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(54) **METHOD FOR FLOOD CONTROL**

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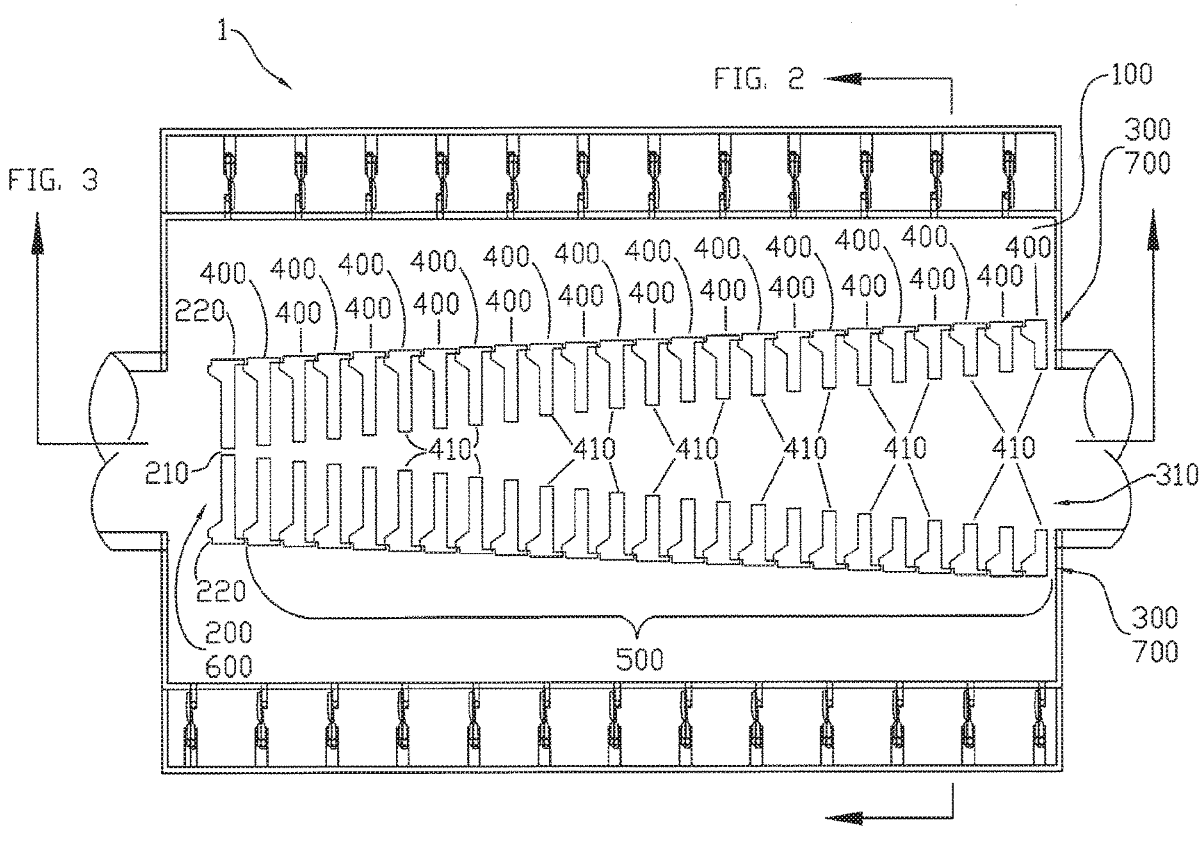
(57) **ABSTRACT**

A dynamic fluid flow control structure is provided that allows precise control over fluid flow using a series of two or more orifices, at least one of which may be reconfigured to change its flow characteristics. A flood control system and a flood control process are provided that emulate a preset discharge profile over time. Some versions of the structure, process, and system can be used to provide controlled storm discharge patterns in a developed area that emulate the natural pre-development discharge patterns.



