City of Riverside

# WASTEWATER COLLECTION AND TREATMENT FACILITIES INTEGRATED MASTER PLAN

## VOLUME 8: SOLIDS TREATMENT AND HANDLING
## CHAPTER 5: SOLIDS PROCESSING

**FINAL**
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City of Riverside

**WASTEWATER COLLECTION AND TREATMENT FACILITIES INTEGRATED MASTER PLAN**

**VOLUME 8: SOLIDS TREATMENT AND HANDLING**
**CHAPTER 5: SOLIDS PROCESSING**

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# SOLIDS PROCESSING

## 5.1 PURPOSE

The purpose of this chapter is to evaluate biosolids digestion alternatives for the City of Riverside (City) Regional Water Quality Control Plant (RWQCP) expansion. Acid-Phased Anaerobic Digestion (APAD) is compared with the existing conventional anaerobic digestion. Final decisions about a detailed layout and specific equipment type would be determined during the preliminary and final design.

## 5.2 CONCLUSIONS AND RECOMMENDATIONS

- The City could reduce digestion construction to a minimum of one 90-foot digester and possibly not have to build any additional digestion during the master plan planning period by using APAD versus conventional anaerobic digestion.
- The City has selected the APAD system with a new multi-compartment acid-phase digester for their digestion facilities.
- It is recommended that the City use Digester No. 3 for downstream digester sludge storage, as this would provide the City with 3 days of storage versus 2 days, if the City were to use Digester No. 5 instead.

## 5.3 SOLIDS PROJECTION

The calibrated Biotran™ model was used to estimate the thickened solids production for an Average Daily Flow (ADF) of 52.2 mgd. The projections were based on the thickening discussions in Chapter 4 in which Gravity Belt Thickeners (GBTs) selected to thicken both primary sludge and Waste Activated Sludge (WAS). The GBTs were assumed to have a solids capture rate of 95 percent and able to thicken both the primary sludge and WAS solids to 5 to 7 percent. However, for master planning level purposes, 6-percent solids concentration was used because it maybe difficult to get continuous 7-percent solids from the thickeners. Furthermore, for conventional anaerobic digestion, 6 percent is the upper feed solids concentration to avoid digester process control problems. Table 5.1 summarizes the thickened solids projections for the 52.2-mgd annual ADF condition.

**Table 5.1 Thickened Solids Projections**
**Wastewater Collection and Treatment Facilities Integrated Master Plan**
**City of Riverside**

| 52 mgd | Primary Sludge | WAS |
|---|---|---|
| % Thickened Solids Concentration | 6 | 6 |
| Total Solids, lbs/day | 91,000 | 65,500 |

| Table 5.1 | Thickened Solids Projections<br>Wastewater Collection and Treatment Facilities Integrated Master Plan<br>City of Riverside | |
|---|---|---|
| **52 mgd** | **Primary Sludge** | **WAS** |
| Volatile Solids, % | 81 | 85 |
| Volatile Solids, lbs/day | 73,800 | 55,700 |
| Maximum Month Flow, mgd | 0.182 | 0.131 |
| Peak Flow, mgd | 1.34 | 2.36 |
| Organic N, total lb/d | 3,820 | 4,525 |

## 5.4 EXISTING DIGESTION FACILITIES

As stated in Volume 8, Chapter 1 - Existing Facilities, the City currently has five digesters with the smallest unit being out of service. Table 5.2 summarizes the descriptions of each of the digesters. The RWQCP currently operates with only the two 90-foot diameter tanks as active digesters. These are labeled as Digester Nos. 1 and 2. Digester No. 3 is being retrofitted and will be put back in service. After digestion, the stabilized solids are transferred into Digester No. 4, which serves as a holding tank for the dewatering process.

