizations representing an architecture of a fluvial reservoir, the channel belt margins being predefined in response to a set of rock classifications, the method steps comprising: generating a plurality of channel realizations in response to the predefined channel belt margins; rejecting invalid ones of the plurality of channel realizations thereby generating a plurality of valid channel realizations; and gridding tops and bases of the plurality of valid channel realizations.

Further scope of applicability of the present invention will become apparent from the detailed description presented hereinafter. It should be understood, however, that the detailed description and the specific examples, while representing a preferred embodiment of the present invention, are given by way of illustration only, since various changes and modifications within the spirit and scope of the invention will become obvious to one skilled in the art from a reading of the following detailed description.

BRIEF DESCRIPTION OF THE DRAWINGS

A full understanding of the present invention will be obtained from the detailed description of the preferred embodiment presented herein below, and the accompanying drawings, which are given by way of illustration only and are not intended to be limitative of the present invention, and wherein:

figures 1 and 2 illustrates a workstation or personal computer that stores the ChannelMod software of the present invention which receives rock classifications as input data and generates a computer model representation of grids that represent the architecture of fluvial reservoirs;

figure 3 illustrates by aerial photograph of a modern river the processes by which 'fluvial reservoirs' are formed;

figure 4 illustrates an example of how the rock classification input data may be derived;

figure 5 illustrates the concept of two-dimensional (2-D) and three-dimensional (3-D) grids;

figure 6 illustrates a construction of the FlowGrid software of figure 2 including a simulator for generating simulation results and displaying the simulation results on the 3D Viewer;

figure 7 illustrates an example of a set of simulation results that are generated by the simulator and displayed on the 3D Viewer of figure 6;

figure 8 illustrates an example of the 'grids representing the architecture of fluvial reservoirs' 22 of figure 2 representing the base of a channel belt which are generated as an output by the ChannelMod software of figure 2 when the ChannelMod software of the present invention is executed by the workstation processor, the 'grids' 22 being provided as input data to the FloGrid software 30 via GeoFrame of figure 2;

figure 9 illustrates an example of a three dimensional computer representation of the channel belt of figure 8 that is displayed on the 3D Viewer 42 of figure 2 and which corresponds to the 'grids representing the architecture of fluvial reservoirs' 22 of figure 2 generated by the workstation computer system of figure 1;

figure 10 illustrates a schematic cross section of the channel belt of figure 9.

figure 11 illustrates a more detailed construction representing a workflow of the ChannelMod software stored in the memory of the computer system shown in figure 1;

figure 12 illustrates the input parameters that can be controlled in the ChannelMod software;

figure 13 illustrates the definition of base channel radius and channel width and the manner in which channel radius varies between successive meander loops;

figure 14 illustrates the control exerted on channel direction by the Wiggle Factor;

figure 15 illustrates the process whereby successive channel units stack to form a channel belt;

figure 16 which includes figures 16A, 16B, and 16C illustrates three model realizations generated by the ChannelMod software;

figure 17 illustrates the process applied to ensure that all input data are honored in the minimum number of realizations;

figure 18, which includes figures 18A and 18B, and figure 19, which includes figures 19A and 19B, illustrate the method embodied in the ChannelMod software for testing the validity of each model realization;

figure 20, which includes figures 20A and 20B, and figure 21, which includes figures 21A and 21B, illustrate the grids generated by the ChannelMod software;

figure 22 illustrates the process of simulating channel scouring by surface truncation in Framework 3D software 29 of figure 2;

figure 23 illustrates the different rock volumes that can be calculated using the ChannelMod software; and

figures 24 through 45 are referenced in the 'Detailed Description of the Invention' section of this specification, wherein:

figure 24 illustrates an Aerial view of a modern channel belt;

figure 25 illustrates a Conceptual model of a channel belt, as applied in ChannelMod;

figure 26 illustrates Control on amount of base level rise;

figure 27 illustrates a Schematic representation showing the logic of simulating successive channel units to fit wells with progressively shallower channel unit bases;

figure 28 illustrates a definition in terms of circles;

figure 29 illustrates a depiction of the ChannelModeling process;

figure 30 illustrates a Chart depicting a Point Bar sheet showing one simulation of the channel course and point bar locations;

figure 31 illustrates a CPS-3 base map showing channel belt margins in purple, wells within channels in white and wells outside channels as red circles;

figure 32 illustrates an Input Polyline worksheet;

figure 33 illustrates an Input Parameters worksheet;

figure 34 illustrates a Test – Point Bar worksheet;

figure 35 illustrates a first part of macro "Export2" in workbook Export.xls;

figure 36 illustrates a First dialogue box to appear after macro "Export2" has created text files Book1.txt to Book40.txt;

figure 37 illustrates a third dialogue box to appear after macro "Export2" has created text files Book1.txt to Book40.txt.

figure 38 illustrates a Dialogue box that appears when macro "Export2" has finished running;

figure 39 illustrates a First part of macro "FRAMEWORK" in the CPS directory;

figure 40 illustrates a Map of channels and point bars generated in CPS-3 by macro "Map";

figure 41 illustrates a Model Editor window showing how polygon (yellow) can be defined for adding a value of –1 to all grid values within the polygon;

figure 42 illustrates Structure contours on base of channel belt;

figure 43 illustrates the First part of macro "VOLUMETRICS" in the CPS directory;

figure 44 illustrates the First part of macro "Vol_Import" in workbook ChannelMod*.xls; and

figure 45 illustrates a Workbook Vol_Table, generated by macro "Vol_Import".

Description of the Invention

As rivers meander across a floodplain, they deposit sediments on the inside bank of each meander loop. The resulting accumulation of sand or gravel, together with minor proportions of mud, is known as a "point bar". As the meandering process continues, the meander loops move in a downstream direction, such that sediment is continually eroded from the upstream edge of each point bar and deposited at the downstream edge. This process continues until the river changes course upstream, at which point the channel is abandoned. The abandoned meander loops then become "oxbow lakes" that eventually fill with mud. At some later time, an active river channel might return to the area as a result of further changes in course; this new channel will tend to erode away all or part of the earlier-formed point bars and channel mud fills. However, continuing subsidence will reduce the severity of this erosion. The end result of a long period of river flow is the deposition of a "channel belt" containing a complex spatial distribution of partly preserved point bars, channel mud fills and the predominantly muddy sediments of the floodplain.

After burial under a sediment overburden, channel belts can become filled with oil or gas to become "fluvial reservoirs" in oil or gas fields. In such reservoirs, the point bars provide storage capacity for the oil or gas and also a conduit for fluid movement, while the channel mud fills, now lithified to shale, act as barriers to the movement of oil or gas.

Since fluvial reservoirs do not comprise or include uniform slabs of sand, there exists in each such reservoir a plurality of curvilinear lines of shale (the channel mud fills) that can badly affect the production of oil or gas from the reservoir. The 'method and program storage device' of the present invention 'for generating grids representing the architecture of fluvial reservoirs' will predict the specific locations in the oil or gas reservoir where the plurality of curvilinear lines of mud will exist. These locations of the curvilinear channel mud fills in the reservoir will be displayed on a 'computer representation of the

reservoir' which is generated as an output display by the present invention. The aforementioned 'computer representation of the reservoir' is actually a model of the 'heterogeneity' of the oil or gas reservoir.

Referring to figure 1, a workstation or other computer system, which stores the ChannelMod software of the present invention for generating grids representing the architecture of fluvial reservoirs, is illustrated. In figure 1, a computer system 10 includes a processor 12 operatively connected to a system bus, a recorder or display device 14 operatively connected to the system bus, and a memory 16 operatively connected to the system bus.

Referring to figure 2, the memory 16 is adapted to store a 'ChannelMod' software 18 in accordance with the present invention. The 'ChannelMod' software 18 is initially stored on a CD-Rom or other program storage device, the 'ChannelMod' software 18 being loaded from the CD-Rom into the memory 16 of the computer system 10 for storage therein. The computer system 10 may be a personal computer (PC), a workstation, or a mainframe. Examples of possible workstations include a Silicon Graphics Indigo 2 workstation or a Sun SPARC workstation or a Sun ULTRA workstation or a Sun BLADE workstation. The memory 16 is a computer readable medium or a program storage device which is readable by a machine, such as the processor 12. The processor 12 may be, for example, a microprocessor, microcontroller, or a mainframe or workstation processor. The memory 16, which stores the ChannelMod software 18, may be, for example, a hard disk, ROM, CD-ROM, DRAM, or other RAM, flash memory, magnetic storage, optical storage, registers, or other volatile and/or non-volatile memory.

In figures 1 and 2, the computer system 10 receives, as input data, a plurality of wireline logs which further include a plurality of rock classifications 20, to be described with greater detail below with reference to figure 4. When the processor 12 executes the ChannelMod software 18 stored in the memory 16 of the workstation 10, a plurality of 'grids' 22 are generated as output data (see figure 2), the 'grids' 22 of figure 2

representing a 'plurality of model realizations which further represent the architecture of a fluvial reservoir'. The concept of 'grids' will be discussed in greater detail below with reference to figure 5. A computer model representation of the grids 22 is ultimately displayed on a 3D Viewer 42.

In figure 2, the memory 16 of the computer system 10 is illustrated. The memory 16 stores the ChannelMod software 18 adapted for generating the 'grids representing the architecture of fluvial reservoirs' 22 (hereinafter called 'grids 22') in response to the rock classifications 20, the 'grids 22' of figure 2 further representing a 'plurality of model realizations which further represent the architecture of a fluvial reservoir'. The GeoFrame software 24 includes a CPS software 26, a Framework 3D software 29, a Property 3D software 28, and a Master Database 27. The grids 22 are provided to the 'Framework 3D' 29 and 'Property3D' 28 software in GeoFrame 24. The CPS software 26 is operatively connected to the ChannelMod software 18 via line 19 in figure 2. The output of the Property3D software 28 is operatively connected to a FloGrid software 30, and the output of the FloGrid software 30 is operatively connected to the 3D Viewer 42 via a simulator 40.

Seven separate blocks of software are illustrated in figure 2: (1) 'GeoFrame' 24, (2) 'CPS' 26, (3) 'Framework3D' 29, (4) 'Property3D' 28, (5) 'FloGrid' 30, (6) ChannelMod 18 and (7) the simulator 40. Each of these seven blocks of software are owned by Schlumberger Technology Corporation of Houston, Texas. The 'FloGrid' software 30 is disclosed and claimed in U.S. Patent 6,106,561 to Farmer, the disclosure of which is incorporated by reference into the specification of this application.

In figure 2, the grids 22 of figure 2, generated as an output by the ChannelMod software 18 of the present invention in response to the rock classifications 20, are used by the 'Framework3D' 29 and 'Property3D' 28 portion of 'GeoFrame' 24 for subsequent use by the 'FloGrid' 30 software. The 'Framework 3D' 29 software is used to truncate grids 22 as a means of simulating channel erosion, while the 'Property 3D' 28 software is used to

generate 3-D grids to embody the reservoir architecture represented by the grids 22 of figure 2. When the FloGrid software 30 receives the grids 22 from the GeoFrame software 24, a 'simulation grid output' is generated by the FloGrid software 30. A simulator 40 receives that 'simulation grid output', and, responsive thereto, the simulator 40 generates a plurality of 'simulation results' which are displayed on a 3D Viewer 42. These concepts are discussed in greater detail in U.S. Patent 6,106,561 to Farmer and hereinbelow with reference to figures 7 and 8 of the drawings.

Referring to figure 3, an aerial photo of a channel belt or fluvial reservoir is illustrated. Recall from figure 2 that a plurality of grids 22 representing the architecture of a 'fluvial reservoir' are generated by the ChannelMod software 18. Figure 3 illustrates an example of an aerial photograph of a modern river. In figure 3, sands consisting mainly of sand are deposited in the point bar 31. Following channel abandonment, the channel 32 will become filled with mud 35. If the river channel of figure 3 subsequently forms a part of an oilfield reservoir, the channel mud fill 35 will represent a barrier to the subsequent flow of oil or gas from that oilfield reservoir.

Referring to figure 4, a more detailed description of the rock classifications 20, being provided as input data to the workstation or computer system of figure 1, is illustrated. Wireline log responses 33 are interpreted in terms of the depositional environment in which the sediments causing the responses were laid down. A indicator log 34 is then constructed to represent the interpreted depositional environment; the different values assigned to this log 34 thus represent a rock classification scheme 20. In figure 4 three such facies or rock classifications 20 are shown: channel 35, splay 36 and floodplain 37. In this example, no channel fill shale is interpreted. The 'rock classification' 20 in figure 4 is provided as input data to the computer system 10 of figure 1 which stores the ChannelMod software 18 of the present invention in the memory 16. As an alternative approach, the rock classification generation software as described in prior pending U.S patent application serial number 10/338,380 filed January 8, 2003, entitled "Rock

Classification Method and Apparatus", may be used. The disclosure of the latter is incorporated by reference into the specification of this application.

Referring to figure 5, a more detailed discussion of the 'grids' in block 22 of figure 2 (i.e., grids 22) is set forth in the following paragraph with reference to figure 5. In figure 5, 2-D grids represent the upper 51 and lower 52 bounding surfaces of a point bar. Such 2-D grids are generated by the ChannelMod software 18 (see 'grids representing architecture of fluvial reservoirs' 22 in figure 2). However, the FloGrid software 30 of figure 2 operates on grid representations of rock volumes rather than surfaces. Thus, the point bar of figure 5 must be represented as a 3D grid 53 of figure 5. This conversion is carried out by 'Property 3D' software 28 (figure 2).

Referring to figure 6, a more detailed construction of the FloGrid software 30 is illustrated. The FloGrid software 30 is operatively connected to the simulator 40, the simulator 40 being operatively connected to the 3D Viewer 42. In figure 5, the FloGrid software 30 receives 'horizon data, fault data, and geo-cellular models' 50; however, the FloGrid software 30 also receives the grids 22 of figure 2. The FlowGrid software 30 includes the following blocks: a reservoir data store which receives the 'horizon data, fault data, and geo-cellular models' 50, a structural framework, an upgridder, a property modeler, structured and unstructured gridders, either of which can receive the grids 22 of figure 2, and an upscaler. Each of these blocks of the FloGrid software 30 in figure 6 are described in detail in U.S. Patent 6,106,561 to Farmer, the disclosure of which has already been incorporated by reference into the specification of this application. In figure 6, the upscaler of the FloGrid software 30 will generate a 'simulation grid output' and the 'unstructured gridder' of the FloGrid software 30 will also generate a 'simulation grid output'. In response to both 'simulation grid outputs', the simulator 40 will generate a plurality of 'simulation results' which will be displayed on the 3D Viewer 42.

Referring to figure 7, an example of the 'simulation results' generated by the simulator 40 and displayed on the 3D Viewer 42 of figure 6 is illustrated.

Referring to figure 8, recall from figures 1 and 2 that the ChannelMod software 18 will generate the 'grids' 22, representing the 'architecture of fluvial reservoirs' when the processor 12 executes the ChannelMod software 18 stored in the memory 16 in response to the rock classifications 20. Figure 8 illustrates an example of the 'grids' 22 of figure 2 which represents a 'plurality of model realizations representing an architecture of a fluvial reservoir' generated by the ChannelMod software 18 of figure 2. Figure 8 comprises a plurality of grid cells. Each grid cell will be assigned a color depending on the numerical property assigned to that grid cell. As a result, figure 8, which represents depth to the base of a channel belt, includes a plurality of colors corresponding, respectively, to the plurality of grid cells which comprise the channel belt of figure 8.

Referring to figure 9, when the ChannelMod software 18 is executed by the processor 12 of the computer system 10 of figure 1, a 'final output display' is displayed on the 3D Viewer 42, and that 'final output display' is illustrated in figure 9. Figure 9 illustrates a three dimensional 'computer model representation' of the channel belt aerial photo of figure 3, figure 9 representing a plurality of grids, the plurality of grids being adapted for display on a display device, such as the 3D Viewer 42. Figure 9 appears on the 3D Viewer 42 and it corresponds to the 'grids' 22 in figures 2 and 8 that are generated by the ChannelMod software 18 representing the 'architecture of fluvial reservoirs'. In figure 9, an illustration 42 which is displayed on the 3D Viewer 42 of figure 2 includes a channel belt 52. The channel belt 52 includes a first element 52a representing sand through which oil or gas can flow and a second element 52b representing shale, through which oil or gas cannot flow. The impervious rock of the second element 52b represents a barrier because oil or gas cannot flow through the barrier. As a result, the oil or gas cannot flow directly from a first element 52a, through a second element 52b, and back into another first element 52a because the impervious rock of the second element 52b represents a barrier through which oil or gas cannot flow. As a result, the illustration 42 of figure 9 is a 'computer model representation' of the internal architecture of a fluvial reservoir.. Consequently, the illustration 42 in figure 9 is a visualization of the ultimate grid output

generated in response to the execution of the ChannelMod software 18 by the processor 12 of computer system 10. The illustration 42 of figure 9 is displayed on the 3D Viewer 42.

Referring to figure 10, a cross section of the channel belt 52 of figure 9 is illustrated. In figure 10, several layers of the reservoir or channel belt 52 of figure 9 are illustrated in cross section. Note a plurality of the first elements 52a in a plurality of layers of the channel belt 52 which represent the sand through which the oil and/or gas can flow and further note a plurality of the second elements 52b in another plurality of layers of the channel belt 52 which represents the shale or other impervious rock through which the oil and/or gas cannot flow.

Referring to figures 11 through 23, a workflow, for which the ChannelMod software 18 stored in the memory 16 of the computer system 10 of figure 1 is designed, is illustrated in figure 11. In figure 11, that workflow includes the following steps: (1) Define channel belt margins and digitize 18a, (2) Set other input parameters 18b, (3) Generate multiple channel realizations 18c, (4) Reject invalid realizations 18d, (5) Grid tops and bases of channel units 18e, (6) Simulate scour by surface truncation 18f, (7) Export 'final 2D grids' 18g, where the 'final 2D grids' represent the grids 22 of figure 2, the grids 22 further representing the 'plurality of model realizations representing the architecture of a fluvial reservoir', (8) Convert grids to 3D 18h, (9) Export final 3D grids to FloGrid 18i, and (10) Volumetrics 18j and 18k. Each of these steps will be discussed in detail below. Steps 18b to 18f inclusive, and 18j, are performed by the ChannelMod software 18 of figure 2.

Define Channel Belt Margins and Digitize, step 18a of figure 11

In figure 2, it is necessary to set up a framework in GeoFrame 24, since the Master Database 27 resides in GeoFrame 24. Using the data residing in GeoFrame 24, and, in particular, the rock classifications 20 of figures 1 and 2, we can define the 'limits of the

channel belt', such as the channel belt 52 in figure 9 (see also Figure 31). In figure 2, those 'limits', as defined in GeoFrame 24, are then provided by the GeoFrame software 24 to the ChannelMod software 18 via line 17 in figure 2.

Set Other Input Parameters, step 18b of figure 11

In figure 11, 12, 13, 14, and 15, the output from Channel Mod software 18 in figure 2 depends not only on the 'rock classifications' input data 20 of figure 2 and the 'limits of the channel belt' from step 18a but also on the settings assigned to a number of input parameters. The parameters that can be altered by the user are shown in figure 12. Those parameters may be classified into three groups 54, 55 and 56 in figure 12. First are the parameters that control the size and shape of the individual meander loops as shown in 54 of figure 13. The software incorporates a random number generator 54a in figure 13 to allow generation of a plurality of loop sizes. Second are the parameters that influence extent to which the course of the modeled channel varies, or "wiggles", as shown in 55 of figure 14. Another random number generator 55a in figure 14 is incorporated to allow generation of a plurality of channel courses within the constraint provided by the wiggle factor 55b in figure 14. Third are the parameters that control the vertical thickness of the channel belt and its component channel units, as illustrated in 56 of figure 15. Note that the thickness of each channel unit 56a, 56b and 56c in figure 15 represents its original deposited thickness, such that the sum of thicknesses of individual channel units can exceed the thickness of the channel belt, as is the case in 56 of figure 15. In such cases, part of all or some of the units is removed by simulated erosion to ensure that the sum of the final thicknesses of the channel units 56c, 56d and 56e in figure 15 is equal to the thickness of the channel belt.

Generate Multiple Channel Realizations, step 18c of figure 11

In figures 11, 16A, 16B, 16C, and 17, when the 'limits of the channel belt' are provided to the ChannelMod software 18 from step 18a, the ChannelMod software 18 will then

generate a plurality of channels (first one channel then another channel). As a result, when the ChannelMod software 18 generates the plurality of channels, a 'plurality of statistical realizations' 57a, 57b and 57c in figures 16A, 16B, and 16C, are created corresponding, respectively, to the plurality of channels. Figures 16A-16C depict one of the well data points as being a "conditioning well" 57d. This well is selected on the 'Input Parameters' worksheet of ChannelMod software 18; the program then ensures that all realizations are 'conditioned' by, or honor, that data point. Thus the 'conditioned well' 57d is known from 'Rock Classifications' 20 to contain a point bar in the channel unit being modeled for figures 16A through 16C. However it will not necessarily be possible to honor all the other wells using one specific well for conditioning. In such cases, other wells need to be selected for conditioning. The logical process for doing this is shown in figure 17. Channel units are modeled one at a time. After selecting the first channel unit 66, one well 67 is selected as the conditioning well. Multiple realizations 68 are then run; invalid realizations are rejected 69 and grids are saved for each valid realization 70. This continues until no improvement in the degree of fit to the input data is possible. At that point, a different well is selected for conditioning 71 unless all the wells in the channel unit have been honored in at least one realization 72. The process is then repeated using a series of new conditioning wells until all the wells have been honored. Once that has happened, the process is repeated for the next channel unit 73.

Reject Invalid Realizations, step 18d of figure 11

In figures 11, 18A-18B, and 19A-19B, the following paragraph describes the process whereby invalid realizations are rejected, as shown in step 69 of figure 17. If a particular statistical realization indicates that there is a sand body in a particular well and it is known that shale (and not sand) exists in that particular well, that particular statistical realization must be rejected. Thus, for example, Channel unit 1 58a in figures 18A and 18B can occur in Well 4 58b but not Wells 1, 2 and 3 58c. Similarly, Channel unit 2 59a in figures 19A and 19B can occur in Wells 3 59c and 4 59b but not in Wells 1 and 2 59d. The 'plurality of statistical realizations' is continuously tested in this manner via a do-

loop 18d1 in figure 11. The do-loop 18d1 in figure 11 ensures that the multiple channel realizations of step 18c are continuously generated and that the generated multiple channel realizations are continuously tested in the 'reject invalid realizations' step 18d of figure 11. Testing is carried out using the spreadsheet 60 in figures 19A and 19B. As a result, a plurality of 'valid channel realizations' are generated by the ChannelMod software 18 of figure 11.

Grid Tops and Bases of Channel Units, step 18e of figure 11

In figures 11, 17, 20A-20B, and 21A-21B, for every valid realization generated by ChannelMod software 18, grids representing the tops and bases of the modeled channel units are saved as indicated at 70 in figure 17. Examples of the resulting 2-D grids are shown in figures 20A-20B and 21A-21B. The numbers in red correspond to the value of the grid at the grid nodes represented by black crosses. Note that the grids are indeterminate outside the area occupied by the channel unit being modeled.

Simulate Scour by Surface Truncation, step 18f of figure 11

In figures 11 and 22, at this point, it is necessary to simulate an occurrence, called 'scouring', whereby one channel will cut into another channel; that is, a later generated channel will erode away another previously generated channel. The Framework3D software 29, part of GeoFrame 24, will simulate the 'scouring' by surface truncation as illustrated in figure 22. Three simulations, of Channel Units 61a, 61b and 61c of figure 22, are submitted to surface truncation in the Framework3D software 29 to produce 2-D grids representing the configuration 62 in figure 22.

Export Final 2D Grids, step 18g of figure 11

When the 'scouring' is completed, the 'two-dimensional (2-D) grids of the original and eroded top and base surfaces of these channels' are transferred to the 'Property3D'

software 28 of figure 2. The aforementioned 'two-dimensional (2-D) grids of the original and eroded top and base surfaces of these channels' represent the 'plurality of model realizations representing the architecture of a fluvial reservoir'.

Convert Grids to 3D, step 18h of figure 11

Export Final 3D Grids to FloGrid, step 18i of figure 11

Volumetrics, steps 18j and 18k of figure 11

In figures 11 and 23, the 'two-dimensional (2D) grids of the original and eroded top and base surfaces of these channels' can now be converted to threedimensions (3-D) using the 'Property3D' software 28 and transferred to FloGrid 30 in RESCUE file format. The Volumetrics can be accomplished either in either step 18j using 'CPS' 26, or in step 18k using 'Property3D' 28. Referring to figure 23, step 18j is part of ChannelMod software 18 and allows calculation of total channel belt volume 63, channel unit volume 64, sand volume 65a, and shale volume 65b.

Detailed Description of the Invention

The following 'Detailed Description of the Invention' represents a functional specification associated with the ChannelMod software 18 shown in figure 2 of the drawings.

Refer now to figures 24 through 45.

1. INTRODUCTION

The objectives of this document are to:

1. Record the philosophy and mathematical basis of the ChannelMod algorithm;
2. Provide guidance as to how the algorithm should be used.

ChannelMod was developed to provide a means of modeling fluvial reservoirs that would be complementary to FluvSim, the currently available method in GeoFrame. This was deemed necessary for two reasons:

a. Because FluvSim does not allow generation of realistic models representing the shale plugs that commonly form important barriers within fluvial reservoirs

b. Because FluvSim does not provide grids that represent the bounding surfaces of the sand bodies; such grids are required under circumstances in which a deterministic reservoir model is to be simulated in Eclipse.

ChannelMod is designed to be used with GeoFrame. The grids are generated in CPS-3 so that they can be exported directly into FlowGrid. However, owing to lack of access to the GeoFrame code, the channel simulation itself is done in an Excel 2000 workbook. Ultimately it would probably be advisable to incorporate the Excel logic into GeoFrame code so that simulation and mapping can be done in a single environment. The next section of the report discusses the workflow under which information moves from Excel to GeoFrame and back to Excel.

Following the workflow discussion, the report describes in detail the structure and content of the Excel workbook containing the simulation algorithm. After this description, instructions are provided for applying ChannelMod.

2. WORKFLOW

ChannelMod generates grids that represent the tops and bottoms of point bars and channel fills within a multi-storey channel belt that is a product of deposition from successive channel systems. The channel belt associated with a modern river is illustrated in Figure 24, which shows how abandoned channel fills are partially preserved between point bar deposits.

A key requirement of the method is to generate grids that represent the channel fills, which commonly comprise mud and thus act as important barriers to fluid flow within reservoirs.

The ChannelMod system comprises 2 Excel workbooks and 4 CPS-3 macros:

ChannelMod*.xls

Export.xls

FRAMEWORK.mac

VOLUMETRICS.mac

VOLUMETRICS_AOI.mac

Map.mac

The workflow is shown in Figure 11. It is assumed that all the well and seismic data that will provide constraint to the ChannelModel are contained within an existing GeoFrame project. The process begins with definition of the margins of the channel belt within GeoFrame. These margins are digitized and exported to the Excel workbook ChannelMod*.xls, in which the simulation is performed. After simulation, the resulting polygon and data files representing the modeled point bars and channel fills are exported to GeoFrame where CPS-3 is used to truncate each storey base and point bar top by successively younger storeys of the channel belt. Volumetrics can be calculated at this point. The final step is to convert the 2-D grids from CPS-3 into 3-D grids within Property3D.

