The HYDRA Difference:

Understanding HYDRA's Design-Solution Approach

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EXECUTIVE SUMMARY

While many options for sewer modeling software have become available in recent years, HYDRA® by Pizer Incorporated continues to be an important option to consider. But an understanding of HYDRA's unique design-solution approach is necessary in order to properly compare it to competing software, because the feature sets are inherently different. This paper explains six fundamental differences between HYDRA and other software for the benefit of those entrusted with evaluating options for upcoming projects.

1. **Hydraulic Analysis Calculations: Dynamic Wave vs. Dynamic Step**. Most sewer models use the *dynamic wave* approach to hydraulic calculations, but HYDRA uses a fundamentally different *dynamic step* approach. While the dynamic wave process is in wide use, HYDRA's process can have remarkable advantages that are not always fully comprehended by engineers, including ability to model very large systems, design optimization, and accuracy in head losses at manholes.
2. **Backwater Calculations and Sewer Overflows.** The primary strength of a dynamic wave model is its ability to detect overflows and calculate how much flow leaves the collection system. While HYDRA does this too, it takes a different approach to this condition. HYDRA assumes that overflows are not an acceptable design solution. By returning the overflow back into the system, HYDRA is able to flag all problem areas throughout the collection system in a single analysis. If pipes are overloaded, it returns several possible design solutions, including ones to eliminate all overflows
3. **Methods for Estimating Flow Input.** Having realistic flows in a sewer model is critically important to the end results. HYDRA comes standard with a variety of powerful features for estimating all types of flow using parameters and data structures that are easy to maintain over time. HYDRA also includes features for non-uniform rainfall, including historic gauge-adjusted radar data.
4. **Extended Period Simulation vs. Dynamic Design Storm.** To ensure that systems have sufficient capacity into the future, many sewer modeling programs rely on use of historic rainfall data analyzed in sessions simulating periods of many years as the design criteria. HYDRA takes a totally different approach by testing each pipe in the system against a dynamic design storm – ensuring that the collection system is tested against the perfect storm.
5. **System Design and Construction Cost Estimation**. Surprisingly few model evaluation studies explore the area of design and construction cost. Most programs are very weak in this area. HYDRA designs new system components, whole new optimized sewer systems, and provides design solutions for each overloaded or surcharged pipe in existing systems. Working in concert with these design features, HYDRA can calculate very detailed costs for construction based on local cost factors using the client's design criteria.
6. **Cost of the Software**. The cost of sewer modeling software ranges wildly. In addition to initial purchase price, other costs include learning curve, software maintenance, consultant costs, and technical support. HYDRA's suitability to all types of sewers (storm, sanitary, and combined) from small to large systems, enables Pizer Incorporated to offer the product at a cost far less than most of the competition.

A primary objective of sewer modeling software evaluation should be to ensure that the municipal client will get the best value for the design project. HYDRA's design-solution approach to sewer modeling is worthy of serious consideration for upcoming sewer projects.

The Model Evaluation Process

The first step in most municipal sewer design projects is to decide which sewer modeling software is the best for the project. This often involves a formal software evaluation process, complete with a matrix which presumably covers all the essential and desirable features. Model evaluations are most useful when prepared for a specific project, taking into consideration the client needs, available data, steps involved in the project, expected problems, and time and budget constraints. Generic model evaluations are interesting, but may not be useful to specific projects because they may emphasize irrelevant features, and overlook features that are critical for the project goals. To weigh the options objectively, it is important to structure evaluation studies around function, rather than specific features.

Any evaluation study should answer the question of whether the model solves the immediate design problems, meets ongoing goals for the model, and is an appropriate choice for the skill sets of staff members. An evaluation should also consider costs in terms of time, training, data collection, project work and software maintenance and upgrades. It is important to weigh the practical considerations of how to integrate the modeling process into organizational processes, for the best return on investment.

In 1973 HYDRA® software by Pizer Incorporated of Seattle, Washington became the first commercially available sewer modeling software in the United States. Many sewer modeling software products have become available in recent years, yet even today many of HYDRA's core features are still unique. These features are a reflection of HYDRA's unique design-solution approach to the problem of sewer modeling.

This paper explains some of what makes HYDRA different from other sewer modeling software. We hope it will be helpful to model evaluators in the future to better understand the most important considerations of function.