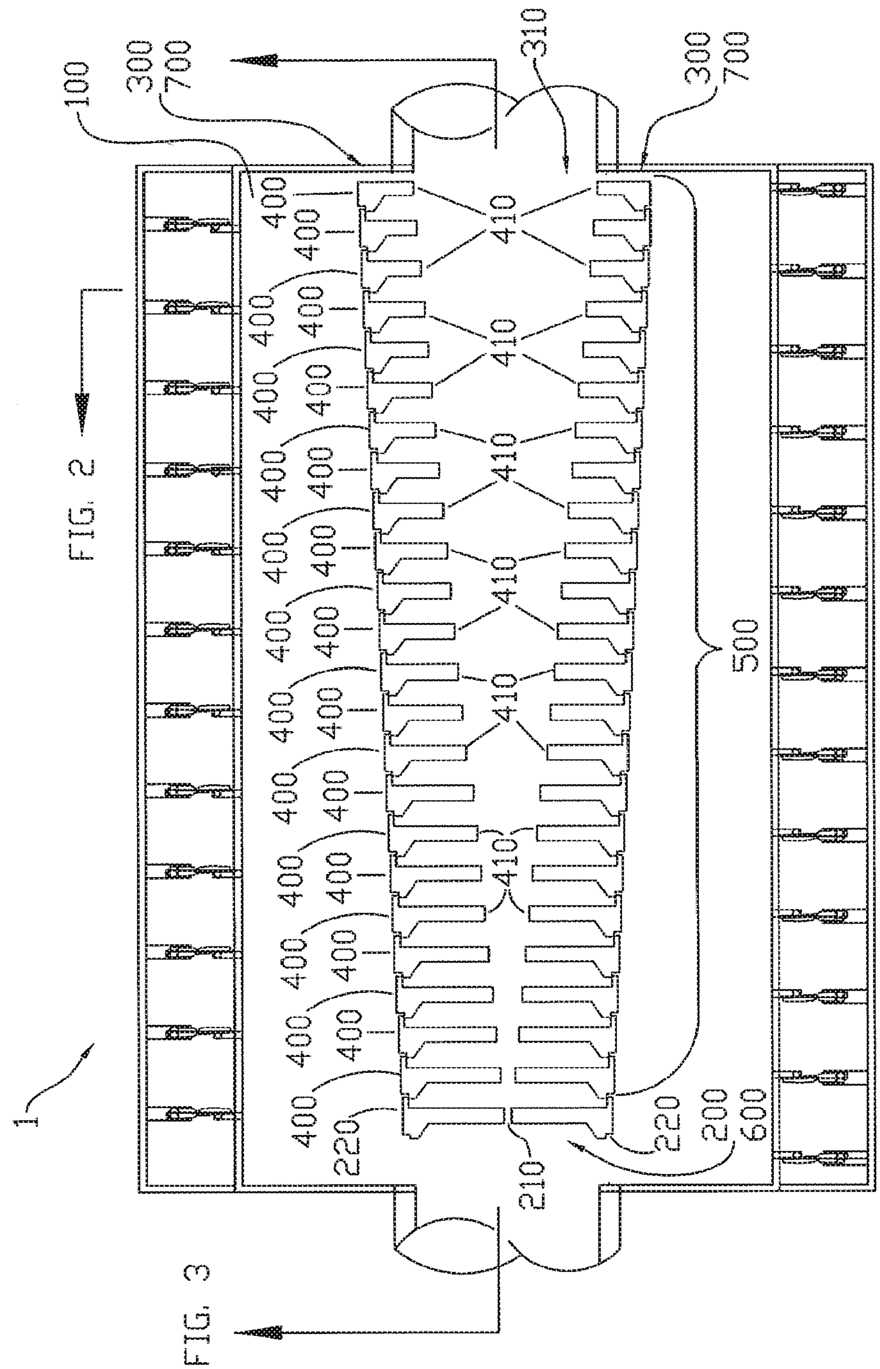


FIG. 1

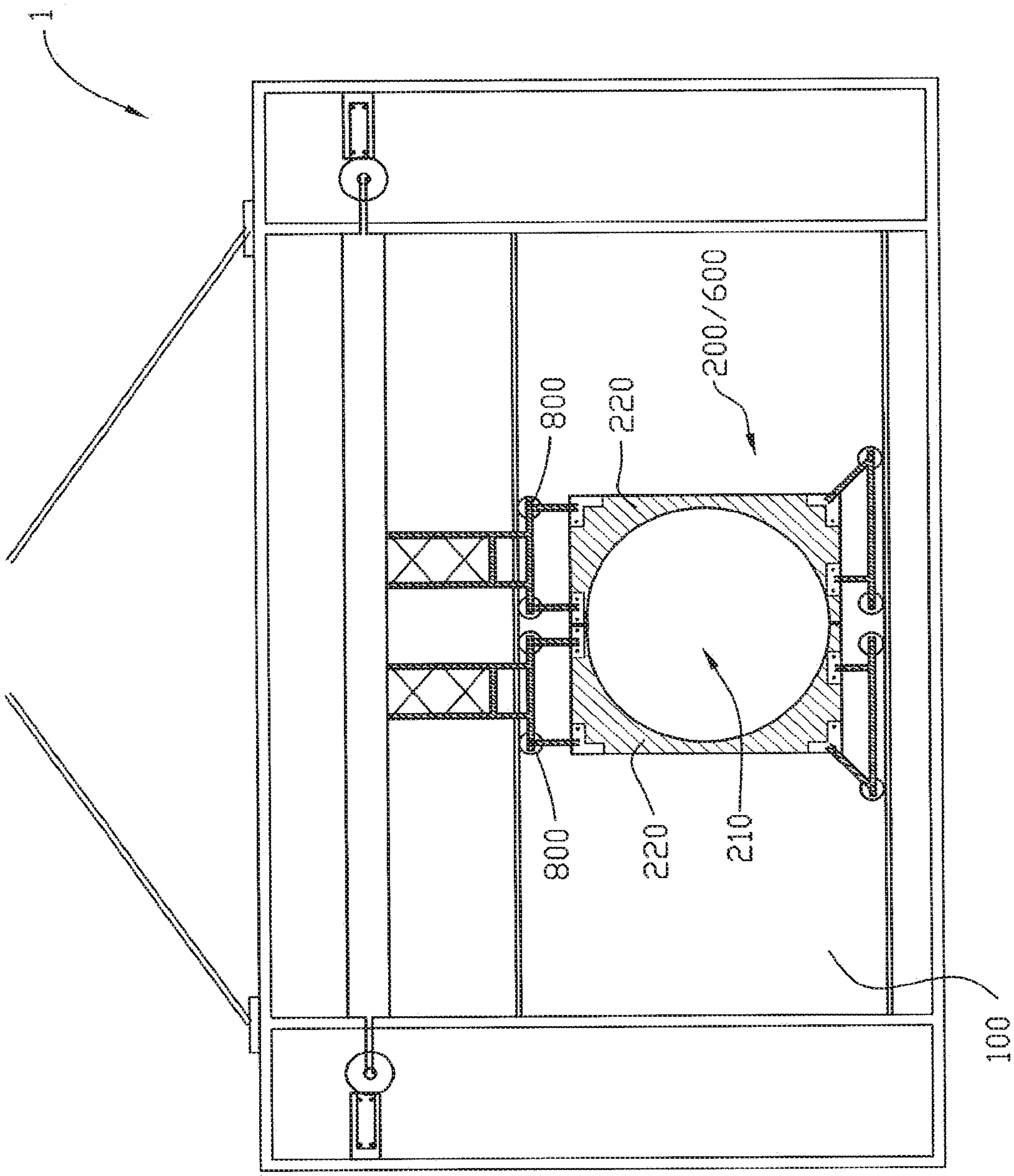


FIG. 2

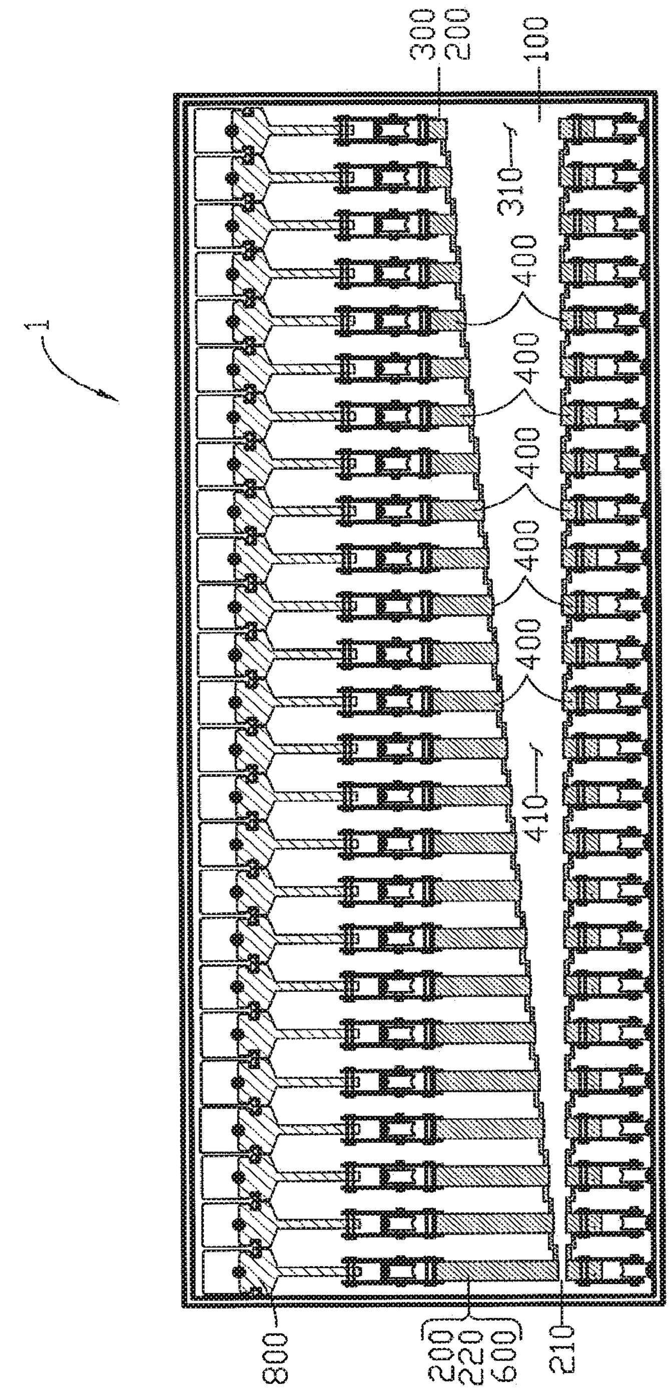


FIG. 3

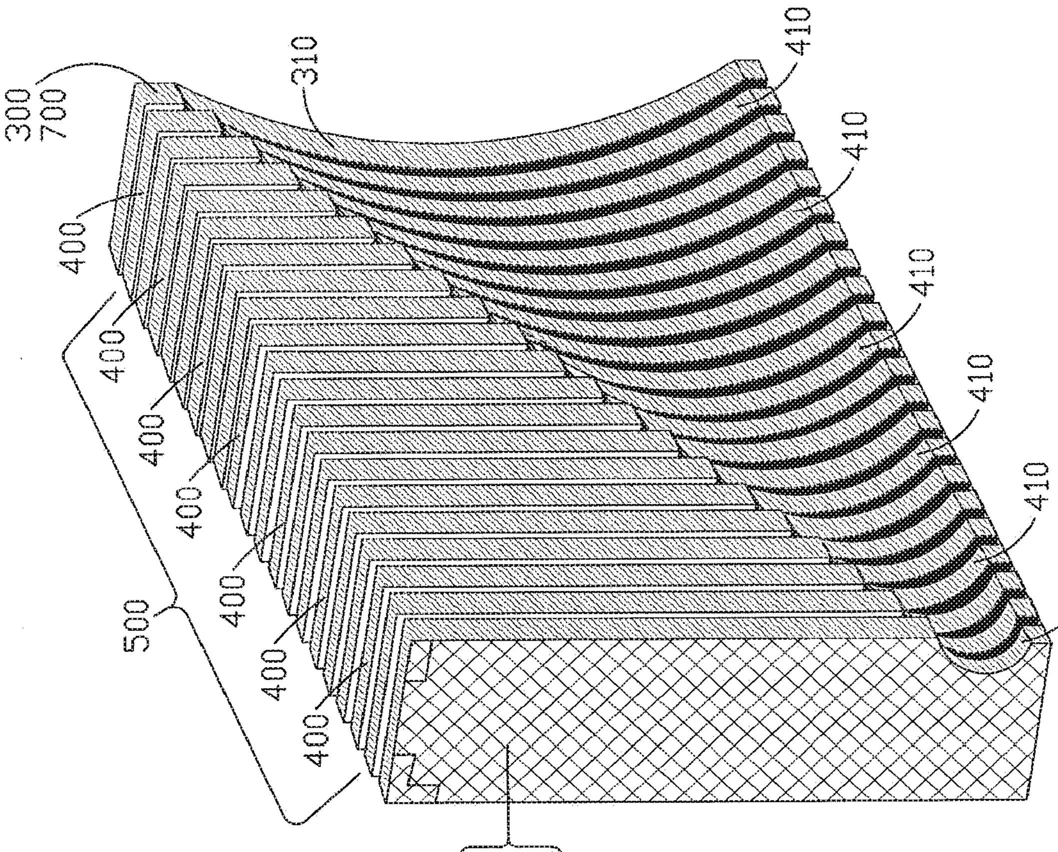

300
700
310
410
410
410
410
410
410
400
400
400
400
400
400
400
400
500
210
200
220
600