3. THE CHANNELMOD SIMULATION ALGORITHM

The algorithm is designed to model a channel and its associated point bars for all the storeys in a multi-storey channel belt. It is assumed that the channel belt is represented in all the wells penetrating it by a single interval comprising point bar sandstones or channel-fill shales. The base of this interval is set relative to the top, such that the depth of the base corresponds to the thickness of the channel belt (Figure 25). This interval is divided into successive storeys, such that the relative depths of each successive storey represent the amount of rise in base level (Figure 26). The interval of rock deposited before erosion to generate a storey is termed a "channel unit" (Figure 27).

Each channel unit is modeled separately by one or more simulations. Simulation is repeated until all the wells representing a point bar or channel for the channel unit in question have been correctly located within point bars or channels (Figure 27). For each simulation, one well is set as a data point to which the simulation is conditioned. The same well can be used in any number of simulations. In addition the algorithm determines how many of the other wells are correctly located.

The algorithm resides within Excel workbook ChannelMod*.xls, which contains 9 worksheets. The purpose of each of these is discussed below.

3.1. Input Polyline sheet

The purpose of this sheet is to interpolate X,Y values for the channel belt margins imported from GeoFrame. Up to 28 points can be imported; from these the worksheet interpolates 2 Y values (representing the margins of the channel belt) for each of 121 X values.

3.2. Input Parameters sheet

All the input parameters are specified in this sheet. Point bars and channel fills are assumed to be bounded by a combination of circle segments and circle chords, as shown in Figure 28.

Variation is allowed in the radius of each successive bounding circle by random proportions of a maximum percentage of a defined base radius. Variation in channel width is similarly defined. The extent to which the channel bends back on itself is controlled by means of a parameter termed "Wiggle Control", which can comprise any number greater than or equal to 0.5. The larger the number, the closer will be the center of each circle to the center of the channel belt.

Other parameters defined in this sheet are the thicknesses of the channel belt and the channel belt storeys and the depths to the top and base of the story being modeled. The sheet also specifies the locations of all the wells that provide

constraint on the location of the channel belt, channels and point bars, and the location of the particular well to which the model is being conditioned.

3.3. Calculation – Point Bar sheet

The simulated channel path is constrained to stay almost entirely within the defined channel belt by ensuring that the maximum and minimum Y values of each circle are respectively less than and greater than the maximum and minimum Y values of the channel belt margin at a certain search distance from the center of the previous circle, as illustrated in Figure 29. The search distance is set at the sum of the radii of the circle in question and the previous circle.

The worksheet generates a channel containing 21 loops based on 21 circles placed as shown in Figure 29. Each re-calculation of the sheet generates a new simulation, or realization. In each case, the conditioning well specified in the Input Parameters sheet falls within the point bar of Circle 1. The worksheet also determines whether each of the other wells specified in the Input Parameters sheet falls inside or outside a point bar.

3.4. Calculation – Channel sheet

This sheet differs from the Calculation – Point Bar sheet only in forcing the conditioning well to fall within a channel, and in determining whether each of the other wells falls inside or outside a channel.

3.5. Chart – Point Bar sheet

This chart shows a map of the channel and point bar boundaries for the simulation that was last performed, together with the boundaries of the channel belt and the locations of the conditioning well and all other control points (Figure 30).

3.6. Test – Point Bar sheet

This sheet indicates how many of the wells are modeled correctly, in simulations conditioned to a well inside a point bar, as falling inside or outside a point bar or channel. It also allows the top and base of each successive story to be recorded.

3.7. Test – Channel sheet

This sheet is similar to the Test – Point Bar sheet except that it indicates results for simulations conditioned to a well inside a channel.

3.8. Output Polygons

This sheet contains the X,Y coordinates of the polygons that bound all the point bars and channel fills of the realization that was last performed. Successive realizations may be exported to a single workbook (Export.xls) using a macro entitled "Export" within ChannelMod*.xls.

3.9. Output Data

This sheet contains Z values corresponding to the top and base of the storey for all of the points specified in the Output Polygons sheet. These values are exported at the same time as the polygons when the "Export" macro is run.

4. INSTRUCTIONS FOR USE

4.1. In GeoFrame CPS-3

4.1.1. Digitize channel belt margins as polyline (Figure 31).

4.1.2. Export as ASCII file.

4.2. In Excel

4.2.1. Copy workbooks ChannelMod*.xls and Export.xls into project directory.

4.2.2. Open Export.xls and delete all worksheets except Sheet 1, which should be blank.

4.2.3. Open ChannelMod*.xls.

4.2.4. Open ASCII file created in step 4.1.2 and copy to "Input Polyline" sheet of ChannelMod*.xls (Figure 32).

4.2.5. Set input parameters on "Input Parameters" sheet of ChannelMod*xls, including the depth to the top of the storey to be modeled (Figure 33).

4.2.6. Input well locations and depths to channel belt base, relative to the top of the channel belt in each well, to "Input Parameters" sheet and sort the wells in order of decreasing channel belt thickness (Figure 33).

4.2.7. Insert the value 1 in columns B and E of the "Test – Point Bar" or "Test – Channel" sheet for each well located in a point bar or channel for the storey being modeled (Figure 34). Start with a storey corresponding to the thickest channel belt.

4.2.8. Copy the X,Y coordinates of the well selected for conditioning into cells B14 and B15 of the "Input Parameters" sheet (Figure 33).

4.2.9. Set workbook to Manual calculation without "Recalculate before Save".

4.2.10. From the "Test – Point Bar" or "Test – Channel" sheet, run macro "ChkFirstUntil" to run first simulation. This will generate a realization having the correct number of wells located outside point bars and channels (Figure 34).

4.2.11. Check to see how many wells are correctly located within a point bar or channel (Figure 34). For each correct well, set the base and top of the appropriate storey to the depths specified in the "Input Parameters" sheet. Run macro "Export" in ChannelMod*.xls to copy output polygons and data to new worksheets in Export.xls.

4.2.12. If the first simulation does not correctly locate all the wells for the storey being modeled in point bars or channels, run macro "ChkFirstUntil" repeatedly until that condition is met. Run macro "Export" in ChannelMod*.xls.

4.2.13. Repeat Steps 4.2.8 to 4.2.13, working down the list of wells in point bars or channels until each well has been modeled within a channel in at least one realization. The conditioning option can be used for any well that is difficult to

fit. In each case, any number of wells with deeper storey bases than in the well in question can be located within the same channel as the latter well (Figure 27).

4.2.14. Delete text files Book1.txt to Book40.txt in destination directory.

4.2.15. Edit macro "Export2" in Export.xls to ensure that correct destination directory is specified (Figure 35). Then run macro "Export2" to copy all output polygons and data to text files Book1.txt to Book40.txt. Files in excess of number of channels modeled will automatically be assigned the same polygons as the first ChannelModeled, and data values of zero so that they do not truncate older surfaces. After starting the macro, click on the icon for Export.xls. When the macro has finished creating files Book1.txt to Book40.txt, a dialogue box will come up (Figure 36); the answer to this question is "No", for the first and all subsequent boxes asking the same question. The box will come up twice, and then another box will appear, to which the answer is "Yes" (Figure 37). A long series of boxes will then appear, to which the answers are alternately "No" (for Figure 36 type) and "Yes" (for Figure 37 type). Finally, the box shown in Figure 38 will appear; the "End" button should be pressed.

4.3. In GeoFrame CPS-3

4.3.1. Select modeling and display environment that will areally encompass all channel realizations.

4.3.2. Digitize area of interest (e.g. lease area) as a sub-area of the project area if desired.

4.3.3. Copy macro files FRAMEWORK.mac, VOLUMETRICS.mac, VOLUMETRICS_AOI.mac and Map.mac to the CPS directory.

4.3.4. Edit macro "FRAMEWORK" to ensure that correct source directory is specified for importing text files Book1.txt to Book40.txt (Figure 39). Run macro "FRAMEWORK" to generate truncated and gridded surfaces.

4.3.5. If desired, run macro "Map" to generate map of channels (Figure 40).

4.3.6. Open Model Editor and load surface D1_base_merged_trunc, making the contour maximum and the contour interval both greater than the maximum thickness of the channel belt.

4.3.7. In Model Editor, create a closed polygon corresponding to the channel belt margins (Figure 41).

4.3.8. Add –1 to all grid values inside the polygon and set all grid values outside the polygon to NULL. Save the resulting surface as CB_base.

4.3.9. Close Model Editor.

4.3.10. Back in the Main Module of CPS-3, perform Single Surface Logical Operation (B = b, if A = a, otherwise B = A) to substitute the minimum base storey depth for the –1 grid node values in surface CB_base (use the name CB_base as output).

4.3.11. Perform Multiple Surfaces Logical Operation (C = MAX(A,B) If A or B is NULL, then C = NULL) to create a corrected Base Channel Belt surface from surfaces CB_base and D1_base_merged_trunc (use name CB_base as output).

4.3.12. If desired, use Display functions in CPS-3 Main Module to generate a map of the base of the channel belt (Figure 42).

4.3.13. Perform another Single Surface Logical Operation (B = b, if A = a, otherwise B = A) to substitute zero values for the NULL grid node values in surface CB_base (use the name CB_base as output).

4.3.14. Copy D20_top as CB_top.

4.3.15. Transfer the grids for CB_base and CB_Top to GeoFrame, remembering to set attributes with named surfaces.

4.3.16. In Framework3D, create a structural framework from CB_Top and CB_Base.

4.3.17. Volumetrics can be calculated in CPS-3 using macros as described in the following steps, or they can be derived in Property3D using Grid Operations.

4.3.18. Edit Macros "VOLUMETRICS" and "VOLUMETRICS_AOI"to ensure that the correct destination directory is specified for the volumetric output (Figure 43).

4.3.19. Run Macro "VOLUMETRICS" to generate text file of results for entire channel belt (rjames.vlm) after deleting all data from previous runs in rjames.vlm.

4.3.20. Run Macro "VOLUMETRICS_AOI" to generate text file of results for channel belt within the area of interest (rjames.vlm) after deleting all data from previous runs in rjames.vlm.

4.4. In GeoFrame Property3D

4.4.1. Create a structural model from the above structural framework

4.4.2. Use Direct Assignment in Property Population Manager to create 3-D grids corresponding to the CPS grids for channel fills (i.e. same value throughout columns at each X,Y location). Name them D1_CF_Top, D1_Base, etc.

4.4.3. Multiply the ZAverage grid by –1 to convert it to a depth grid

4.4.4. Use Blank Maximum and Blank Minimum in Grid Operations to create depth grids that have non-null values only between top and base of each channel. Name them D1_CF_Top_Depth, D1_Base_Depth, etc.

4.4.5. Use Direct Assignment in Property Population Manager to overwrite non-null depth values with value 1. Name the grids D1_CF_Flag, etc. The value 1 will represent channel fills.

4.4.6. Use Direct Assignment in Property Population Manager to overwrite null depth values with value 0. Overwrite the D*_CF_Flag grids. The value 0 will represent point bars.

4.4.7. Add all of the D*_CF_Flag grids together to create a composite flag grid (e.g. CB_CF_Flag).

4.4.8. Correct for any edge effects by using Direct Assignment in Property Population Manager to overwrite all Flag values greater than 1 with the value 1. Overwrite the CB_Flag grid.

4.5. In Excel

4.5.1. In ChannelMod*.xls, edit macro "Vol_Import" to ensure that correct source directory is specified (Figure 44).

4.5.2. In ChannelMod*.xls, run macro "Vol_Import" to create workbook Vol_Table.xls (Figure 45).

The invention being thus described, it will be obvious that the same may be varied in many ways. Such variations are not to be regarded as a departure from the spirit and scope of the invention, and all such modifications as would be obvious to one skilled in the art are intended to be included within the scope of the following claims.

I CLAIM:

1. A method of generating a plurality of simulation results adapted for display on a display device, comprising the steps of:

(a) generating, responsive to a plurality of rock classifications, a plurality of model realizations representing an architecture of a fluvial reservoir; and

(b) generating, responsive to said plurality of model realizations representing said architecture of said fluvial reservoir, a plurality of grids, said plurality of grids representing said simulation results adapted for display on said display device.

2. The method of claim 1, wherein the generating step (a) comprises the step of:

defining, responsive to said plurality of rock classifications, channel belt margins.

3. The method of claim 1, wherein the generating step (a) comprises the step of:

generating a plurality of channel realizations.

4. The method of claim 1, wherein the generating step (a) comprises the step of:

rejecting invalid ones of a plurality of channel realizations thereby generating a plurality of valid channel realizations.

5. The method of claim 1, wherein the generating step (b) comprises the step of:

gridding tops and bases of a plurality of valid channel realizations.

6. The method of claim 1, wherein the generating step (b) comprises the step of:

generating 3-D grids corresponding to gridded tops and bases of a plurality of valid channel realizations, said 3-D grids representing said plurality of model realizations representing said architecture of said fluvial reservoir.

7. A program storage device readable by a machine, tangibly embodying a program of instructions executable by the machine, to perform method steps for generating a plurality of simulation results adapted for display on a display device, said method steps comprising:

(a) generating, responsive to a plurality of rock classifications, a plurality of model realizations representing an architecture of a fluvial reservoir; and

(b) generating, responsive to said plurality of model realizations representing said architecture of said fluvial reservoir, said plurality of grids, said plurality of grids representing said simulation results adapted for display on said display device.

8. The program storage device of claim 7, wherein the generating step (a) comprises the step of:

defining, responsive to said plurality of rock classifications, channel belt margins.

9. The program storage device of claim 7, wherein the generating step (a) comprises the step of:

generating a plurality of channel realizations.

10. The program storage device of claim 7, wherein the generating step (a) comprises the step of:

rejecting invalid ones of a plurality of channel realizations thereby generating a plurality of valid channel realizations.

11. The program storage device of claim 7, wherein the generating step (b) comprises the step of:

gridding tops and bases of a plurality of valid channel realizations.

12. The program storage device of claim 7, wherein the generating step (b) comprises the step of:

generating 3-D grids corresponding to gridded tops and bases of a plurality of valid channel realizations, said 3-D grids representing said plurality of model realizations representing said architecture of said fluvial reservoir.

13. A system adapted for generating a plurality of simulation results adapted for display on a display device, comprising:

apparatus adapted for generating, responsive to a plurality of rock classifications, a plurality of model realizations representing an architecture of a fluvial reservoir; and

apparatus adapted for generating, responsive to said plurality of model realizations representing said architecture of said fluvial reservoir, a plurality of grids, said plurality of grids representing said simulation results adapted for display on said display device.

14. The system of claim 13, wherein said apparatus adapted for generating said plurality of model realizations representing the architecture of a fluvial reservoir comprises:

apparatus adapted for defining, responsive to said plurality of rock classifications, channel belt margins.

15. The system of claim 13, wherein said apparatus adapted for generating said plurality of model realizations representing the architecture of a fluvial reservoir comprises:

apparatus adapted for generating a plurality of channel realizations.

16. The system of claim 13, wherein said apparatus adapted for generating said plurality of model realizations representing the architecture of a fluvial reservoir comprises:

apparatus adapted for rejecting invalid ones of a plurality of channel realizations thereby generating a plurality of valid channel realizations.

17. The system of claim 13, wherein said apparatus adapted for generating said plurality of grids, which represents the architecture of a fluvial reservoir, comprises:

apparatus adapted for gridding tops and bases of a plurality of valid channel realizations.

18. The system of claim 13, wherein said apparatus adapted for generating said plurality of grids, which represents the architecture of a fluvial reservoir, comprises:

apparatus adapted for generating 3-D grids corresponding to gridded tops and bases of a plurality of valid channel realizations, said 3-D grids representing said plurality of model realizations which further represent said architecture of said fluvial reservoir.

19. A method of generating, responsive to a set of predefined channel belt margins, a plurality of model realizations representing an architecture of a fluvial reservoir, said channel belt margins being predefined in response to a set of rock classifications, comprising the steps of:

generating a plurality of channel realizations in response to the predefined channel belt margins;

rejecting invalid ones of said plurality of channel realizations thereby generating a plurality of valid channel realizations; and

gridding tops and bases of said plurality of valid channel realizations,

said plurality of model realizations being generated in response to the gridding of the tops and bases of said plurality of valid channel realizations.

20. The method of claim 19, wherein the step of generating a plurality of channel realizations further comprises the steps of:

setting input parameters; and

generating said plurality of channel realizations in response to the predefined channel belt margins.

21. The method of claim 19, wherein the step of gridding the tops and bases of said plurality of valid channel realizations comprises the steps of:

gridding the tops and bases of said plurality of valid channel realizations; and

simulating scour by surface truncation,

said plurality of model realizations being generated in response to the simulating step.

22. A program storage device readable by a machine tangibly embodying a program of instructions executable by the machine to perform method steps for generating,

responsive to a set of predefined channel belt margins, a plurality of model realizations representing an architecture of a fluvial reservoir, said channel belt margins being predefined in response to a set of rock classifications, said method steps comprising:

generating a plurality of channel realizations in response to the predefined channel belt margins;

rejecting invalid ones of said plurality of channel realizations thereby generating a plurality of valid channel realizations; and

gridding tops and bases of said plurality of valid channel realizations.

23. The program storage device of claim 22, wherein the step of generating a plurality of channel realizations further comprises the steps of:

setting input parameters; and

generating said plurality of channel realizations in response to the predefined channel belt margins.

24. The program storage device of claim 22, wherein the step of gridding the tops and bases of said plurality of valid channel realizations comprises the steps of:

gridding the tops and bases of said plurality of valid channel realizations; and

simulating scour by surface truncation.

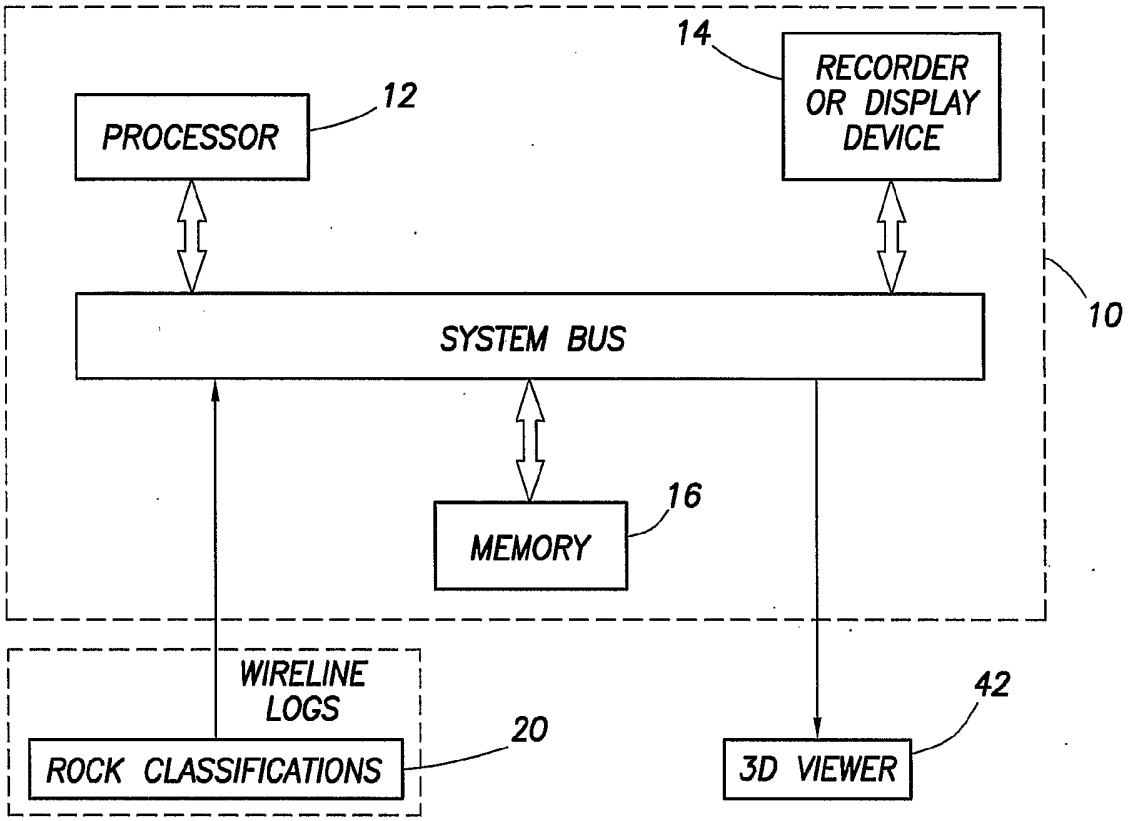

14
RECORDER OR DISPLAY DEVICE
12
PROCESSOR
10
SYSTEM BUS
16
MEMORY
WIRELINE LOGS
20
ROCK CLASSIFICATIONS
42
3D VIEWER

FIG. 1

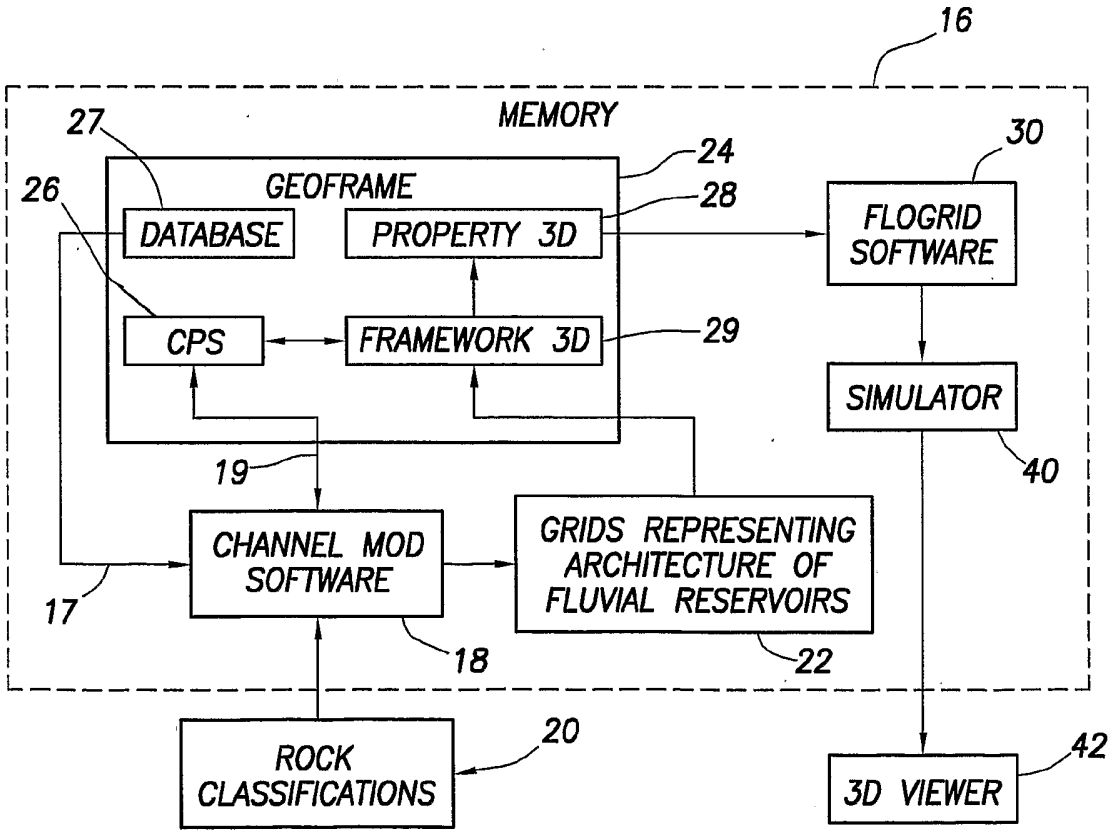

16
MEMORY
27
GEOFRAME
24
26
28
DATABASE
PROPERTY 3D
30
FLOGRID SOFTWARE
CPS
FRAMEWORK 3D
29
SIMULATOR
40
19
CHANNEL MOD SOFTWARE
GRIDS REPRESENTING ARCHITECTURE OF FLUVIAL RESERVOIRS
17
18
22
ROCK CLASSIFICATIONS
20
3D VIEWER
42