**Table 5.2 Existing Digestion Facilities**
**Wastewater Collection and Treatment Facilities Integrated Master Plan**
**City of Riverside**

| Description | | | | |
|---|---|---|---|---|
| **Digester No.** | **Diameter, ft** | **Side water Depth, ft** | **Digester Volume, MG** | **Notes** |
| 1, 2 | 90 | 32 | 1.64 | |
| 3 | 75 | 32 | 1.06 | |
| 4 | 88 | 38.5 | 1.8 | Digested Sludge Storage |
| 5 | 60 | 28.5 | .63 | Out of Service |
| | **Current Active Volume** | | 4.34 | Digester Nos. 1-3 |
| | **Current Storage Volume** | | 1.8 | Digester No. 4 |

The RWQCP has been running a project since April 2005 in which restaurant grease is added directly to Digester No. 2 to increase gas production. The project results have shown that solids destruction in the digester is also increased.

## 5.5 DIGESTION ALTERNATIVES

The two digestion alternatives evaluated for the master plan are variations of mesophilic anaerobic digestion:

1. Conventional anaerobic digestion.
2. APAD.

As mentioned earlier, the City is adding grease to one of the digesters. This alternative evaluation assumes this procedure will continue. The City's plan for their grease study is to expand it and begin adding heated grease along with thickened sludge into Digester No. 3, using it for upstream storage. For this plan, Digester Nos. 1, 2, and 4 would be active digesters and Digester No. 5 would be downstream storage. Effectively, if the City upgrades the heating capability of Digester No. 3, they would have an APAD system. Heating Digester No. 3 is recommended because if the heated grease is added to relatively cold sludge (estimated at 70 degrees Fahrenheit), a grease layer may form. Hence, poor mixing within the reactor would occur, and the City would also experience problems with pumping. More importantly, if Digester No. 3 is not heated the digester would perform similarly as an acid-phase digester, but it would not work optimally since it is not heated. The digester would then move in and out of the acid-phase digester operating range, and the City would have process control issues with the remaining digesters.

### 5.5.1 Design Criteria

Table 5.3 lists the design criteria for the two anaerobic digestion processes. In most cases, the Volatile Solids Loading Rate (VSLR) is the controlling parameter.

**Table 5.3 Anaerobic Digestion Design Criteria**
**Wastewater Collection and Treatment Facilities Integrated Master Plan**
**City of Riverside**

| | **Value** |
|---|---|
| **Conventional Anaerobic Digestion** | |
| Volatile Solids Loading (lbs/ft$^3$/day) | |
| All Units in Service | 0.12 |
| Largest Unit Out of Service | 0.15 |
| Detention Time (days) | |
| All Units in Service | 20 |
| One Unit Out of Service | 15 |
| **Acid-Phase Anaerobic Digestion** | |
| Acid Phase | |
| Volatile Solids Loading (lbs/ft$^3$/day) | 1 to 3 |

| Table 5.3 | Anaerobic Digestion Design Criteria<br>Wastewater Collection and Treatment Facilities Integrated Master Plan<br>City of Riverside |
|---|---|
| | **Value** |
| Detention Time (days) | |
| All Units in Service | 1 to 3 |
| **Methane Phase** | |
| Detention Time (days) | |
| All Units in Service | 15 |
| One Unit Out of Service | 12 |
| Acid Phase Out of Service | 15 |
| Volatile Solids Loading ($lbs/ft^3/day$) | |
| Acid Phase in Service | N/A |
| Acid Phase Out of Service | 0.15 |