FIG. 4

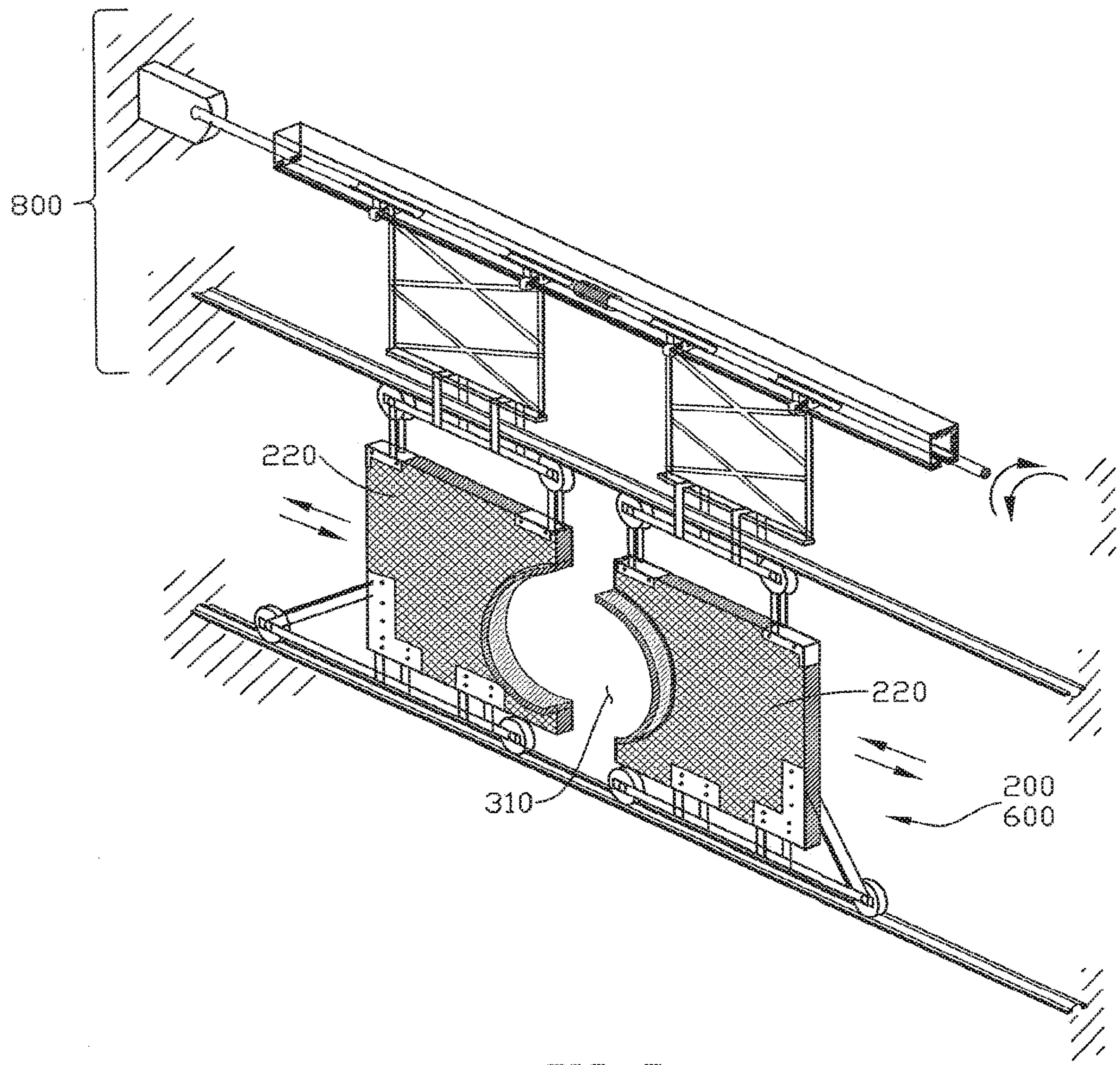


FIG. 5

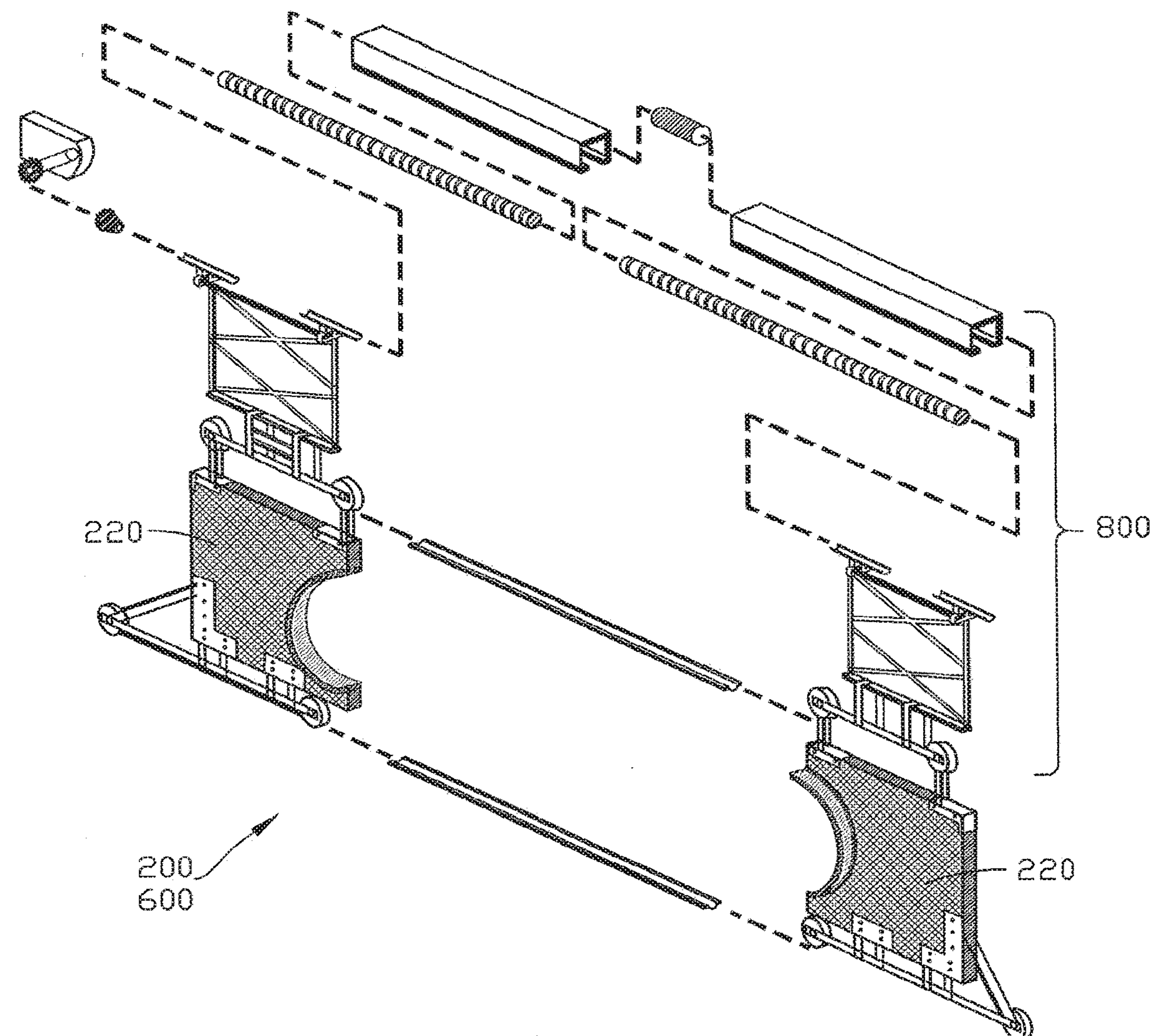


FIG. 6

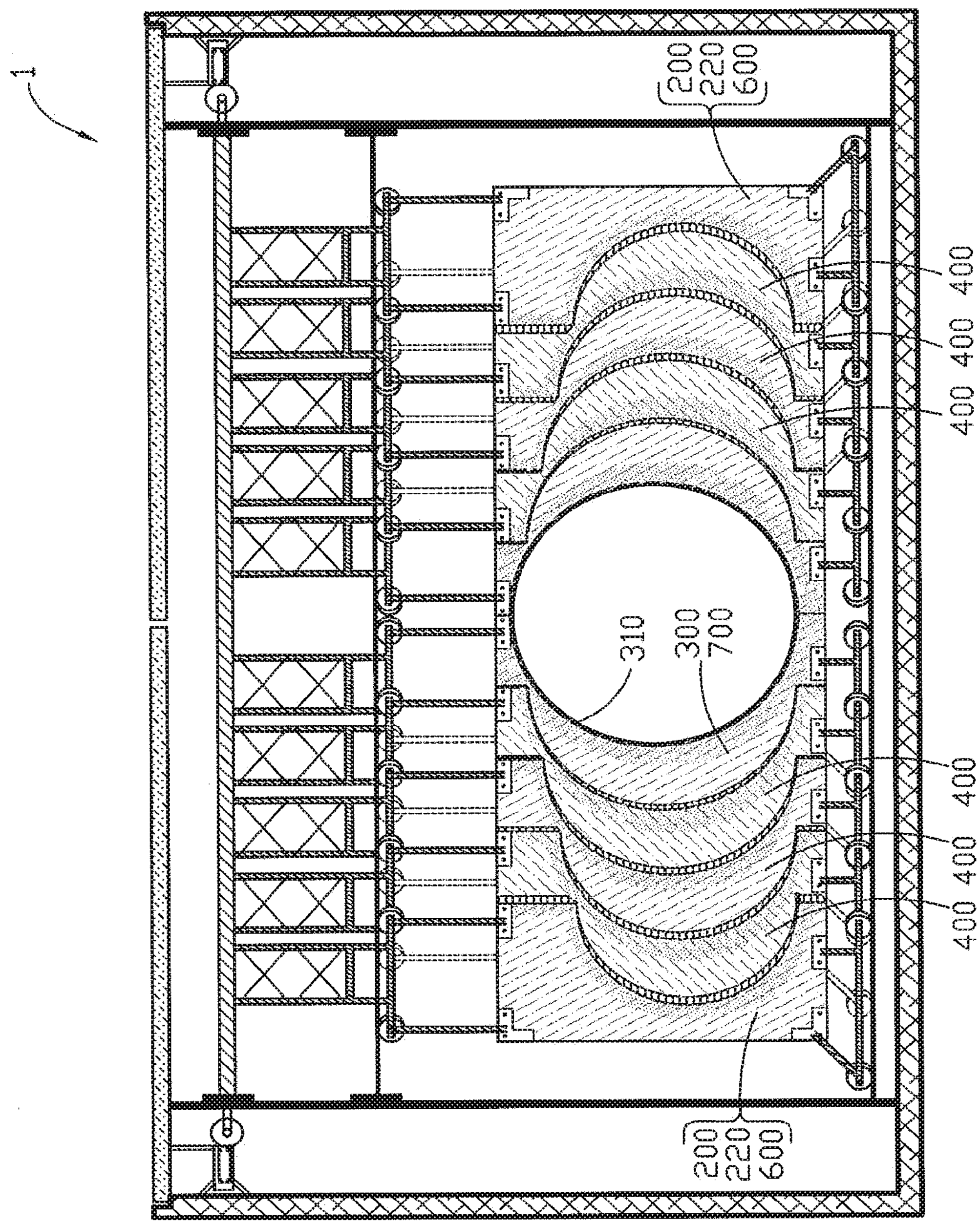


FIG. 7

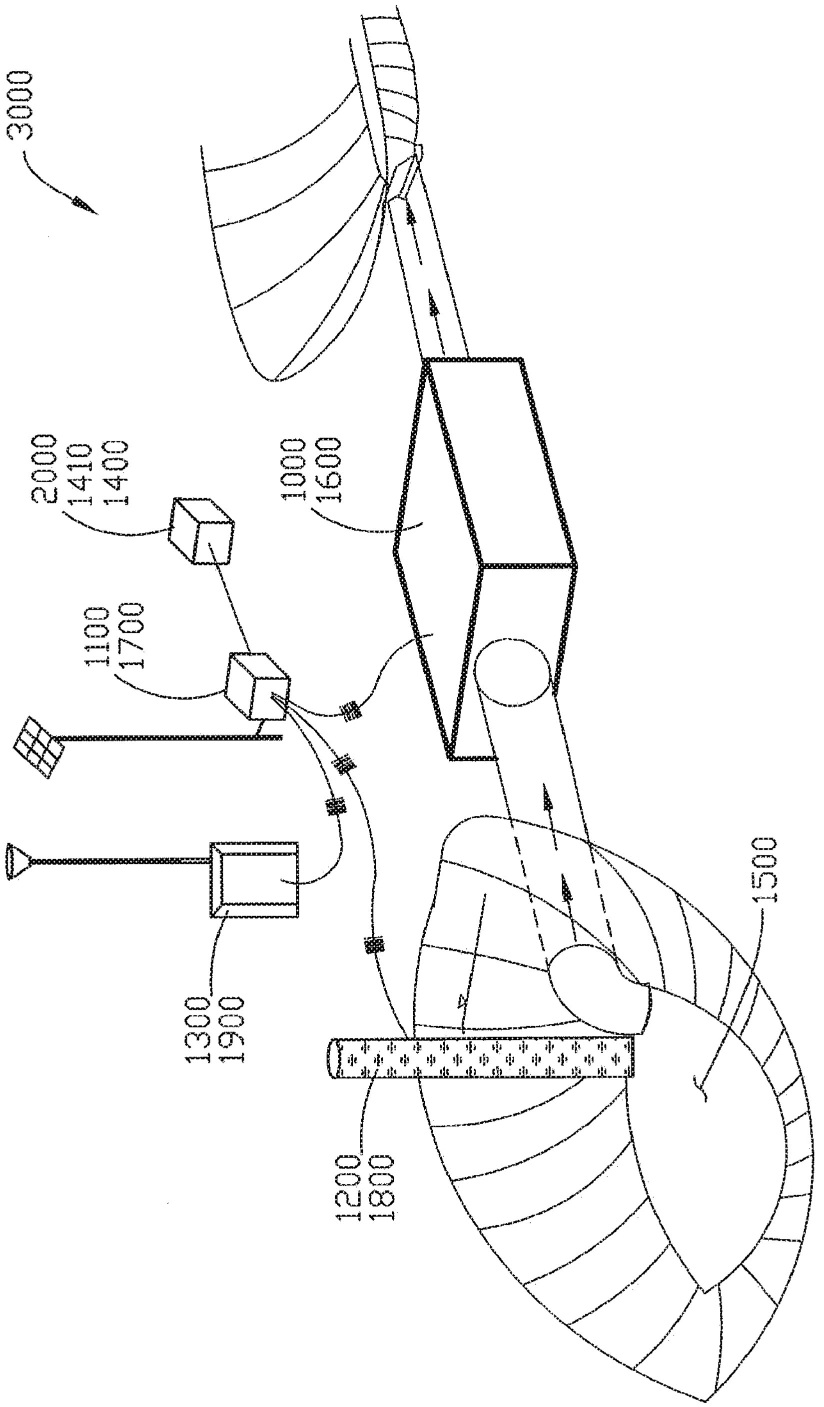

3000
2000
1410
1400
1000
1600
1100
1700
1300
1900
1200
1800
1500

FIG. 8

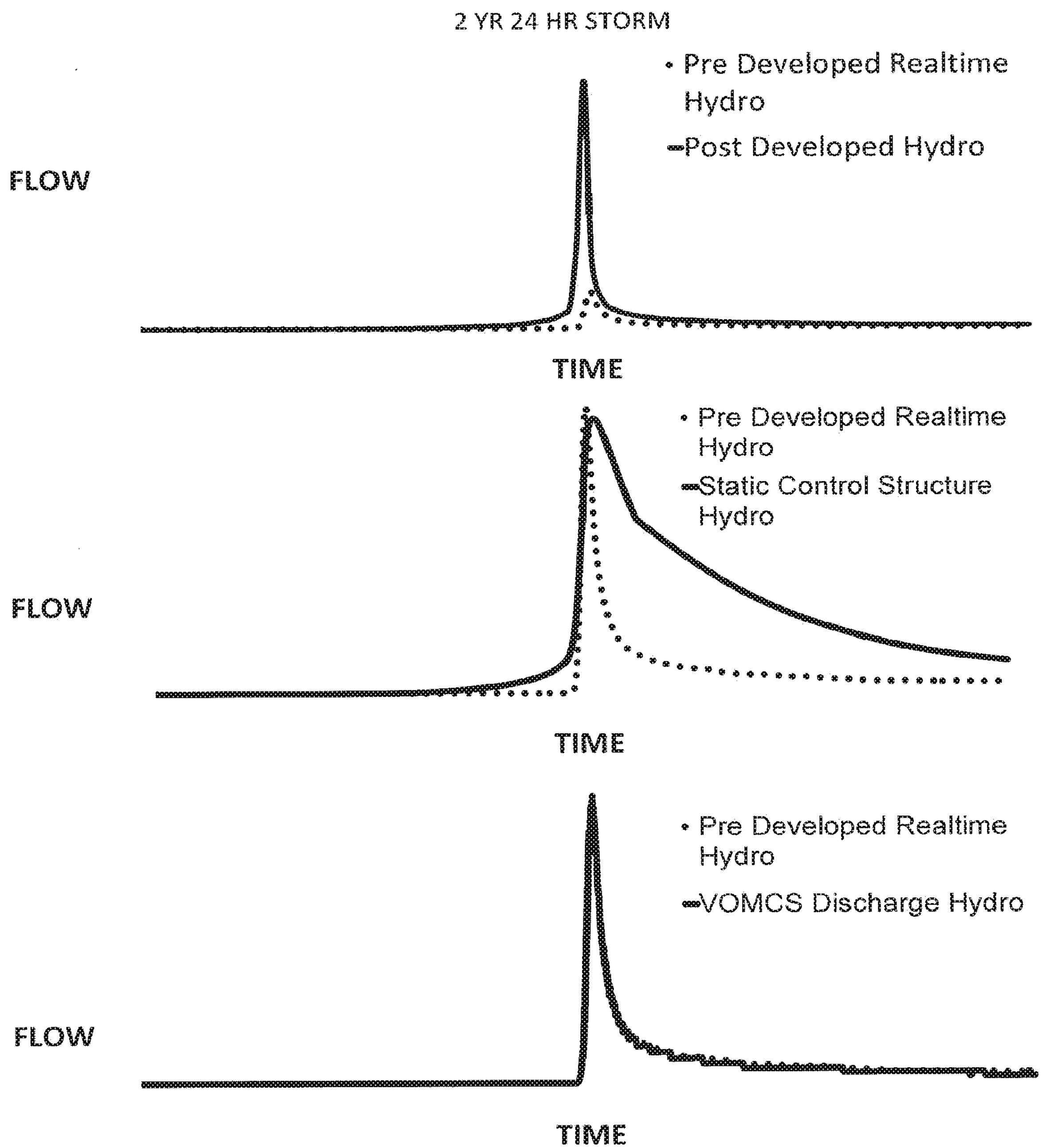

2 YR 24 HR STORM
Pre Developed Realtime Hydro
Post Developed Hydro
FLOW
TIME
Pre Developed Realtime Hydro
Static Control Structure Hydro
FLOW
TIME
Pre Developed Realtime Hydro
VOMCS Discharge Hydro
FLOW
TIME