FIG. 2

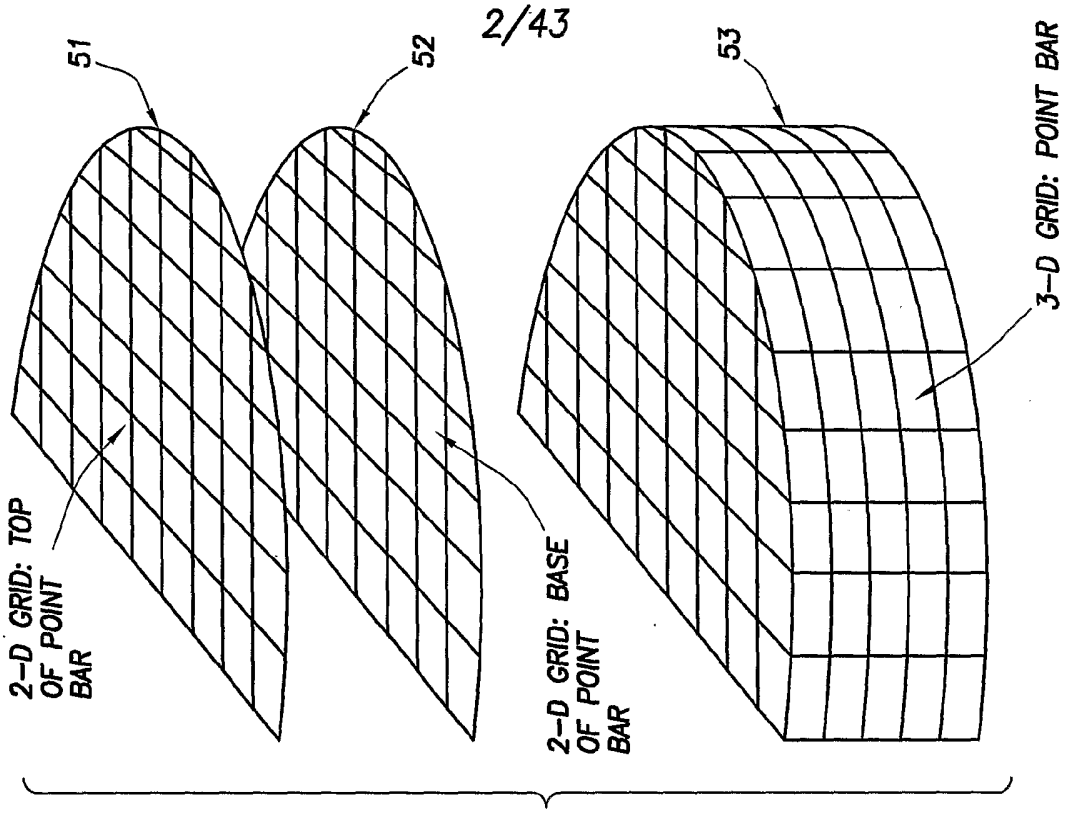

51
52
53
2-D GRID: TOP OF POINT BAR
2-D GRID: BASE OF POINT BAR
3-D GRID: POINT BAR

FIG.5

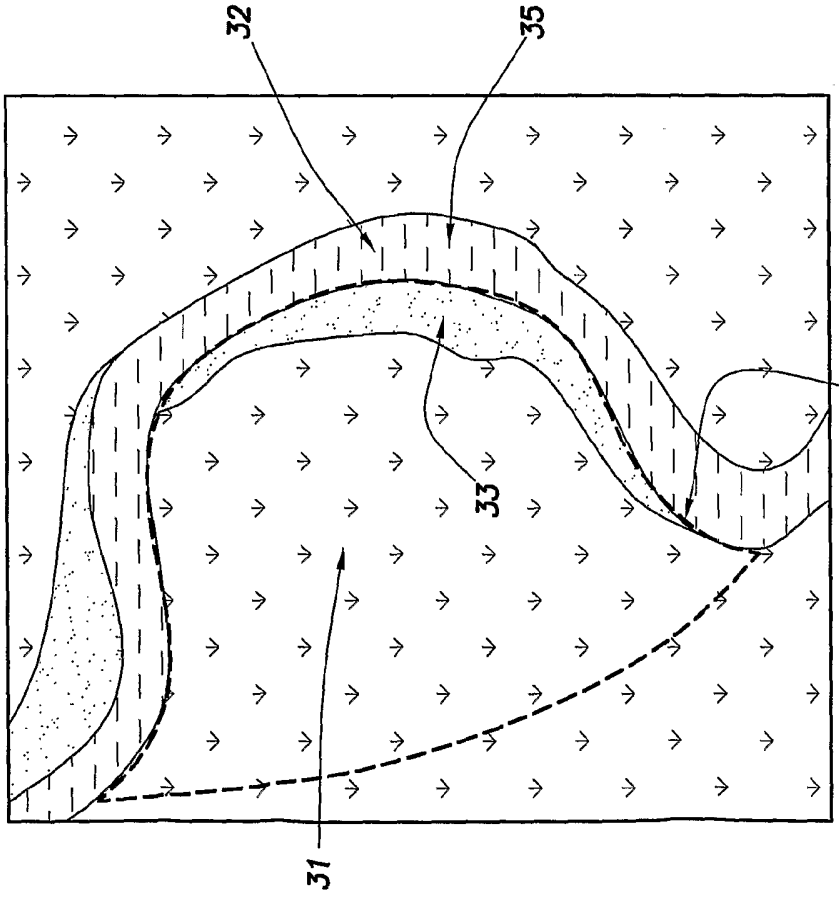

32
35
33
31
BOUNDARY OF POINT BAR

FIG.3

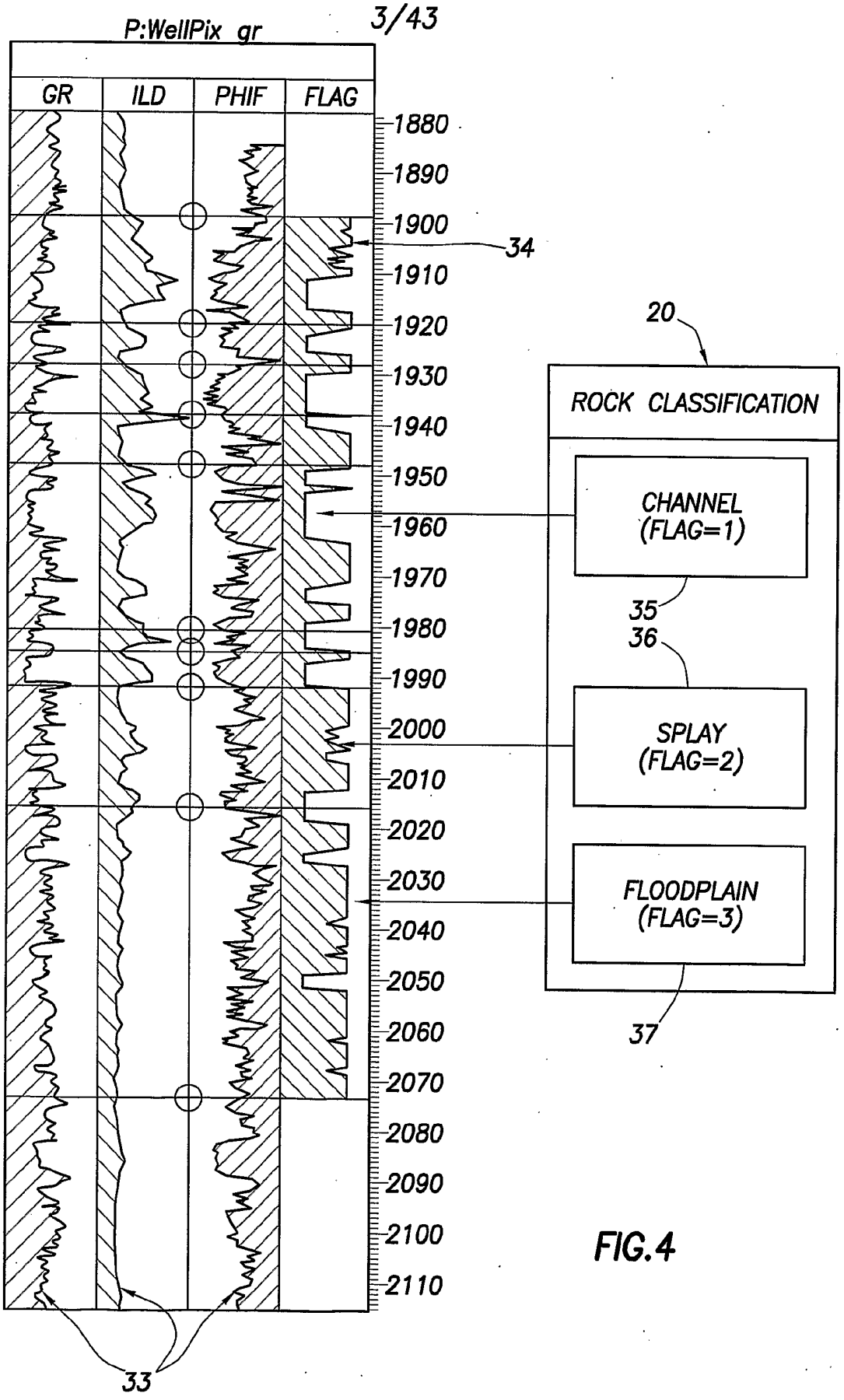

P:WellPix gr
GR
ILD
PHIF
FLAG
1880
1890
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
2110
34
20
ROCK CLASSIFICATION
CHANNEL (FLAG=1)
35
36
SPLAY (FLAG=2)
FLOODPLAIN (FLAG=3)
37
33

FIG.4

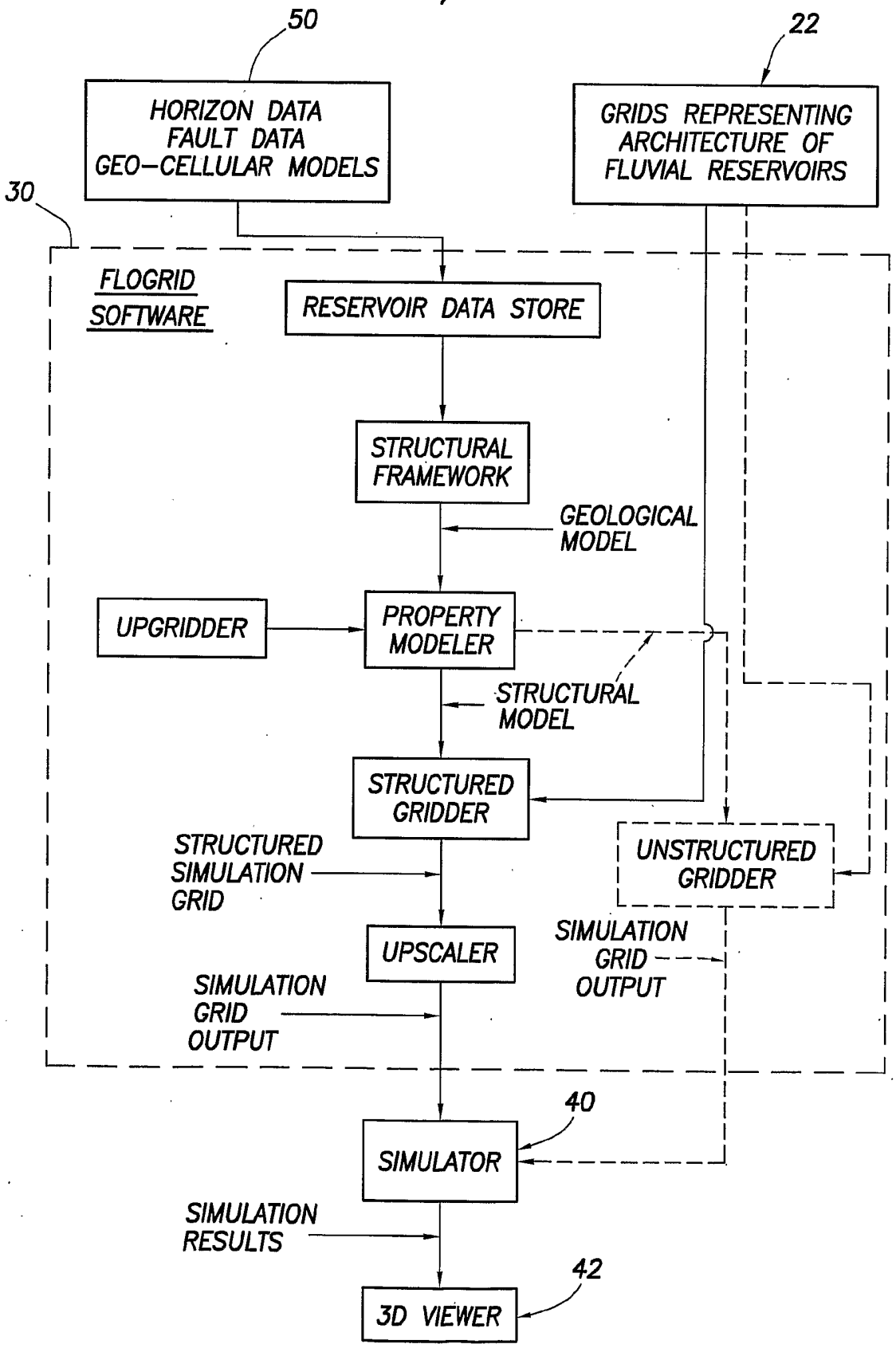

50
22
HORIZON DATA
FAULT DATA
GEO-CELLULAR MODELS
GRIDS REPRESENTING
ARCHITECTURE OF
FLUVIAL RESERVOIRS
30
FLOGRID
SOFTWARE
RESERVOIR DATA STORE
STRUCTURAL
FRAMEWORK
GEOLOGICAL
MODEL
UPGRIDDER
PROPERTY
MODELER
STRUCTURAL
MODEL
STRUCTURED
GRIDDER
STRUCTURED
SIMULATION
GRID
UNSTRUCTURED
GRIDDER
SIMULATION
GRID
OUTPUT
UPSCALER
SIMULATION
GRID
OUTPUT
40
SIMULATOR
SIMULATION
RESULTS
42
3D VIEWER

FIG.6

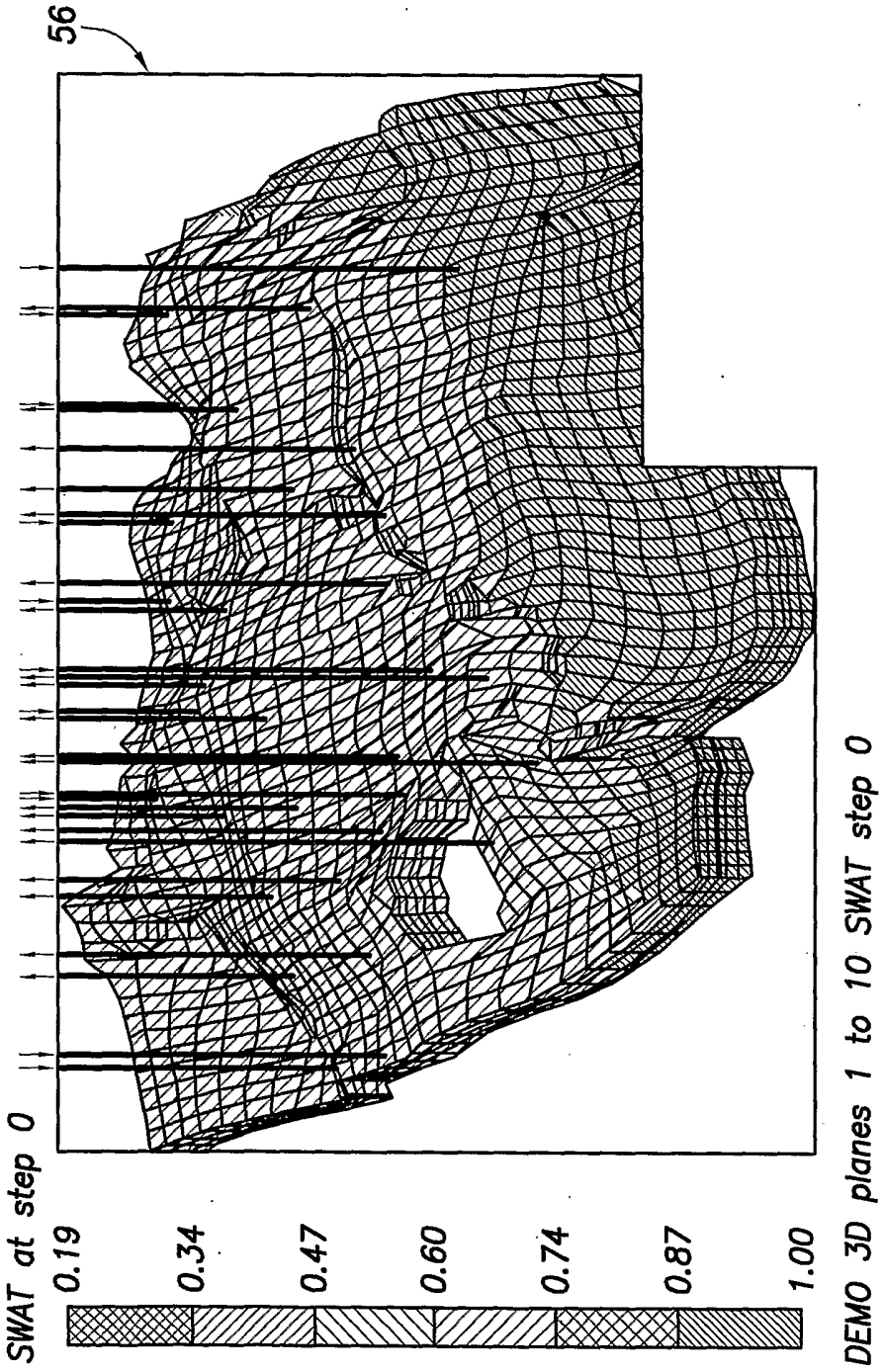

56
SWAT at step 0
0.19
0.34
0.47
0.60
0.74
0.87
1.00
DEMO 3D planes 1 to 10 SWAT step 0

FIG.7

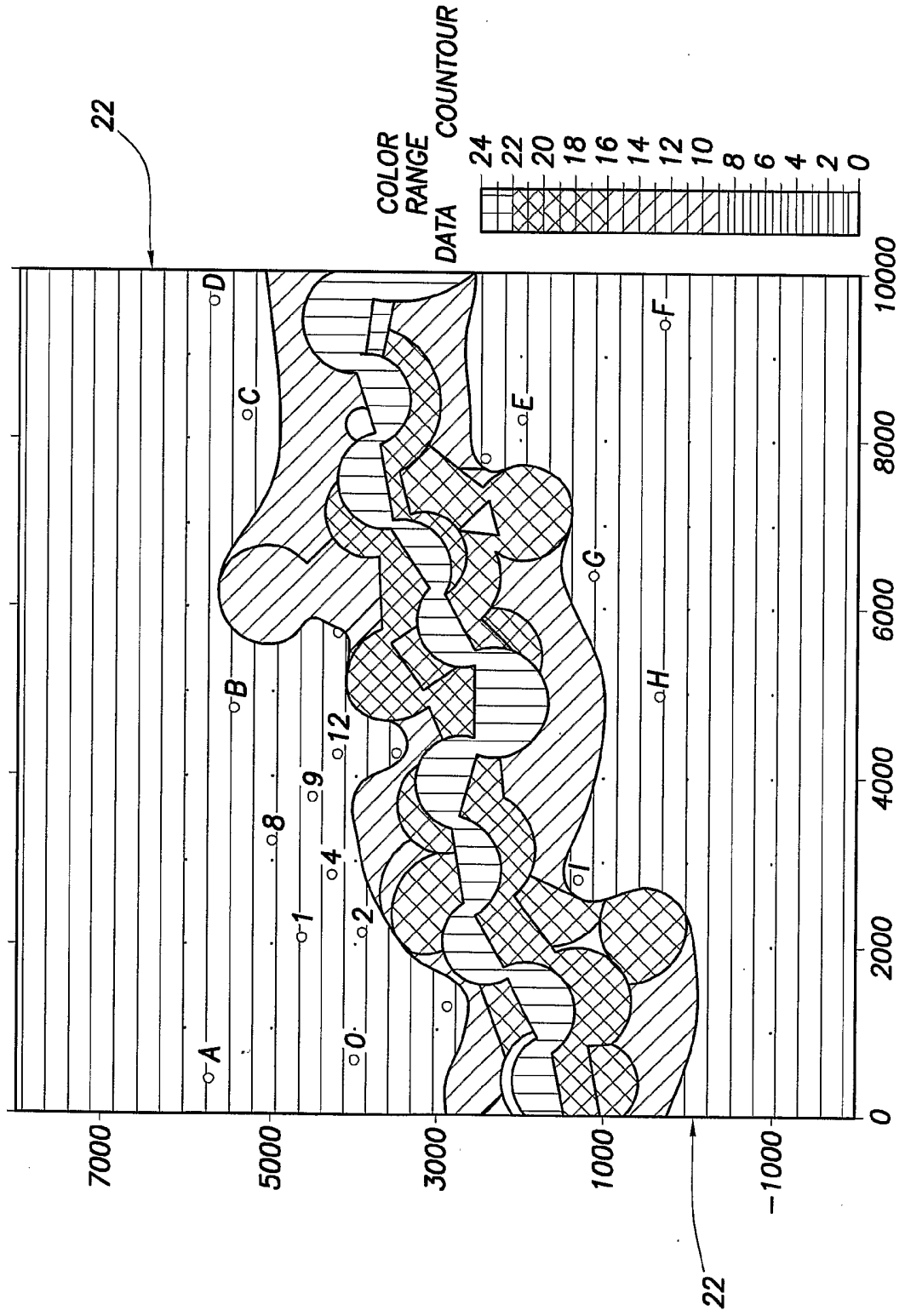

22
COLOR RANGE DATA
COUNTOUR
24 22 20 18 16 14 12 10 8 6 4 2 0
A
B
C
D
E
F
G
H
I
0
1
2
4
8
9
12
7000
5000
3000
1000
-1000
0
2000
4000
6000
8000
10000
22

FIG.8

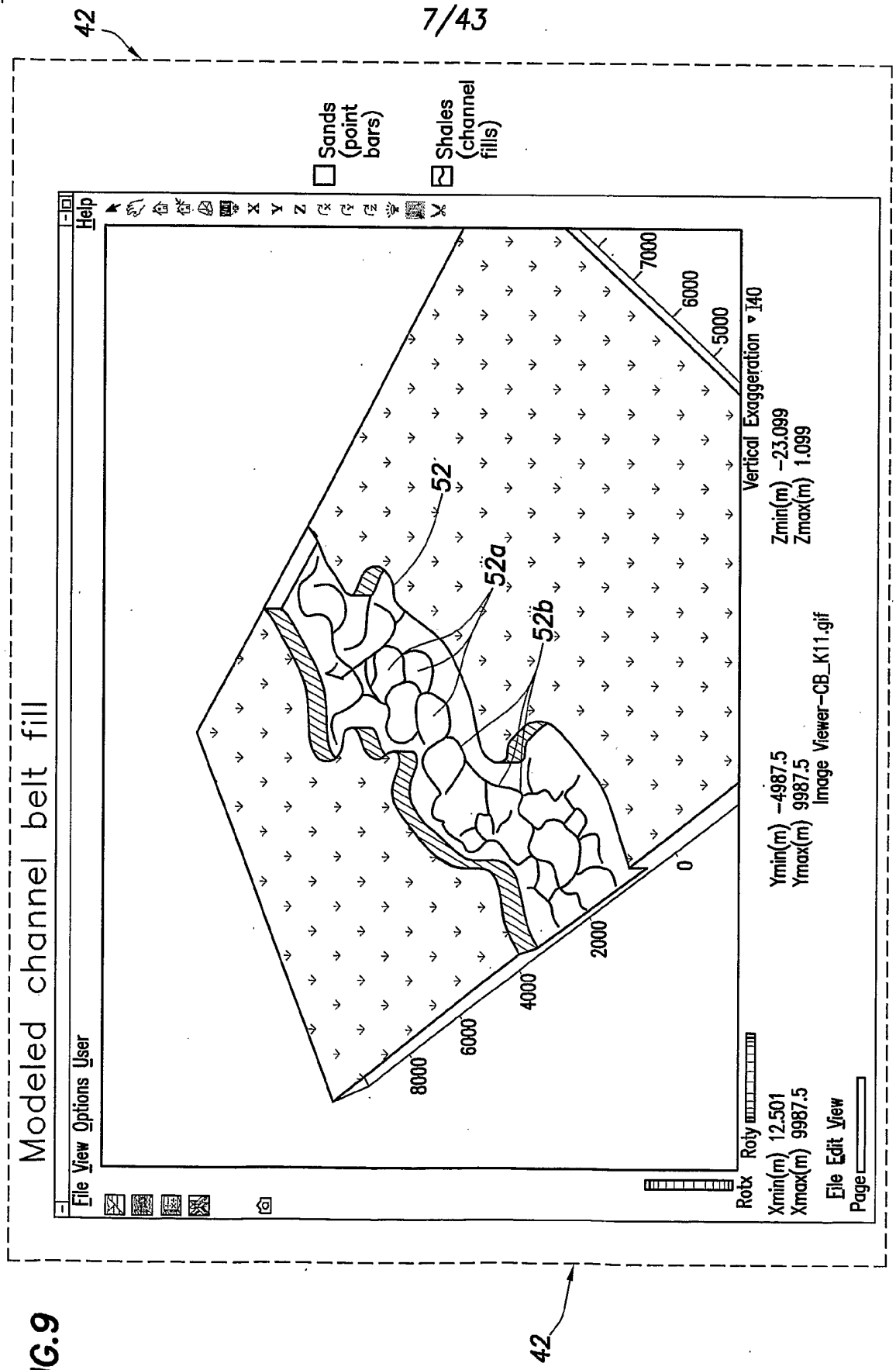

42
Modeled channel belt fill
Sands (point bars)
Shales (channel fills)
File View Options User
Help
52
52a
52b
7000
6000
5000
0
2000
4000
6000
8000
Vertical Exaggeration 140
Zmin(m) -23.099
Zmax(m) 1.099
Ymin(m) -4987.5
Ymax(m) 9987.5
Image Viewer-CB_K11.gif
Rotx Roty
Xmin(m) 12.501
Xmax(m) 9987.5
File Edit View
Page
42

FIG.9

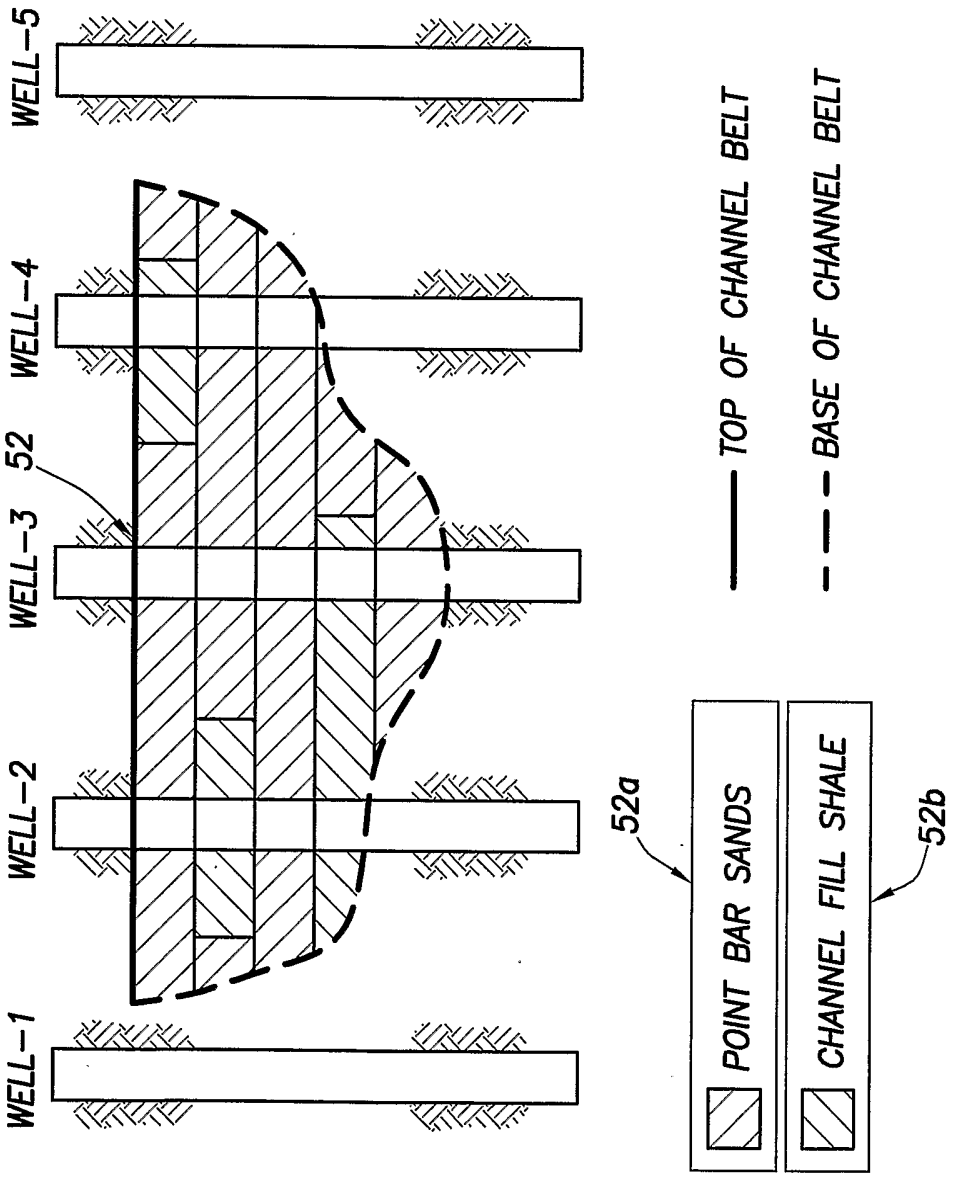

WELL-5
WELL-4
WELL-3
WELL-2
WELL-1
52
TOP OF CHANNEL BELT
BASE OF CHANNEL BELT
52a
POINT BAR SANDS
CHANNEL FILL SHALE
52b