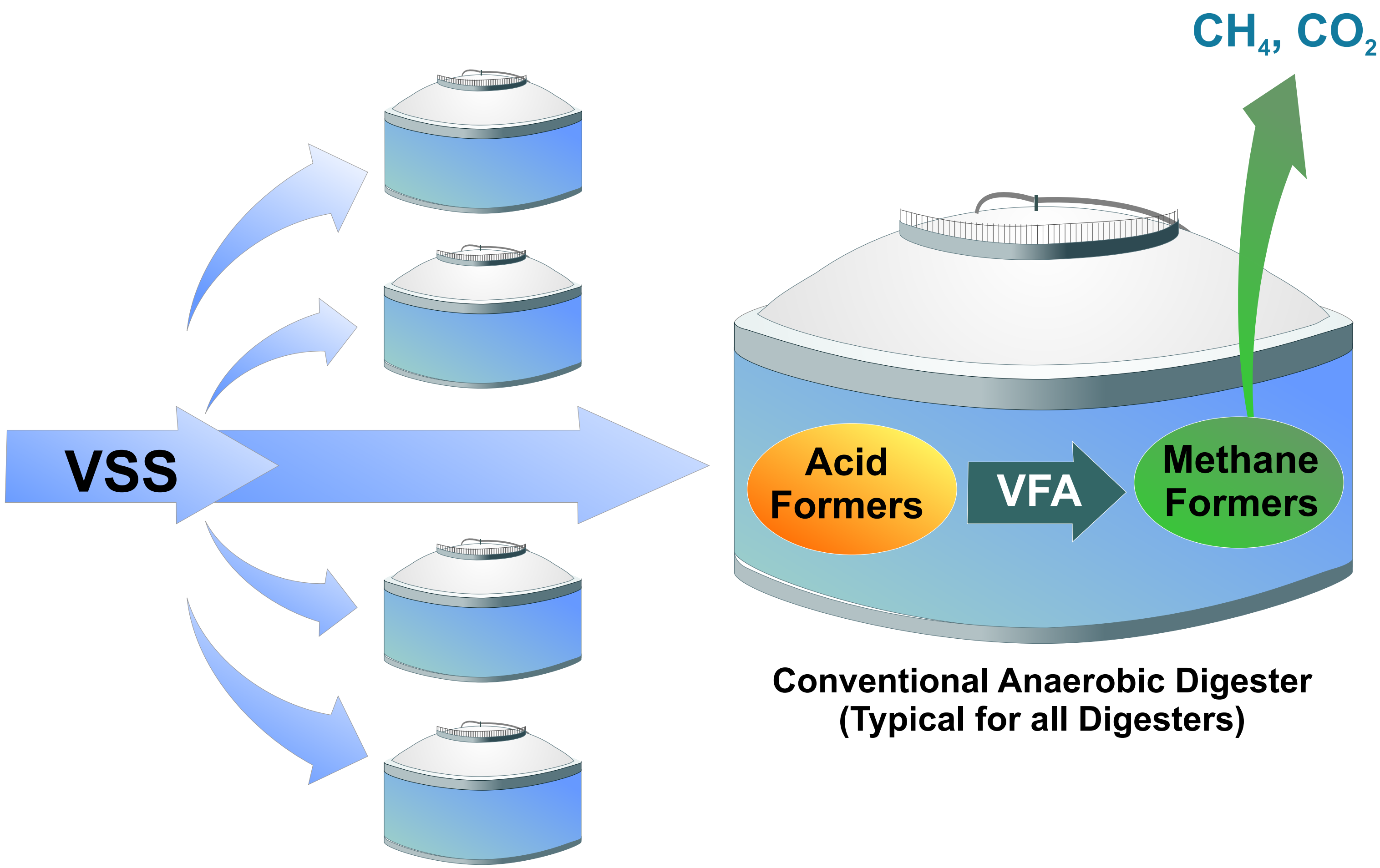
The controlling parameter for the methane-phase digester when the acid-phase digester is out of service (assuming there is only one acid-phase digester) in the APAD system is also the VSLR. During this time, the methane-phase digesters would operate as conventional anaerobic digesters and, therefore, the VSLR criteria (0.15 $lbs/ft^3/day$) for the conventional anaerobic digestion process is applied.

Since the start of the City's grease-to-gas project, the City has experienced an increase in Volatile Suspended Solids (VSS) destruction. However, the City does not have any information on the VSLR at this time. As the City runs this grease-to-gas project longer and is able to collect information on the VSLR, the City might be able to increase this parameter for design in the future, which could decrease the requirement for additional digestion.