FIG. 9

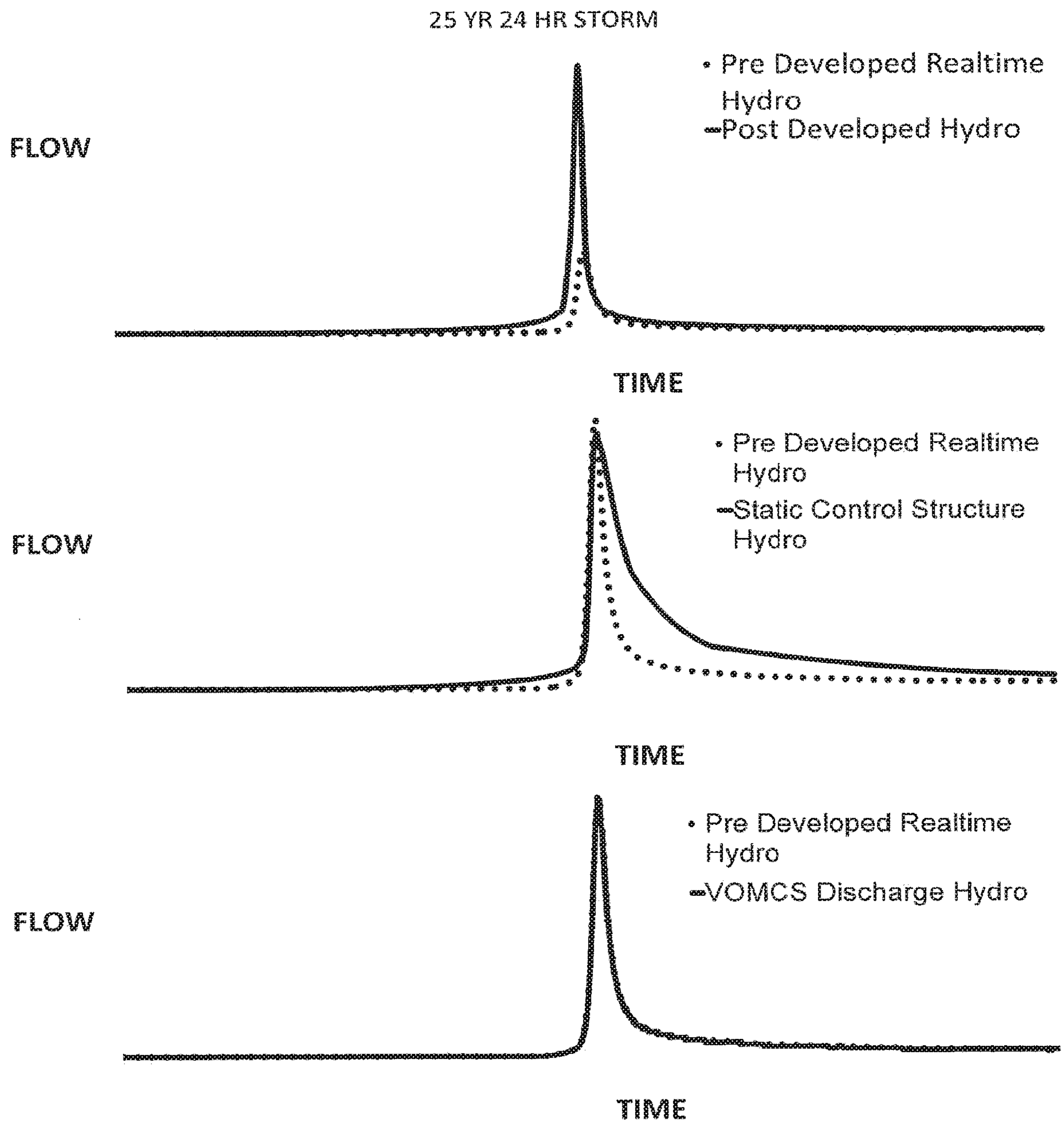

25 YR 24 HR STORM
FLOW
TIME
Pre Developed Realtime Hydro
Post Developed Hydro
FLOW
TIME
Pre Developed Realtime Hydro
Static Control Structure Hydro
FLOW
TIME
Pre Developed Realtime Hydro
VOMCS Discharge Hydro

FIG. 10

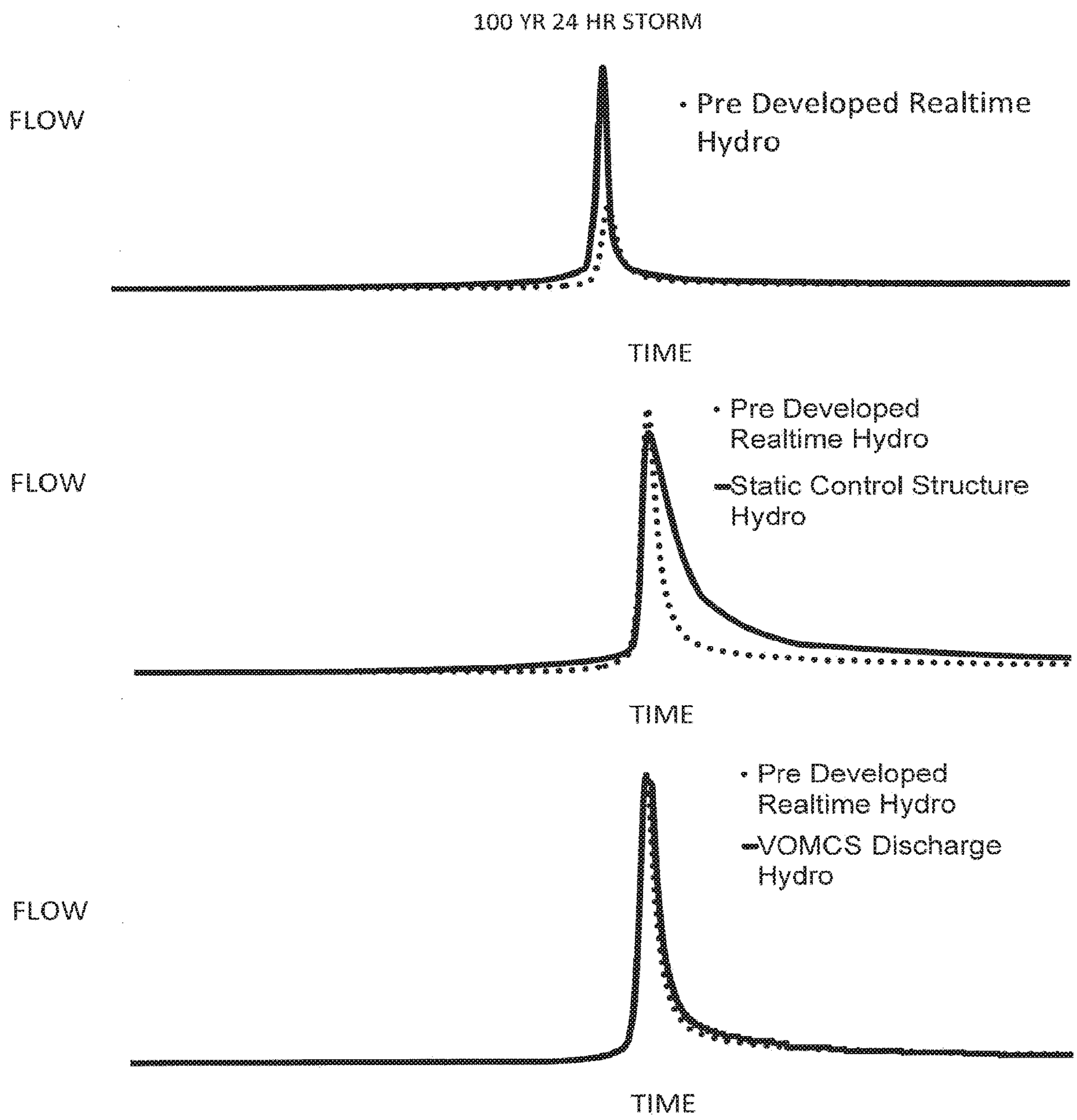

100 YR 24 HR STORM
FLOW
Pre Developed Realtime Hydro
TIME
FLOW
Pre Developed Realtime Hydro
Static Control Structure Hydro
TIME
FLOW
Pre Developed Realtime Hydro
VOMCS Discharge Hydro
TIME

FIG. 11

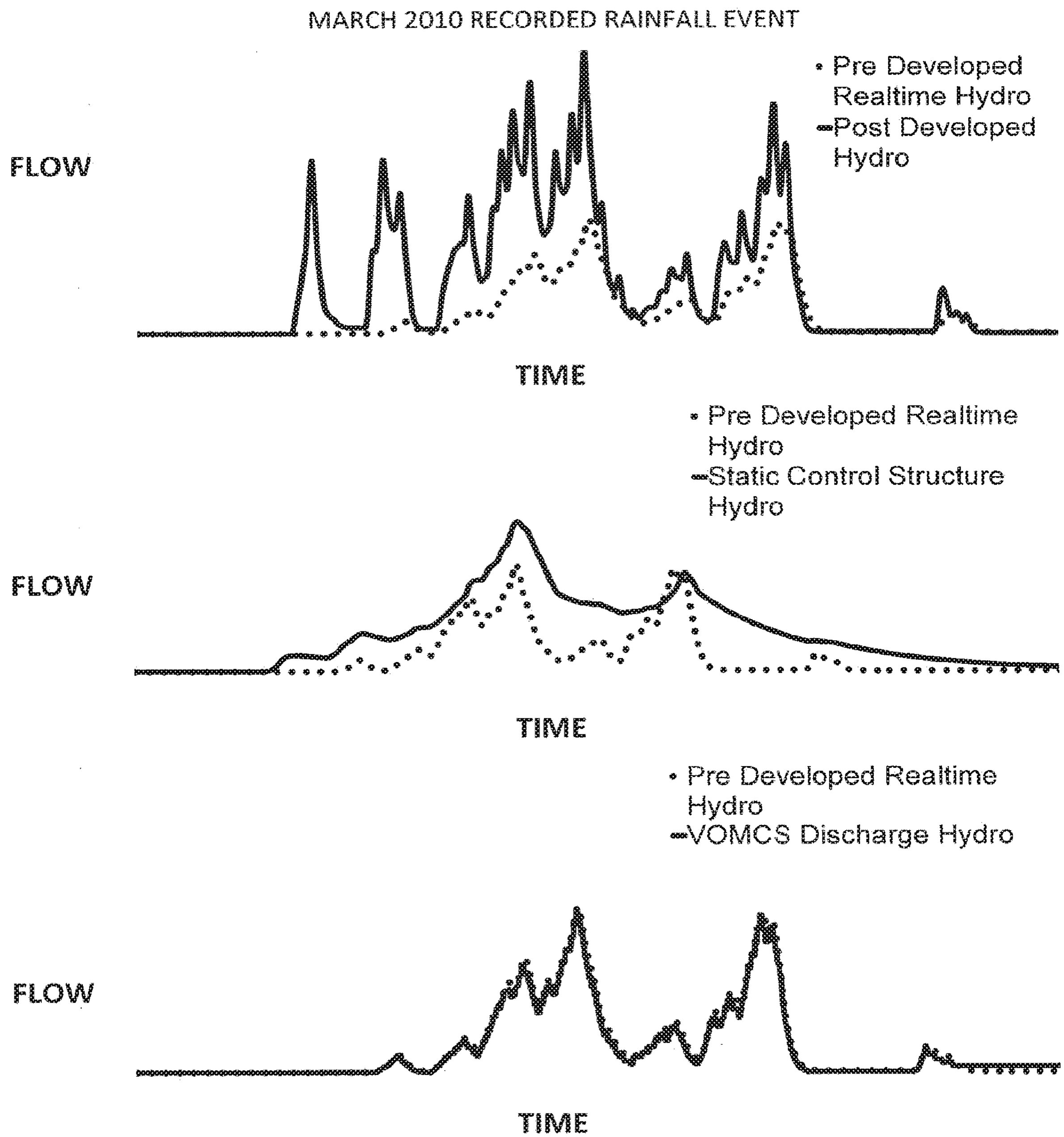

MARCH 2010 RECORDED RAINFALL EVENT
Pre Developed Realtime Hydro
Post Developed Hydro
FLOW
TIME
Pre Developed Realtime Hydro
Static Control Structure Hydro
FLOW
TIME
Pre Developed Realtime Hydro
VOMCS Discharge Hydro
FLOW
TIME

FIG. 12

METHOD FOR FLOOD CONTROL

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is a continuation of U.S. patent application Ser. No. 15/164,569, filed May 25, 2016 (pending). U.S. patent application Ser. No. 15/164,569 is a divisional of U.S. patent application Ser. No. 14/127,329, filed Dec. 18, 2013 (now U.S. Pat. No. 9,400,085). U.S. patent application Ser. No. 14/127,329 is a national stage under 35 U.S.C. 371 of International Application PCT/US2013/73671, filed on Dec. 6, 2013 (currently published). International Application PCT/US2013/73671 cites the priority of U.S. Patent Application 61/739,555, filed Dec. 19, 2012 (expired).

BACKGROUND

A. Field of the Disclosure

[0002] The present disclosure relates generally to flood control. More specifically, the disclosure relates to the control of the discharge of flood waters from a source body of water.

B. Background

[0003] Controlling the effects of flood events has long been an engineering challenge. The development of agricultural areas or wild areas inevitably changes the patterns of runoff into streams during rainfall events. During the course of development permeable soil is covered with buildings and roads, which are impermeable to water. As a result, the flow of water that hits the ground as precipitation is not slowed by percolation into the ground. This causes runoff to enter rivers and streams at very high rates of volumetric discharge in developed areas. The attendant runoff problems can cause flooding of downstream areas, erosion, and non-point source pollution of rivers and streams.

[0004] The conventional approach to controlling runoff from precipitation events is to provide a static flood control structure. In the absence of flood control structures, runoff from a developed area will usually occur at an extremely high initial rate ("peak flow") and then decline abruptly. Static flood control structures, such as dams and weirs, reduce the peak flow rate and cause the flow to taper off slowly.

[0005] Static control structures typically consist of a fixed opening that is designed to restrict the discharge flow rate for a hypothetical design storm event. Of course, a design storm event will never occur. Design storms are based on statistical data compiled over the course of several years from weather stations and other sources. One commonly used process for developing the design storm events is described in a document published by the United States Department of Commerce prepared for the Natural Resources Conservation Service, often referred to as Technical Paper 40 (TP40), published May 1961. This document is widely used for controlling storm water runoff for post-developed watersheds.

[0006] Although static controls reduce the impacts of development significantly, they do not emulate the natural pre-development flow patterns in response to precipitation. The standard of practice in site development is to restrict the post-developed peak flow rate to pre-developed peak flow rate conditions for a hypothetical design storm event. This results in gradual decline in the recession limb of the hydrograph consequently resulting in higher discharge velocities and higher discharge flow rates over the duration of the storm event.

