THE PROBLEM OF DATA IN WATER RESOURCES MANAGEMENT - THE CASE OF DAMS

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INTRODUCTION

The dam sector needs all the attention it can get to keep Nigeria productive and viable in achieving sustained development. There can never be enough contribution on dams' management as far as data for dam structures are concerned. If any nation thinks it has enough data on the management of dam structures, then it could think of improving, then expanding and updating its data base. Make the distinction here, projection is not the same thing as updating or filling in the missing data. The data topography is a function of time and space, it is dynamic and therefore must be current, never to be out dated. To properly orient attention on the topic in hand, it is necessary to look at the 'how' is data associated with the problem at hand.

LACK OF DATA

The lack of reliable and adequate data that is up to date and timely is a common phenomenon in third world countries: Nigeria is not an exception. One may suppose that these inadequacies are the scourge of say Local governments, but sadly, no, it is also a national problem, it is a State Government problem, it is also the problem of other stake holders.

The problem of lack of data is mitigating against Nigeria's effective and efficient integrated water resources management. Despite all odds, Nigeria must be seen to truly overcome the problems of data associated with water structures, especially dams. Water resources allocation in the most efficient and effective way that meets specific and general needs and demands of the society can never be overemphasized, dams being the most important and the major impoundment source. Excellent data is the vehicle. Information system is the base necessary, especially when it comes to the assessment and management of the resource called water. It must be done in a most suitable and friendly manner. Given the modern computer assisted and fast changing IT (Information Technology) there is no excuse not only to catch up, but Nigeria must be able to update its data base on dam structures for the required effective and efficient management. High speed and high capacity reliable data storage and retrieval systems continue to evolve very frequently. It only takes the political will to authorize, finance, purchase and put these systems into operation. Let us now look at management defined.

MANAGEMENT

Management exercises control over something. In this context, management is the exercise of control over an activity, it is the ability to handle, manipulate, influence economically and with foresight, so that the manager can succeed in handling, even if with difficulty, certain activity, thereby enabling him to cope with the situation. In terms of data for dam management, it is a tall order. The details are formidable and frightening, the job is demanding and the cost is taxing. It is not the question of which came first, the chicken or the egg. For dam resources management, the first order of priority is the data. Without water resources data, the chicken, (that is water resources) is a dead bird that can lay no egg. So expecting an efficient water management would be premature without data. So data must as a matter of urgency be available. If it is not available, it must be gathered (collected), collated, and stored in a retrievable and useable form.

It would be criminal to restrict our discussion today on the dam structure. Given the hue and cry of ecologists, every conceivable problem that could militate against building a dam must be considered. It must contribute to the weighing of the decision of whether to build the structure or not. Once the decision to build has been taken, then attention moves to actual execution that will ensure the correct structure is built. Beginning from data gathering, analysis, design, building and its safety thereafter. In each step, the management faces different problems and therefore different challenges. Actually in the professional jargon – data gathering is pre-feasibility studies. That supposedly is to aid the decision whether to build or not, then feasibility studies is the actual detailed data that finally tips the scale. When the feasibility studies line is reached, it is assumed the dam would be built, except if a discovery is made of a serious problem that could endanger the whole project. So, to treat the topic as I would – For a muilti-disciplinary topic, for an inter disciplinary project, there is a need to consider whether the following data is available.

1. How and why was the idea conceived.
2. Location in terms of geography and area
3. Investigation of the location (on a natural drain course) commonly called rivers.
4. Location choice from several options.
5. what type of dam structure is most suitable.

Data Gathering

1. Hydrological data
2. Meteorological data
3. Seismic data
4. Foundation data
5. Soil type data
6. Environmental data
7. Water quality data
8. Social data
9. Health data
10. Political and economic consideration data.

A. A lot of the success or lack of it in managing a water structure such as dams begins at conception and investigation stages. For example, is it a political conception or is it an economic one? Is it purely social or what truly led to the conception to build the structure? This piece of data colours the entire management activity of the investigation, building the structure and its future existence vis-a-vis its safety.

B. Data gathering itself is more mechanical and is entirely controlled by trained technicians to ensure that the best is given in terms of quality and quantity. By this it is meant enough information, data wise, is necessary to get a most efficient structure. Enough data must be presented so that if it is to be tested statistically it has enough data to provide the answer without guessing – or to provide possible projection of a piece of data that would fit the mainstream data.