FIG. 10

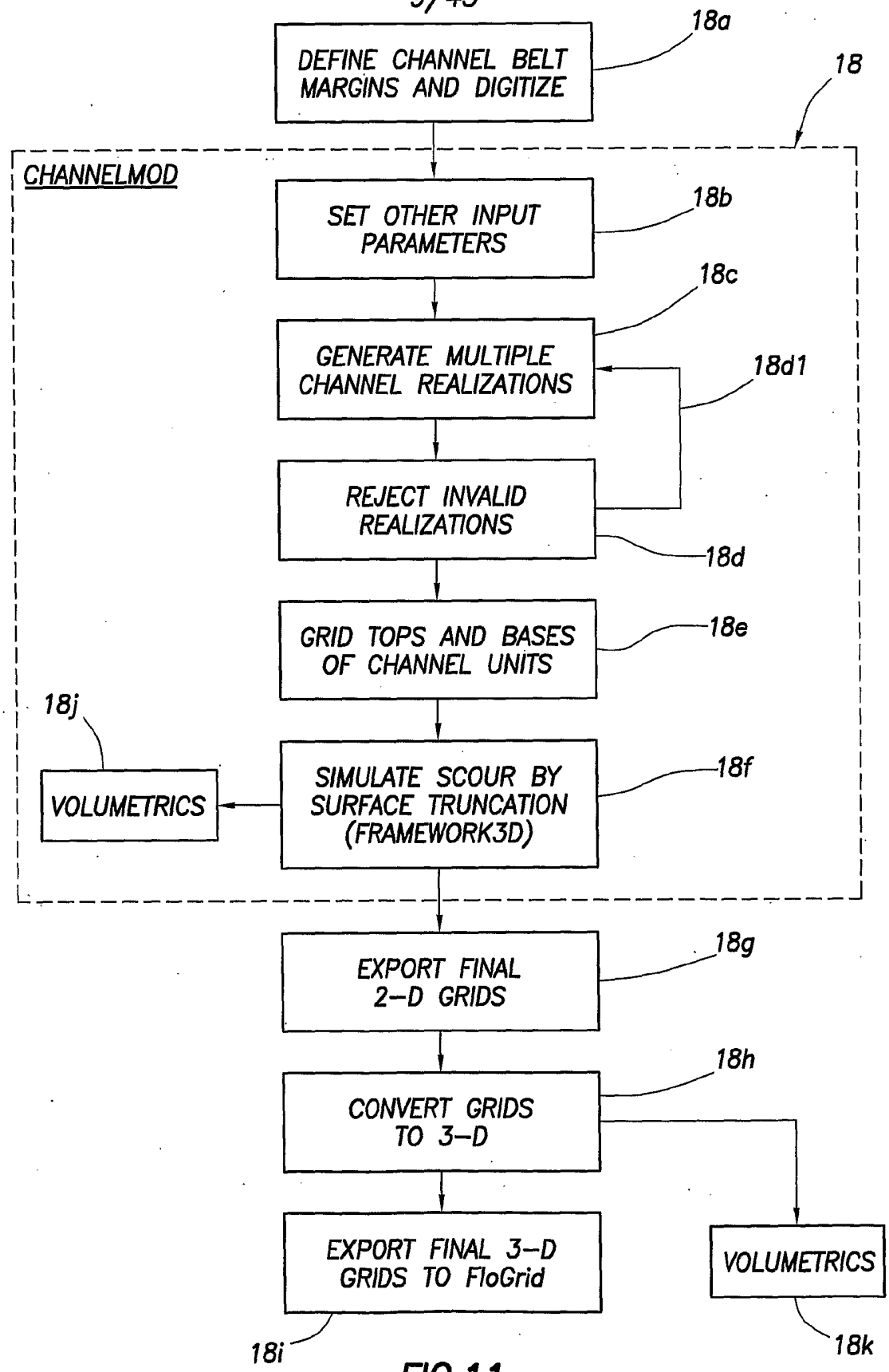

DEFINE CHANNEL BELT MARGINS AND DIGITIZE
18a
18
CHANNELMOD
SET OTHER INPUT PARAMETERS
18b
18c
GENERATE MULTIPLE CHANNEL REALIZATIONS
18d1
REJECT INVALID REALIZATIONS
18d
GRID TOPS AND BASES OF CHANNEL UNITS
18e
18j
VOLUMETRICS
SIMULATE SCOUR BY SURFACE TRUNCATION (FRAMEWORK3D)
18f
EXPORT FINAL 2-D GRIDS
18g
18h
CONVERT GRIDS TO 3-D
EXPORT FINAL 3-D GRIDS TO FloGrid
VOLUMETRICS
18i
18k

FIG.11

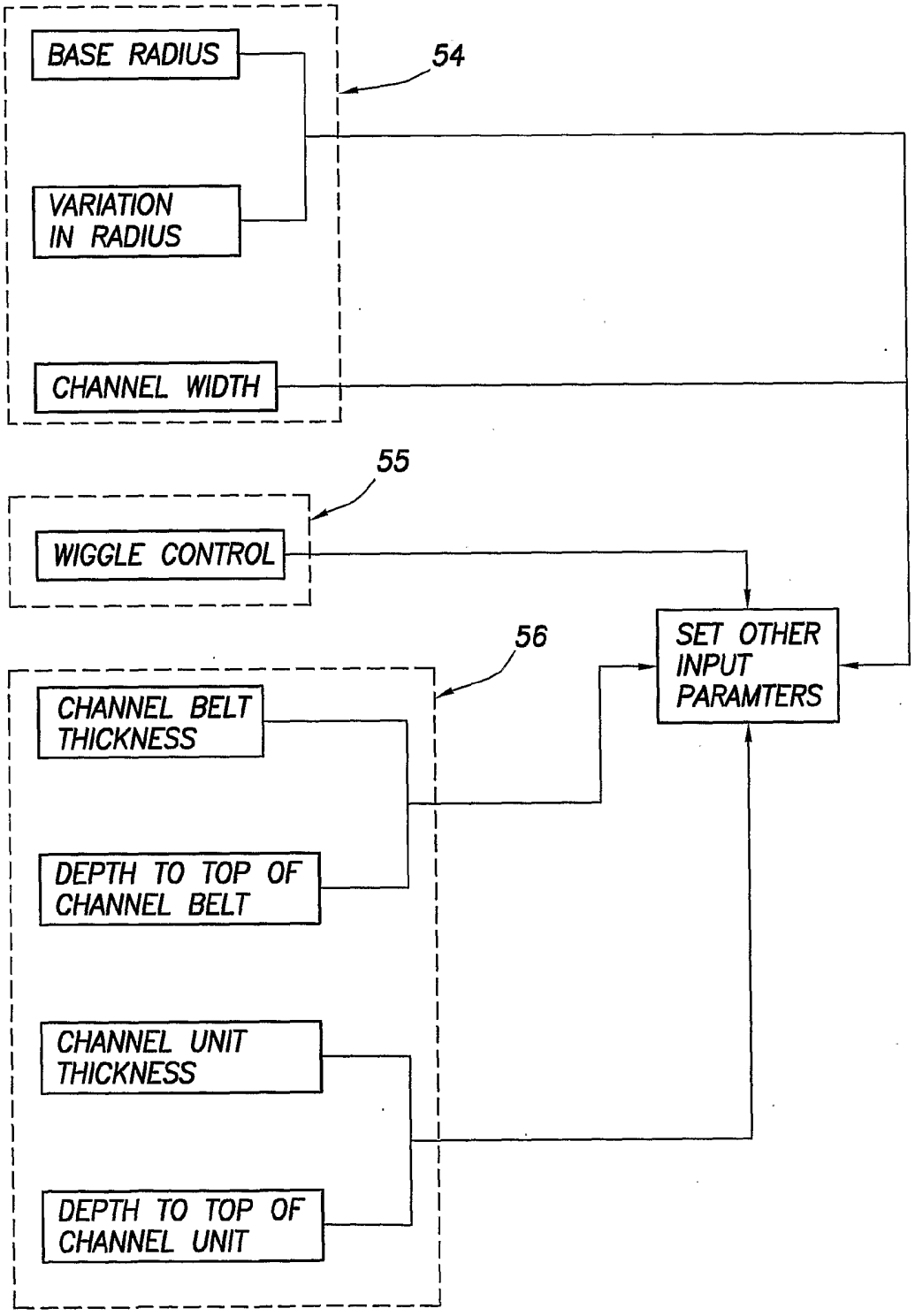

BASE RADIUS
54
VARIATION IN RADIUS
CHANNEL WIDTH
55
WIGGLE CONTROL
56
SET OTHER INPUT PARAMTERS
CHANNEL BELT THICKNESS
DEPTH TO TOP OF CHANNEL BELT
CHANNEL UNIT THICKNESS
DEPTH TO TOP OF CHANNEL UNIT

FIG. 12

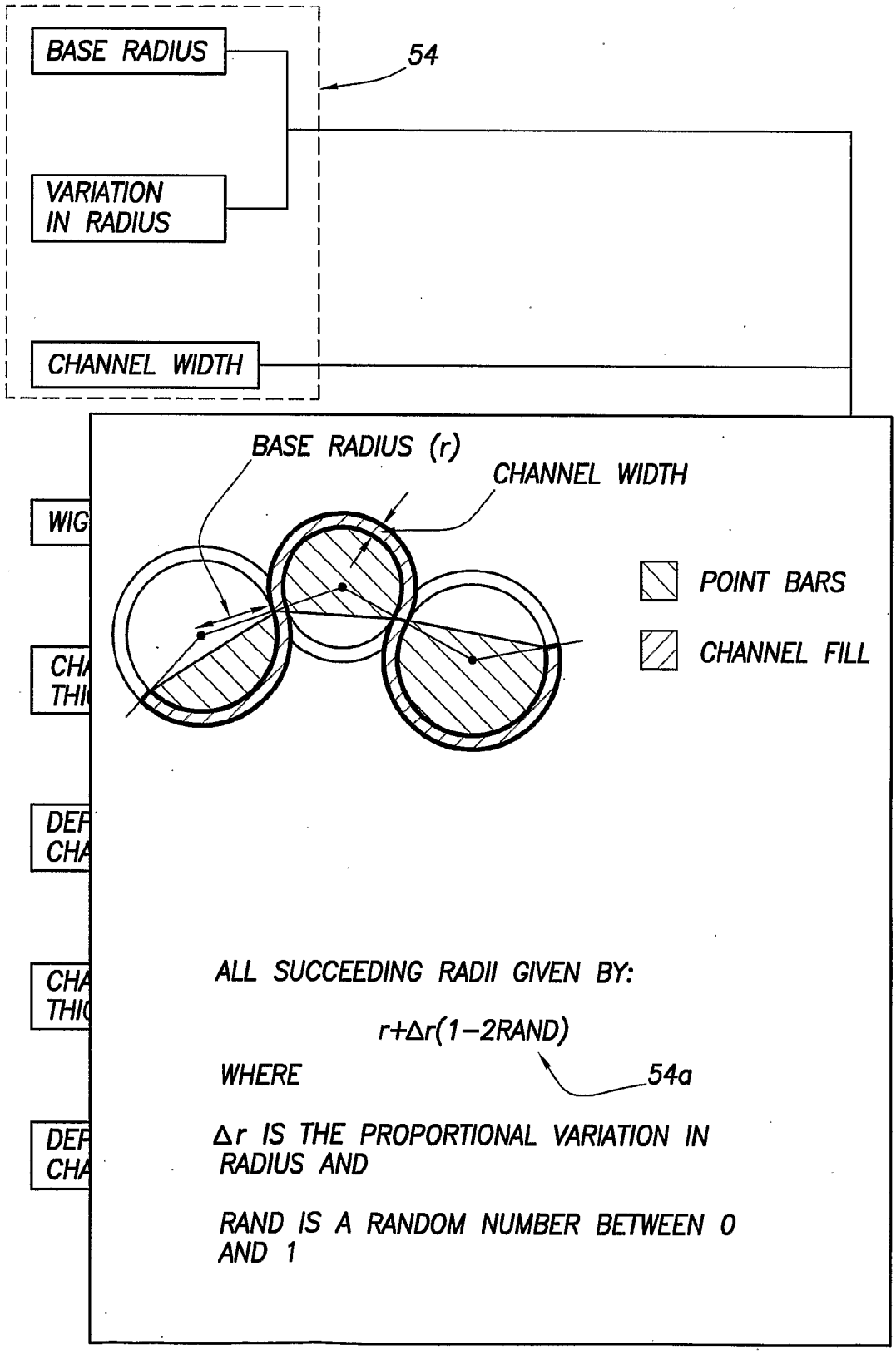

BASE RADIUS
VARIATION IN RADIUS
CHANNEL WIDTH
54
BASE RADIUS (r)
CHANNEL WIDTH
POINT BARS
CHANNEL FILL
ALL SUCCEEDING RADII GIVEN BY:
r+Δr(1−2RAND)
WHERE
54a
Δr IS THE PROPORTIONAL VARIATION IN RADIUS AND
RAND IS A RANDOM NUMBER BETWEEN 0 AND 1

FIG. 13

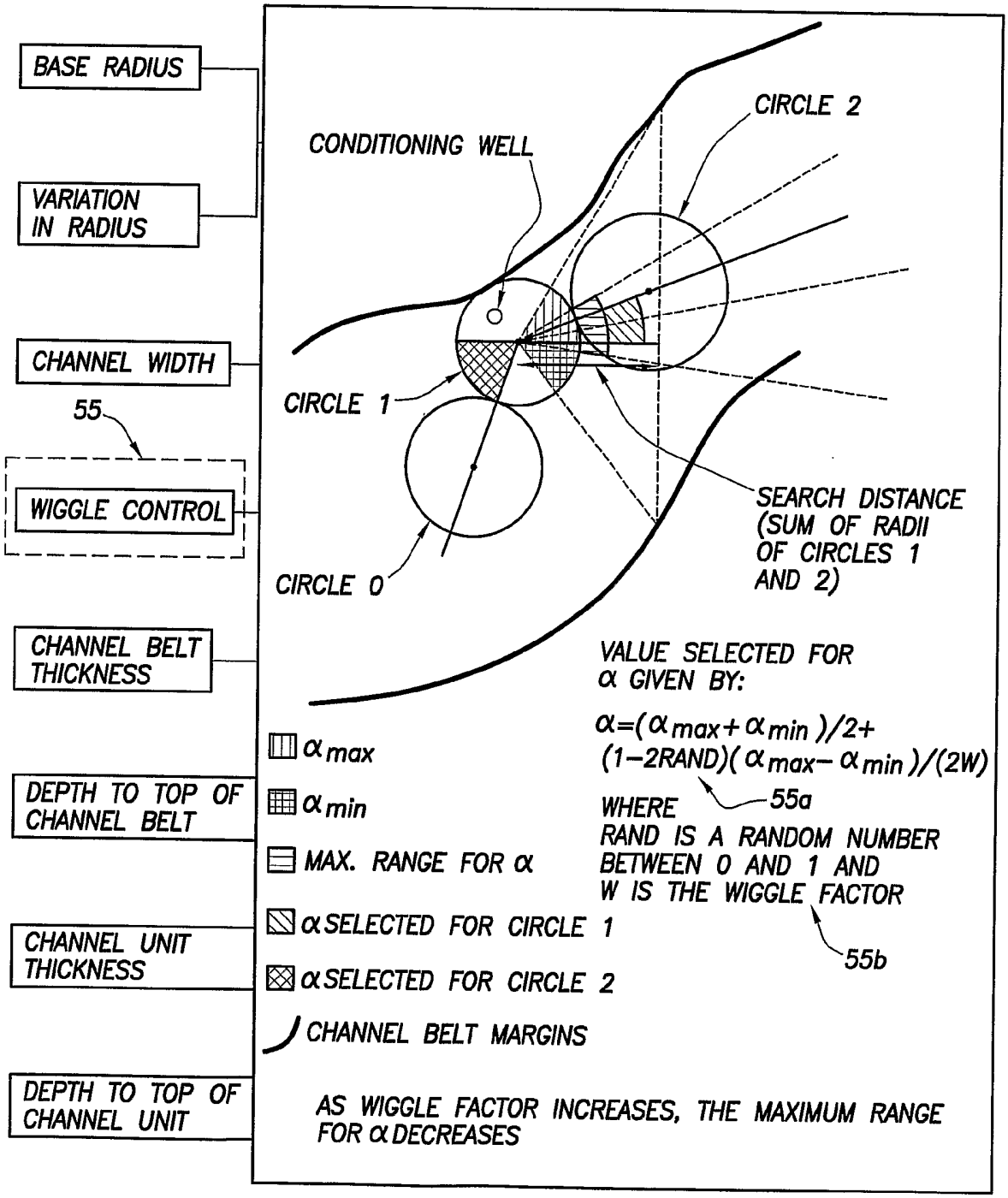

BASE RADIUS
VARIATION IN RADIUS
CHANNEL WIDTH
55
WIGGLE CONTROL
CHANNEL BELT THICKNESS
DEPTH TO TOP OF CHANNEL BELT
CHANNEL UNIT THICKNESS
DEPTH TO TOP OF CHANNEL UNIT
CONDITIONING WELL
CIRCLE 2
CIRCLE 1
CIRCLE 0
SEARCH DISTANCE (SUM OF RADII OF CIRCLES 1 AND 2)
VALUE SELECTED FOR α GIVEN BY:
α=(αmax+αmin)/2+
(1−2RAND)(αmax−αmin)/(2W)
55a
WHERE
RAND IS A RANDOM NUMBER BETWEEN 0 AND 1 AND
W IS THE WIGGLE FACTOR
55b
αmax
αmin
MAX. RANGE FOR α
α SELECTED FOR CIRCLE 1
α SELECTED FOR CIRCLE 2
CHANNEL BELT MARGINS
AS WIGGLE FACTOR INCREASES, THE MAXIMUM RANGE FOR α DECREASES

FIG. 14

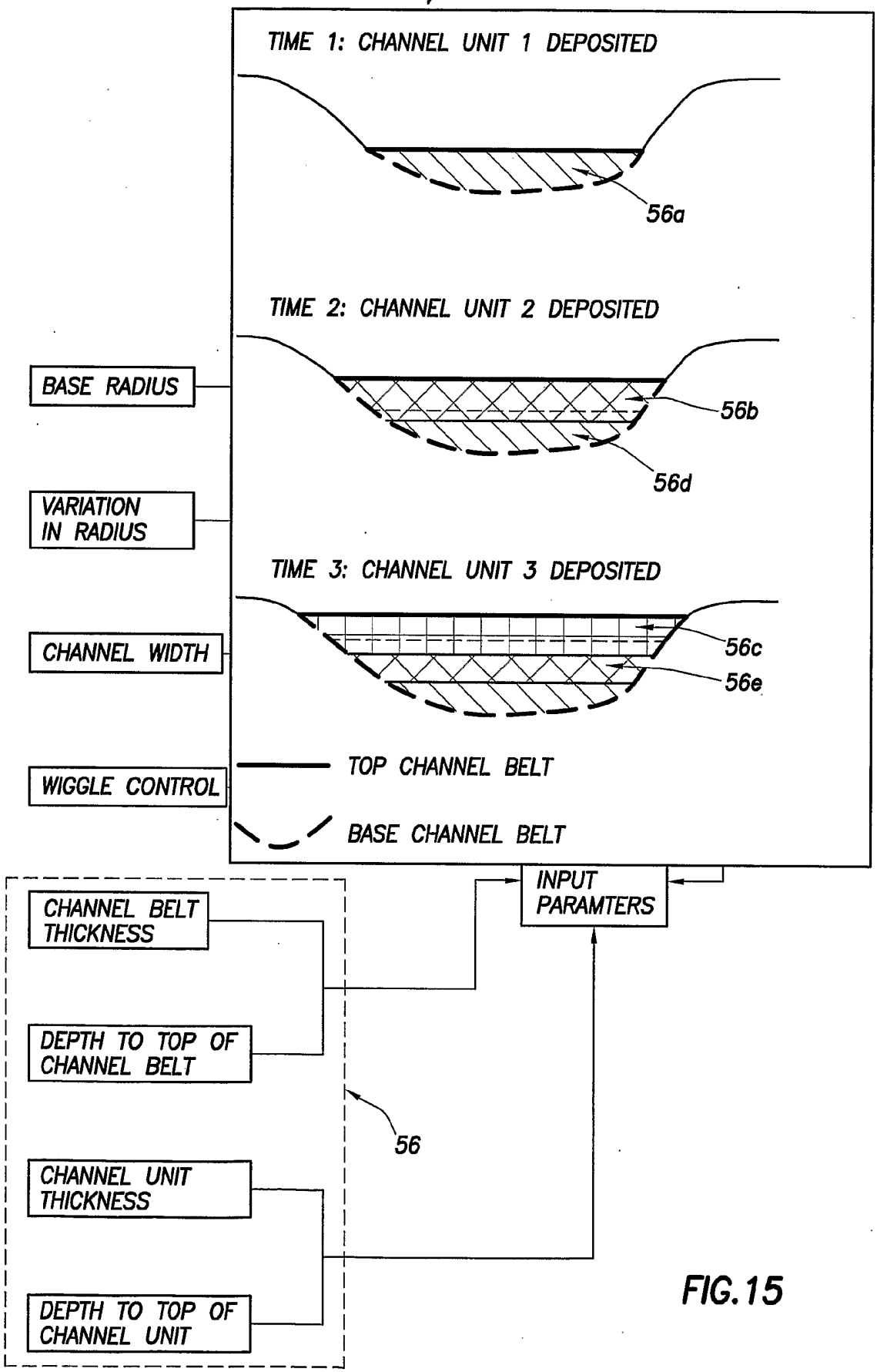

TIME 1: CHANNEL UNIT 1 DEPOSITED
56a
TIME 2: CHANNEL UNIT 2 DEPOSITED
56b
56d
TIME 3: CHANNEL UNIT 3 DEPOSITED
56c
56e
TOP CHANNEL BELT
BASE CHANNEL BELT
BASE RADIUS
VARIATION IN RADIUS
CHANNEL WIDTH
WIGGLE CONTROL
INPUT PARAMTERS
CHANNEL BELT THICKNESS
DEPTH TO TOP OF CHANNEL BELT
CHANNEL UNIT THICKNESS
DEPTH TO TOP OF CHANNEL UNIT
56