Hydraulic Analysis Calculations: Dynamic Wave vs. Dynamic Step

There are two basic approaches to dynamic hydraulic analysis calculations: ***Dynamic wave*** and ***dynamic step***. SWMM and most other programs use the dynamic wave approach. HYDRA uses the dynamic step approach. It is important to understand both the differences and the similarities between the two, and the advantages and disadvantages of both.

The dynamic wave approach performs hydraulic calculations by routing a system wide wave simultaneously through all conveyance entities in the collection system for every time step in the analysis. The dynamic step approach starts at the top of the collection system and routes the entire wave down the conveyance system entity by entity, rather than the entire system on each step, flagging those entities that violate the user normal flow design criteria, and then doing its backwater calculations starting at the outfalls and working upstream to determine the hydraulic grade line (HGL). Both approaches calculate an HGL for each step in the time period, however, HYDRA automatically sifts through the results to find the worst-case HGL for each entity for the entire time period, and displays the problems resulting from that HGL.

It is sometimes assumed that the dynamic wave process, used by SWMM and others, is inherently superior to the dynamic step process used by HYDRA. While the dynamic wave process has its uses, the dynamic step process can have remarkable advantages that are not always fully comprehended by engineers. Also, the dynamic wave process has some fundamental methodology problems which are often overlooked.

What ultimately matters is not the calculation method, but the results. Pizer developed a data exchange module in 2001 to model the exact same data with both HYDRA's dynamic step and SWMM's dynamic wave models to compare hydraulic analysis results. Reports from customers using HYDRA's SWMM module indicate that hydraulic analysis outputs similar results under most conditions found in most collection systems, illustrating clearly that there is more than one way to approach the same hydraulic analysis. There are often big advantages to using both methods on a single project.

The dynamic step process used by HYDRA is much faster than the dynamic wave process. In practice, this means HYDRA is able to analyze tens of thousands of pipes together in one analysis session in minutes. In contrast, most dynamic wave analysis programs have serious limitations on the size of system that can be analyzed and can have analysis times that are orders of magnitude longer. HYDRA's speed and size capability is an advantage for several reasons. It enables the municipality to model every pipe in the system in accordance with the principles of CMOM regulations (There is typically 1 pipe for every 10 people served by the sewer). The municipality can use the same data set for hydraulic analysis that is used for system maintenance. On large sanitary sewer projects, modeling every pipe in the system is important. Rainfall often has a big impact on the system flows, and it is critical to take into account that rainfall is not uniform over the basin. Also, the accuracy and shape of the hydrographs as they move through the collection system is a critical component of a model, as it will have a huge impact on the analysis, evaluation and design solutions.

The dynamic step process is inherently superior for design of new laterals and by-passes. The very nature of the analysis process used by SWMM and other programs using the dynamic wave approach makes the design of proposed pipe a tedious "trial and error" process. This is because pipe diameters and invert elevations cannot be modified during a dynamic wave analysis. But with the dynamic step analysis, HYDRA is able to select and modify the diameters and invert elevations to optimize the design. As an added bonus, it will also return detailed cost estimates of the design. This difference alone saves countless hours and project costs.

There is one additional point that is often overlooked when evaluating the accuracy of hydraulic calculations: head losses at manholes. Accuracy in this area is very important because losses in manholes have a significant impact on the hydraulic grade line. In most or all dynamic wave programs, manhole losses are simulated in hydraulic analysis by increasing the friction factors in the downstream pipe. This approach is problematic because when manholes switch from flooded to running free, there can be significant changes in head losses. In contrast, HYDRA uses an empirical approach based on American Society of Civil Engineers field research for drop and bend losses, resulting in more sensitivity to surcharging.

Backwater Calculations and Sewer Overflows

If there are collection system overloads (current or projected), the project engineer needs to predict the location of these overloads using the model and decide what to do about them.

The *dynamic wave* process used by SWMM is inherently superior to HYDRA's *dynamic step* process in certain conditions, such as system backwater resulting in unpredictable overflows, and dynamic adjusting of control hardware - such as diversion dams, activated on downstream flows. To analyze these conditions, HYDRA's *dynamic step* method would require multiple runs in a trial-and-error approach.

The dynamic wave process has the ability to give you a clear picture of what may be actually happening in the collection system if there is backwater. It simulates overflows and calculates how much actually leaves the collection system. Dynamic wave models, by their nature remove the overflow from the collection system. However, by removing overflows, it may (probably will) mask downstream capacity problems. Before you can detect any of these, you must find an acceptable solution to the first detected overflow. But remember that solving upstream problems may not solve downstream problems, so the solution may be to remove more flow upstream, rather than solve problems one at a time through this "trial-by-error" approach.