[0007] Natural flow patterns are more desirable than the types of less attenuated patterns that static control structures provide. In addition to reducing erosion, downstream flooding, and non-point source pollution, natural flow patterns serve to maintain waterlogged (hydric) soils that form and maintain wetlands. The wetlands in turn mitigate floods, remove pollutants, and spawn wildlife. Static control structures cannot emulate natural flow. The natural flow patterns from a given drainage area are the result of many complex interacting factors, such as heterogeneous soil porosity, the presence (or absence) of impermeable soil layers, and topography. Furthermore, natural flow patterns will vary with the severity of a precipitation event. Current control structure designs are generated from idealized "design storm events." Design storm events are created from hypothetical methods calculated from historical data. These data, being generated by mathematical models, may not reflect the variations of depth, intensity, and durations of actual precipitation events. Furthermore, the rate of discharge of static control structures is a direct function to the hydrostatic pressure (also known as "head," which is directly related to depth) in the detention body, making it impossible to replicate pre-developed hydrology.

[0008] Consequently there is a need in the art to provide natural flow patterns even after areas have been developed.

SUMMARY

[0009] A dynamic fluid flow control structure **1** is provided which provides incremental flow control (as opposed to continuous flow control). In a general embodiment, the fluid flow control structure **1** comprises: a conduit **100** through which the fluid flows; an upstream reconfigurable barrier **200** in the conduit **100**, the upstream barrier **200** comprising an upstream orifice **210**, and the upstream barrier **200** capable of assuming a first upstream configuration and a second upstream configuration; a downstream barrier **300** in the conduit **100**, the downstream barrier **300** comprising a downstream orifice **310**; wherein the upstream orifice **210** restricts the flow of the fluid more than does the downstream orifice **310** when the upstream barrier **200** assumes the first configuration, and wherein the upstream orifice **210** restricts the flow of the fluid no more than does the downstream orifice **310** when the upstream barrier **200** assumes the second configuration.

[0010] Another general embodiment the fluid flow control structure **1** comprises a means for providing a first orifice **600** in the path of the fluid flow; a means for providing a second orifice **700** orifice larger than the first orifice in the path of the fluid flow downstream from the first orifice; and a structure selected from the group consisting of: (i) a means for expanding the first orifice **800** to a size greater than the size of the second orifice; and (ii) a means for removing the first orifice **900** from the path of the fluid flow.

[0011] A method of controlling fluid flow through a conduit **100** is provided, wherein the conduit **100** comprises an upstream orifice **210** and a downstream orifice **310**, the method comprising: reconfiguring the upstream orifice **210** from a configuration in which the upstream orifice **210** reduces the flow of the fluid more than does the downstream orifice **310** to a configuration in which the upstream orifice **210** reduces the flow of the fluid no more than does the downstream orifice **310**.

[0012] A flood control system **3000** is provided. A general embodiment of the flood control system **3000** comprises means for variably controlling the rate of volumetric discharge **1600** from an intake point to a release point; means for automated control **1700** of the means for variably controlling the rate of volumetric discharge **1600**; means for measuring the water level **1800** at the intake point that transmits water level data to the means for automated control **1700**; means for measuring rainfall **1900** that transmits rainfall data to the means for automated control **1700**; and means for storing a storm discharge function **1410** that is readable by the means for automated control **1700**.

[0013] Another general embodiment of the flood control system **3000** comprises a flow control structure **1000** configured to variably control the rate of volumetric discharge from an intake point to a release point; a computing device **1100** in control of the flow control structure **1000**; a water level meter **1200** positioned to measure the water level at the intake point and configured to transmit water level data to the computing device **1100**; a rain gauge **1300** configured to transmit rainfall data to the computing device **1100**; and a machine-readable data storage device **1400** comprising a storm discharge function **1410**, wherein the machine-readable data storage device **1400** is configured to be read by the computing device **1100**.

[0014] A process for controlling discharge from a body of water during a storm event is provided, the process comprising: reading a storm discharge function **1410** from a machine-readable storage device, wherein the storm discharge function **1410** sets a rate of volumetric discharge as a function of rainfall rate; computing a target rate of volumetric discharge by plugging a rainfall rate value into the function; and configuring a flow control structure **1000** to provide approximately the target rate of volumetric discharge from the body of water. A machine-readable storage device is provided containing a program which when read by a computing device causes the computing device to perform this process.

[0015] The above presents a simplified summary in order to provide a basic understanding of some aspects of the claimed subject matter. This summary is not an extensive overview. It is not intended to identify key or critical elements or to delineate the scope of the claimed subject matter. Its sole purpose is to present some concepts in a simplified form as a prelude to the more detailed description that is presented later.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. **1**: A cross-sectional illustration of an embodiment of the dynamic flood control structure **1**.

[0017] FIG. **2**: An illustration of the longitudinal cross-section from FIG. **1** (labeled FIG. **2**).

[0018] FIG. **3**: An illustration of the longitudinal cross-section from FIG. **1** (labeled FIG. **3**).

[0019] FIG. **4**: A perspective view of an embodiment of the reconfigurable barriers comprising two retractable sections **220**, the view showing only one section of each barrier and not showing the rest of the flood control structure **1**.

[0020] FIG. **5**: A perspective view of an embodiment of a single reconfigurable barrier, which serve as the upstream reconfigurable barrier **200/600** or the intermediate reconfigurable barrier **400**; not showing the rest of the flood control structure **1**.

[0021] FIG. **6**: An exploded view of the embodiment of the reconfigurable barrier shown in FIG. **5**.

[0022] FIG. **7**: A frontal plan view of an embodiment of the dynamic flood control structure showing a series **500** of intermediate reconfigurable barriers **400** in their expanded configurations, such that the intermediate orifices are all larger than the downstream orifice **310**.

[0023] FIG. **8**: A perspective view of en embodiment of the flood control system.

[0024] FIG. **9**: Modeled results of discharge over time from a retaining body to a receiving water during a two-year storm event in a developed basin that was previously undeveloped. The top frame compares uncontrolled post-developed discharge to pre-developed discharge. The middle frame shows a comparison of post-developed discharge controlled by a static flood control structure to pre-developed discharge. The bottom frame shows a comparison of post-developed discharge controlled according to an embodiment of the flood control method provided in this application to pre-developed discharge.

[0025] FIG. **10**: Modeled results of discharge over time for the same drainage basin as in FIG. **9**, but for a 25-year storm event. The top frame compares uncontrolled post-developed discharge to pre-developed discharge. The middle frame shows a comparison of post-developed discharge controlled by a static flood control structure to pre-developed discharge. The bottom frame shows a comparison of post-developed discharge controlled according to an embodiment of the flood control method provided in this application to pre-developed discharge.

[0026] FIG. **1***i*: Modeled results of discharge over time for the same drainage basin as in FIGS. **9** and **10**, but for a 100-year storm event. The top frame compares uncontrolled post-developed discharge to pre-developed discharge. The middle frame shows a comparison of post-developed discharge controlled by a static flood control structure to pre-developed discharge. The bottom frame shows a comparison of post-developed discharge controlled according to an embodiment of the flood control method provided in this application to pre-developed discharge.

[0027] FIG. **12**: Modeled results and actual measurements of a historical storm event for the same developed drainage basin as in FIGS. **9-11**. The top frame compares uncontrolled post-developed discharge to pre-developed discharge. The middle frame shows a comparison of post-developed discharge controlled by a static flood control structure to pre-developed discharge. The bottom frame shows a comparison of post-developed discharge controlled according to an embodiment of the flood control method provided in this application to pre-developed discharge.

DETAILED DESCRIPTION

A. Definitions

[0028] With reference to the use of the word(s) "comprise" or "comprises" or "comprising" in the foregoing description and/or in the following claims, unless the context requires otherwise, those words are used on the basis and clear understanding that they are to be interpreted inclusively, rather than exclusively, and that each of those words is to be so interpreted in construing the foregoing description and/or the following claims.

[0029] The terms "about" or "approximately" mean within a range of reasonable error around a central value. Such reasonable error may for example stem from the precision of an instrument or method used to measure the value. The error could also stem from the precision of a method of making a composition, such as the ability to measure particular ingredients within a margin of error.

[0030] The term "machine-readable data storage device" or "data storage device" as used herein refers to a machine-readable device that retains data that can be read by mechanical, optical, or electronic means, for example by a computer. Such devices are sometimes referred to as "memory," although as used herein a machine-readable data storage device cannot comprise a human mind in whole or in part, including human memory. A storage device may be classified as primary, secondary, tertiary, or off-line storage. Examples of a storage device that is primary storage include the register of a central processing unit, the cache of a central processing unit, and random-access memory (RAM) that is accessible to a central processing unit via a memory bus (generally comprising an address bus and a data bus). Primary storage is generally volatile memory, which has the advantage of being rapidly accessible. A storage device that is secondary storage is not directly accessible to the central processing unit, but is accessible to the central processing unit via an input/output channel. Examples of a storage device that is secondary storage include a mass storage device, such as a magnetic hard disk, an optical disk, a drum drive, flash memory, a floppy disk, a magnetic tape, an optical tape, a paper tape, and a plurality of punch cards. A storage device that is tertiary storage is not connected to the central processing unit until it is needed, generally accessed robotically. Examples of a storage device that is tertiary storage may be any storage device that is suitable for secondary storage, but configured such that it is not constantly connected to the central processing unit. A storage device that is off-line storage is not connected to the central processing unit, and does not become so connected without human intervention. Examples of a storage device that is off-line storage may be any storage device that is suitable for secondary storage, but configured such that it is not constantly connected to the central processing unit, and does not become so connected without human intervention. Secondary, tertiary, and offline storage are generally non-volatile, which has the advantage of requiring no source of electrical current to maintain the recorded information.

[0031] The term "machine-readable media" as used herein refers to a medium of storing information that is configured to be read by a machine. Such formats include magnetic media, optical media, and paper media (punch cards, paper tape, etc.). Printed writing in a human language, if not intended or configured to be read by a machine, is not considered a machine readable format. In no case shall a human mind be construed as "machine readable format."

[0032] Neither a storage device nor machine-readable media can be construed to be a mere signal, although information may be communicated to and from a storage device or machine-readable media via a signal.

[0033] The term "database" as used herein refers to an organized data structure comprising a plurality of records stored in machine-readable format.

[0034] The term "variable" as used herein refers to a symbolic name corresponding to a binary value stored at a given memory address on a data storage device (although this address may change). The binary value may represent information of many types, such as integers, real numbers, Boolean values, characters, and strings, as is understood in the art. As used herein the value of a variable is always stored in a data storage device, and shall not be construed to refer to information only stored in a human mind. Any recitation of a variable implicitly requires the use of a data storage device.

[0035] The terms "about" or "approximately" mean within a range of reasonable error around a central value. Such reasonable error may for example stem from the precision of an instrument or method used to measure the value. The error could also stem from the precision of a method of making a component of a device.

B. Fluid Flow Control Structure

[0036] A dynamic fluid flow control structure **1** is provided. In a general embodiment (and as illustrated in FIGS. **1-7**), the structure comprises a series of barriers each comprising an orifice, the orifices decreasing in the degree to which they restrict flow as a function of pressure, in the direction of the flow (from the upstream-most orifice to the downstream-most orifice). This restriction in flow is a function of the size of the orifice, the shape of the orifice, or both. The structure functions to control the volumetric rate of flow (also known as "discharge," Q) by directing the fluid flow through a more restrictive orifice (either of smaller size or of a shape that restricts flow) that is upstream of one or more less restrictive orifices (larger or of less restrictive shape). The flow of the fluid will be a function of change in hydrostatic head (h) between the upstream and downstream end of the structure, the diameter (D) of the most restrictive orifice through which the fluid must flow, and the cross-sectional area (A) of the most restrictive orifice through which the fluid must flow. To increase Q at a given h, the most restrictive orifice in the structure is effectively removed. In this context "effectively removed" means that the most restrictive orifice is either expanded in size or altered in shape such that it is no longer the most restrictive orifice in the structure, or the most restrictive orifice may be removed entirely from the device (for example by moving the barrier in which the orifice resides out of the flow of the fluid). This will effectively increase D or A for the orifice (or both), which will increase Q at a given h.

[0037] The basic physics of the control structure are provided below. Although the description provided below assumes that the structure is used to control flow from an open body of water to an unsubmerged receiving point, it should be understood that the uses of the control structure are not limited to such scenarios.

[0038] Flows that do not submerge the receiving point may be modeled as weir flow and such flows are considered an "unsubmerged condition." Without wishing to be bound by any given hypothetical model, the equation for unsubmerged orifice flow for the structure is:

$$Q=A\,D^{0.5}\{(h-H_C-C_sD)(KD)^{-1}\}^{(l/m)} \quad \text{eq. 1}$$

[0039] A=cross-sectional area of the orifice;

[0040] D=diameter of the orifice;

[0041] h=depth of source water,

[0042] H_c=specific energy at critical depth ($H_c=Y_c+V^2/2g$);

[0043] C_s=slope correction factor,

[0044] K, m=constants determined by the shape of the orifice.