### 5.5.2 Alternative 1: Conventional Anaerobic Digestion

Figure 5.1 shows a schematic representation of the conventional digestion process. In general, an anaerobic digestion process is divided into three stages: hydrolysis, formation of soluble organic compounds (short-chained organic acids), and methane formation. In the first stage, the complex organic matter is converted into a soluble form through hydrolysis. In the second stage, the acetogenic organisms convert these soluble organics into Volatile Fatty Acids (VFAs), and finally in the third stage, the methanogenic bacteria convert the VFAs to methane and carbon dioxide gases.

In conventional anaerobic digestion, all three reactions take place in one tank, hence, both acetogenic and methanogenic organisms must co-exist in the same tank. The acetogenic




## CONVENTIONAL ANAEROBIC DIGESTION PROCESS

FIGURE 5.1

organisms are fast-growing bacteria while the methanogenic organisms are slow growing bacteria, and the VFAs that the acid formers produce are toxic to the methane formers. In order to have the acetogenic and methanogenic organisms co-exist in the same environment, it is necessary to starve the acetogenic organisms by artificially limiting the VSS in the feed to create a balance between the acid formers and the methane formers. The advantages and disadvantages of conventional anaerobic digestion are as follows:

#### 5.5.2.1 Advantages

- Produces methane gas, which can be used to produce heat and electricity.
- Stable process.
- Relatively low operating costs.

#### 5.5.2.2 Disadvantages

- Methane-producing bacteria are slow growing, and therefore, larger tankage and longer detention time is required for process completion.
- High capital costs.

#### 5.5.2.3 Conventional Anaerobic Digestion Facilities

Based on the design criteria for conventional anaerobic digestion and the thickened solids projections, Table 5.4 summarizes the digestion facilities required for this alternative.

**Table 5.4 Conventional Anaerobic Digestion Facilities Design**
**Wastewater Collection and Treatment Facilities Integrated Master Plan**
**City of Riverside**

| | All Units in Service | One Unit Out of Service |
|---|---|---|
| **Facilities Requirement Based on HRT** | | |
| Total Required Digester Volume (MG) | 6.26 | 4.7 |
| Additional Required Volume (MG) | 0.63 | 0.81 |
| **Facilities Requirement Based on VSS Loading** | | |
| Total Required Digester Volume (MG) | 6.45 | 8.1 |
| Additional Required Volume (MG) | 2.58 | 2.44 |

This is based on the assumption of using Digester No. 3 as downstream storage, which would provide the City with approximately 3 days of storage. As Table 5.4 shows, the VSLR is the controlling parameter, and the City would need to install two new 90-foot digesters to meet the additional digestion volume requirement.

### 5.5.3 Alternative 2: Acid-Phased Anaerobic Digestion

Figure 5.2 shows a schematic representation of the APAD concept. The acid-phased digestion, unlike conventional anaerobic digestion, makes use of the different growth conditions of the anaerobic organisms. In APAD, the organisms are separated into an acid-phase digester and a methane-phase digester. The first two stages of the anaerobic digestion process take place in the acid-phase digester, where the complex organics are hydrolyzed and converted into VFAs. Once the acids are formed, the sludge is sent to the methane-phase digester where the methanogenic organisms break down the VFAs further into methane and carbon dioxide. Due to the conditions present in the acid-phase digester, the solubility of the complex organic matter is increased. Because of the improved hydrolysis, the volatile solids destruction is increased, and the amount of solids resulting from the digestion process is reduced.

The gas from the acid-phase digester, which accounts for about 5 to 10 percent of the methane produced, has relatively high $H_2S$ and low methane concentrations. This poor-quality gas cannot be used as a fuel source and, therefore, needs to be flared off. The methane digester gas, however, has a higher methane concentration due to a higher pH in this digester. It also has a lower $H_2S$ concentration compared to gas produced in the conventional digesters. Furthermore, higher VSS destruction results in higher methane gas volumes.