HYDRA takes a different approach to overflows. Unless you indicate otherwise, it assumes that overflows are not an acceptable design solution. It flags the problem, and then re-injects this flow back into the system. This approach allows a single run to detect all system overloads as well as pipes that exceed the desired d/D's. For pipes, it flags the problem, and returns three possible solutions – the quantity to remove, the size of the replacement pipe, and the diameter of a parallel pipe. These may not be the final design solution, but are extremely useful in the process of finalizing the solution. For example, if you scan the downstream proposed removal suggestions, pick the largest and go upstream of the first point of overload and insert a bypass with a side-flow weir, and divert that flow to a new lateral – all problems solved! HYDRA's results will allow you to re-inject the removed flow downstream of the last point of overload. . With this process of identifying problem areas, a solution is possible using HYDRA's dynamic step method after only one analysis run.

When deciding whether to use the dynamic wave a , dynamic step process, be sure to consider which approach will result in the best design solutions. Keep in mind that if overflows are not an acceptable solution, then all that is needed is to find the points of overflow and correct them. This is much quicker done with HYDRA's dynamic step process than the dynamic wave process. If surcharging is being considered, it needs to be understood that few sanitary sewer systems were designed for surcharge, and if surcharged, there is a potential risk for flooding basements or causing pipe failures. In addition, using surcharging as a solution is risky because HGL calculations are so sensitive to difficult-to-estimate system flows (which in the best of conditions are often not within 10% to 15% of reality). If surcharging is not an acceptable solution, then you will find that HYDRA is a better tool for finding design solutions.

Methods for Estimating Flow Inputs

One of the most important aspects of the sewer design process is estimating the flow upon which the design will be based. In fact, having realistic flows is far more critical than the method of backwater analysis, because backwater calculations are especially sensitive to flows. You can use the most sophisticated hydraulic calculation methods known to mankind to calculate the hydraulic grade line, but if the flows upon which the calculations are based are unrealistic, then the results will be unrealistic, and consequently the design solutions may be deficient. The old saying in the computer industry, "Garbage in = garbage out" is very relevant to sewer modeling. It is not enough to accurately model based on current metered flows, or even adjusted metered flows, because the whole point of sewer modeling is to predict future conditions. The basis from which modeled flows are derived, must be capable of predicting changes in flows, resulting from changes in land use, increased population, or new added areas.

Yet despite the critical importance of flow injections, this part of the project is often treated as an after-thought. Most sewer modeling programs have very rudimentary features for estimating injections compared to HYDRA, often requiring the user to create his own technique or module outside of the sewer modeling software, to derive these critical injections for each pipe.

HYDRA, on the other hand, comes standard with a variety of powerful features for estimating all types of flow, including sanitary, seasonal groundwater infiltration, rainfall-dependant infiltration and stormwater runoff or inflow, and automatically create flow totals and hydrographs for every pipe in a collection system. These flow injection features use parameters and data structures that are easy to maintain over time.

For management of data used for estimating sanitary flows, HYDRA maintains several types of GIS graphical layers for ownership parcels, land use zones, and sanitary service areas (sometimes called "sewersheds"). HYDRA automatically calculates flow totals from sanitary contributors, even allowing you to adjust for users on septic tanks not contributing. Optional features allow you to automatically adjust sanitary flows based on population and zoning changes in land use polygons. It shapes injection hydrographs for each pipe or manhole by combining any number of daily flow patterns (diurnal curves) for different land use characteristics. New analysis scenarios for updated or projected population figures can be made very quickly using these automated features.

For realistic modeling of rain-derived infiltration, HYDRA's Defect Database provides a way to model rain events by considering defects related to the condition of pipes and manholes. The information on defects may come from maintenance inspections, or it can be deduced from flow metering data. This reality-based method allows the user to calibrate the model to a high level of accuracy and perform useful analysis scenarios for prioritizing pipeline rehabilitation projects.

For stormwater runoff/inflow estimation, the user defines runoff basins with associated parameters for the Rational Method, SCS Method (Santa Barbara), or full hydrographic simulation (Stanford Watershed Approach) appropriate for the land characteristics of the basins.

