SWaRM
Self-learning Water Reservoir Model

Self-Learning Water Reservoir Models -The Future of Reservoir Management

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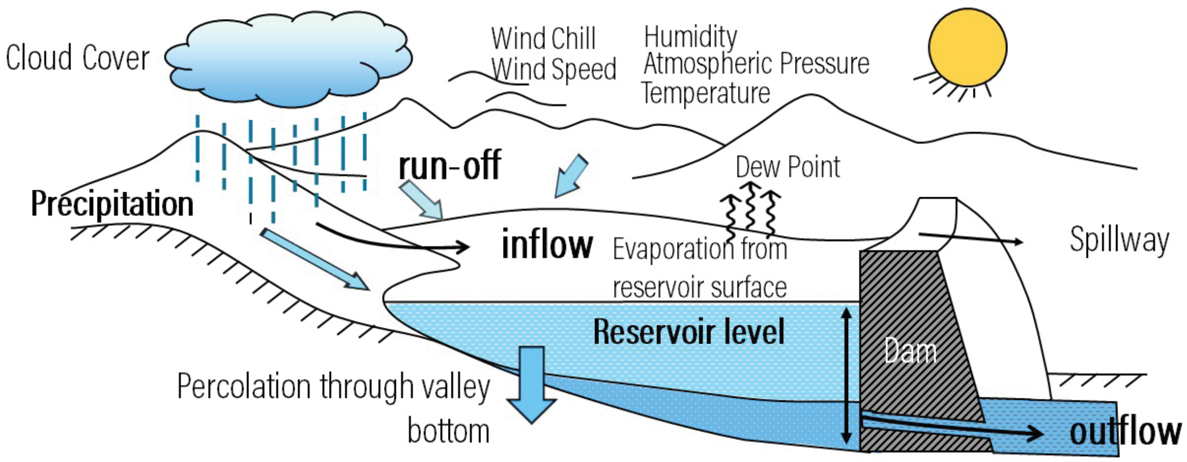
UNCERTAIN WATERS

With the increasing unreliability of water supply, insufficient flow, frequent cases of contamination, and growing population demands, many developed urban centers of the world are increasingly facing water insecurity (Jury and Vaux 2005)(Connor 2015)(Vishwakarma and Sinha 2020). ***Among the large list of cities in the world under the immediate threat of day zero, the case of Bengaluru city is arguably one of the most severe (Ramachandra et al. 2014).***

With increasing demand due to population growth, high non-revenue water due to aging water pipe infrastructure, and the increasing threat of climate change, it is critical that the Bengaluru Water Supply and Sewerage Board (BWSSB) has precise information on the water availability in the reservoirs it depends on. ***This will help support strategic (identification of long-term overall policy and economic decisions), tactical (identification of problem areas and hotspots), and operational (identification of day-to-day local-level water management decisions) decisions for the BWSSB water managers.*** However, water availability prediction in reservoirs is a complex task due to various interconnected factors influencing water reservoirs, dependencies with upstream reservoirs, and uncertainties related to extreme weather events.

UNDERSTANDING COMPLEX RESERVOIR SYSTEMS

Team Poseidon emerged as a collaborative group to participate in the Wave2Web Hackathon. The team consisted of researchers and industry professionals from different domains like water infrastructure performance modeling, reinforcement learning, time-series modeling, scientific communication, product lifecycle and software development. This inter-disciplinary mix of expertise helped us look at this complex problem from different perspectives and bring unique solutions. Over a course of 4 months, our team spent time understanding the complexity of reservoir systems by reviewing peer-reviewed literature, technical reports and utility case studies. The complexity of the reservoir systems can be understood by the sheer number of factors that influence reservoir performance. Some of these factors are shown in the figure below.