C. Political and economic considerations: There is a very important aspect of data gathering for water structures such as dams in Nigeria that lies outside the technical orbit, having its ambience squarely situated in a factor called political will. It is an important piece of data because it could determine the time it takes a project to be conceived, built ad run. This political will is sometimes called project completed on schedule and the lack of it is called abandoned project. The completed project could be efficiently and technically excellently executed or it could have been poorly and shoddily done, bearing inside it the seed of disaster. When data for a water structure shows completion or abandonment, each has its consequential economic condition. Thus, the importance of economic considerations. For completed projects, the economic returns would be of importance, but for the abandoned one it becomes an economic drain pipe, such projects are the ones that put stress and strain on political will. How much more funds are required or if it were to be abandoned, what would be the political cost?

D. Outside Pressure Data: Allow me discuss only two such data briefly. Some organizations would come and try to dictate to Nigeria the type and size of dam structures they can build. The truth is that they use low interest rates to lure Nigeria into borrowing and building a dam. One question that easily comes to mind is with the size of foreign debt Nigeria has, does Nigeria need to borrow for dams? Let us assume yes, because the internal rate of return on the investment would indeed promptly pay for the loan. Then must Nigeria be dictated to on the size of dams she needs? If I choose to give you money free, is it not true that once I give you that money I have no moral right to dictate to you how to use it even on that item for which the money was agreed on? How much more if you have to pay back even at low interest rates? This tangentially affects the issue of political will and economic consequences. The second question is like unto it, must ecology distort Nigeria's order of priority? By this it is meant the location of a dam may not be suitable. There are indeed many good reason why a dam may not be built, the only point of divergence is when humans are sacrificed on the altar of ecology. Humans would be denied water because there is a specie that is difficult to find elsewhere. The specie is to survive and man, created in God's image may perish. Where are our priorities as regards man and other lower animals, lower flaura and fauna? Indiscriminate dam building is not recommended, but when that time comes to choose between man and others, let us give man a chance first. Ecology is to maintain its priority position especially when alternatives are available. But a balance must be struck or else, it will be the man specie that may sooner than later be extinct.

E. Technical Aspects: As stated earlier, we are treating dams as a multi and interdisciplinary topic, so the problem of data in water structures management – the case of dam – may be very long. Allow me treat it by choosing what I consider are the more important issues, this way the paper will not be long.

F. Meteorological Data: By far the most important data is the meteorological data. For from it you have an idea of the entire water budget. Nigeria has had meteorological data, some longer than 100 years. The data is not just precipitation but also data such as sun shine hours, type of rays, humidity, relative humidity etc. All crucial. Above all the quality of the data has to be perfect or almost perfect. Within a data, more often than not there is a data subset. What is meant by that is frequency and spatial distribution of the meteorological data. The quality of equipment and instruments also determine the quality of the data being sought. The qualification and dedication of the person collecting the data all bring to bear on the quality of the data being collected. Similarly hydrological data such as the channel (river) geometry, characteristics and above all the volume of water passing any given point at any given time is very important, the quality of the data must be very dependable. For example you would want to know how long it will take to empty a given dam under normal draw down circumstances, for the former rate of inflow is important and for the latter the geography or channel geometry and channel characteristics are crucial.

EVEN DURING BUILDING: Even during dam building, commonly called construction, unique data acquisition is necessary. There are certain items that may not seem to be data, but they are. As designed and as built drawings, rate of raising the embankment and compaction rate or concrete mixture details at any time and for all times must be preserved. They are important reference points should any problem arise. Now let us assume all has gone well, all data have been kept and the dam has been successfully completed. What next?

MANAGING AN EXISTING DAM: The day the dam is completed, commissioned or not commissioned, the dam has become an existing dam and therefore qualifies as a possible 'risk' structure. Given all the benefits of water behind a dam structure, that water imposes an element of risk to life and property downstream because of hazard potentials in case the dam fails. Failure could be for any of the following reasons:

1. Faulty spillway design because of under designed capacity. (Overtopping normally occurs)
2. Seepage through dam body and foundation.
3. Dam reservoir capacity reduction due to sedimentation.
4. lack of appurtenances for proper and systematic draw down.
5. lack of reliable metrological and hydro metrological data.
6. Lack of data clearly showing reservoir operations guidelines and rules.