FIG. 15

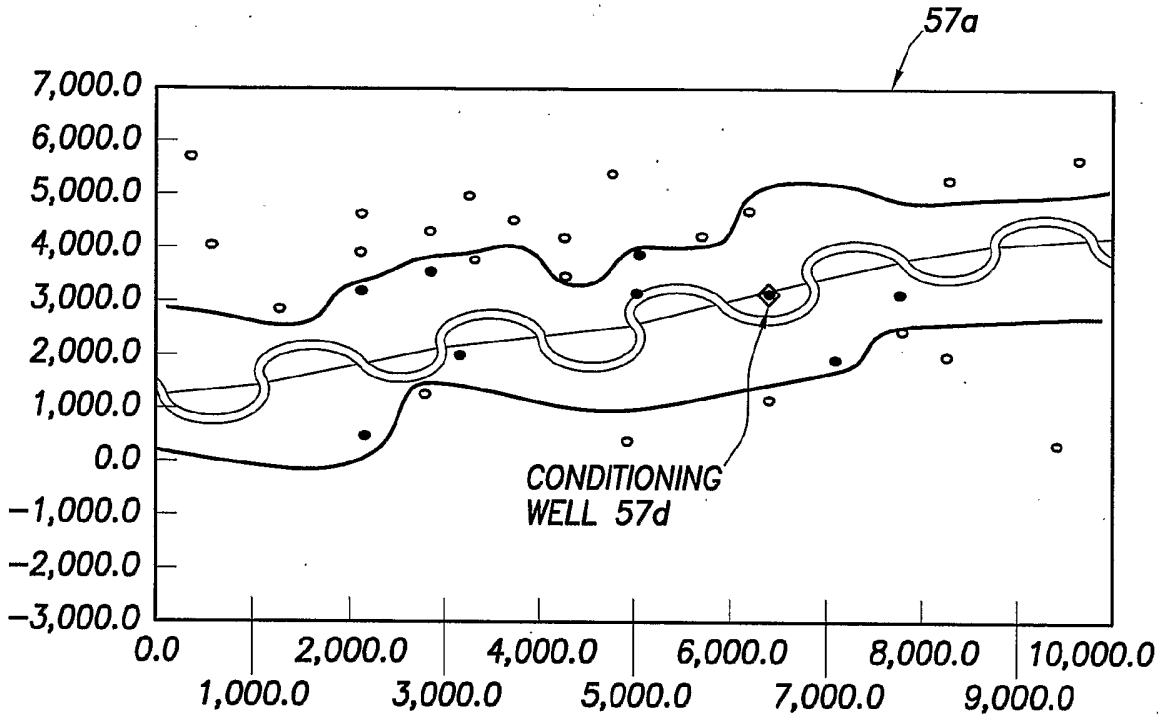


FIG. 16A

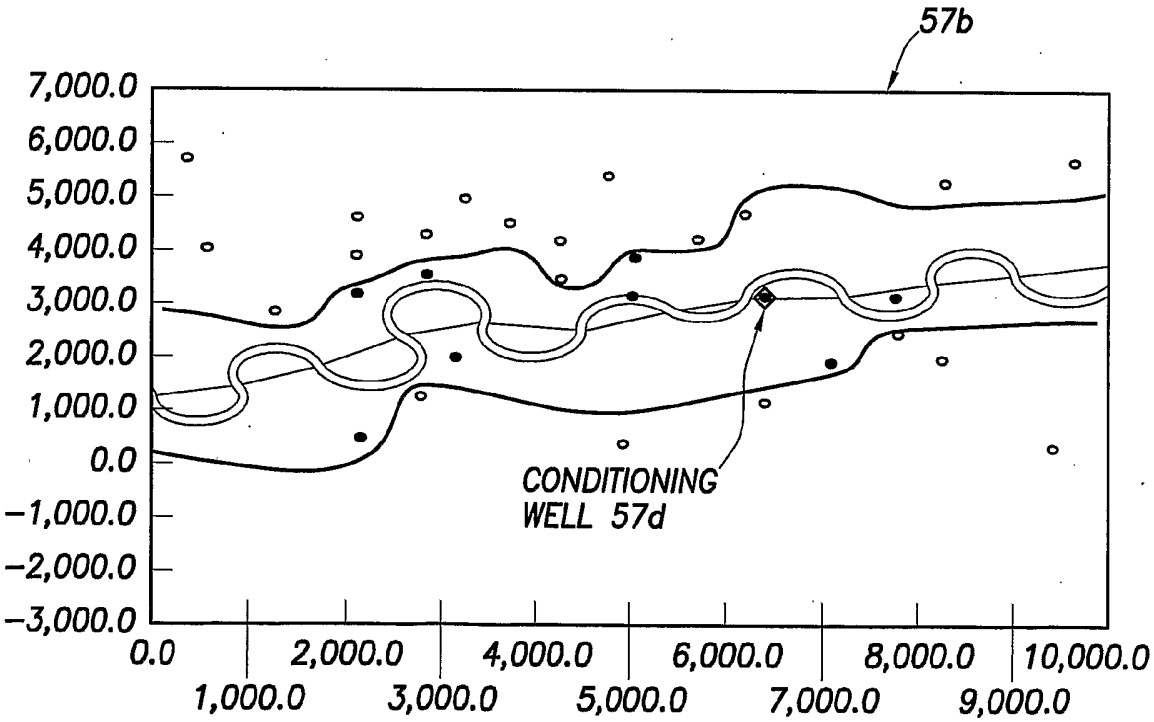


FIG. 16B

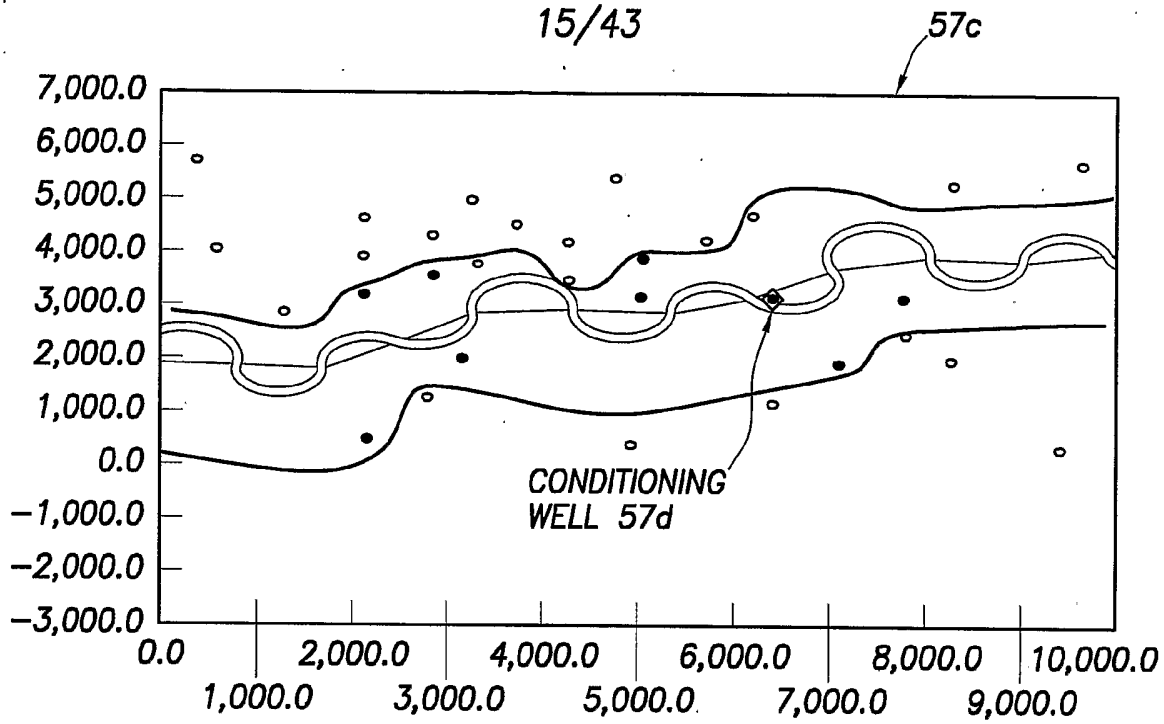


FIG. 16C

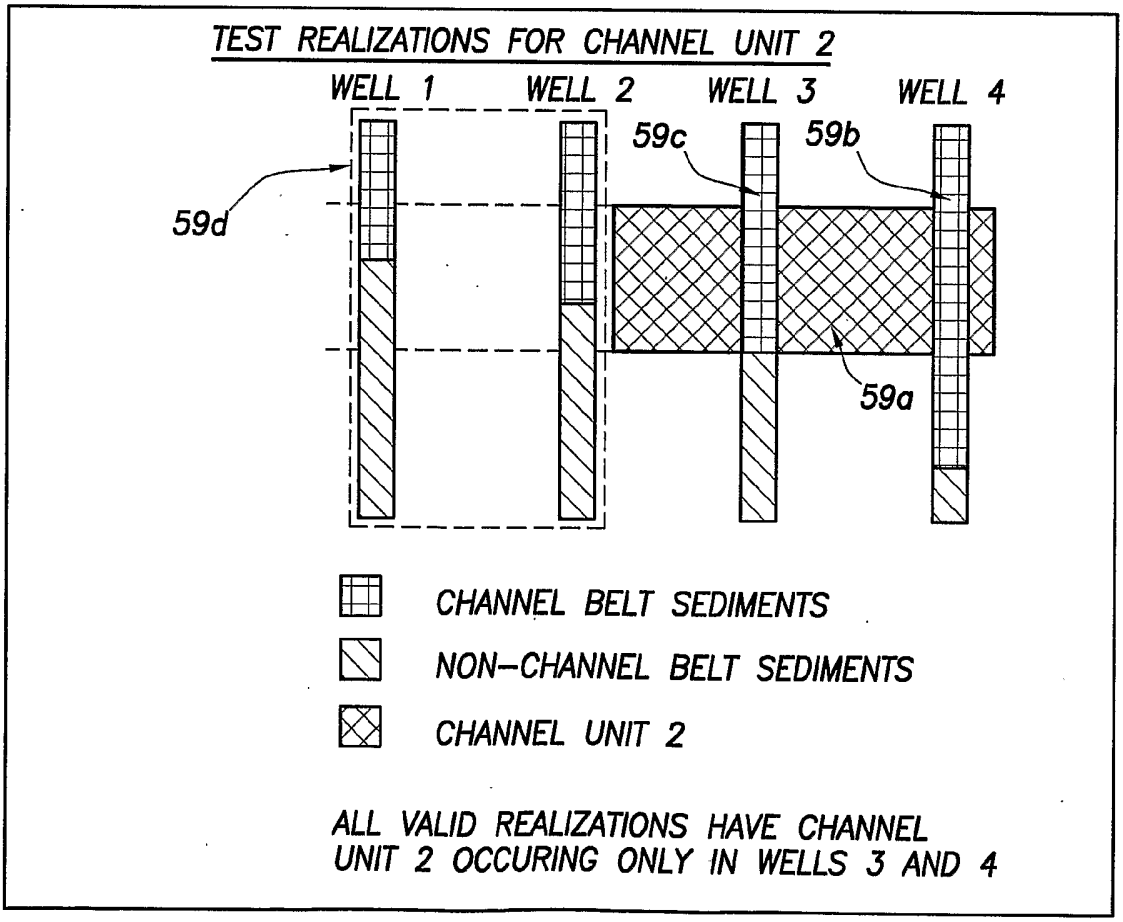
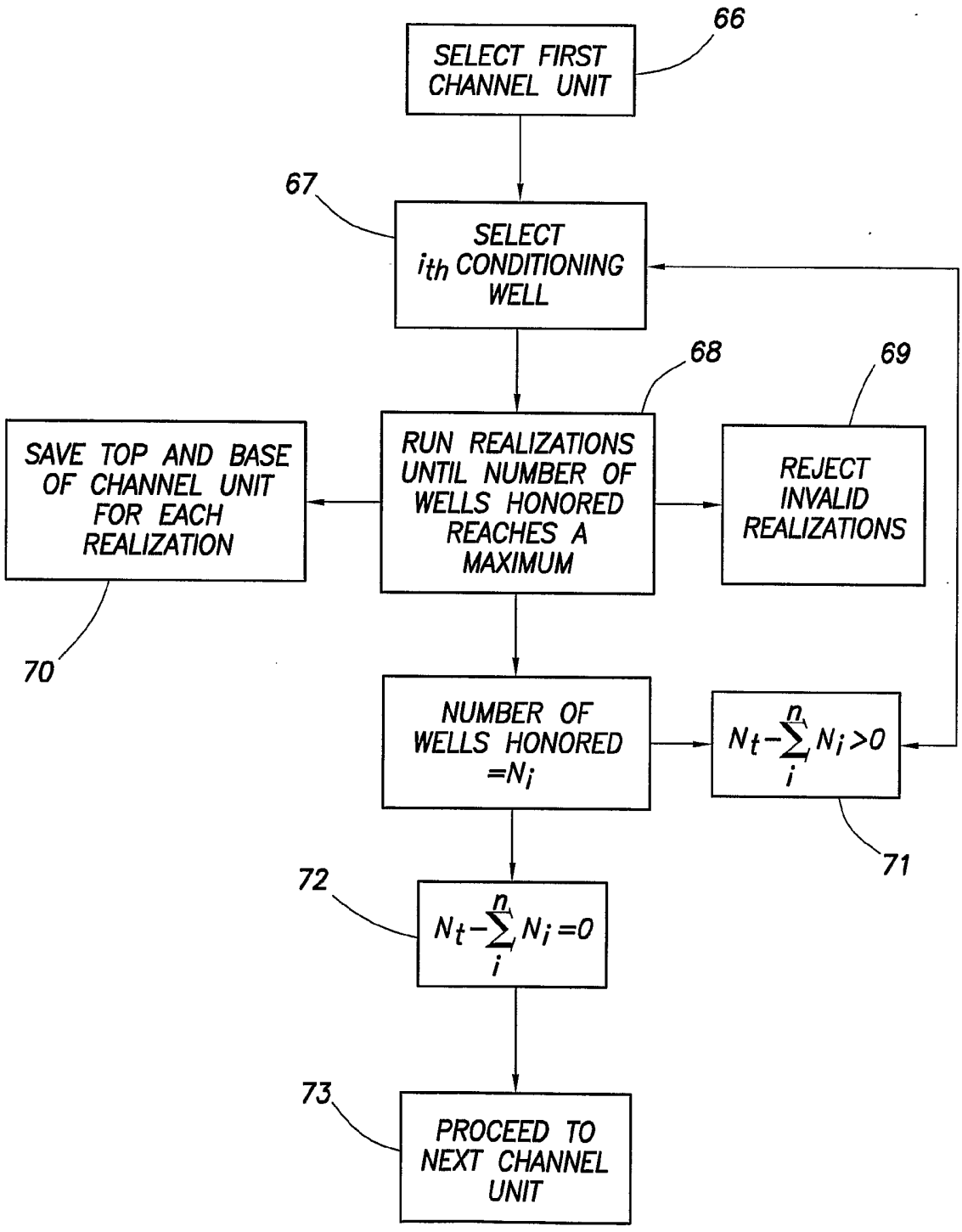


FIG. 19A



N_t =NUMBER OF WELLS PENETRATING CHANNEL UNIT
n=1+TOTAL NUMBER OF CONDITIONING WELLS PREVIOUSLY USED FOR THE CHANNEL UNIT

FIG. 17

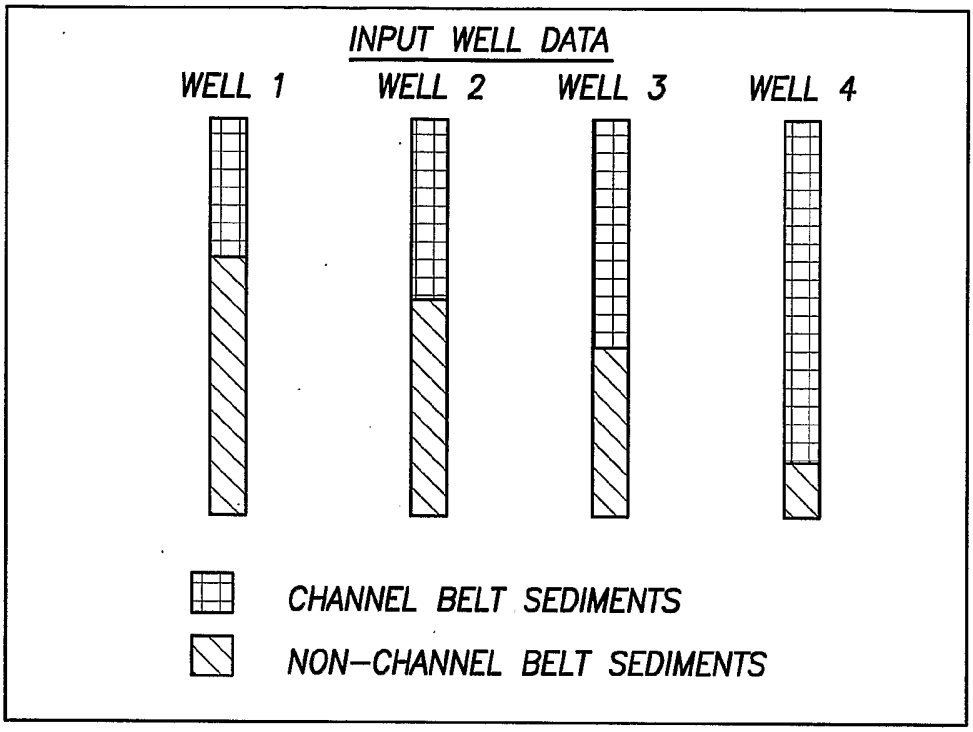


FIG. 18A

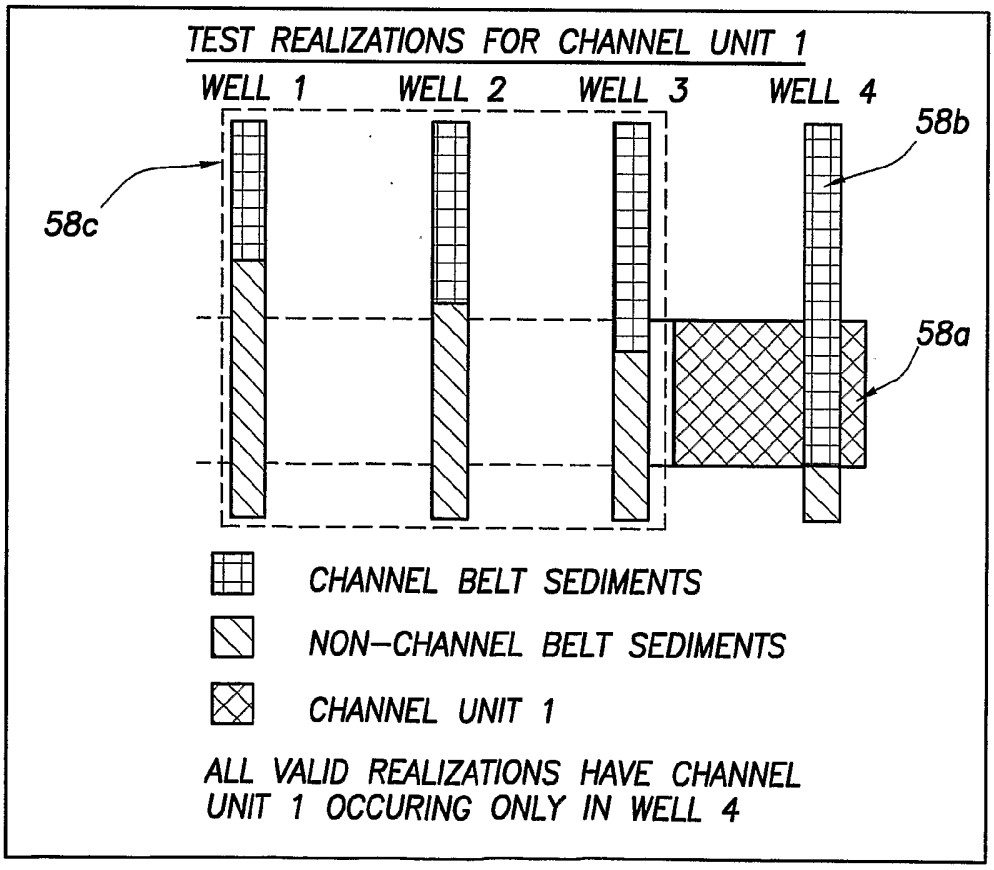


FIG. 18B

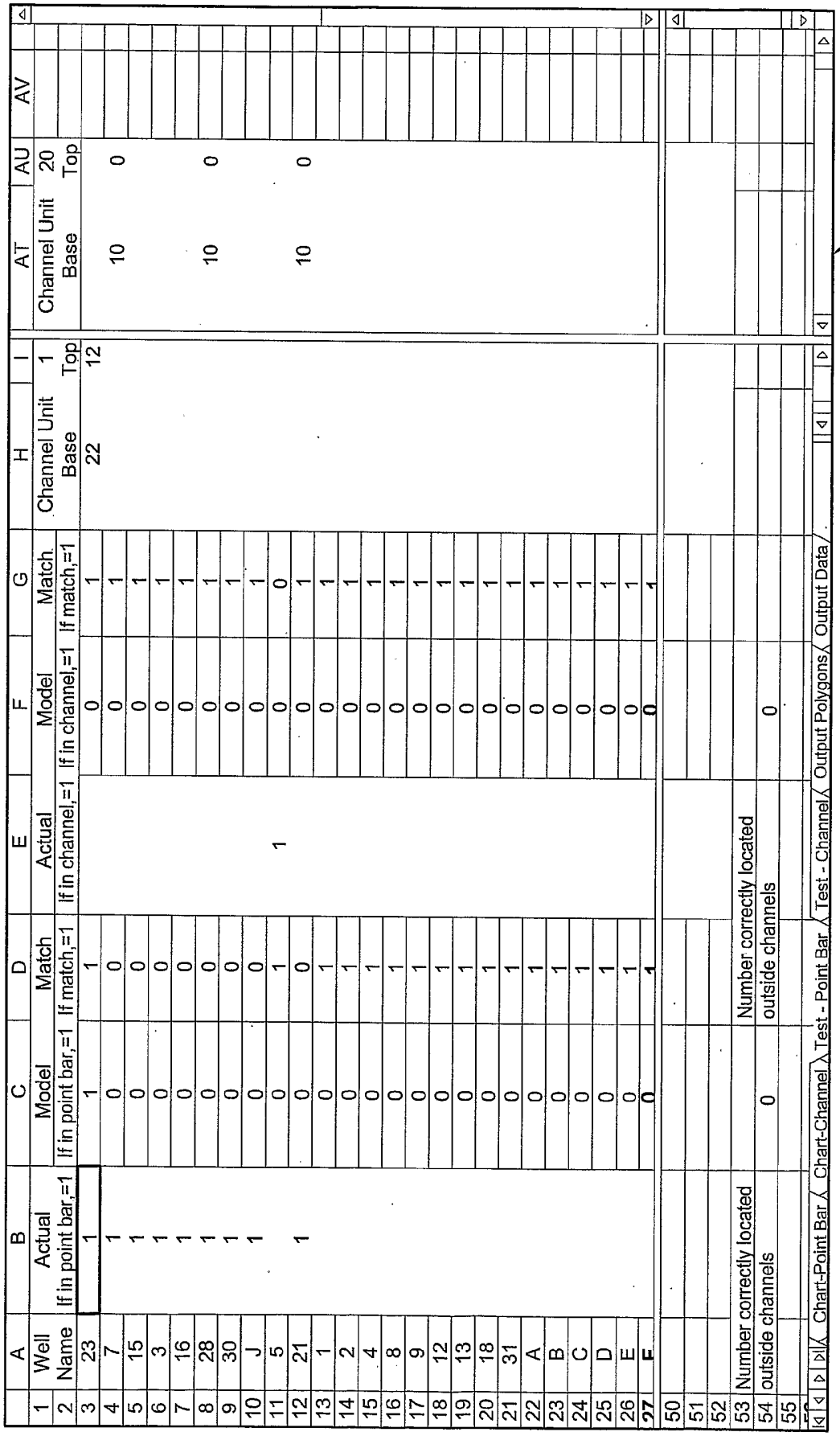

Well Name
Actual If in point bar,=1
Model If in point bar,=1
Match If match,=1
Actual If in channel,=1
Model If in channel,=1
Match If match,=1
Channel Unit Base
Channel Unit Top
Number correctly located
outside channels
Chart-Point Bar
Chart-Channel
Test - Point Bar
Test - Channel
Output Polygons
Output Data
60