[0045] Equation 1 is found in the United States Federal Highway Administration publication "Hydraulic Design of Highway Culverts" HDS-5. During unsubmerged conditions the depth of flow just past the orifice reaches critical depth. Under conditions in which the orifice is completely submerged flow through the orifice can be modeled as follows:

$$Q=C_d A(2g\,h)^{0.5} \quad \text{eq. 2}$$

in which C_d is the coefficient of discharge and g is acceleration due to gravity. Under more generalized circumstances, when flow is driven by a pressure differential between two ends of the conduit, submerged orifice flow can be modeled as follows:

$$Q=C_d A(2\,\Delta P/\rho)^{0.5} \quad \text{eq. 3}$$

in which ΔP is the difference in pressure between the inlet and the outlet of the structure and in which ρ is the density of the fluid. Assuming the orifice is of constant size and shape, and assuming that the slope of the conduit is also constant, discharge is a function of the depth of the source water. When the source water is at a given depth, discharge can be modulated by changing the size of the orifice, the shape of the orifice, or both.

[0046] In the above equation Q is proportional to the cross-sectional area A of the orifice such that as Q increases the orifice diameter increases. Using an orifice with a given area and shape, assuming that the density of the water is constant (which is true under the conditions relevant to flood control applications), Q becomes a function of the depth of the source water. Under conditions in which the depth of the source water is constant, and the size of the orifice may be varied (but the shape does not vary), Q will be a function of cross-sectional area of the orifice.

[0047] These properties can be used to regulate discharge in a flow control structure **1** comprising a plurality of barriers each having an orifice of roughly the same shape, in which each orifice has a minimum size which is smaller than the minimum size of the next orifice downstream in the series. Discharge from the structure is dependent only on the size of the smallest orifice through which the fluid flows. Because the structure varies the smallest orifice size incrementally by effectively removing the smallest orifice in the series, the structure will vary discharge incrementally, as opposed to continuously. Of course, the same type of control could be achieved by providing orifices of varying shapes (or of varying shapes and sizes), although such structures would be more complex in design.

[0048] Conventional designs for variably controlling flow rely on flow control devices that constantly vary discharge by constantly varying the size of an opening through which the fluid flows, such as valves and gates. A consequence of this approach is that in order to precisely determine discharge, one must know the precise degree to which the valve or gate is open (more accurately, one must precisely know the size and shape of the opening created by the valve or gate). It is very difficult to monitor the exact degree to which a valve or gate is open without the use of a sensor. In addition, sensors often require periodic calibration if they are to provide accurate measurements. If the exact degree to which the valve or gate is open cannot be readily ascertained, then the resulting discharge cannot be predicted with any degree of precision. Those embodiments of the structure that provide incremental control of discharge provide a technologically simple means to control discharge with greater precision. Some embodiments of the structure function to control the flow of a liquid. The liquid may be an incompressible liquid, water being one example.

[0049] In all general embodiments, as many barriers will be present as necessary to provide the desired range of discharge. Some embodiments of the structure **1** comprise one barrier. Other embodiments comprise two or more barriers. Specific embodiments comprise at least 3, at least 4, and at least 16 barriers. In a further specific embodiment the structure comprises at least 36 barriers. In a further specific embodiment the structure comprises at least 72 barriers. In some embodiments of the device the orifices increase in diameter in the downstream direction by an approximately uniform increment; the increment may be, for example, about ½"-6" (or exactly this range). The increment may be any sub-range of ½"-6". In a specific embodiment the increment is ½".

[0050] A general embodiment of the structure **1** comprises a fluid conduit **100** through which the fluid flows; an upstream reconfigurable barrier **200** in the conduit **100**, the upstream barrier **200** comprising an upstream orifice **210**, and the upstream barrier **200** capable of assuming a first upstream configuration and a second upstream configuration; a downstream barrier **300** in the conduit **100**, the downstream barrier **300** comprising a downstream orifice **310**; wherein the upstream orifice **210** restricts the flow of the fluid more than does the downstream orifice **310** when the upstream barrier **200** assumes the first configuration, and wherein the upstream orifice **210** restricts the flow of the fluid no more than does the downstream orifice **310** when the upstream barrier **200** assumes the second configuration.

[0051] An alternate general embodiment of the structure comprises means for providing a first orifice **600** in the path of the fluid flow; means for providing a second orifice **700** larger than the first orifice **600** in the path of the fluid flow downstream from the first orifice; and a structure selected from the group consisting of: (i) means for expanding the first orifice **800** to a size greater than the size of the second orifice; and (ii) means for removing the first orifice **900** from the path of the fluid flow. The means for providing the first orifice **600** may be, for example, the upstream barrier **200**. The means for providing the second orifice **700** may be, for example, the downstream barrier **300**. The means for expanding the first orifice **800** may be any suitable structure described below; and the means for removing the first orifice **900** may be any suitable structure described below.

[0052] In this context a first orifice "restricts" the flow of the fluid more than another orifice if the discharge of the fluid through the first orifice (Q_1) is lower than the discharge of the fluid though the other orifice (Q_2) under otherwise identical conditions (i.e., same ΔP, same conduit 100 diameter, same C_d, same depth of the source water). Under conditions in which equation 2 controls, a first orifice "restricts" the flow of the fluid more than another orifice if the C_dA value of the first orifice is smaller than the C_dA value of the other orifice. If both orifices are of the same shape, the first orifice will have a smaller diameter and a smaller cross-sectional area than the other orifice. Thus, in some embodiments of the structure, the upstream orifice **210** has a lesser upstream C_dA value when the upstream barrier

200 assumes the first upstream configuration; the upstream orifice 210 has a greater upstream CA value when the upstream barrier 200 assumes the second upstream configuration; the downstream orifice 310 has a downstream C_dA value; the lesser upstream C_dA value is smaller than the greater upstream C_dA value; the lesser upstream C_dA value is less than the downstream C_dA value; and the greater upstream C_dA value is not less than the downstream C_dA value.

[0053] Some embodiments of the upstream orifice **210** will be designed to vary in size so as to control fluid flow. In such embodiments the upstream orifice **210** is a contracted upstream size when the upstream barrier **200** assumes the first upstream configuration; the upstream orifice **210** is an expanded upstream size when the upstream barrier **200** assumes the second upstream configuration; the downstream orifice **310** is a downstream orifice **310** size; the contracted upstream size is smaller than the expanded upstream size; the contracted upstream size is smaller than the downstream orifice **310** size; and the expanded upstream size is no smaller than the downstream orifice **310** size. The shape of the upstream orifice **210** and the downstream orifice **310** will have about the same ratio of diameter to cross-sectional area in some such embodiments (resulting in about the same C_dA if the two orifices are about the same size). In these embodiments the upstream barrier **200** is reconfigured to increase or decrease the size of the upstream orifice **210**. This can be accomplished by various means of expanding and contracting an orifice as known in the art. For example, the upstream orifice **210** may be expanded and contracted using an iris valve or a gate valve.

[0054] Specific embodiments of the reconfigurable upstream barrier **200** comprise a plurality of retractable sections **220**. The sections are "retractable" in that they may be retracted away from one another to increase the size of the orifice (and in most embodiments the retractable sections **220** can then be extended toward one another). The upstream reconfigurable barrier **200** may comprise two retractable sections **220**. Some versions of the upstream barrier **200** can be reconfigured such that the two retractable sections **220** are retracted at least partially from the conduit **100** in the second upstream configuration and are fully extended into the conduit **100** in the first upstream configuration.

[0055] In some embodiments the retractable sections **220** themselves will at least partially define the rim of the orifice. In some such embodiments, the upstream reconfigurable barrier **200** comprises two retractable sections **220** that are retracted at least partially from the conduit **100** in the second upstream configuration and that are fully extended into the conduit **100** in the first upstream configuration; and each of the two retractable sections **220** define a portion of the perimeter of the upstream orifice **210**. Each of the two retractable sections **220** may define half of the perimeter of the upstream orifice **210**. In a specific embodiment the upstream reconfigurable barrier **200** comprises two retractable sections **220** that each define a semicircular portion of a circular orifice **210** such that when extended into contact with one another, they create a circular orifice in the barrier **200**. In other related embodiments the retractable sections **220** each define half of an orifice **210** of another shape, for example an orifice that is a rectangle, square, polygon, oval, or an ellipse. If the reconfigurable barrier **200** comprises more than two retractable sections **220**, then each retractable section **220** may define a portion of the perimeter of the orifice **210**. In some embodiments each of the more than two retractable sections **220** will define an equal fraction of the portion of the perimeter of the orifice **210**. For example, if three retractable sections **220** are used they may each define one third of the perimeter of the orifice **210**; if four retractable sections **220** are used they may each define one quarter of the perimeter of the orifice **210**; and so on.

[0056] The sections **220** may be extended and retracted by any means known in the art. For example, given sections **220** may be slid toward and away from one another in a direction perpendicular to the direction of flow. Such embodiments have the advantage of never moving the sections **200** against the flow of the fluid. The sections **220** may be slid along tracks that are recessed in the conduit **100**. In a specific embodiment the reconfigurable barrier comprises two retractable sections **220**, each of which is connected to a threaded rod that may be rotated in either direction to retract or extend each section **220**.

[0057] In some embodiments of the reconfigurable barrier **200** in which the upstream orifice **210** assumes a contracted and expanded size (in the first and second configurations, respectively), the upstream orifice **210** is maximally contracted in the first upstream configuration. In some embodiments, the upstream orifice **210** is maximally expanded in the second upstream configuration. In more specific embodiments the upstream orifice **210** is maximally contracted in the first upstream configuration and the upstream orifice **210** is maximally expanded in the second upstream configuration. In such embodiments the orifice can be placed in the first configuration by contracting it as much as possible, and placed in the second configuration by expanding it as much as possible. This eliminates the need to assess the degree to which the orifice **210** is expanded or contracted in order to determine the extent to which the orifice **210** restricts the flow of the fluid. In some embodiments of the structure, the upstream reconfigurable barrier **200** is inserted into the conduit **100** when in the first upstream configuration and the upstream reconfigurable barrier **200** is withdrawn from the conduit **100** when in the second upstream configuration. Thus, instead of varying the size or shape of the orifice **210**, the barrier **200** is reconfigured by removing the barrier **200** and the orifice **210** from the conduit **100** altogether.

[0058] Some embodiments of the structure **1** comprise an intermediate reconfigurable barrier **400**. Such embodiments comprise an intermediate reconfigurable barrier **400** in the conduit **100** between the upstream barrier **200** and the downstream barrier **300**. The intermediate barrier **400** comprises an intermediate orifice **410**, and the intermediate barrier **400** is capable of assuming a first intermediate configuration and a second intermediate configuration. The intermediate orifice **410** restricts the flow of the fluid more than does the downstream orifice **310** when the intermediate barrier **400** assumes the first configuration. The intermediate orifice **410** restricts the flow of the fluid no more than does the downstream orifice **310** when the intermediate barrier **400** assumes the second configuration. The upstream orifice **210** restricts the flow of the fluid more than does the intermediate orifice **410** when the upstream barrier **200** assumes the first configuration and the intermediate barrier **400** assumes the first configuration. The upstream orifice **210** restricts the flow of the fluid no more than does the intermediate orifice **410** when the upstream barrier **200** assumes the second configuration and the intermediate orifice **410** assumes the first configuration. Consequently, the intermediate barrier **400** can function to provide an intermediate level of flow control (allowing less flow than the upstream barrier **200**, but more than the downstream barrier **300**).

[0059] Some embodiments of the intermediate barrier **400** can be reconfigured to expand or contract the size of the intermediate orifice **410**. In such embodiments of the intermediate barrier **400**, the intermediate orifice **410** is a contracted intermediate size when the intermediate barrier **400** assumes the first intermediate configuration, and the intermediate orifice **410** is an expanded intermediate size when the intermediate barrier **400** assumes the second intermediate configuration. In some embodiments of the device in which the intermediate orifice **410** may be expanded or contracted, the upstream orifice **210** is a contracted upstream size when the upstream barrier **200** assumes the first upstream configuration, and the upstream orifice **210** is an expanded upstream size when the upstream barrier **200** assumes the second upstream configuration. The downstream orifice **310** can be said to have a downstream orifice **310** size. The contracted upstream size is smaller than the expanded upstream size. The contracted intermediate size is smaller than the expanded intermediate size. The contracted upstream size is smaller than the contracted intermediate size. The contracted intermediate size is smaller than the downstream orifice **310** size. The expanded upstream size is no smaller than the downstream orifice **310** size. The expanded intermediate size is no smaller than the downstream orifice **310** size. Thus, neither the upstream **210** nor intermediate **410** orifices in their expanded configurations are smaller than the downstream orifice **310**, although both are smaller in their contracted configurations than the downstream orifice **310**. When the intermediate orifice **410** is contracted it is larger than the upstream orifice **210** when it is contracted.