7. Inadequate or poor instrumentation or lack of it.
8. No funding for operation and maintenance. No funding for rehabilitation.
9. Lack of political will.

These risk factors should be able to guide one towards the data required to keep dams safe in Nigeria for more efficient management. It is not difficult to design and collect data that could be used in minimizing the listed risks number 1-9 above.

DAM FAILURE: Data to prevent dam failure was highlighted because of the consequential impact a dam imparts both on the downstream and the upstream. The best reference point is the International Committee On Large Dams (ICOLD) at their 11th congress in Madrid. ICOLD came up with the following:

- Risk due to geology such as physical mechanical and chemical properties of rock and soil.
- Risk due to hydraulic features scouring, unexpected floods, overtopping, clogging, sloughing, wave action, artesian water etc.
- Risk due to type and construction according to the probability of conservation of specific works and the prospective decay of building material.
- Risk due to the operation and maintenance such as initial dam filling, uneven settlement, rapid draw down, upstream slope sliding into the reservoir, extended draw down, dynamic stress, false operations, insufficient maintenance, neglect of safety instrumentation and appliances.
- Risk coming from MAN and the environment such as hostile action (sabotage).
- Risk due to the consequences of wrongful siting of dam (reservoirs), such as cascading failures, decay due to aging, earth quake, due to reservoir abandonment.

These points must be kept in mind as they also could generate requisite data to minimize risk. Most of them could be avoided with a little care and effort, making management of water structure easier.

Grunner further gave world wide compiled statistical risks as:

Risk Class	**Percentage of Dams that would probably fail**
Geology	7%
Hydraulic Features	45%
Type and Construction	30%
Operation and Maintenance	6%
Man and the Environment	6%
Reservoir Consequences	6%

It is easy to see that the higher risk probability lies with hydraulic features followed by dam type and construction. Careful design and excellent construction would eliminate a high failure probability. Let us compare Grunner's statistical approach with that of ICOLD which was based on national and Man controlled factors, they further listed evolutionary factors as aging of dams and opportunences, foundation weathering, and reservoir bank weathering.

ICOLD's Risk Percentage

S/No	Causes	Risk percentage
1.	Foundation problems	40%
2.	Inadequate spillway	23%
3.	Poor construction	12%
4.	Uneven settlement	10%
5.	High pore pressure	5%
6.	Acts of war	3%
7	Inept operation	2%
8	Earthquakes	1%
9	Miscellaneous	4%

It is interesting to note that both the ICOLD and Grunner risk percentages are high on similar causes or class of risk. Foundation is close enough to geology, while poor construction and uneven settlement are akin to type and construction. But it is noteworthy that ICOLD included a problem with bad design. Inadequate spillway is a major risk from the start.

INSTRUMENTATION: After all is said and done, the management of a water structure such as a dam requires measurements to quantify deviation from the norm. Luckily dam technology has devised some form of instrumentation to solve some of the problems. When dam structures hold stream flow for future releases in a controlled manner for whatever reason, the dam goes through hydrostatic forces exerted against the structure. Should such forces force the dam to go beyond its resistance threshold, the force it can withstand, there are disastrous consequences. The instruments would monitor the behavior of the structure from construction, through filling of the dam to post construction phases. This would indicate and record any violation of safety features. This provides a record of what was happening and in some cases it helps makes easy any prediction of unusual events affecting the water structure. It makes management to have different decision variable with which to evaluate problems and there are also several solution options to choose from.

A dam with complete instrumentation is capable of providing a history of the structure's performance. It gives the basis of comparison between the past and present (current) records. Future measurements have a ready made comparative analysis information data base. Furthermore, similar dams without instrumentation have a reservoir of information for evaluating their problems.

- Data from reliable instruments are a gold mine for researchers so that new improvement in dam building may be suggested.
- Litigation, should it arise, could and would use valid recorded instrumentation data.

- For rational decisions and taking appropriate remedial action, there can be no better basis than data provided by instrumentation.

Some may still wondering what actually is being measured?

The instruments measure:

- Temperatures within the dam structure as reservoir at different depths.
- Uncontrolled movement of water, through, around and in drains is measured.
- Reservoir level movement
- Pore pressure within the dam structure foundations and abutments are measured.
- Strain in dam and foundation materials
- Measurement of events serious enough to trigger alarm system, warning about changes in structural integrity.
- Reservoir water quality to show seepage water is dissolving solids in embankments materials.