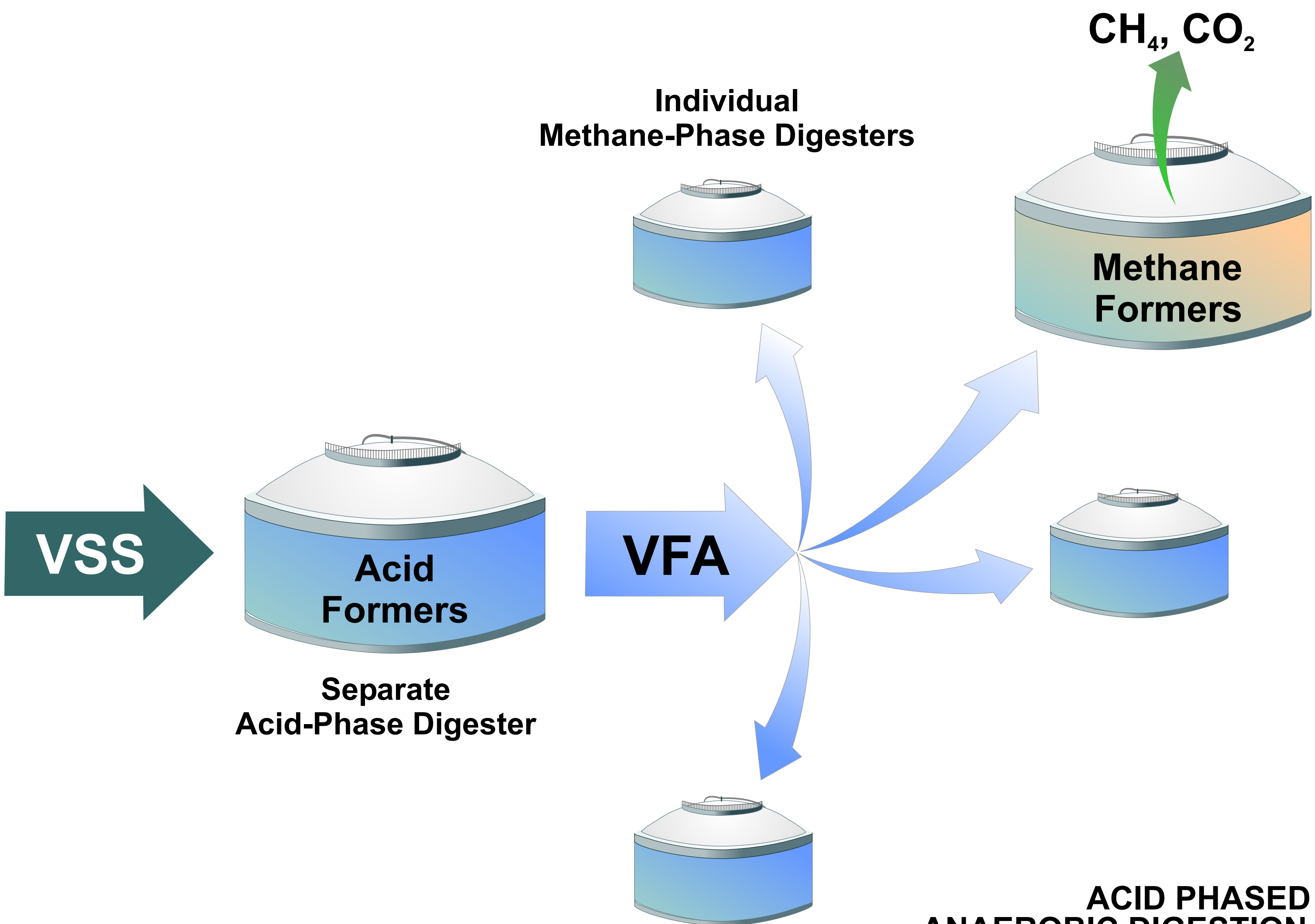
The following summarizes the advantages and disadvantages of the APAD system.

#### 5.5.3.1 <u>Advantages</u>

- Higher reaction rates, hence smaller digester volumes.
- Decreased solids to disposal.
- Equalized feed to the methane-phase digester, which equalizes gas production.
- Higher methane gas production.
- Improved quality of methane-phase digester gas.
- Decreased foaming and improved dewatering characteristics.
- Improved solids dewater ability.