For project areas larger than 1 square mile, in order to have accurate injection hydrographs, you must account for non-uniform rainfall distribution over the project basin, as well as the critical "shaping" of flow hydrographs resulting from collection system geometry. This applies for rain-derived infiltration as well as stormwater runoff/inflow. This capability of a model is critical to accurate flow estimates. If the non-uniform distribution is not taken into account, and rainfall is assumed to be uniform over a basin, flows in collectors and trunks always are over estimated, resulting in costly and unnecessary over-design. For non-uniform rainfall, HYDRA provides for use of multiple rain gauges for up to 32,000 data sets. Radar data for historic rain events is available from OneRain Corporation in a HYDRA-ready format. If good statistical data is available for local weather patterns, HYDRA's storm cell routing feature is a good option for analyzing synthetic rain data.

Between all the methods for estimating flow loading for sewer models, HYDRA provides unmatched features. The flow generation features alone are worth the price of the software. In fact, HYDRA can be used as a data preparation pre-processor for other models, if desired. Once the model has been created in HYDRA including all flow loading, it is not difficult to export to a dynamic wave model using HYDRA's SWMM module.

Extended Period Simulation vs. Dynamic Design Storm

"Extended Period Simulation" is a feature that many other models have, but HYDRA's analysis period is limited to 7 days. In comparison matrices, HYDRA's limitations in this area might appear to be a weakness. Yet the reason HYDRA does not need this feature because its unique dynamic design storm feature is a better way to address the problem of designing for the worst case scenario.

Municipalities need to ensure that their system will have adequate capacity under a wide range of weather conditions that will likely occur. If the collection system is stressed by rainfall, most models are only capable of simulating the conditions for a specific rain event that occurs at a specific time. But the larger the collection system, the more difficult it is to find a storm that adequately represents the design criteria. There are many issues, including:

- Timing (eg. What if the storm came in at 8:00am rather than 3:00 pm?) and
- Weather patterns (eg. Whether if it came in from the North, rather then from the SW) and
- Scale (eg. How much of the collection system is really effected by the rainfall measured at a single guage?) and
- Routing (How do cumulative flows combine as they travel down the system?) and
- Landuse (Different shape hydrographs in different land use zones).

The number of rainfall permutations required to find a rain event that meets the design criteria is significant, not even taking into account the effort it takes to create all the different conditions. The worst-case scenario storm pattern will be different for every pipe in the collection system.

The theory behind the extended period simulation approach is that by running the model through enough years of historic rainfall data, you have probably covered all the expected conditions. This is really a shot-gun approach; the extra random rain-fall data in the analysis does not guarantee you'll hit your target. In addition, the distributed rainfall (requiring many rain gauges) data may not be available for the entire period of analysis. Another disadvantage of this approach to modeling is the time and effort required to perform extended period simulation.

HYDRA takes a totally different approach to the problem. It takes the peak of the hydrograph for rainfall-derived flows (including stormwater runoff, inflow, and rain-derived infiltration) and automatically aligns it with the peak of the hydrograph for dry weather flows (including sanitary and groundwater infiltration) from selected design storms to find the worst conditions. This automatic alignment, is performed dynamically for every pipe in the system. HYDRA performs this in a way that does not distort the downstream flows and does not compound safety factors. No matter how steep or flat the collection system is, or how many pumps, or how many different land use patterns you have in your service area, HYDRA finds the "worst case scenario" for every pipe, given any design storm, real or synthetic. Effectively, HYDRA creates the "perfect design storm". In HYDRA terminology, this is called "shuffling the storm" or "worst-case scenario analysis". In contrast to the shot gun approach of extended period simulation, HYDRA's dynamic design storm is like a shooting at a target with a laser-sighted rifle.

System Design and Construction Cost Estimation

Curiously, design features are rarely included in sewer model comparisons. Yet, isn't design evaluation ultimately the whole purpose of sewer modeling? Most available sewer modeling software is weak or completely deficient in this area. A sewer model that fails to provide robust design tools is like a car without wheels. It may have some fancy features, but it won't take you where you want to go.

For each overloaded or surcharged pipe in existing systems, HYDRA provides a design solution of replacement pipe, parallel pipe, and how much flow must be removed to meet design criteria. Also, HYDRA has unmatched features for designing new system components or whole new systems. To lay out new sewer line, HYDRA uses design criteria, including desired pipe depth, flow velocity, pipe diameter options, and d/D to optimize the design. HYDRA calculates invert elevations, pipe diameters, slopes and you can dictate match crowns for pipes. HYDRA includes design features for pipes, force mains, manholes, channels, detention facilities and pump wet wells.