Now how often the measurements are done depends on the situation and what is to be measured. Instrument measurement could change to fit demands and requirement of the moment. For example if increase in seepage, excessive structural movement, or rapid fluctuation in reservoir level is observed, attention for data collected could be focused on the problem of the moment.

MOST DAMS IN NIGERIA: Most dams in Nigeria are earth dams. To monitor earth dams, the following instruments are necessary:

- Peizometer (open stand pipe)
- Observation wells which are to indicate the magnitude and distribution of pressures, patterns of seepage within the fill, zones of potential piping and effectiveness of seepage control. These instruments are also placed at regular intervals. They are capable of measuring rates of uncontrolled seepage flow surfacing at downstream of the dam and through toe drains.
- V-notch weir for measuring low rates of flow from the drain and channelised seepages down stream of the earth dam.
- Rectangular wier can be used for measuring larger flow rates.
- Relief wells could be used to monitor seepage and to control pore pressure at various locations within the dam structure.
- For water quality, use of a good water is advocated. It will also help discern the ‘health’ of the reservoir, an important factor with the environmentalists. Water analysis will help determine the how much dissolved oxygen content there is at different reservoir depths.

By way of summary, other dam instrumentation are designed to measure deformation or horizontal and vertical movement in a dam. Common types are:

- Seepage measuring devices
- Target deflection
- Base plate to measure vertical movement
- Cross arm settlement devise
- Bench mark caps, surface monuments, profile settlement points.
- Tilt meters, inclinometers and extensometers.
- Internal movement devices
- Peizometers (hydrometer twin table, pneumatic vibrating wire)

For concrete dam, measuring devices are to measure:

- Horizontal movements
- Defamation
- Joint openings and closings
- Foundation behaviors – settlement, uplift pressures
- Internal stresses and strains in concrete mass (joint meters are used)
- Water quality
- Temperature – mass concrete, water in the reservoir.

Mathematical approach would confirm the necessity of good quality reliable data. Let us take the time the dam is first filled and see what happens:

Volume of water Q, stored is a function of time t.

Q = $f(t)$ ……………………………………………………….. (1)

to get volume stored

Q = $\int f(t)$ ……………………………………………………(2)

dQ = $\int_{t_0}^{t_1} f(t)dt$

$$\frac{dQ}{dt} = \left[f'(t)\right]$$

From t_0, zero time to some time t_1 defines a definite quantity of water in the dam – defined as Q_1, but if the dam is not full Q_1 = $\left[f'(t)\right]_{t_0}^{t_1}$ in filling continues.

Similarly Q_2 = $f(t)$

Q_2, a definite quantity is such that $\frac{dQ_2}{dt} = \left[f'(t)\right]_{t_0}^{t_2} > \frac{dQ_1}{dt}\left[f'(t)\right]_{t_0}^{t_1}$, this is for $t_2 > t_1$.

dQ = $\int_{t_1}^{t_2} f(t)dt$

$$\frac{dQ}{dt} = \left[f'(t)\right]$$

Q_2 = $\left[f'(t)\right]_{t_1}^{t_2}$

In similar vein, when $t_n > t_2 > t_1 > t_0$, filling in has progressed to overflow point

$Q_n = \left[f'(t)\right]^{t_n}$

Three conditions are possible:

1. $Q_t = Q_{tn}$
2. $Q_t > Q_{tn}$
3. $Q_t < Q_{tn}$

$Q_t = Q_{tn}$ When $Q_t = Q_{tn}$ we have a perfect steady state. The water structures is perfectly balnced, because inflow equals outflow. No draw down, the water level is constant.

$Q_t > Q_{tn}$ When inflow is greater than outflow, then you have a build up in the reservoir where maximum capacity is reached. Then it triggers spillway action. If $Q_t >> Q_{tn}$, only enough spillway capacity can now maintain the integrity of the dam. You can now begin to see the importance of ‘rate’ of discharge/inundation data.

$Q_t < Q_{tn}$ When outflow is greater than inflow, then draw down is faster than water build up in the dam, if $Q_t << Q_{tn}$, then the fast draw down give rise to hydrostatic imbalances which normally challenge the integrity of the dam.