[0060] In the above description, the C_dA value can serve to replace any mention of "size," although it is to be understood that the C_dA value can be affected by shape as well as by size. Taking into consideration the role of the C_dA value in determining the rate of discharge through an orifice, in some embodiments of the structure the upstream orifice **210** has a lesser upstream C_dA value when the upstream barrier **200** assumes the first upstream configuration, and the upstream orifice **210** has a greater upstream C_dA value when the upstream barrier **200** assumes the second upstream configuration. The lesser upstream C_dA value is smaller than the greater upstream C_dA value. The downstream orifice **310** may be said to have a downstream C_dA value. The intermediate orifice **410** has a lesser intermediate C_dA value when the intermediate barrier **400** assumes the first intermediate configuration; and a greater intermediate C_dA value when the intermediate barrier **400** assumes the second intermediate configuration. The lesser intermediate C_dA value is smaller than the greater intermediate C_dA value. The lesser upstream C_dA value is smaller than the lesser intermediate C_dA value; the lesser intermediate C_dA value is smaller than the downstream C_dA value; the greater upstream C_dA value is no smaller than the downstream C_dA value; and the greater intermediate C_dA value is no smaller than the downstream C_dA value.

[0061] In an alternative embodiment of the intermediate barrier **400**, the intermediate reconfigurable barrier **400** is inserted into the conduit **100** when in the first intermediate configuration and the intermediate reconfigurable barrier **400** is withdrawn from the conduit **100** when in the second intermediate configuration. As described for the upstream barrier **200** above, in these embodiments the barrier is simply removed from the fluid flow instead of being reconfigured to change the size or shape of the orifice.

[0062] Some embodiments of the structure comprise a series **500** of reconfigurable intermediate barriers **400** between the upstream **200** and downstream **300** barriers each comprising an intermediate orifice **410**. In such embodiments each of the intermediate barriers **400** have a first intermediate configuration, a second intermediate configuration, and a given intermediate orifice **410** restricts the flow of the fluid more than does the orifice immediately downstream when the given intermediate barrier **400** assumes the first intermediate configuration. The given intermediate orifice **410** reduces the flow of the fluid no more than does the orifice immediately downstream when the given intermediate barrier **400** assumes the second configuration. Such embodiments of the device allow incremental control of the rate of discharge of the fluid through the conduit **100** by reconfiguring each intermediate barrier **400** as needed such that the upstream-most intermediate barrier **400** restricts the flow to a greater extent than any barrier downstream.

[0063] As in the intermediate barrier **400** described above, each of the series of intermediate barriers **400** may be reconfigured by expanding or contracting the orifice. In some embodiments of the structure each intermediate orifice **410** is a contracted intermediate size when the intermediate barrier **400** assumes the first intermediate configuration and each intermediate orifice **410** is an expanded intermediate size when the intermediate barrier **400** assumes the second intermediate configuration. In such embodiments the contracted intermediate size of a given intermediate orifice **410** is smaller than the size of the orifice immediately downstream; and the expanded intermediate size of the given intermediate orifice **410** is no smaller than the size of the orifice immediately downstream. In further such embodiments the orifice in the downstream barrier **300** can be said to have a downstream orifice **310** size, and the expanded size of each intermediate orifice **410** is no smaller than the downstream orifice **310** size.

[0064] Again, when a series **500** of reconfigurable intermediate barriers **400** is present, each may serve to reduce the rate of discharge by providing an orifice having a given C_dA value, instead of a given size (although of course the C_dA value may be varied by varying the size). In such embodiments, each given intermediate orifice **410** has a lesser intermediate C_dA value when the given intermediate barrier **400** assumes the first intermediate configuration and a greater intermediate C_dA value when the given intermediate barrier **400** assumes the second intermediate configuration. The lesser intermediate C_dA value is smaller than the greater intermediate C_dA value. The lesser intermediate C_dA value of the given intermediate barrier **400** is smaller than C_dA value of the orifice immediately downstream; and the greater intermediate C_dA value is no smaller than the C_dA value of the orifice immediately downstream.

[0065] In further such embodiments, it can be said that the orifice in the downstream barrier **300** has a downstream C_dA value; the lesser intermediate C_dA value of each intermediate barrier **400** is smaller than the downstream C_dA value; and the greater intermediate C_dA value of each intermediate barrier **400** is no smaller than the downstream C_dA value.

[0066] In another embodiment of the device comprising a series **500** of reconfigurable intermediate barriers **400**, the intermediate barriers **400** are reconfigured by inserting or withdrawing them from the conduit **100**. In such embodiments each intermediate orifice **410** is inserted into the conduit **100** when the intermediate barrier **400** assumes the first intermediate configuration; and each intermediate orifice **410** is withdrawn from the conduit **100** when the intermediate barrier **400** assumes the second intermediate configuration. As described in other embodiments, this allows the barriers **400** to simply be removed from the fluid flow instead of reconfiguring the barrier **400** to change the characteristics of the orifice **410**.

[0067] A method is provided for controlling fluid flow through a conduit **100** wherein the conduit **100** comprises an upstream orifice **210** and a downstream orifice **310**, the method comprising: reconfiguring the upstream orifice **210** from a configuration in which the upstream orifice **210** reduces the flow of the fluid more than does the downstream orifice **310** to a configuration in which the upstream orifice **210** reduces the flow of the fluid no more than does the downstream orifice **310**. The step of reconfiguring the upstream orifice **210** may comprise increasing the size of the upstream orifice **210**. In some embodiments the step of reconfiguring the upstream orifice **210** comprises changing the shape of the upstream orifice **210**.

[0068] The step of reconfiguring the upstream orifice **210** may comprise increasing the C_dA value of the orifice. In some embodiments of the method the upstream orifice **210** is in an upstream barrier **200**, and the method comprises withdrawing the upstream barrier **200** from the conduit **100**. A method is provided for controlling fluid flow through a conduit **100** comprising providing any of the fluid flow control structures **1** described herein and reconfiguring at least one of the upstream barrier **200** or an intermediate barrier **400** from its first configuration to its second configuration.

[0069] Turning now to the prophetic example in FIGS. **1-7**, an embodiment of the structure is provided as a conduit **100** comprising a series of orifice plates, each plate containing an orifice ranging in diameter from 1-36" in one-half inch increments. Thus there are 72 plates. The most upstream plate contains no orifice (when closed it arrests flow completely). The next plate downstream comprises the smallest orifice (1" in diameter). Each plate comprises two retractable sections **220**. Each plate is rectangular, having a cross sectional area equal to or slightly greater than the cross-sectional area of the conduit **100**. The orifice is in the middle of each plate. Each retractable section **220** makes up half the plate and defines the perimeter of half of the orifice. Each retractable section **220** is configured to be retracted from the conduit **100** in a direction opposite to the other retractable section **220** of the plate. This is achieved by means of a threaded rod bolt attached to the retractable section **220** by an anchor plate. A reversible electric motor with a worm gear is used to move the threaded bolt in either direction, which causes the retractable section **220** to either retract from the conduit **100** or extend into the conduit **100**. Once the retractable sections **220** meet, they cannot be extended into the conduit **100** any further. Consequently, when the retractable sections **220** meet, they mutually define the orifice at its minimum size. Retracting the retractable sections **220** causes the effective size of the orifice to increase. Because each orifice is only one-half inch narrower than the next orifice downstream, if each retractable section **220** for a given orifice plate is retracted only ¼" then the next orifice downstream effectively controls discharge from the conduit **100**. Of course, each plate is capable of being retracted to an extent that will allow its orifice to assume a diameter that is at least equal to the diameter of the largest orifice in the structure (which would be the orifice in the most downstream plate).

[0070] In a specific embodiment, the series of barriers fit together to form a conduit **100** with a water tight connection throughout the structure. By doing so, flow through the most restrictive opening operates under inlet control and each subsequent less restrictive downstream opening is a component of the conduit **100** to convey the flow through the structure. Inlet control occurs when the control is immediately upstream of the most restrictive orifice and headwater depth and orifice configuration determine the amount of water entering the structure. Under inlet control conditions the amount of water entering the structure at the most restrictive opening is less than the conduit's **100** flow capacity. Consequently, the conduit **100** is flowing less than full.

C. Flood Control System

[0071] A flood control system **3000** that provides a volumetric discharge pattern during an ongoing storm event is provided. A general embodiment of the system comprises: a flow control structure **1000** configured to variably control the rate of volumetric discharge from an intake point to a release point; a computing device **1100** in control of the flow control structure **1000**; a water level meter **1200** positioned to measure the water level at the intake point and configured to transmit water level data to the computing device **1100**; a rain gauge **1300** configured to transmit rainfall data to the computing device **1100**; and a machine-readable data storage device **1400** comprising a plurality of storm flow functions that each set a rate of volumetric discharge as a function of rainfall rate, wherein the machine-readable data storage device **1400** is configured to be read by the computing device **1100**. The flow control structure **1000** may be any known in the art. In specific embodiments of the system the flow control structure **1000** is any one of the dynamic flood control structures **1** provided in this disclosure.

[0072] Either of both of the water level meter **1200** and the rain gauge **1300** may be configured to transmit data they collect to the computing device **1100** with very little delay between the time at which the data are collected and the time at which the data are transmitted. Such "real time" data transmission has the advantage of providing the computing device **1100** with a constant stream of up to date information. Alternatively there may be a small delay between data collection and transmission, so long as the delay allows the computing device **1100** to send instructions to the flood control structure based on the data in a timely manner. Such small delays have the advantage of saving energy by sending less frequent signals.

[0073] The computing device **1100** is specifically configured or programmed to control the flow control structure **1000** in response to data from the one or both of the rainfall gauge and the water level meter **1200** based on an ongoing storm event. The computing device **1100** includes a bus or other communication mechanism for communicating information, and a processor coupled with bus for processing information. The computing device **1100** may also include a main memory, such as a random access memory (RAM) or other dynamic storage device, coupled to the bus for storing information and instructions to be executed by the processor. Main memory also may be used for storing temporary, variable or other intermediate information during execution of instructions to be executed by the processor. The computing device **1100** further includes a read only memory (ROM) or other static storage device coupled to the bus for storing static information and instructions for the processor.

[0074] The water level meter **1200** may be any that is known in the art. Non-limiting examples include sonic level sensors, guided-wave radar level sensors, pressure sensors, float-based level sensors, and vibrating short-fork sensors. The water level meter **1200** transmits water level measurements to the computing device **1100**. The water level measurements may be transmitted periodically or constantly. In some embodiments of the system water level measurements are transmitted to the computing device **1100** only after a rainfall event has been detected via the rain gauge **1300**.

[0075] The rain gauge **1300** may be any known in the art that is capable of automated reporting. Non-limiting examples include a weighing precipitation gauge, a tipping bucket rain gauge, an optical rain gauge, and an acoustic rain gauge. The rain gauge **1300** may transmit digital or analog signals correlated to measured rainfall.

[0076] Each storm flow function is recorded on machine-readable media and allows a rate of volumetric discharge to be calculated from a rainfall rate. The rainfall rate may be any of various types of measurements. Non-limiting examples of the rainfall rate include a peak rate of rainfall, and average rate of rainfall over the course of the event, an incremental rate of rainfall, an instantaneous rate of rainfall, a running average rate of rainfall over a given period, and a total amount (depth) of rainfall over the course of the event.

[0077] The function may be derived from a modeled rainfall event, such as a two-year storm event, a 25-year storm event, and a 100-year storm event. The function may be derived from an historic storm event. Any number of functions may be recorded on the data storage device **1400**. In a specific embodiment, the data storage device **1400** contains a function derived from a two-year storm function, a 25-year storm function, and a 100-year storm function. The function may be a function of a pre-development rainfall event.

[0078] The intake point may be any point at which standing water would be expected to be present during a rainfall event (regardless of whether standing water would be present at the point apart from the rainfall event). Non-limiting examples of likely intake points include a drainage ditch, a detention pond, a subterranean drain, a controlled section of a watercourse, and a storm drain. One specific embodiment of the intake point is a retention body **1500**. The rain gauge **1300** will be positioned at a location that would be representative of the watershed. Non-limiting examples of suitable rain gauge **1300** positions include any nearby location in a static open body of water (such as a lake or a pond), a location within the watershed open to the sky, or at a location about the same point in the grade of the structure.

[0079] An alternate embodiment of the flood control system **3000** comprises a means for variably controlling the rate of volumetric discharge **1600** from an intake point to a release point; a means for automated control **1700** of the means for variably controlling the rate of volumetric discharge **1600**; means for measuring the water level **1800** at the intake point that transmits water level data to the means for automated control **1700**; means for measuring rainfall **1900** that transmits rainfall data to means for automated control **1700**; and means for storing a plurality of storm flow functions **2000** that is readable by the means for automated control **1700**. The means for variably controlling the rate of volumetric discharge **1600** may be, for example, any of the flow control structures **1000** described herein. The means for automated control **1700** of the means for variably controlling the rate of volumetric discharge **1600** may be, for example, any embodiment of the computing device described herein. The means for measuring the water level may be, for example, any embodiment of the rain gauge described herein. The means for storing a plurality of storm flow functions **2000** that is readable by the means for automated control **1700** may be, for example, any embodiment of the machine-readable data storage device described herein.