HYDRA has some unique features for calibrating a model which are very relevant to design work. It tracks sanitary, seasonal groundwater infiltration, rain-dependant infiltration and stormwater runoff/inflow each in separate hydrographs. It allows you to apply "Safety Factors" to adjust any or all of the types of flow. This means you can calibrate using a Safety Factor of 1.0 and then change the Safety Factors to increase the system flow for design without creating new injections. Perhaps even more important is that it allows you to easily assign different Safety Factors for every entity, so that new pipes are designed with one Safety Factor and existing pipes are analyzed with another. If this is not done, you can overestimate the problems in the existing pipes or under design new pipes. Also, HYDRA's dynamic design storm feature (explained earlier) is ideal for design work, because it allows you to base your design on the perfect worst-case scenario storm.

HYDRA's design features also can be used to quickly model large existing systems with minimal data input. If you don't know all the diameters or inverts, or don't have time to input the data, HYDRA will assign realistic values. This allows you to get a model up and running quickly. You can refine the data later or where needed.

Working in concert with design features, HYDRA can calculate very detailed costs for construction based on your local cost factors. These include costs for bedding, backfill, soil shrinkage, excavation and hauling costs, pipe depth, unit prices for piping, and surface restoration. These are calculated using highly sophisticated calculations considering trench width, side slope, breakheight for a drag box, bedding and pipe zone depth, and a variety of other cost factors. Since HYDRA's detailed cost calculations are so quick and easy – essentially automatic once you've defined the cost factors – this feature can potentially save much laborious calculation work or provide a cross check for your own methods.

Cost of the Software

As any model evaluation will show, the cost of sewer modeling software ranges wildly. Initial licensing can range from no cost to as much as US$55,000. Annual maintenance fees in the range of 10% to 25%, upgrade fees, consulting fees, technical support service upgrades, training, staff time, hardware and third-party software requirements, and other items further add to the cost of using sewer modeling software.

It is sometimes assumed that the more expensive software product is the better one. This conclusion results from the mistake of comparing software to manufactured products, like cars. You expect to pay more for one car brand than another brand, because one car is more luxurious, better quality materials, has more features, therefore is better. But computer software doesn't equate to cars, because the manufacturing costs for each software sale is minimal. What are you paying for when you buy sewer modeling software? You are paying for some portion of the research and development cost, for technical support to set up the software and keep it working, and sales and marketing. In fact, in many software markets, the best product is the least expensive, because it is supported by the largest customer bases and has the least technical support burden. High cost may simply indicate a small market.

When evaluating sewer modeling software, before you assume that a higher cost means a better product, carefully consider how difficult it is to use the product, how many maintenance updates are released, and how dependant you'll be on consulting help from the vendor to use the product. Consider whether its features are really required for your project.

The market for HYDRA is large and broad. HYDRA is powerful enough for the largest municipalities, yet easy enough to use for the smallest design project. It can be used for sewer systems of all types: sanitary, stormwater, and combined. Software sales, rather than consulting, are the focus of the company, and all development and documentation work geared to helping customers be self-guiding and efficient in their own work. The initial cost is a modest US$4500, to make it easier to put on the desktop of every wastewater engineer involved in a project. (The module for export to SWMM is an additional $500). The optional annual software maintenance fee of US$1250 includes all upgrades to all components of the package.

Conclusion

When evaluating sewer modeling software, professionals in the sewer design industry need to compare the strengths and weaknesses of the each software product objectively. Rather than focus on whether or not a particular model has a particular feature or uses a particular methodology, a good model evaluation study should answer the question of whether the model can simulate the real system well enough to base decisions and whether the design will be optimized.

When selecting sewer modeling software, make sure that you build your own comparison matrix, based on your actual project needs. Don't get distracted by fancy features that may not actually be the best approach to solving system design problems. A primary objective should be to ensure that the client will get the best value for the design project.

There is more than one approach to sewer modeling, just as there is more than one way to skin a cat. HYDRA's design-solution approach to the problem of sewer modeling is very different than other software packages available today. It is worthy of consideration for any upcoming sewer project. It is an approach that has stood the test of time.

Allen Peyser, PE, is the founder of Pizer Incorporated and the original author of the HYDRA® program. Cindy Peyser, is Chief Operating Officer of Pizer Incorporated. We welcome your responses to this article! Please visit the HYDRA User Group discussion forum at the Pizer Website at http://www.pizer.com in "Community". HYDRA is a registered trademark owned by Pizer Incorporated.