Overview of Water Reservoir System

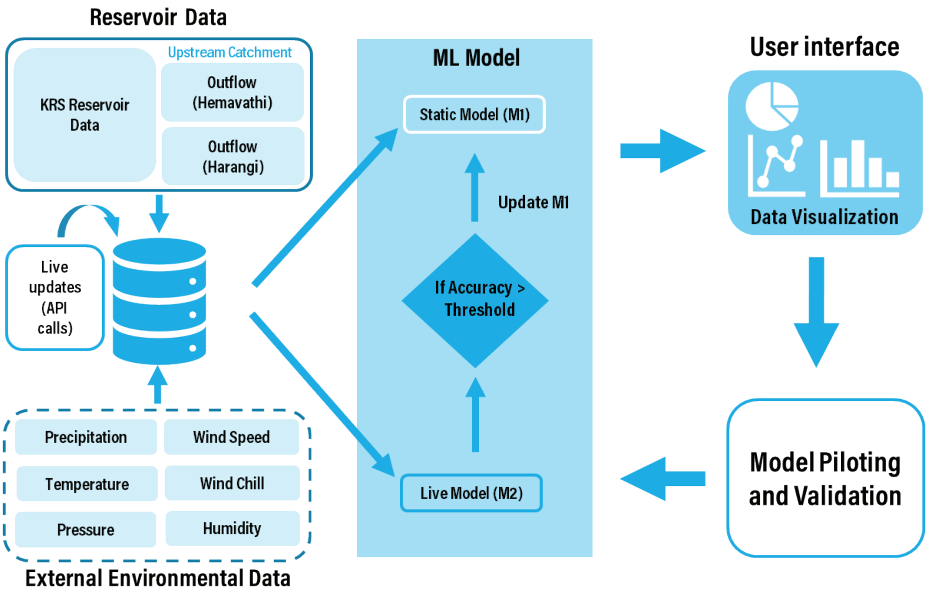
We developed a comprehensive feature set based on preliminary analysis and literature review to ensure that our modeling framework is reality-driven and can support tactical decisions.

DEVELOPING A PREDICTIVE MODEL

As engineering decisions have a major impact on society, trust in any decision support system is critical. Decision Trees (DT), as a collection of if-else rules are interpretable, work on small-to-medium structured/tabular data and therefore can be used reliably in the real world. On the other hand, deep learning techniques built on artificial neural networks (ANNs) like long short-term memory (LSTM) or Convolutional Neural Network (CNNs) work better on unstructured data (such as images, text and videos), are infamously non-interpretable and fall into the "black-box" models' category.

Our experimentation with different algorithms reinforced this where DTs outperformed other algorithms with an 88% prediction accuracy and errors within 12 feet of the real reservoir levels.
We also engaged with experts and mentors who guided us to improve our predictions during high variability monsoon months. We weighted our datasets in the months from May to October, representing the high wet and dry weather cycles. This weighing was performed by allowing the model to learn the high influence of monsoon data in the limited months of occurrence using a bias factor. This improved the model's 90-day prediction performance from 88% to 94%.

In summary, we developed a Self-learning Water Reservoir Model (SWaRM) powered by a Gradient Boosting Decision Tree Algorithm trained to predict the forecasts for a 90-day window using historical information. The workflow is presented in the following figure.

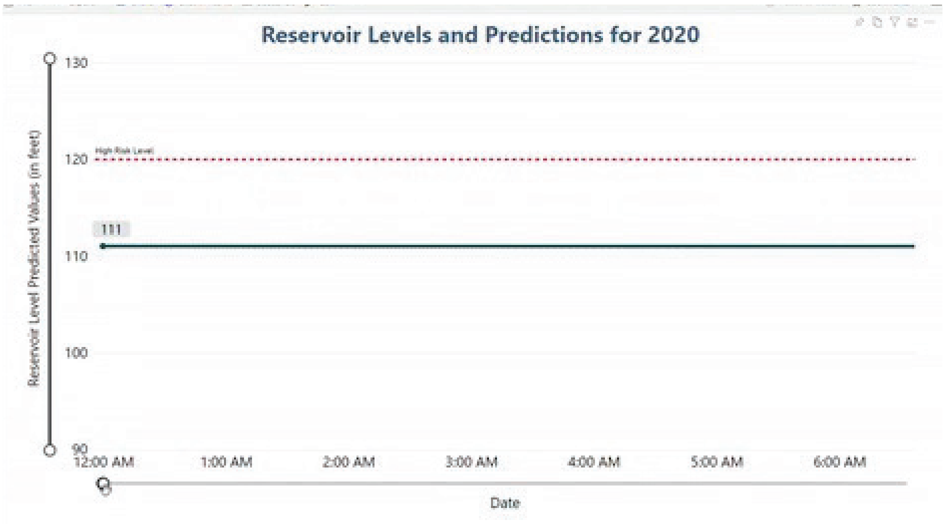


Overview of Water Reservoir System

Our model boasts an accuracy of predictions up to 7 feet, which is equivalent to 94% prediction accuracy for the 90-day forecast.