#### 5.5.3.2 <u>Disadvantages</u>

- Higher recycle costs due to higher ammonia concentration in the recycle stream.
- Poor quality of acid-phase gas.




**ACID PHASED**
**ANAEROBIC DIGESTION PROCESS**

FIGURE 5.2

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#### 5.5.3.3 Acid-Phased Anaerobic Digestion Facilities Design

Based on the design criteria for conventional anaerobic digestion and the thickened solids projection, Tables 5.5 and 5.6 summarize the digestion facilities required for this alternative.

**Table 5.5 APAD Facilities Design - Acid-Phase Digester**
**Wastewater Collection and Treatment Facilities Integrated Master Plan**
**City of Riverside**

| | Value |
|---|---|
| **Acid-Phase Digester Requirement Based on HRT** | |
| Total Required Digester Volume (MG) | 0.31 to 0.94 |
| Digester 5 Volume (MG) | 0.6 |
| Digester 3 Volume (MG) | 1.06 |
| Additional Required Volume (MG) | None |
| **Acid-Phase Digester Requirement Based on VSS Loading** | |
| Total Required Digester Volume (MG) | 0.32 to 0.97 |
| Digester 5 Volume (MG) | 0.6 |
| Digester 3 Volume (MG) | 1.06 |
| Additional Required Volume (MG) | None |

Table 5.5 shows that there would be no requirement for any additional acid-phase digesters using either Digesters Nos. 3 or 5 as the acid-phase digester.

**Table 5.6 APAD Facilities Design - Methane-Phase Digester**
**Wastewater Collection and Treatment Facilities Integrated Master Plan**
**City of Riverside**

| | All Units in Service | One Unit Out of Service |
|---|---|---|
| **Methane-Phase Digester Requirement Based on HRT** | | |
| Total Required Digester Volume (MG) | 4.7 | 3.76 |
| Additional Required Volume (MG) | None | 0.48 |
| | **Acid-Phase Digester Out of Service** | |
| **Facilities Requirement Based on VSS Loading** | | |
| Total Required Digester Volume (MG) | 6.46 | |
| Additional Required Volume (MG) | 1.43 | |

Table 5.6 shows that the VSLR is the controlling parameter for the methane-phase digester when the acid-phase digester is out of service (assuming there is only one acid-phase digester). This would require the City to add one 90-foot diameter digester. As a reminder, this is based on the 0.15 lbs/ft$^3$/day VSLR for a conventional anaerobic digester. If the City's APAD project proves that it is possible to get a VSLR up to 0.19 lbs/ft$^3$/day or higher, the

City would have enough methane-phase digester volume and would not require an additional digester for the 52.2-mgd flow condition. Therefore, using the APAD design, the City can save, at a minimum, the cost of one digester and possibly up to two digesters.

In the case that the City does require extra digester volume, another alternative is to build a new multi-compartment acid-phase digester. The multi-compartment tank is more expensive than a circular digester; however, this type of tank is configured specifically to work as an acid-phase digester and to provide process reliability. It reduces the likelihood for sludge short-circuiting and, therefore, works more effectively. The multi-compartment tank provides a plug flow condition, which would enhance the hydrolysis performance. It would also give the City the flexibility to isolate any of its compartments for maintenance, without adversely impacting digester operation.

## 5.6 ALTERNATIVE COMPARISON

A comparison of the two anaerobic digestion alternatives is presented in Table 5.7. In summary, APAD would provide an extra ammonia load in the recycle stream. However, it would require less space, achieve higher VSS destruction, and hence, produce less solids for disposal. The amount of good-quality methane gas is also increased by using the APAD system.

**Table 5.7 Comparison of Conventional and Acid-Phased Anaerobic Digestion
Wastewater Collection and Treatment Facilities Integrated Master Plan
City of Riverside**

| | Alternative 1: Conventional Anaerobic Digestion | Alternative 2: Acid Phased Anaerobic Digestion |
|---|---|---|
| Space Requirement | – | + |
| Recycle Treatment | + | – |
| Operation/Maintenance Requirement | + | 0 |
| Methane Gas Production | 0 | + |
| Dewatering Polymer Usage | 0 | + |
| Total Solids Production/Solids Disposal | – | + |
| Acid-Phase Gas Quality | N/A | – |
| Methane Gas Quality | 0 | + |

Ratings:
+ = Positive comparative characteristic.
– = Negative comparative characteristic.
0 = Neutral comparative characteristic.