FIG. 19B

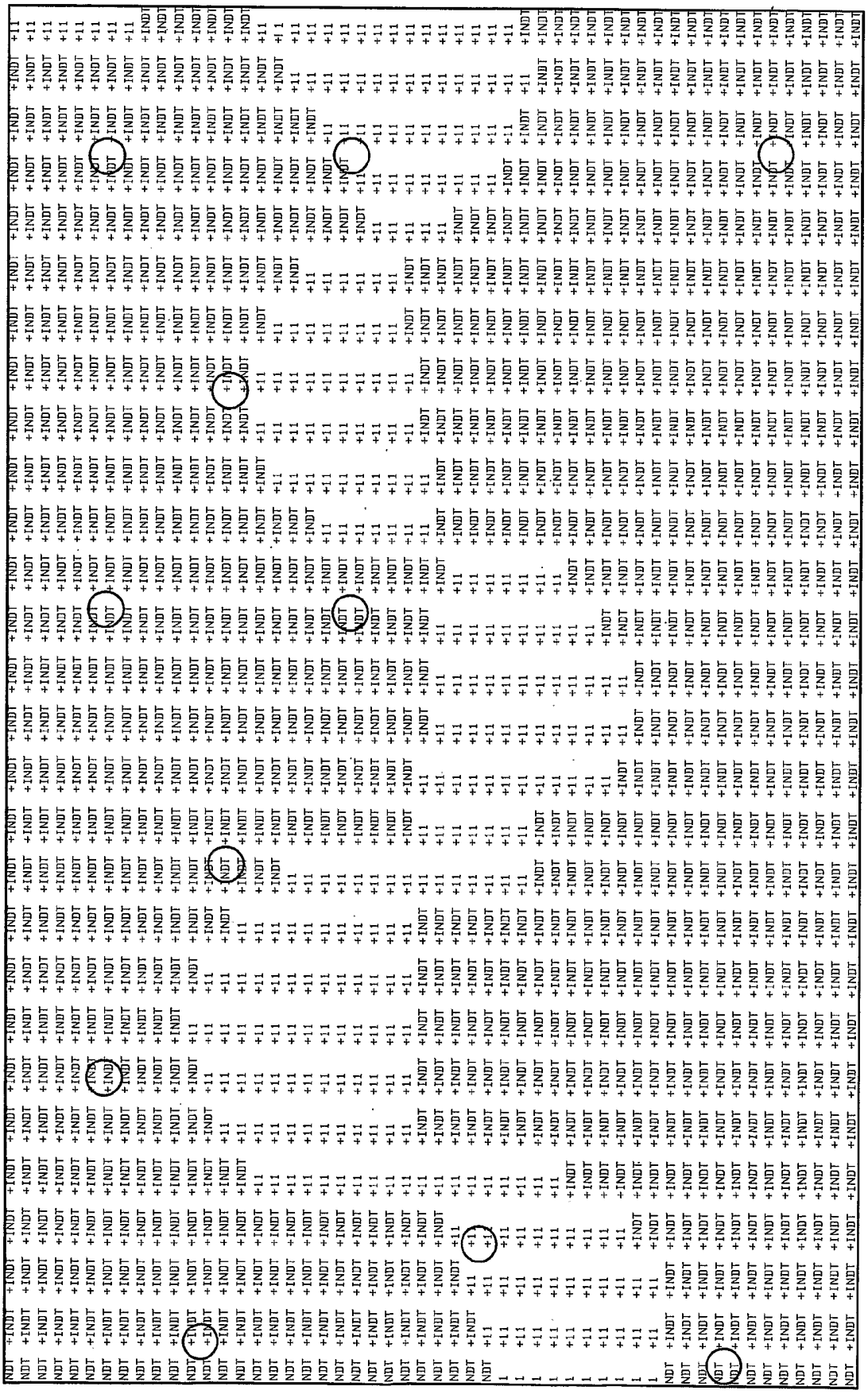


FIG.20A

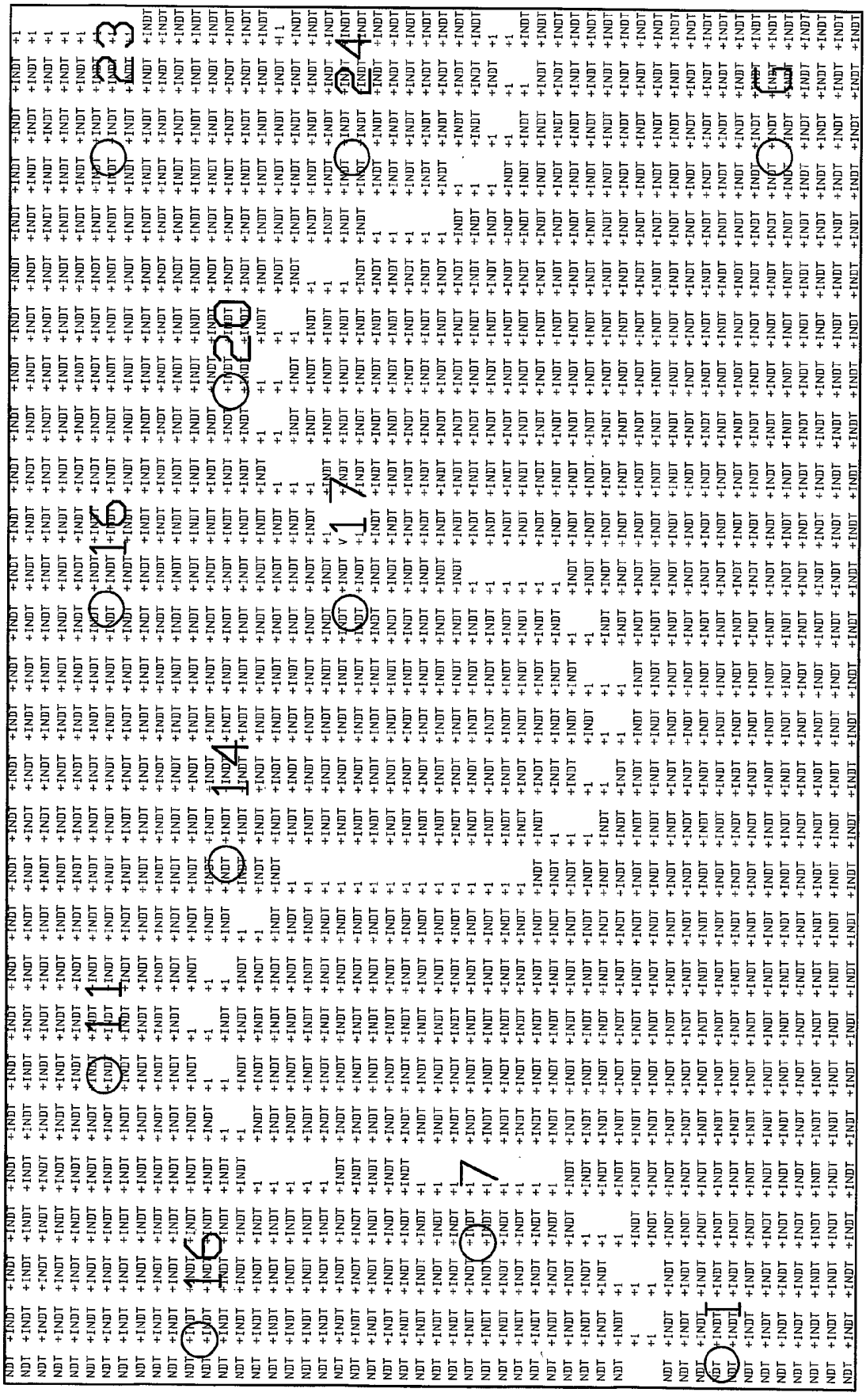


FIG.20B

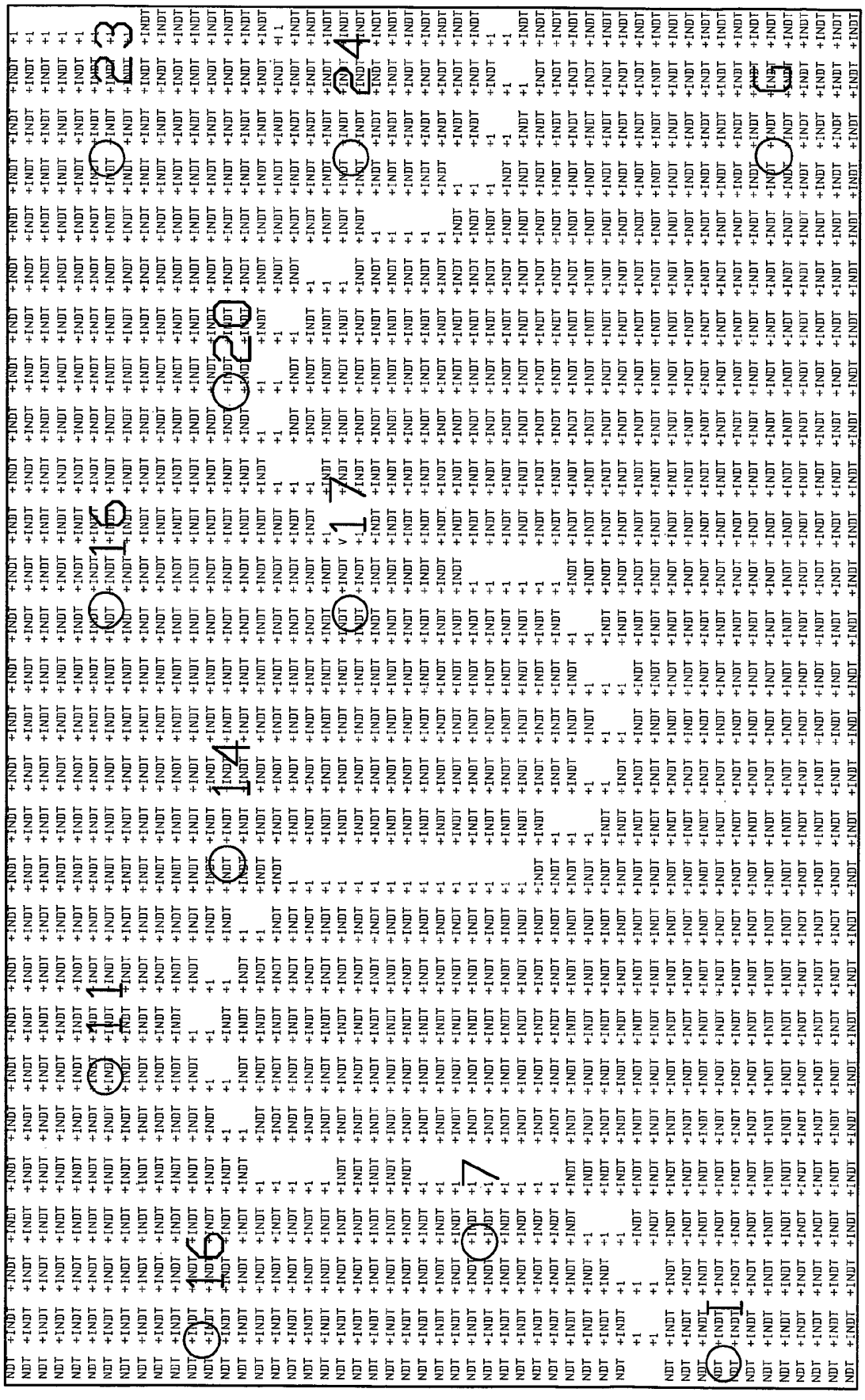


FIG.21A

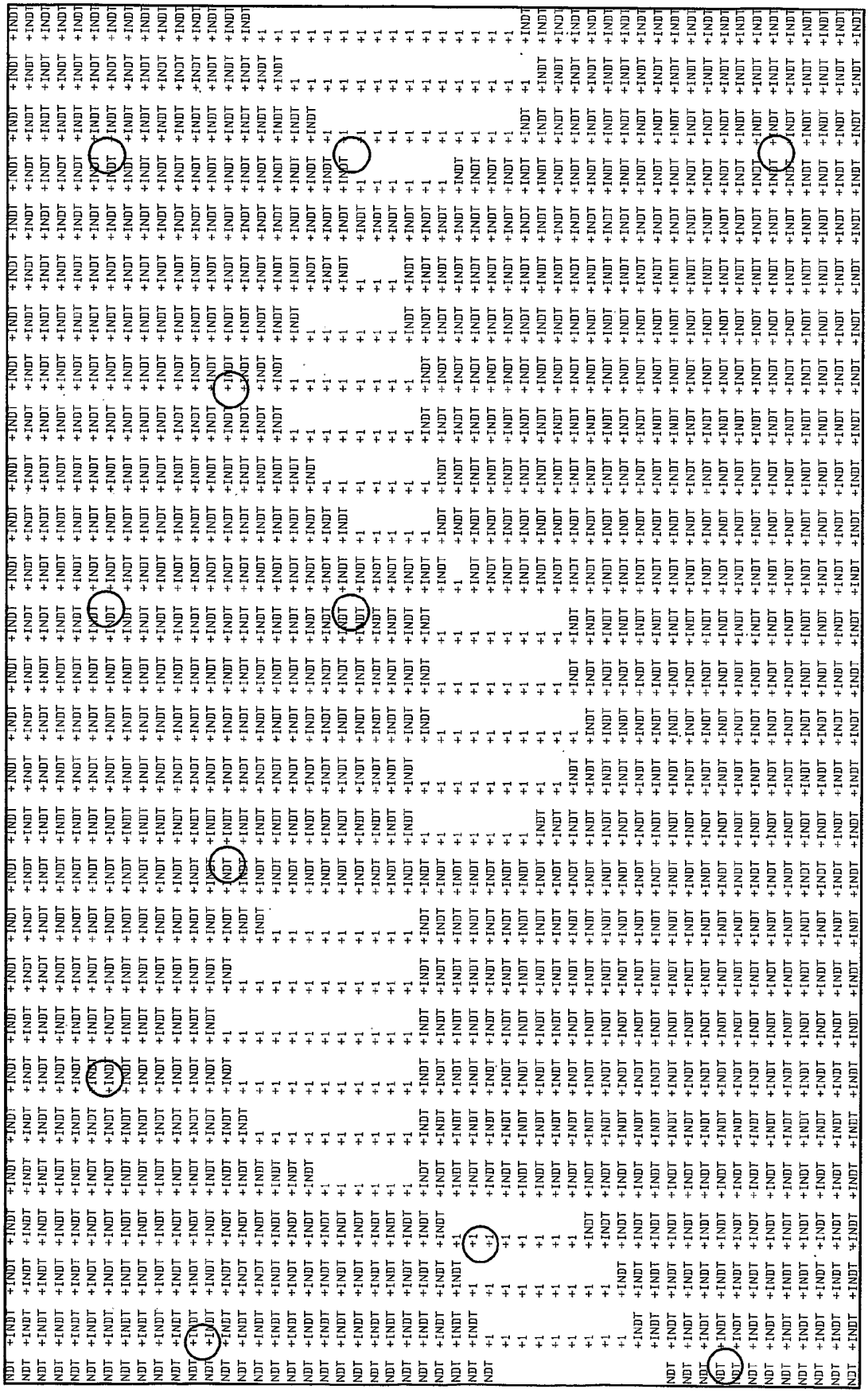


FIG.21B

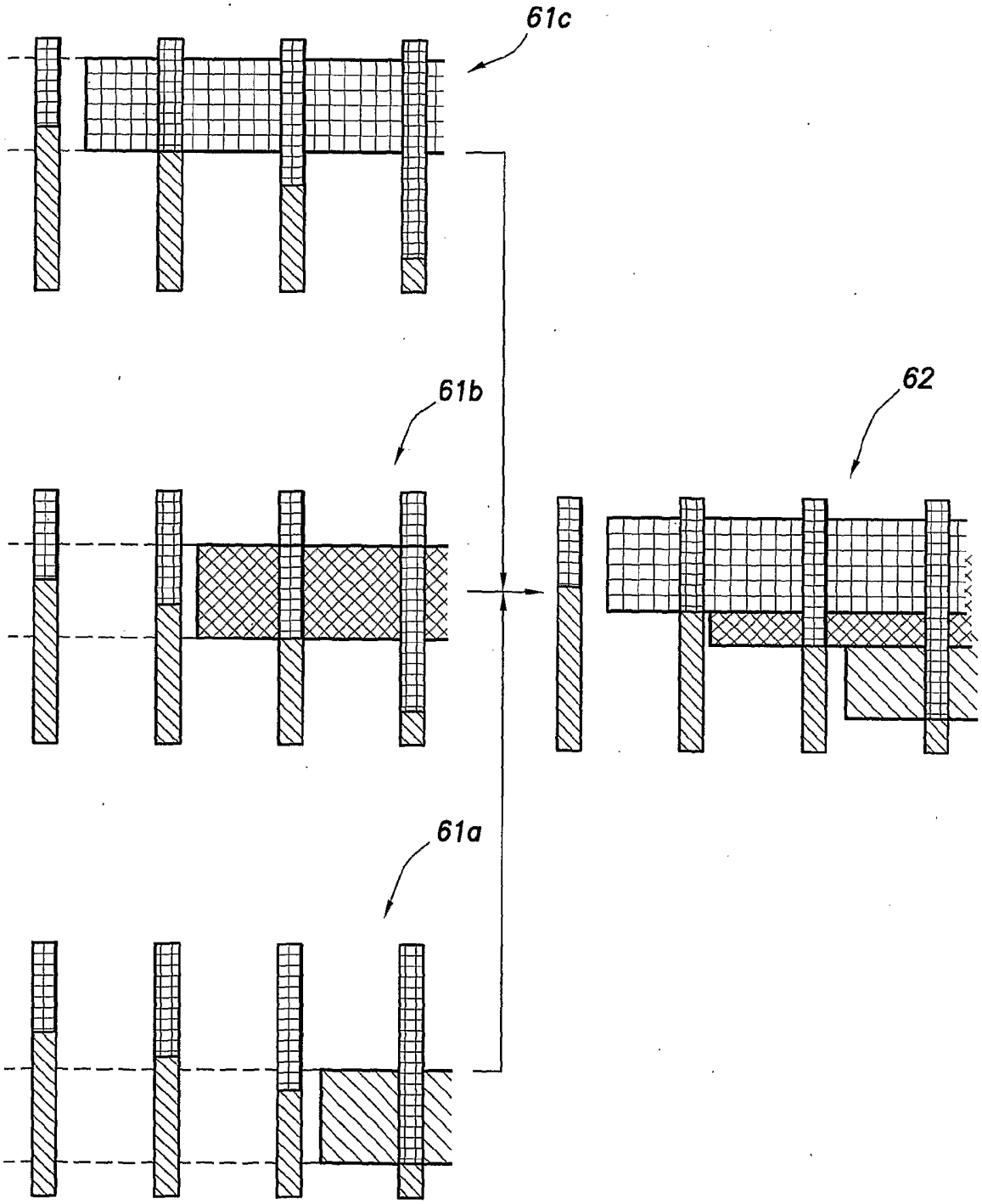


FIG.22

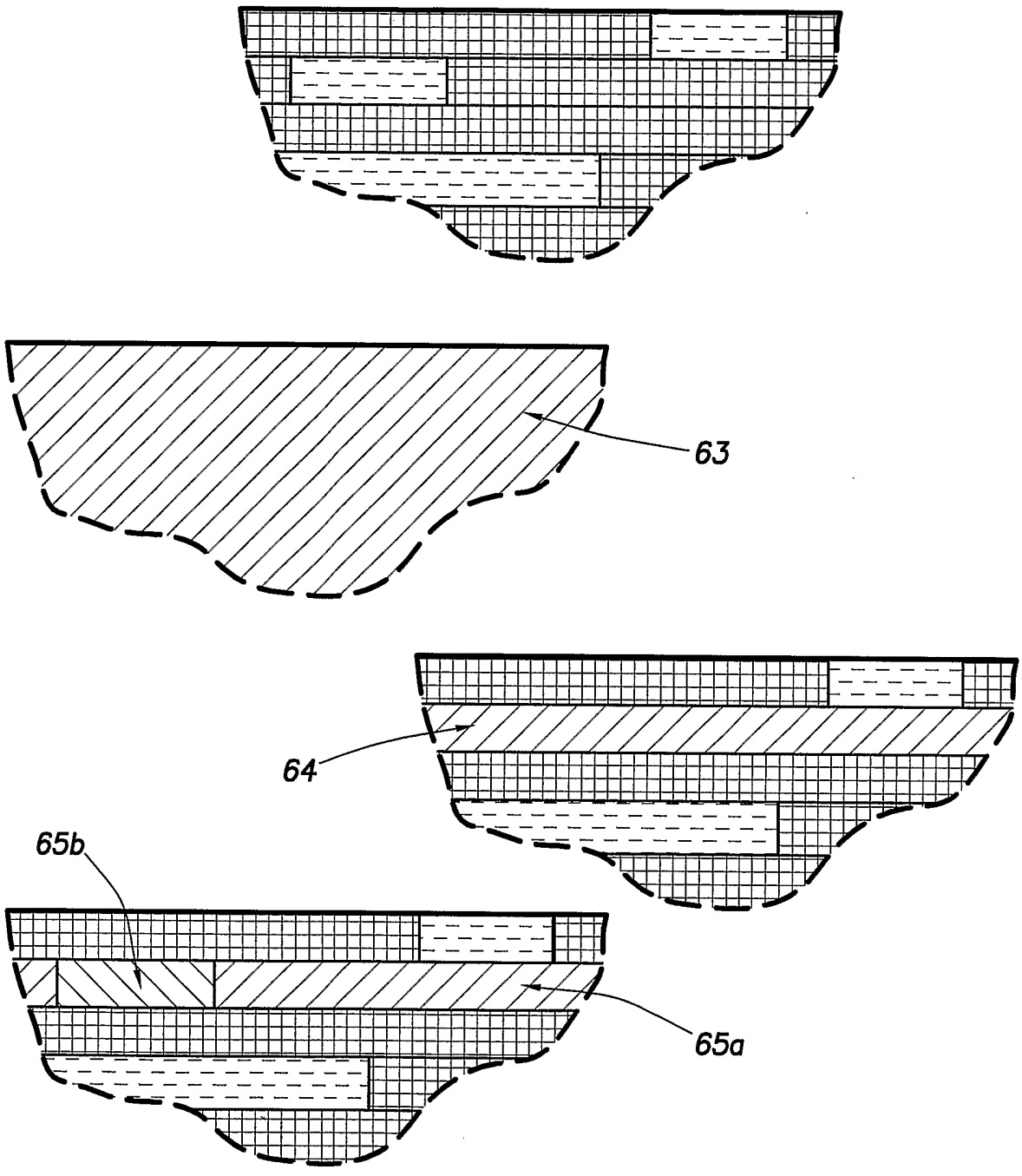

63
64
65b
65a
POINT BAR SANDS
CHANNEL FILL SHALE
TOP OF CHANNEL BELT
BASE OF CHANNEL BELT

FIG.23

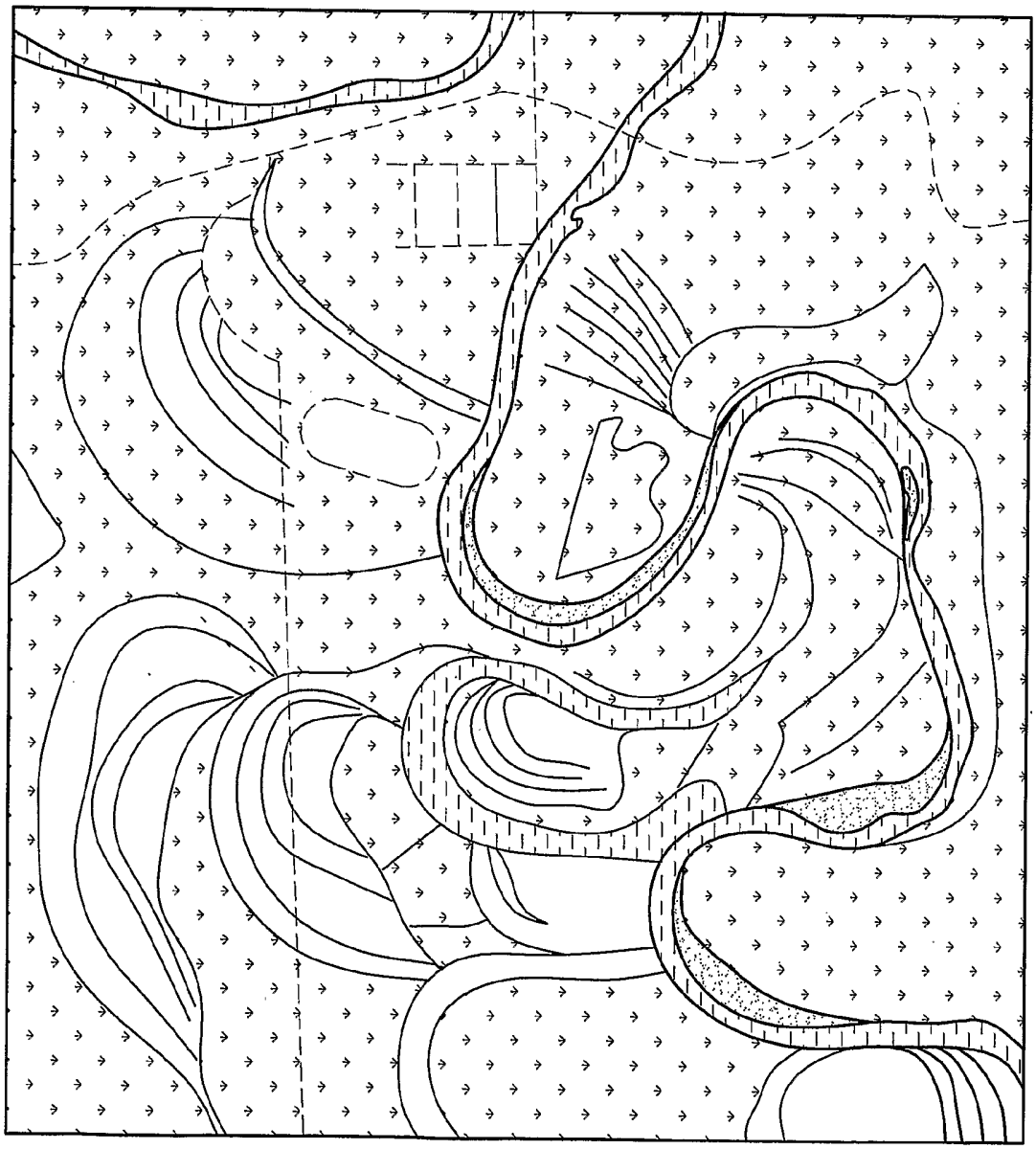


FIG.24

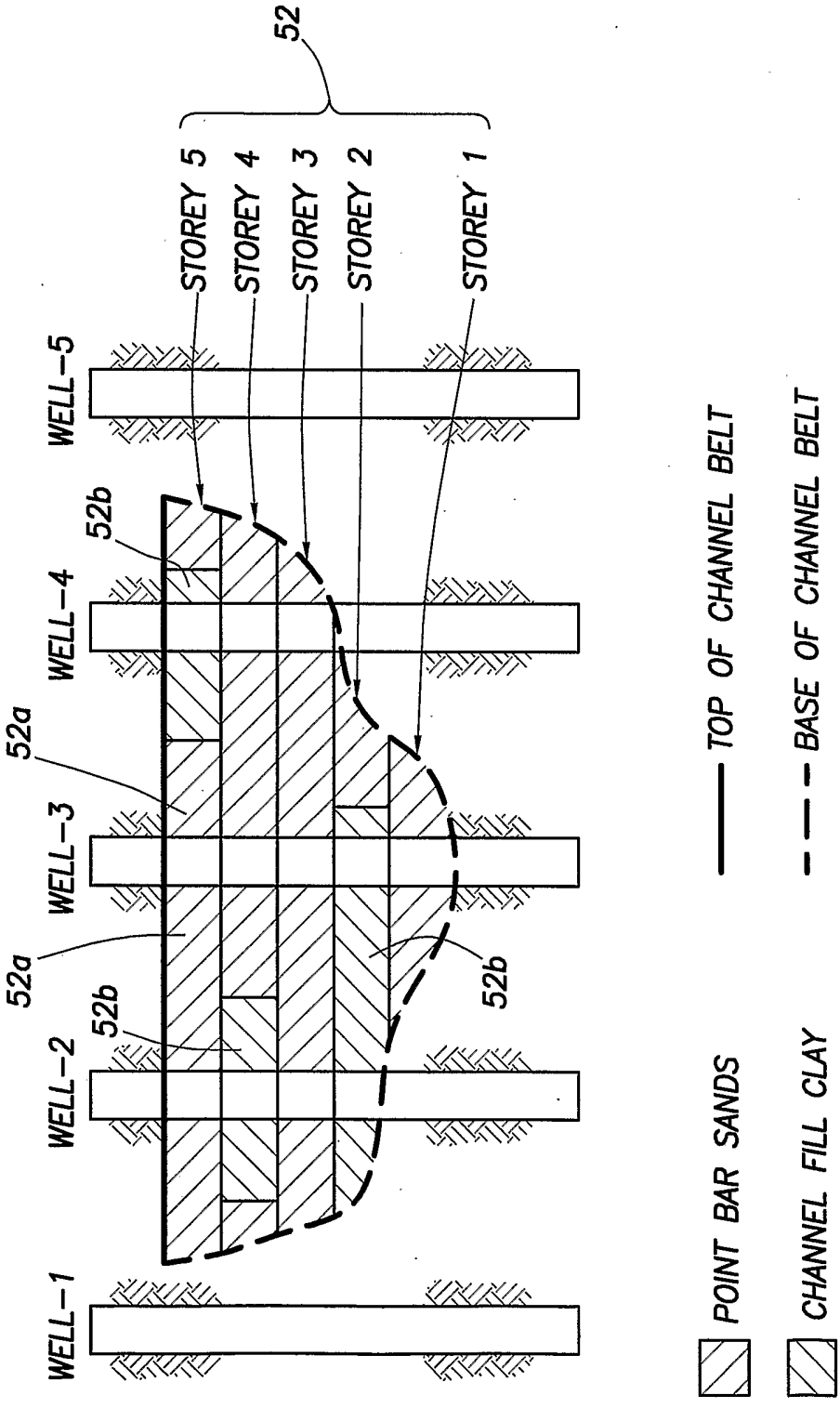

52
STOREY 5
STOREY 4
STOREY 3
STOREY 2
STOREY 1
WELL-5
WELL-4
WELL-3
WELL-2
WELL-1
52b
52a
52a
52b
52b
TOP OF CHANNEL BELT
BASE OF CHANNEL BELT
POINT BAR SANDS
CHANNEL FILL CLAY

FIG.25

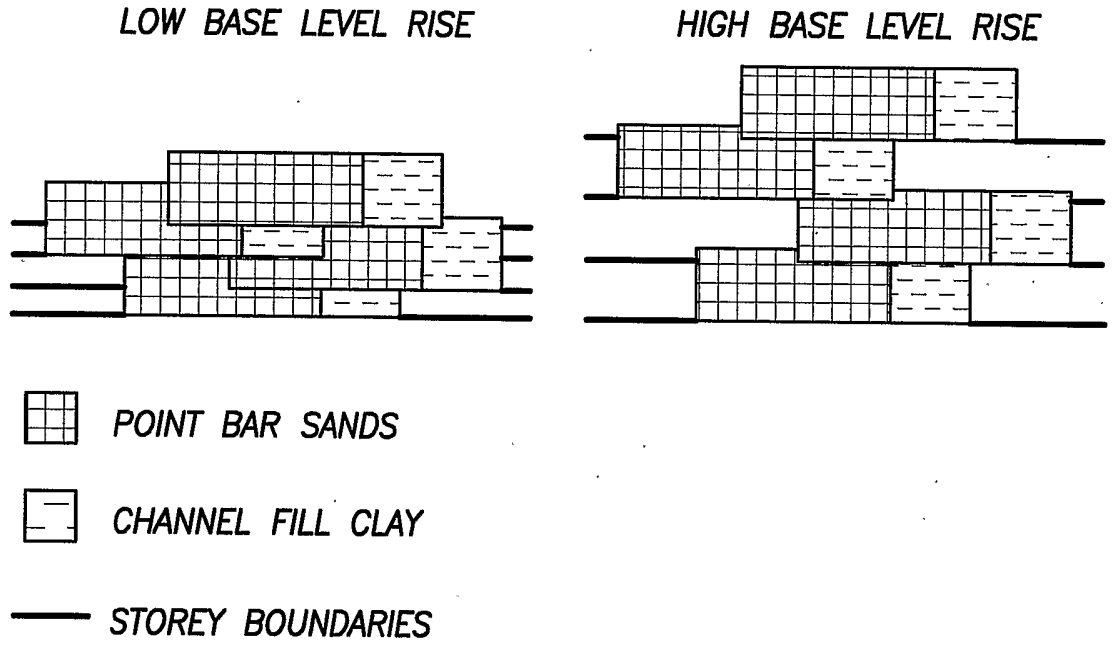

LOW BASE LEVEL RISE
HIGH BASE LEVEL RISE
POINT BAR SANDS
CHANNEL FILL CLAY
STOREY BOUNDARIES

FIG.26

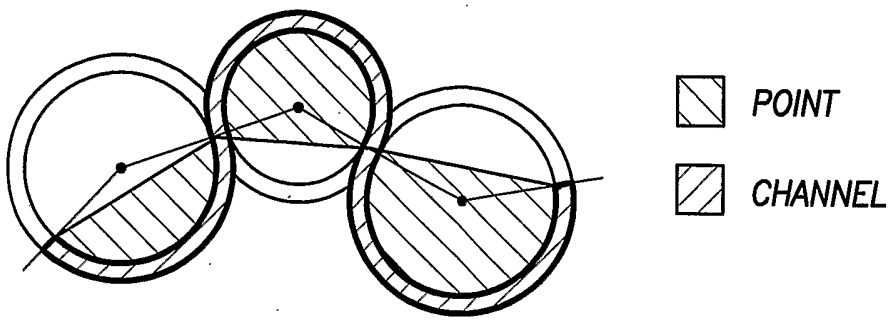

POINT
CHANNEL

FIG.28

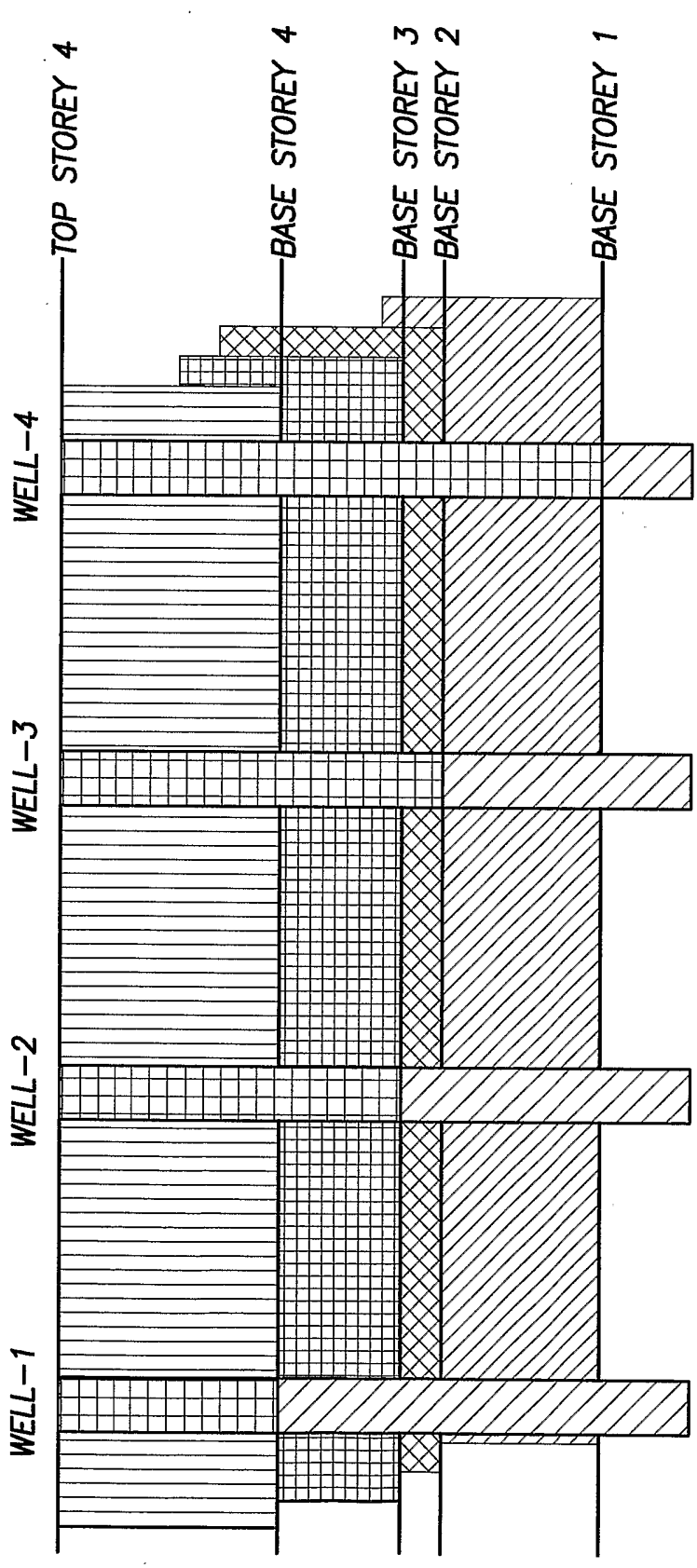

TOP STOREY 4
BASE STOREY 4
BASE STOREY 3
BASE STOREY 2
BASE STOREY 1
WELL-4
WELL-3
WELL-2
WELL-1
CHANNEL UNIT 4
CHANNEL UNIT 3
CHANNEL UNIT 2
CHANNEL UNIT 1
CHANNEL UNIT 1 CAN CONTAIN A POINT BAR OR CHANNEL ONLY IN WELL-4
CHANNEL UNIT 2 CAN CONTAIN A POINT BAR OR CHANNEL IN WELL-3 OR WELL-4 OR BOTH
CHANNEL UNIT 3 CAN CONTAIN A POINT BAR OR CHANNEL IN ANY OR ALL OF WELL-2, WELL-3 AND WELL-4
CHANNEL UNIT 4 CAN CONTAIN A POINT BAR OR CHANNEL IN ANY WELL