Peak Infill and subsequent discharge:

The amount of water in the dam structure is Q and the graph is represented by Q = $f(t)$.

By definition $\frac{dQ}{dt} > 0$ to show an increasing function which tallies with necessary water volume infill over time. Then it peaks, where $\frac{dQ}{dt} = 0.$ The maximum volume, no spill, any increase would have to see the amount increased/returned/discharged. Finally when the volume is being discharged through the spillway, then $\frac{dQ}{dt} < 0,$ negative storage over time.

Actually the infilling of a dam is a continuous cycle of build up, equilibrium, and then draw down. Each cycle corresponding to the amount of water volume coming in. The tipping of any data demands managers to be prepared with a solution.

Let us move to a different plane and obtain a logical solution range. For all data collected solution are found – for example optimum compaction, optimum filling rate, piping rate, structural stress or strains etc. There is a maximum before failure but there is also a minimum data that could start the crisis. These data can be plotted over time and it may look something like the following:

These all give an envelope solution, providing predictive ability for similar dams having similar maintenance problems. The answer developed from enough data would be somewhere within the shaded area. Projections could be made on dams/water structures that are similar. So that even without its unique data, similarity would dictate a possible solution because other data exist. In some, meteorological problems such as rainfall (precipitation) data there are reliable methods to generate a missing number. But the longer the data, the higher the accuracy of the projected data, (missing figure).

The Carlson type electric resistance gauge are read by comparison with standard resistance. Embankment failures are preceded by warning signals such as:

- Increase rate of deformation
- Strain discontinuities
- Cracking
- Leakages
- Pore pressure build up

WHY DATA: The major reason for needing proper data in water structure – the case of dam is to ensure the efficient raising up of a safe structure, and make its maintenance effective and less problematic and profitably productive. Without the necessary data it would be a costly venture where valuable resources which could have been used elsewhere are sunk. The project could become:

- A white elephant project
- An environmental hazard
- A health problem
- An ecological disaster waiting to happen.

Above all, structural failure would lead to the breaching of the dam , there could be a dam break. That would be the worst scenario. Lack of data has brought catastrophe! Should this happen then another already set of data could be used to mitigate the problem. Channel data, topography, geography, characteristics would have been developed into a sound answer and provide solution for a dam break where development of inflow and outflow hydrographs, flood routing and modeling would give ideas on how to minimize the impact of the catastrophe. Computer simulation would give one an idea of what the proposed solution would do. If not, factors such as routing pattern channelisation possibilities including larger capacity capabilities could be considered. Things that are difficult to mitigate include shock wave, Q, (rate of flow) depth of flow and velocity, all dependent on the terrain. Other less drastic scenarios exist, but management's ultimate aim is to ensure that efficiency is maintained, and the integrity of the structure assured, a situation where dam breaching would never occur.

WHAT NEXT: In a technical paper such as this, some solution or preventive action must be suggested. Fortunately all such solutions or preventive actions depend on data. First as the dam is being built an emergency action plan is being designed for all possible major emergencies. Surely emergency caused by earthquake is very different from major flooding emergency, or from massive land slide into the dam. An emergency action plan (EAP) should be readied, constantly reviewed and occasionally simulation must be done to ensure that the EAP would work. An EAP check list must be provided and well publicized and if possible rehearsed. Proactive, preventive EAP is advocated. They include:

- Surveillance, monitoring and warning system.
- Alert and alarm levels for surveillance and monitoring systems
- Adverse time response
- The nature of materials that may potentially be released in a failure
- Alternative source of power and communications (back up systems)
- Emergency supplies and resources
- Co-coordinating information (e.g. weather forecasts, stream flow etc)
- Action to lower the reservoir or limit inflows and outflows
- Action to remedy, alleviate or mitigate the potential impact.

These then form the preventive EAP which must be widely publicized.

CONCLUSION: a stitch in time saves nine it is often said. How true. Gathering of data, enough quality data for effective and efficient management of water structures such as dam is a must. For it assists in keeping intact the integrity of dams, thereby ensuring profitable economic activities. It also maintains social balance in safety within health boundaries instead of unleashing a wanton catastrophe because requisite data and plan are not available. Pre and post dam structure management skills are necessary to keep providing water to the society at large. Thus it is clear that data collection, storage and retrieval are crucial in minimizing the problems of managing water resources stored behind dam structures.

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