## 5.7 LIFE-CYCLE COST ANALYSIS

The life cycle cost analysis included the following capital costs and O&M costs:

**Capital Costs:**

- Digestion facility.
- Support facilities:
  - New sludge transfer pump station.
  - Retrofitting existing transfer pump station.
  - New flare for APAD.
  - Heat exchanger for acid-phase digester.

**O&M Costs:**

- Operation (labor).
- Recycle treatment.
- Dewatering polymer.
- Maintenance.
- Solids disposal.
- Credit from gas production.

A cost comparison of conventional anaerobic digestion and APAD are presented in Table 5.8. There are three options for Alternative 2. Option 1 is to add one extra circular digester, Option 2 is to add a new multi-compartment acid-phase digester, and Option 3 is not adding any new digesters (assuming the City will be able to achieve a VSLR of 0.19 $lbs/ft^3/day$). The higher annual O&M costs for conventional anaerobic digestion are because less credit was given to this alternative for gas production, while APAD options were able to produce more gas and therefore, receive a higher credit for the gas produced, hence reducing the O&M costs.

**Table 5.8 Life-Cycle Cost of Anaerobic Digestion Facilities
Wastewater Collection and Treatment Facilities Integrated Master Plan
City of Riverside**

| | | Alternative 2: APAD | | |
|---|---|---|---|---|
| | Alternative 1: Conventional Anaerobic Digestion | Option 1: With Circular Digester | Option 2: With Multi-Compartment Acid-Phase Digester | Option 3: Without Extra Digester |
| Digestion Facility Project Costs | $8,500,000 | $4,300,000 | $7,700,000 | $0 |

**Table 5.8 Life-Cycle Cost of Anaerobic Digestion Facilities Wastewater Collection and Treatment Facilities Integrated Master Plan City of Riverside**

| | | Alternative 2: APAD | | |
|---|---|---|---|---|
| | Alternative 1: Conventional Anaerobic Digestion | Option 1: With Circular Digester | Option 2: With Multi-Compartment Acid-Phase Digester | Option 3: Without Extra Digester |
| Support Facilities Project Costs | $3,600,000 | $5,100,000 | $5,100,000 | $4,000,000 |
| Total Project Cost | $12,100,000 | $9,400,000 | $12,800,000 | $4,000,000 |
| Annual O&M Cost | $2,900,000 | $800,000 | $820,000 | $770,000 |
| Life-Cycle Cost | $58,500,000 | $22,300,000 | $26,100,000 | $16,000,000 |

At the project meeting on February 21, 2007, the City selected APAD for the master plan. The decision was made because conventional anaerobic digestion is not economical when compared to APAD. In addition, APAD will increase the gas production, which will allow the City to better utilize their cogeneration facilities. The addition of grease to an APAD will further increase the gas production. For the master plan, the City chose the multi-compartment acid-phase digester option. An alternative treatment scenario for the Master Plan Manager™ (MPM™) will include Option 3 (without addition of a new digester), for the possibility that the City can increase the VSLR to 0.19 lbs/ft$^3$/day.

## 5.8 DIGESTION FACILITY LAYOUT

Figure 5.3 shows a proposed layout of the digestion facilities with the multi-compartment acid-phase digester. The City said in the March meeting that it is planning to place fuel cells in the open area to the west of the co-generation facility. The City staff estimated that the fuel cells facilities will take up about 1/3 of that area. This would leave the western portion of this open area for the new digester facilities.