FIG.27

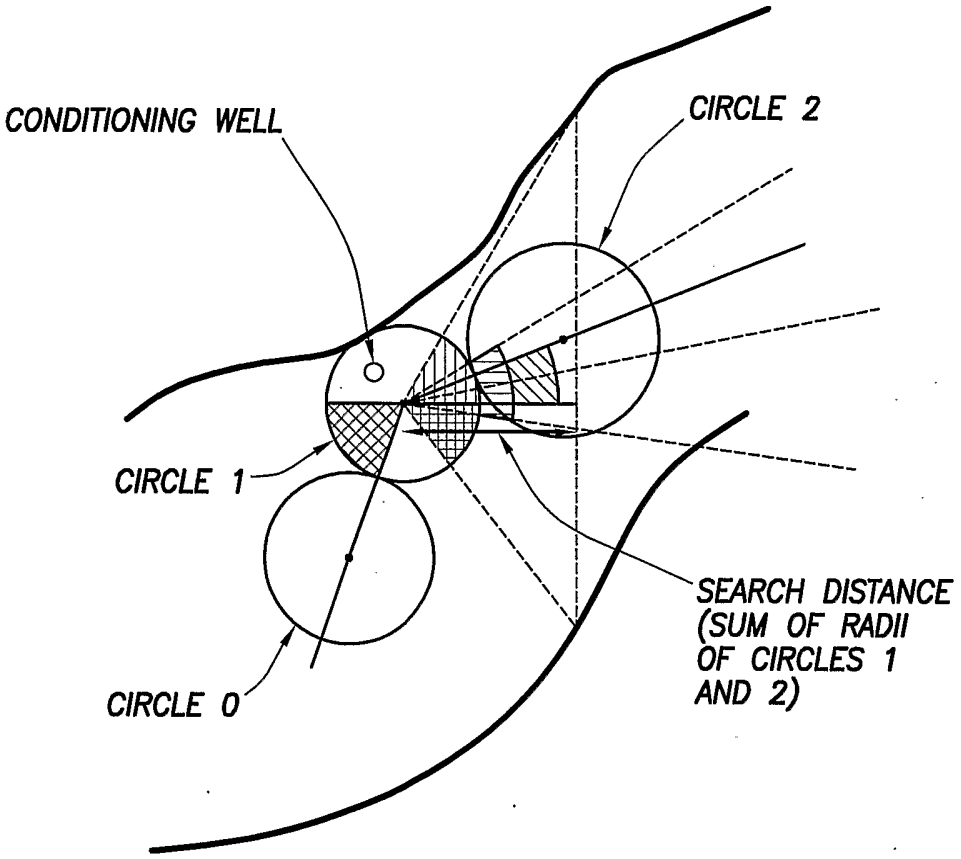

CONDITIONING WELL
CIRCLE 2
CIRCLE 1
CIRCLE 0
SEARCH DISTANCE (SUM OF RADII OF CIRCLES 1 AND 2)
α_{max}
α_{min}
MAX. RANGE FOR α
α SELECTED FOR CIRCLE 1
α SELECTED FOR CIRCLE 2
CHANNEL BELT MARGINS

FIG.29

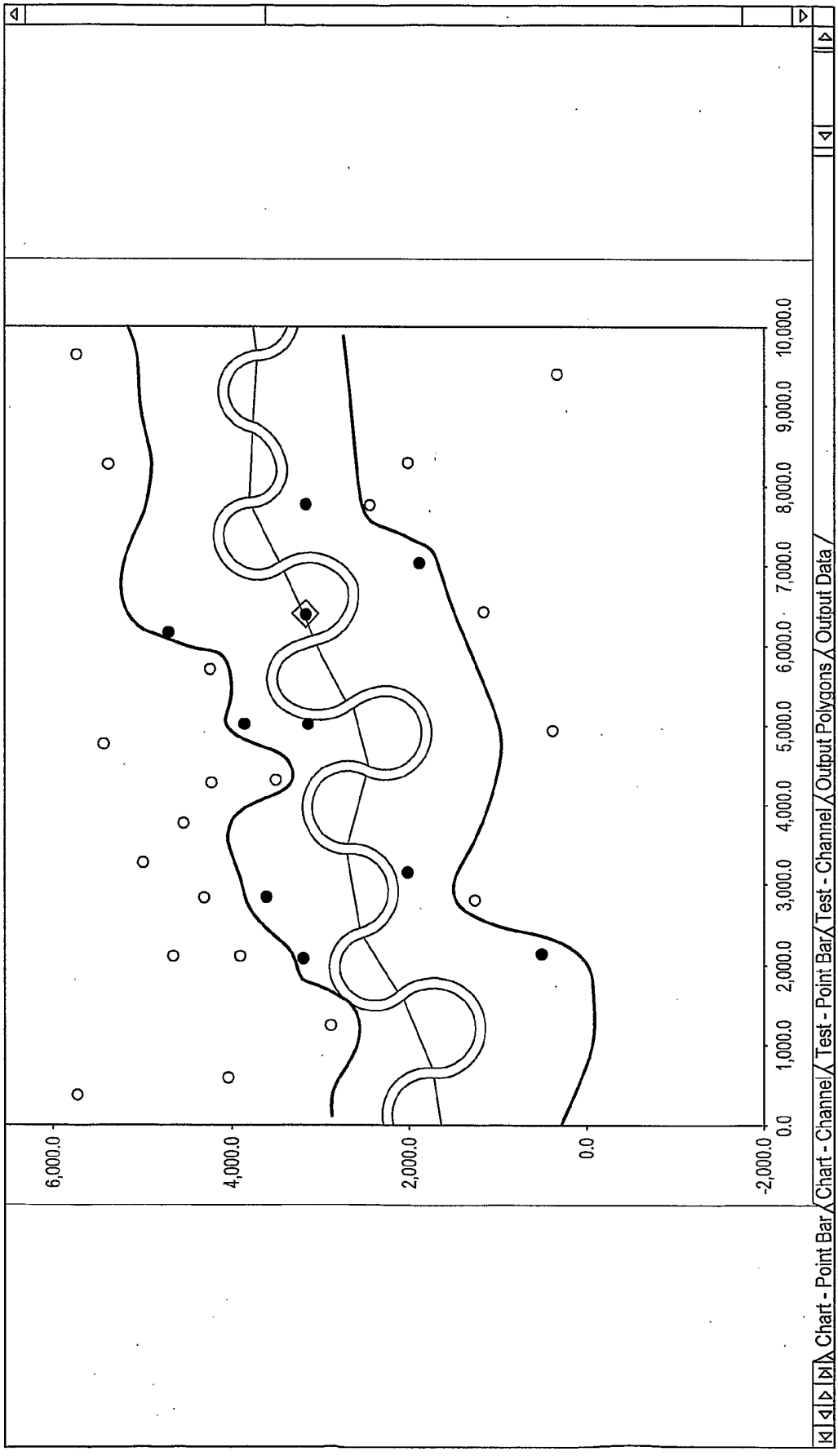

6,000.0
4,000.0
2,000.0
0.0
-2,000.0
0.0
1,000.0
2,000.0
3,000.0
4,000.0
5,000.0
6,000.0
7,000.0
8,000.0
9,000.0
10,000.0
Chart - Point Bar
Chart - Channel
Test - Point Bar
Test - Channel
Output Polygons
Output Data

FIG.30

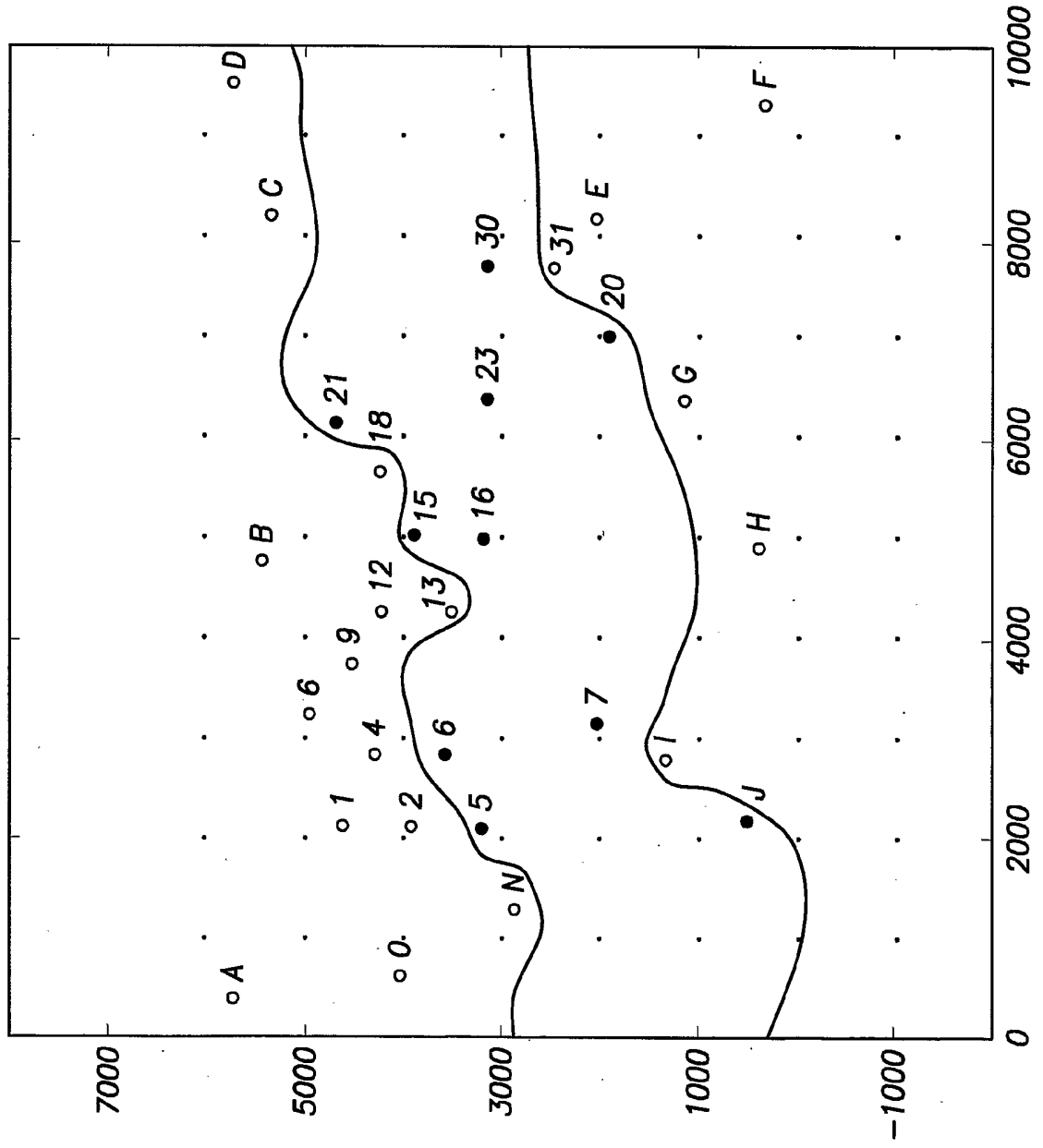

7000
5000
3000
1000
-1000
0
2000
4000
6000
8000
10000
A
B
C
D
E
F
G
H
I
J
N
0
1
2
4
5
6
7
9
12
13
15
16
18
20
21
23
30
31

FIG.31

	A	B	C	D	E	W	X	Y	Z	AA	AB	AC	AD	AE	AF
1	Input polyline		Independent	Interpolated Y				Y		Input polyline		Independent	Interpolated Y		
2	Xmin	Ymin	X	Eq 1	Eq 2	Eq 20	Eq 21	selected		Xmin	Ymin	X	Eq 1	Eq 2	Eq 3
3	-53	283	0	268.9026	FALSE	FALSE	FALSE	268.9026		58	2,872	0	FALSE	FALSE	FALSE
4	185	220	100	242.2473	FALSE	FALSE	FALSE	242.2473		422	2,856	100	2870.202	FALSE	FALSE
5	564	46	200	FALSE	212.6628	FALSE	FALSE	212.6628		818	2,683	200	2865.809	FALSE	FALSE
6	1,324	-143	300	FALSE	166.9834	FALSE	FALSE	166.9834		1,308	2,572	300	2861.416	FALSE	FALSE
7	1,909	-49	400	FALSE	121.3039	FALSE	FALSE	121.3039		1,640	2,698	400	2857.023	FALSE	FALSE
8	2,289	283	500	FALSE	75.62446	FALSE	FALSE	75.62446		1,814	3,203	500	FALSE	2861.831	FALSE
9	2,479	883	600	FALSE	FALSE	FALSE	FALSE	37.33666		2,194	3,377	600	FALSE	2777.978	FALSE
10	2,637	1,372	700	FALSE	FALSE	FALSE	FALSE	12.39209		2,700	3,803	700	FALSE	2734.126	FALSE
11	2,890	1,530	800	FALSE	FALSE	FALSE	FALSE	-12.5525		3,191	3,930	800	FALSE	2690.274	FALSE
12	3,397	1,372	900	FALSE	FALSE	FALSE	FALSE	-37.497		3,571	4,056	900	FALSE	FALSE	2664.0
13	4,219	1,056	1000	FALSE	FALSE	FALSE	FALSE	-62.4416		3,935	3,390	1000	FALSE	FALSE	2641.4
14	4,947	978	1100	FALSE	FALSE	FALSE	FALSE	-87.3862		4,093	3,551	1100	FALSE	FALSE	2618.9
15	5,422	1,104	1200	FALSE	FALSE	FALSE	FALSE	-112.331		4,330	3,298	1200	FALSE	FALSE	2596.3
16	6,166	1,420	1300	FALSE	FALSE	FALSE	FALSE	-137.275		4,615	3,409	1300	FALSE	FALSE	2573.8
17	6,672	1,562	1400	FALSE	FALSE	FALSE	FALSE	-130.925		4,852	3,898	1400	FALSE	FALSE	FALSE
18	7,178	1,735	1500	FALSE	FALSE	FALSE	FALSE	-114.774		4,995	4,056	1500	FALSE	FALSE	FALSE
19	7,368	2,067	1600	FALSE	FALSE	FALSE	FALSE	-98.623		5,485	4,008	1600	FALSE	FALSE	FALSE
20	7,574	2,462	1700	FALSE	FALSE	FALSE	FALSE	-82.4718		5,881	4,056	1700	FALSE	FALSE	FALSE
21	8,049	2,588	1800	FALSE	FALSE	FALSE	FALSE	-66.3205		5,992	4,514	1800	FALSE	FALSE	FALSE
22	8,840	2,635	1900	FALSE	FALSE	FALSE	FALSE	-50.1693		6,150	4,956	1900	FALSE	FALSE	FALSE
23	9,473	2,683	2000	FALSE	FALSE	FALSE	FALSE	30.54169		6,482	5,192	2000	FALSE	FALSE	FALSE
24	9,995	2,746	2100	FALSE	FALSE	FALSE	FALSE	117.87		7,147	5,192	2100	FALSE	FALSE	FALSE
25			2200	FALSE	FALSE	FALSE	FALSE	205.1983		7,732	4,924	2200	FALSE	FALSE	FALSE
26			2300	FALSE	FALSE	FALSE	FALSE	317.5552		8,349	4,892	2300	FALSE	FALSE	FALSE
27			2400	FALSE	FALSE	FALSE	FALSE	633.3711		9,045	5,003	2400	FALSE	FALSE	FALSE
28			2500	FALSE	FALSE	FALSE	FALSE	947.8199		9,710	5,066	2500	FALSE	FALSE	FALSE
29			2600	FALSE	FALSE	FALSE	FALSE	1257.151		9,916	5,114	2600	FALSE	FALSE	FALSE
30			2700	FALSE	FALSE	FALSE	FALSE	1411.245		10,042	5,161	2700	FALSE	FALSE	FALSE
31			2800	FALSE	FALSE	FALSE	FALSE	1473.584				2800	FALSE	FALSE	FALSE
32			2900	FALSE	FALSE	FALSE	FALSE	1526.866				2900	FALSE	FALSE	FALSE
33			3000	FALSE	FALSE	FALSE	FALSE	1495.697				3000	FALSE	FALSE	FALSE

Input Polyline | Input Parameters | Calculation

FIG.32

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	Channel Parameters				Well Name	X	Y	Base CB(C)	Facies (C)				
2	Base Radius	500			23	6401.4704	3158.1912	22	Point Bar				
3	Variation in Radius	0.1			7	3145.5968	2019.4584	21	Point Bar				
4	Channel Width	100			15	5043.5864	3866.8512	21	Point Bar				
5	Variation in Channel Width	0.1			3	2116.592	3208.788	19	Point Bar				
6	Wiggle Control	1.5			16	5043.5864	3158.1912	19	Point Bar				
7	Channelbelt Thickness	24			28	7084.5272	1892.9664	19	Point Bar				
8	Channel Unit Thickness	10			30	7767.8888	3158.1912	19	Point Bar				
9	Depth to Top Channelbelt	0			J	2156.47	515.88	19	Point Bar				
10	Depth to Base Channelbelt	24			5	2859.0848	2580.0344	16	Channel				
11	Depth to Top Channel Unit	0			21	6173.7848	4676.4	14	Point Bar				
12	Depth to Base Channel Unit	10			1	2116.592	4617.2688		Floodplain				
13	Conditioned Well				2	2116.592	3908.9136		Floodplain				
14	X	6401.47			4	2850.5504	4288.3896		Floodplain				
15	Y	3158.191			8	3255.3248	4954.6824		Floodplain				
16					9	3744.5288	4516.0752		Floodplain				
17					12	4275.7952	4221.0288		Floodplain				
18					13	4275.7952	3504.1392		Floodplain				
19	Channelbelt Limits				18	5692.8104	4221.0288		Floodplain				
20	X max	Y max	Y min		31	7767.8888	2441.3016		Floodplain				
21	0		268.9026		A	383.55	5720.39		Floodplain				
22	100	2870.202	242.2473		B	4789.18	5420.62		Floodplain				
23	200	2865.809	212.6628		C	8280.41	5324.1		Floodplain				
24	300	2861.416	166.9834		D	9624.07	5697.48		Floodplain				
25	400	2857.023	121.3039		E	8266.44	1999.24		Floodplain				
26	500	2821.831	75.62446		F	9403.09	322.84		Floodplain				
27	600	2777.978	37.33666		G	6410.97	1139.45		Floodplain				
28	700	2734.126	12.39209		H	4941.58	377.45		Floodplain				
29	800	2690.274	-12.5525		I	2794.01	1291.85		Floodplain				
30	900	2664.003	-37.497		N	1283.98	2857.76		Floodplain				
31	1000	2641.467	-62.4416		O	605.8	4021.08		Floodplain				
32	1100	2618.931	-87.3862										
33	1200	2596.394	-112.331										

Input Polyline | Input Parameters | Calculation - Point Bar | Calculation - Channel | Chart - Point Bar | Chart - Channel | Test - Point Bar | Test - Channel

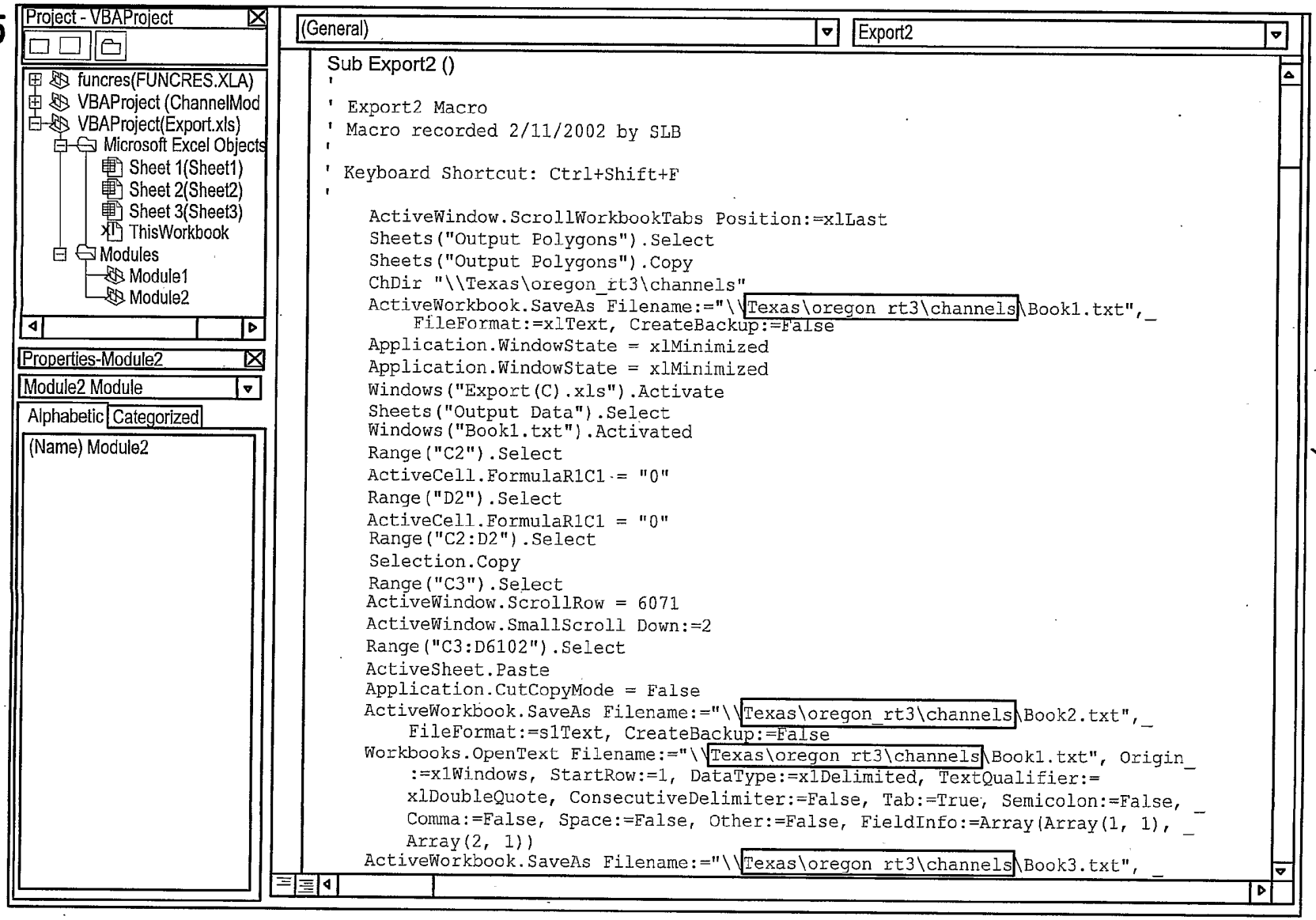
FIG.33

	A	B	C	D	E	F	G	H	I	AT	AU	AV
1	Well	Actual	Model	Match	Actual	Model	Match	Channel Unit	1	Channel Unit	20	
2	Name	If in point bar,=1	If in point bar,=1	If match,=1	If in channel,=1	If in channel,=1	If match,=1	Base	Top	Base	Top	
3	23	1	1	1		0	1	22	12			
4	7	1	0	0		0	1			10	0	
5	15	1	0	0		0	1					
6	3	1	0	0		0	1					
7	16	1	0	0		0	1					
8	28	1	0	0		0	1			10	0	
9	30	1	0	0		0	1					
10	J	1	0	0		0	1					
11	5		0	1	1	0	0					
12	21	1	0	0		0	1			10	0	
13	1		0	1		0	1					
14	2		0	1		0	1					
15	4		0	1		0	1					
16	8		0	1		0	1					
17	9		0	1		0	1					
18	12		0	1		0	1					
19	13		0	1		0	1					
20	18		0	1		0	1					
21	31		0	1		0	1					
22	A		0	1		0	1					
23	B		0	1		0	1					
24	C		0	1		0	1					
25	D		0	1		0	1					
26	E		0	1		0	1					
27	F		0	1		0	1					
50												
51												
52												
53	Number correctly located			Number correctly located								
54	outside channels		0	outside channels		0						
55												

Chart-Point Bar | Chart-Channel | Test - Point Bar | Test - Channel | Output Polygons | Output Data