[0080] Turning now to the prophetic example in FIG. **8**, an embodiment is provided in which the intake point is at a downstream opening in a detention pond, which leads to the embodiment of the flood control structure provided in FIGS. **1-7**, and which then leads to a discharge pipe and discharges into a receiving stream. The water level meter **1200** is a float device proximate to the storm pipe which transmits water level measurements to the computing device **1100** at one minute intervals. An electronic rain gauge **1300** accurate to about 0.001" is connected to the computing device **1100**. The computing device **1100** is connected to and controls the flow control structure **1000**. The computing device **1100** communicates with a storage device (not shown) that calculates a rate of discharge that is equivalent to the pre-developed condition based on data transmitted by the rain gauge **1300**.

D. Flood Control Process

[0081] A flood control process is provided for achieving a predetermined volumetric discharge pattern in response to a rainfall event. A general embodiment of the process comprises: receiving a rainfall measurement from an automated rain gauge **1300**; reading a storm discharge function **1410** from a machine-readable storage device **1400**, wherein the storm discharge function **1410** sets a rate of volumetric discharge as a function of rainfall rate; computing a target rate of volumetric discharge by plugging a rainfall rate value into the function **1410**; and configuring a flow control structure **1000** to provide approximately the target rate of volumetric discharge from the body of water. In some embodiments of the method the predetermined volumetric discharge pattern approximates or recreates a discharge pattern for the local watershed in a natural or undeveloped state.

[0082] The process may comprise selecting a storm discharge function **1410** that corresponds to a measurement of storm severity. The measurement of storm severity may be obtained from the automated rain gauge **1300** in some embodiments. For example, the total accumulated rainfall could be used to measure storm severity. In another example, a predicted peak flow rate to or from a given body of water could be used to measure storm severity. In another example the rainfall rate could be used to measure storm severity. In embodiments of the method in which the storm discharge function **1410** is selected based on storm severity, the discharge function corresponds to a storm of comparable severity to the ongoing storm. For example, the storage device may contain four discharge functions: one corresponding to a two-year 24-hour model storm, one corresponding to a 25-year 24-hour storm, and one corresponding to a 100-year 24-hour storm. Such functions may be selected if the severity of the storm rises above certain threshold levels. Examples of such threshold levels include a threshold total rainfall depth, a threshold predicted peak flow rate, and a threshold rainfall rate.

[0083] In a prophetic example, during a storm event a function may be initially selected that corresponds to a storm that is less severe than a two-year 24-hour storm. Upon receipt of a rainfall measurement indicating that the total rainfall depth threshold defining a two-year 24-hour storm has been reached, a function corresponding to a storm more severe than a two-year 24-hour storm may be selected. Upon receipt of a rainfall measurement indicating that the total rainfall threshold defining a 25-year 24-hour storm has been reached, a function corresponding to a storm more severe than a 25-year 24-hour storm may be selected. Upon receipt of a rainfall measurement indicating that the total rainfall threshold defining a 100-year 24-hour storm has been reached, a function **1410** corresponding to a storm more severe than a 100-year 24-hour storm may be selected. The target rate of volumetric discharge may be constantly calculated using the selected function **1410** and the rainfall rate, and the flow control structure **1000** may be constantly configured to provide approximately the target rate of volumetric discharge from the body of water. As the severity of the storm changes, the selected function **1410** changes.

[0084] In some versions of the process, once a function **1410** corresponding to a storm of a given severity has been selected, the process will not select a function **1410** corresponding to a less severe storm during the course of the storm, even if the severity of the storm decreases. In such embodiments the function **1410** may change if the severity of the storm increases, but not if it decreases. Such measures may often be necessary because it is inevitable that even the most severe storm will pass and decrease in severity; however it may still be desirable to simulate the trailing portion of the severe storm during this period, as opposed to simulating a less severe storm.

[0085] The functions **1410** associating target discharge to rainfall rate may be based on the hydrologic parameters of the watershed. In certain embodiments of the process some or all of the hydrologic parameters may be stored in a "junction summary file" on a machine-readable storage device **1400**. For example, such parameters may include a weighted curve number, a time of concentration, and the area of watershed. The curve number (also known as runoff curve number) is based on the permeability of the groundcover of the watershed, and represents the rate of surface runoff flow (volume per time) as a function of total rainfall (depth); the runoff curve number will in some cases be based on the pre-development watershed. Time of concentration represents the time required to for water to flow from the most hydraulically remote location in the watershed to a drainage point (in this case the drainage point is the body of water at the intake point of the control structure).

[0086] Some embodiments of the process allow a user to select the appropriate function **1410**. For example, if the severity of an ongoing storm increases above a threshold (for example, more severe than a two-year 24-hour storm but less than or equal to a 25-year 24-hour storm) the user may be presented with the option to continue to use the function **1410** corresponding to the less severe storm, or to switch to the function corresponding to the more severe storm. In another example, the severity of the ongoing storm may be below a threshold, and the user is presented with the option to use the function **1410** corresponding to a more severe storm. This option to select the function **1410** associated with the more severe storm event could be used in cases in which the required volume of the upstream reservoir is not achievable due to some hardship, such as a limited amount of area available for storm water detention. Simulating a more severe storm will increase flow from the upstream reservoir.

[0087] Some embodiments of the process comprise configuring the flow control structure **1000** to provide a constant drainage rate of discharge after the storm event is complete. More specific embodiments of the process comprise receiving a later rainfall measurement from the rain gauge **1300**, wherein the later rainfall measurement is below a threshold value indicative of the termination of the storm event. The threshold value may be zero, or about zero. The constant rate of discharge will be sufficient to prevent adverse impacts downstream of the flow control structure **1000**. The constant flow rate may be based on at least one of the capacity of the downstream receiving body or bodies, the ecological sensitivity of the downstream receiving body or bodies, the erosional sensitivity of the downstream receiving body or bodies, water rights in the downstream receiving body or bodies, and other environmental sensitivities in the downstream receiving body or bodies. Such embodiments allow the upstream source water body to be drained without adverse downstream impacts. In some embodiments of the process the constant drainage rate will be provided until the upstream source water body reaches a predetermined depth. In some cases the predetermined depth may be zero, in which case the upstream source water body will be drained.

[0088] The water level gauge, source point, machine-readable data storage device **1400**, storm flow function **1410**, and flow control structure **1000** may be any that are described herein as suitable for the flood control system.

[0089] Turning now to the prophetic examples of FIGS. **9-12**, the storm flow profiles from a model system are shown for four different flood events. These profiles are from an actual drainage basin. In each figure, the top frame compares uncontrolled post-developed discharge to pre-developed discharge. FIGS. **9-11** show the calculated discharge over time for modeled storm events in the system (two-year, 25-year, and 100-year storms) and FIG. **12** shows actual results from an actual rainfall event for a pre-development storm event compared to the same rainfall modeled for post-development. As can be seen in all of FIGS. **9-12**, uncontrolled post-development discharge is much more intense and occurs over a much shorter period of time than either the pre-development discharge or controlled post-development discharge. The middle frames of FIGS. **9-12** show a comparison of post-developed discharge controlled by a static flood control structure to pre-developed discharge. It should be noted that, although a static control structure provides significantly attenuated discharge when compared to uncontrolled post-development patterns, it significantly differs from pre-development discharge patterns and discharge patterns when the embodiment of the flood control process is used. The bottom frames of FIGS. **9-12** show a comparison of post-developed discharge controlled according to an embodiment of the flood control method provided in this application to pre-developed discharge. Note that the bottom frame of FIG. **11** displays elevated flow during recession period used the embodiment of the process over the pre-development model due to the selection of a function corresponding to a more severe storm. Note also that the elevated flow at the tail-end of the storm in bottom frame of FIG. **12** is due to the process configuring the flow control structure **1000** to provide constant discharge after the end of the storm event so as to reduce the water level in the upstream source body. Apart from the noted deviations, the embodiment of the process closely approximates natural flow in all four examples. Note that all prophetic examples model a static control structure designed not to exceed the pre-developed peak flow rate for any of the two year, 25-year, and 100-year 24 hour design storms. This example demonstrates that static control structures, even when designed for multiple design storms, are not capable of attenuating real storm peak flow rates. It also demonstrates that static control structures can shift the time at which the storm peaks, causing a delay in the peak flow rate, which can lead to downstream flooding.

E. Conclusions

[0090] It is to be understood that any given elements of the disclosed embodiments of the invention may be embodied in a single structure, a single step, a single substance, or the like. Similarly, a given element of the disclosed embodiment may be embodied in multiple structures, steps, substances, or the like. The foregoing description illustrates and describes the processes, machines, manufactures, compositions of matter, and other teachings of the present disclosure. Additionally, the disclosure shows and describes only certain embodiments of the processes, machines, manufactures, compositions of matter, and other teachings disclosed, but, as mentioned above, it is to be understood that the teachings of the present disclosure are capable of use in various other combinations, modifications, and environments and is capable of changes or modifications within the scope of the teachings as expressed herein, commensurate with the skill and/or knowledge of a person having ordinary skill in the relevant art. The embodiments described hereinabove are further intended to explain certain best modes known of practicing the processes, machines, manufactures, compositions of matter, and other teachings of the present disclosure and to enable others skilled in the art to utilize the teachings of the present disclosure in such, or other, embodiments and with the various modifications required by the particular applications or uses. Accordingly, the processes, machines, manufactures, compositions of matter, and other teachings of the present disclosure are not intended to limit the exact embodiments and examples disclosed herein. Any section headings herein are provided only for consistency with the suggestions of 37 C.F.R. § 1.77 or otherwise to provide organizational queues. These headings shall not limit or characterize the invention(s) set forth herein.

I claim:

1. A method of mimicking a pre-development response to a storm event in a developed watershed at an outlet point, the method comprising:

(a) providing a flow control structure at the outlet point, wherein the flow control structure can be reconfigured to control the rate of flow at the outlet point;

(b) measuring a first rainfall amount at a first time;

(c) calculating a first direct runoff hydrograph based on the first rainfall amount and based on characteristics of the watershed prior to development;

(d) measuring a second rainfall amount at a second time;

(e) calculating a second direct runoff hydrograph based on the second rainfall amount and based on characteristics of the watershed prior to development;

(f) calculating a predevelopment total runoff hydrograph by summing at least the first direct runoff hydrograph and the second direct runoff hydrograph, wherein the total runoff hydrograph is a line having exactly one flow rate value for each time value; and

(g) reconfiguring the flow control structure at a third time to provide a rate of flow about equal to the flow rate value on the predevelopment total runoff hydrograph corresponding to the third time.

2. The process of claim **1** wherein the predevelopment total runoff hydrograph emulates the relationship between rainfall and rate of volumetric discharge as observed in the developed watershed prior to development.

3. A machine-readable data storage device comprising a computer program which, when read by a computing device, causes the computing device to perform the process of claim **1**.

4. A method of mimicking a pre-development response to a storm event in a developed watershed at an outlet point, the method comprising:

(a) providing a flow control structure at the outlet point, wherein the flow control structure can be reconfigured to control the rate of flow at the outlet point;

(b) measuring a first rainfall amount at a first time;

(c) calculating a first direct runoff volume based on the first rainfall amount and based on characteristics of the watershed prior to development;

(d) multiplying the first direct runoff volume to the first ordinate of a unit hydrograph to obtain a first predeveloped total runoff hydrograph value;

(e) reconfiguring the flow control structure at a first time to provide a rate of flow about equal to the flow rate value on the predevelopment total runoff hydrograph corresponding to the first time;

(f) measuring a second rainfall amount at a second time;

(g) calculating a direct runoff volume based on the second rainfall amount and based on characteristics of the watershed prior to development;

(h) multiplying the second direct runoff volume to the first ordinate of a unit hydrograph to obtain a first direct unit hydrograph value for the second time;

(i) multiplying the first direct runoff volume to the second time ordinate of the unit hydrograph to obtain a second direct unit hydrograph value for the second time;

(j) calculating a predevelopment total runoff hydrograph by summing at least the first direct runoff hydrograph value and the second direct unit runoff hydrograph value at the second time, wherein the total runoff hydrograph is a line having exactly one flow rate value for each time value; and

(k) reconfiguring the flow control structure at a second time to provide a rate of flow about equal to the flow rate value on the predevelopment total runoff hydrograph corresponding to the second time.

5. The process of claim **4** wherein the predevelopment total runoff hydrograph emulates the relationship between rainfall and rate of volumetric discharge as observed in the developed watershed prior to development.

6. A machine-readable data storage device comprising a computer program which, when read by a computing device, causes the computing device to perform the process of claim **4**.

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