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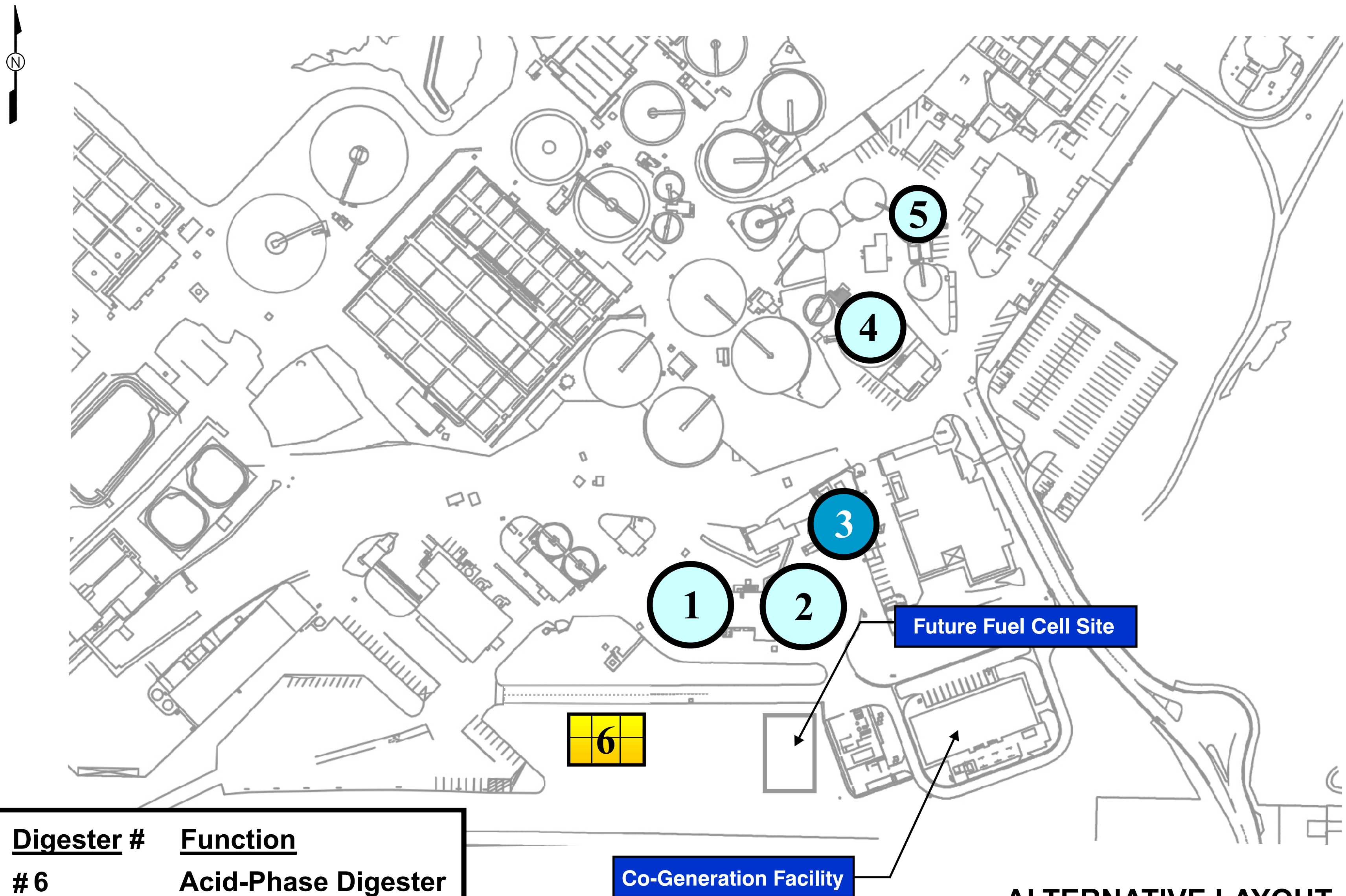


| Digester # | Function |
| --- | --- |
| # 6 | Acid-Phase Digester |
| #1, 2, 4, 5 | Methane-Phase |
| #3 | Storage |

## ALTERNATIVE LAYOUT FOR APAD SYSTEM

FIGURE 5.3