FIG.34

FIG.35


Project - VBAProject
funcres(FUNCRES.XLA)
VBAProject (ChannelMod
VBAProject(Export.xls)
Microsoft Excel Objects
Sheet 1(Sheet1)
Sheet 2(Sheet2)
Sheet 3(Sheet3)
ThisWorkbook
Modules
Module1
Module2
Properties-Module2
Module2 Module
Alphabetic
Categorized
(Name) Module2
(General)
Export2
Sub Export2 ()
'
' Export2 Macro
' Macro recorded 2/11/2002 by SLB
'
' Keyboard Shortcut: Ctrl+Shift+F
'
ActiveWindow.ScrollWorkbookTabs Position:=xlLast
Sheets("Output Polygons").Select
Sheets("Output Polygons").Copy
ChDir "\\Texas\oregon_rt3\channels"
ActiveWorkbook.SaveAs Filename:="\\Texas\oregon rt3\channels\Book1.txt",_
FileFormat:=xlText, CreateBackup:=False
Application.WindowState = xlMinimized
Application.WindowState = xlMinimized
Windows("Export(C).xls").Activate
Sheets("Output Data").Select
Windows("Book1.txt").Activated
Range("C2").Select
ActiveCell.FormulaR1C1 = "0"
Range("D2").Select
ActiveCell.FormulaR1C1 = "0"
Range("C2:D2").Select
Selection.Copy
Range("C3").Select
ActiveWindow.ScrollRow = 6071
ActiveWindow.SmallScroll Down:=2
Range("C3:D6102").Select
ActiveSheet.Paste
Application.CutCopyMode = False
ActiveWorkbook.SaveAs Filename:="\\Texas\oregon_rt3\channels\Book2.txt",_
FileFormat:=s1Text, CreateBackup:=False
Workbooks.OpenText Filename:="\\Texas\oregon rt3\channels\Book1.txt", Origin_
:=xlWindows, StartRow:=1, DataType:=xlDelimited, TextQualifier:=
xlDoubleQuote, ConsecutiveDelimiter:=False, Tab:=True, Semicolon:=False, _
Comma:=False, Space:=False, Other:=False, FieldInfo:=Array(Array(1, 1), _
Array(2, 1))
ActiveWorkbook.SaveAs Filename:="\\Texas\oregon rt3\channels\Book3.txt", _

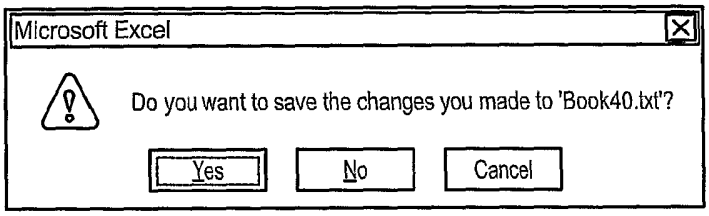


FIG.36

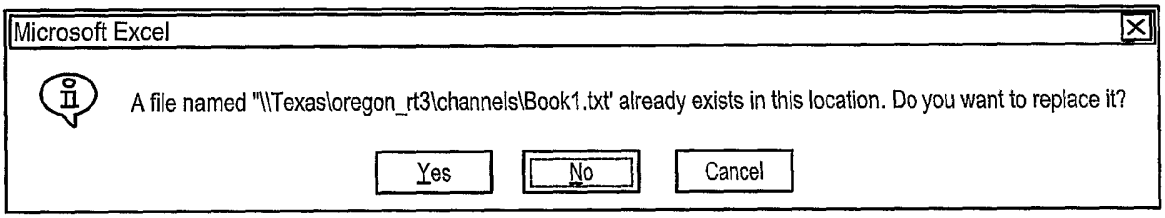


FIG.37

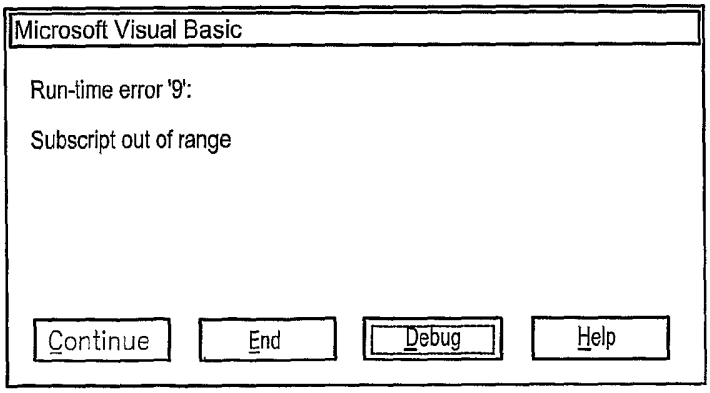


FIG.38

```
!CPS_VERSION_6.0 T=98
!------------------M1BACH "Create"  Request ----------------
! This is file FRAMEWORK, a batch macro written by M1BACH.
! ------------------------------------------------------------
M1OPEN "DA" "D1" "UNKNOWN"
!...
M1OPEN "DA" "D1" "UNKNOWN"
!...
M1OPEN "DA" "D1" "UNKNOWN"
FDASCI 0 2 "Computed" 0 1E30 0
F1TRAS "."
FDATTR 1 2 2 0
FDATNM 1 "" "" "" ""
FDAFIL 3 0 0
M1ASCI "d" "i" "/home/oregon/rt3/channels/Book2.txt"
!...
M1OPEN "DA" "D2" "UNKNOWN"
!...
M1OPEN "DA" "D2" "UNKNOWN"
!...
M1OPEN "DA" "D2" "UNKNOWN"
FDASCI 0 2 "Computed" 0 1E30 0
F1TRAS "."
FDATTR 1 2 2 0
FDATNM 1 "" "" "" ""
FDAFIL 3 0 0
M1ASCI "d" "i" "/home/oregon/rt3/channels/Book2.txt"
!...
M1OPEN "DA" "D3" "UNKNOWN"
```

FIG.39

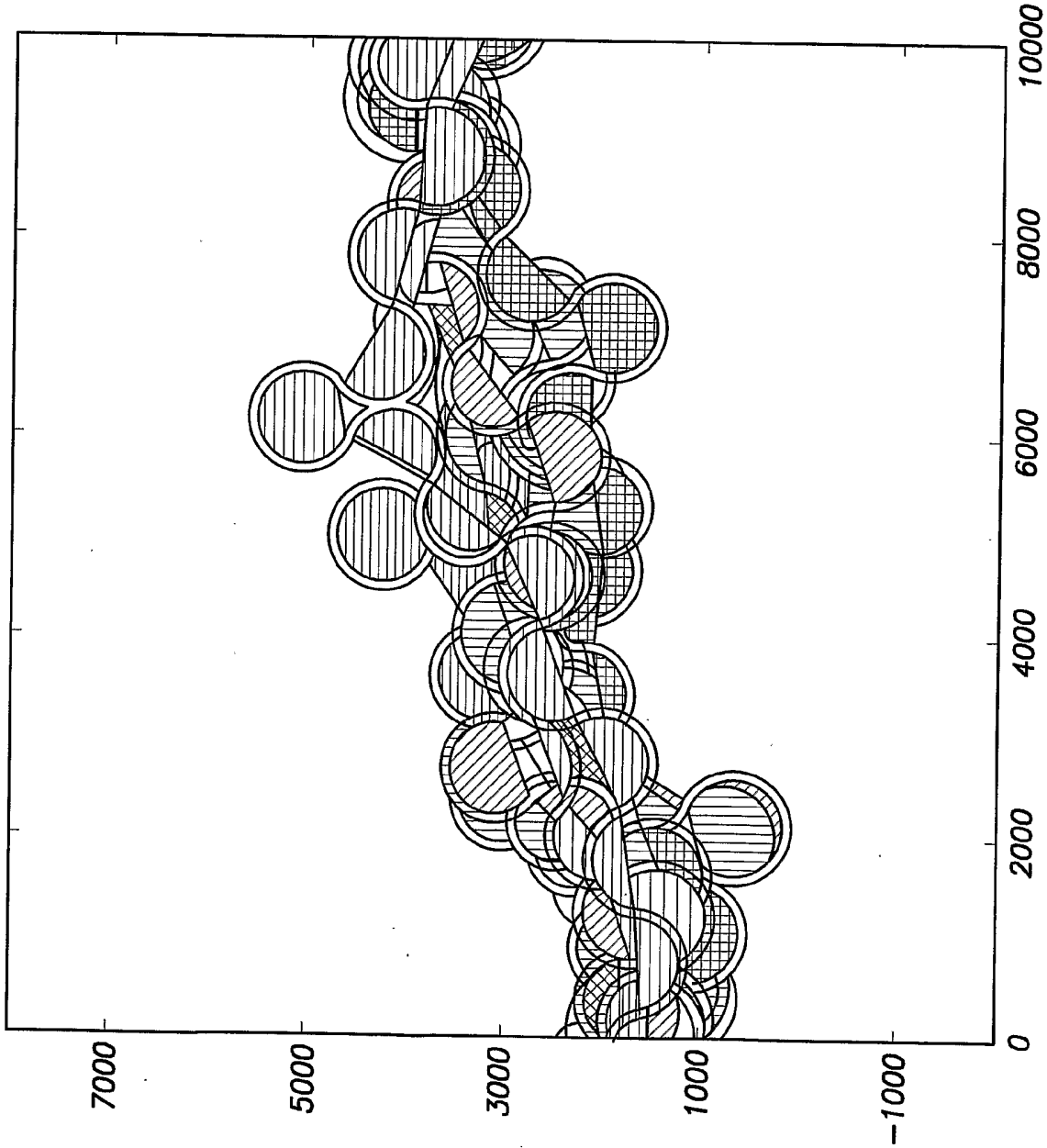


FIG.40

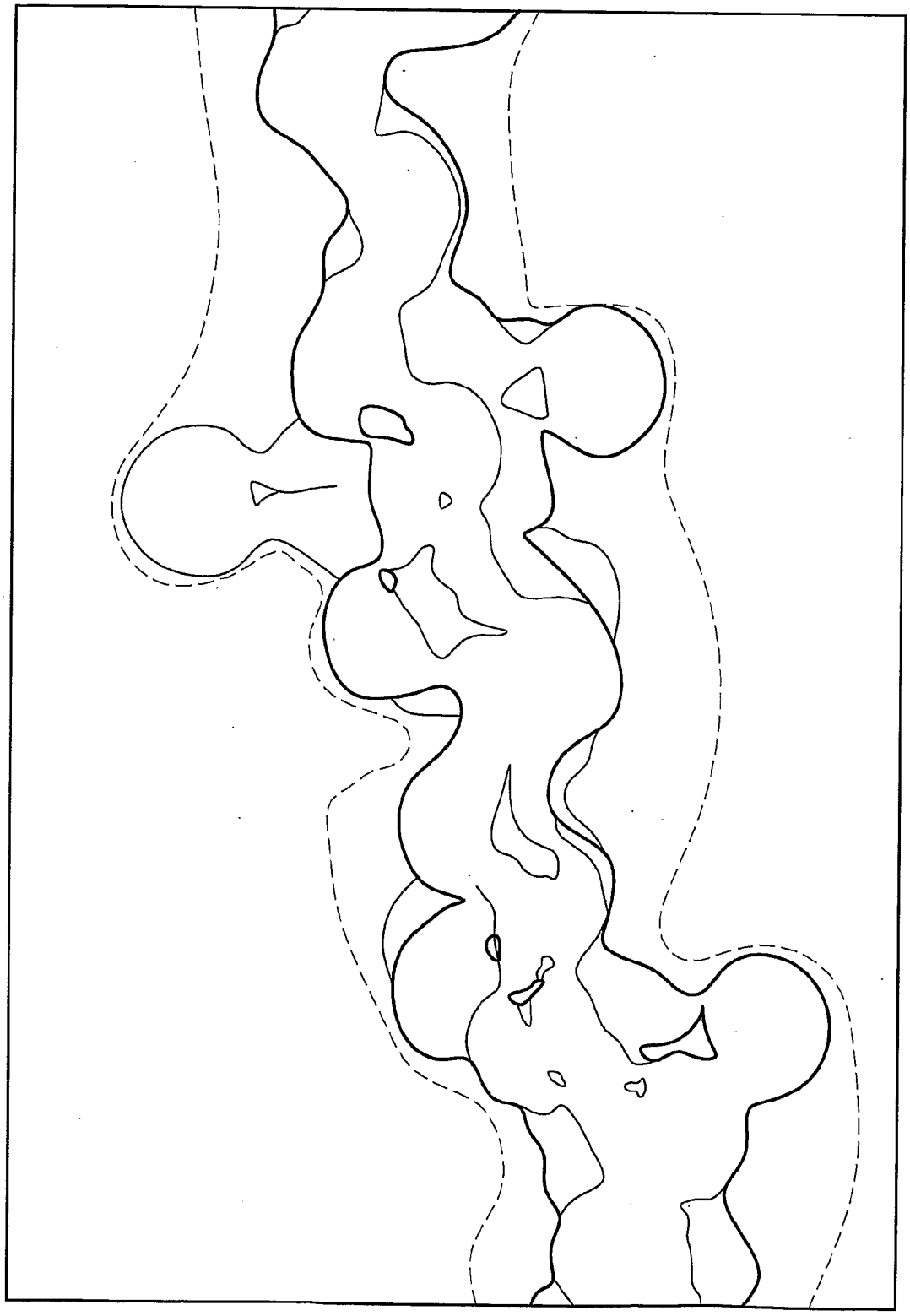


FIG.41

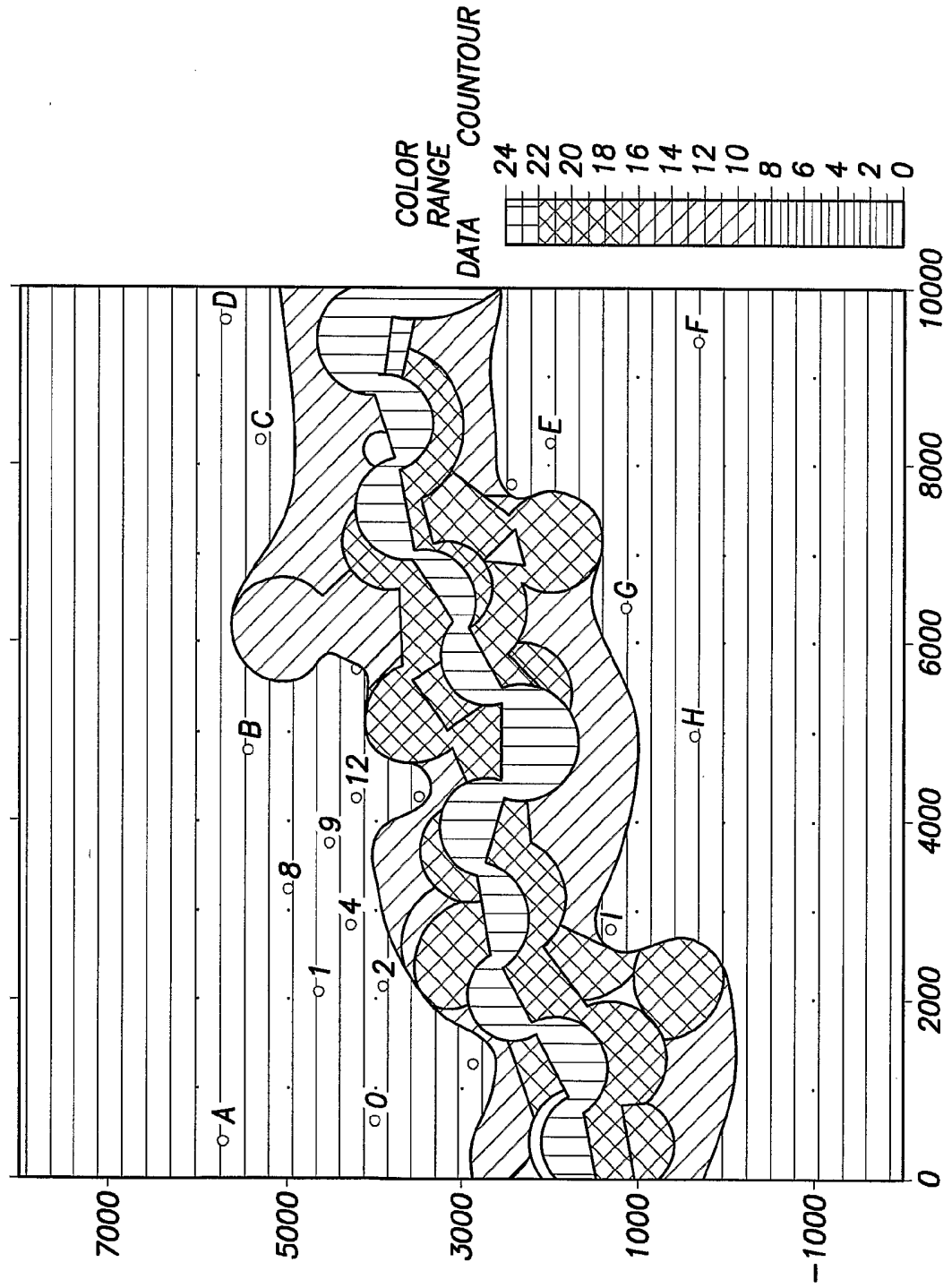

COLOR RANGE DATA COUNTOUR
24 22 20 18 16 14 12 10 8 6 4 2 0
A B C D E F G H
0 1 2 4 8 9 12
7000 5000 3000 1000 −1000
0 2000 4000 6000 8000 10000

FIG.42

```
!CPS_VERSION_6.0 T=98
!------------------M1BACH "Create" Request ----------------
! This is file VOLUMETRICS, a batch macro written by M1BACH.
! ------------------------------------------------------------
M1OPEN "SA" "D1_PB_isochore" "OLD"
!...
M1OPEN "F" "null" "OLD"
!...
M1OPEN "P" "null" "OLD"
!...
M1OPEN "SA" "D1_PB_isochore" "OLD"
!...
M1OPEN "F" "null" "OLD"
!...
M1OPEN "P" "null" "OLD"
!...
M1OPEN "SA" "D1_PB_isochore" "OLD"
!...
M1OPEN "F" "null" "OLD"
!...
M1OPEN "P" "null" "OLD"
!...
M1OPEN "SA" "D1_PB_isochore" "OLD"
!...
M1OPEN "F" "null" "OLD"
!...
M1OPEN "P" "null" "OLD"
!...
M1OPEN "SA" "D1_PB_isochore" "OLD"
M1OPEN "F" "null" "OLD"
M1OPEN "P" "null" "OLD"
F1CONF 0 INDT INDT 1
FSVALG 1 4 0 0
FSVSCL 1 1
FSVREP "" "/home/oregon/rt2/channels/CHANNELS/CPS/rjames.vlm" "" 1
FSVSLI 0 0
MSVOLM
```

FIG.43

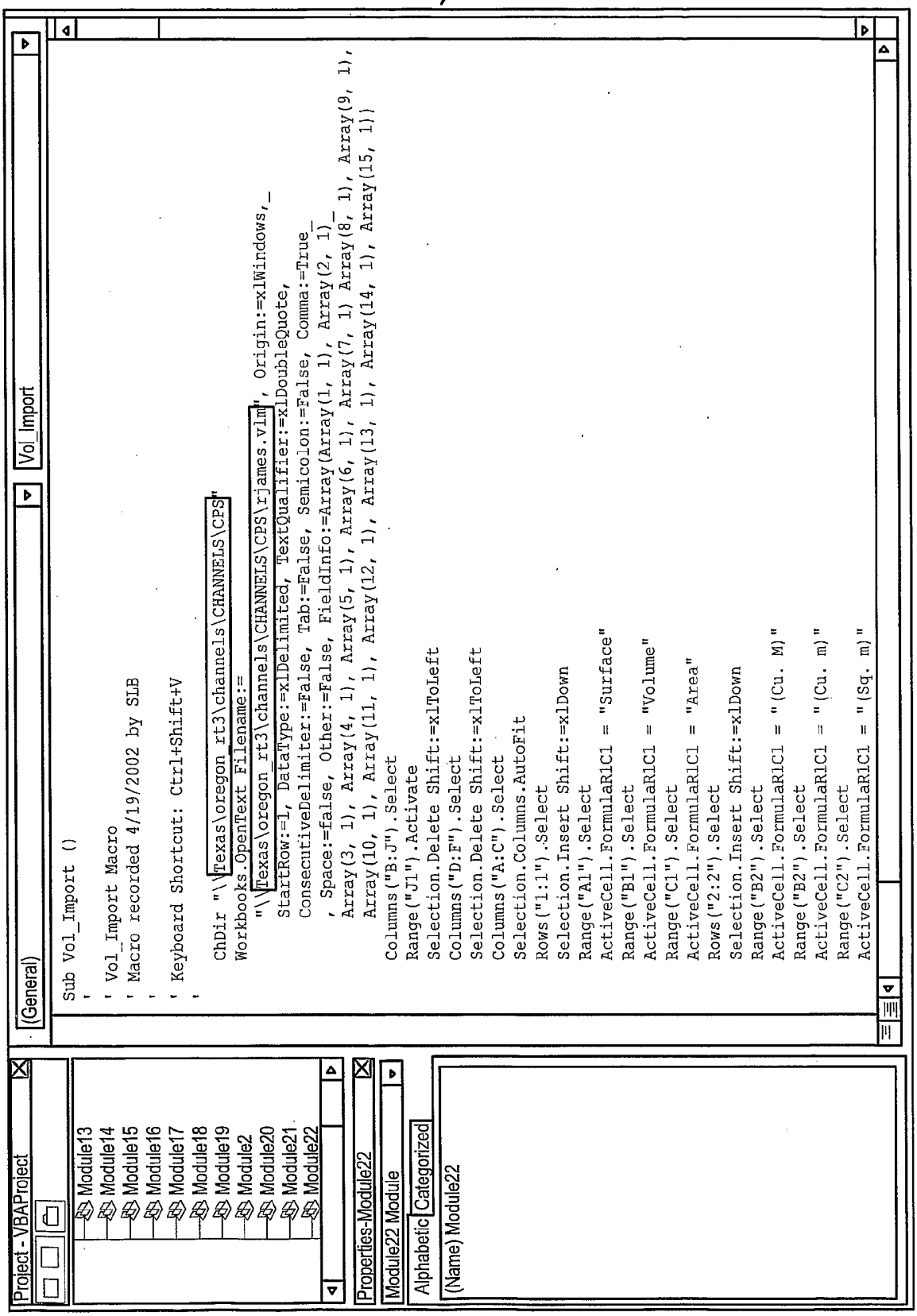

Project - VBAProject
Module13
Module14
Module15
Module16
Module17
Module18
Module19
Module2
Module20
Module21
Module22
Properties-Module22
Module22 Module
Alphabetic
Categorized
(Name) Module22
(General)
Vol_Import
Sub Vol_Import ()
Vol_Import Macro
Macro recorded 4/19/2002 by SLB
Keyboard Shortcut: Ctrl+Shift+V
ChDir "\\Texas\oregon_rt3\channels\CHANNELS\CPS"
Workbooks.OpenText Filename:=
"\\Texas\oregon_rt3\channels\CHANNELS\CPS\rjames.vlm", Origin:=xlWindows,_
StartRow:=1, DataType:=xlDelimited, TextQualifier:=xlDoubleQuote,
ConsecutiveDelimiter:=False, Tab:=False, Semicolon:=False, Comma:=True_
, Space:=false, Other:=False, FieldInfo:=Array(Array(1, 1), Array(2, 1)_
Array(3, 1), Array(4, 1), Array(5, 1), Array(6, 1), Array(7, 1) Array(8, 1), Array(9, 1),
Array(10, 1), Array(11, 1), Array(12, 1), Array(13, 1), Array(14, 1), Array(15, 1))
Columns("B:J").Select
Range("J1").Activate
Selection.Delete Shift:=xlToLeft
Columns("D:F").Select
Selection.Delete Shift:=xlToLeft
Columns("A:C").Select
Selection.Columns.AutoFit
Rows("1:1").Select
Selection.Insert Shift:=xlDown
Range("A1").Select
ActiveCell.FormulaR1C1 = "Surface"
Range("B1").Select
ActiveCell.FormulaR1C1 = "Volume"
Range("C1").Select
ActiveCell.FormulaR1C1 = "Area"
Rows("2:2").Select
Selection.Insert Shift:=xlDown
Range("B2").Select
ActiveCell.FormulaR1C1 = "(Cu. M)"
Range("B2").Select
ActiveCell.FormulaR1C1 = "(Cu. m)"
Range("C2").Select
ActiveCell.FormulaR1C1 = "(Sq. m)"

FIG. 44

	A	B	C
1		Volume	Area
2	Surface	(Cu. m)	(Sq. m)
3	D1_PB_isochore[381817143]	1.383E+07	2.196E+06
4	D2_PB_isochore[381817652]	1.141E+07	3.086E+06
5	D3_PB_isochore[381817685]	6.487E+06	2.835E+06
6	D4_PB_isochore[381816996]	7.332E+06	2.888E+06
7	D5_PB_isochore[381817891]	1.189E+07	2.870E+06
8	D6_PB_isochore[381817700]	9.531E+06	2.909E+06
9	D7_PB_isochore[381817191]	1.205E+07	2.432E+06
10	D8_PB_isochore[381817190]	2.084E+07	1.575E+06
11	D9_PB_isochore[381816917]	7.204E+06	2.005E+06
12	D10_PB_isochore[381818452]	1.277E+07	2.899E+06
13	D11_PB_isochore[381817723]	2.917E+07	3.523E+06
14	D12_PB_isochore[381816834]	2.281E+07	3.071E+06
15	D13_PB_isochore[381816883]	1.653E+07	3.110E+06
16	D14_PB_isochore[381817320]	3.521E+07	4.166E+06
17	D15_PB_isochore[381818767]	2.940E+07	2.519E+06
18	D16_PB_isochore[381818126]	5.000E+07	2.896E+06
19	D17_PB_isochore[381818335]	3.622E+07	3.089E+06
20	D18_PB_isochore[381818268]	6.157E+07	4.398E+06
21	D19_PB_isochore[381818813]	0.000E+00	1.016E+06
22	D20_PB_isochore[381818842]	0.000E+00	1.106E+06
23	CB_base [2056514667]	4.037E+08	2.503E+07
24			

rjames

FIG.45

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US03/18567

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G06G 7/48
US CL : 703/10, 2; 702/5, 6; 345/419

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 703/10, 2; 702/5, 6; 345/419

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 6,106,561 A (FARMER) 22 August 2000.	1-24
A	US 6,052,520 (WATTS, III) 18 April 2000.	1-24
A	US 6,044,328 A (MURPHY et al) 28 March 2000.	1-24
A	US 5,835,882 A (VIENOT et al) 10 November 1998.	1-24
A	BENES. B. et al. Layered Data Representation for Visual Simulation of Terrain Erosion. ITESM Campus Ciudad de Mexico. 2001, pages 1-6. Download from http://citeseer.nj.nec.com/506000.html.	1-24
A	BROADHEAD. R. Elevator Basin Models--Implications for Exploration in Central New Mexico. Oil & Gas Journal. 22 January 2001, Vol. 99. No 4, pages 30-36.	1-24
A	KWOUN. O. et al. Variable Resolution Topographic Mapping of Ancient Fluvial Landscapes in Australia. 1998 IEEE International Geoscience and Remote Sensing Symposium. July 1998, Vol. 5, pages 2360-2362.	1-24

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
19 October 2003 (19.10.2003)

Date of mailing of the international search report
07 NOV 2003

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Samuel Broda Peggy Harrod
Telephone No. (703) 305-9700

Form PCT/ISA/210 (second sheet) (July 1998)

PCT/US03/18567

INTERNATIONAL SEARCH REPORT

C. (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	SYVERSVEEN. A. et al. A Method for Approximate Fully Bayesian Analysis of Parameters. Norwegian University of Science and Technology. September 1996, pages 1-12. Download from http://citeseer.nj.nec.com/syversveen97method.html.	1-24

INTERNATIONAL SEARCH REPORT

PCT/US03/18567

Continuation of B. FIELDS SEARCHED Item 3:
EAST, IEEE, Proquest, SiteSeer
search terms: fluvial, reservoir, model