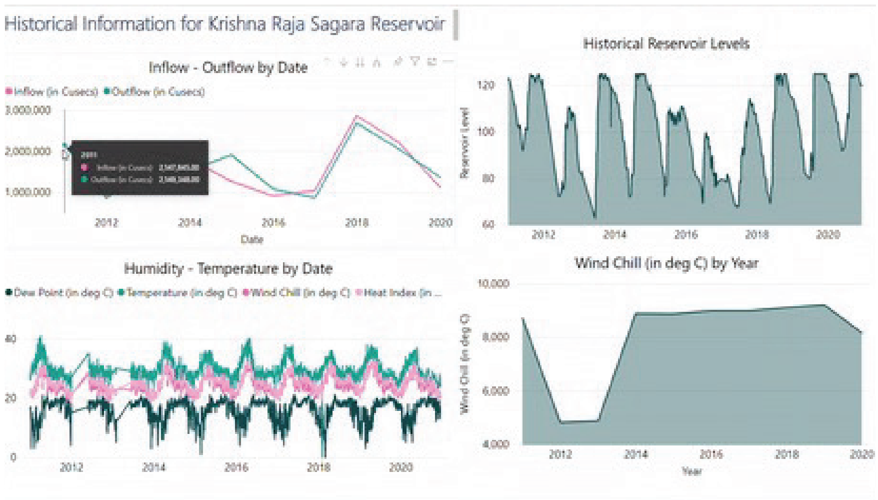
Dashboard to enhance the user experience
To visualize results, we created a user centric interactive dashboard with accessibility in mind.
The dashboard can provide:

- Short- and long-term reservoir level predictions to support risk mitigation decisions based on user-defined benchmarks.



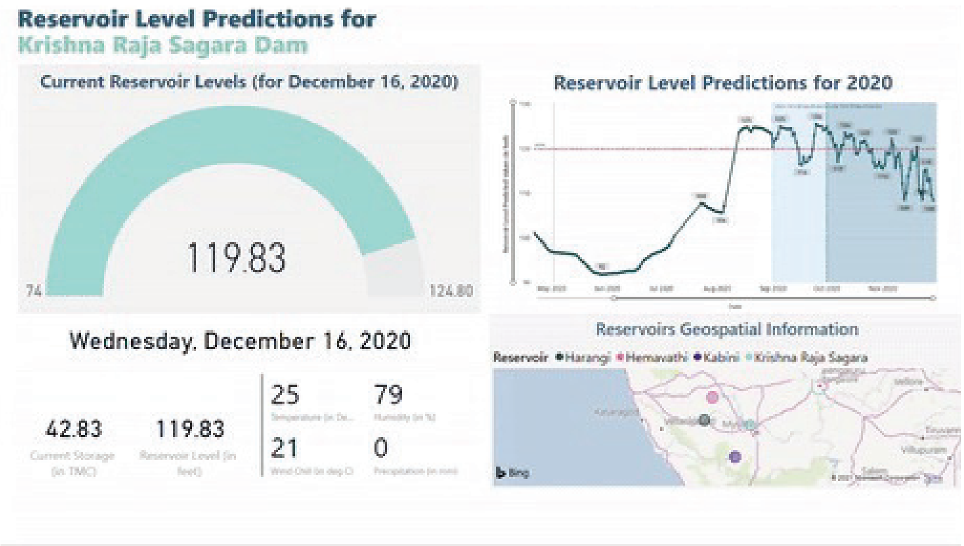
Dashboard has charts (on top right) to show short-and-long-term reservoir level predictions

- Current reservoir status and historical environmental conditions to find historical evidence to support strategic decisions



Dashboard has charts for visualizing historical data

- Summaries of all managed reservoirs on Geospatial Information Systems (GIS) to relate reservoir performance with spatial characteristics.



Dashboard can show reservoir summaries on GIS

In summary, the proposed SWaRM modeling framework can be a critical decision support tool for various stakeholders:

- As an asset manager you will be able to make better strategic decisions to mitigate water shortage or flood risks
- As a policy maker you will be able to make better long-term economic, environmental, and infrastructural policies
- As an academic you can utilize our model as a baseline for future research, and more importantly
- As a Bengaluru resident you will experience affordable and regular water supply

At Team Poseidon, we hope you join us in making a massive impact on millions of lives.

REFERENCES

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